Finding and Prioritizing Barriers on the Landscape

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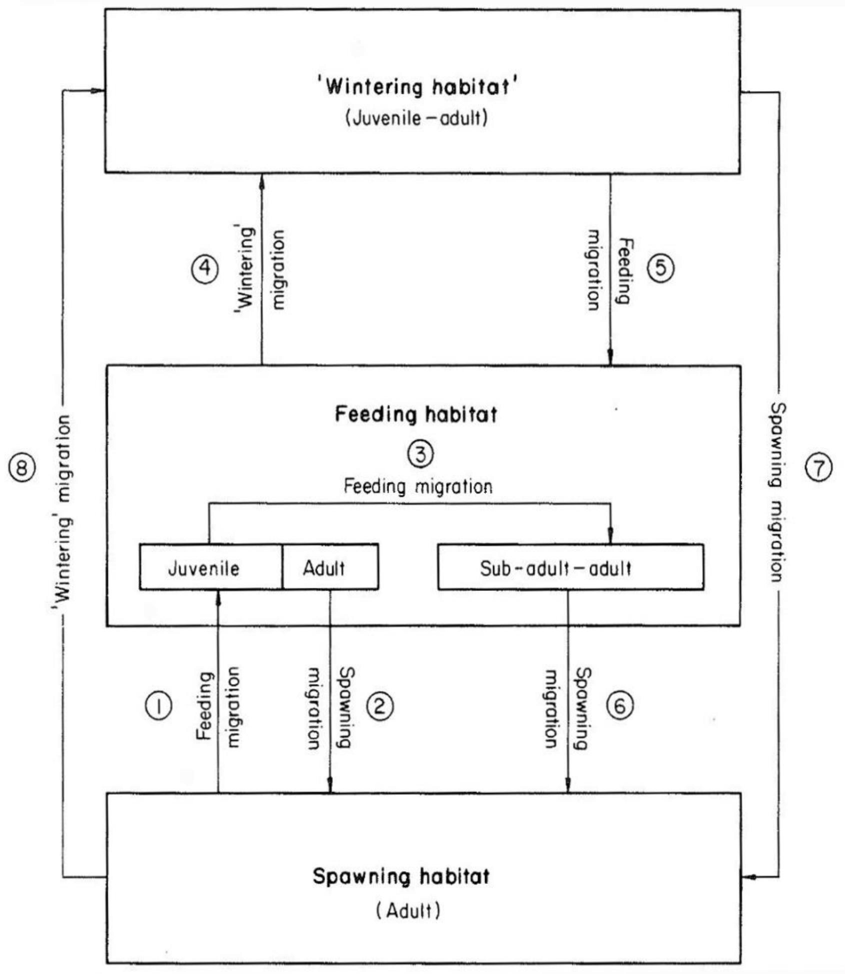
Fish Habitat and Movement in Stream Networks

Fish exploit their environment to maximize fitness.

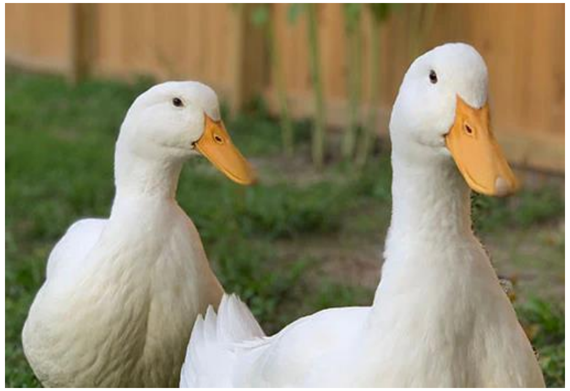
This may require long distance movements.

Fish require access to a variety of habitats in which to spawn, feed, and seek refuge from predators and adverse environmental events.



