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Application and Evaluation of a Biotic Index to Sand Hills and Streams of Nebraska

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APPLICATION AND EVALUATION OF A BIOTIC INDEX TO SAND HILLS STREAMS OF NEBRASKA

by

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APPLICATION AND EVALUATION OF A BIOTIC INDEX TO SAND HILLS STREAMS OF NEBRASKA

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Sand Hills streams of northcentral Nebraska are relatively unimpacted by anthropogenic disturbances and development of appropriate methods for monitoring the health of these unique aquatic ecosystems is important. The Index of Biotic Integrity (IBI), which uses features of fish communities to assess stream and watershed quality was first adapted and then modified by deleting two metrics and modifying three others to better reflect the faunal characteristics of Sand Hills streams. Overall, the modified IBI ranked sites similarly and consistently between years and across seasons. Fish assemblages were better predicted by discharge velocity and substrate than by stream order. The IBI approach appears to be a valid method evaluating streams in the Sand Hills of Nebraska and continued long-term monitoring is suggested to better define distributional patterns and ranges of natural variability in fish populations.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Sand Hills region is unique for numerous reasons, but perhaps two of the most interesting aspects relating to this study are: (1) streams draining this region, for the most part, have not been severely impacted by anthropogenic disturbances and (2) fish assemblages are represented by species with affinities to faunal regions of the north, south, east, and west. It is theorized that since streams in western Nebraska once flowed in a southerly direction fish from the west and south were able to move north. Also, as glaciers advanced south, fish with affinities north and east were moved into the Sand Hills where they found suitable habitats (Hrabik 1989). Fish such as the pearl dace (*Margariscus margarita*), finescale dace (*Phoxinus neogaeus*), and the northern redbelly dace (*P. eos*), are believed to be on the southern edge of their native range (Lee et al. 1980) and are considered glacial relics. Because these species and others (Hrabik 1989) appear to be sensitive to environmental degradation they can be useful biological indicators.

The Index of Biotic Integrity (IBI) was developed by Karr (1981) to provide fisheries managers and state regulatory agencies with a method for assessing physical and chemical habitat degradation using fish. The IBI incorporates measures of community composition, trophic composition, fish health, and abundance to evaluate response of fish populations to environmental stressors. Each of the measures or metrics is scored according to its demonstrated or presumed response to impacts on a stream. These scores are summed to yield a total index score for a particular stream site or reach. Scores from degraded sites are then compared with scores from undisturbed sites to determine the biotic integrity of the degraded site.

The purpose of my research was to evaluate how well the IBI predicts habitat and watershed conditions of streams located in the Sand Hills region of northcentral Nebraska. To date, the IBI has been applied to degraded streams in the Midwest and Western Great Plains Rivers (Karr 1981; Angermeier and Schlosser 1987; Ohio Environmental Protection Agency 1987; Bramblett and Fausch 1991). Sand Hills streams are unique because they have few tributaries, remarkably constant discharge, rarely flood, and minimal anthropogenic disturbance (Bentall 1989). It is theorized that a key factor affecting the presence and distribution of fish in Sand Hills streams is their habitat stability (Hrabik 1989). This stability can be attributed to the hydrologic regimes of these streams. Streams systems possessing these unique attributes make them excellent candidates for evaluating the usefulness and versatility of the IBI. In addition, because the Sand Hills region is a large, remote area, where aquatic faunal distributions are poorly known, further study should provide us with better insights and greater understanding of how these streams and their watersheds function.

Concern over the deteriorating quality of water resources in the past several decades has resulted in federal legislation: the Water Pollution Control Act of 1966, the Federal Water Pollution Act Amendments of 1972 (PL 92-500), and the Clean Water Act of 1977 (PL 95-217) (Karr et al. 1986). These acts explicitly set forth the objective of restoring and maintaining the "...chemical, physical and biological integrity of the Nation's waters..." (Karr 1981). The summation of these three components are generally equated with ecological integrity (Cairns 1975). An ecosystem possessing integrity can withstand and recover from most perturbations imposed by natural environmental processes, as well as anthropogenically induced disturbances (Cairns 1975). Most monitoring programs rely on measurement of physical and chemical parameters to determine the condition or "health" of aquatic ecosystems (Miller et al. 1988). Biological monitoring of aquatic ecosystems has often been relinquished under the assumption that by meeting physicochemical standards for water quality, improvements in biological quality would follow (Karr and Dudley 1981). Assessment of aquatic resources using only physicochemical variables has been criticized as being inadequate (Thurston et al. 1979; Karr and Dudley 1981). Weber (1981) and Karr et al. (1986) point out that biological assessment of water quality has been hampered by the lack of standardized methods for summarizing and interpreting biological data.

The terms stream health and biotic integrity have commonly been used to describe the overall fitness of aquatic ecosystems (Karr 1981). A widely accepted definition of biotic integrity states: "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region" (Karr and Dudley 1981). Biological communities or assemblages are recognized as being useful monitors for assessing biological integrity because they are sensitive to low level disturbances in and around their environment (Berkman et al. 1986). The ability of an aquatic ecosystem to sustain a balanced biotic community is most likely the best indicator of watershed conditions because as water moves over and through the land to the stream channel, it acquires and integrates characteristics from the land, especially the soils, topography, and vegetation (Hynes 1970). In general, streams displaying biotic integrity are described as being unimpacted by anthropogenic activities, and are therefore in a "natural" or "pristine" state. Anthropogenic activities such as agriculture, grazing, channelization, urban development, etc., can affect stream conditions and change aquatic habitat and biota that can render a stream "unhealthy" or cause it to have low biotic integrity (Fausch et al. 1984; Karr et al. 1986; Hughes and Gammon 1987). However, not all anthropogenic activities result in degradation, natural disasters such as floods and wildfires may also degrade streams.

Various groups of organisms such aquatic invertebrates (Hilsenhoff 1982) have been useful for assessing biotic integrity, but fish have been more widely used and accepted (Hocutt and Stauffer 1980; Hocutt 1981; Karr 1981). Numerous indices have been proposed to assess water quality using fish community data. These measures include diversity indices of Shannon and Brillioun (Pielou 1975), the Index of Well Being (Gammon 1976), and the relative abundance of desirable species (Coble 1982). These indices are useful in limited situations, but most ignore the complex interdependence of species richness, abundance, and other functions that may be important in assessing condition of an aquatic ecosystem (Karr et al. 1986). The IBI has proven to be a suitable index for detecting various forms habitat degradation and changing watershed conditions on a broad scale (Miller et al. 1988). It has been used to evaluate impacts of agriculture on midwestern streams (Fausch et al. 1984; Karr et al. 1986), influences of sewage, mining, and urbanization on Appalachian streams in West Virginia (Leonard and Orth 1986), impacts of grazing and other events on Colorado streams (Schrader and Fausch 1987), and various cultural impacts in Oregon (Hughes and Gammon 1987).

The IBI integrates 12 measurable attributes (Table 1) of stream fish communities to assess long term changes in habitat quality of a stream (Fausch et al. 1984). This combination of metrics is designed to provide insights from an individual, population, community, ecosystem, and zoogeographic perspective (Karr et al. 1986). Each metric conveys information about the overall structure and function of the stream ecosystem. There are nine primary underlying assumptions of the IBI; "...as perturbation levels increase: (1) the number of all native species and those in specific taxa guilds declines, (2) the number of intolerant species declines, (3) the proportion of individuals that are members of tolerant species increases, (4) the proportion of trophic specialists such as insectivores and top carnivores declines, (5) the proportion of trophic generalists such as omnivores increases, (6) fish abundance generally declines, (7) the proportion of individuals in reproductive guilds requiring silt free coarse spawning substrate declines, and the incident of hybrids may increase, (8) the incidence of externally evident disease, parasites, and morphological anomalies increases, and (9) the proportion of individuals that are members of introduced species increases" (Fausch et al. 1990). All are concerned with how specific attributes of the fish community change in a consistent and characteristic fashion with increasing degradation of the stream (Leonard and Orth 1986).

Application of the IBI requires that data about the fish community be obtained for all of the metrics at each site. Data are then evaluated in relation to what is expected at an unimpacted or relatively unimpacted site on a stream of comparable size located in a similar geographical region. Ratings of 5, 3, and 1 are assigned to each metric according to whether its value approximates or deviates from the value expected at minimally disturbed sites. The sum of the 12 metrics is then used to rate sampling sites. As originally proposed, the range of possible IBI scores is divided into six classes, ranging from excellent to no fish (Table 2).

Table 1.— Metrics used for the original Index of Biotic Integrity as developed for streams in the midwestern United States (from Karr et. al 1986).

Category	Metric	Scoring Criteria[a] 5	3	1
Species richness and composition	1. Total number of fish species	Expectations for metrics 1-5 vary with stream size and region.		
	2. Number and identity of darter species			
	3. Number and identity of sunfish species			
	4. Number and identity of sucker species			
	5. Number and identity of intolerant species			
	6. Proportion of individuals as green sunfish	<5%	5-20%	>20%
Trophic composition	7. Proportion of individuals as omnivores[b]	<20%	20-45%	>45%
	8. Proportion of individuals as insectivorous cyprinids	>45%	20-45%	<20%
	9. Proportion of individuals as piscivores (top carnivores)	>5%	1-5%	<1%
Fish abundance and condition	10. Number of individuals in sample[c]	Expectations for metrics 1-5 vary with stream size and region.		
	11. Proportion of individuals as hybrids	0%	>0-1%	>1%
	12. Proportion of individuals with tumors, fin damage, and skeletal anomalies	0-2%	>2-5%	>5%

[a]Ratings of 5, 3, and 1 are assigned to each metric according to whether its value approximates, deviates somewhat from, or deviates strongly from the value expected at a comparable site that is relatively undisturbed.

[b]Omnivores are defined here as species with diets composed of ≥25% plant material and ≥25% animal material.

[c]Expressed as catch-per-unit effort.

Table 2.— Integrity classes, class attributes, and scoring ranges of the Index of Biotic Integrity (from Karr et al. 1986).

Class	Attributes	IBI Range
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most tolerant forms, are present with full array of age and classes; balanced trophic structure.	58-60
Good	Species richness somewhat below expectations, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52
Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g., increasing frequency of omnivores and green sunfish or other tolerant species); older age classes of top predators may be rare.	40-44
Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22
No Fish	Repeated sampling finds no fish.	

CHAPTER I.

EVALUATION OF AN ADAPTED AND MODIFIED BIOTIC INDEX FOR ASSESSING NEBRASKA SAND HILLS STREAMS

INTRODUCTION

Use of biological monitoring to assess aquatic ecosystems has gained more interest from water resource managers. However, appropriate methods for summarizing and interpreting biological data are limited (Weber 1981; Karr et al. 1986). Historically, it has been assumed that meeting physicochemical standards for water quality would support biotic integrity (Karr and Dudley 1981). This approach has been criticized as being inadequate (Thurston et al. 1979; Karr and Dudley 1981). The IBI proposed by Karr (1981) is designed to evaluate the condition or health of stream ecosystems based on fish assemblages. The IBI integrates information from 12 metrics based on species composition, trophic composition, and health and abundance of fish. Each metric is designed to address several attributes of an ecosystem and the combination of metrics provide insight from an individual, population, community, ecosystem, and zoogeographic perspective (Karr et al. 1986). Metrics are scored by comparison with conditions expected in the absence of disturbances. Summation of the 12 metric scores should model the condition of the aquatic ecosystem being evaluated.

The IBI is based on the assumption that selected fish community attributes change in a consistent and characteristic fashion with increasing stream degradation (Leonard and Orth 1986). The IBI was originally developed for low-gradient, warm water streams affected by intense agricultural activity (Karr 1981), but by design, it can be modified to model stream types in other regions. To date, the IBI has been applied in several geographic regions on a variety of stream types and sizes (Fausch et al. 1984; Angermeier and Karr 1986; Karr et al. 1986; Berkman et al. 1986; Leonard and Orth 1986; Schrader and Fausch 1987; Hughes and Gammon 1987). However, it has been recognized that further testing and evaluation of the IBI is needed in other geographic regions to determine its consistency is assessing biological integrity (Miller et al. 1988).

The objectives for this study were (1) provide a detailed description of the study sites, including pre-1950 fisheries information, (2) evaluate the IBI for assessing biotic integrity of Sand Hills streams and propose modification of metrics where needed, (3) evaluate the temporal stability of a modified IBI seasonally and between sampling years, (4) evaluate seasonal effects of changes in fish communities as they relate to index scores, and (5) examine the effects of longitudinal changes in fish communities on index scores.

METHODS

Study Area

I focused my study on the Loup and Niobrara drainage basins in the Sand Hills of northcentral Nebraska (Figure 1). This region encompasses approximately 49,987 square km, is the largest sand dune area in the western hemisphere, and is one of the largest grass stabilized dune regions in the world (Bleed and Flowerday 1989). These dunes are estimated to be only 8,000 years old. Streams in this region have few

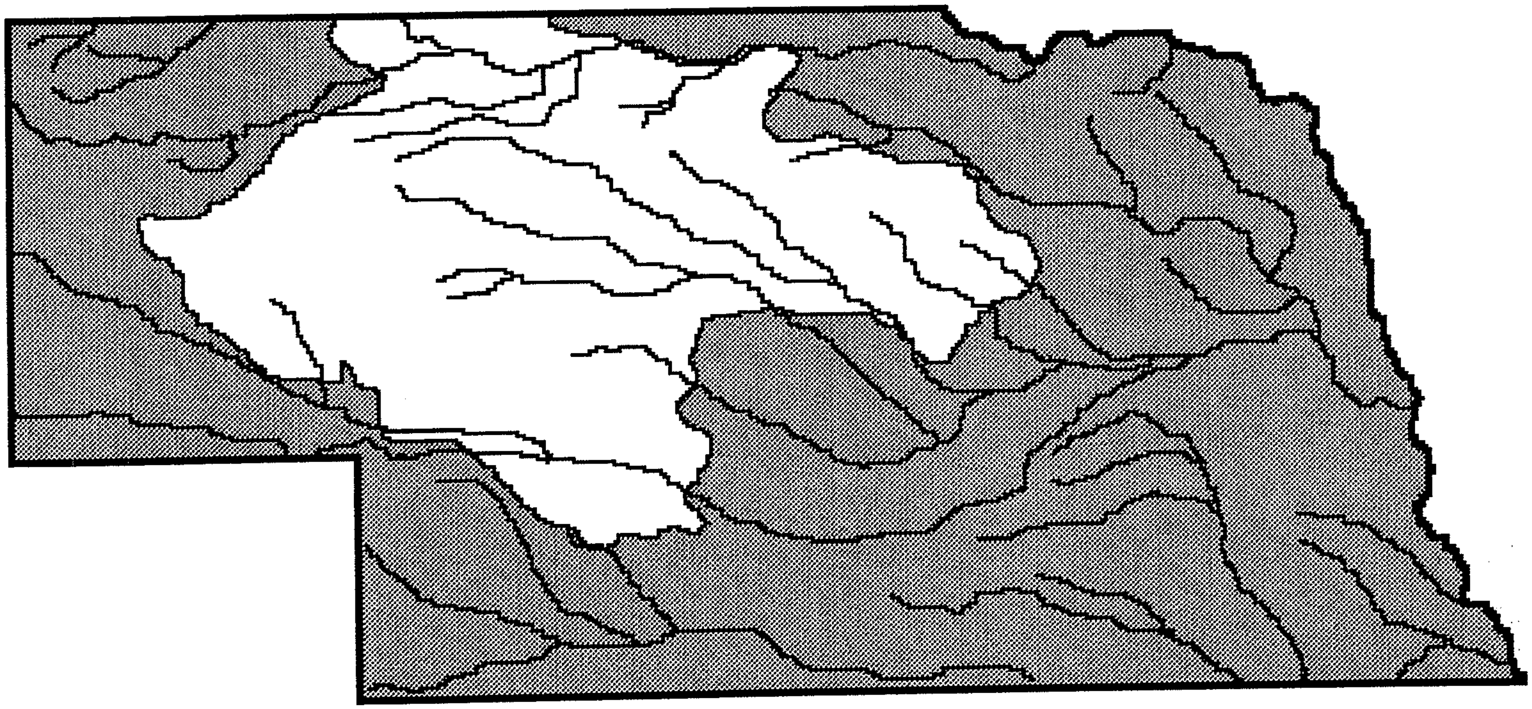

Figure 1.— Sand Hills ecoregion in northcentral Nebraska (from Omernik 1987).

tributaries, their discharge is remarkably constant, flooding is rare, and anthropogenic disturbances are minimal (Bentall 1989). A key factor affecting the presence and distribution of fish species in Sand Hills streams is the stability of their habitat (Hrabik 1989). This stability can be attributed to the hydrologic regimes of these streams. Overland runoff in this region is rare because the sandy Valentine soils enhance percolation of water. Even during heavy downpours, the precipitation is absorbed by these soils and transmitted to the groundwater. In turn the groundwater provides streams and rivers with a source of high quality water that is relatively constant in quantity and temperature (Bentall 1989). These conditions appear to provide aquatic life with a relatively stable environment that should be reflected in the fish communities.

Fish Community Data

Because the Sand Hills region is a large, remote area, aquatic fauna distributions are poorly known. In the late 1890's Evermann and Cox (1896) reported sampling a few streams in the eastern portion of this region but only provided general information on sampling localities and species collected. Johnson (1942) sampled numerous streams throughout the Sand Hills and in 1972 the Nebraska Game and Parks Commission resampled many of Johnson's same areas, however, fish specimens collected were not retained for verification. (Bliss and Schainost 1973a; Bliss and Schainost 1973b). For comparison, I have included a summary of Johnson's and Evermann and Cox's collections where sampling localities are believed to be close to sampling sites in this study (Appendix A). Data used in this study were collected from 37 Sand Hills stream sites (Figure 2) between 1983 and 1988. Seasonal data used were collected during May, July, and October, 1989 (Appendix F) from 20 sites at localities shown in Figure 3.

Sampling procedures followed those outlined in Karr et al. (1986) and Angermeier and Karr (1986). Each sample was taken from a stream reach on one day using a backpack electrofishing unit. Although fish collection procedures were standardized, effort varied substantially between sites due to variations in stream size and habitat conditions. Each sample included at least two riffle--pool--run sequences if possible. Fish captured were identified, counted by species, and recorded in the field. Representative samples and specimens requiring verification were preserved in ten percent formalin and returned to the laboratory. Taxonomic keys employed in identification of fish species included: Becker (1983), Pflieger (1975), and Trautman (1981) following scientific names in Robins et al. (1991). Table 3 summarizes information regarding origin (native or introduced), trophic guild, and relative tolerance status of fish species (Nebraska Department of Environmental Control, NDEC 1991).

Scoring of the Adapted and Modified Fish Community Metrics

All twelve of the original IBI metrics (Karr 1981; Karr et al. 1986) were adapted to regional conditions and used in the first phase of this evaluation (Table 4).

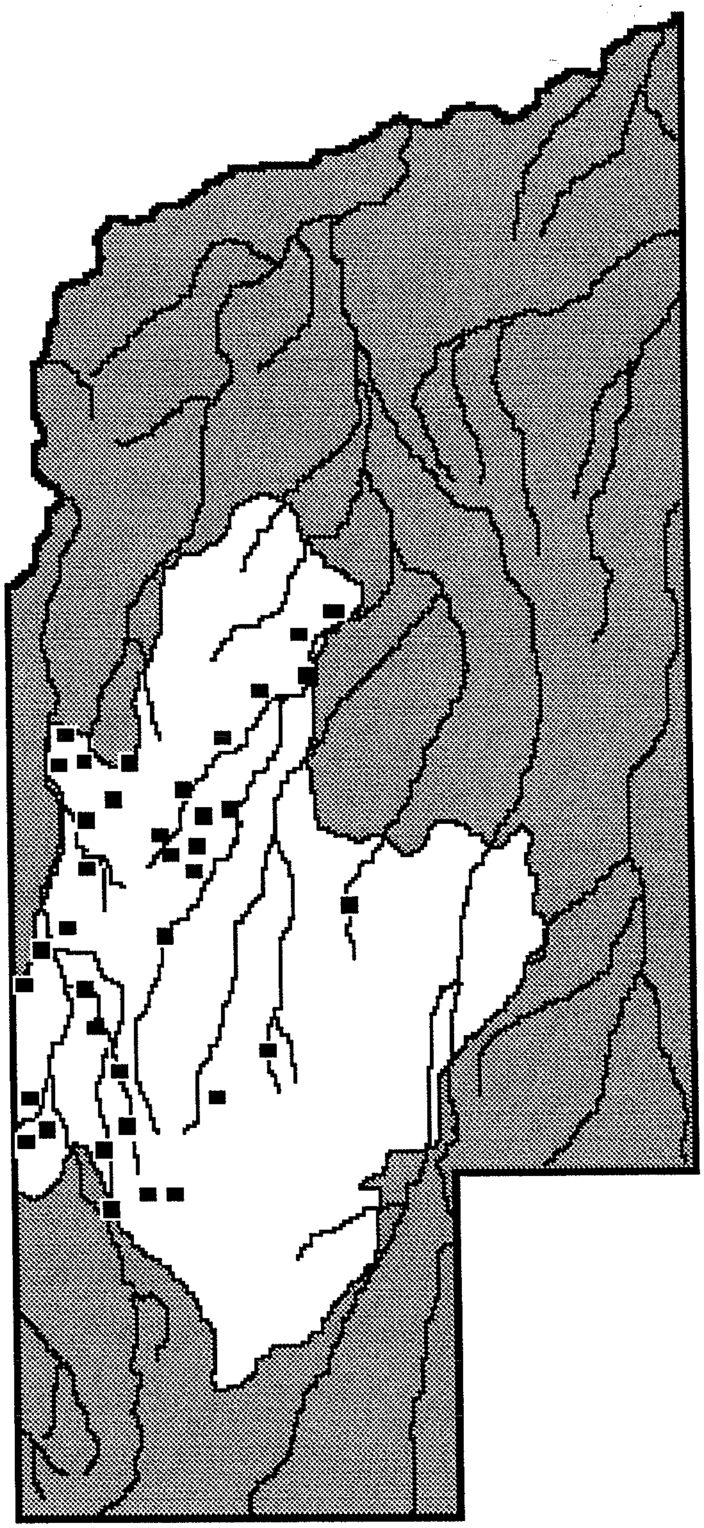

Figure 2.— Major streams and sampling sites in the Sand Hills ecoregion (Omernik 1987) in northcentral Nebraska.

