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ARENA

A TARGET FISH COMMUNITY TO GUIDE RIVER RESTORATION

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ABSTRACT

A method is proposed and demonstrated to specify a fish community to serve as a target for planning river restoration projects and as an endpoint for evaluating programme progress. Our target fish community is appropriate for small rivers in southern New England with basins characterized by dispersed human activities. Our study was part of a multi-agency improvement effort of the Quinebaug River in southern Massachusetts and northeast Connecticut, USA. We identify fish species expected to be found in streams, lakes and river reaches of the Quinebaug River basin. An expected rank order of abundance was computed using fish surveys from rivers identified by restoration programme managers as being in a desirable condition for a human-dominated landscape. The rank order of species was converted to expected community proportions following a theoretical log–log relation between species abundances and occurrences in complex communities. Criteria from a committee of agency and water use representatives were influential in specifying a target community; so the overall method blends policy, objective zoogeography analyses and theory-based parameters of community structure. We believe the use of a target community can be an important element in the design and evaluation of river restoration where the aim cannot be to copy pristine, natural ecosystem properties.

KEY WORDS: target fish community (TFC); restoration; human-dominated landscape; river management

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INTRODUCTION

River restoration has received greatly increased attention in the last decade, with many government and private conservation organizations removing dams, reshaping channels, establishing riparian forests, curtailing non-point source pollution and performing other enhancements. Nevertheless, returning an ecosystem to its former, undisturbed state with the original functions and structure (definition of restoration in US National Research Council 1992) has almost never been achieved even when restoration is a primary programme aim. If restoration is not a realistic goal, then what is the aim of efforts to better streams and rivers?

Cairns (1990) described three approaches for recovery of environmental health: replicate features of the natural state, strive for select attributes that are of human interest and develop an alternative sustainable ecosystem. Mimicking natural conditions is probably most common and it is the simplest conceptually when natural reference systems exist. Natural ecosystem properties have been promoted as ideal and necessary (Sparks *et al*., 1990; Richter *et al*., 1996; Poff *et al*., 1997) but may be impractical for waterways in much of the world. The second approach, seeking selected ecosystem outputs, is perhaps the oldest management philosophy because the primary aim is maximizing commodities such as wood, water and fish. In recent times additional ecosystem properties have been used in this approach: biological diversity, support for native fauna and flora and wild genetic and biochemical resources. Finally, striving for an alternative human-dominated ecosystem has come forward as realistic for human-dominated landscapes. Here, we provide a key planning tool for designing a river restoration effort in concert with human uses and settings.

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A clear goal is needed for river improvement programs not only to design activities and projects but also to justify funding and anticipated accomplishments. Generally, conservation organizations are rehabilitating degraded waterways, with rehabilitation meaning a return to a better condition, normal state or desirable character. Nevertheless, we will use the term restoration here for consistency with other papers in this set. An explicit restoration goal could be attaining a self-sustaining system integrated into the surrounding landscape. Once a goal is stated, efforts to enhance the streams and rivers for the support of aquatic communities should be guided by clear objectives and be open to quantitative evaluation. Measurable ecosystem objectives have been called endpoints, characteristics, indicators, targets and conditions. The distinguishing property is a management aim defined in quantitative and measurable terms.

This paper presents the results of an effort by fish biologists, federal and state environmental agency managers and private conservation interests to specify a fish community to serve as a target for river restoration and progress evaluation. We propose and demonstrate a method to define a target fish community appropriate for small rivers in southern New England with basins dominated by dispersed human activities. We specify fish community members and the relative abundances of common species to serve as a single broad and quantitative restoration target to guide river restoration.

METHODS

The Quinebaug River is a small river (404 km^2 basin, 7.8 $m^3 s^{-1}$ mean annual flow) with multiple impoundments and a history of industrial use. It is a tributary of the Thames River in eastern Connecticut, USA, which discharges into Long Island Sound. The river is highly varied in gradient and habitat with a concentrated industrial and urban area (Southbridge, Massachusetts) surrounding the river in the middle of the basin. New electric generating development prompted state and federal environmental agencies to implement a programme to improve the river environment while permitting further use of water. The Quinebaug River management agencies wanted a single measurable objective to provide programme direction, progress assessment and public relevance. The concept of a target fish community was determined by the agencies to meet these needs.