Types of barriers

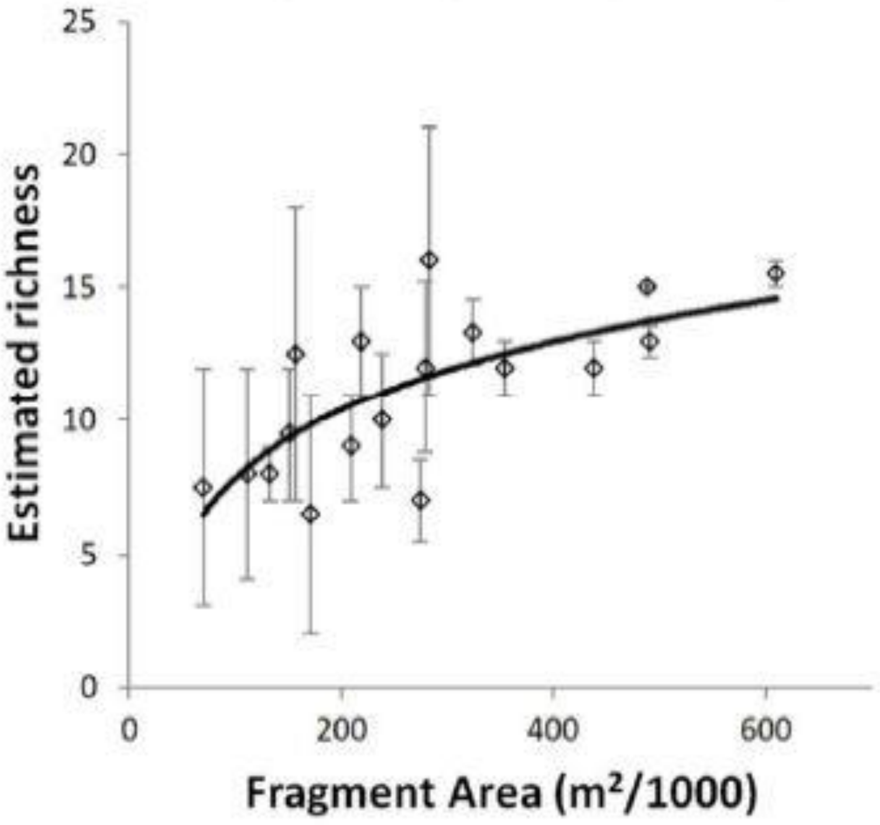
Types of barriers – private ponds



Habitat Fragmentation – Ecosystems

Fragmentation has ecosystem consequences.

1. Decreased ecosystem resilience.
2. Decreased biodiversity.
3. Decreased productive capacity.



Habitat Fragmentation - Populations

There are demographic and genetic consequences of fragmentation.

Demographic:

Small fragmentated populations are more susceptible to adverse environmental events such as droughts, floods, spills, or disease.

Small populations are more strongly affected by random demographic variation such as reduced reproductive success or changes in sex ratios (Soulé and Simberloff 1986).

Genetic:

Decreases in population size can increase genetic drift and inbreeding which may decrease genetic diversity

Deleterious traits may accumulate, reduce fecundity and offspring survival, and decrease a populations' ability to adapt to environmental changes.

Intentional Fragmentation as a Management Strategy in Aquatic Systems

FRANK J. RAHEL

Maintaining or restoring connectivity in aquatic systems can enhance migratory fish populations; maintain genetic diversity in small, isolated populations; allow organisms to access complementary habitats to meet life-history needs; and facilitate recolonization after local extirpations. However, intentional fragmentation may be beneficial when it prevents the spread of nonnative species or exotic diseases, eliminates hybridization between hatchery and wild stocks, or stops individuals from becoming entrapped in sink environments. Strategies for fragmenting aquatic systems include maintaining existing natural barriers, taking advantage of existing anthropogenic features that impede movement, severing artificial connectivity created by human actions, and intentionally creating new barriers. Future challenges for managing fragmentation include maintaining hydrologic connectivity while blocking biological connectivity in water development projects; identifying approaches for maintaining incompatible taxa, such as sport fishes and small nongame species; and developing selective barriers that prevent the passage of unwanted species while allowing normal life-history movements of other species.

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The Conundrum

- Native fishes often face simultaneous threats from habitat fragmentation and invasion by non-native species.
- Management actions to address fragmentation may allow invasive species to extend their range.
- Conversely, not addressing fragmentation may lead to local extirpation of a species whose population is too small and isolated to persist (Fausch et al. 2009).

