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EDITORIAL: APPLICATIONS OF MESOHABSIM USING FISH COMMUNITY TARGETS

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INTRODUCTION

There are opposing opinions concerning what constitutes a sustainable riverine ecosystem. For some, it is maximizing angler harvest whether through natural reproduction or through elaborate fish culture and stocking programmes (Nickum *et al*., 2005). Some of the most notable sport fisheries in the world are founded on tailwater releases from impoundments, wherein non-native fishes (principally stocked trout) flourish in the cold, clear waters where warmwater communities would have otherwise existed (White River, Arkansas and Missouri). For others, preservation of self-sustaining populations of native fluvial specialists supported in largely undeveloped catchments devoid of human alterations is the idealistic goal.

The reference fish community, serving as the foundation for assessing ecological condition, in the index of biotic integrity (Karr *et al*., 1986) was based on the fish community structure found in undisturbed catchments. The reference fish community composition (species, species complexes, trophic associations and gross observations of fish health) served as the point of reference for comparing the degree to which an unknown stream community deviated from the reference. The closer the community structure in the stream in question came to the reference condition, the 'healthier' the stream was judged to be. Conversely, the further from the reference condition, the less healthy. It is notable however, that although this technique has proven popular for assessing ecological integrity (Fausch *et al*., 1984; Karr *et al*., 1986; Miller *et al*., 1988; Smogor and Angermeier, 2001; Pirhalla, 2004), it is not designed to identify cause and effect relationships, or to correlate index scores with discrete measures of anthropogenic changes in underlying forces driving community structure or abundance (Angermeier and Karr, 1986; Karr *et al*., 1986).

Karr's approach seems reasonable when there are sufficient numbers of 'un-altered' catchments in the region of index development. However, in regions where successive generations of landscape alteration, exotic species introductions and broadscale stocking programmes have irrevocably changed species distribution and community composition (including but not limited to extirpation), alternate approaches to developing a reference fish community are required. Some have questioned the relevance of reference conditions that ignore regional changes in community composition, dominant land cover conditions, discontinuities in lateral connectivity and climatic, temperature, and hydrologic patterns (Fisher and Burroughs, 2003; Clarkson *et al*., 2005). The question of what constitutes the most useful reference condition for the biotic community structure frequently turns to suggestions that exotic species, inextricably integrated into fluvial systems should be counted among the species in the reference condition. However, the species promoted for inclusion are typically limited to sport species, or those deemed

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*Correspondence to: Richard A. Jacobson, Department of Environmental Protection, State of Connecticut, 79 Elm Street, Hartford, CT 06106, USA. E-mail: rick.jacobson@po.state.ct.us 'beneficial' as opposed to those viewed as a threat to ecological integrity (Clarkson *et al*., 2005). Inclusion of such species in the reference condition reflects the values of those advocating for their inclusion. Such considerations must be viewed with caution, as those with countervailing values and interests may reasonably advocate for an alternate species composition.

TARGET FISH COMMUNITIES

One approach to developing target fish communities (Bain and Meixler, this issue) embraces the limitations imposed by highly altered landscapes and biotic communities. It removes value-laden expressions of 'preferred' species in the community assemblage, focusing the quantification of deviation from an objective reference condition. The importance ascribed to deviations from the reference condition is subjective with interpretation based on resource management goals and expectations.

Establishing a framework to meld the concepts of a reference fish community with physical habitat modelling is necessary for developing a cogent strategy for simulating the success of restoration options (Parasiewicz, 2007b). By necessity, the framework is based on gross assumptions of the relative significance of discrete habitat quantities and population size. However, the results are only applicable within the constraints of the season(s) during which the data were collected, noting that habitat associations during other seasons may change substantially. In spite of the assumptions and constraints, the framework represents a rational approach to modelling community response to changing habitat conditions. With a deeper understanding of the causal relationships between habitat and fish productivity, the framework may become a useful tool for resource restoration planning.

HABITAT MODELLING

Approaches to simulating biological response to habitat alterations have become the subject of intense focus. The physical habitat simulation model as developed by the US Fish and Wildlife Service (Bovee, 1982) has proven an effective, if hotly debated, tool in assessing the habitat implications of spatially discrete alterations of the hydrologic regime. Faced with ever increasing numbers of proposals to develop water projects throughout the western world, resource managers embraced the technique as the most rigorous and explanatory process for quantifying the ecological costs of these projects (Stalnaker, 1993; Payne *et al*., 2004). The approach was also criticized for the level of effort required for rigorous application, and the failure of many practitioners and funding entities to commit the resources necessary for a comprehensive solution (Mathur *et al*., 1985; Castleberry *et al*., 1996; Williams, 1996). Among the applications for which the approach is ill suited is watershed level planning (Parasiewicz, 2003). By its very nature, watershed planning requires projections of habitat response over larger spatial scales, requiring extensive data collection and analytical problem solving at scales impractical for most resource management questions.

