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The Impact of Dredging on Heterogeneity and Fish Communities in Agricultural Streams of the greater Sandusky River Watershed, Ohio

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Abstract

Headwater streams comprise about half of the total stream length in the U.S. They help control floods, transport suspended and dissolved matter, and connect upstream landscapes with downstream water bodies. They may also serve as spawning, feeding and nursery habitat for native fish species. Over the last century, however, many of these streams have been dredged into agricultural drainage ditches with homogenous habitat, straight channels and steep bank slopes. Due to the success of erosion control practices, dredging frequency has now been reduced in places and some ditches are returning to a more natural and heterogeneous morphology with meanders, pools, and vegetated benches. As a part of a 4-year project, 20 ditch segments (each 50m long) were block-seined in the Sandusky River drainage for their fish communities in June and September 2011 and sampled for selected habitat variables. Streams varied in time of last dredging and frequency resulting in their level of channel heterogeneity. A total of 6,887 fish belonging to 32 different species were netted, identified to species, assessed for condition, aged (adult, Young-of-Year), and released. Richness varied from 0 to 15 species and abundance varied between 0 and 1851 per 50m ditch segment. Fish species richness was positively correlated with stream heterogeneity in the horizontal and vertical plane of the wetted channel. Horizontal heterogeneity was a better predictor for the presence of more fish species. Species richness of YOY fishes was positively correlated with horizontal stream heterogeneity, while no relationship was detected between YOY species richness and vertical heterogeneity or percent plant cover. In spite of their sometime degraded conditions, ditches may replace important lost fish habitat, particularly when dredging practices are minimized. Opportunities to incorporate environmental considerations into the management of these channels, while maintaining the drainage function, should be considered.

Keywords: Agricultural ditches, fish community, heterogeneity

1. Introduction

Agricultural streams are often modified to improve their efficiency to drain farmland. The modifications that are most commonly performed on these waterways are the straightening of the original stream, if one was present, the creation of new channels, and the continued maintenance dredging when their drainage function has reduced due to sedimentation, bank erosion and encroaching plants (Stammler *et al*. 2008). These rural 'ditches' are part of a critical infrastructure to protect homes, businesses, highways and farmland from flooding (Frothingham 2002). Although they are rarely managed as such, they may also provide important spawning, nursery, and refuge habitat for fish that were native to the region prior to the development of these drainage channels (Stammler *et al*. 2008; Crail *et al.* 2011).

Unless disturbed by dredging, these ditches will respond over time by stabilizing their cross-sectional profile with sediment deposits and plant growth (Lyons *et al*. 2000, Rhoads *et al*. 2003) creating patches of narrower and deeper habitat that alternate with wider and shallower stream sections (Fig. 1). It is unclear if these changes actually inhibit the drainage properties of these ditches or if drainage capacity can be restored with means other than dredging down to the conventional trapezoidal cross-section (Fig. 1, left panel). Advances in soil conservation, perhaps coupled with a reduced need for dredging, have contributed to research and applications for managing these systems both as stream habitat and drainage ditches using compound channels with sediment deposits and plant growth (Landwehr and Rhoads 2003, Ward and Trimble 2004, Boody *et al*. 2005).

Figure 1: Boyd Feasel ditch, Seneca County (Ohio) in 2008. The left panel shows the ditch North of County Road 36 that was dredged in 2007. The right panel shows the same ditch, dredged pre-2002, South of CR36.

Studies on fish communities in agricultural streams that are influenced by maintenance dredging have been conducted in the Great Lakes region (Rhoads *et al*. 2003), east-central Indiana (Sullivan *et al*. 2004), northwest Ohio (Crail *et al.* 2011), and southwestern Ontario (Stammler *et al*. 2008). Fish populations and communities in meandering, unmodified reaches in streams with drainage areas ranging from 38 to 167 km^2 had greater species richness, diversity and biomass than those in straight, channelized reaches. Crail *et al.* (2011) studied the impact of habitat homogeneity and heterogeneity in agricultural streams on the structure and composition of fish communities. Homogeneous stream segments were defined as having uniformity in the vertical (depth) and horizontal (width) profiles. Conversely, heterogeneous segments lacked such uniformity. This contrast in stream geomorphology also included the sinuosity of the channel and the presence of vegetated "benches" (Fig. 1, right panel). They also showed that only four of 13 physical habitat features were significantly different between modified and unmodified streams. These features included substrate size, percent riffle, percent grass riparian vegetation and percent tree riparian vegetation.

