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Ecological Indicators 7 (2007) 329–338

ECOLOGICAL INDICATORS

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Quantifying tolerance indicator values for common stream fish species of the United States

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Received 7 October 2005; received in revised form 21 February 2006; accepted 22 February 2006

Abstract

The classification of fish species tolerance to environmental disturbance is often used as a means to assess ecosystem conditions. Its use, however, may be problematic because the approach to tolerance classification is based on subjective judgment. We analyzed fish and physicochemical data from 773 stream sites collected as part of the U.S. Geological Survey's National Water-Quality Assessment Program to calculate tolerance indicator values for 10 physicochemical variables using weighted averaging. Tolerance indicator values (TIVs) for ammonia, chloride, dissolved oxygen, nitrite plus nitrate, pH, phosphorus, specific conductance, sulfate, suspended sediment, and water temperature were calculated for 105 common fish species of the United States. Tolerance indicator values for specific conductance and sulfate were correlated (rho = 0.87), and thus, fish species may be co-tolerant to these water-quality variables. We integrated TIVs for each species into an overall tolerance classification for comparisons with judgment-based tolerance classifications. Principal components analysis indicated that the distinction between tolerant and intolerant classifications was determined largely by tolerance to suspended sediment, specific conductance, chloride, and total phosphorus. Factors such as water temperature, dissolved oxygen, and pH may not be as important in distinguishing between tolerant and intolerant classifications, but may help to segregate species classified as moderate. Empirically derived tolerance classifications were 58.8% in agreement with judgment-derived tolerance classifications. Canonical discriminant analysis revealed that few TIVs, primarily chloride, could discriminate among judgment-derived tolerance classifications of tolerant, moderate, and intolerant. To our knowledge, this is the first empirically based understanding of fish species tolerance for stream fishes in the United States.
Published by Elsevier Ltd.

Keywords: Fish; Tolerance values; Biological assessment; Streams

1. Introduction

Fish assemblage characteristics have been used for over 100 years to assess ecosystem conditions (Simon, 1999). The use of fish assemblage characteristics has accelerated greatly over the past 30 years with implementation of the Clean Water Act of 1972, requiring protection and restoration of biological integrity as part of water-quality standards. A focus on biological integrity led to the development and use of biological criteria, and a variety of quantitative

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1470-160X/$ – see front matter. Published by Elsevier Ltd.
doi:10.1016/j.ecolind.2006.02.004

indices such as the widely used Index of Biological Integrity (IBI; Karr, 1981). The perception of fish species tolerance to environmental disturbance was integral to the development of the IBI (Fausch et al., 1990) and three general classes of fish tolerance to environmental disturbance – tolerant, moderate, and intolerant – are widely recognized (Halliwell et al., 1999).

The classification of fish species tolerance to environmental disturbance, and thus, its use as a component of the IBI may be problematic because the approach to tolerance classification is based on subjective judgment of overall tolerance to disturbance — including both physicochemical water quality and physical habitat. Assignment of fish species into tolerance classes has generally been based on professional judgment in terms of a general application of Shelford's law of tolerance (Shelford, 1912), which states that the growth and distribution of organisms can be limited both by too little or too much of an essential factor. When occasional differences of opinion have occurred among ecologists, the problem generally has been solved by expanding the three classes into four, for example — tolerant, moderately tolerant, moderately intolerant, and intolerant. Whittier and Hughes (1998), in developing a quantitatively derived tolerance classification for lake-dwelling fishes, noted that they could find no evidence that quantitative methods had been applied in assigning fish species to overall tolerance classes.

A related problematic issue may be the assignment to a tolerance classification based on fish species relations to general environmental disturbance. For example, tolerance classifications are often based on an understanding of the cumulative tolerance to ''water-quality changes'' and ''habitat alteration'' (Jester et al., 1992). Whittier and Hughes (1998) suggested that tolerance classifications to such general environmental disturbance may have been relatively successful in the Midwestern United States, where the IBI was originally developed, because of a perceived relative homogeneity of environmental conditions in this region. Thus, tolerance classifications based on cumulative understanding to general environmental disturbance may have limited utility across a broad geographic area beyond detecting significant levels of disturbance. The U.S. Environmental Protection Agency has produced a dataset of commonly used tolerance classifications for selected fish species in the United States (Barbour et al., 1999), based on a classification for each species from selected literature sources. However, such tolerance classifications seem to beg the question, ''tolerant to what''? The application of tolerance classifications across multiple geographic scales would require a greater understanding of tolerance to specific environmental stressors.

Fish assemblage structure is characterized as part of an integrated physical, chemical, and biological assessment of the Nation's water quality in the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program. Data collected as part of the NAWQA Program provided the opportunity to quantify fish species tolerances to selected physicochemical variables. Specifically, our objectives were to (1) calculate fish species tolerance indicator values (TIVs) to selected physicochemical variables from a national-scale dataset, (2) examine relations among TIVs, (3) assess variation in TIVs among fish species, and (4) assess the ability of TIVs to discriminate among judgment-based tolerance classes.

2. Methods

The NAWQA Program's design focuses on major river basins across the United States (Gilliom et al., 1995). Together, these areas account for 60–70% of the Nation's population and cover about one-half of the Nation's land area. Major river basins were selected based on several factors including population and water use, importance of water-quality issues, and geographic distribution. River basin selection focused on agricultural and urbanized basins and used forested basins as a type of control to reflect undisturbed land use. Whereas the river basins are geographically distributed across the United States, their locations are biased towards areas where population, water use, and agricultural land uses are greater than average. The sites were not selected to be a statistically representative sample of the Nation's streams. Data for this analysis were collected from 773 stream sites sampled from 1993 to 2004. Combined, these sites are located downstream of 43% of the total kilometers of streams and rivers in the Nation and represent a wide range of environmental settings (Table 1).