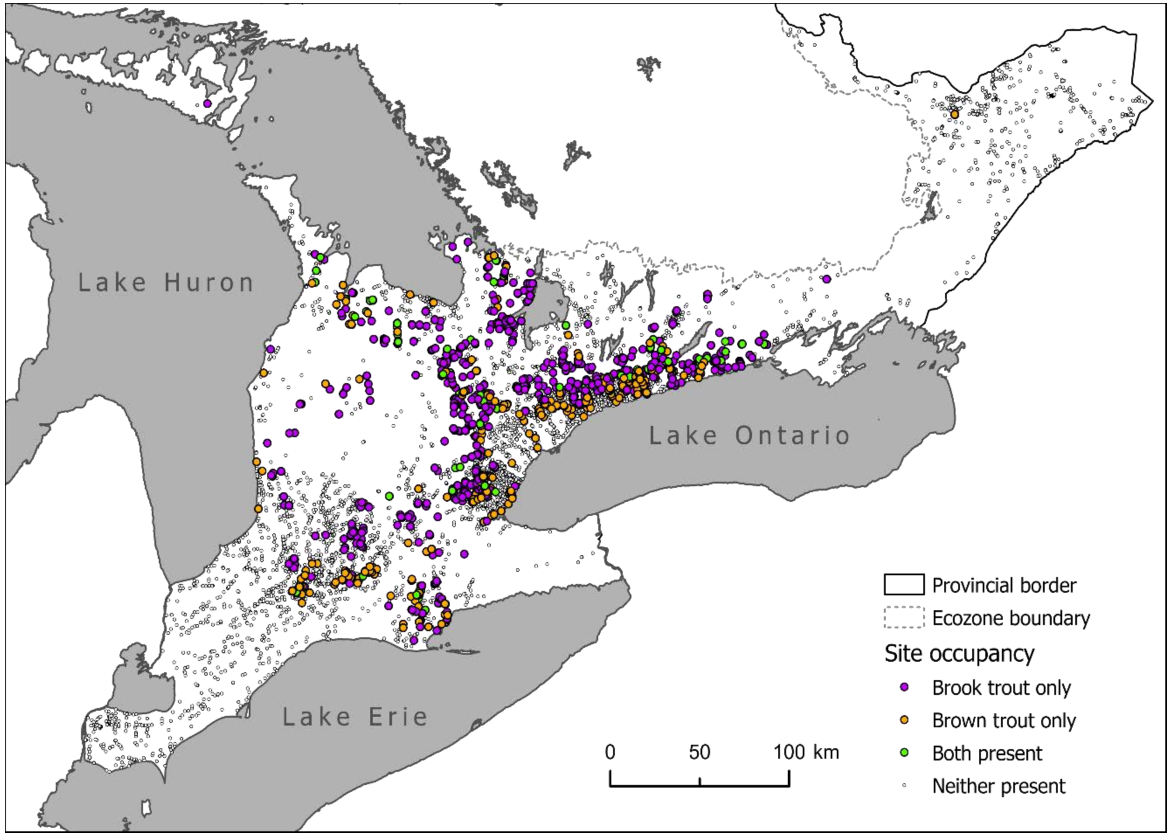
Decision Support

- Watersheds often have many barriers but not many are needed for species partitioning and the extra barriers limit the health and resilience of fish populations.
- A decision process is needed to guide biologists on when and where intentional use or removal of barriers is the most appropriate action.
- Understanding how environmental variables influence the distribution of brook and brown trout can be used in this decision process.

Example: Occupancy of brook and brown trout in streams of the Mixedwood Plains Ecozone

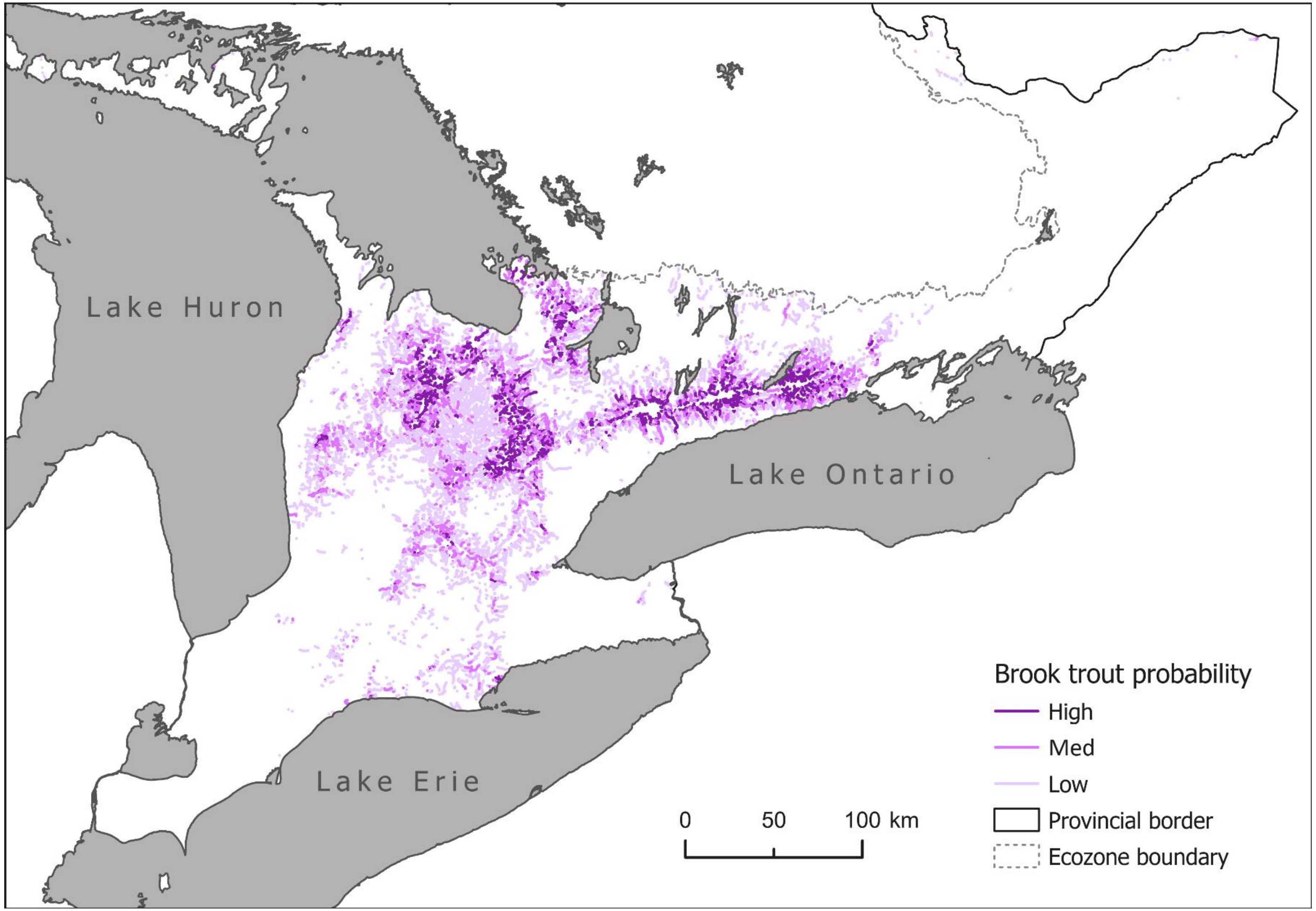
Samples collected using electrofishing in the Mixedwood Plains Ecozone from 1990 to 2019 that contain brook and or brown trout.