An alternate suite of habitat modelling techniques was highlighted at the final COST 626 European Aquatic Modeling Network meeting in 2005, Silkeborg, Denmark (Harby *et al*., 2005). Members of the International Aquatic Modeling Group continue to seek means to meet the mandates of the European Water Framework Directive through the evolution of habitat modelling approaches. In this pursuit, substantial effort is invested in mesoscale approaches (MesoCASMiR (Eisner *et al*., 2005), MesoHABSIM (Parasiewicz and Dunbar, 2001), Meso-scale Habitat Classification Method Norway (Borsanyi *et al*., 2004), Rapid Habitat Mapping (Maddock *et al*., 2001)). The MesoHABSIM method (Parasiewicz, 2001) was developed to build on the strengths of the PHABSIM protocols while simultaneously addressing its shortcomings as a watershed level planning tool.

The MesoHABSIM approach has at its foundation regression based assessments of the correspondence of fishes and habitat features (Binns and Eiserman, 1979). In effect the 'productivity' of each mesohabitat, and collectively all mesohabitats combined, is determined by the association of fishes captured and the physical attributes attributed to discrete mesohabitats corresponding with stream discharge at the time of capture. Each such association is developed from the correlation of habitat features with successive, corresponding discharges. These in turn represent and continuum of habitat quantity and quality scores over the array of discharges investigated.

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TIME SERIES ANALYSIS

The concepts of habitat time series (Milhouse *et al*., 1990) and an adaptation of the Continuous Under Threshold analytical techniques (Capra *et al*., 1995) can be integrated to assess and place inter-annual and intra-annual limits on deviations from a natural flow regime (Jacobson *et al*., in press). The limits are intimately tied to the frequency and duration of habitat change as affected by deviations in a reference flow regime. From the integration of habitat simulation and hydrologic patterns, the frequency and duration of extreme events can be quantitatively described in terms reflecting the hydrology and biotic response to stress imposed both by the natural flow regime and deviations there from.

FUTURE DIRECTIONS IN HABITAT MODELLING

Relationships between fish populations and aquatic habitats are multi-dimensional, involving biotic, hydrologic, geomorphic, chemical, and spatial and temporal continuity gradients, see for example (Junk *et al*., 1989; Ward, 1989; Schlosser, 1991; Stanford and Ward, 1993; Puckridge *et al*., 1998; Annear *et al*., 2004). The challenge resides in separating these inextricably linked components.

Fishes, and other aquatic biota, live in dynamic equilibrium with their surroundings (Schlosser, 1991). For each individual, and by extension each population, reproduction, growth and mortality ebbs and flows in response to energy fluxes (Elwood *et al*., 1983). During periods of net energy loss (energy losses exceed energy gain), mortality rates rise and reproductive rates fall. Conversely, during periods of energy gain mortality rates fall and reproductive rates rise. The relative gain or loss in energy is a product of each fishes' interaction with all physical, chemical and biological features around them. In total, the features are manifest in the habitats into which each species and life stage is forced. Minnows, for example, occupy a diverse array of depth, velocity and substrate and cover conditions and may select one suite of conditions over all others when presented these options in the absence of any other fishes. However, when a predator is present, the minnow may vacate preferred habitat in an effort to avoid predatory losses (Power and Matthews, 1983). In effect, the predator affects the productivity of the minnow species both in the form of direct predatory losses (the primary effect) and through changes in the net energy budget for the minnow (the secondary effect).

More complicating still is the effect on the overall (long duration) energy balance on any individual species over time as the physical, biological and chemical features of their habitat change, whether the effects are cumulative, temporal (at time of energy balance bottle-neck) or ephemeral. Future enhancements to assessment of human effects on aquatic systems would be greatly improved by identification of the mechanisms and relative consequence of habitat conditions for each species, life stage and species interaction. One area ripe for further exploration involves establishing resource utilization functions (Boyce *et al*., 2002) based on bioenergetic responses (Boyce and McDonald, 1999; Hayes *et al*., 2000) to changes in hydrologic regime, and indexing the changing regimes to deviations from the reference condition.

Future research and management action should explore the relationships between inter and intra-annual hydrologic variability, changes in channel form and biological response. Each approach fits within an overarching framework that is designed to equate biological response to manipulations in the physical and biological structures of fluvial systems. In total, these approaches show significant promise for quantifying the implications of deviations from the reference flow regime and structured decision-making on restoring habitat and ecological integrity consistent with the natural flow paradigm.

The following three papers build on a previously published set (Parasiewicz, 2007a, 2007b; Parasiewicz and Walker, 2007) to demonstrate a practical integration of meso-scale habitat modelling, target fish communities and time series analysis to define to define catchment scale river restoration strategies.

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