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Using geomorphology to predict fish assemblages in eastern Illinois streams

Project Objectives:
1. To determine the role stream geomorphology has in structuring fish assemblages at the reach and sub-watershed (upstream of sampling sites) spatial scales.
2. To build a model that predicts fish assemblages from stream geomorphological characteristics.

Completed Project Description:
Project identified that fluvial geomorphology is unique along a longitudinal stream size continuum and it differs between channelized and unchannelized streams in eastern Illinois. Fish assemblages are unique to each of the geomorphic types.

Introduction

Stream fish assemblages are often considered to be limited by instream habitat availability. Therefore, much current research has focused on determining habitat features that limit the abundance and persistence of stream fishes, as these studies provide valuable information to managers who are concerned with managing species at local scales. To date, the relationship between geomorphology and warmwater stream fish assemblages in agriculturally impacted watersheds has received little attention and further investigation was warranted. Information from this study can be used to provide managers with information essential to improving stream management/restoration efforts as these efforts often rely on channel modification that affect the geomorphic function of

the restored stream channel. As such, understanding the linkages between fluvial geomorphology and fish assemblage structure is essential to the success of management/restoration activities. This study investigated the role stream geomorphology has on fish assemblage structure at the reach scale in several agriculturally impacted east-central Illinois streams.

Methods

Fish assemblages were sampled and geomorphic features were delineated in 25 streams within the Embarras River watershed, Illinois. Sampling sites were stratified by upstream watershed areas of 5, 25, and 100 km^2, and 8, 7, and 10 streams were sampled per respective size group. Geomorphic variables we sampled included: bankfull stage, entrenchment ratio, flood prone area (FPA) width, width/depth (W/D) ratio, and average depth at bankfull stage. To sample fish assemblages we used a backpack electrofisher in streams <5 m in wetted width and a 10 m electric seine (AC current) was used in streams >5 m in wetted width. Principal Components Analysis was used to elucidate gradients in geomorphology among the sites and Multivariate Analysis of Variance was used to identify significant differences in geomorphology among the size and type groups. We used multi-dimensional scaling to determine if grouping existed among fish assemblages. To determine if fish assemblage composition was different among size and disturbance classes we used Distance-based Redundancy Analysis; which is essentially a multivariate regression on similarity. To determine which fish species most influenced the assemblage structure among the size and type groups, we used a BVSTEP procedure.

Results

PCA identified four principal components that explained 72% of the among site variation in geomorphology Significant differences were found among stream sizes ($F_{8, 34} = 4.32, p = 0.0011$) and types ($F_{4, 16} = 22.26, p < 0.0001$); there was no significant interaction between stream size and type ($F_{8, 34} = 0.9, p = 0.5278$). We found that 5 km^2 streams significantly differed from the 100 and 25 km^2 streams (least squares means post-hoc tests $5 \times 100 \, \text{km}^2 \, p < 0.0001$, $5 \times 25 \, \text{km}^2 \, p = 0.014$). The 25 and 100 km^2 streams were not significantly different in geomorphic structure (least squares means post-hoc test $25 \times 100 \, \text{km}^2$, $p = 0.1076$).

The MDS indicated that there was grouping of the fish assemblages. Badness-of-fit criterion (0.2) indicated that the groupings were accurately represented in two-dimensional space. Distance-based Redundancy Analysis revealed significant differences in fish assemblage composition among the stream size and type groups. We saw the same trend in assemblage composition as we did in the geomorphic characterization (PCA) for the size and type groups. Fish assemblage composition in 5 km^2 streams differed from the larger stream groups, while the assemblage composition of the 100 and 25 km^2 streams was not different ($F_{2, 19} = 4.892, p = 0.0001$). Although they were not obviously channelized, two 5 km^2 streams appeared to function as channelized

streams and as such, the assemblage analyses were conducted with these streams classified as channelized. The Redundancy analysis also revealed significant differences in fish assemblage composition between channelized and unchannelized streams ($F_{1, 19}$ = 5.5858, p = 0.0006). The Analysis of Similarity also identified the same differences in fish assemblage composition as the Redundancy analysis.