Used presence and absence data to develop boosted regression models to predict the summertime occupancy of trout.



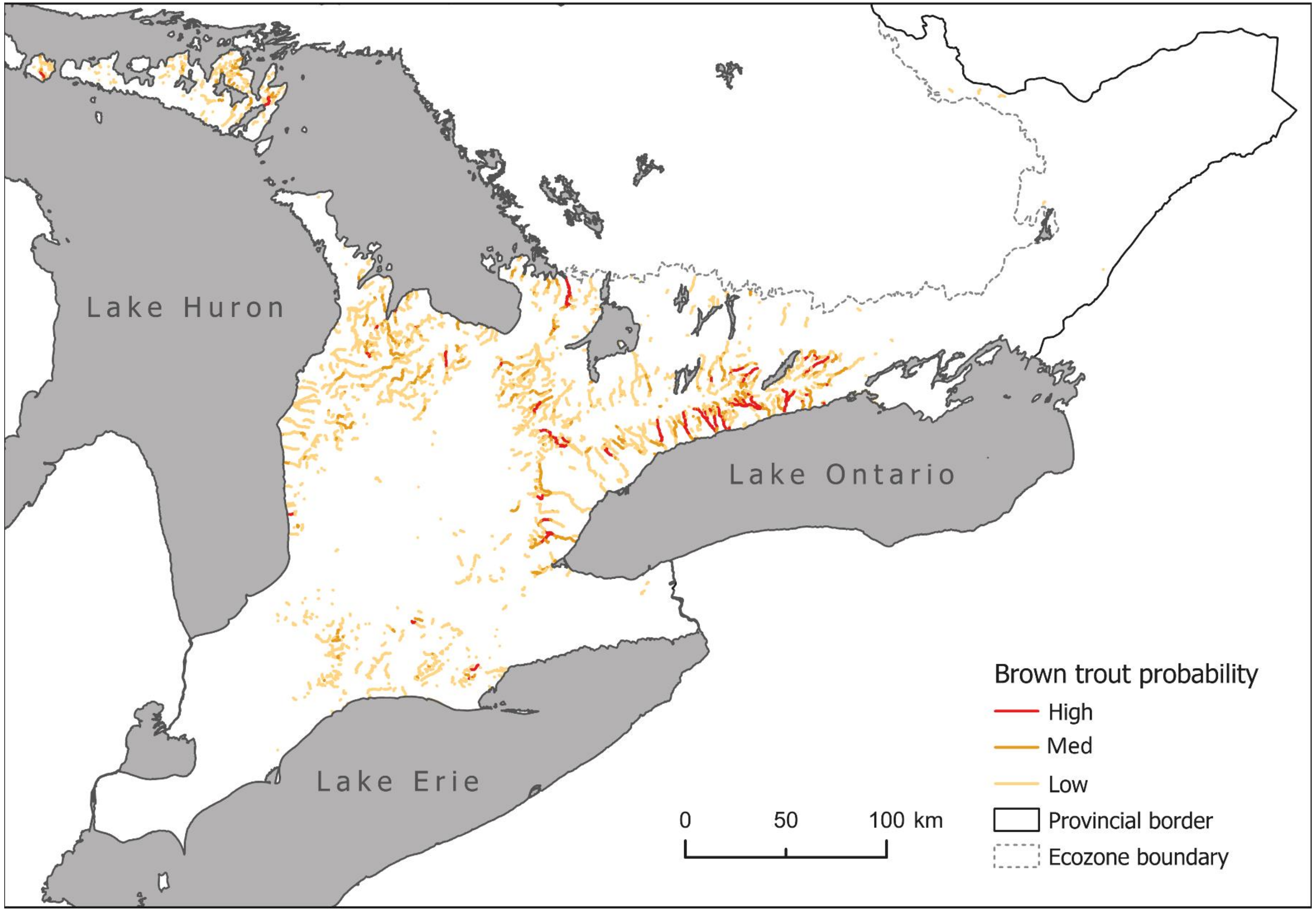
Brook trout occupancy

Reach contributing areas and their predicted occupancy probabilities for brook trout in the Mixedwood Plains Ecozone, southern Ontario.



