Acknowledgements

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References

Borrini-Feyerabend, G. and N. Dudley. 2005. Elan Durban—Nouvelles perspectives pour les aires protégées à Madagascar. First report of the second mission to Madagascar on the behalf of two commissions of the World Conservation Union (UICN): the commission on Environmental, Economic and Social Policy (CEESP) and the World Commission on Protected Areas (WCPA). www.equilibriumresearch.com/upload/document/elandurban.pdf.

Gade, D.W. 1985. Savanna woodland, fire, protein and silk in highland Madagascar. *Journal of Ethnobiology* 5:109–122.

Kull, C.A. 2000. Deforestation, erosion, and fire: degradation myths in the environmental history of Madagascar. *Environment and History* 6:421–50.

Kull, C.A. 2002. The 'degraded' tapia woodlands of highland Madagascar: rural economy, fire ecology, and forest conservation. *Journal of Cultural Geography* 19:95–128.

Lowry II, P.P., G.E. Schatz and P.B. Phillipson. 1997. The classification of natural and anthropogenic vegetation in Madagascar. Pages 93–123 *in* S.M. Goodman and B.D. Patterson (eds.), *Natural Change and Human Impact in Madagascar*. Washington, DC: Smithsonian Institution Press.

Phillipson, P.B., G.E. Schatz, P.P. Lowry II and J.N. Labat. 2006. A catalogue of the vascular plants of Madagascar. Pages 613–627 *in* S.A. Ghazanfar and H.J. Beentje (eds.), *Taxonomy and Ecology of African Plants: their Conservation and Sustainable Use*. Proceedings 17th AETFAT Congress, Addis Ababa, Ethiopia. Royal Botanic Gardens, Kew.

Rabemanambola, M.F. and J. Rakotoarisoa. 2009. Globalisation et regionalization: mutations et recompositions territoriales sur le massif d'Ibity (Région du Vakinankaratra). XLVIème colloque de l'ASRDLF.

Generating Heterogeneity: Construction of Fish Hooks in the Humber River Induces Community Change

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The diversity in morphology of fishes is a product of the competitive processes that necessitate niche partitioning (MacArthur and MacArthur 1961). For example, interspecific competition is mediated through differentiation in mouth orientation; fishes with ventral mouths feed in the lower water column, whereas fishes with dorsal mouths feed in the upper water column (Wikramanayake 1990). Variation in water velocity reduces interspecific competition through character displacement, where low velocity waters contain fish with deep bodies and shorter fins and shallow, long-finned fishes are characteristic of high velocity waters (Wikramanayake 1990). Habitat heterogeneity facilitates the maintenance of morphological variation though an increase in dimensionality and habitat availability (MacArthur and MacArthur 1961). However, industrialization and development can strip lotic systems of heterogeneity. The Lower Humber River (LHR) watershed is entirely developed (TRCA 2008), with the LHR flowing from the Peel Plain through the City of Toronto and terminating at Lake Ontario. The LHR is surrounded by massive urban infrastructure; highway overpasses, rail lines, water treatment facilities, and residential high-rises surround the area. The watercourse is substantially altered to protect this infrastructure. There is extensive channelization resulting in the elimination of levee wetland systems and emergent and submergent aquatic vegetation that characterize natural estuaries. The channelization of the river has produced a single habitat type within the LHR, where fine grain size material and soft sediments dominate the substrate and natural structure or refugia are absent. This reduction in heterogeneity subjects individuals to competition, predation and extirpation (Gause 1932).

Historical data from the LHR watershed documents the presence of 54 fish species; however, only 22 fish species were captured in 2004 aquatic surveys. Monitoring data indicates the LHR watershed only supports generalist, tolerant and cool-warmwater fishes, whereas habitat specialists and higher trophic species are absent from the watershed (TRCA 2008).