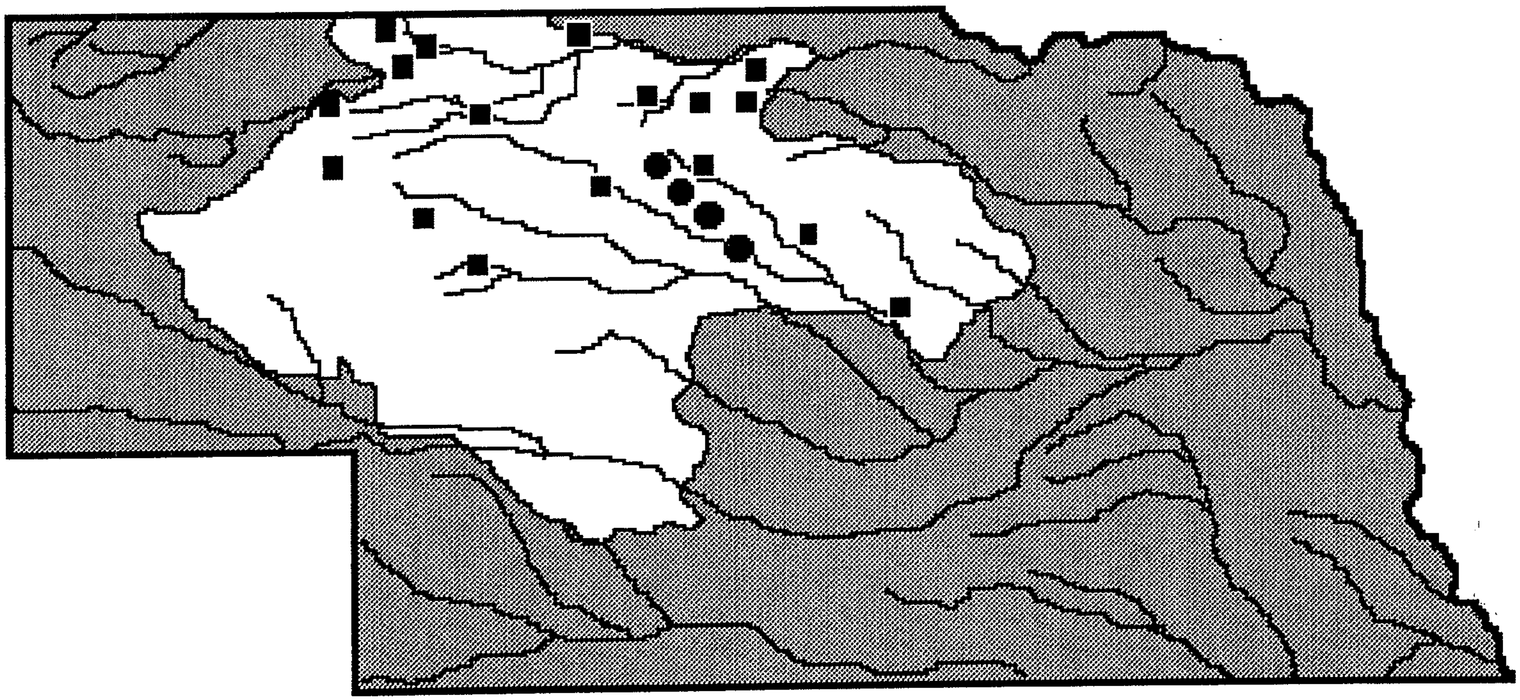

Figure 3.— Collection sites sampled during May, July and October, 1989 (▪), including sites along Goose Creek used to evaluate longitudinal variability (•).

Table 3.— Family and species represented in Sand Hills stream collections along with species origin, assigned trophic status and relative tolerance category (NDEC 1991).

Family/Species	Origin[1]	Trophic[2] Guild	Relative[3] Tolerance
Clupeidae			
Dorosoma cepidianum	N	O	MT
Esocidae			
Esox americanus	N	C	I
Esox lucius	N	C	I
Salmonidae			
Salmo trutta	I	G	I
Salvelinus fontinalis	I	G	I
Oncorhynchus mykiss	I	G	I
Cyprinidae			
Campostoma anomalum	N	H	MT
Cyprinella lutrensis	N	I	T
Cyprinus carpio	I	O	T
Hybognathus hankinsoni	N	H	MT
Hybopsis gracilis	N	I	MT
Margariscus margarita	N	I	I
Notemigonus crysoleucas	N	O	MT
Notropis dorsalis	N	BI	MT
Notropis heterolepis	N	I	I
Notropis stramineus	N	I	T
Notropis topeka	N	I	I
Phoxinus eos	N	I	I
Phoxinus neogaeus	N	I	I
Phoxinus eos X *P. neogaeus*	N	I	I
Pimephales promelas	N	O	T
Rhinichthys atratulus	N	BI	I
Rhinichthys cataractae	N	BI	I
Semotilus atromaculatus	N	G	T

[1]Origin: N = Native; I = Introduced

[2]Trophic Guild: I = Insectivore; BI = Benthic Insectivore; O = Omnivore; C = Carnivore; G = Generalist; H = Herbivore

[3]Relative Tolerance: I = Intolerant; MT = Moderately Tolerant; T = Tolerant

Table 3.— continued.

Family/Species	Origin[1]	Trophic[2] Guild	Relative[3] Tolerance
Catostomidae			
Carpiodes carpio	N	O	T
Carpiodes cyprinus	N	O	T
Catostomus commersoni	N	I	T
Moxostoma macrolepidotum	N	BI	MT
Ictaluridae			
Ameiurus melas	N	BI	T
Ictalurus punctatus	N	G	MT
Noturus flavus	N	I	MT
Fundulidae			
Fundulus sciadicus	N	I	I
Gasterosteidae			
Culaea inconstans	N	I	I
Centrarchidae			
Ambloplites rupestris	I	C	I
Lepomis cyanellus	N	G	T
Lepomis humilis	N	I	MT
Lepomis macrochirus	N	I	MT
Micropterus salmoides	N	C	MT
Pomoxis nigromaculatus	N	G	MT
Percidae			
Etheostoma exile	N	I	I
Perca flavescens	N	I	MT

[1]Origin: N = Native; I = Introduced
[2]Trophic Guild: I = Insectivore; BI = Benthic Insectivore; O = Omnivore; C = Carnivore; G = Generalist; H = Herbivore
[3]Relative Tolerance: I = Intolerant; MT = Moderately Tolerant; T = Tolerant

Table 4.— Adapted Index of Biotic Integrity metric scoring criteria for Sand Hills streams (modified from Karr et. al 1986).

Category	Metric	Scoring Criteria[a] 5	3	1
Species Richness	1. Total number of fish species and composition	Varied	Varied	Varied
	2. Number and identity of darter species	1	0	—
	3. Number and identity of sunfish species	≥2	1	0
	4. Number and identity of sucker species	≥1	0	—
	5. Number and identity of intolerant species	≥2	1	0
	6. Proportion of individuals as green sunfish	<5%	5-20%	>20%
Trophic Composition	7. Proportion of individuals as omnivores[b]	<20%	20-45%	>45%
	8. Proportion of individuals as insectivorous cyprinids	>45%	20-45%	<20%
	9. Proportion of individuals as piscivores (top - carnivores)	>5%	0-5%	—
Fish Abundance and Condition	10. Number of individuals in sample	>5	2-5	<2
	11. Proportion of individuals as hybrids	0%	>0-1%	>1%
	12. Proportion of individuals with tumors, fin damage, and skeletal anomalies	0-2%	>2-5%	>5%

[a]Ratings of 5, 3, and 1 were assigned to each metric according to whether its value approximated or deviated from the value expected at an undisturbed site.

[b]Omnivores are defined as species taking at least 25% plant material and 25% animal material.

Criteria proposed by Fausch et al. (1984) and Karr et al. (1986) were followed to score all metrics. The first five metrics, total number of fish species, number of darter species, number of sunfish species, number of sucker species, and number of intolerant species require adjustment for stream size and local faunal characteristics. This was accomplished by plotting numbers for each metric as a function of stream order (Strahler 1957) for each of the 37 sites sampled (e.g., Figure 4). Where appropriate, lines were then fitted visually to divide the sites into three scoring classes ; best (5), fair (3), and worst (1) in order of decreasing species richness. The adapted IBI metrics and scoring criteria for Sand Hills streams are summarized in Table 4 and fish community attribute information is provided in Appendix B.

To make the IBI more sensitive to the unique stream and faunal characteristics of the Sand Hills I modified the metrics proposed by Karr (1981). The resultant modified index (MIBI) retains ten of the original 12 metrics; seven of which are unchanged and three which were either modified or replaced with suitable substitutes (Table 5). Possible scores for the MIBI range from 10 to 50 and are divided into six classes, ranging from excellent to no fish (Table 6). Information used in scoring the MIBI metrics is provided in Appendix C and a detailed description of the metrics follows.

Metric 1. Total number of fish species. The number of fish species supported by streams similar in size and exhibiting like features in a given region should

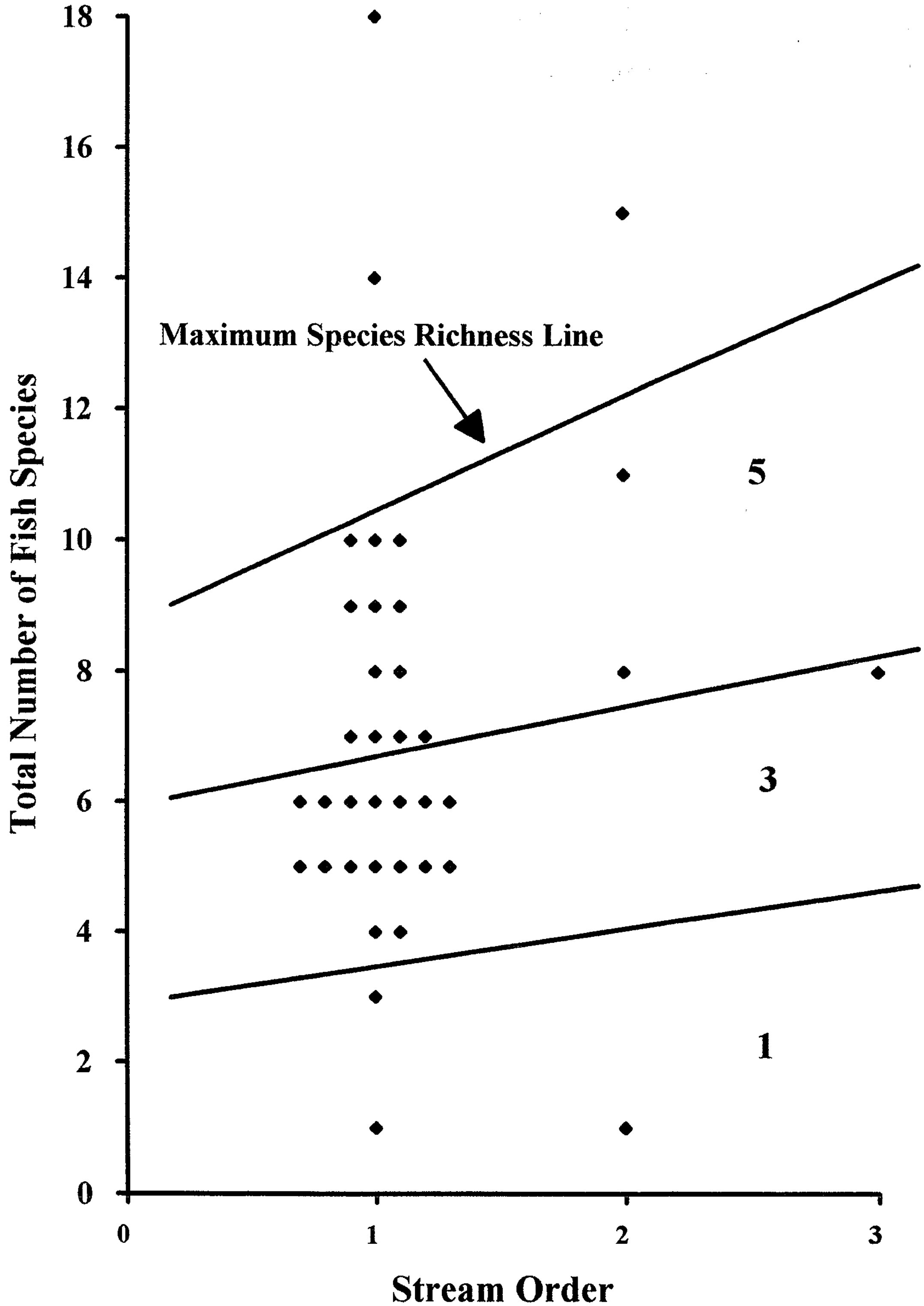

Figure 4.- Total number of fish species as a function of stream order for 37 sites in the Sand Hills region of northcentral Nebraska.

Table 5.— Modified IBI metrics for assessing Sand Hills streams.

Category	Metric	Type[b]	Scoring Criteria[a] 5	3	1
Species Richness	1. Total number of fish	1	>5	3-5	$\leq$2
	species and composition	2	>6	4-6	$\leq$3
	2. Presence of a specialized		Present	—	Absent
	feeder		>3	2-3	$\leq$1
	3. Number and identity of	1	>4	3-4	$\leq$2
	native cyprinids	2			
	4. Number and identity of intolerant species		$\geq$2	1	0
	5. Proportion of individuals as creek chubs		<5%	5-20%	>20%
Trophic Composition	6. Proportion of individuals as omnivores[c]		<20%	20-45%	>45%
	7. Proportion of individuals as insectivorous cyprinids		>45%	20-45%	<20%
Fish Abundance and Condition	8. Number of individuals in sample[d]		>5	2-5	<2
	9. Proportion of individuals as hybrids		0%	>0-1%	>1%
	10. Proportion of individuals with tumors, fin damage, and skeletal anomalies		0-2%	>2-5%	>5%

[a]Ratings of 5, 3, and 1 were assigned to each metric according to whether its value approximated or deviated from the value expected at an undisturbed site.

[b]Scoring criteria differed for stream types as described in text.

[c]Omnivores are defined as taking at least 25% plant material and 25% animal material.

[d]Expressed as catch-per-unit effort; minutes were used in this study.

Table 6.— Scores for and attributes of integrity classes for the adapted IBI and the modified IBI.

Class	Attributes	Adapted	Modified
Excellent	Comparable to the best situations without influence of man; all regionally expected species for the habitat and stream size, including the most tolerant forms, are present with full array of age and classes; balanced trophic structure.	58-60	48-50
Good	Species richness somewhat below expectations, especially due to loss of most intolerant forms; some species with less than optimal abundances or size distribution; trophic structure shows some signs of stress.	48-52	38-42
Fair	Signs of additional deterioration include loss of intolerant forms, fewer species, highly skewed trophic structure (e.g., increasing frequency of omnivores and green sunfish or other tolerant species); older age classes of top predators may be rare.	40-44	30-34
Poor	Dominated by omnivores, tolerant forms, and habitat generalists; few top carnivores; growth rates and condition factors commonly depressed; hybrids and diseased fish often present.	28-34	18-24
Very Poor	Few fish present, mostly introduced or tolerant forms; hybrids common; disease, parasites, fin damage, and other anomalies regular.	12-22	<18
No Fish	Repeated sampling finds no fish.		

Note: Sites falling between classes may be assigned to an appropriate class by an informed biologist (Karr et al. 1986).

decrease with environmental degradation (Karr et al. 1986). As previously described, in the first phase of this study, stream order was utilized to define the relationship between species richness and stream size. The Sand Hills is primarily represented by low order streams and the majority included in this study were of the first order. Scoring criteria for this metric varies for individual streams sites (Figure 4).

To score MIBI metrics I propose using "stream type" as a predictor of species richness. Two general stream characteristics, dominant substrate and discharge velocity, were used to categorize streams. The classification categories proposed are: Type I - streams exhibiting higher discharge velocities, and substrates are generally shifting sand free of silt and organic matter, and Type II - streams which exhibit slower discharge velocities, and silt and organic matter are able to settle, especially in pools. This approach, at least in the streams I studied, appears to be a more appropriate method for predicting species richness (Appendix C). In "Type I" streams, overall species richness is expected to be lower because it appears fewer microhabitats exist compared to "Type II" streams. Scoring criteria using this concept varies with stream type (Figure 5).

Metric 2. Number of darter species. Species belonging to the subfamily Etheostomidae of the family Percidae are used in the scoring this metric. Because of their specificity for reproduction and feeding in benthic habitats, darters are particularly sensitive to degradation (Karr et al. 1986). Scoring criteria for this metric

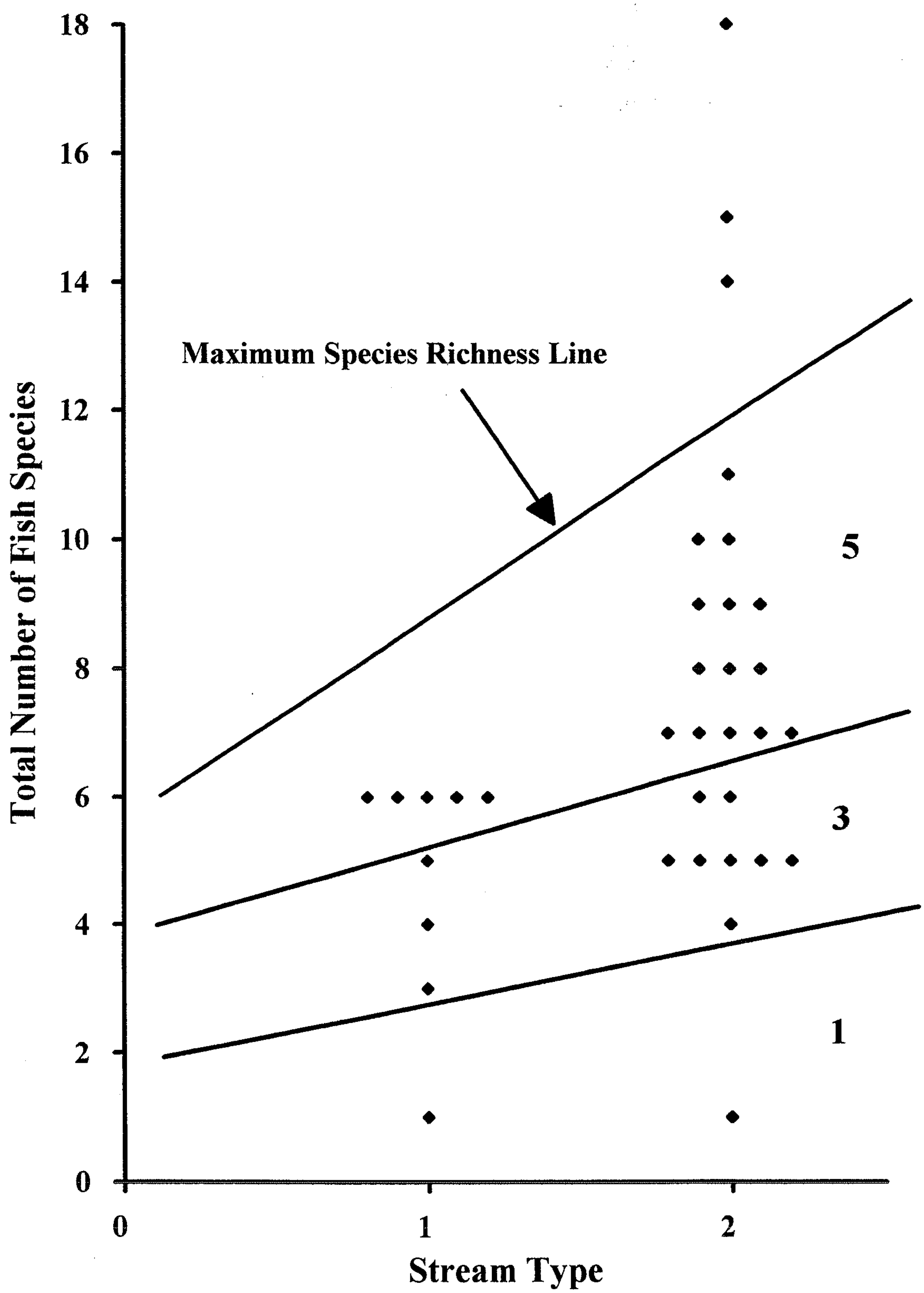

Figure 5.- Total number of fish species as a function stream type for 37 sites in the Sand Hills region of northcentral Nebraska.

were determined solely by the presence or absence of the Iowa darter (*Etheostoma exile*). A score of 5 was assigned if this species was present or a 3 if not present. Absence of this species is not necessarily indicative of degraded conditions.

In the MIBI I modified this metric because I felt its usefulness as an indicator of degradation was limited. Iowa darters are not expected in all streams. Metric modifications were based on recommendations by Karr et al. (1986) and Leonard and Orth (1986) who suggest that when richness of darter species is low, the metric can be replace by using another specialized feeder. Instead of totally replacing darters with another species, I chose to include it along with two additional specialized feeders *Rhinichthys cataractae* and *R. atratulus*. *Rhinichthys cataractae* is common throughout the Sand Hills while and *R. atratulus* is more common in the northeastern portion. Though these species may be found together, their usefulness as environmental indicators for this metric stems from the fact that they are generally found under different stream conditions. A score of 5 was assigned if any of these species was present at a site or a 1 if none was present.

Metric 3. Number of sunfish species. This metric includes green sunfish (*Lepomis cyanellus*), but excludes largemouth bass (*Micropterus salmoides*). Sunfish are used in this metric as indicators of pool and other instream conditions because their populations decline with degradation of such habitats (Karr et al. 1986). I adjusted the scoring criteria for this metric because only five sunfish species were collected among all collection sites and only two or more species were found at six of the 37 sites. A score of 5 was assigned if two or more species was present, 3 if one was present, and a 1 if none.