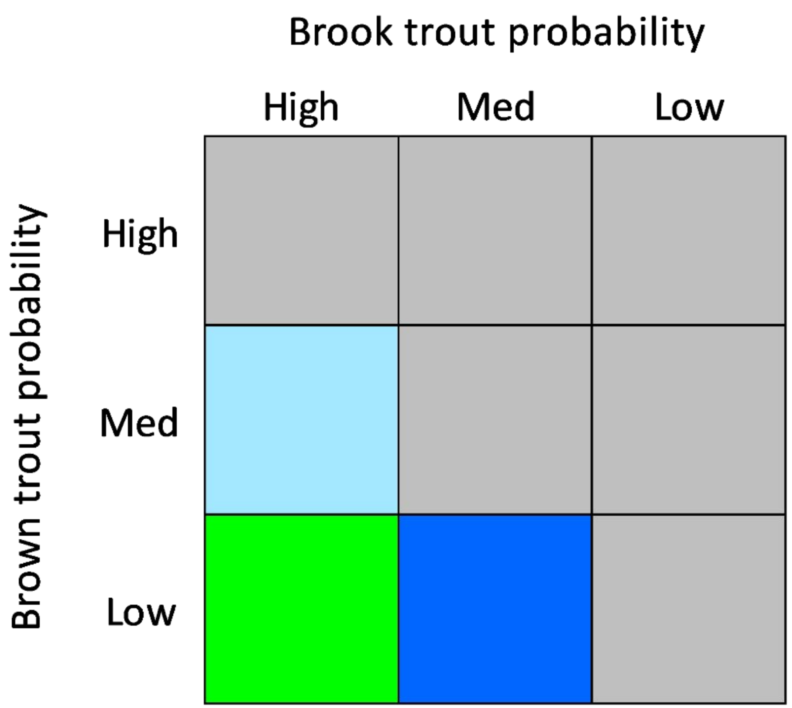
Brown trout occupancy

Reach contributing areas and their predicted occupancy probabilities for brown trout in the Mixedwood Plains Ecozone, southern Ontario.

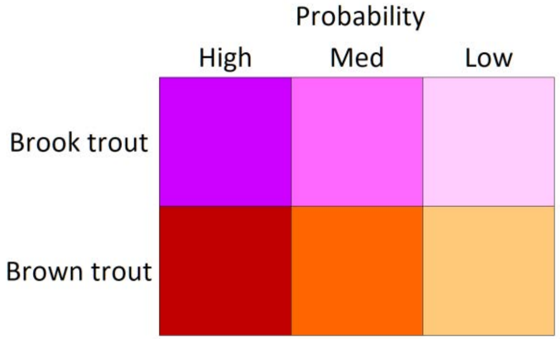


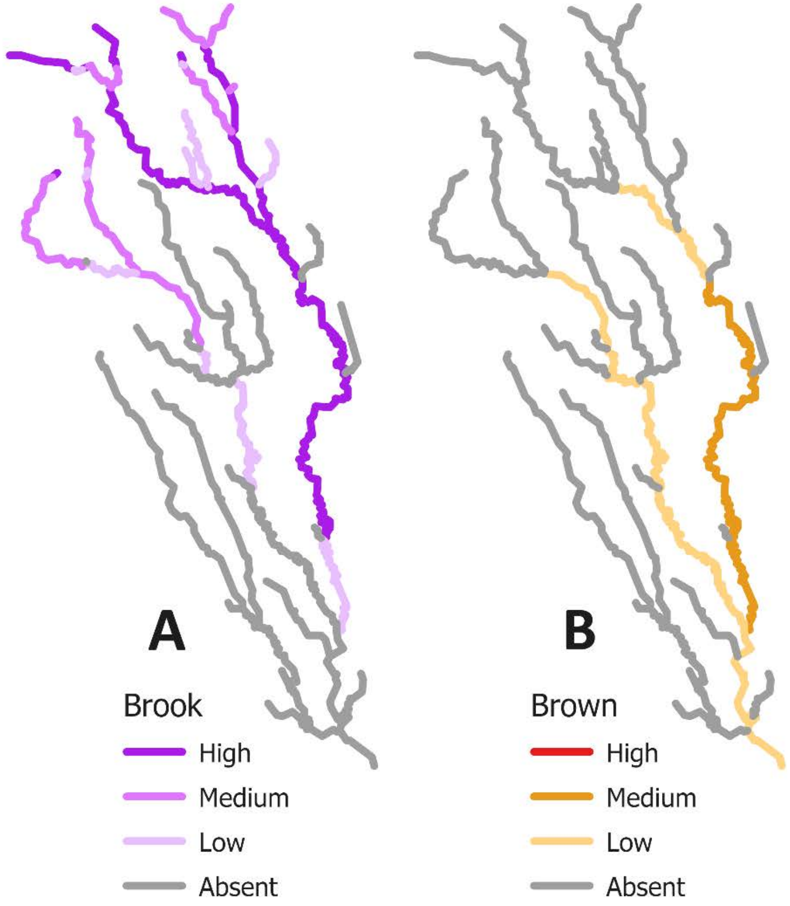
Occupancy Overlap

- Brook trout will successfully compete with brown trout under certain circumstances.
- Small steep cold streams.
- Brook trout will do best when their probability is high and brown trout is low.

