PERFORMANCE REPORT

As Required by
FEDERAL AID IN SPORT FISH RESTORATION ACT

Investigations of Indices of Biotic Condition for Streams in New Mexico

Federal Aid Grant F-59-R-10

Investigations of Indices of Biotic Condition
for Streams in New Mexico
Project No. 01

by

Gerald Z. Jacobi, James E. Sublette, Scott J. Herrmann,
David E. Cowley, and Michael D. Hatch

Larry Bell, Director
New Mexico Department of Game and Fish

Michael Sloane, Chief
Fisheries Management Division

Lisa Evans, Federal Aid Coordinator
Administrative Services Division

May 21, 2001

PERFORMANCE REPORT

State: New Mexico Grant Number: F-59-R-10
Project Title: Investigations of Indices of Biotic Condition for Streams in New Mexico.
Contract Period: March 1, 2000 to February 28, 2001
Study Objective: To develop objective and diagnostic biomonitoring criteria for the assessment of stream ecosystem health in New Mexico.

ABSTRACT

This report presents results of research regarding the development of indices of biotic condition for perennial streams in New Mexico. To date, the focus of study has been to: (1) evaluate schemes for landscape classification with respect to chemical and physical environmental factors, (2) identify "faunal regions" and determine if they are consistent with regional strata defined by environmental factors, (3) characterize associations, or assemblages, of biota, (4) initiate identification of summary statistics for inclusion in indices of biotic condition for streams, and (5) develop taxonomic keys for benthic macroinvertebrates and an atlas of chironomid pupal exuviae to facilitate application of an index of biotic condition.

The development of biotic-based indices of aquatic ecosystem condition awaits data analyses in four principle areas. These areas include: (1) reanalysis of environmental data using corrected data as described in the previous section, (2) use of criteria external to our data sets to develop two groups of sites for subsequent analysis (more impaired and less impaired), (3) compilation of summary metrics from fish and benthic macroinvertebrate data for use in analyses to develop indices of biotic integrity, and (4) within each landscape stratum, analyze data with discriminant function analysis to find an index of biotic integrity based on features of the biotic community.

INTRODUCTION

This report presents results of research regarding the development of indices of biotic condition (IBC's) for perennial streams in New Mexico. To date, our research efforts have focused on understanding biota-environment relationships and how such knowledge can be employed in the development of these indices.

Biotic-based criteria for the assessment of stream ecosystem health is not a new concept (Karr, 1993). Monitoring of the environmental health of freshwater systems has progressed from the near universal measurement of BOD earlier in this century, to measurement of a broader spectrum of chemical and physical quantities, to incorporation of biota into indices that are reflective, at least to some extent, of environmental health (e.g., Karr, 1981; Hilsenhoff, 1982). In spite of this progression, and even with the acknowledgment that biota provide better interpretability than chemical parameters (Steedman and Haider, 1993), there is much to be learned. Indeed, the "agony of community ecology" (Lewontin, 1974) is that we often do not know which variables are important and we lack simple quantitative models to describe environmental variation and its effect on the biota (Keddy et al., 1993).

IBC's have important potential uses in fisheries management and in watershed protection. When properly constructed, an IBC will identify sites where single or multiple stressors begin to cause species composition to differ substantially from expectation. Complementing this, IBC's offer easily observable measures of ecosystem response to management.

JOB OBJECTIVES

2. Identify faunal regions for benthic macroinvertebrate and midges and compare these to aquatic ecoregions.

3. Produce maps of fish and invertebrate faunal regions in a geographical information system.

4. Develop an index of biotic integrity for each ecoregion where possible.

6. Prepare an illustrated atlas of chironomid pupal exuviae and a checklist of taxa and dichotomous keys to the Plecoptera, Ephemeroptera, and Trichoptera.

7. Prepare performance or final reports

RESULTS AND DISCUSSION

Over the past several segments, sampling has been conducted at 154 aquatic sites representing the major river basins in New Mexico, including the San Juan, Zuni, San Francisco, Gila, Mimbres, Rio Grande, Tularosa, Salt, Pecos, and Canadian/Arkansas basins. Results and discussions of analyses of the environmental data and data from icthyofaunal and benthic macroinvertebrate collections have been previously reported (Jacobi et al. 1998, 1999 and 2000). This report emphasizes initial results of the adult Trichoptera collections, collections of Chironomidae and exploratory analysis in the development of biotic-based indices for the assessment of stream ecosystem health.

Objective 2.

Environmental Data

In July 2000, a few errors were noted in the environmental data for the biotic condition project. These errors led to an extensive examination of data for elevation, growing season length, substrate composition, and latitude-longitude coordinates. All questionable data values that were identified have been checked against maps, original data sheets, and other sources and all errors that were identified have been corrected. In addition to data corrections, additional data were compiled for habitat scores for each sample site and statistics for historical stream discharge. Data for historical stream discharge were obtained from the U. S. Geological Survey (USGS). Daily stream discharge statistics were added to data for sites that are situated at or near USGS gage stations. These summary statistics include: mean, median, maximum value, minimum value, range, standard deviation, variance, skewness, and kurtosis.