In the MIBI I replaced this metric because overall numbers of sunfish species were low and individual abundances of species were sporadic over all study sites. In addition, the origin of two species, rock bass (*Ambloplites rupestris*) and bluegill (*Lepomis macrochirus*) are questionable. Karr et al. (1986) and Hughes and Gammon (1987) suggest that a substitute for this metric in small streams may be the total number of native cyprinids. Species belonging to the family Cyprinidae were the most common and abundant for all sites studied; making this an appropriate substitute. In "Type I" streams a score of 5 was assigned if more than three species of cyprinids were present, 3 if there were two or three species, and 1 if there were one or fewer. In "Type II" streams a score of 5 was assigned if more than four species were present, 3 if there were three or four species, and 1 if there were two or fewer.

Metric 4. Number of sucker species. All members of the family Catostomidae are included in this metric because many species are intolerant of habitat and chemical degradation (Karr et al. 1986). Adjusting the scoring criteria for this metric was necessary because only four species was collected among all collection sites and more than two species was supported by only one of 37 sites. A score of 5 was assigned if one or more species was present and 3 if not present since the absence of these species is not necessarily indicative of degraded conditions in this region. I eliminated this metric from the MIBI because species diversity was low and a suitable replacement for this metric could not be found in this region.

Metric 5. Number of intolerant species. This metric includes intolerant species from all families. Species of many families are intolerant of various types of degradation (from Karr et al. 1986). Seventeen of the 40 species collected during this study have been classified as being intolerant (Table 3). The maximum number of intolerant species collected at a site on a single date was six, and the mode for all sampling dates was two. A score of 5 was assigned if two or more intolerant species were present, 3 if one was present, and 1 if none. In the MIBI this metric and its scoring criteria remained unchanged.

Metric 6. Proportion of individuals as green sunfish. The green sunfish (*Lepomis cyanellus*), is known to increase in relative abundance in degraded streams throughout the midwest and may increase from an incidental to the dominant species (Karr et. al 1986). Because this species was collected at almost 50% of sampling sites, scoring criteria for this metric remained the same for Sand Hills streams as those proposed for midwest streams by Karr et al. (1986). A score of 5 was assigned if the community was represented by less than 5% of green sunfish, 3 if the range was between 5 and 20%, and 1 if they represented more than 20% of the fish collected.

Though green sunfish were commonly found at several study sites, I replaced it in the MIBI with the creek chub (*Semotilus atromaculatus*) because it was found under a wider range of stream types. Based on these observations, the usefulness of creek chub as an environmental indicator appears to be more appropriate than green sunfish in the Sand Hills.

Metric 7. Proportion of individuals as omnivores. Omnivores are defined here as fish species whose diets consist of at least 25% plant and 25% animal material. Omnivores are used as indicators because their opportunistic foraging habits makes them more successful than specialized foragers when specific components of the food base becomes less reliable and enables them to become more dominant in the community (Karr et al. 1986). Scoring criteria for this metric remained the same for Sand Hills streams as those proposed for midwest streams by Karr et al. (1986). A score of 5 was assigned if the community was represented by less than 20% of omnivores, 3 if the range was between 20 and 45%, and 1 if they represented more than 45% of the fish collected. In the MIBI this metric and its scoring criteria remained unchanged.

Metric 8. Proportion of individuals as insectivorous cyprinids. Insectivorous cyprinids are used as an indicator in this metric because their relative abundances decrease with water and habitat quality degradation. A score of 5 was assigned if the community was comprised of more than 45% insectivorous cyprinids, 3 if the range was between 20 and 45%, and 1 if they represented less than 20% of the fish collected (Karr et al. 1986). In the MIBI this metric and its scoring criteria remained unchanged.

Metric 9. Proportion of individuals as piscivores. This metric includes all species in which the adults are predominantly piscivorous. Viable and healthy populations of top carnivores are generally an indicator of a trophically diverse community (Karr et al. 1986). Adjusting the scoring criteria for this metric took into account that most of the streams included in this study were headwaters where piscivores are not expected to be abundant. A score of 5 was assigned if the community was represented by more than 5% piscivores and 3 if the range was between 0 and 5% of the fish collected. Absence of this trophic group is not necessarily indicative of degraded conditions. I eliminated this metric from the MIBI because few top carnivores are expected in the headwater streams I studied.

Metric 10. Number of individuals in a sample. This metric evaluates populations and is expressed as catch per unit effort (fish per minute in this study). Sites of lower quality are generally expected to yield fewer individuals than higher quality sites (Karr et al. 1986). A score of 5 was assigned if more than 5 individuals were captured per minute, 3 if the range was between 2 and 5, and 1 if less than 2. In the MIBI this metric and its scoring criteria remained unchanged.

Metric 11. Proportion of individuals as hybrids. This metric evaluates the extent to which degradation has altered reproductive isolation among species that can lead to increased frequency of hybridization (Karr et al. 1986). This metric is often omitted because of the difficulty in identifying hybrids. I retained this metric in both because it is unlikely that habitat quality in most Sand Hills streams has been reduced to the degree that it causes increased hybridization. I found hybrids in between *Phoxinus eos* and *P. neogaeus* in two streams. Joswiak et al. (1982 and 1984) report that these hybrids are generally females and it has been shown they can be parthenogenic. They also suggest that the original disturbance that resulted in this hybridization may have occurred prior to any human disturbance. For these reasons, *Phoxinus* hybrids collected were not used in the calculation of IBI scores nor did these sites receive lower scores. Following the scoring criteria proposed by Karr et al. (1986) a score of 5 was assigned if no other hybrids were represented in the community, a 3 if the range was between 0 and 1%, and 1 if they represented more than 1% of the fish collected. In the MIBI this metric and its scoring criteria remained unchanged.

Metric 12. Proportion of individuals with tumors, fin damage, and skeletal anomalies. Severely degraded sites often yield high numbers of fish in poor health; often represented by fish with tumors, fin damage or other deformities, parasites, discoloration, excessive mucous, and hemorrhaging (Karr et al. 1986). A score of 5 was assigned if the proportion of individuals with tumors, fin damage, and skeletal anomalies was between 0 to 2%, 3 if the range was between 2 and 5%, and 1 if the proportion was greater than 5% of the fish collected. In the MIBI this metric and its scoring criteria remained unchanged.

DATA ANALYSIS

Relationships between each metric and the adapted IBI and MIBI scores were examined using Kendall's tau (τ), a nonparametric correlation coefficient. First, this analysis was performed on the raw metric data (Appendices D and E), then each metric was omitted sequentially from the IBI and MIBI calculations and the omission scores were compared with scores initially calculated. This procedure made it possible to gauge the relative contribution of each metric after it was scored according to its established contribution. Finally, correlation between adapted IBI and MIBI with H' values were evaluated using Spearman's rho (r_s) and τ. Diversity indices such as H' have commonly been used to summarize community data and formulate water quality assessments (Wilhm and Dorris 1968; Kaesler et al. 1978). Since H' incorporates both species richness and evenness, which are assumed to be positively correlated with biotic or ecological integrity (Angermeier and Schlosser 1987), I wanted to examine its relationship with the adapted IBI and modified IBI. Shannon-Weiner diversity index values were calculated as:

$$H' = -\sum_{i=1}^{N} P_i(\log_e P_i);$$

Note: P_i is the proportion (usually of individuals) that species i contributes to the entire community (Appendices B and C).

Stability of the MIBI at predicting site conditions seasonally and between sampling years was assessed using analysis of variance (ANOVA), τ and r_s. Effects of longitudinal variation in fish communities on MIBI scores from four locations along a single Sand Hills stream was also evaluated using ANOVA. All data analysis was preformed using SAS Institute Inc. (1989) statistical software.

RESULTS

A total of 14,159 fishes representing 40 species and 10 families was sampled from 37 Sand Hills stream localities in the Sand Hills (Table 3). The family Cyprinidae was represented by the most species (17), comprising 84 percent of the total fishes collected (Table 7).

Total adapted IBI scores ranged from 38 (fair) to 54 (good) (Figure 6; Appendix D), and MIBI scores ranged from 28 (fair) to 50 (excellent) (Figure 7; Appendix E). Based on assessment of stream habitat quality that included evaluations of instream cover, streambank stability, flow fluctuation, riffle/run/pool quality, and substrate, conducted at each study site, the MIBI predicted conditions most accurately. The MIBI also showed greater sensitivity in distinguishing site quality across the range

Table 7.— Frequency, total number of individuals, and percentages of fish species collected.

Species	Frequency of Occurrence	Total Number Collected	Percent of Total Individuals
Rhinichthys cataractae	63%	2181	15%
Semotilus atromaculatus	60%	922	7%
Pimephales promelas	60%	962	7%
Fundulus sciadicus	55%	708	5%
Catostomus commersoni	55%	870	6%
Notropis dorsalis	50%	1881	13%
Notropis stramineus	50%	2082	15%
Lepomis cyanellus	48%	239	2%
Hybognathus hankinsoni	43%	1938	14%
Ameiurus melas	35%	44	<1%
Phoxinus eos	28%	112	1%
Cyprinella lutrensis	28%	273	2%
Etheostoma exile	25%	76	<1%
Margariscus margarita	25%	469	3%
Noturus flavus	25%	61	<1%
Phoxinus neogaeus	25%	392	3%
Micropterus salmoides	23%	40	<1%
Cyprinus carpio	20%	68	<1%
Culaea inconstans	18%	37	<1%
Campostoma anomalum	15%	477	3%
Esox americanus	15%	28	<1%
Lepomis humilis	15%	15	<1%
Lepomis macrochirus	15%	25	<1%
Salmo trutta	15%	24	<1%
Esox lucius	10%	14	<1%
Moxostoma macrolepidotum	10%	36	<1%
Perca flavescens	10%	33	<1%
Carpiodes carpio	8%	6	<1%
Hybopsis gracilis	8%	15	<1%
Ictalurus punctatus	8%	4	<1%
Ambloplites rupestris	5%	8	<1%
Notemigonus crysoleucas	5%	20	<1%
Oncorhynchus mykiss	5%	21	<1%
Phoxinus eos X *P. neogaeus*	5%	8	<1%
Pomoxis nigromaculatus	5%	6	<1%
Salvelinus fontinalis	5%	22	<1%
Carpiodes cyprinus	3%	1	<1%
Dorosoma cepidianum	3%	1	<1%
Notropis heterolepis	3%	4	<1%
Notropis topeka	3%	2	<1%
Rhinichthys atratulus	3%	34	<1%

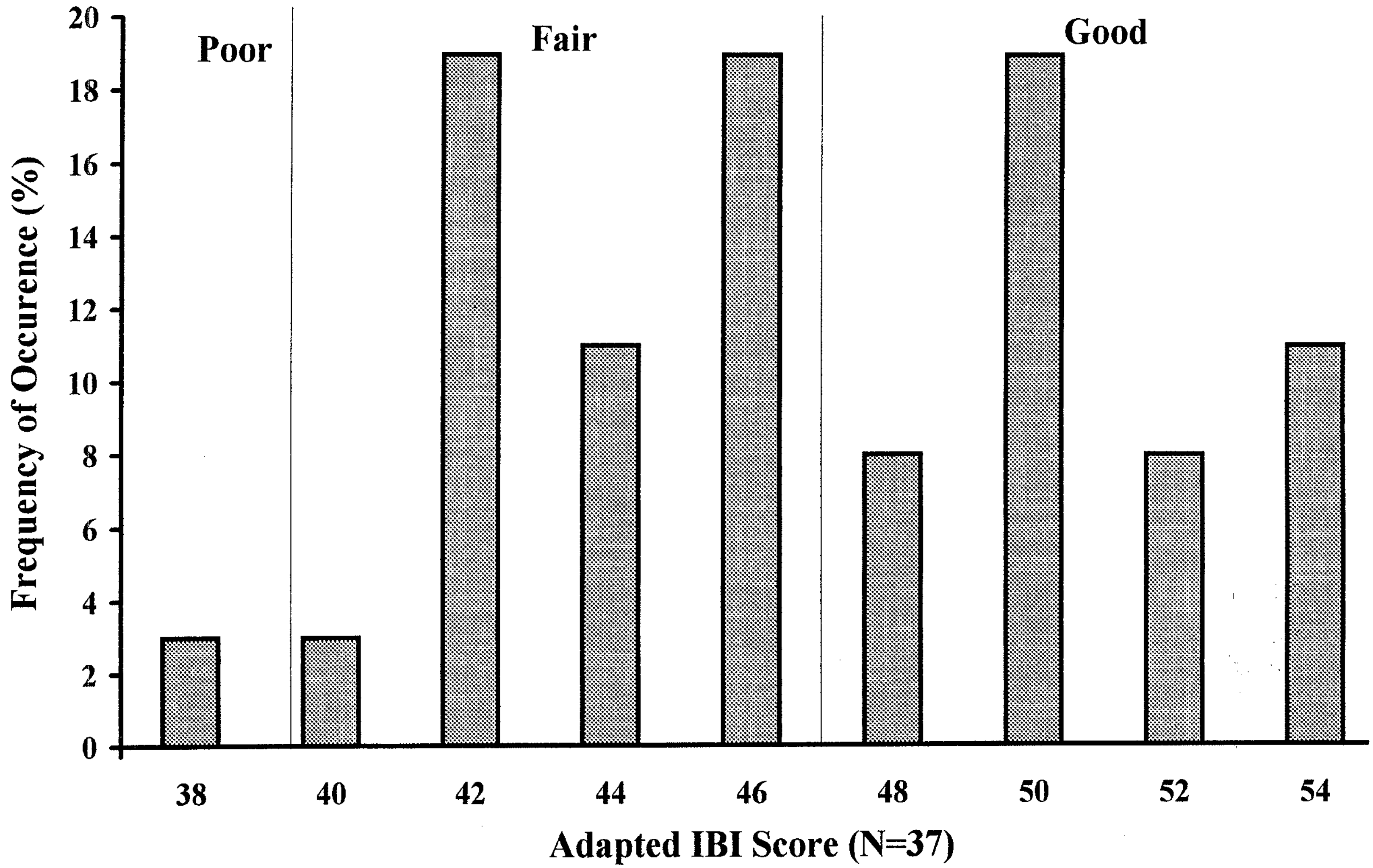

Figure 6.-Distribution of adapted Index of Biotic Integrity (IBI) scores and classes for 37 sites in the Sand Hills region of northcentral Nebraska.

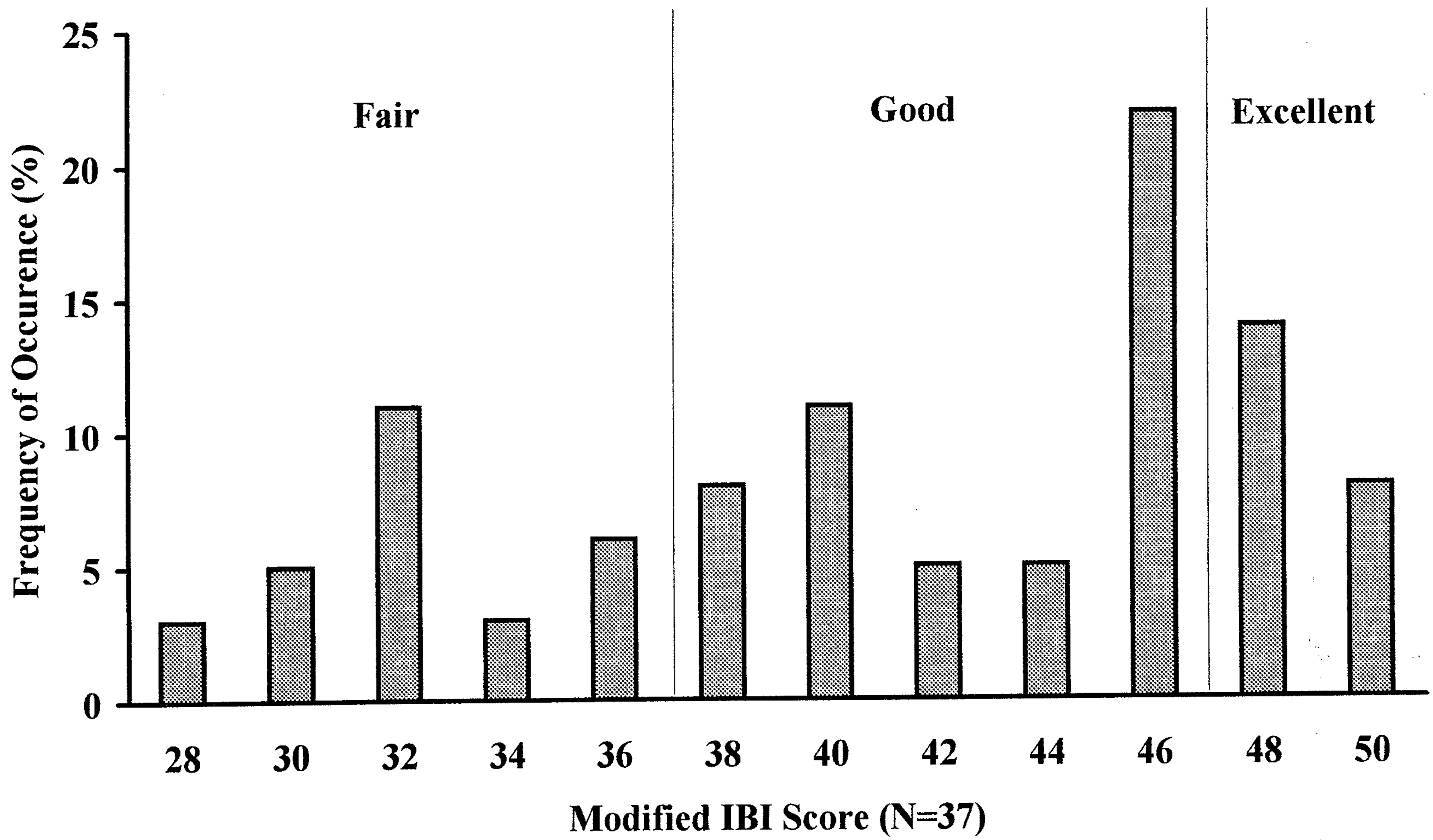

Figure 7.-Distribution of Modified Index of Biotic Integrity (MIBI) scores and classes for 37 stream site localities in the Sand Hills region of northcentral Nebraska.

of stream types encountered and accurately classified streams into appropriate integrity categories. No correlation existed between actual habitat evaluation scores and adapted IBI or MIBI scores; this inconsistency is most likely related to the qualitative and subjective nature of the habitat evaluations.

Significantly correlations were expected (positively or negatively) between MIBI metrics and MIBI scores. However, significant correlations were not expected between adapted IBI metrics and adapted IBI scores since their applicability and sensitivity in assessment of local conditions was questionable. With the exception of invariant metrics, only five adapted IBI metrics significantly correlated with the adapted IBI scores (Table 8). Adapted metrics not significantly correlated included; number of sunfish species, number of sucker species, proportion as omnivores, proportion as insectivorous cyprinids, and total number of individuals. All but two MIBI metrics; proportion as creek chubs and proportion as omnivores, significantly correlated with MIBI scores (Table 8). Because these two metrics can indicate declining biotic integrity their lack of correlation with the MIBI is good evidence that most streams studied were relatively unimpacted. Adapted metrics uncorrelated with the adapted IBI included all those that were either modified, deleted, or had their scoring criteria adjusted, to better reflect faunal characteristics of Sand Hills streams.

The relative contribution of adapted and modified metrics to adapted IBI and MIBI scores were evaluated by comparing final index scores with an index from

Table 8.— Coefficients of correlation (Kendall's tau) between individual metric scores and adapted IBI and modified IBI scores for 37 Sand Hills stream sites. An asterisk indicates the coefficient is significant ($P<0.05^*$).

Adapted / Modified Metrics	Adapted IBI (τ) (N=37)	Modified IBI (τ) (N=37)
Total number of species	0.408*	0.543*
Number of darter species / specialized feeders	0.321*	0.572*
Number of sunfish species / native cyprinids	0.023	0.690*
Number of sucker species	0.067	---
Number of intolerant species	0.378*	0.512*
Proportion as green sunfish / creek chubs	0.321*	-0.062
Proportion as omnivores	0.000	0.210
Proportion as insectivorous cyprinids	0.224	0.514*
Total number of individuals	-0.255	0.707*
Proportion as piscivores	0.516*	---
Proportion as hybrids	1.000*	1.000*
Proportion having anomalies	1.000*	1.000*

which a particular metric score was omitted. Where individual metrics were omitted, the adapted IBI and MIBI scores were 5, 3, or 1, units lower than original scores. Significant correlations were found between all metrics and both indices (Tables 9). The high correlations observed indicate that individual metrics omitted contribute little information to the overall final assessment, but each is important to the final index score.

No correlation existed between *H′* and the adapted IBI (r_s = 0.289, τ = 0.194) or MIBI (r_s = 0.137, τ = 0.106). This result was expected since diversity indices like *H′* only take into account numbers of individuals and evenness among species. For instance, Type I Sand Hills streams generally exhibit relatively low species richness. A diversity index would falsely categorize most sites as having low biotic integrity. This illustrates the utility of a multi-metric index that integrates and combines several different attributes of a fish community in the assessment process.

Table 9.— Coefficients of correlation (Kendall's tau) between adapted IBI and modified IBI scores with scores for which individual metrics were omitted from the computation for 37 Sand Hills stream sites.