The BVSTEP procedure identified 14 species that contribute to the observed differences in assemblage composition among the stream size and type groups. The species identified were; black bullhead (*Ameiurus malus*), blackstripe topminnow (*Fundulus notatus*), bluntnose minnow (*Pimephales notatus*), central stoneroller (*Campostoma pullum*), creek chub (*Semotilus atromaculatus*), creek chubsucker (*Erimyzon oblongus*), fantail darter (*Etheostoma flabellare*), longear sunfish (*Lepomis megalotis*), orangespotted sunfish (*Lepomis humilis*), orangethroat darter (*Etheostoma spectabile*), pirate perch (*Aphredoderus sayanus*), silverjaw minnow (*Notropis buccatus*), spotfin shiner (*Cyprinella spiloptera*), and white sucker (*Catostomus commersoni*).
Fish assemblages were distinct among the size and type groups. Species that were characteristic of the 5 km^2 streams were the creek chub, orangethroat darter, and white sucker. The central stoneroller, longear sunfish, silverjaw minnow, and fantail darter characterized the 100 and 25 km^2 streams. Channelized streams were mostly comprised of generalist species, they were: the blackstripe topminnow, bluntnose minnow, creek chubsucker, longear sunfish, orangespotted sunfish, and pirate perch. Unchannelized streams were composed of several habitat specialists, such as the central stoneroller, creek chub, silverjaw minnow, and fantail darter.

Discussion

We observed that streams within an agriculturally impacted watershed have longitudinal and site specific trends in fluvial geomorphology and that those trends have a strong association with fish assemblage composition. Several concepts have been proposed that attempt to explain abiotic and biotic patterns in lotic environments. One concept that has had a profound impact on stream ecological theory is the River Continuum Concept (RCC). The RCC is derived from geomorphological theory and empirical evidence of longitudinal patterns in invertebrate community structure. It states that streams have predictable patterns in channel morphology that are related to stream gradient and riparian zone conditions as you progress down a stream's longitudinal continuum. Along this abiotic continuum, the stream's biotic assemblages are said to respond to changes in primary production (the transition from heterotrophy in headwaters to autotrophy in lower reaches) and in thermal regime. A concept in opposition to the RCC has been developed by Montgomery (1999) and has been termed the Process Domains Concept (PDC). The PDC suggests that local geomorphic processes and disturbance regimes influence the local stream habitat and biota. Our results suggest that streams in east-central Illinois respond in a similar fashion to the RCC as stream geomorphology and fish assemblages change in a predictable manner as we progress down the continuum (i.e., from 5 km^2 to the 25 and 100 km^2 streams). Headwater streams were characterized by narrow and shallow channels with more sinuosity, steeper gradients, and coarser

substrates than the larger streams, further down the continuum, and subsequently, fish assemblages were associated with those changes in channel structure. However, due to our observed differences in geomorphology and fish assemblages between channelized and unchannelized streams, we see that local scale (e.g., reach) geomorphic features may be the best determinate of fish assemblage structure, thus lending support to the PDC. These local differences in geomorphology appear to more profoundly affect species composition than do the longitudinal patterns. Of the species we identified to be characteristic of each geomorphic type (i.e., the stream size and type groups), there appears to be more commonality in species abundance among the size groups than between the two stream types. We would expect headwater streams to have a few species that dominate the assemblage, and that large wadeable streams would have similar assemblages, unless they are near large tributaries which contribute additional species. However, we have shown that severe channel alteration has profound impacts on assemblage structure regardless of its place along a longitudinal continuum. A better understanding of these geomorphic processes in agriculturally impacted watersheds, both locally and along the river continuum, may lead to more successful stream management and restoration practices.

Incorporating knowledge of geomorphic processes into stream restoration and management efforts is essential to the success of these projects. To meet the goals of stream restoration, the project designer must understand how the proposed restoration will affect channel morphology, thus instream habitat and stream biota. Illinois streams are mostly channelized due to agricultural activities that require land draining. Widespread channelization has permanently altered geomorphic processes and biotic communities of streams to such an extent that pristine stream conditions will probably never exist again. Rhoads and Herricks (1996) suggest we should attempt to 'naturalize' these streams. This involves determining morphological and ecological configurations that are compatible with current fluvial processes, while understanding that humans will continue to utilize natural resources. This can be accomplished by working with, rather than against (e.g., changing channel planform), the geomorphic processes controlling stream function. Channelized streams have been successfully modified/restored to various channel configurations that meet the needs of both land drainage constituents and those interested in restoring ecological function to streams (cf. Evans et al. 2007). Thus, understanding the geomorphic condition of streams and how stream fishes respond to those processes, whether they are natural or anthropogenic, is essential to effective stream naturalization or restoration.

In east-central Illinois, channelized stream reaches are in the greatest need of remediation, at least from an ecological perspective. Our data suggest that remediation of channelized streams should involve restoring a more sinuous planform in an effort to create naturally occurring mesohabitat units other than pools. By reducing the frequency of channel maintenance activities (e.g., dredging) fluvial benches may begin to form, which would increase W/D ratio, thus increasing depth heterogeneity and possibly promoting channel migration which could lead to a larger diversification in available habitat. Thus, management activities that restore natural fluvial processes and increase

geomorphic complexity will help re-establish stream ecological function and native fish assemblages.

Budget will be sent by Business office.