This report includes a number of graphical summaries that were developed to depict in a statewide fashion the character of surface waters with respect to various chemical parameters (Appendix A). These chemical parameters include alkalinity, calcium, carbonate, chloride, hardness, magnesium, sodium, sulfate, and total dissolved solids. In addition, we have developed a new way of viewing relative anionic and cationic composition of surface waters that preserves the spatial relationship of sample sites while retaining the information content formerly displayed with triangular coordinate graphs. In each of the graphical depictions included in this report, except for relative anionic and cationic compositions, the size of a circle representing a sample location is proportional to the value of the parameter for that sample location relative to the sample location that had the maximum value for that constituent. Site locations that have small relative values for a chemical constituent are represented by very small circles and may not be obvious to the viewer.

For relative anionic and cationic compositions, all sample sites were represented by a common sized circle and primary colors (red, yellow, and blue) were used to represent a dominance of a single anion or cation. Secondary colors (orange, green, and purple) were used to represent a combination of two anions or cations, and secondary colors shaded to a grayish color were used to represent a combination of three anions or cations of distinctly unequal concentrations. When three anions or cations occurred in roughly equal proportions, a gray color (20% black) was used to represent a sample location.

Adult Trichoptera Data

Some 132 species of adult Trichoptera have been identified from 114 sample sites. These represent collections from all of the major drainage basins in the state. These samples were obtained by night light sampling, sweep net sampling, and from Thienemann (skim) net sampling. Taxa collected in these collections are listed in Appendix B, Table 1.

Time did not permit cluster analysis of adult Trichoptera species to reveal broad-scale distributional associations among taxa or similarities among sample sites. However, superficial examination of the record of collections shows a diverse and endemic fauna. Along with the common Rocky Mountain species, many neotropical and eastern species were represented in the collections. An abundance of new species of Hydroptilidae was particularly obvious. This high diversity of hydroptilids is probably a response to the prevalence of fine sediments in most of the lotic sites studied.

Chironomidae Data

Samples of adult Chironomidine (midges) have been collected from 154 stream sites. Collection methods include UV light traps, sweep netting and Thienemann (skim) net technique to collect pupal exuviae (floating cast skins left behind after the adults emerged). The latter collection method is the preferred because it is the least invasive and the most time economical method. The 154 stream sites selected have been sampled by this technique. UV light trap collecting for adults is more time consuming and, frequently, less productive or not practical to employ in remote or high elevation sites. However, these samples, together with the sweep net samples, were a most significant adjunct to the project in that it permitted species level identifications that are frequently not possible with pupae unless they have been previously associated.

A total of 414 species (or taxa) has been identified to date. These are shown in Appendix B, Figure 2 and listed in Appendix B, Table 2. As the remaining slides are examined many of the pupal/adult associations will be clarified. Nomenclature is continually changing as new species are described and as new life histories are elucidated. The classification codes given in Appendix B, Figure 2 are as follows:

First number: Subfamily or Tribe
Second number: Genus code (repeated in each subfamily)
Third number: Species code (repeated in each genus)

Subfamilies: 1 - Tanypodinae
2 – Podonominae
3 – Diamesinae
4 – Prodiamesinae
5 – Orthocladiinae
6 – Chironominae/Chironomini
7 – Chironominae/Tanytarsini

Members of subfamilies 2-5 are restricted to or predominate in higher elevation streams while tribes 6-7 of the subfamily Chironominae dominate the lower elevation streams together with those species of subfamily 5 which are warm adapted.

Objective 3.

Geographical information-based maps of fish and invertebrate faunal regions will be generated when the compilation of site collection records for the faunal groups included in this study have been finalized.

Objective 4.

The development of biotic-based indices of aquatic ecosystem condition awaits data analyses in four principle areas. These areas include: (1) reanalysis of environmental data using corrected data as described in the previous section, (2) use of criteria external to our data sets to develop two groups of sites for subsequent analysis (more impaired and less impaired), (3) compilation of summary metrics from fish and benthic macroinvertebrate data for use in analyses to develop indices of biotic integrity, and (4) within each landscape stratum, analyze data with discriminant function analysis to find an index of biotic integrity based on features of the biotic community.

Objective 6.
A manuscript key, which was presented in the 1999-2000 annual report, has had some additions and emendations but is not presented here.

In order to complete a publication quality report, many additional illustrations must be made. All of the species known to date have been photographed and an atlas assembled, but the quality is not sufficient for publication purposes. Consequently, publication quality photos are being taken with a spot insight digital camera that is coupled with a Zeiss compound research microscope. Completion of the Handbook of Chironomid Pupae is now much closer to fruition.

Objective 7.

A performance report has been prepared.