A Management Committee composed of a set of federal (US Fish & Wildlife Service, US Environmental Protection Agency, US Army Corps of Engineers), state (Massachusetts Division of Fisheries & Wildlife and Connecticut Department of Environmental Protection) and water user (Millennium Power Partners, LP) organizations defined a 38 km section of the Quinebaug River, between the East Brimfield Dam (MA) and West Thompson Lake (CT), as a restoration area. We worked with the Management Committee to develop a fish resource objective for river restoration. Our approach sought to extract the minimum necessary information from natural resource managers and past fishery surveys to construct a future target community to be attained through river enhancement practices.

The target fish community was developed using a four-step process. First, we developed a list of fish species expected in the study river area. Fish distribution references were used to develop a grand list of species in the Thames River basin. Local fish collections and stocking records were used to add species, and impediments (migration barriers, absence of appropriate habitats) to occupation of the Quinebaug River were used to delete species. Final adjustments to the species list were made using information from experts.

Second, we obtained fish survey data for a set of reference rivers identified by the Management Committee as being in a desirable condition for a human-dominated landscape in southern New England. The reference rivers were not considered to be in a natural or pristine state but instead were recognized as the best source for data characterizing a feasible and currently relevant fish fauna that could inhabit the Quinebaug River. The rivers chosen and the years of the fish sampling data were the Ware River in Massachusetts (1980, 1992), and the Fivemile (1994), Natchaug (1994), Scantic (1989) and Willimantic (1994) Rivers in Connecticut. The fish survey records used were comprehensive in species identifications and considered by natural resource agency staff to be indicative of local fish faunas.

Our third task was to estimate the rank order of fish species in a river community using the reference river survey data. The numbers of fish were tallied by species for all collections available from each of the reference rivers. Then, the species tallies were divided by the total number of individuals captured to obtain the proportion of total

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individuals by species in each river. Stocked species (trout, Salmonidae) were removed from the analysis since these only inhabit the rivers at stocked sizes. Proportions of each species were averaged across the five reference rivers. Next, all other introduced fishes were excluded because the Management Committee decided that river restoration should target native species. For native species, the averaged proportions were ranked (1 being the most common dominant species, 2 the next most common dominant and so on). The outcome of these data manipulations was a ranked list of native fish species reflecting the order of abundance of species in the pooled reference river data.

Fish species ranks were converted to expected target fish community proportions. Expected proportions were computed by converting species ranks to reciprocals (1/rank), summing these in decimal form, and dividing the reciprocal rank (decimal) by the sum of all reciprocal ranks. Uncommon species (less common than the 10th ranked species) were combined into a group called other, and the expected proportion of this group was the remainder of the expected proportions that together sum to one. The calculations follow a rank-weighting technique that has been found through experience (Edwards, 1977; Johnson and Huber, 1977; Bakus *et al*., 1982) to closely approximate category count distributions seen in social research results. The technique is easy to apply (e.g. Bain, 1987) in place of more elaborate, data-intensive analyses and it yields results consistent with linear log–log relations widely documented across most fields of science (reviewed in Bak, 1996; Solé and Goodwin, 2000).

RESULTS

A comprehensive list of fish species known to have inhabited the Thames River basin was obtained from Schmidt (1986). He reported 57 species present including 14 species introduced many decades ago. Whitworth's (1996) reference book on freshwater fishes of Connecticut was then reviewed which raised the total list of potential species to 63. From this list, species were deleted for a variety of reasons:

- Ten marine and estuarine species only enter coastal freshwater habitats (e.g. Atlantic silverside, *Menidia menidia* and hogchoker, *Trinectes maculatus*).
- Four species are restricted to estuarine and coastal areas in the New England region but are more prevalent in other United States regions (e.g. threespine stickleback, *Gasterosteus aculeatus*).
- Five species with migrations and habitats are mainly limited to the Atlantic coastal plain (e.g. rainbow smelt, *Osmerus mordax* and pirate perch, *Aphredoderus sayanus*). Trout-perch (*Percopsis omisomaycus*) was judged out of range by detailed distribution information in Whitworth (1996).
- Four introduced species failed to become established (e.g. lake trout *Salvelinus namaycush*).

