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A Thermal Habitat Classification for Lower Michigan Rivers

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Abstract.–We developed a thermal classification for Lower Michigan rivers that characterizes the spatial variation in summer (July) temperatures in terms of both mean temperatures and temperature fluctuations. We used patterns of change in community composition, species richness, and abundance of key species to partition continuous gradients of mean temperature and temperature fluctuation to identify discrete thermal categories.

We identified three mean temperature categories (cold <19°C; cool 19 to 21 °C; and warm > 21°C) and three temperature fluctuation categories (stable < 5°C; moderate 5 to 9°C; and extreme > 9°C). These categories were combined to create a 3 x 3 matrix with 9 discrete thermal regimes. Species distribution data were plotted on this 3 x 3 matrix to examine how selected species were distributed across thermal regimes. In order to quantify patterns of distribution and abundance, we calculated both the average density of a species within each thermal regime and the proportion of sites within each thermal regime where that species was present. We also generated habitat suitability scores within each thermal regime for each species in order to identify appropriate thermal habitats for individual species.

Within the MRI database, 92% of 667 sites occurred in the categories exhibiting moderately fluctuating temperatures. Relatively few sites occurred in the stable (3%) or extreme fluctuation categories (5%). The total percentages of sites were evenly distributed in cold (36%), cool (36%), and warm (28%) mean categories.

We found a continuous increase in species richness from sites with cold to warm mean temperatures. Species richness ranged from 6 in the cold-stable regime to 31 in the warm-stable regime. Within the cold and cool mean categories, species richness increased with increasing levels of temperature fluctuation. The opposite trend was observed within the warm categories with the lowest richness occurring at high fluctuations.

Distributions of fish representing distinct thermal guilds showed considerable overlap and in all cases species were distributed across more than one thermal category. Differences in species distribution patterns were also observed for fish within each thermal guild, indicating that individual species within a guild occupied different thermal habitats. In general, there was poor correspondence between guild membership and fish presence within a thermal category.

The classification developed in this study provides a framework to describe the summer thermal distribution of stream fishes, and can be used to generate expectations of species assemblage structure and standing stocks of key species at sites having similar thermal characteristics. Biologically meaningful patterns in fish species assemblage and abundance of selected species were observed across gradients. This suggests that summer thermal regime may be an important factor structuring fish communities in Lower Michigan rivers.

In lotic ecosystems, physical habitat is an important factor structuring patterns of species distribution and abundance for both fishes (Gorman and Karr 1978; Schlosser 1982) and aquatic insects (Richards et al. 1996; Wright 1995). This has been attributed to the characteristically large variation that exists among sites in variables such as streamflow, thermal regime, and substratum (Poff and Ward 1990). This variation in habitat can be viewed as a template (sensu Southwood 1977) that directly constrains life-history attributes and also can modify the influence of biotic interactions in regulating species assemblage structure. In addition, spatial and temporal variation in habitat quality can influence the resiliency of biota subjected to perturbations. For example, fish that naturally experience large diel fluctuations in temperatures and oxygen concentrations are less likely to be sensitive to human-induced impacts and are more likely to re-colonize disturbed areas than fish occupying more benign habitats (Matthews 1987). Consequently, quantifying temporal and spatial variation in key habitat features is critical to understanding mechanisms regulating species assemblage structure, and to evaluating the impacts of environmental perturbations (Poff and Ward 1990; Schlosser 1990).

Water temperature is a key habitat feature that affects both fishes (Huet 1959; Matthews 1987; Cech et al. 1990; Rahel and Hubert 1991) and aquatic insects (Vannote and Sweeney 1980; Ward and Stanford 1982; Haro and Wiley 1992; Hawkins et al. 1997). Temperature can affect stream biota directly by controlling rates of feeding, metabolism, and growth (Fry 1971; Brett 1979); or indirectly by mediating biotic interactions (Baltz et al. 1982; DeStaso and Rahel 1994; Hinz and Wiley 1998). As a result, spatial and temporal variation in stream temperature is likely an important factor contributing to the observed differences in species assemblages between sites.

Thermal regimes in stream reaches have been traditionally described in terms of cold-, cool-, and warmwater categories based on the dominant fish species present. Numerous studies have described changes in species composition along longitudinal temperature gradients from cold, headwater reaches to warm, downstream reaches (Burton and Odum 1945; Huet 1959; Hynes 1970; Moyle and Nichols 1973; Hawkes 1975; Cech et al. 1990; Rahel and Hubert 1991). Recently, ecological assessment protocols have been developed that incorporate the influence of these broad-scale temperature categories on differences in expected species assemblage structure across sites (e.g., development of a coldwater index of biotic integrity: Lyons et al. 1996).

Although specific thermal requirements of individual fish species have been used to formally group fish into cold-, cool-, and warmwater categories (Hokanson 1977; Magnuson et al. 1979), such classifications have had limited utility in lotic systems. This has been, in part, a result of inconsistencies between laboratory and field observations, and also in regional differences in available thermal habitat across a species' range. For example, summer thermal regimes available to warm-water fishes in Michigan are substantially different than those available to similar species in Alabama. Furthermore, a growing number of observations suggest that finer-scale differences in temperature within these broad categories also affect species composition (Matthews and Styron 1981; Matthews 1987; DeStaso and Rahel 1994; Smale and Rabeni 1995). We