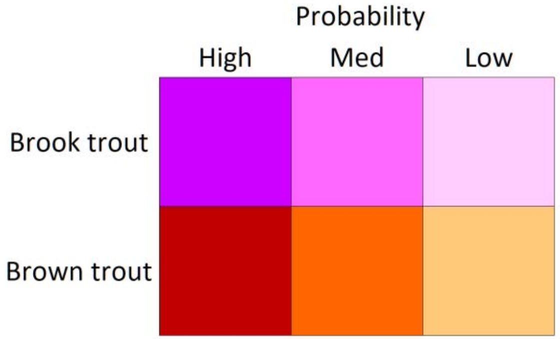


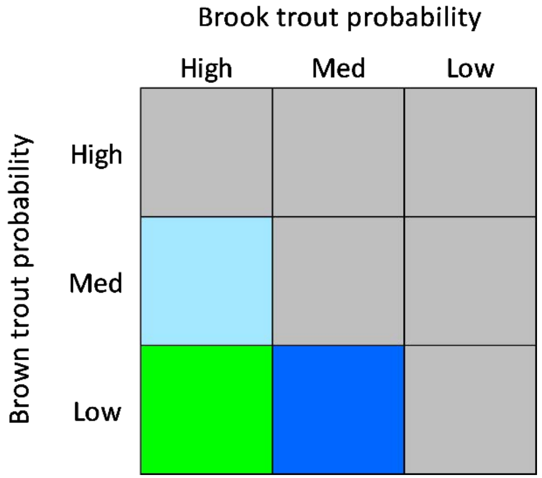
Occupancy Overlap

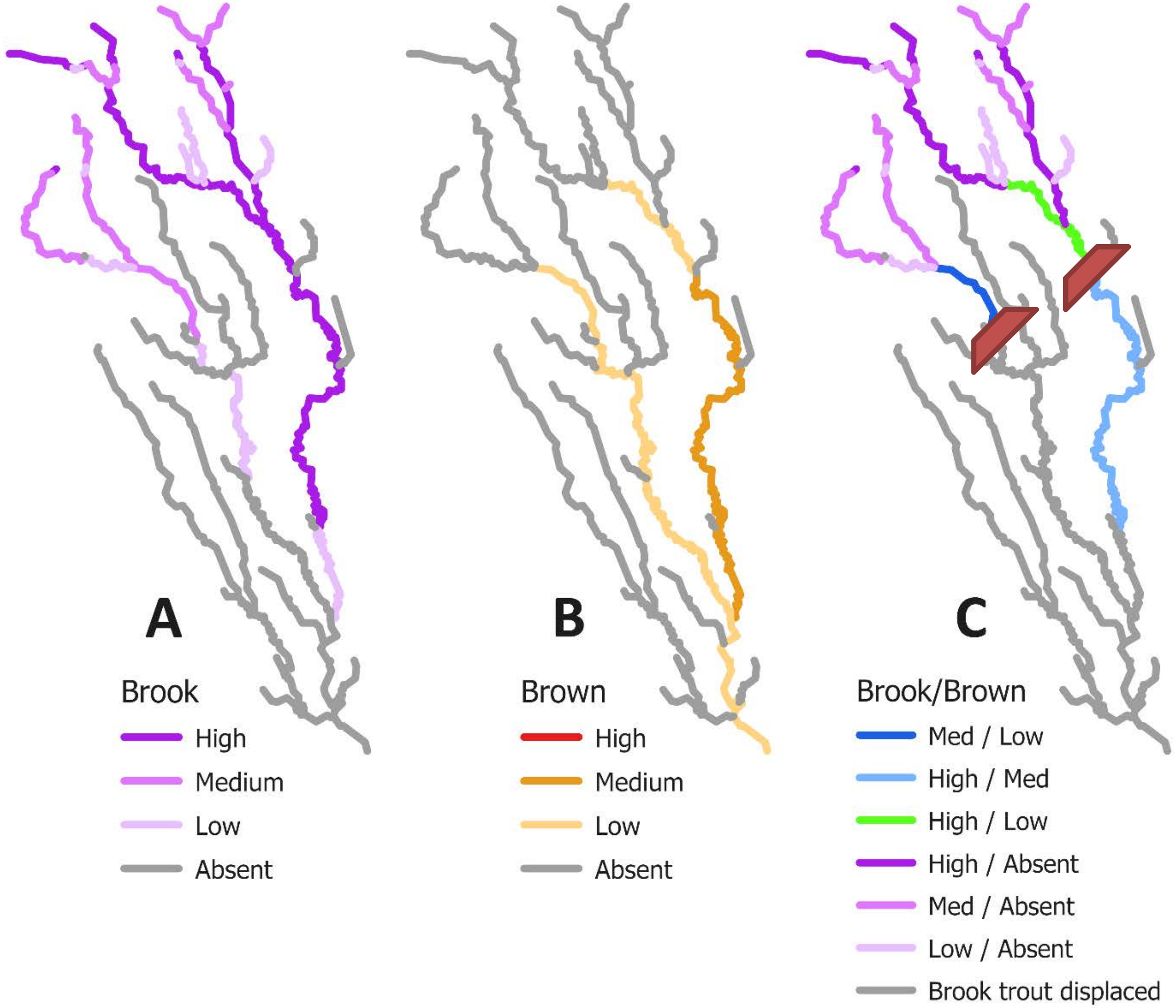




Occupancy Overlap







Barrier Permeability

- The permeability of a barrier depends on river discharge, water velocity, vertical height, longitudinal length of the barrier, fish species and size, and water temperature.
- A barrier might be impassable during certain flows for smaller juveniles and adults of a species.
- Only a few in the population might be able to pass a potential barrier but these few individuals may have a disproportionate impact on recruitment. (e.g. strongest, largest, higher metabolic rate, ventricle size and myoglobin level).

Ontario

Identifying Barriers on the Landscape

Diversity and Distributions, (Diversity Distrib.) (2014) 1–11

BIODIVERSITY RESEARCH