Construction of artificial habitat can regenerate heterogeneity in anthropogenically simplified habitats (Gore and Bryant 1988). Stream and river restoration is predicated on generating a diversity of available habitats. Current deflectors, dams, cover structures, and bank protection elements are regularly installed to provide diversity in abiotic conditions (Gore and Bryant 1988). Restoration of heterogeneity in the LHR was performed using standard river restoration practices; however, in 2006 the Toronto Region Conservation Authority (TRCA) implemented a novel restoration method to increase the diversity of habitats available for fishes (TRCA 2008). The TRCA constructed 2 fish hooks at the mouth of the Humber River to supply static, low velocity backwater areas in the Humber River. The fish hooks form 2 semi-enclosed areas along the east bank of the Humber River (Figure 1). The structures deflect and concentrate flows, entrain bedload sediments, encourage the establishment of emergent vegetation, and provide small eddy pools for habitat and primary production. The fish hooks are comprised of 3 layers: a 300-mm thick granular bedding stone, forming the base of the structure against the

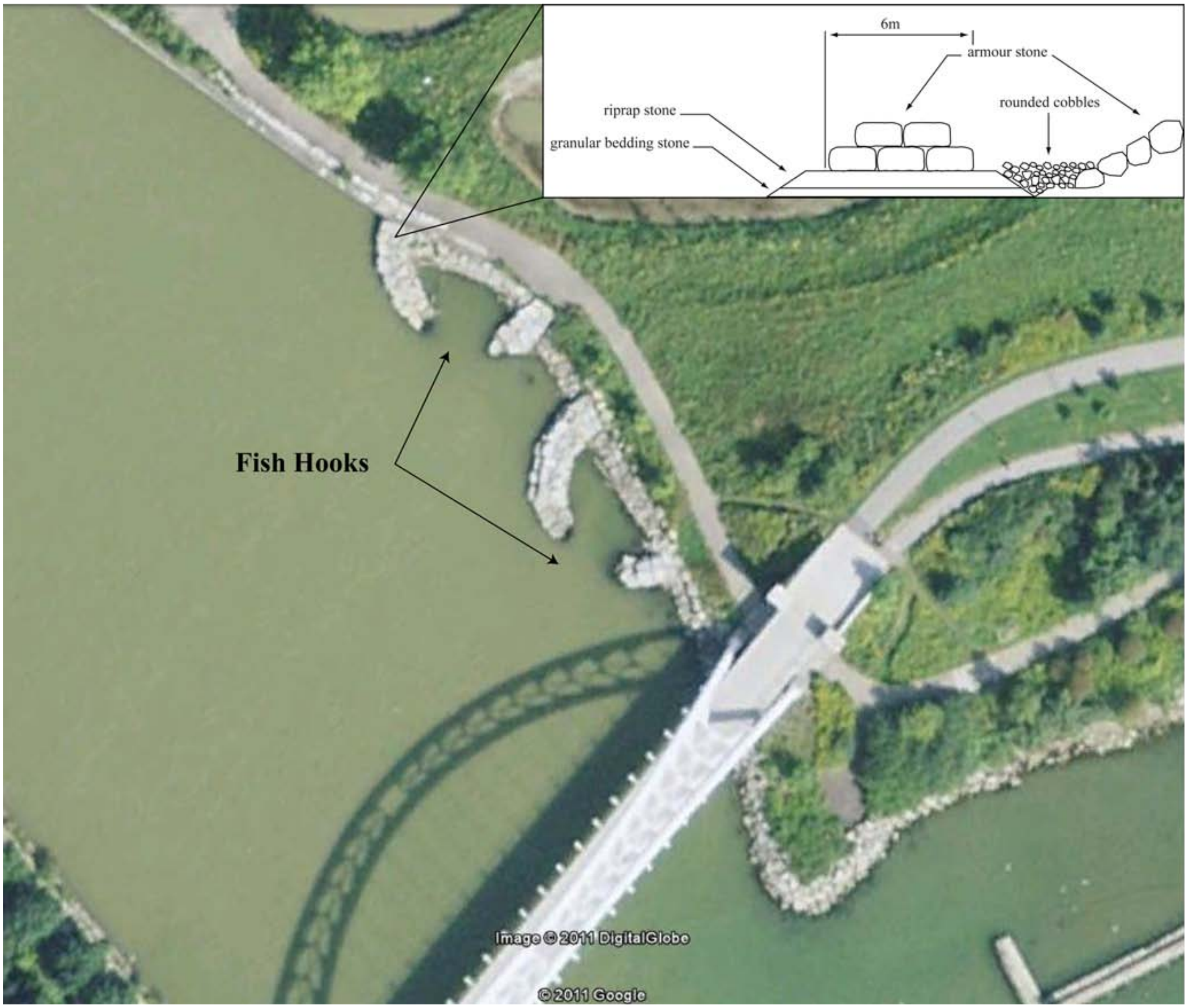

Figure 1. Satellite image of the fish hooks in the Humber River, Toronto, Canada. Arrows denote fish hooks. Inset is a cross section of the fish hooks.

riverbed; a 600-mm thick riprap stone affixed to the base; and armor stone at the surface interface. The fish hooks are 30 m wide at the base and jut out 8 m into the river.

To determine the fish community response to the novel habitat, we assessed both pre- and post-fish hook communities by electroshock sampling. Between 1989 and 2010 at a site adjacent to the fish hooks (43°37'54.7568", -079°28'18.7388"), we performed boat electrofishing 25 times (6 pre-construction and 19 post-construction). We performed boat electrofishing