The success of upland erosion control practices (such as conservation tillage and buffer strips) in northern Ohio since the late 1980s may have reduced the frequency of ditch dredging and may therefore have impacted the stream habitat. Some ditches in Sandusky and Seneca counties (Ohio), for example, have not been cleaned out in more than 20 years and are showing evidence of heterogeneous channel features. Examples of such features include meanders, undercut banks, riffle and pool sequences, woody debris and a developing aquatic macrophyte community. Other ditches continue to be cleaned out on a frequent basis and show no evidence of these habitat features. In a sense, a "natural experiment" has been underway in this region of Ohio that is supported by available records of the dates for the most recent clean-out in each ditch under the counties' drainage maintenance program (Baker 2008). This U.S. EPA-sponsored project takes advantage of this natural experiment. My objective was to determine whether fish community metrics (e.g., fish species richness, spawning success) are linked with habitat characteristics of these streams (e.g., heterogeneity, plant cover). Specifically, I tested the hypotheses that increased stream heterogeneity is positively correlated with species richness of fish and Young-of-Year (YOY) communities and that the latter is positively correlated with total plant cover.

2. Methods

This research was part of a larger targeted watershed project. The 20 stream segments sampled for this project are located in the greater Sandusky River basin, a nearly 3,700 km^2 watershed covering most of Sandusky, Seneca and Crawford counties, northern Ohio. The river flows into the central basin of Lake Erie. Land-use is largely agricultural, mostly glacial till with some morainal areas in the southern portion. The stream segments were chosen based on several criteria. They had to be surrounded by farmland, without canopy cover, part of the county ditch maintenance program (so that management records were available), and accessible through landowner permission. Each stream segment was 50m long, sampled for fish and plant species, as well as a suite of habitat variables in both June and September 2011. Fish were block-seined, identified to species, assigned to an age class (adult, YOY), assessed for condition and gravidity, and released. Taxonomic identification followed Trautman (1981). When needed, photographs were taken to confirm taxonomic identity. In-stream plants were identified at five across-stream transects (50cm wide) per segment and quantified as percent cover within that transect. Water quality (dissolved oxygen, pH, conductivity, temperature) was measured directly upstream from the segment using a standard water quality probe (YSI model 550A). Discharge was measured within the segment with an electro-magnetic flow meter (Marsh-McBirney, model 2000). Stream heterogeneity in the horizontal and vertical plane of the wetted channel were estimated by computing the coefficient of variation (CV) of 11 wetted-stream channel widths and maximum depths, respectively, at five meters intervals along the length of the entire segment. Riparian parameters, such as bank-full width/depth, buffer strip width and bank slope, were also quantified for each stream segment.

3. Results

In the June and September sampling of these ditches, a remarkable total of 6,887 fish (30% juveniles) belonging to 32 species were netted, identified to species, assessed for condition, and released outside of the sampling segment to prevent recapture. Communities were dominated (in order of abundance) by typical headwater species such as fathead minnow (*Pimephales promelas)*, creek chub (*Semotilus atromaculatus)*, bluntnose minnow (*Pimephales notatus)*, blacknose dace (*Rhinichthys atratulus*), central stoneroller (*Campostoma anomalum)* and blackstripe topminnow (*Fundulus notatus*). Subdominants included johnny darter (*Etheostoma nigrum)*, yellow bullhead (*Ameiurus natalis*), and white sucker (*Catostomus commersonii)*. Remarkably, considering the regional prevalence of exotics, only 0.14% of the total catch was non-native species.