Predicting road culvert passability for migratory fishes

Stephanie R. Januchowski-Hartley[1]*, Matthew Diebel[2], Patrick J. Doran[3] and Peter B. McIntyre[1]

Gradient of the stream segment was the most important predictor in the outlet drop model, while upstream drainage area was the most important predictor in the three water velocity models.

In steep hills it is difficult not to perch culverts or create a velocity barrier.

Likely better to span the floodplain (countersunk culvert) allowing the stream to move inside the culvert and create low velocity areas amongst substrate.

Here the culvert is slightly perched but the velocity looks very fast.

Many fishes could likely make the jump but few might have the burst speed to make it to the other side.

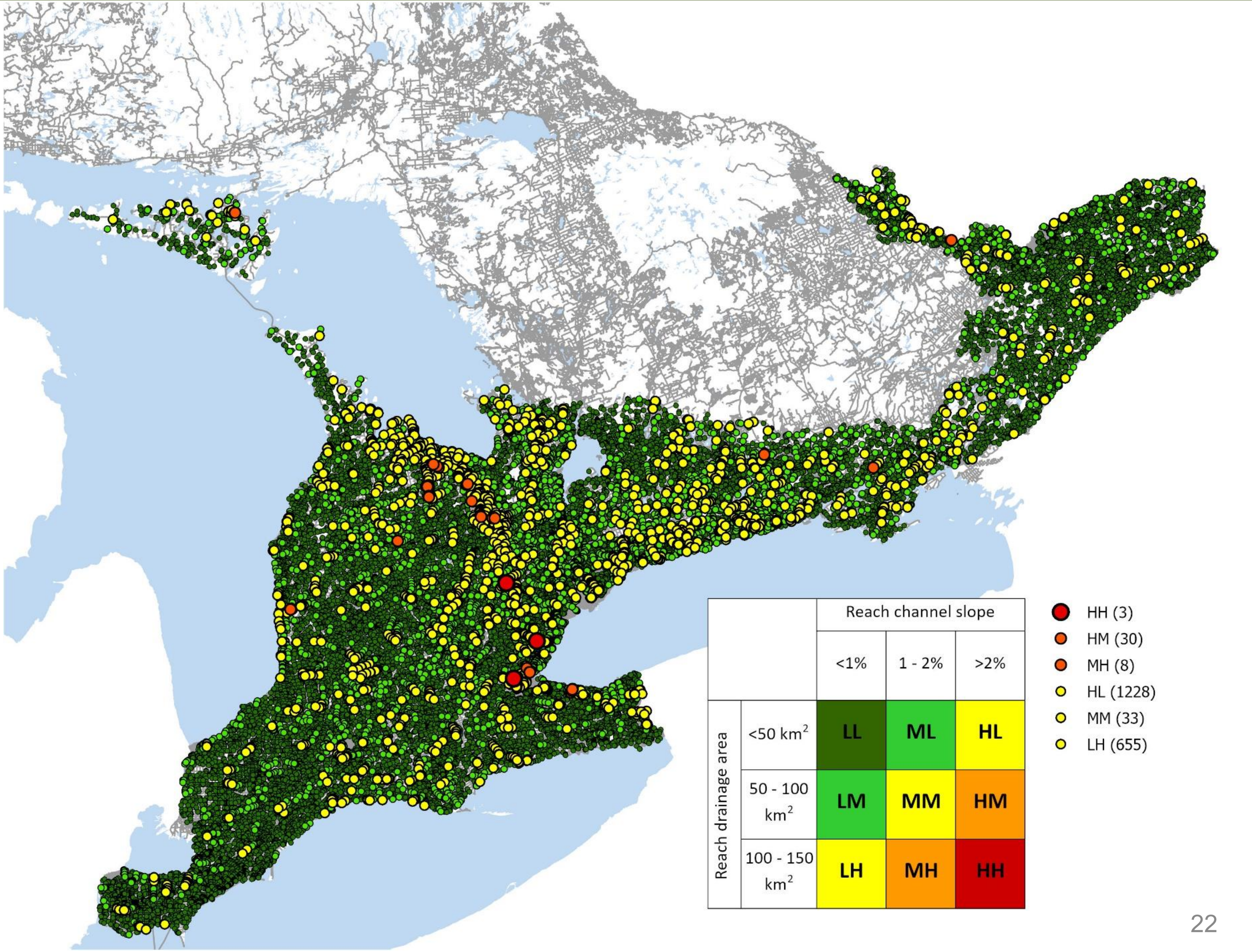
Here the culvert is installed incorrectly.