RECOMMENDATIONS

Because of the number of corrections made to the environmental data, the updated environmental data will be reanalyzed with respect to possible stratification of sites for index development. If analyses indicate substantially different boundary locations from our original aquatic ecoregions stratification, then the manuscript on the aquatic ecoregions may be revised to include the updated analyses. An additional analysis will seek to identify a stream/watershed size that might yield a better stratification with respect to development of indices of biotic condition at sites above 5500 ft elevation.

An important aspect of development of indices of biotic condition is the segregation of sampling sites into more impaired versus less impaired groups of sites. To accomplish this efficiently and to avoid circularity in logic, it is imperative to use grouping criteria external to the data to be analyzed in biotic condition index development. We have two criteria available. First, a habitat assessment score was assigned at the time of field sampling. Second, stream segments are classified as meeting or not meeting designated uses and these designations are published on the

303d list by the New Mexico Environment Department Surface Water Quality Bureau. If these two criteria do not yield a clear segregation of sites into more versus less impaired, then we will also incorporate expert opinion from team members other than the data analyst.

Our approach to index development will begin at a coarser level of taxonomy and move to a finer level only if the coarser level(s) fail to yield good indices of biotic condition. We believe that by pursuing index development beginning with a coarser summary level, that we can obtain indices of biotic condition that may require a lesser amount of field and laboratory work. We intend to use in our initial analyses for index development summary metrics such as numbers of extant and absent native fish species, number of nonnative fish species present, number of benthic macroinvertebrate taxa, number or relative abundance of feeding groups among benthic macroinvertebrates, Winget-Mangum tolerance scores, and Hilsenhoff sensitivity scores.

By utilizing the segregation of sites into more impaired or less impaired, we can apply discriminant function analysis to find, within aquatic ecoregion, a linear combination of summary metrics that best separates more impaired from less impaired stream sites. A discriminant function provides an attractive basis for an index of biotic condition because it is objectively derived, it takes into consideration variances and covariances among the summary metrics, and it can be applied to new sites that were not included in the development of the discriminant function.

If our initial effort to develop indices of biotic condition using coarser summary level metrics does not yield good indices, then we will continue our development with a finer-scale level of taxonomy and summarization. It may ultimately be necessary to utilize relative abundance data at a species level of community composition.

We anticipate that the IBC's developed through this project will involve a combination of water and habitat quality measures and multiple aspects of the fish and benthic macroinvertebrate biota. For the final phase of the project, we intend to carry out sampling at new sites so that the efficacy of the IBC's can be validated.

LITERATURE CITED

Hilsenhoff, W. L. 1982. Using a biotic index to evaluate water quality in streams. Wisconsin Department of Natural Resources Technical Bulletin No. 132, 22 pp.

Jacobi, G. Z., J. E. Sublette, S. L. Herrmann, D. E. Cowley and M. D. Hatch. 1998. Investigations of indices of biotic integrity in New Mexico. Federal Aid in Sport Fish Restoration Act final report, Grant F-59-R. New Mexico Department of Game and Fish, Santa Fe.

Jacobi, G. Z., J. E. Sublette, S. L. Herrmann, D. E. Cowley and M. D. Hatch. 1999. Investigations of indices of biotic integrity in New Mexico. Federal Aid in Sport Fish Restoration Act performance report, Grant F-59-R. New Mexico Department of Game and Fish, Santa Fe.

Jacobi, G. Z., J. E. Sublette, S. L. Herrmann, D. E. Cowley and M. D. Hatch. 2000. Investigations of indices of biotic condition for streams in New Mexico. Federal Aid in Sport Fish Restoration Act performance report, Grant F-59-R. New Mexico Department of Game and Fish, Santa Fe.

Karr, J. R. 1993. Measuring biological integrity: Lessons from streams. pp. 83-104, In: S. Woodley, J. Kay, and G. Francis (eds.), Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Delray, FL.

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

Keddy, P. A., H. T. Lee, and I. C. Wisheu. 1993. Choosing indicators of ecosystem integrity: Wetlands as a model system. pp. 61-79, In: S. Woodley, J. Kay, and G. Francis (eds.), Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Delray, FL.

Lewontin, R. C. 1974. The Genetic Basis of Evolutionary Change. Columbia University Press, NY.

Steedman, R. and W. Haider. 1993. Applying notions of ecological integrity. pp. 47-60, In: S. Woodley, J. Kay, and G. Francis (eds.), Ecological Integrity and the Management of Ecosystems. St. Lucie Press, Delray, FL.

Stewart, A. J. and J. M. Loar. 1994. Spatial and temporal variation in biomonitoring data. pp. 91-124, In: S. L. Loeb and A. Spacie (eds.), Biological Monitoring of Aquatic Systems. Lewis Publishers, Boca Raton, FL.

Winget, R. W., and Mangum, F. A. 1979. Biotic condition index: integrated biological, physical, and chemical stream parameters for management. Provo, Utah, U. S. Forest Service, Intermountain Region. 51 p.