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Are Anurans of Great Lakes Coastal Wetlands Reliable Indicators of Ecological Condition?

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ABSTRACT. *Frogs and toads (anurans) are sensitive to a variety of anthropogenic stressors and are widely suggested as indicators of ecological condition. We surveyed 220 coastal wetlands along the U.S. shores of the Laurentian Great Lakes and quantified relationships between presence of anuran species and degree of anthropogenic disturbance. Results were used to derive explicit, functional relationships between environmental condition and anuran occurrences. These functions were subsequently used to calculate a multi-species indicator of ecological condition at other (novel) wetlands. Of 14 anuran species observed, spring peeper* (Pseudacris crucifer) *exhibited the strongest and most consistent relationship with environmental condition across the entire study area. Other species exhibited significant relationships with the environmental gradient, but the direction of association varied geographically or the overall species abundance was very low (e.g., mink frog,* Rana septentrionalis*). Even if applied to separate ecological provinces (Laurentian Mixed Forest or Eastern Deciduous Forest), multi-species estimates of wetland condition based on anurans are not much better indicators of environmental condition based on human disturbance than are indices based solely on occurrence of spring peeper. Nevertheless, indicators grounded in explicit relationships with environmental stress are superior to traditional measures (e.g., species richness) that combine species with different responses to the stress gradient. At least one anuran species (spring peeper) can contribute meaningfully to the assessment of ecological condition in Great Lakes coastal wetlands; its value as an indicator will be improved if it can be combined with information from other wetland species such as birds, fishes, and vascular plants.*

INDEX WORDS: *Amphibians, frogs, biological indicator, ecological condition, coastal wetlands, Great Lakes.*

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INTRODUCTION

Coastal wetlands of the Great Lakes are used as breeding habitat by at least 14 species of frogs and toads, many of which occur widely across the entire region (Hecnar 2004, Price *et al.* 2005). The Great Lakes basin also contains ten percent of the U.S. human population and has been heavily affected by human activities (Niemi *et al.* 2006). Land use and landscape changes within the basin have been particularly dramatic, especially the conversion of wetlands to agricultural, urban, and industrial land uses (Brazner 1997, Detenbeck *et al.* 1999). Point and non-point pollution (Marsalek and Ng 1989, Nature Conservancy 1994), exotic species (Brazner *et al.* 1998, Herrick and Wolf 2005), and hydrological modifications (Meadows *et al.* 2005), among other factors, also affect the condition of Great Lakes wetlands and likely influence amphibian distributions in the coastal zone.

Amphibians have several physiological and ecological traits that imply sensitivity to anthropogenic disturbance (Vitt *et al.* 1990). Their thin, semi-permeable skin readily absorbs moisture (Duellman and Trueb 1986), facilitating the uptake of toxicants, pollutants, and other contaminants from the environment (Bishop and Gendron 1998, DeGarady and Halbrook 2006), especially when those substances are contained in water. Many amphibians exhibit a bi-phasic life cycle, depending on aquatic habitat for reproduction and larval development, and terrestrial habitat for adult growth, hibernation, foraging, and dispersal. The use of multiple habitats potentially exposes amphibians to a greater range of environmental and anthropogenic stresses at various spatial scales (Johnson *et al.* 2002) than would be expected for organisms using only terrestrial or aquatic habitats. Several studies document the sensitivity of amphibians to landscape-scale anthropogenic threats such as habitat fragmentation (Kolozsvary and Swihart 1999, Knutson *et al.* 2000, Willson and Dorcas 2003), whereas other studies highlight importance of local-scale factors such as hydroperiod (Pechmann *et al.* 1989) and introduced predators (Hecnar and M'Closkey 1997, Adams 1999). These characteristics suggest that amphibians may be excellent indicators of overall ecological condition.

Although several studies have identified relationships between the presence and/or abundance of anuran species and specific environmental stressors, few have tested whether amphibians can serve as effective indicators of overall ecological condition. Noss (1990) and Niemi and McDonald (2005) suggest one of the roles of an ecological indicator should be to measure the response of an ecosystem to a wide range of anthropogenic disturbances. We used field data collected in Great Lakes coastal wetlands to evaluate the relationship between presence of anuran species and degree of anthropogenic disturbance. We subsequently used these biotic response (BR) relationships to calculate a multispecies indicator of ecological condition for 13 coastal wetlands that were not included in the development of species-disturbance relationships. Comparisons of our index of ecological condition (IEC) based on amphibian occurrences with the actual degrees of disturbance or stress provided a test of the utility of amphibians as reliable ecological indicators in the Great Lakes coastal zone.

METHODS

Study Sites

We surveyed anurans at 351 sampling points in 220 coastal wetland complexes along the U.S. shores of Lakes Erie, Huron, Michigan, Ontario, and Superior (Niemi *et al.* 2006). The 220 coastal wetlands represented a random sample of coastal wetlands along a multivariate gradient of disturbance (Danz *et al.* 2005). Study sites consisted of individual wetlands or geographically connected wetland complexes (range = approximately 1 ha to 945 ha of wetland habitat, mean = 48.1 ha, SE = 7.1) within two ecoregions (Albert 1995), the Laurentian Mixed Forest Province in the north (n = 122) and the Eastern Broadleaf Forest Province in the south (n = 98). Three wetland types were sampled including open coastal wetlands, riverine-influenced wetlands, and barrier-protected wetlands within 1 km of the Great Lakes shoreline (Keough *et al.* 1999). All wetlands had plant communities typical of marshes, sedge meadows, wet meadows, or shrub swamp (Eggers and Reed 1987). We did not conduct surveys in forested wetlands.

Anuran Calling Surveys

We used calling surveys following the Marsh Monitoring Program protocol (Weeber and Vallianatos 2000) to collect presence/absence (i.e., detected/non-detected) data for anurans on three separate evenings in spring and summer of either 2002 or 2003. Survey 1 was conducted primarily in April when overnight air temperatures were $\geq 5°C$; Survey 2 was conducted in late May when overnight air temperatures were $\geq 10°C$; and Sur-

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