Four anadromous species have been blocked for over a century from reaching the Quinebaug River by several dams. Our review of the potential and known fishes of the Quinebaug River basin resulted in a list of 35 species we would expect to find in streams, lakes and river reaches of the basin. Many of these fish have not been recorded in recent sampling, but they are considered candidate species for collection in any survey. In addition to the 35 expected species in the basin, there are four anadromous fish that could be restored to the fauna by actions outside the study area: blueback herring (*Alosa aestivalis*), American shad (*Alosa sapidissima*), sea lamprey (*Petromyzon marinus*) and Atlantic salmon (*Salmo salar*). The Management Committee wanted these species recognized as potential inhabitants of the Quinebaug River even though there is no plan to restore access to the river for anadromous species at this time.

The fish composition data for the five reference rivers provided the minimum information needed for specifying the rank order of species in the target community. Fallfish (*Semotilus corporalis*) were clearly dominant in two of the five rivers, and highly abundant in the other three. Common shiner (*Luxilus cornutus*) was a dominant species in two rivers and abundant in another river. These two fishes were ranked first and second, respectively, with other highly ranked (low rank number) fishes common in most of the reference rivers. After about the 10th ranked species (pumpkinseed, *Lepomis gibbosus*) the presence of species in the reference river collections were increasingly sporadic. We pooled all species below the 10th rank into a group called other. The rank order of species in our target community for the Quinebaug River is: fallfish (*S. corporalis*), common shiner (*L. cornutus*), white sucker (*Catostomus commersoni*), tessellated darter (*Etheostoma olmstedi*), longnose dace (*Rhinichthys cataractae*), blacknose dace (*Rhinichthys atratulus*), redbreast sunfish (*Lepomis auritus*), American eel (*Anguilla rostrata*),

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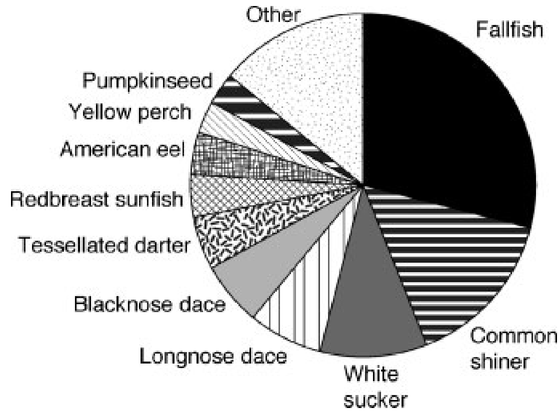

Figure 1. Target community specification for restoration of the Quinebaug River. Percent community composition is provided in the text

yellow perch (*Perca flavescens*) and pumpkinseed (*L. gibbosus*). We project from these results a target community that would have 10 common species comprising 84% of all fish. In terms of expected proportions, the target fish community (Figure 1) for the Quinebaug River comprises fallfish (29%), common shiner (15%), white sucker (10%), tessellated darter (7%), longnose dace (6%), blacknose dace (5%), redbreast sunfish (4%), American eel (4%), yellow perch (3%), pumpkinseed (3%) and other (14%).

DISCUSSION

The fish community we developed as a restoration objective for the Quinebaug River is precise in its definition, feasible to attain and functional as a standard for measuring environmental improvement. The final species list for the Quinebaug River basin fish fauna emerged from an objective review of ichthyological information tempered by management aims. This species list provides the foundation for combining fish community data, ecological theory and environmental policy considerations to develop a target community. Natural resource agencies bounded the context for specifying a target fish community, and the combination of fish survey data and ecological system properties provided the details of community composition.