Omitted Variable	Adapted IBI (τ) (*N*=37)	Modified IBI (τ) (*N*=37)
Total number of species	0.916	0.973
Number of darter species / specialized feeders	0.971	0.923
Number of sunfish species / native cyprinids	0.898	0.962
Number of sucker species	0.922	---
Number of intolerant species	0.894	0.944
Proportion as green sunfish / creek chubs	0.928	0.905
Proportion as omnivores	0.957	0.979
Proportion as insectivorous cyprinids	0.817	0.919
Total number of individuals	0.959	0.947
Proportion as piscivores	0.896	---
Proportion as hybrids	1.000	1.000
Proportion having anomalies	1.000	1.000

Stability of the MIBI

Sand Hills fish data were analyzed to determine whether the MIBI rated sites similarly among seasons sampled and between sampling years (site 34 was excluded because it was pooled in October of 1989). Calculated MIBI scores for individual sample sites (Table 10) showed no specific pattern, either increasing or decreasing across seasons or years (Figure 8 and 9). A *F*-test performed on mean MIBI scores for seasons spring (May - 41.8), summer (July - 42.6), and fall (October - 41.7) showed they were not significantly different ($P<0.05$) ($F = 0.11$; 2 df; $P = 0.8982$). Mean seasonal MIBI scores for seventeen sites were also compared to first year samples taken in 1987 and 1988 at the same localities. Index scores for only two of the seventeen sites varied more than 5 points. A *F*-test on ranks by season performed on the raw metric data showed study sites ranked similarly across seasons, with only one metric, proportion of omnivores, being significantly different ($P<0.05$) (Table 11). First year data was then included in this analysis to determine if MIBI metrics ranked similarly across sampling years. There were no significant differences ($P<0.05$) among metric rankings between sampling years (Table 11).

The consistency with which sites were classified by the MIBI was evaluated by comparisons among seasons from 1989 and data collected during 1987 or 1988 using τ. Coefficients of correlation (τ) indicate that the MIBI rated sites consistently ($P<0.05$) across seasons and years (Table 12). Similar results were also observed when r_s was used to compare MIBI rankings among sampling seasons and years

(Table 13). Although, the MIBI did not rank sites identically each time they were sampled, rankings were highly concordant. Statistical consistency of the MIBI was also evaluated using τ by comparing mean site MIBI scores (all sampling dates included) with corresponding MIBI standard deviations (N=17). Like the findings of Karr et al. (1986), the resulting τ value was negative (-0.324). Though not significant, it implies that variance tended to decrease as MIBI values increased or stream sites with lower MIBI scores tended to be more variable.

Table 10.— Modified IBI scores for 20 Sand Hills streams, 1987-1989. An empty cell indicates a site was not sampled.

Site	1987 - 1988 Spring/Summer	1989 Spring	1989 Summer	1989 Fall
4	42	36	32	34
5	38	34	36	38
7	40	36	42	44
9	46	50	46	50
10A		42	44	42
10B		40	48	32
10C	50	46	48	50
10D		48	44	48
11	40	40	40	46
12	48	48	46	48
17	46	40	48	42
18	48	46	42	42
20	46	38	42	42
21	38	42	40	36
24	48	48	50	50
30	50	48	48	44
32	32	30	30	30
33	32	28	28	26
34	48	42	48	*
36	46	48	50	42
37	48	48	48	48

*Site was pooled.

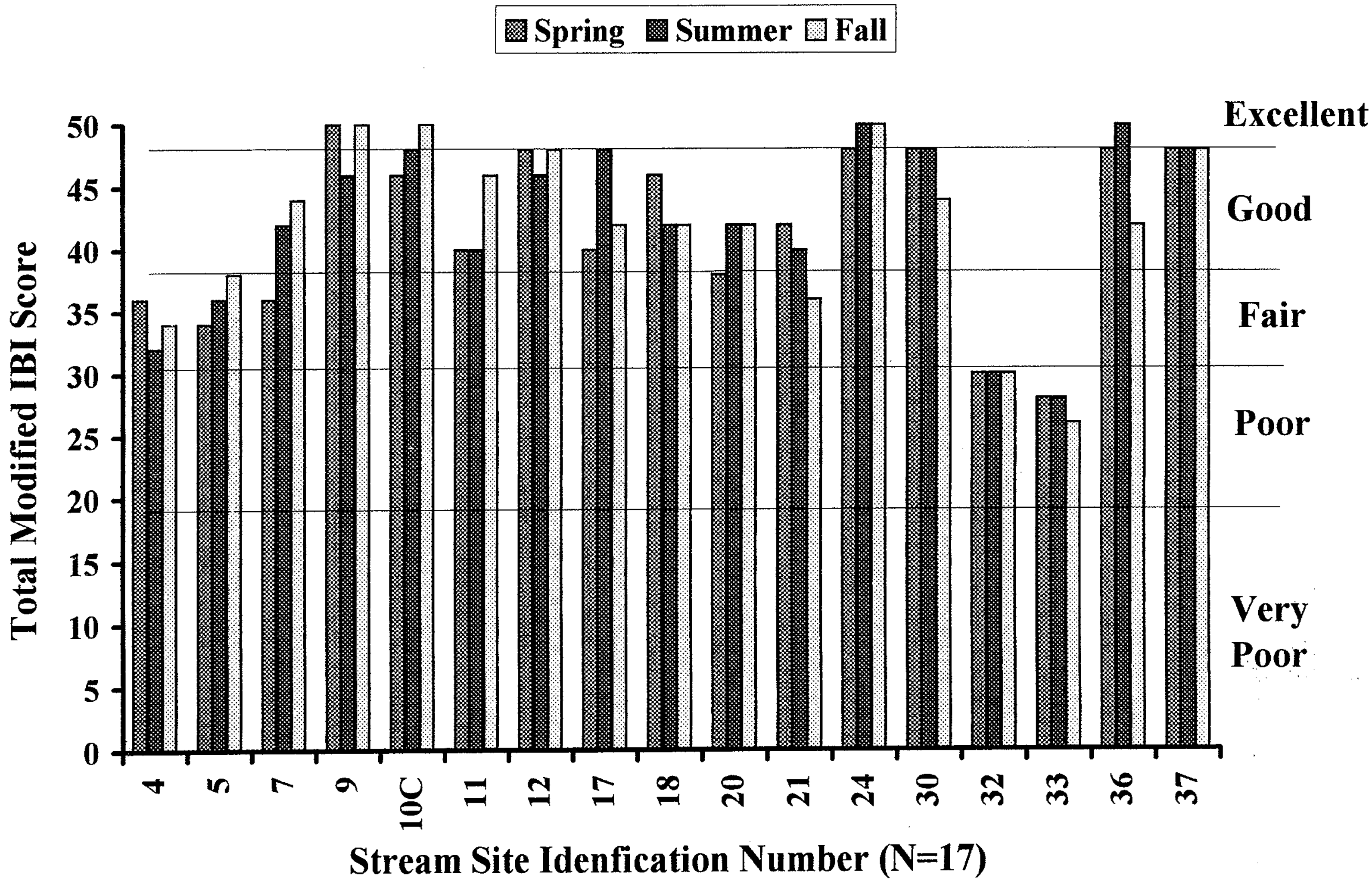

Figure 8.-Modified Index of Biotic Integrity (MIBI) scores and classes for 17 sites sampled seasonally during 1989 in the Sand Hills region of northcentral Nebraska.

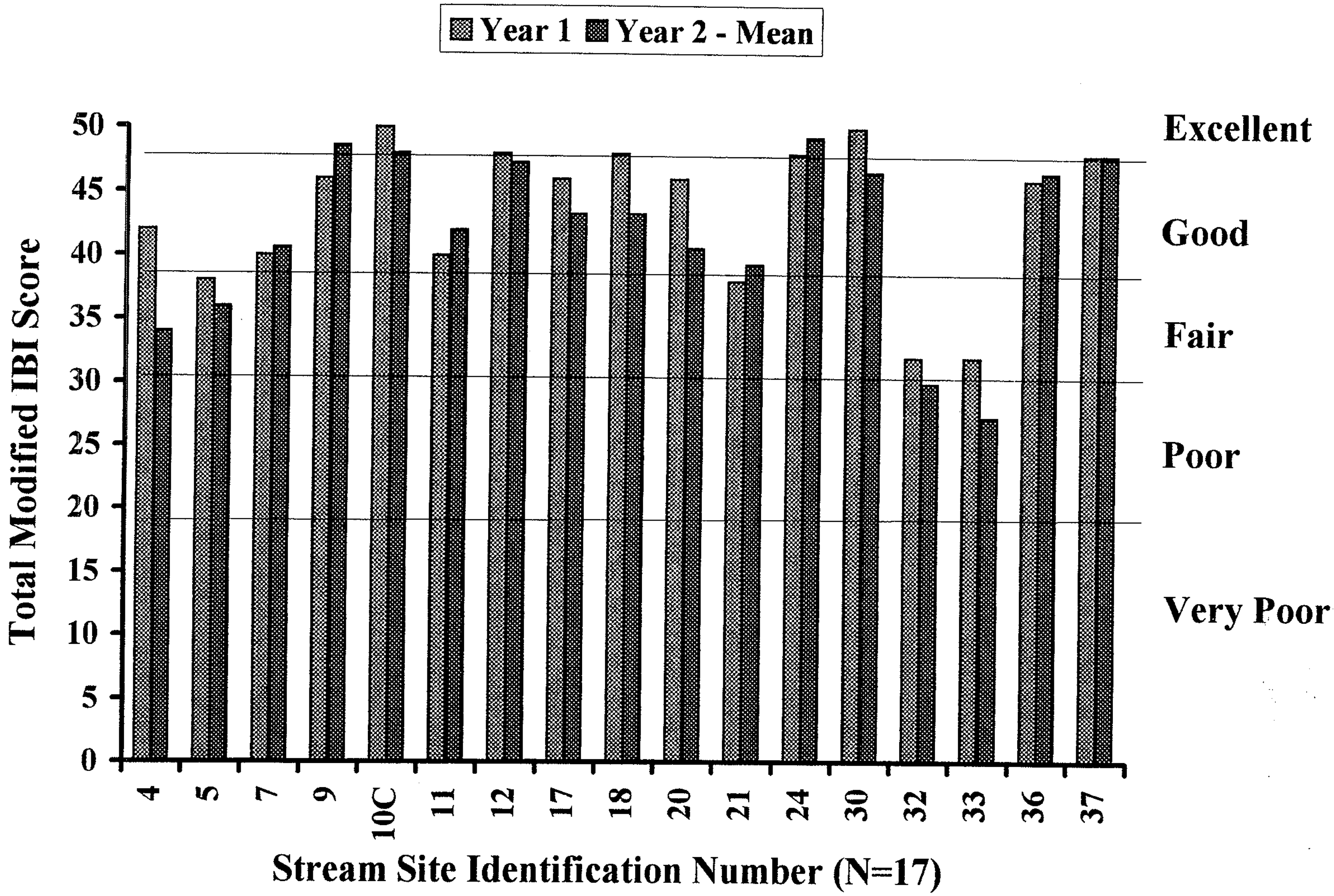

Figure 9.-Modified Index of Biotic Integrity (MIBI) scores and classss for 17 sites in the Sand Hills region of northcentral Nebraska. Year 1 data were collected in 1987 - 1988, and year 2 seasonal data were collected in 1989.

Table 11.— Values for F-tests on ranks by season and across sampling years performed on the MIBI metric data. Blank cells indicate that the metric was invariant. An asterisk indicates the ranking of a particular metric is significant ($P<0.05^*$).

Metric	Between Seasons	Between Sampling Years
Total number of species	2.24	2.76
Presence of specialized feeders	0.32	0.41
Number of native cyprinids	2.98	2.58
Number of intolerant species	0.49	1.22
Proportion as creek chubs	0.56	1.13
Proportion as omnivores	3.62*	2.10
Proportion as insectivorous cyprinids	1.32	1.32
Total number of individuals	1.34	1.61
Proportion as hybrids		
Proportion having anomalies		

Table 12.— Coefficients of correlation for Kendall's tau (τ) on MIBI scores between seasons and between sampling years. An asterisk indicates the coefficient is significant ($P<0.05^*$).

Between Seasons - 1989	τ N=20	Year 1 vs Year 2 (Seasons)	τ N=17
Spring vs Summer	0.614*	Year 1 vs Year 2 - Spring	0.609*
Spring vs Fall	0.626*	Year 1 vs Year 2 - Summer	0.664*
Summer vs Fall	0.503*	Year 1 vs Year 2 - Fall	0.596*

Table 13.— Coefficients of correlation for Spearman's rho (r_s) on MIBI scores between seasons and between sampling years.

Between Seasons - 1989	r_s N=20	Year 1 vs Year 2 (Seasons)	r_s N=17
Spring vs Summer	0.739	Year 1 vs Year 2 - Spring	0.764
Spring vs Fall	0.759	Year 1 vs Year 2 - Summer	0.797
Summer vs Fall	0.588	Year 1 vs Year 2 - Fall	0.725

Longitudinal Variability and the MIBI

The longitudinal (upstream - downstream) distribution of a fish community and its influence on MIBI scores was evaluated by sampling Goose Creek at four locations, from its headwaters to near its confluence with the North Loup River. No specific pattern, either increasing or decreasing across seasons was observed in MIBI scores (Figure 10; Table 10). Mean seasonal MIBI scores for upstream sites 10A (42.6) and 10B (40.0) appeared to be considerably lower than downstream sites 10C (48.0) and 10D (46.6), but an *F*-test preformed on means showed they were not significantly different ($F = 2.17$; 3 df; $P = 0.1699$). Only one site, 10B, varied more than 4 points through all seasons. In the fall of 1989, site 10B exhibited a much lower MIBI score in comparison to its spring and summer values (Figure 10). This low score was the result of a natural disturbance rather than an anthropogenic perturbation. When fish collections were taken, beaver dams present downstream from the reach normally sampled formed a large pool. This probably inhibited fish migration and possibly changed the microhabitat.

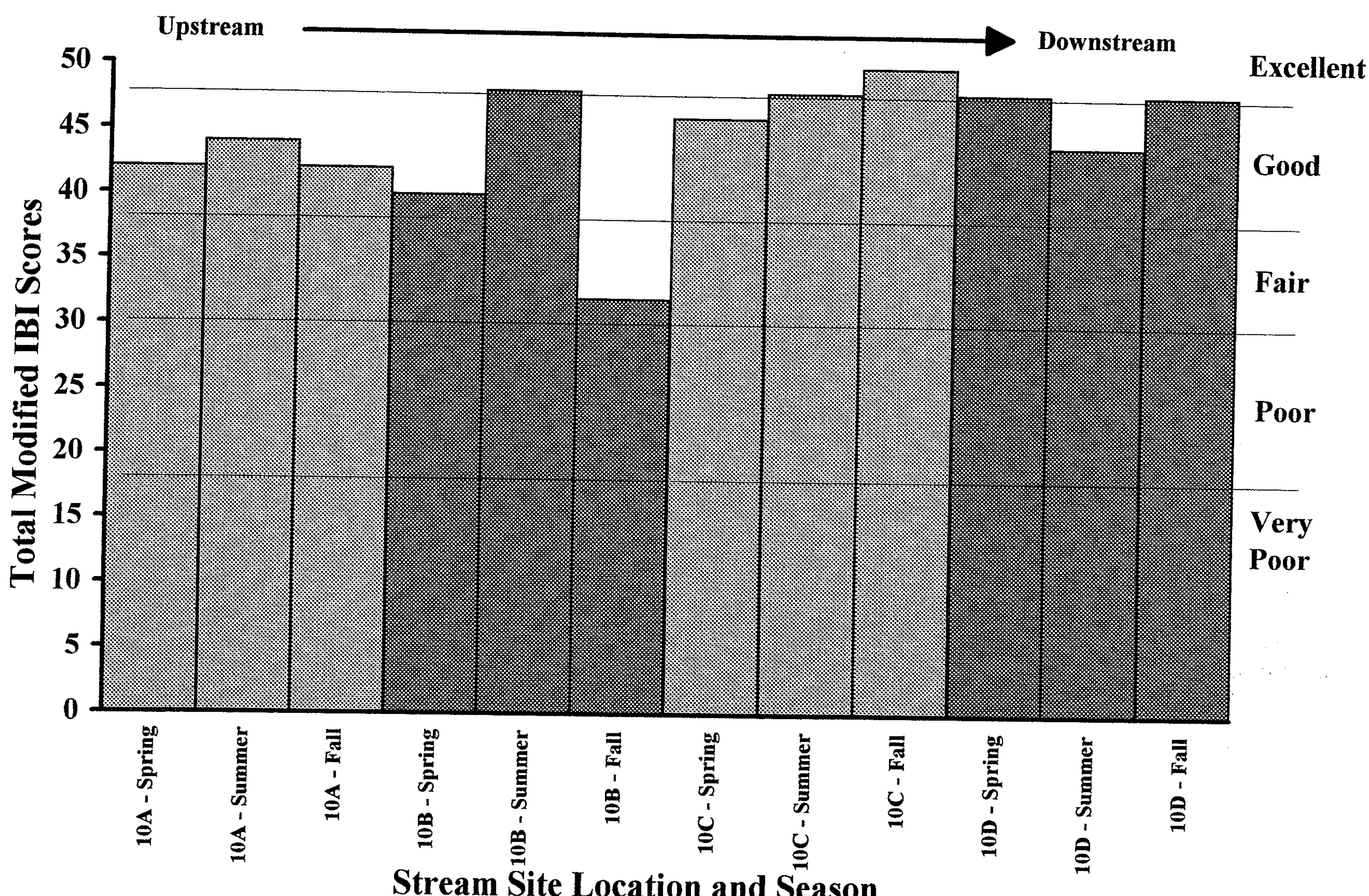

Figure 10.-Comparison of Modified Index of Biotic Integrity (MIBI) scores and classes for 4 Goose Creek sites.

DISCUSSION

The IBI was originally developed based on fish communities of midwestern streams. Karr et al. (1986) cautioned against applying the original IBI metrics outside the midwestern United States. Nebraska may be considered a midwestern state geographically, but the species richness and composition of Sand Hills streams is quite different from those farther east (Lee et al. 1980). In addition, these streams exhibit unique physical and chemical characteristics. For these reasons, the original IBI metrics (Karr 1981) were not expected to be good predictors of site quality. Most users of the IBI in other geographical regions have had to modify the IBI metrics to match local conditions (Leonard and Orth 1986; Schrader and Fausch 1987; Hughes and Gammon 1987; Bramblett and Fausch 1991). There are however, no generally accepted guidelines for such modifications. Often a particular metric is simply inapplicable to a region. In such instances it may be possible to replace that metric with one of similar ecological implication (Hughes and Gammon 1987). For example, in Sand Hills streams "proportion of green sunfish" was not a useful metric and was replaced by "proportion of creek chubs". Alternatively, some users have given a fixed score to the inapplicable metric. Karr et al. (1987) arbitrarily assigned a score of 5 to the proportion of hybrids metric because no information was available to score it. This maintains the overall numerical ranges of the biotic integrity classes, but can artificially inflate IBI scores. I adopted this approach because streams throughout the Sand Hills have not been degraded to the extent where increased hybridization is expected. Still, others have simply deleted inapplicable metrics (Leonard and Orth

1986; Steedman 1988). "Number of sucker species" and "proportion of top carnivores", were deleted from the MIBI because suitable replacements could not be found in this region. This required a reduction of the biotic integrity class ranges and did not appear to reduce the sensitivity of the index.

Another important aspect of applying the IBI is adjusting the scoring criteria based on expected species richness for local conditions and stream size. To date, developers of the IBI have suggested using stream order (Strahler 1957) or watershed size to relate species richness and stream size. Whiteside and McNatt (1972) and Gorman and Karr (1978) proposed that fish species richness increases from headwater regions to the mouth in streams because habitat diversity increases with stream size. However, stream order and overall watershed size have little bearing on discharge of Sand Hills streams (Bentall 1989). An attempt was made to define this relationship by comparing discharge and species richness. My data do not support the theory that a positive linear relationship exists between stream size and species richness. I found a more accurate predictor of species richness to be what I called "Stream Type". This general classification system was based on stream gradient (velocity) and dominant substrate. Type I streams have discharge velocities swift enough to keep pools free of silt and organic matter. Type II streams exhibit slower velocities where silt and organic matter tend to deposit in pools. In some cases more species were collected, but the maximum number of fish species expected in Type I streams was six, compared to 12 species in Type II streams. Karr et al. (1986) expected species richness in the streams for which the IBI was developed to be two to four times greater than this with all trophic classes present. Since fish communities of Sand Hills streams are quite different, modifications to several individual metrics were required. This made it possible for the MIBI to classify a wider range of stream types and increased its sensitivity. All MIBI metrics appeared to contribute useful information to final index scores. The most important metrics appeared to those measuring species richness. Angermeier and Karr (1986) suggest that the relative importance of a metric not only varies with region and stream quality but also with stream size, according to composition of the fish assemblage present. I found expectations of metrics dependent on species richness varied according to two stream characteristics and not just on stream size. Testing of the importance of other habitat characteristics was limited by the availability of quantitative habitat data.

The MIBI ranked stream sites similarly and consistently between seasons and sampling years when site quality conditions did not change. Higher quality sites exhibited less variability in their rankings over time than did sites of lower quality. Therefore, lower quality sites were more likely to be overrated rather than underrating of good sites. Effects of seasonal changes in fish distribution patterns on the MIBI were evaluated to determine whether there was an optimal season for sampling fish. Other studies have shown that late summer and early fall collections generally produced higher index scores caused by seasonal changes in recruitment and migration (Angermeier and Karr 1986; Angermeier and Schlosser 1987). Results from this study did not indicate any one season (spring, summer, fall) as being better or worse than another because mean MIBI scores for all seasons were not significantly different.

Evaluation of longitudinal changes in fish distributional patterns was conducted to determine if sampling site locations along a stream influenced MIBI scores. Mean seasonal MIBI scores for Goose Creek's upstream sites were not significantly different than downstream sites. It is important to point out that when indices like the IBI are used too much emphasis may be placed on final scores, when the attention should be focused on the classification categories (Karr et al. 1986). With the exception of one sampling date, all Goose Creek sites were appropriately classified in the good to excellent range. The one sampling date where a lower MIBI score was exhibited, physical habitat conditions at that particular site had changed due to beaver activity in the reach sampled and this was reflected in a lower MIBI score.