Fish species richness was positively correlated with stream heterogeneity in the horizontal and vertical plane of the wetted channel (Fig. 2). Regressions showed R^2 values of 0.23 and 0.38 in June (for vertical and horizontal heterogeneity, respectively). Corresponding values for the September sampling were 0.21 and 0.36, respectively. All p values were less than 0.05, except for the regression between richness and vertical heterogeneity in September where p=0.055. The higher values associated with horizontal heterogeneity suggest it was a better predictor for the presence of more fish species. The implication of these findings is that dredging and maintenance of these streams, which reduces heterogeneity of the channel, may reduce species richness of the fish community. The heterogeneity in these streams creates different habitats (riffles, pools, meanders, bank undercuts, etc.) suitable for different species of fish.

Similarly, species richness of YOY fish was positively correlated (R^2=0.27; p=0.02) with horizontal stream heterogeneity (Fig. 3), while no relationship was detected between YOY species richness vertical heterogeneity. Up to 12 YOY species were found in a single stream segment emphasizing the use of these ditches as nursery habitat. Contrary to my prediction, percent plant cover was not related to richness of YOY species (r=0.31; p=0.10). Plant communities at a particular transect could exceed one hundred percent cover because the whole water column was assessed, not just looking at it from above. Plant communities were dominated by reed canary grass (*Phalaris arundinacea*), marsh seedbox (*Ludwigia palustris*), spikerush (*Eleocharis palustris*), sago pondweed (*Potamogeton pectinatus*), water plantain (*Alisma subcordatum*), rice cutgrass (*Leersia oryzoides*), smartweed (*Polygonum* sp.), and filamentous green algae (*Cladophora* sp.).

New undergraduate students in the lab will now continue analyzing possible associations between the fish community (diversity, trophic structure, number of gravid species, index of biotic integrity) and habitat variables, such as water quality and velocity, ditch size, land-use, and the size of the watershed upstream from the sampled segment.

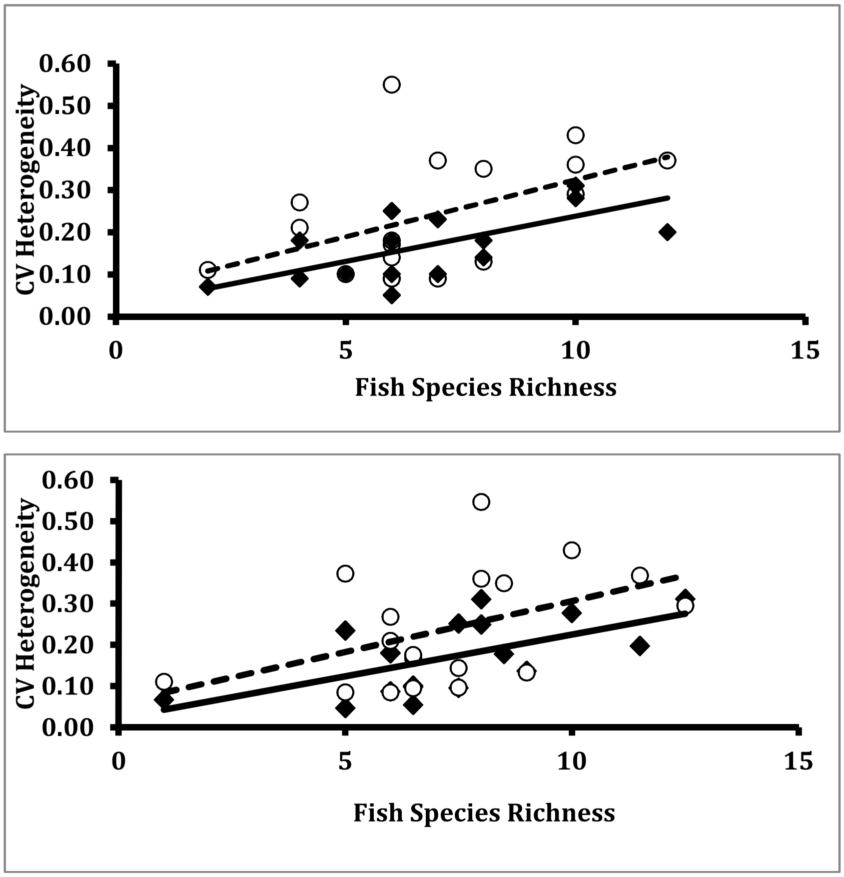
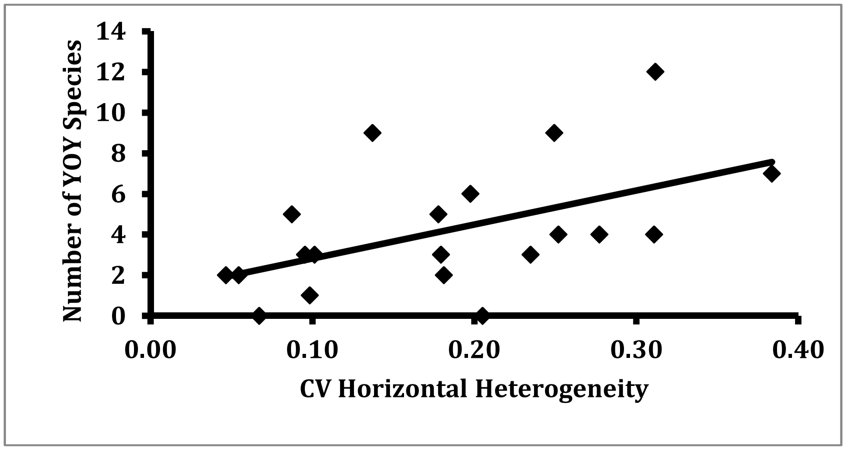