along a 350-m transect sampled upstream and downstream, executing each complete transect over a period of 1000 s. We subsequently transformed the site-by-species data into a similarity matrix, which we produced with a Pearson's Phi resemblance measure for multivariate presence/absence data was produced. From the dissimilarity matrices, we produced a 2-dimensional PCoA ordination to facilitate visual interpretation, where similarity among sites is concordant with distance in the ordination (Legendre and Legendre 1998).

The ordination indicates 2 clusters of points that align with pre- and post construction sampling (Figure 2). An analysis of similarities (ANOSIM) procedure, which measures the variation within groups relative to the between group variation, indicated the groups were statistically different (ANOSIM R = 0.502, $p = 0.001$). The results demonstrate that post-construction sampling points are more similar to post-construction points than pre-construction points. The similarity within groups is generated by species differences between groups and suggests the construction of the fish hooks induced the differences.

Following the construction of the fish hooks, we detected the presence of several fish species that had been absent from the LHR over the last decade, including alewife (*Alosa pseudoharengus*), golden shiner (*Notemigonus crysoleucas*), bluntnose minnow (*Pimephales notatus*), and common shiner (*Luxilus cornutus*). Rainbow smelt (*Osmerus mordax*) and Alaskan stickleback (*Gasterosteus aculeatus*), which were last detected in the LHR in 1989 and 1999, respectively,

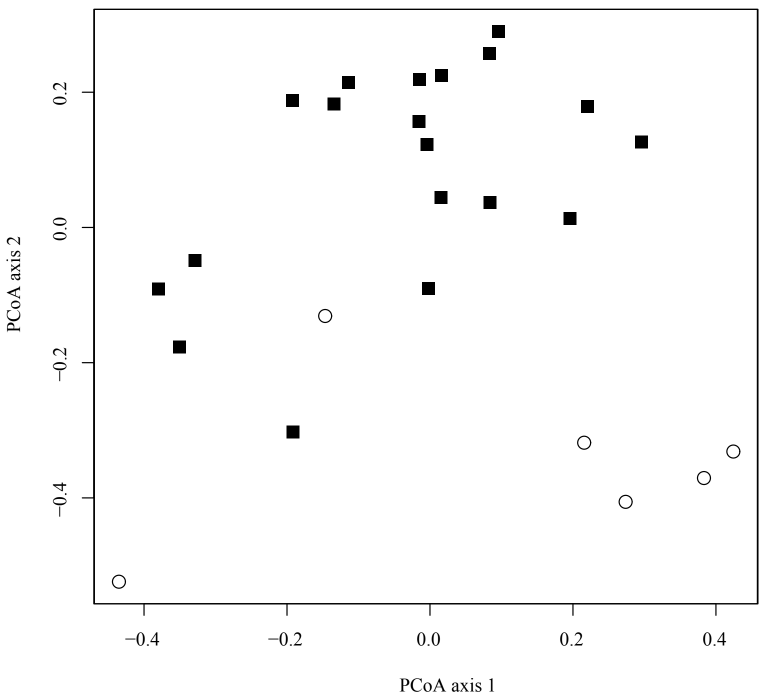

Figure 2. Two-dimensional PCoA ordination of pre- and post-fish hook construction sampling. Open circles and solid squares denote pre- and post-sampling, respectively. ANOSIM procedure indicated the groups were significantly different (ANOSIM R = 0.502, *p* = 0.001).