In many areas, one concern in applying the IBI to headwater type streams like the ones studied, is that they exhibit greater temporal variability in fish community structure (Schlosser 1990). Increased variability can cause complications in interpreting fish based index results because distinguishing between natural and anthropogenic causes of variation is often difficult (Karr et al. 1986; Schlosser 1990). This does not appear to be a concern in Sand Hills streams because of the stability in flow regimes and habitat conditions. In addition, the IBI tends to be robust with regard to measurement error (Fore et al. 1994) and subtle shifts in community structure due to natural variability.

Overall, my study indicates that through modification of the metrics and scoring criteria, a useful fish based index (MIBI) was developed for assessing conditions of small Sand Hills streams. However, further refinement of the proposed changes will require continued long-term monitoring of Sand Hills stream fish communities to better define distributional patterns and ranges of natural variability.

LITERATURE CITED

Angermeier, P. L., and J. R. Karr. 1986. Applying an index of biotic integrity based on stream fish communities: considerations in sampling and interpretation. North American Journal of Fisheries Management 6:418-429.

Angermeier, P. L., and I. J. Schlosser. 1987. Assessing biotic integrity of the fish community in a small Illinois stream. North American Journal of Fisheries Management 7:331-338.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Berkman, H. E., C. F. Rabeni, and T.P. Boyle. 1986. Biomonitors of stream quality in agricultural areas: fish vs. invertebrates. Environmental Management 10:413-419.

Bentall, R. 1989. Streams. Pages 93-114. In: Bleed, A., and C. Flowerday. 1989. An atlas of the Sand Hills. Conservation Survey Division. Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln. Resource Atlas No. 5.

Bleed, A., and C. Flowerday. 1989. An atlas of the Sand Hills. Conservation Survey Division. Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln. Resource Atlas No. 5.

Bliss, Q. P., and S. Schainost. 1973a. Niobrara River stream inventory report. Nebraska Game and Parks Commission, Lincoln.

____1973b. Loup River stream inventory report. Nebraska Game and Parks Commission, Lincoln.

Bramblett, R. G., and K. D. Fausch. 1991. Variable fish communities and the index of biotic integrity a western Great Plains river. Transactions of the American Fisheries Society 120:752-769.

Cairns, J. Jr., 1975. Quantification of biological integrity. In: R. K. Ballintine and L. J. Guarraie, editors. The integrity of water: A symposium. U. S. Environmental Protection Agency, Washington, D. C.

Coble, D. W. 1982. Fish populations in relation to dissolved oxygen in the Wisconsin River. Transactions of the American Fisheries Society 111:612-623.

Evermann, B. W., and U.O. Cox. 1896. A report upon the fishes of the Missouri River Basin. Report of the United States Fisheries Commission for 1894, 20:325-429.

Fausch, K. D., J. R. Karr, and P. R. Yant. 1984. Regional application of an index of biotic integrity based on stream-fish communities. Transactions of the American Fisheries Society 113:39-55.

Fausch, K. D., J. Lyons, J. R. Karr, and P. L. Angermeier. 1990. Fish communities as indicators of environmental degradation. American Fisheries Society Symposium 8:123-144.

Fore, L. S., J. R. Karr, and L. L. Conquest. 1994. Statistical properties of an index of biological integrity used to evaluate water resources. Canadian Journal of Fisheries and Aquatic Sciences 51:1077-1087.

Gammon, J. R. 1976. The fish populations of the middle 340 km of the Wabash River. Purdue University Water Resources Research Center, Technical Report 86, West Lafayette, Indiana.

Gorman, O. T., and J. R. Karr. 1978. Habitat structure and stream fish communities. Ecology 59:507-515.

Hilsenhoff, W. L. 1982. Using a biotic index to evaluate water quality in streams. Technical Bulletin No. 132. Department of Natural Resources, Madison, Wisconsin.

Hocutt, C. H. 1981. Fish as indicators of biological integrity. Fisheries 6:28-31.

Hocutt, C. H., and J. R. Stauffer, Jr. 1980. Biological monitoring of fish. Lexington Books, Lexington, Massachusetts.

Hrabik, R. A. 1989. Fishes. Pages 143-154. In Bleed, A., and C. Flowerday. 1989. An atlas of the Sand Hills. Conservation Survey Division. Institute of Agriculture and Natural Resources. University of Nebraska-Lincoln. Resource Atlas No. 5.

Hughes, R. M., and J. R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. Transactions of the American Fisheries Society 116:196-209.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Toronto.

Johnson, R.E. 1942. The distribution of Nebraska fishes. Ph.D. Dissertation. University of Michigan, Ann Arbor.

Joswiak, G.R., R.H. Stasiak, and W. S. Moore. 1982. Allozyme analysis of the hybrid *Phoxinus eos* x *Phoxinus neogaeus* in Nebraska. Canadian Journal of Zoology, 60(5):968-973.

Joswiak, G.R., R.H. Stasiak and B.F. Koop. 1984. Diploidy and triploidy in the hybrid minnow, *Phoxinus eos* x *Phoxinus neogaeus*. Experientia. 41:505-507.

Kaesler, R. L., E. E. Herricks, and J. S. Crossman. 1978. Use of indices of diversity and hierarchial diversity in stream surveys. American Society for Testing and Materials, Special Technical Publication 652:92-112.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Karr, J.R., and D.R. Dudley. 1981. Ecological perspective on water quality goals. Environmental Management 5:55-68.

Karr, J. R., K. D. Fausch, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey, Special Publication 5, Champaign.

Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, P. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina State Museum of Natural History, Raleigh.

Leonard, P. M., and D. J. Orth. 1986. Application and testing of an index of biotic integrity in small, coolwater streams. Transactions of the American Fisheries Society 115:401-414.

Miller, D. L., P. M. Leonard, R. M. Hughes, J. R. Karr, P. B. Moyle, L. H. Schrader, B. A. Thompson, R. A. Daniels, K. D. Faucsh, G. A. Fitshugh, J. R. Gammon, D. B. Haliwell, P. L. Angermeier, and D. J. Orth. 1988. Regional applications of an index of biotic integrity for use in water resource management. Fisheries 13:12-20.

Nebraska Department of Environmental Control (NDEC). 1991. Nebraska stream classification study. Nebraska Department of Environmental Control, Lincoln.

Ohio Environmental Protection Agency (EPA). 1987. Users manual for biological assessment of Ohio surface waters. Ohio Environmental Protection Agency, Columbus.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

Pfleiger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City.

Pielou, E. C. 1975. Ecological Diversity. John Wiley and Sons, New York, New York.

Robins, C. R., R. M. Baily, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. A list of common and scientific names of fishes from the United States and Canada. 5th edition. American Fisheries Society Special Publication No. 20.

SAS Institute Inc. 1989. SAS/STAT® User's Guide - Version 6, 4th edition, Volume 1, Cary, North Carolina.

Schlosser, I. J. 1990. Environmental variation, life history attributes, and community structure in stream fishes: Implications for environmental management and assessment. Environmental Management 14:621-628.

Schrader, L. H. and K. D. Fausch. 1987. Use of the index of biotic integrity to evaluate the effects of habitat, flow, and water quality on fish communities in three Colorado front range rivers. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins.

Strahler, A. N. 1957. Quantitative analysis of watershed geomorphology. Transactions of the American Geophysical Union 38:913-920.

Thurston, R. V., R. C. Russo, C. M. Fetterolf, Jr., T. A. Edsall, and Y. M. Baber, Jr., editors. 1979. A review of the EPA Red Book: quality criteria for water. Water Quality Section, American Fisheries Society, Besthesda, Maryland.

Trautman, M. B. 1981. The fishes of Ohio. Ohio State University Press, Columbus.

Weber, C. I. 1981. Evaluation of the effects of effluents on aquatic life in a receiving waters - an overview. American Society for Testing and Materials Special Technical Publication 730:3-13.

Whiteside, B. G., and R. M. McNatt. 1972. Fish species diversity in relation to stream order and physicochemical conditions in the Plum Creek drainge basin. American Midland Naturalist 88:90-101.

Wilhm, J. L., and T. C. Dorris. 1968. Biological parameters of water quality criteria. Bioscience 18:477-481.

Appendix A

Loup Basin Site Descriptions

Stream Name:	Davis Creek
Site Number:	1
Drainage Basin:	Loup
County:	Greeley
Legal Description:	T17N, R12W, Sec. 33
Stream Order:	1

Collection Date(s):	8-10-88
Collector(s):	NDEQ
Sample Time:	20 minutes
Sample Distance:	148 m
Sampling Gear:	Backpack electrofish

Species	Count
Noturus flavus	8
Notropis stramineus	6
Lepomis cyanellus	5
Pimephales promelas	4
Moxostoma macrolepidotum	3
Carpiodes carpio	3
Semotilus atromaculatus	2
Cyprinella lutrensis	1
Ictalurus punctatus	1
Hybognathus hankinsoni	1
Dorosoma cepedianum	1
Lepomis humilis	1
Micropterus salmoides	1
Carpiodes cyprinus	1

Description: Davis Creek is located on the eastern boundary of the Sand Hills ecoregion. Near the confluence of this stream with the North Loup River where these specimens were collected, discharge was 0.08 m^3/s, with an average velocity of 0.2 m/s. Average width and depth were 3.7 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (7.2 mg/L) and temperature (27°C). Davis Creek is low gradient Sand Hills stream, bordered almost entirely by grassland used for pasture with the exception of some cropland in the upland regions of its watershed. Grazing damage to riparian and streambank areas was reported as being moderate. Substrate was composed primarily of sand and gravel. However, in areas where stream velocity was low, fine sediment was present. Riffle areas with exposed gravel were rare, and pools, ranging in depth from 0.25 - 0.60 m, were common. Other instream habitat included occasional patches of submerged vegetation (*Potamogeton* sp.), logs, brush, and overhanging vegetation. Overall habitat conditions were rated as good.

Stream Name: Mira Creek
Site Number: 2
Drainage Basin: Loup
County: Greeley
Legal Description: T18N, R12W, Sec. 31
Stream Order: 1

Collection Date(s): 8-10-88
Collector(s): NDEQ
Sample Time: 14 minutes
Sample Distance: 182 m
Sampling Gear: Backpack electrofish

Species	Count
Cyprinella lutrensis	26
Pimephales promelas	10
Cyprinus carpio	9
Lepomis cyanellus	2
Carpiodes carpio	2
Ameiurus melas	2
Catostomus commersoni	2
Notropis stramineus	2
Semotilus atromaculatus	2
Micropterus salmoides	1

Description: Mira Creek is located on the eastern boundary of the Sand Hills ecoregion. Near the confluence of this stream with the North Loup River where these specimens were collected, discharge was 0.07 m^3/s, with an average velocity of 0.1 m/s. Average width and depth were 2.7 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (7.6 mg/L) and temperature (24°C). Mira Creek is bordered by grassland used for pasture but it is not a typical Sand Hills stream in that it receives irrigation return flow from surrounding cropland. Grazing damage to riparian and streambank areas was reported as being minimal. Substrate was composed primarily of silt and sand. Riffle areas were occasional, and pools, ranging in depth from 0.25 - 0.40 m, were occasional as well. Other instream habitat included thick patches of *Elodea* sp., filamentous algae, stands of *S. latifolia*, and overhanging vegetation. Overall habitat conditions were rated as being good.

Stream Name:	Turtle Creek
Site Number:	3
Drainage Basin:	Loup
County:	Valley
Legal Description:	T20N, R14W, Sec. 31
Stream Order:	1
Collection Date(s):	8-9-88
Collector(s):	NDEQ
Sample Time:	9 minutes
Sample Distance:	152 m
Sampling Gear:	Backpack electrofish

Species	Count
Cyprinella lutrensis	2
Catostomus commersoni	2
Carpiodes carpio	1
Ictalurus punctatus	1
Micropterus salmoides	1

Description: Turtle Creek is located on the southeastern boundary of the Sand Hills ecoregion. Near the confluence of this stream with the North Loup River where these specimens were collected, discharge was 0.1 m^3/s, with an average velocity of 0.1 m/s. Average width and depth were 4.7 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (7.0 mg/L) and temperature (28°C). Turtle Creek is bordered by a wooded riparian area and grassland used for pasture. Grazing damage to riparian and streambank areas was reported as being minimal. Turtle Creek does receive irrigation return flow from surrounding cropland which may be having an impact on the aquatic community. Turbid water conditions made sampling difficult. Substrate was composed primarily of silt and sand. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were common as well. Other instream habitat included logs, brush, and overhanging vegetation. Overall instream habitat conditions were rated as fair.

Stream Name: Bean Creek
Site Number: 4
Drainage Basin: Loup
County: Valley
Legal Description: T20N, R15W, Sec. 10
Stream Order: 1

Collection Date(s):	7-29-88	5-30-89	7-10-89	10-2-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	14 minutes	28 minutes	42 minutes	13 minutes
Sample Distance:	114 m	91 m	91 m	91 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Pimephales promelas	37	10	11	4
Hybognathus hankinsoni	35	61	42	24
Catostomus commersoni	10	45	47	7
Fundulus sciadicus	5	-	-	-
Etheostoma exile	3	-	-	-
Lepomis cyanellus	1	-	2	1
Semotilus atromaculatus	1	10	18	4
Cyprinella lutrensis	1	17	1	12
Cyprinus carpio	1	1	26	1
Lepomis macrochirus	-	2	1	1
Notropis dorsalis	-	8	-	-
Notropis stramineus	-	60	17	-
Micropterus salmoides	-	-	1	5
Pomoxis nigromaculatus	-	-	-	2

Description: Bean Creek is located on the southeastern boundary of the Sand Hills ecoregion. Near the confluence of this stream with the North Loup River where these specimens were collected, discharge ranged between 0.03 and 0.06 m^3/s, with average velocities ranging from of 0.15 - 0.2 m/s. Average width and depth were 1.5 m and 0.1 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 4.0 - 7.7 mg/L), temperature (ranged from 15 - 23°C) and conductivity (ranged from 195 - 330 µmhos/cm). Bean Creek is a typical eastern Sand Hills stream bordered by a sparsely wooded riparian area and grassland used for pasture. Grazing damage to riparian and streambank areas was reported as being minimal. Some cropland exists in the upland regions surrounding the stream. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were occasional. Other instream habitat included occasional patches of *Elodea* sp., filamentous algae, stands of *S. latifolia*, brush, and overhanging vegetation. Overall habitat conditions were rated as being excellent, but the stream had been straightened in the past.

Visual assessment of instream habitat conditions from 1988 to 1989 appeared not to have changed. However, several beaver dams were present when the fall (10-2-89) collection was taken which probably affected fish distribution and migration throughout this stream segment.

Stream Name: Gracie Creek
Site Number: 5
Drainage Basin: Loup
County: Loup
Legal Description: T23N, R17W, Sec. 29
Stream Order: 1
NDEQ Flow Class: 3

Collection Date(s):	7-26-88	5-30-89	7-10-89	10-2-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	20 minutes	30 minutes	36 minutes	21 minutes
Sample Distance:	160 m	192 m	192 m	192 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Catostomus commersoni	17	6	61	34
Salvelinus fontinalis	16	2	1	2
Rinichthys cataractae	8	12	7	21
Semotilus atromaculatus	3	9	6	18
Lepomis cyanellus	1	-	-	-
Pimephales promelas	-	10	6	2
Culaea inconstans	-	1	-	12
Fundulus sciadicus	-	-	9	1
Micropterus salmoides	-	-	1	-

Description: Gracie Creek is located in the southeastern portion of the Sand Hills ecoregion. Near the confluence of this stream with the Calamus River (Calamus Reservoir) where these specimens were collected, discharge ranged between 0.3 and 0.34 m^3/s, with average velocities ranging from of 0.2 - 0.3 m/s. Average width and depth were 3.5 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 8.6 - 17.2 mg/L), temperature (ranged from 15 - 18°C) and conductivity (ranged from 95 - 130 μmhos/cm). Gracie Creek is a typical, Sand Hills stream bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was non-existent in the sampling reach due to fencing. However, above and below the sampling reach grazing damage was moderate. Substrate was composed primarily of sand and gravel. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.80 m, were occasional. Other instream habitat included thick patches of filamentous algae, *N. officinale*, *S. latifolia*, and *Ranunculus* sp., and overhanging vegetation. Overall habitat conditions were rated as being excellent and no visual changes in instream habitat conditions were observed from 1988 to 1989.

Stream Name: Bloody Creek
Site Number: 6
Drainage Basin: Loup
County: Loup
Legal Description: T24N, R19W, Sec. 5
Stream Order: 1

Collection Date(s): 7-26-88
Collector(s): NDEQ
Sample Time: 18 minutes
Sample Distance: 182 m
Sampling Gear: Backpack electrofish

Species	Count
Fundulus sciadicus	48
Notropis dorsalis	22
Rhinichthys cataractae	11
Lepomis cyanellus	5
Esox lucius	4
Semotilus atromaculatus	3
Hybognathus hankinsoni	2
Lepomis macrochirus	1
Ameiurus melas	1

Description: Bloody Creek is located in the southeastern portion of the Sand Hills ecoregion. Near the confluence of this stream with the Calamus River where these specimens were collected, discharge was 0.01 m^3/s, with an average velocity of 0.1 m/s. Average width and depth were 2.5 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (5.8 mg/L) and temperature (20.5°C). Bloody Creek is bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was reported as being minimal. Substrate was composed primarily of sand. Riffle areas were occasional, and pools, ranging in depth from 0.25 - 0.60 m, were occasional as well. Other instream habitat included patches of filamentous algae, *Elodea* sp., *C. demersum*, and overhanging vegetation. Overall instream habitat conditions were rated as good.

Stream Name: Calamus River
Site Number: 7
Drainage Basin: Loup
County: Brown
Legal Description: T26N, R23W, Sec. 3
Stream Order: 1

Collection Date(s):	7-26-88	5-30-89	7-10-89	10-03-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	17 minutes	43 minutes	30 minutes	20 minutes
Sample Distance:	182 m	222 m	222 m	222 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Cyprinus carpio	14	1	6	-
Esox lucius	5	-	2	-
Notropis stramineus	4	-	2	-
Cyprinella lutrensis	2	-	-	1
Notropis dorsalis	2	-	-	2
Lepomis cyanellus	2	20	-	2
Fundulus sciadicus	1	-	21	10
Rhinichthys cataractae	1	-	2	12
Ameiurus melas	-	7	3	17
Culaea inconstans	-	1	-	-
Pimephales promelas	-	1	-	-
Etheostoma exile	-	1	-	-
Catostomus commersoni	-	-	2	1
Perca flavescens	-	-	10	-
Hybognathus hankinsoni	-	-	4	-
Lepomis macrochirus	-	-	10	-

Description: The Calamus River is located in the northeastern portion of the Sand Hills ecoregion. Approximately 15 miles below the headwater region where these specimens were collected, discharge ranged between 0.6 and 0.7 m^3/s, with average velocities ranging from of 0.2 - 0.4 m/s. Average width and depth were 6.5 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 9.6 - 12.4 mg/L), temperature (ranged from 15 - 25°C) and conductivity (ranged from 140 - 180 µmhos/cm). The Calamus River is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture and sparse stands of willows. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.9 m, were common. Other instream habitat included occasional patches of *C. demersum*, *Elodea* sp., exposed willow roots and overhanging vegetation. Overall habitat conditions were rated as being excellent.

Visual changes in instream habitat conditions included increased growth of submerged aquatic vegetation and a reduction in stream discharge during observed during the summer (7-10-89) sampling period. In addition, the fall collections were taken downstream of the road because a plugged culvert had ponded the river on the upstream side.

Stream Name: Unnamed Creek (Tributary to Calamus River)
Site Number: 8
Drainage Basin: Loup
County: Brown
Legal Description: T27N, R24W, Sec. 12
Stream Order: 1

Collection Date(s): 7-26-88
Collector(s): NDEQ
Sample Time: 13 minutes
Sample Distance: 160 m
Sampling Gear: Backpack electrofish

Species	Count
Fundulus sciadicus	25
Ameiurus melas	2
Cyprinus carpio	2
Lepomis cyanellus	1

Description: This Unnamed Creek is located in the northeastern portion of the Sand Hills ecoregion. Near the confluence of this stream with the Calamus River where these specimens were collected, discharge was 0.03 m^3/s, with an average velocity of 0.15 m/s. Average width and depth were 2.2 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (8.9 mg/L) and temperature (27°C). This creek is bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand and detritus. Riffle areas were rare, and pools, ranging in depth from 0.25 - 0.60 m, were occasional as well. Other instream habitat included thick patches of filamentous algae, *Elodea* sp., *C. demersum*, *Ranunculus* sp., *S. latifolia,* undercut banks, and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Stream Name: Brush Creek
Site Number: 9
Drainage Basin: Loup
County: Cherry
Legal Description: T27N, R29W, Sec. 26
Stream Order: 1

Collection Date(s):	7-28-88	5-18-89	7-17-89	10-3-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	11 minutes	34 minutes	23 minutes	11 minutes
Sample Distance:	91 m	77 m	77 m	77 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Notropis stramineus	34	119	23	31
Hybognathus hankinsoni	34	165	28	13
Catostomus commersoni	12	42	16	23
Phoxinus eos	7	2	20	6
Margariscus margarita	5	23	67	10
Noturus flavus	2	4	-	-
Pimephales promelas	2	1	15	23
Notropis dorsalis	1	61	1	10
Fundulus sciadicus	1	-	-	-
Cyprinella lutrensis	1	28	-	7
Semotilus atromaculatus	-	3	-	-
Phoxinus neogaeus	-	6	-	-
Notropis topeka	-	2	-	-
Rhinichthys cataractae	-	6	-	-
Etheostoma exile	-	1	-	2
Culaea inconstans	-	-	3	1
Campostoma anomalum	-	-	-	2

Description: Brush Creek is located in the central portion of the Sand Hills ecoregion. Near the confluence with the North Loup River where these specimens were collected, discharge ranged between 0.01 and 0.1 m^3/s, with average velocities ranging from of 0.03 - 0.2 m/s. Average width and depth were 2.3 m and 0.3 m, respectively.