Figure 2. Relationship between stream heterogeneity and fish community species richness in June (upper panel) and September (lower panel) for 20 streams in the greater Sandusky basin, Ohio. Solid line and closed symbols represent the coefficient of variation for horizontal heterogeneity measurements; dotted line and open symbols represent same for vertical measurements.

4. Conclusion

In spite of their sometimes degraded conditions, ditches may serve as important fish habitat particularly when dredging practices are minimized. As such, environmental consideration should be incorporated into the management of these drainage channels. With the large reduction in headwater habitat in the agricultural mid-western United States, the ecological services of these ditches deserve attention of the research and management community. This is particularly appropriate with the increased success of erosion control on agricultural lands, which has lessened the need for dredging and has allowed some channels to return to a more natural stream morphology (e.g., meanders, undercut banks, riffles) with little apparent loss in cross-sectional area and drainage function. Reducing the frequency of maintenance dredging in agricultural streams may preserve their drainage function, enhance the integrity of fish assemblages and, therefore, the biological community as a whole. To help promote this, I actively involved participating landowners by giving them a photo collage of the fish and plant species in their ditches, highlighting the environmental services of these streams.



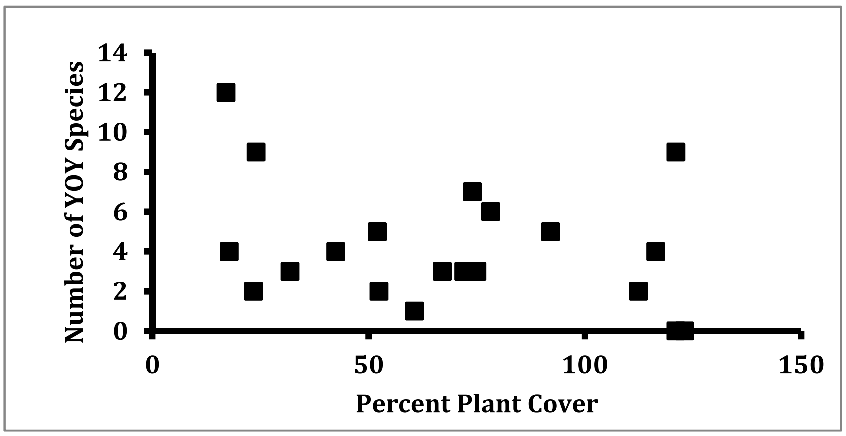


Figure 3. Relationship between Young-of-Year (YOY) species richness and horizontal stream heterogeneity (upper panel) and percent total plant cover (lower panel) for 20 streams in the greater Sandusky basin, Ohio.

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