Developing a list of species in the river basin initially appeared to be an easy and straightforward task. The main starting material (Schmidt, 1986; Whitworth, 1996) readily yielded a grand list of species expected to inhabit the river and associated waters. Most refinements to this list could be easily made by a biologist familiar with the regional fauna. However, decisions on inclusion of some species were difficult to resolve because regional fish biologists had conflicting accounts of the local distribution of some fish and management agencies differed on the feasibility of removing barriers to anadromous fishes downstream of the study area. Another complication was variation in community composition of the five reference rivers. The variability among similar size rivers in the region suggests it would likely be impossible to specify precisely what the fish community should be for the Quinebaug River. Our approach sought to specify a realistic and generalized target community stated in precise terms for use as a standard. We lessened the influence of individual reference rivers by using mean rank abundances to define target community composition instead of observed proportions from the reference rivers. Also, by using a set of reference rivers we moderated the influence of any one river in defining a target community. Our approach extracts the minimum needed information from the reference rivers (species ranks) and then combines this empirical information with a theoretical community composition property.

Species ranks were used to specify species abundances (community proportions) following the theory that community composition patterns are properties of complex systems. The calculation method used (rank-weighting technique) yields a community that forms a straight-line relation between the Log 10 of species rank and the Log 10 of community proportion. These double logarithmic relations are often called power laws, and they fit many patterns in nature (Solé *et al.*, 1999; West *et al.*, 1999; Csete and Doyle, 2002; Marguet, 2002). The composition of

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communities often follows a power law relation between species abundance ranks or number of species and relative abundance levels (Bell, 2001; Hubbell, 2001), and this common community pattern can be responsive to disturbance and recovery (Schoener *et al*., 2001). Power laws also approximate many socioeconomic system properties (Zipf, 1949; Mandelbrot, 1983) and the rank-weighting technique provides an easily applied tool to estimate these relations. In the past three decades, social scientists commonly observed that the rank-weighting technique produced parameter relations that fit results obtained in more intensive studies (Edwards, 1971; Edwards, 1977; Johnson and Huber, 1977) and others have found it to be a useful approximation algorithm (Hwang and Yoon, 1981; Bakus *et al*., 1982; Bain, 1987). Power laws are now being reported for many phenomena and are useful as a fundamental mathematical relation for a target fish community. This approach also allows us to generalize the specific fish catch numbers from reference river surveys when developing a target fish community. With the rank-weighting calculation we could proceed with the least possible information from the reference rivers and convert that into an expected community composition pattern.

The Quinebaug River Management Committee had a strong influence on the target community we developed even though the computations and target community projections appear fixed. First, managers and agency biologists can specify the reference rivers. In this case the rivers were selected as regionally comparable rivers considered in good to excellent status. In practical terms, we proceeded with the implied perspective that the Quinebaug River would be regarded as restored to a proper status if it contained a fish community much like that seen in the reference rivers. Therefore, the choice of reference rivers frames the expectations of river improvement with the target fish community acting as a tool to illustrate the goal in tangible and measurable units. A second avenue for Management Committee influence was seen in the exclusion of introduced fishes. The Management Committee decided that enhancement of the Quinebaug River should be oriented to native fishes even if some introduced species are important sportfish. This decision resulted in the removal of three common fishery species (bluegill, *Lepomis macrochirus*; largemouth bass, *Micropterus salmoides* and smallmouth bass, *Micropterus dolomieu*) from the key specifications (10 most common fishes) of the target fish community.

A target fish community can be used as a guide to identify the composition of a healthy fish community for large streams and small rivers in the region. Healthy is a relative term that is influenced by the management agencies when they shape the development of a target fish community through policy decisions. In this case, the Management Committee provided important input in selecting reference rivers, making a clear decision on handling introduced species and providing a perspective in anadromous fishes. We used this guidance in forming a target community so the overall process blends policy, objective zoogeography analyses and theory-based parameters of community structure. In the end we believe the process and product reported here can guide and evaluate river restoration in the many cases where objectives cannot simply be to copy pristine, natural ecosystem properties.

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