Physicochemical parameters measured were dissolved oxygen (ranged from 8.3 - 9.7 mg/L), temperature (ranged from 11 - 22°C) and conductivity (ranged from 130 - 205 µmhos/cm). Brush Creek is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture and sparse stands of willows. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand and detritus. Riffle areas with exposed gravel were rare, and pools, ranging in depth from 0.25 - 1.0 m, were common as well. Other instream habitat included thick patches of *Elodea* sp., filamentous algae, exposed willow roots and overhanging vegetation. Overall habitat conditions were rated as being good and no visual changes in instream habitat conditions were observed from 1988 to 1989.

Stream Name: Goose Creek
Site Number: 10A
Drainage Basin: Loup
County: Cherry
Legal Description: T27N, R28W, Sec. 35
Stream Order: 1

Collection Date(s):	5-19-89	7-11-89	10-3-89
Collector(s):	NDEQ	NDEQ	NDEQ
Sample Time:	21 minutes	18 minutes	13 minutes
Sample Distance:	85 m	85 m	85 m
Sampling Gear:	Backpack electrofish	same	same

Species	Count		
Hybognathus hankinsoni	145	117	96
Margariscus margarita	65	32	19
Campostoma anomalum	26	59	30
Semotilus atromaculatus	20	24	7
Catostomus commersoni	7	16	2
Phoxinus neogaeus	5	8	-
Notropis dorsalis	4	10	1
Fundulus sciadicus	4	53	8
Phoxinus eos	4	4	1
Noturus flavus	2	-	-
Pimephales promelas	2	-	2
Lepomis cyanellus	1	5	1
Etheostoma exile	-	2	-
Phoxinus eos X *P. neogaeus*	-	2	3

Description: Goose Creek is located in the central portion of the Sand Hills ecoregion.

In the headwater region of Goose Creek where these specimens were collected, discharge ranged between 0.08 and 0.1 m^3/s, with average velocities ranging from of 0.01 - 0.17 m/s. Average width and depth were 2.1 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 7.3 - 11.3 mg/L), temperature (ranged from 11 - 25°C) and conductivity (ranged from 140 - 300 µmhos/cm). Goose Creek is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture and sparse stands of willows and cottonwood trees. This reach appears to have been channelized many years ago and since has begun to meander. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand and detritus. Riffle areas with exposed gravel were rare, and pools, ranging in depth from 0.25 - 1.0 m, were occasional. Other instream habitat included stands of cattails, filamentous algae, exposed willow roots, overhanging vegetation and the surface in many areas was covered with *Lemna* sp.. Overall habitat conditions were rated as being excellent and no visual changes in instream habitat conditions were observed in 1989.

Stream Name:	Goose Creek		
Site Number:	10B		
Drainage Basin:	Loup		
County:	Cherry		
Legal Description:	T26N, R25W, Sec. 8		
Stream Order:	1		
Collection Date(s):	5-19-89	7-11-89	10-3-89
Collector(s):	NDEQ	NDEQ	NDEQ
Sample Time:	32 minutes	40 minutes	25 minutes
Sample Distance:	124 m	124 m	124 m
Sampling Gear:	Backpack electrofish	same	same

Species	**Count**		
Hybognathus hankinsoni	41	62	11
Catostomus commersoni	16	41	19
Fundulus sciadicus	15	37	1
Campostoma anomalum	13	19	4
Pimephales promelas	9	14	-
Lepomis cyanellus	7	2	-
Margariscus margarita	5	47	6
Semotilus atromaculatus	3	6	3
Noturus flavus	3	6	-
Phoxinus eos	3	4	-
Phoxinus neogaeus	2	5	-
Micropterus salmoides	2	-	-
Etheostoma exile	-	1	-
Cyprinus carpio	-	1	-
Ameiurus melas	-	1	-
Notropis stramineus	-	7	-
Rhinichthys cataractae	-	3	-

Description: Goose Creek is located in the central portion of the Sand Hills ecorgion. In the central region of Goose Creek where these specimens were collected, discharge ranged between 0.23 and 0.58 m^3/s, with average velocities ranging from of 0.3 - 1.0 m/s. Average width and depth were 5.9 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 9.5 - 11.8 mg/L), temperature (ranged from 13 - 25°C) and conductivity (ranged from 110 - 160 µmhos/cm). Goose Creek at this location is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand and detritus. Riffle areas with exposed gravel were non-existent and pools, ranging in depth from 0.25 - 1.0 m, were occasional. Other instream habitat included patches of *Elodea* sp., overhanging vegetation, and the surface in many areas was covered with *Lemna* sp.. Overall habitat conditions were rated as being good. In the fall of 1989, beaver dams present below the stream normally sampled appeared to have reduced discharge velocities and caused a large pool to form. No other visual changes in instream habitat conditions were observed in 1989.

Stream Name: Goose Creek
Site Number: 10C
Drainage Basin: Loup
County: Cherry
Legal Description: T25N, R25W, Sec. 2
Stream Order: 1

Collection Date(s):	7-26-88	5-19-89	7-11-89	10-3-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	18 minutes	43 minutes	39 minutes	24 minutes
Sample Distance:	137 m	134 m	134 m	134 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Notropis stramineus	96	15	19	192
Catostomus commersoni	26	22	44	66
Campostoma anomalum	26	12	33	9
Pimephales promelas	15	6	3	1
Rhinichthys cataractae	14	20	20	2
Hybognathus hankinsoni	11	67	40	37
Semotilus atromaculatus	10	-	9	12
Notropis dorsalis	9	10	12	33
Margariscus margarita	8	9	15	17
Lepomis cyanellus	8	2	12	-
Cyprinella lutrensis	7	1	6	108
Fundulus sciadicus	6	4	17	15
Noturus flavus	5	4	6	6
Phoxinus eos	3	2	1	-
Cyprinus carpio	3	-	-	-
Phoxinus eos X *P. neogaeus*	1	-	2	-
Moxostoma macrolepidotum	1	-	-	-
Etheostoma exile	2	1	3	6
Ameiurus melas	1	-	-	-

Description: Goose Creek is located in the central portion of the Sand Hills ecoregion. In the headwater region of Goose Creek where these specimens were collected, discharge ranged between 0.19 and 0.22 m^3/s, with average velocities ranging from of 0.1 - 0.2 m/s. Average width and depth were 2.8 m and 0.6 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 7.6 - 11.0 mg/L), temperature (ranged from 11 - 19°C) and conductivity (ranged from 120 - 205 µmhos/cm). Goose Creek is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture and sparse stands of willows and cottonwood trees. This reach also appears to have been channelized many years ago and since is beginning to meander again. Grazing damage to riparian and streambank areas was reported to have been minor in 1988, however, in 1989, uncontrolled livestock access appeared to be degrading these areas; resulting impacts were: degraded riparian areas, streambanks, widening and shallowing of the stream channel, and loss of deep pool habitat. The stream had a shifting sand substrate. Riffle areas were common, and pools, ranging in depth from 0.5 - 1.0 m, were rare. Other instream habitat included patches of *C. demersum*, *Ranunculus* sp., overhanging vegetation, and undercut banks. Overall habitat conditions were rated as being good in 1988. It did appear that in 1989 instream habitat conditions worsened due to the uncontrolled livestock access.

Stream Name:	Goose Creek		
Site Number:	10D		
Drainage Basin:	Loup		
County:	Blaine		
Legal Description:	T24N, R24W, Sec. 4		
Stream Order:	1		
Collection Date(s):	5-19-89	7-11-89	10-3-89
Collector(s):	NDEQ	NDEQ	NDEQ
Sample Time:	25 minutes	32 minutes	20 minutes
Sample Distance:	208 m	208 m	208 m
Sampling Gear:	Backpack electrofish	same	same

Species	**Count**		
Notropis stramineus	51	9	57
Lepomis cyanellus	15	2	1
Catostomus commersoni	14	7	15
Cyprinella lutrensis	13	4	6
Hybognathus hankinsoni	11	9	6
Rhinichthys cataractae	10	10	1
Semotilus atromaculatus	3	3	1
Moxostoma macrolepidotum	2	-	1
Fundulus sciadicus	1	1	1
Pimephales promelas	1	-	1
Noturus flavus	1	7	-
Cyprinus carpio	-	3	-
Lepomis macrochirus	-	3	-
Notropis dorsalis	-	5	7

Description: Goose Creek is located in the central portion of the Sand Hills ecorgion. Near the confluence with the North Loup River where these specimens were collected, discharge ranged between 0.61 and 1.22 m^3/s, with average velocities ranging from of 0.3 - 0.6 m/s. Average width and depth were 6.7 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 9.2 - 11.5 mg/L), temperature (ranged from 14 - 25°C) and conductivity (ranged from 110 - 130 µmhos/cm). Goose Creek at this location is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was non-existent. Goose Creek is wide and shallow with a shifting sand substrate at this location. Riffle areas were common, and pools, located near cutting banks ranged in depth from 0.5 - 1.0 m, were common. Other instream habitat included stands of patches of *Elodea* sp., *C. demersum*, overhanging vegetation, and undercut banks. Overall habitat conditions were rated as being good and no visual changes in instream habitat conditions were observed in 1989.

Stream Name: North Fork Dismal River
Site Number: 11
Drainage Basin: Loup
County: Hooker
Legal Description: T22N, R34W, Sec. 21
Stream Order: 1

Collection Date(s):	8-3-88	5-31-89	7-19-89	10-12-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	25 minutes	37 minutes	26 minutes	19 minutes
Sample Distance:	429 m	216 m	216 m	216 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Rhinichthys cataractae	23	36	40	78
Pimephales promelas	3	21	6	7
Catostomus commersoni	1	-	-	-
Salmo trutta	-	1	-	-
Fundulus sciadicus	-	1	-	-
Oncorhynchus mykiss	-	-	-	12

Description: North Fork Dismal River is located in the central portion of the Sand Hills ecorgion. Upstream approximately 11 miles from the confluence of this river with the South Fork Dismal River where these specimens were collected, discharge ranged between 0.54 and 0.66 m^3/s, with average velocities ranging from of 0.4 - 1.4 m/s. Average width and depth were 5.0 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 8.0 - 12.5 mg/L), temperature (ranged from 16 - 20°C) and conductivity (ranged from 160 - 190 µmhos/cm). North Fork Dismal River at this location is a semi-high gradient, Sand Hills stream lying within a somewhat deep valley. Riparian areas are generally marshy in this reach and uplands are grasslands used for pasture. Grazing damage to riparian and streambank areas was minor. The stream has a swift current with a predominantly shifting sand substrate. Riffle areas were common, and pools, located near cutting banks ranged in depth from 0.5 - 1.0 m, were occasional. Other instream habitat included stands of patches of *C. demersum*, overhanging vegetation, and undercut banks. Overall habitat conditions were rated as being fair and no visual changes in instream habitat conditions were observed from 1988 - 1989.

Stream Name:	South Branch Middle Loup River
Site Number:	12
Drainage Basin:	Loup
County:	Cherry
Legal Description:	T25N, R36W, Sec. 32
Stream Order:	1

Collection Date(s):	8-2-88	5-31-89	7-11-89	10-12-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	12 minutes	30 minutes	30 minutes	15 minutes
Sample Distance:	182 m	131 m	131 m	131 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Notropis stramineus	125	53	36	30
Pimephales promelas	87	73	242	17
Hybognathus hankinsoni	9	4	228	9
Rhinichthys cataractae	8	106	36	35
Notropis dorsalis	5	122	126	26
Etheostoma exile	5	8	-	-
Fundulus sciadicus	3	7	11	15
Phoxinus neogaeus	-	-	4	-
Lepomis cyanellus	-	-	17	-

Description: South Branch Middle Loup River is located in the west-central portion of the Sand Hills ecoregion. In the headwater region where these specimens were collected, discharge ranged between 0.02 and 0.04 m^3/s, with average velocities ranging from of 0.1 - 0.3 m/s. Average width and depth were 1.6 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 6.3 - 11.9 mg/L), temperature (ranged from 9.5 - 23°C) and conductivity (ranged from 170 - 220 μmhos/cm). South Branch Middle Loup River at this location is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture. Upstream of the sampling reach, the stream has been channelized. Grazing damage to riparian and streambank regions was moderate in 1988 due to uncontrolled livestock access; resulting impacts documented through 1989 were: degradation to riparian areas and streambanks, widening and shallowing of the stream channel, and loss of pool habitat. Substrate was composed primarily of sand. Riffle areas were rare, and pools deeper than 0.2 m, were rare. Other instream habitat included filamentous algae, overhanging vegetation, and brush. Overall habitat conditions were rated as being fair. It did appear that in 1989 instream habitat conditions worsened due to the uncontrolled livestock access.

Stream Name: South Loup River
Site Number: 13
Drainage Basin: Loup
County: Logan
Legal Description: T18N, R27W, Sec. 34
Stream Order: 1

Collection Date(s): 8-8-88
Collector(s): NDEQ .
Sample Time: 19 minutes
Sample Distance: 182 m
Sampling Gear: Backpack electrofish

Species	Count
Esox americanus	6
Ictalurus punctatus	3
Noturus flavus	3
Lepomis cyanellus	2
Esox lucius	1

Description: The South Loup River is located in the south-central portion of the Sand Hills ecoregion. At the location where these specimens were collected, discharge was 0.1 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 2.2 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (8.7 mg/L) and temperature (23°C). The South Loup River at this location is bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand and detritus. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were common as well. Other instream habitat included *S. latifolia,* brush, and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Historical Collections: Jonhnson (1942) reported making collections in the South Loup River. The exact location where he made collections is unknown, however, according to his map it appears to have been relatively close to this site. Species reported being collected include: *Margariscus margarita, Rhinicthys cataractae, Semotilus atromaculatus, Phoxinus eos, Cyprinella lutrensis, Pimephales promelas, Notropis stramineus,* and *Campostoma anomalum.*

Niobrara Basin Site Descriptions

Stream Name: Willow Creek
Site Number: 14
Drainage Basin: Niobrara
County: Rock
Legal Description: T32N, R18W, Sec. 27
Stream Order: 1

Collection Date(s): 6-18-87
Collector(s): NDEQ
Sample Time: 12 minutes
Sample Distance: 55 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys atratulus	34
Semotilus atromaculatus	7
Fundulus sciadicus	3
Phoxinus eos	2
Pimephales promelas	2

Description: Willow Creek is located near the northeast boundary of the Sand Hills ecoregion. At the location where these specimens were collected, discharge was <0.1 m^3/s, with an average velocity of 0.2 m/s. Average width and depth were 1.7 m and 0.2 m, respectively. No physicochemical parameters were measured. Willow Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a semi-wooded riparian area. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were common as well. Other instream habitat included *S. latifolia,* brush, and overhanging vegetation. Overall instream habitat conditions were rated as being excellent.

Stream Name: Elk Creek
Site Number: 15
Drainage Basin: Niobrara
County: Rock
Legal Description: T31N, R19W, Sec. 6
Stream Order: 1

Collection Date(s): 6-18-87
Collector(s): NDEQ
Sample Time: 9 minutes
Sample Distance: 91 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys cataractae	34

Description: Elk Creek is located near the northeast boundary of the Sand Hills ecoregion. At the location where these specimens were collected, discharge was 0.1 m^3/s, with an average velocity of 0.2 m/s. Average width and depth were 2.0 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (5.0 mg/L), temperature (25°C), and conductivity (150 µmhos/cm). Elk Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand and gravel. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were common as well. Other instream habitat included brush, logs, and overhanging vegetation. Overall instream habitat conditions were rated as being excellent.

Stream Name: Sand Creek
Site Number: 16
Drainage Basin: Niobrara
County: Rock
Legal Description: T32N, R19W, Sec. 30
Stream Order: 1

Collection Date(s): 6-18-87
Collector(s): NDEQ
Sample Time: 9 minutes
Sample Distance: 91 m
Sampling Gear: Backpack electrofish

Species	Count
Notropis stramineus	90
Rhinichthys cataractae	7
Cyprinella lutrensis	6
Hybopsis gracilis	4
Semotilus atromaculatus	2
Salmo trutta	2

Description: Sand Creek is located near the northeast boundary of the Sand Hills ecoregion. Near the confluence of this stream with the Niobrara River where these specimens were collected, discharge was 0.1 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 1.7 m and 0.1 m, respectively. Physicochemical parameters measured were dissolved oxygen (8.2 mg/L), temperature (22°C), and conductivity (220 µmhos/cm). Sand Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand and gravel. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.60 m, were common as well. Other instream habitat included brush, logs, and overhanging vegetation. Overall instream habitat conditions were rated as being excellent.

Stream Name: Short Pine Creek
Site Number: 17
Drainage Basin: Niobrara
County: Rock
Legal Description: T32N, R20W, Sec. 34
Stream Order: 1

Collection Date(s):	6-18-87	5-22-89	7-26-89	10-4-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	15 minutes	21 minutes	23 minutes	12 minutes
Sample Distance:	109 m	128 m	128 m	128 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Notropis stramineus	27	-	44	33
Rhinichthys cataractae	8	11	8	1
Cyprinella lutrensis	7	7	3	3
Semotilus atromaculatus	6	1	2	7
Hybopsis gracilis	4	-	4	-
Salmo trutta	1	1	1	-

Description: Short Pine Creek is located near the northeast boundary of the Sand Hills ecoregion. Near the confluence of this stream with Long Pine Creek where these specimens were collected, discharge ranged between 0.02 and 0.04 m^3/s, with average velocities ranging from of 0.2 - 0.3 m/s. Average width and depth were 1.4 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 8.2 - 13.2 mg/L), temperature (ranged from 12 - 22°C) and conductivity (ranged from 140 - 205 µmhos/cm). Short Pine Creek is a relatively short, semi-high gradient, Sand Hills stream. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of a shifting sand bottom with some areas of claypan and gravel being exposed. Riffle areas were common, and pools, ranging in depth from 0.5 - 0.6 m, were occasional. Other instream habitat included overhanging vegetation, brush, logs, and undercut banks. Overall habitat conditions were rated as being excellent and no visual changes in instream habitat conditions were observed from 1988 - 1989.

Stream Name:	Long Pine Creek
Site Number:	18
Drainage Basin:	Niobrara
County:	Brown
Legal Description:	T29N, R20W, Sec. 19
Stream Order:	1

Collection Date(s):	6-83	5-17-89	7-12-89	10-4-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	42 minutes	22 minutes	36 minutes	12 minutes
Sample Distance:	115 m	169 m	169 m	169 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Rhinichthys cataractae	368	112	91	1
Oncorhynchus mykiss	3	4	2	-
Catostomus commersoni	3	15	7	-
Pimephales promelas	1	56	5	-
Salmo trutta	1	2	1	-
Salvelinus fontinalis	1	-	-	-
Lepomis cyanellus	-	5	-	-
Notropis stramineus	-	-	-	33
Cyprinella lutrensis	-	-	-	3
Semotilus atromaculatus	-	-	-	7

Description: Long Pine Creek is located near the northeast boundary of the Sand Hills ecorgion. Near the headwater area of this stream where these specimens were collected, discharge ranged between 0.2 and 0.4 m^3/s, with average velocities ranging from of 0.35 - 0.42 m/s. Average width and depth were 6.4 m and 0.1 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 9.3 - 13.1 mg/L), temperature (ranged from 12 - 16°C) and conductivity (ranged from 80 - 120 µmhos/cm). Long Pine Creek is semi-high gradient, Sand Hills stream. It is situated in a deep valley surrounded entirely by grasslands used for pasture and has a wooded riparian area. Flat, upland regions are used for crop production and at one time contributed significant amount of irrigation return flow to the creek. Grazing damage to riparian and streambank areas was non-existent. Substrate was composed primarily of a shifting sand bottom. Riffle areas were common, and pools, ranging in depth from 0.5 - 0.9 m, were occasional. Other instream habitat included *N. officinale*, *Ranunculus* sp., logs, cedar revetments, and overhanging vegetation. Overall habitat conditions were rated as being good and it didn't appear that any significant changes in instream habitat conditions took place from 1983 - 1989.

Historical Collections: Everman and Cox (1896) report making collections in Long Pine Creek at several locations. No specific site descriptions were provided, but species they reported taking included: sunfish (exact specie unknown), *Culaea inconstans*, and other minnows. Jonhnson (1942) reported making collections in Long Pine Creek and as with Evermann and Cox sampling locations are unknown. Species Johnson reported on include: *Oncorhynchus mykiss, Salmo trutta, Salvelinus fontinalis, Moxostoma macrolepidotum, Culaea inconstans, Lepomis cyanellus, Catostomus commersoni, Fundulus sciadicus, Rhinicthys cataractae, Semotilus atromaculatus, Notemigonus crysoleucas, Pomoxis nigromaculatus, Perca flavescens, Cyprinella lutrensis, Notropis dorsalis, Notropis stramineus, Etheostoma exile, Notropis heterolepis, Hybognathus hankinsoni, Micropterus salmoides, Pimephales promelas,* and *Ameiurus melas.*

Stream Name: Bone Creek
Site Number: 19
Drainage Basin: Niobrara
County: Brown
Legal Description: T30N, R22W, Sec. 27
Stream Order: 2

Collection Date(s): 8-30-83
Collector(s): NDEQ
Sample Time: 18 minutes
Sample Distance: 65 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys cataractae	47
Semotilus atromaculatus	38
Hybognathus hankinsoni	20
Notropis dorsalis	10
Phoxinus eos	10
Pimephales promelas	7
Margariscus margarita	6
Notropis stramineus	6
Culaea inconstans	4
Fundulus sciadicus	3
Catostomus commersoni	3

Description: Bone Creek is located in the northeast portion of the Sand Hills ecorgion. At the location where these specimens were collected, no discharge, velocity, or physicochemical parameters information was available. Average width and depth were 1.5 m and 0.1 m, respectively. Bone Creek at this location is bordered entirely by grasslands used for pasture. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.25 - 0.90 m, were occasional as well. Other instream habitat included brush, *T. latifolia*, and overhanging vegetation. Overall instream habitat conditions were rated as being fair.