were also present. We captured most species in low numbers, detecting only 1 golden shiner and Alaskan stickleback, 4 bluntnose minnows, and 6 rainbow smelts. However, alewife and common shiner demonstrated marked increases in abundance in post-construction sampling. Prior to the installation of the fish hooks neither alewife nor common shiner was detected at the site, but we captured 1,344 alewife and 181 common shiner individuals in post-construction sampling. In addition, we detected a novel species, a singleton spotfin shiner (*Cyprinella spiloptera*), which had never been recorded in the LHR watershed. The results suggest that construction of the fish hooks create habitat that is suitable for species in higher trophic levels.

We also detected the reoccurrence of 3 piscivorous species, including rainbow trout (*Oncorhynchus mykiss*), largemouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavescens*). These species had not been captured in the watershed since at least 1999. Post-construction sampling detected the presence of 1 rainbow trout, 1 largemouth bass, and 3 yellow perch individuals. However, 3 species, American eel (*Anguilla rostrata*), bluegill (*Lepomis macrochirus*), and white perch (*Morone americana*), that were present during pre-construction sampling were not detected in subsequent sampling.

Our results suggest the installation of fish hooks generate heterogeneity in the fish community. The availability of backwater areas increased the structural heterogeneity of the Humber River and facilitated the persistence of species that are precluded by the velocity of the water. The composition of novel detections was dominated by species with low velocity habitat preferences. Golden shiner is partial to slow moving sections of rivers, whereas bluntnose minnow, rainbow smelt, Alaskan stickleback, and spotfin shiner prefer the pools of larger rivers (Page and Burr 2011). We hypothesize that the detection of novel piscivorous species at the sampling site was a function of an increase in prey availability mediated by the increase in habitat availability. The loss of American eel post-construction could be attributed to its overall widespread decline, and low abundances of bluegill and white perch could be due to a sampling effect, given the species were originally detected as singletons. A description of the niche generated by the fish hooks is required to understand the species patterns observed. A characterization of the abiotic factors of the habitat within the fish hooks would elucidate the relationship between the habitat species composition. Though the mechanism is speculative, the detection of novel, relatively rare species and piscivores indicates a positive response to the construction of the fish hooks. The fish hooks appear to provide additional habitat for species and a resource base for piscivores. These results indicate the construction of fish hooks can be a viable restoration technique to provide novel habitat for deteriorated rivers.

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References

Gause, G.F. 1934. *The Struggle for Existence*. Baltimore, MD: Williams & Wilkins.

Gore, J.A. and F.L. Bryant. 1988. River and stream restoration. Pages 23– 38 *in* J. Carins (ed), *Rehabilitating Damaged Ecosystems Volume I*. Boca Raton, FL: CRC Press.

Legendre, P. and L. Legendre. 1998. *Numerical Ecology*. Amsterdam: Elsevier Science.
MacArthur, R.H. and J.W. MacArthur. 1961. On Bird Species Diversity. *Ecology* 42:594–598.
Page, L.M. and B.M. Burr. 2011. *Peterson Field Guide to Freshwater Fishes of North America North of Mexico*. New York, NY: Houghton Mifflin Harcourt.
TRCA (Toronto Region Conservation Authority). 2008. Humber River Watershed Plan.
Wikramanayake, E.D. 1990. Ecomorphology and biogeography of a tropical stream fish assemblage: evolution of assemblage structure. *Ecology* 71:1756–1764.

