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Research article

Maintenance of agricultural drains alters physical habitat, but not macroinvertebrate assemblages exploited by fishes

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ABSTRACT

The effects of drain maintenance on fish habitat and benthic macroinvertebrate assemblages (fish prey) were investigated for eight agricultural drains in southwestern Ontario, Canada. Our investigation employed a replicated Before-After-Control-Impact (BACI) design where each maintained section of a drain was paired with an unmaintained section downstream and an unmaintained section on a nearby reference drain of similar size and position in the watershed. Seven variables characterizing physical habitat features important to fishes and three variables characterizing the taxonomic abundance, densities, and relative densities of benthic macroinvertebrates were measured before drain maintenance and 10–12 times over 2 years following maintenance. Pulse responses were detected for three habitat variables quantifying vegetative cover: percent vegetation on the bank, percent in-stream vegetation, and percent cover. All three variables returned to pre-maintenance levels within two years of maintenance. No consistent changes were observed in the remaining habitat features or in the richness and densities of benthic invertebrate assemblages following drain maintenance. Our findings suggest that key features of fish habitat, structural properties and food availability, are resistant to drain maintenance.

1. Introduction

Much of the world's land area has been impacted by human activities and pristine areas of wilderness no longer exist (Kareiva et al., 2007; Sanderson et al., 2002). Concern for fisheries, wildlife, and biodiversity continues to heighten as human populations further domesticate landscapes (Malmqvist and Rundle, 2002). Domesticated ecosystems are systems where certain ecosystem services have been favoured over others, such as the production of food for human consumption over biodiversity in agricultural landscapes (Kareiva et al., 2007). Approaches, tools, and data that improve our understanding of ecosystem responses to human activities will assist in the characterization of trade-offs associated with the domestication of ecosystems and contribute to the development of practices that minimize these trade-offs (Kareiva et al., 2007).

Ecologists conceptualize the stability of assemblages and ecosystems in the face of natural and anthropogenic disturbances in terms of resilience. Resilience refers to the property of a system to reorganize and recover following a disturbance to a state with the same structure and function present prior to the disturbance (Grimm and Wissel, 1997). Resistance measures the amount of disturbance that a system can withstand before it shifts to an alternate state (Grimm and Wissel, 1997). These properties are used to characterize whether a biological assemblage or ecosystem remains unchanged (resistant), or whether any change is short lived (pulse response) or persists (press response). The concept of resilience has important policy implications. For example, productivity-state curves integrating resilience have been used as science aids in the amended Canadian *Fisheries Act* (Koops et al., 2012).

This study tested how the maintenance (digging out) of agricultural drains affects physical habitat features offering refuge, movement, feeding, and spawning opportunities for fish and features of benthic invertebrate assemblages that represent potential prey resources for fish. Drain maintenance provides an opportunity to examine the stability of these ecosystem features in a domesticated ecosystem and in a context important to natural resource managers. Agricultural drains are ubiquitous in agricultural regions. Roughly 50% of global land area is managed for crops or pasture

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(Kareiva et al., 2007). Drains remove water from fields inundated with standing water, or where the water table is too high, to provide aerated soil for root growth. Removal of excess water allows crop plants to access nutrient-rich soils (Van der Gulik et al., 2000). Agricultural drains can be man-made channels or channelized headwater streams redirected to run between fields and along roadsides (Edwards et al., 1984; Emerson, 1971). Both eventually outlet water to larger, unmaintained watercourses. Drains require maintenance when they no longer move water efficiently from crop fields and pastures, due to erosion and destabilization of banks, sedimentation, and growth of in-stream vegetation (Skaggs et al., 1994). Drains also provide habitat for fishes (Stammler et al., 2008). Drain maintenance has the potential to alter physical habitat features and invertebrate prey assemblages important to fishes, including removal of (i) riparian vegetation providing cover from overhead predators and solar radiation, (ii) sediment and in-stream vegetation influencing water velocity, depth-width ratios, discharge, and degree of channelization, and (iii) benthic prey. A comprehensive management plan for agricultural drains would balance the need to produce crops (food) for human consumption with the management of fish diversity.

This study focused on maintenance of drains in Southern Ontario, Canada. In this region, a more thorough understanding of how fishes, and their habitat and food sources, respond to drain maintenance is needed to develop management strategies and practices that reconcile the trade-off between crop production and biodiversity conservation, and to ease tensions between the stakeholders and agencies involved with drain maintenance (Needelman et al., 2007). The management of drains has been a source of tension between farmers and drainage superintendents responsible for drain maintenance and federal fisheries managers and conservation authorities tasked with preserving aquatic habitat and fishes. Drainage superintendents manage drains according to the provincial *Drainage Act*, which has provisions for the creation and maintenance of surface drains. Until 2013, fish habitat was managed under the federal *Fisheries Act* and the guiding principle of no net loss of fish habitat. The revised *Fisheries Act* now manages serious harm to fishes important to commercial, recreational, or aboriginal (CRA) fisheries, rather than fish habitat, as before (Rice et al., 2015). However, uncertainty surrounding how to manage drain maintenance remains. Most fish species fall under the CRA definition, and habitat alteration has the potential to cause serious harm.