Historical Collections: Jonhnson (1942) reported making collections in Bone Creek. The exact location where he made collections is unknown, however, according to his map it appears to have been relatively close to this site. Species reported being collected include: *Semotilus atromaculatus, Pimephales promelas, Notropis dorsalis, Hybognathus hankinsoni*, and *Fundulus sciadicus.*

Stream Name: Sand Draw Creek
Site Number: 23
Drainage Basin: Niobrara
County: Brown
Legal Description: T30N, R23W, Sec. 12
Stream Order: 1

Collection Date(s):	5-10-83	5-17-89	7-12-89	10-4-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	18 minutes	22 minutes	25 minutes	15 minutes
Sample Distance:	69 m	94 m	94 m	94 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Rhinichthys cataractae	174	45	44	19
Semotilus atromaculatus	9	121	65	64
Notropis dorsalis	39	41	21	73
Phoxinus eos	1	-	-	-
Hybognathus hankinsoni	10	-	-	-
Catostomus commersoni	3	5	-	3
Pimephales promelas	1	-	-	-
Fundulus sciadicus	-	-	10	3
Margariscus margarita	-	-	1	-

Description: Sand Draw Creek is located in the north-east portion of the Sand Hills ecorgion. In the headwater region where these specimens were collected, discharge ranged between 0.1 and 0.2 m^3/s, with average velocities ranging from of 0.2 - 0.4 m/s. Average width and depth were 3.7 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 9.1 - 11.3 mg/L), temperature (ranged from 13 - 17°C) and conductivity (ranged from 130 - 175 μmhos/cm). Sand Draw Creek at this location is a typical, low gradient, Sand Hills stream bordered by grasslands used for pasture with some irrigated cropland in the uplands. Grazing damage to riparian and streambank regions was reported as being moderate in 1986 due to uncontrolled livestock access and similar observations were made in 1989. Substrate was composed primarily of sand. Riffle areas were common, and pools deeper than 0.6 m, were rare. Other instream habitat included overhanging vegetation, and brush. Overall habitat conditions were rated as being fair and it didn't appear that any significant changes in instream habitat conditions took place from 1986 - 1989.

Stream Name:	Dry Creek
Site Number:	21
Drainage Basin:	Niobrara
County:	Brown
Legal Description:	T30N, R24W, Sec. 4
Stream Order:	1

Collection Date(s):	6-24-87	5-17-89	7-12-89	10-10-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	15 minutes	21 minutes	21 minutes	10 minutes
Sample Distance:	137 m	182 m	182 m	182 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Semotilus atromaculatus	36	20	47	14
Notropis dorsalis	19	321	92	53
Rhinichthys cataractae	8	14	1	-
Lepomis cyanellus	2	-	-	-
Ameiurus melas	2	-	-	-
Pimephales promelas	1	-	-	-

Description: Dry Creek is located in the north-east portion of the Sand Hills ecorgion. Near the headwater region where these specimens were collected, discharge ranged between 0.01 and 0.04 m^3/s, with average velocities ranging from of 0.01 - 0.2 m/s. Average width and depth were 3.2 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 10.1 - 13.7 mg/L), temperature (ranged from 18 - 25°C) and conductivity (ranged from 100 - 205 µmhos/cm). Dry Creek at this location is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture. Grazing damage was reported as being minor in 1987, however, when the stream was visited in July of 1989, uncontrolled livestock access had caused serious damage to the riparian and streambank regions; resulting impacts were: degraded riparian areas, streambanks, widening and shallowing of the stream channel, and loss of pool habitat. Substrate was composed primarily of sand in 1987 and much fine silt/organic matter was present in summer and fall of 1989. Riffle areas were rare, and pools deeper than 0.2 m, were rare. Other instream habitat included filamentous algae and brush. Overall habitat conditions were rated as being good in 1987, however, in 1989 they were observed as being poor.

Stream Name: Muleshoe Creek
Site Number: 22
Drainage Basin: Niobrara
County: Keya Paha
Legal Description: T32N, R24W, Sec. 22
Stream Order: 1

Collection Date(s): 6-25-87
Collector(s): NDEQ
Sample Time: 20 minutes
Sample Distance: 137 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys cataractae	45
Catostomus commersoni	14
Semotilus atromaculatus	6
Notropis stramineus	4
Hybopsis gracilis	3
Notropis dorsalis	1

Description: Muleshoe Creek is located near the north boundary of the Sand Hills ecorgion. Near the confluence of this stream with the Niobrara River where these specimens were collected, discharge was <0.1 m^3/s, with an average velocity of 0.2 m/s. Average width and depth were 2.0 m and 0.07 m, respectively. Physicochemical parameters measured were dissolved oxygen (8.5 mg/L), temperature (22°C), and conductivity (330 µmhos/cm). Muleshoe Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand, gravel and cobble. Riffle areas were common, and pools, deeper than 0.6 m, were rare. Other instream habitat included filamentous algae, brush, logs, and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Stream Name: Turkey Creek
Site Number: 23
Drainage Basin: Niobrara
County: Keya Paha
Legal Description: T33N, R23W, Sec. 36
Stream Order: 1

Collection Date(s): 6-25-87
Collector(s): NDEQ
Sample Time: 15 minutes
Sample Distance: 114 m
Sampling Gear: Backpack electrofish

Species	Count
Notropis stramineus	38
Rhinichthys cataractae	9
Semotilus atromaculatus	8
Catostomus commersoni	1

Description: Turkey Creek is located near the north boundary of the Sand Hills ecorgion. Near the confluence of this stream with the Niobrara River where these specimens were collected, discharge was <0.05 m^3/s, with an average velocity of 0.2 m/s. Average width and depth were 1.3 m and 0.1 m, respectively. Physicochemical parameters measured were dissolved oxygen (7.0 mg/L), temperature (21°C), and conductivity (310 µmhos/cm). Turkey Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand, bedrock and gravel. Riffle areas were common, and pools, deeper than 0.9 m, were rare. Other instream habitat included filamentous algae, *T. latifolia*, brush, overhanging vegetation, and undercut banks. Overall instream habitat conditions were rated as being excellent.

Stream Name:	Minnechaduza Creek			
Site Number:	24			
Drainage Basin:	Niobrara			
County:	Cherry			
Legal Description:	T34N, R30W, Sec. 1			
Stream Order:	2			
Collection Date(s):	7-21-87	5-18-89	7-18-89	10-11-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	15 minutes	30 minutes	24 minutes	20 minutes
Sample Distance:	109 m	119 m	119 m	119 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Campostoma anomalum	72	15	10	9
Notropis stramineus	30	85	107	59
Rhinichthys cataractae	30	15	15	7
Fundulus sciadicus	25	-	14	1
Notropis dorsalis	23	69	112	175
Catostomus commersoni	9	4	4	11
Semotilus atromaculatus	7	7	3	9
Lepomis cyanellus	2	1	-	1
Cyprinus carpio	2	-	-	-
Pimephales promelas	2	2	8	4
Phoxinus neogaeus	2	-	-	-
Phoxinus eos	1	-	1	-
Hybognathus hankinsoni	1	4	18	1
Noturus flavus	1	1	-	-
Lepomis humilis	1	-	-	-
Ambloplites rupestris	-	2	-	-
Etheostoma exile	-	-	1	-

Description: Minnechaduza Creek is located near the north boundary of the Sand Hills ecoregion. At the location where these specimens were collected, discharge ranged between 0.1 and 0.5 m^3/s, with average velocities ranging from of 0.1 - 0.3 m/s. Average width and depth were 4.4 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 6.5 - 11.7 mg/L), temperature (ranged from 14.5 - 22°C) and conductivity (ranged from 240 - 320 µmhos/cm). Minnechaduza Creek is a typical, low gradient, Sand Hills stream bordered by grasslands used for pasture, wet meadows used for hay production and sparse stands of willows. Grazing damage to riparian and streambank areas was reported as being minor. The stream had a shifting sand substrate with many cutting banks. Riffle areas were common, and pools, ranging in depth from 0.5 - 1.0 m, were common. Other instream habitat included patches of *C. demersum*, *Elodea* sp., overhanging vegetation, exposed willow roots, brush, and undercut banks. Overall habitat conditions were rated as being good and it didn't appear that any significant changes in instream habitat conditions took place from 1987 - 1989.

Historical Collections: Jonhnson (1942) reported making collections near the lower end of Minnechaduza Creek. The exact location where he made collections is unknown, however, I estimated my site to be several miles upstream according to his map. Species reported being collected near the lower end of Minnechaduza Creek include: *Semotilus atromaculatus, Pimephales promelas, Notropis stramineus, Lepomis cyanellus, Catostomus commersoni, Fundulus sciadicus, Rhinicthys cataractae, Notemigonus crysoleucas, Cyprinella lutrensis, Etheostoma exile, Micropterus salmoides, Ameiurus melas, Noturus flavus, Phoxinus eos, Lepomis macrochirus,* and *Hybopsis gracilis.*

Stream Name: Minnechaduza Creek
Site Number: 25
Drainage Basin: Niobrara
County: Cherry
Legal Description: T35N, R31W, Sec. 24
Stream Order: 2

Collection Date(s): 7-21-87
Collector(s): NDEQ
Sample Time: 15 minutes
Sample Distance: 68 m
Sampling Gear: Backpack electrofish

Species	Count
Esox americanus	3

Description: Minnechaduza Creek is located near the north boundary of the Sand Hills ecoregion. Near the headwater region of this stream where these specimens were collected, discharge was 0.04 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 3.7 m and 0.6 m, respectively. Physicochemical parameters measured were dissolved oxygen (4.3 mg/L), temperature (21°C), and conductivity (420 μmhos/cm). Minnechaduza Creek is a typical, low gradient, Sand Hills stream bordered by grasslands used for pasture, wet meadows used for hay production and sparse stands of willows. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand and detritus.

Riffle areas were rare due to many beaver dams which ponded the stream in many areas. Pools, deeper than 0.9 m, were occasional throughout the stream reach sampled. Other instream habitat included filamentous algae, *T. latifolia*, *Ranunculus* sp., exposed willow roots, brush, and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Stream Name: Schlagel Creek
Site Number: 26
Drainage Basin: Niobrara
County: Cherry
Legal Description: T33N, R28W, Sec. 25
Stream Order: 1

Collection Date(s): 7-20-87
Collector(s): NDEQ
Sample Time: 20 minutes
Sample Distance: 46 m
Sampling Gear: Backpack electrofish

Species	Count
Perca flavescens	18
Salmo trutta	9
Catostomus commersoni	6
Rhinichthys cataractae	5
Semotilus atromaculatus	1
Ameiurus melas	1

Description: Schlagel Creek is located near the north boundary of the Sand Hills ecoregion. Near the confluence of this stream with the Niobrara River where these specimens were collected, discharge was 0.4 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 3.7 m and 0.6 m, respectively. Physicochemical parameters measured were dissolved oxygen (7.2 mg/L) and temperature (25°C). Schlagel Creek discharges directly into the Niobrara River. It is situated in a somewhat deep valley surrounded entirely by grasslands used for pasture in the uplands and has a wooded riparian area. Grazing damage to riparian and streambank areas was reported as being non-existent. Substrate was composed primarily of sand. Riffle areas were common, and pools, deeper than 0.9 m, were occasional. Other instream habitat included brush, overhanging vegetation, and undercut banks. Overall instream habitat conditions were rated as being good.

Historical Collections: Everman and Cox (1896) report examining the lower portion of Schlagel Creek but provide no account of fish collected. Jonhnson (1942) reported making collections in lower Schlagel Creek. Species Johnson reported on include: *Notropis stramineus, Etheostoma exile, Pimephales promelas,* and *Hybopsis gracilis.*

Stream Name: Boardman Creek
Site Number: 27
Drainage Basin: Niobrara
County: Cherry
Legal Description: T30N, R31W, Sec. 14
Stream Order: 1

Collection Date(s): 8-15-88
Collector(s): NDEQ
Sample Time: 27 minutes
Sample Distance: 205 m
Sampling Gear: Backpack electrofish

Species	Count
Micropterus salmoides	24
Notemigonus crysoleucas	19
Lepomis humilis	8
Ambloplites rupestris	6
Esox americanus	5
Lepomis macrochirus	5
Ameiurus melas	1

Description: Boardman Creek is located in north-central portion of the Sand Hills ecoregion. Near the confluence of this stream with Merritt Reservoir where these specimens were collected, discharge was 0.3 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 3.7 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (6.8 mg/L), temperature (27°C), and conductivity (210 µmhos/cm). Boardman Creek is a typical, low gradient, Sand Hills stream. At this location it the entire stream is bordered by wild grasslands and thick stands of willows. Upstream the grasslands are used for pasture. Grazing damage to riparian and streambank areas was reported as being non-existent. Substrate was composed primarily of sand. Riffle areas were common, and pools, deeper than 0.9 m, were occasional. Other instream habitat included patches of *Ranunculus* sp., brush, overhanging vegetation, and exposed willow roots. Overall instream habitat conditions were rated as being excellent. No explanation for low fish diversity and total numbers.

Stream Name: Boardman Creek
Site Number: 28
Drainage Basin: Niobrara
County: Cherry
Legal Description: T30N, R32W, Sec. 33
Stream Order: 1

Collection Date(s): 7-21-87
Collector(s): NDEQ
Sample Time: 14 minutes
Sample Distance: 91 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys cataractae	5
Notemigonus crysoleucas	1
Lepomis humilis	1
Esox americanus	1
Ameiurus melas	1

Description: Boardman Creek is located in north-central portion of the Sand Hills ecoregion. Near the streams headwaters where these specimens were collected, discharge was 0.25 m^3/s, with an average velocity of 0.3 m/s. Average width and depth were 2.7 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (8.6 mg/L), temperature (22°C), and conductivity (250 μmhos/cm). Boardman Creek is a typical, low gradient, Sand Hills stream which has been subject to periodic dredging throughout the 1900's as to drain the wet meadows bordering it. Grasslands used for pasture also border the stream. Grazing damage to riparian and streambank areas was reported as being moderate. Substrate was composed primarily of sand. Riffle areas were occasional, and pools, deeper than 0.9 m, were occasional. Other instream habitat included patches of *Ranunculus* sp., *C. demersum*, and overhanging vegetation. Overall instream habitat conditions were rated as being fair.

Stream Name: Snake River
Site Number: 29
Drainage Basin: Niobrara
County: Cherry
Legal Description: T30N, R40W, Sec. 21
Stream Order: 1

Collection Date(s): 7-23-87
Collector(s): NDEQ
Sample Time: 15 minutes
Sample Distance: 46 m
Sampling Gear: Backpack electrofish

Species	Count
Pimephales promelas	27
Fundulus sciadicus	14
Culaea inconstans	11
Phoxinus eos	4
Phoxinus neogaeus	2
Notropis dorsalis	2
Catostomus commersoni	1
Ameiurus melas	1

Description: The Snake River is located north-central portion of the Sand Hills ecoregion. Near the headwater region of this stream where these specimens were collected, discharge was <0.05 m^3/s, with an average velocity of 0.06 m/s. Average width and depth were 1.3 m and 0.1 m, respectively. Physicochemical parameters measured were dissolved oxygen (2.5 mg/L), temperature (23°C), and conductivity (160 µmhos/cm). Snake Creek at this location represent a typical, low gradient, Sand Hills headwater stream bordered by a marshy riparian area, grasslands used for pasture, wet meadows used for hay production, and sparse stands of willows. Grazing damage to riparian and streambank areas was reported as being non-existent. Substrate was composed primarily of sand and detritus. Riffle areas were rare due to the low flow and pools, deeper than 0.6 m, were rare throughout the stream reach sampled. Other instream habitat included filamentous algae, *C. demersum*,, brush, and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Historical Collections: Johnson (1942) reported making collections in the Snake River. The exact location where he made collections is unknown, however, according to his map it appears to have been relatively close to this site. Species reported being collected include: *Rhinicthys cataractae, Notropis stramineus, Margariscus margarita, Hybognathus hankinsoni, Fundulus sciadicus,* and *Oncorhynchus mykiss.*

Stream Name:	Gordon Creek			
Site Number:	30			
Drainage Basin:	Niobrara			
County:	Cherry			
Legal Description:	T29N, R35W, Sec. 14			
Stream Order:	2			
Collection Date(s):	8-16-88	5-31-89	7-17-89	10-11-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	14 minutes	23 minutes	31 minutes	22 minutes
Sample Distance:	160 m	100 m	100 m	100 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	**Count**			
Hybognathus hankinsoni	35	-	7	1
Notropis dorsalis	27	31	88	7
Rhinichthys cataractae	25	4	8	35
Margariscus margarita	7	5	-	-
Fundulus sciadicus	6	-	1	1
Etheostoma exile	2	3	3	3
Pimephales promelas	2	3	10	-
Lepomis cyanellus	1	-	-	1
Phoxinus neogaeus	-	1	-	-
Notropis heterolepis	-	1	3	-

Description: Gordon Creek is located in central portion of the Sand Hills ecoregion. At the location where these specimens were collected, discharge ranged between 0.2 and 0.3 m^3/s, with average velocities ranging from of 0.1 - 0.3 m/s. Average width and depth were 2.7 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 7.7 - 15.1 mg/L), temperature (ranged from 10 - 23°C) and conductivity (ranged from 110 - 210 μmhos/cm). Gordon Creek is a typical, low gradient, Sand Hills stream which has been subject to periodic dredging throughout the 1900's as to drain the wet meadows bordering it. Grasslands used for pasture also border the stream. Grazing damage to riparian and streambank areas was reported as being non-existent in this location. Substrate was composed primarily of sand and claypan. Riffle areas were occasional, and pools, deeper than 0.9 m, were occasional. Other instream habitat included overhanging vegetation, exposed willow roots, and brush. The stream at this location is nearly straight with little or no meanders. Stream water was stained on each sampling date. Overall instream habitat conditions were rated as being excellent and it didn't appear that any significant changes in instream habitat conditions took place from 1988 -1989.

Stream Name: Unnamed Creek
Site Number: 31
Drainage Basin: Niobrara
County: Cherry
Legal Description: T29N, R37W, Sec. 19
Stream Order: 1

Collection Date(s): 7-23-87
Collector(s): NDEQ
Sample Time: 20 minutes
Sample Distance: 46 m
Sampling Gear: Backpack electrofish

Species	Count
Notropis dorsalis	57
Fundulus sciadicus	34
Phoxinus neogaeus	32
Hybognathus hankinsoni	20
Margariscus margarita	4
Pimephales promelas	4
Culaea inconstans	2
Phoxinus eos	4
Ameiurus melas	1

Description: This unnamed creek is located in the central portion of the Sand Hills ecoregion. Near the headwater region of this stream where these specimens were collected, discharge was 0.01 m^3/s, with an average velocity of 0.08 m/s. Average width and depth were 1.3 m and 0.2 m, respectively. Physicochemical parameters measured were temperature (23°C) and conductivity (120 μmhos/cm). This unnamed creek represents a typical, low gradient, Sand Hills headwater stream bordered by wet meadows used for hay production and grasslands used for pasture. The area below the stream samples appears to have been subject to periodic dredging as to drain the wet meadows bordering it. Grazing damage to riparian and streambank areas was reported as being non-existent. Substrate was composed primarily of sand and detritus. Riffle areas were rare due to the low flow and pools, deeper than 0.6 m, were rare throughout the stream reach sampled. Other instream habitat included filamentous algae, *S. latifolia, Ranunculus* sp., and overhanging vegetation. Overall instream habitat conditions were rated as being good.

Stream Name:	Bear Creek			
Site Number:	32			
Drainage Basin:	Niobrara			
County:	Cherry			
Legal Description:	T34N, R37W, Sec. 8			
Stream Order:	1			
Collection Date(s):	7-22-87	5-23-89	7-18-89	10-11-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	15 minutes	30 minutes	28 minutes	15 minutes
Sample Distance:	73 m	134 m	134 m	134 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Lepomis cyanellus	9	50	25	4
Esox americanus	4	1	2	2
Esox lucius	2	-	-	-
Lepomis humilis	1	-	-	-
Ameiurus melas	-	1	-	-
Lepomis macrochirus	1	-	-	1

Description: Bear Creek is located in north-central portion of the Sand Hills ecoregion. At the location where these specimens were collected, discharge ranged between 0.1 and 0.2 m^3/s, with average velocities ranging from of 0.1 - 0.3 m/s. Average width and depth were 2.3 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 8.1 -12.4 mg/L), temperature (ranged from 13 - 21°C) and conductivity (ranged from 80 - 130 µmhos/cm). Bear Creek is a typical, low gradient, Sand Hills stream which has been subject to periodic dredging throughout the 1900's as to drain the wet meadows bordering it. Grasslands used for pasture and sparse stands of willows also border the stream. Grazing damage to riparian and streambank areas was reported as being non-existent in this location. Substrate was composed primarily of sand. Riffle areas were common and pools, deeper than 0.9 m, were common as well. Other instream habitat included overhanging vegetation, exposed willow roots, and undercut banks. The stream at this location has not been dredged or straightened for a long time, and is starting to meander again. Overall instream habitat conditions were rated as being excellent and it didn't appear that any significant changes in instream habitat conditions took place from 1987 - 1989.

Stream Name:	Dry Creek			
Site Number:	36			
Drainage Basin:	Niobrara			
County:	Cherry			
Legal Description:	T34N, R38W, Sec. 14			
Stream Order:	1			
Collection Date(s):	7-22-87	5-23-89	7-18-89	10-11-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	14 minutes	22 minutes	18 minutes	7 minutes
Sample Distance:	114 m	112 m	112 m	112 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Lepomis cyanellus	19	1	5	1
Esox americanus	4	-	-	-
Micropterus salmoides	3	-	-	-
Perca flavescens	3	-	-	-
Lepomis humilis	3	-	-	-
Ameiurus melas	-	2	2	-
Notropis dorsalis	-	-	1	-

Description: Dry Creek is located in north-central portion of the Sand Hills ecoregion. At the location where these specimens were collected, discharge ranged between 0.02 and 0.1 m^3/s, with average velocities ranging from of 0.1 - 0.2 m/s. Average width and depth were 2.4 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 7.6 -10.3 mg/L), temperature (ranged from 12 - 22°C) and conductivity (ranged from 215 - 350 µmhos/cm). Dry Creek is a typical, low gradient, Sand Hills stream surrounded by wet meadows used for hay production and grasslands used for pasture. Grazing damage to riparian and streambank areas was reported as being minor in this location. Substrate was composed primarily of sand and claypan. Riffle areas were common and pools, deeper than 0.9 m, were occasional. Other instream habitat included overhanging vegetation, brush, and undercut banks. Overall instream habitat conditions were rated as being excellent in 1987. However, instream habitat conditions may have been impacted by increased sedimentation caused by road construction taking place upstream of this site in the spring of 1989. Fish abundance and diversity was significantly lower in 1989.