An Assessment of Foliar Application of Triclopyr of Varying Concentrations for Managing Glossy Buckthorn (*Rhamnus frangula*) Seedlings and Resprouts (Michigan)

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For many governmental and non-governmental conservation agencies, management of invasive species is a top priority. For instance, over the past decade glossy buckthorn (*Frangula alnus*) has been the target of management at Seney National Wildlife Refuge (SNWR) in Upper Michigan, with the goal to reduce the dominance and abundance of this exotic, invasive shrub (USFWS 2009). Current management of glossy buckthorn consists of foliar applications with 2.5% active ingredient glyphosate (brand name *Rodeo*®, Dow AgroSciences, LLC, Indianapolis, IN, USA) (Corace et al. 2008, Nagel et al. 2008). However, as is often the case, plants repeatedly sprayed with the same herbicide can form resistance, eliminating the effectiveness of the selective herbicide (Holt and LeBaron 1990). While resistance by glossy buckthorn to glyphosate has yet to be documented, glyphosate resistance has been documented in several agricultural weeds (Yu et al. 2007). To be proactive, managers at SNWR should consider alternative methods for glossy buckthorn management before glyphosate resistance develops.

Triclopyr (brand name *Garlon*® *4 Ultra*, Dow AgroSciences, LLC, Indianapolis, IN, USA) is an herbicide indicated for management of woody plants and herbaceous broadleaf weeds, including glossy buckthorn (product label). However, little information exists in the literature about the efficacy of foliar applications of triclopyr. Most research conducted with triclopyr on glossy buckthorn and closely related European buckthorn (*Rhamnus cathartica*) has utilized either a cut-stump or basal bark application at relatively high concentrations (>15%) of active ingredient mixed with mineral oil or diesel oil (Pergams and Norton 2006). However, these methods are less attractive than foliar application because cut stems may resprout vigorously and seedlings too must be managed (Corace et al. 2008, Nagel et al. 2008), while the use of fuel oils further increases costs. Moreover, as suggested by Relyea (2005), using the lowest effective concentration is favorable to reduce negative human and environmental health risks. This study tested the efficacy of varying concentrations of triclopyr to determine the best strategy for glossy buckthorn management at SNWR. The study site was located on an anthropogenic dike comprised of coarse sands within SNWR. In June 2011, I set up 40 1-m² plots comprised of glossy buckthorn resprouts and seedlings with at least 1m between each plot. At each plot, I recorded the number of glossy buckthorn stems, as well as the average stem height and diameter. The mean number of pre-treatment stems (± SE) was 14.8 (± 1.6). The majority of the plots (63%) had stems <1 m in height, with the remaining stems between 1–2 m tall. Mean stem diameter was <2 cm in all but 2 of the plots. I then divided the plots evenly into 4 treatment groups: 0% active ingredient (tap water without surfactant, control), 1.25% active ingredient, 2.5% active ingredient, and 5% active ingredient, following the methods of Corace and colleagues (2008). I mixed each solution using a base concentration of 60.45% active ingredient triclopyr diluted with tap water per label recommendations. On 6 June 2011, I treated the plots with low-volume hand-held sprayers during appropriate weather conditions. I treated each stem to a point of about 50% foliar coverage. I then monitored the plots once per week for 5 wks to document a stress gradient from chlorosis (least severe stress), to shriveled leaves, to shriveled/no leaves and brittle stems (indicating a dead stem). After 2 wks, severe chlorosis was apparent on all treated stems, regardless of concentration. Within 3 wks, 99% of stems were dead, with 100% stem mortality observed in the 4th week (Figure 1). These results were similar to those of Corace and others (2008).

Our results indicate that foliar applications of triclopyr at low concentrations mixed with water can be effective for managing glossy buckthorn in Upper Michigan, adding to the repertoire of management techniques for this invasive plant species. While complete removal of invasive plant species is highly unlikely, a broad range of management techniques can help to reduce their geographic extent and dominance over several treatment periods (Pergams and Norton 2006, Nagel et al. 2008). Herbicide resistance to glyphosate and triclopyr has yet to be documented in glossy buckthorn. Utilizing a rotation of these 2 herbicides will greatly reduce the likelihood of glossy buckthorn developing a resistance. This is especially important when managers may be limited in techniques available due to constraints such as wetland approved herbicide use or lack of resources. Based on this study and past studies within