Key uncertainties underlying the concerns about drain maintenance are whether maintaining drains alters fish habitat and for how long. Fish habitat refers to the spawning, nursery, rearing, feeding or migration areas that fishes require, both directly and indirectly, to complete their life cycles. Changes to fish habitat, or food resources, can result in changes to population dynamics and ultimately species diversity (Greer et al., 2012; Walser and Bart, 1999). Stammler et al. (2008) compared the habitat features and fish assemblages of 24 matched pairs of drains and reference watercourses. They found no evidence for consistent differences in physical habitat features important to fishes, or in the kinds, sizes, and life stages of fishes inhabiting the two types of watercourse. They hypothesized that any effects of drain maintenance on fish habitat and assemblage structure might be short-lived, consistent with a pulse response to drain maintenance. However, explicit tests of this hypothesis remain lacking.

We tested for a pulse effect in physical habitat features important to fishes and in benthic invertebrate assemblages (fish prey). Our study considered seven physical habitat variables important to the numbers and kinds of fishes found in a watercourse: channel width, water depth, water velocity, mean substrate size (particle diameter), bank vegetation cover, in-stream vegetation cover, and percent overhead cover (Bain and Stevenson, 1999; Cummins, 1974; Hughes et al., 2006; Matthews, 1998). In response to drain maintenance, we predicted that wetted width, stream depth, and water velocity would increase, while in-stream, bank, and overhead vegetation cover would decrease, due to the physical digging of the excavator, and that mean substrate size would increase with the removal of sediment and increased water velocities. We further tested whether these expected changes were transient or lasting over the two-year study period. Our test also considered changes in three features of benthic macroinvertebrate assemblages: the richness (#) of taxonomic groups (taxonomic richness), overall abundance, and changes in the relative densities of chironomid larvae. The focus on chironomids was due to their common occurrence in agricultural streams in southern Ontario (Barton, 1996), numerical dominance post disturbance in agricultural drains (Collier and Quinn, 2003), and importance as a food resource for fishes. We predicted that drain maintenance would cause a reduction in taxonomic richness and abundance because of alteration of in-stream habitat important to macroinvertebrates and the potential for their physical removal during maintenance. We also predicted that assemblages would be dominated by chironomid taxa following drain maintenance, because these opportunistic omnivores thrive in habitats less conducive to other taxonomic groups of macroinvertebrates. We also tested whether these expected changes were transient or lasting over a two-year study period.

2. Methods

2.1. Site selection and timing of sampling

Our study applied a replicated Before-After-Control-Impact (BACI) design (Stewart-Oaten et al., 1986) consisting of eight pairs of maintained (impact) and reference (control) drains. We use the term reference rather than control, because the selection of impact and control sites was not determined randomly. This created the possibility that the maintained and unmaintained watercourses could differ systematically in features that we did not measure (Harford and McLaughlin, 2007; Hayes et al., 2003), given that maintained sites required drain maintenance, but reference sites did not. Eight drain pairs from four major tributaries were selected with the aid of municipal drainage superintendents (Hall, Kerr, and Lamont drains and their references were located in the Little Maitland watershed; Hanna drain and its reference were located in the middle Maitland River watershed; Hepburn drain and its reference were located in the Thames watershed; and Big Creek, Haymarsh, and Summers drains and their references were located in the Big Creek watershed). Maintained drains were watercourses that required maintenance at the start of the study. Reference drains were watercourses that had not been maintained in the five years prior to the study, did not require maintenance, and were not maintained during the study. Drains that had not been maintained in the recent past were used as reference drains because Stammler et al. (2008) determined that habitat features and fish assemblages occurring in these kinds of drain systems did not differ significantly from habitat features and fish assemblages found in natural (unmaintained) watercourses. Within each pair, reference drains were selected from the same sub-watershed as the maintained drain. Neither the maintained drain nor the reference drain in a pair was consistently positioned above the other within the watershed. Although random selection of maintained and reference drains was not possible, potential reference drains were matched as closely as possible to the maintained drain in terms of size, location in the watershed, and land cover to avoid consistent bias. Maintained and reference drains were similar in their habitat features; sampling