Stream Name: Leander Creek
Site Number: 34
Drainage Basin: Niobrara
County: Cherry
Legal Description: T34N, R38W, Sec. 21
Stream Order: 2

Collection Date(s):	7-22-87	5-23-89	7-18-89
Collector(s):	NDEQ	NDEQ	NDEQ
Sample Time:	9 minutes	22 minutes	11 minutes
Sample Distance:	18 m	76 m	76 m
Sampling Gear:	Backpack electrofish	same	same

Species	Count		
Hybognathus hankinsoni	235	27	88
Phoxinus neogaeus	130	58	136
Margariscus margarita	73	1	40
Pimephales promelas	30	52	45
Etheostoma exile	22	4	3
Fundulus sciadicus	15	55	117
Notropis stramineus	30	-	-
Phoxinus eos	-	-	15

Description: Leander Creek is located in north-central portion of the Sand Hills ecoregion. Near the streams headwaters where these specimens were collected, discharge ranged from being pooled to 0.05 m^3/s, with average velocities ranging from of 0.0 - 0.08 m/s. Average width and depth were 1.3 m and 0.3 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 3.8 -11.0 mg/L), temperature (ranged from 19 - 24°C) and conductivity (ranged from 200 - 620 µmhos/cm). Leander Creek at this location is a typical headwater, low gradient, Sand Hills stream which has been subject to periodic dredging throughout the 1900's as to drain the wet meadows bordering it. Grasslands used for pasture and sparse stands of willows also border the stream. Grazing damage to riparian and streambank areas was reported as being non-existent in this location. Substrate was composed primarily of sand. Riffle areas were occasional and pools, deeper than 0.6 m, were occasional as well. Other instream habitat included overhanging vegetation, brush, and undercut banks. Overall instream habitat conditions were rated as being excellent and it didn't appear that any significant changes in instream habitat conditions took place from 1987 - summer of 1989. In the fall of 1989 the stream was pooled.

Stream Name: Pine Creek
Site Number: 35
Drainage Basin: Niobrara
County: Sheridan
Legal Description: T30N, R44W, Sec. 33
Stream Order: 1

Collection Date(s): 7-23-87
Collector(s): NDEQ
Sample Time: 12 minutes
Sample Distance: 137 m
Sampling Gear: Backpack electrofish

Species	Count
Rhinichthys cataractae	22
Catostomus commersoni	2
Noturus flavus	1
Semotilus atromaculatus	1
Notropis stramineus	1
Notropis dorsalis	1

Description: Pine Creek is located near the western boundary of the Sand Hills ecoregion. Near the confluence of this stream with the Niobrara River where these specimens were collected, discharge was 0.6 m^3/s, with an average velocity of 0.4 m/s. Average width and depth were 3.8 m and 0.3 m, respectively. Physicochemical parameters measured were temperature (24°C) and conductivity (140 µmhos/cm). Pine Creek is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture, wet meadows used for hay production and sparse stands of willows. Grazing damage to riparian and streambank areas was reported as being minor. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.5 - 0.9 m, were occasional. Other instream habitat included thick patches of *C. demersum*, *Elodea* sp., overhanging vegetation, brush, and undercut banks. Overall habitat conditions were rated as being good.

Stream Name:	Pine Creek			
Site Number:	36			
Drainage Basin:	Niobrara			
County:	Sheridan			
Legal Description:	T29N, R44W, Sec. 14			
Stream Order:	1			
Collection Date(s):	7-23-87	5-24-89	7-19-89	10-12-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	38 minutes	36 minutes	20 minutes	24 minutes
Sample Distance:	182 m	132 m	132 m	132 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Fundulus sciadicus	43	15	24	1
Semotilus atromaculatus	35	4	5	5
Catostomus commersoni	34	3	6	4
Rhinichthys cataractae	31	85	88	26
Notropis stramineus	27	9	55	20
Notropis dorsalis	10	7	35	13
Pimephales promelas	8	9	3	-
Pomoxis nigromaculatus	4	-	-	-
Culaea inconstans	2	-	-	-
Noturus flavus	1	-	-	-
Salmo trutta	-	3	1	-
Margariscus margarita	-	-	4	-

Description: Pine Creek is located near the western boundary of the Sand Hills ecoregion. At the location where these specimens were collected, discharge ranged between 0.3 and 0.4 m^3/s, with average velocities ranging from of 0.2 - 0.3 m/s. Average width and depth were 4.8 m and 0.4 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 7.5 -16.2 mg/L), temperature (ranged from 12 - 25°C) and conductivity (ranged from 100 - 120 µmhos/cm). Pine Creek is a typical, low gradient, Sand Hills stream bordered entirely by grasslands used for pasture, wet meadows used for hay production and sparse stands of willows. Grazing damage to riparian and streambank areas was reported as being moderate. Substrate was composed primarily of sand. Riffle areas were common, and pools, ranging in depth from 0.5 - 0.9 m, were occasional. Other instream habitat included thick patches of *C. demersum*, *Elodea* sp., overhanging vegetation, brush, and undercut banks. Overall habitat conditions were rated as being good and it didn't appear that any significant changes in instream habitat conditions took place from 1987 - 1989.

Stream Name:	Niobrara River			
Site Number:	37			
Drainage Basin:	Niobrara			
County:	Sheridan			
Legal Description:	T29N, R46W, Sec. 22			
Stream Order:	3			
Collection Date(s):	7-23-87	5-24-89	7-19-89	10-4-89
Collector(s):	NDEQ	NDEQ	NDEQ	NDEQ
Sample Time:	13 minutes	29 minutes	22 minutes	17 minutes
Sample Distance:	91 m	84 m	84 m	84 m
Sampling Gear:	Backpack electrofish	same	same	same

Species	Count			
Notropis stramineus	93	104	54	145
Rhinichthys cataractae	68	51	48	44
Campostoma anomalum	22	51	20	45
Catostomus commersoni	16	36	20	37
Semotilus atromaculatus	11	79	11	23
Moxostoma macrolepidotum	8	3	1	15
Hybognathus hankinsoni	3	36	42	78
Fundulus sciadicus	2	21	3	1
Pimephales promelas	-	14	5	5
Notropis dorsalis	-	56	4	14
Perca flavescens	-	-	1	1
Phoxinus neogaeus	-	-	1	-
Micropterus salmoides	-	-	-	1

Description: The headwaters of the Niobrara River originate outside the western boundary of the Sand Hills ecoregion. However, for most of its length it is within the Sand Hills ecoregion boundaries. At the location where these specimens were collected, discharge ranged between 0.3 and 0.5 m^3/s, with average velocities ranging from of 0.3 - 0.4 m/s. Average width and depth were 5.0 m and 0.2 m, respectively. Physicochemical parameters measured were dissolved oxygen (ranged from 8.3 -13.5 mg/L), temperature (ranged from 8.5 - 15°C) and conductivity (ranged from 280 - 450 µmhos/cm). The Niobrara River at this location is similar to other typical Sand Hills stream in that it is bordered entirely by grasslands used for pasture, wet meadows used for hay production and sparse stands of willows and cottonwood trees. However, the substrate composition varies between sand, gravel, and claypan. Grazing damage to riparian and streambank areas was reported as being non-existent. Riffle areas were common, and pools, ranging in depth from 0.5 - 0.9 m, were common. Other instream habitat included thick patches of *T. latifolia*, exposed willow roots, overhanging vegetation, brush, beaver dams, and undercut banks. Overall habitat conditions were rated as being excellent and it didn't appear that any significant changes in instream habitat conditions took place from 1987 - 1989. Beaver dams were present during each sampling event.

Appendix B

Fish community attribute information used in scoring the adapted IBI.

Site No.	Stream Order	No. Fish Species	No. Darter Species	No. Sunfish Species	No. Sucker Species	No. Intolerant Species	Prop. as G. Sunfish
1	1	14	0	2	3	0	13
2	1	10	0	1	2	0	3
3	1	5	0	0	2	0	0
4	1	9	1	1	1	2	1
5	1	5	0	1	1	2	2
6	1	9	0	2	0	3	5
7	1	8	0	1	0	3	7
8	1	4	0	1	0	1	3
9	1	10	0	0	1	3	0
10C	1	18	1	1	2	6	3
11	1	3	0	0	1	1	0
12	1	7	1	0	0	3	0
13	1	5	0	1	0	2	13
14	1	5	0	0	0	3	0
15	1	1	0	0	0	1	0
16	1	6	0	0	0	2	0
17	1	6	0	0	0	2	0
18	2	6	0	0	1	4	0
19	2	11	0	0	2	4	0
20	1	7	0	0	1	2	0
21	1	6	0	1	0	1	3
22	1	6	0	0	1	1	0
23	1	4	0	0	1	1	0
24	2	15	0	2	1	3	1
25	2	1	0	0	0	1	0
26	1	6	0	0	1	2	0
27	1	7	0	3	0	2	0
28	1	5	0	1	0	2	0
29	1	8	0	0	1	4	0
30	2	8	1	1	0	4	1
31	1	9	0	0	0	5	0
32	1	5	0	3	0	2	53
33	1	5	0	2	0	1	59
34	1	7	1	0	0	4	0
35	1	6	0	0	1	1	0
36	1	10	0	1	1	3	0
37	3	8	0	0	2	2	0

Appendix B - continued

Fish community attribute information used in scoring the adapted IBI.

Site No.	Prop. as Omnivores	Prop. as Cyprinids	Prop. as Piscivores	No. of Individuals	Fish per Minute	Prop. of Hybrids	Prop. of Diseased	Shannon - Wiener
1	24	18	3	38	1.9	0	0	2.35
2	36	48	2	58	4.1	0	0	1.72
3	14	29	14	7	0.8	0	0	1.55
4	40	1	0	94	6.7	0	0	1.43
5	0	18	0	45	2.3	0	0	1.31
6	0	34	4	97	5.4	0	0	1.50
7	45	29	16	31	1.8	0	0	1.67
8	7	0	0	30	2.3	0	0	0.63
9	2	49	0	99	9	0	0	1.63
10C	11	55	0	251	14	0	0	2.23
11	4	85	0	27	1	0	0	0.50
12	40	57	0	242	20	0	0	1.16
13	0	0	47	15	0.8	0	0	1.46
14	4	75	0	48	4	0	0	0.96
15	0	100	0	34	3.8	0	0	0.00
16	0	96	0	111	12.3	0	0	0.77
17	0	87	0	53	3.5	0	0	1.41
18	1	98	0	377	9	0	0	0.15
19	5	51	0	154	8.6	0	0	1.97
20	1	69	0	335	18.6	0	0	1.27
21	1	40	0	68	4.5	0	0	1.21
22	0	73	0	73	3.7	0	0	1.17
23	0	84	0	56	3.7	0	0	0.91
24	2	27	0	208	13.9	0	0	1.96
25	0	0	100	3	0.2	0	0	0.00
26	0	13	0	40	2	0	0	1.42
27	28	0	43	68	2.5	0	0	1.64
28	11	56	11	9	0.6	0	0	1.30
29	44	13	0	62	4.1	0	0	1.54
30	2	56	0	105	7.5	0	0	1.60
31	3	61	0	158	7.9	0	0	1.65
32	0	0	0	17	1.1	0	0	1.26
33	0	0	0	32	2.3	0	0	1.24
34	6	44	44	535	59.4	0	0	1.53
35	0	86	86	28	2.3	0	0	0.85
36	4	35	35	195	5.1	0	0	1.95
37	0	72	72	223	17.2	0	0	1.51

Appendix C

Fish community attribute information used to score a modified IBI.

Site No.	Stream Type	No. Fish Species	Presence of Spec. Feeder	No. Native Cyprinids	No. Intolerant Species	Prop. as Creek Chubs
1	2	14	A	5	0	5
2	2	10	A	4	0	3
3	2	5	A	1	0	0
4	2	9	P	4	2	1
5	1	5	P	2	2	7
6	2	9	P	4	3	3
7	2	8	P	4	3	0
8	2	4	A	0	1	0
9	2	10	A	7	3	0
10C	2	18	P	10	6	4
11	1	3	P	2	1	0
12	2	7	P	5	3	0
13	2	5	A	0	2	0
14	1	5	P	4	3	15
15	1	1	P	0	1	0
16	1	6	P	5	2	2
17	1	6	P	5	2	11
18	1	6	P	2	4	0
19	2	11	P	8	4	25
20	2	7	P	5	2	27
21	2	6	P	4	1	53
22	1	6	P	5	1	8
23	1	4	P	3	1	14
24	2	15	P	9	3	3
25	2	1	A	0	1	0
26	1	6	P	2	2	3
27	2	7	A	1	2	0
28	2	5	P	2	2	0
29	2	8	A	4	4	0
30	2	8	P	5	4	0
31	2	9	A	6	5	0
32	2	5	A	0	2	0
33	2	5	A	0	1	0
34	2	7	P	6	4	0
35	2	6	P	4	1	4
36	2	10	P	5	3	18
37	2	8	P	5	2	5

Appendix C - continued

Fish community attribute information used to score a modified IBI.

Site No.	Prop. as Omnivores	Prop. as Cyprinids	No. of Individuals	Fish per Minute	Prop. of Hybrids	Prop. of Diseased	Shannon - Weiner
1	24	18	38	1.9	0	0	2.35
2	36	48	58	4.1	0	0	1.72
3	14	29	7	0.8	0	0	1.55
4	40	1	94	6.7	0	0	1.43
5	0	18	45	2.3	0	0	1.31
6	0	34	97	5.4	0	0	1.50
7	45	29	31	1.8	0	0	1.67
8	7	0	30	2.3	0	0	0.63
9	2	49	99	9	0	0	1.63
10C	11	55	251	14	0	0	2.23
11	4	85	27	1	0	0	0.50
12	40	57	242	20	0	0	1.16
13	0	0	15	0.8	0	0	1.46
14	4	75	48	4	0	0	0.96
15	0	100	34	3.8	0	0	0.00
16	0	96	111	12.3	0	0	0.77
17	0	87	53	3.5	0	0	1.41
18	1	98	377	9	0	0	0.15
19	5	51	154	8.6	0	0	1.97
20	1	69	335	18.6	0	0	1.27
21	1	40	68	4.5	0	0	1.21
22	0	73	73	3.7	0	0	1.17
23	0	84	56	3.7	0	0	0.91
24	2	27	208	13.9	0	0	1.96
25	0	0	3	0.2	0	0	0.00
26	0	13	40	2	0	0	1.42
27	28	0	68	2.5	0	0	1.64
28	11	56	9	0.6	0	0	1.30
29	44	13	62	4.1	0	0	1.54
30	2	56	105	7.5	0	0	1.60
31	3	61	158	7.9	0	0	1.65
32	0	0	17	1.1	0	0	1.26
33	0	0	32	2.3	0	0	1.24
34	6	44	535	59.4	0	0	1.53
35	0	86	28	2.3	0	0	0.85
36	4	35	195	5.1	0	0	1.95
37	0	72	223	17.2	0	0	1.51

Appendix D

Adapted IBI metric scores for 37 Sand Hills streams.

Site No.	No. Fish Species	No. Darter Species	No. Sunfish Species	No. Sucker Species	No. Intolerant Species	Prop. as G. Sunfish
1	5	3	5	5	1	3
2	5	3	3	5	1	5
3	3	3	1	5	1	5
4	5	5	3	5	5	5
5	3	3	3	5	5	5
6	5	3	5	3	5	3
7	5	3	3	3	5	3
8	3	3	3	3	3	5
9	5	3	1	5	5	5
10C	5	3	3	5	5	5
11	1	3	1	5	3	5
12	5	5	1	3	5	5
13	3	3	3	3	5	3
14	3	3	1	3	5	5
15	1	3	1	3	3	5
16	3	3	1	3	5	5
17	3	3	1	3	5	5
18	3	3	1	5	5	5
19	5	3	1	5	5	5
20	5	3	1	5	5	5
21	3	3	3	3	3	5
22	3	3	1	5	3	5
23	3	3	1	5	3	5
24	5	3	5	5	5	5
25	1	3	1	3	3	5
26	3	3	1	5	5	5
27	5	3	5	3	5	5
28	3	3	3	3	5	5
29	5	3	1	5	5	5
30	5	5	3	3	5	5
31	5	3	1	3	5	5
32	3	3	5	3	5	1
33	3	3	5	3	3	1
34	5	5	1	3	5	5
35	3	3	1	5	3	5
36	5	5	3	5	5	5
37	3	3	1	5	5	5

Appendix D - continued

Adapted IBI metric scores for 37 Sand Hills streams.

Site No.	Prop. as Omnivores	Prop. as Nat. Cyprinids	Prop. as Piscivores	No. of Individuals	Prop. as Hybrids	Prop. as Diseased
1	3	1	3	1	5	5
2	3	5	3	3	5	5
3	5	3	5	1	5	5
4	3	1	3	5	5	5
5	5	1	3	3	5	5
6	5	3	3	5	5	5
7	3	3	5	1	5	5
8	5	1	3	3	5	5
9	5	5	3	5	5	5
10C	5	5	3	5	5	5
11	5	5	3	1	5	5
12	3	5	3	5	5	5
13	5	1	5	1	5	5
14	5	5	3	3	5	5
15	5	5	3	3	5	5
16	5	5	3	5	5	5
17	5	5	3	3	5	5
18	5	5	3	5	5	5
19	5	5	3	5	5	5
20	5	5	3	5	5	5
21	5	3	3	3	5	5
22	5	5	3	3	5	5
23	5	5	3	3	5	5
24	5	3	3	5	5	5
25	5	1	5	1	5	5
26	5	1	3	3	5	5
27	3	1	5	3	5	5
28	5	5	5	1	5	5
29	3	1	3	3	5	5
30	5	5	3	5	5	5
31	5	5	3	5	5	5
32	5	1	5	1	5	5
33	5	1	5	3	5	5
34	5	3	3	5	5	5
35	5	5	3	3	5	5
36	5	3	3	5	5	5
37	5	5	3	5	5	5

Appendix D - continued

Adapted IBI metric scores for 37 Sand Hills streams.

Site No.	Total IBI Score	Adapted IBI Rating
1	40	F
2	46	F-G
3	42	F
4	50	G
5	46	F-G
6	50	G
7	44	F
8	42	F
9	52	G
10C	54	G-E
11	42	F
12	50	G
13	42	F
14	46	F-G
15	42	F
16	48	G
17	46	F-G
18	50	G
19	52	G
20	52	G
21	44	F
22	46	F-G
23	46	F-G
24	54	G-E
25	38	P-F
26	44	F
27	48	G
28	48	G
29	44	F
30	54	G-E
31	50	G
32	42	F
33	42	F
34	50	G
35	46	G
36	54	G-E
37	50	G

Appendix E

Modified IBI metric scores for 37 Sand Hills streams.

Site No.	No. Fish Species	Presence of Spec. Feeder	No. Native Cyprinids	No. Intolerant Species	Prop. as Creek Chubs	Prop. as Omnivores
1	5	1	5	1	3	3
2	5	1	3	1	5	3
3	3	1	1	1	5	5
4	5	5	3	5	5	3
5	3	5	3	5	3	5
6	5	5	3	5	5	5
7	5	5	3	5	5	3
8	3	1	1	3	5	5
9	5	1	5	5	5	5
10C	5	5	5	5	5	5
11	3	5	3	3	5	5
12	5	5	5	5	5	3
13	3	1	1	5	5	5
14	5	5	5	5	3	5
15	1	5	1	3	5	5
16	5	5	5	5	5	5
17	5	5	5	5	3	5
18	5	5	3	5	5	5
19	5	5	5	5	1	5
20	5	5	5	5	1	5
21	5	5	3	3	1	5
22	5	5	5	3	3	5
23	3	5	3	3	3	5
24	5	5	5	5	5	5
25	1	1	1	3	5	5
26	5	5	3	5	5	5
27	5	1	1	5	5	3
28	3	5	1	5	5	5
29	5	1	3	5	5	3
30	5	5	5	5	5	5
31	5	1	5	5	5	5
32	3	1	1	5	5	5
33	3	1	1	3	5	5
34	5	5	5	5	5	5
35	5	5	3	3	5	5
36	5	5	5	5	3	5
37	5	5	5	5	3	5

Appendix E - continued

Modified IBI metric scores for 37 Sand Hills streams.

Site No.	Prop. as Insect. Cyprinids	No. of Individuals	Prop. as Hybrids	Prop. as Diseased	Total IBI Score	Modified IBI Rating
1	1	1	5	5	30	F
2	5	3	5	5	36	F-G
3	3	1	5	5	30	F
4	1	5	5	5	42	G
5	1	3	5	5	38	G
6	3	5	5	5	46	G-E
7	3	1	5	5	40	G
8	1	3	5	5	32	F
9	5	5	5	5	46	G-E
10C	5	5	5	5	50	E
11	5	1	5	5	40	G
12	5	5	5	5	48	E
13	1	1	5	5	32	F
14	5	3	5	5	46	G-E
15	5	3	5	5	38	G
16	5	5	5	5	50	E
17	5	3	5	5	46	G-E
18	5	5	5	5	48	G-E
19	5	5	5	5	46	G-E
20	5	5	5	5	46	G-E
21	3	3	5	5	38	G
22	5	3	5	5	44	G-E
23	5	3	5	5	40	G
24	3	5	5	5	48	E
25	1	1	5	5	28	P-F
26	1	3	5	5	42	G
27	1	3	5	5	34	F
28	5	1	5	5	40	G
29	1	3	5	5	36	F-G
30	5	5	5	5	50	E
31	5	5	5	5	46	G-E
32	1	1	5	5	32	F
33	1	3	5	5	32	F
34	3	5	5	5	48	E
35	5	3	5	5	44	G-E
36	3	5	5	5	46	G-E
37	5	5	5	5	48	E