Ecological Indicators 7 (2007) 807–826

ECOLOGICAL INDICATORS

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www.elsevier.com/locate/ecolind

Development of a RIVPACS-type predictive model for bioassessment of wadeable streams in Wyoming

Eric G. Hargett [a,*], Jeremy R. ZumBerge [b], Charles P. Hawkins [c], John R. Olson [c]

[a] *Wyoming Department of Environmental Quality-Water Quality Division, 122 W. 25th Street, Herschler Bldg. 4-W, Cheyenne, WY 82002, USA*
[b] *Wyoming Department of Environmental Quality-Water Quality Division, 1866 S. Sheridan Avenue, Sheridan, WY 82801, USA*
[c] *Western Center for Monitoring and Assessment of Freshwater Ecosystems, Department of Aquatic, Watershed, and Earth Resources, Utah State University, Logan, UT 84322, USA*

Received 30 March 2006; received in revised form 2 October 2006; accepted 4 October 2006

Abstract

RIVPACS models produce a community-level measure of biological condition known as *O*/*E*, which is derived from a comparison of the observed (*O*) biota with those expected (*E*) to occur in the absence of anthropogenic stress. We used benthic macroinvertebrate and environmental data collected at 925 stream monitoring stations, from 1993 to 2001, to develop, validate, and apply a RIVPACS model to assess the biological condition of wadeable streams in Wyoming. From this dataset, 296 samples were identified as reference, 157 of which were used to calibrate the model, 46 to validate it, and 93 to examine temporal variability in reference site *O*/*E*-values. We used cluster analyses to group the model development reference sites into biologically similar classes of streams and multiple discriminant function analysis to determine which environmental variables best discriminated among reference groups. A suite of 14 categorical and continuous environmental variables best discriminated among 15 reference groups and explained a large proportion of the natural variability in biota within the reference dataset. Eleven of the predictor variables were derived from GIS. As expected, mean *O*/*E*-values for reference sites used in model development and validation were near unity and statistically similar. Temporal variability in *O*/*E*-values for reference sites was low. Test site values ranged from 0 to 1.45 (mean = 0.73). The model was accurate in both space and time and precise enough (S.D. of *O*/*E*-values for calibration data = 0.17) to detect modest alteration in biota associated with anthropogenic stressors. Our model was comparable in performance to other RIVPACS models developed in the United States and can produce effective assessments of biological condition over a broad, ecologically diverse region. We also provide convincing evidence that RIVPACS models can be developed primarily with GIS-based predictor variables. This framework not only simplifies the extraction of predictor variable information while potentially reducing expenditures of time and money in the collection of predictor variable information, but opens the door for development and/or application of RIVPACS models in regions where there is a paucity of local-scale, abiotic information.

Keywords: Benthic macroinvertebrates; Bioassessment; Biological assessment of freshwater ecosystems; Biological indices; GIS; Modeling; *O*/*E*; Predictive model; RIVPACS; Streams; Wyoming

* Corresponding author. Tel.: +1 307 777 6701; fax: +1 307 777 5973.
E-mail address: eharge@state.wy.us (E.G. Hargett).

1470-160X/$ – see front matter
doi:10.1016/j.ecolind.2006.10.001

1. Introduction

RIVPACS (River InVertebrate Prediction And Classification System) is a multivariate predictive model that allows detection and interpretation of anthropogenic stress on invertebrate assemblages of streams and rivers (Clarke et al., 2003; Moss et al., 1987; Wright et al., 1993, 2000). Its derivative, AUSRIVAS (AUStralian RIVer Assessment System), is widely used to assess the biological condition of streams in Australia (Smith et al., 1999). Although these predictive models have been used in Great Britain and Australia for more than a decade, their potential has not been fully explored in the United States (Hawkins, 2006; Hawkins and Carlisle, 2001; Hawkins et al., 2000).

RIVPACS models make site-specific predictions of the benthic macroinvertebrate fauna expected in the absence of anthropogenic stressors. Those predictions are based on empirical relationships between individual taxon probabilities of capture and natural environmental features (e.g., latitude, substrate composition, alkalinity, elevation, etc.) that are derived from data collected from a reference site network. The deviation of the observed from the expected fauna, is usually (but not necessarily) measured by the ratio (O/E) of the observed (O) to expected (E)-values of one or more biotic index (Clarke et al., 1996). When the O/E index is expressed in units of taxa richness, it can be a measure of compositional similarity and thus a community-level measure of biological integrity (Hawkins, 2006).

There has been growing recognition among natural resource managers throughout the United States that biological indices such as O/E are useful and desirable tools in the evaluation of biological integrity of streams and to satisfy requirements under Sections 305(b) and 303(d) of the Clean Water Act (1972, amended in 1977). Use of RIVPACS models in the United States for bioassessment purposes is still a relatively new concept, but is gaining popularity. Several predictive models developed with datasets from the states of California, Maine, North Carolina, Ohio, Oregon, Washington, and the Mid-Atlantic Highlands region (e.g., Hawkins, 2006; Hawkins et al., 2000) show promise as effective tools in the evaluation of stream biological condition in the United States.

Advantages of a RIVPACS model compared to other bioassessment tools (e.g., multimetric and biotic indices) include intuitive output, ease of biological interpretation and its inherent standardization to site-specific conditions (Hawkins, 2006). One of the goals of the Wyoming Department of Environmental Quality-Water Quality Division (WDEQ/WQD), the primary entity responsible for protecting and managing biological integrity of streams in Wyoming, is the continued development of the most effective and applicable bioassessment tools to ascertain the condition of aquatic life in streams and rivers. The applicability of the RIVPACS approach to freshwater systems internationally as well as its promise as an effective bioindex tool in the United States presents an ideal opportunity to develop such a model for use in bioassessments in Wyoming. To our knowledge, a Wyoming RIVPACS model would represent the first attempt at developing such a regional framework for the United States intermountain west.

The objective of this study was to develop and evaluate a RIVPACS model that was applicable to wadeable streams in the State of Wyoming. To do so, we used an extensive statewide database that contained 9 years of benthic macroinvertebrate, physical, and chemical data collected at reference and non-reference sites by the WDEQ/WQD. We followed the latest techniques in both the development of RIVPACS models as well as assessing their accuracy and precision. We then applied the model to our entire dataset to assess the biological condition of individual sites.

2. Methods and materials

2.1. Study area

Wyoming is biologically diverse, with much of this diversity attributable to variability in geology, climate, topography, and other environmental features of the state (Knight, 1994). The State of Wyoming straddles the continental divide and encompasses 251,489 km^2 (97,100 mi^2). Wyoming is characterized by abrupt topographic relief and numerous types of exposed granitic, volcanic, and sedimentary bedrock. Elevation ranges from 939 to 4207 m (3081–13,802 ft) with a mean of 2030 m (6660 ft). Average annual precipitation ranges from 15 to 150 cm (6–59 in.), which is mostly in