Culvert likely needs to be buried on the upstream side and increased in size.

Likelihood of being a barrier

Assume crossings over streams >150 km^2 are not culverts e.g., bridges.

Of 36,248 crossings only 1,960 (5%) are in the red, orange, and yellow categories.

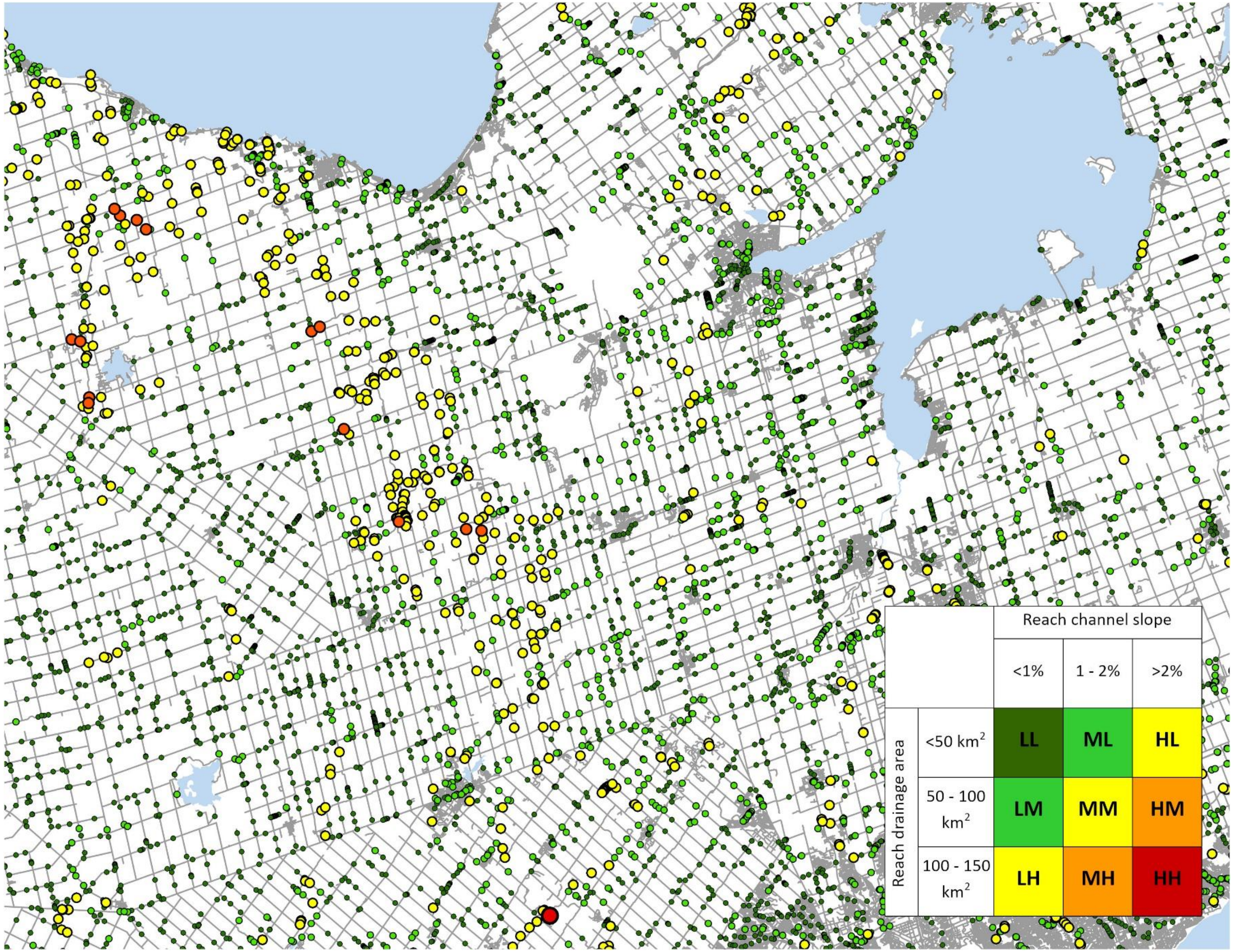


Likelihood of being a barrier

Dufferin County.

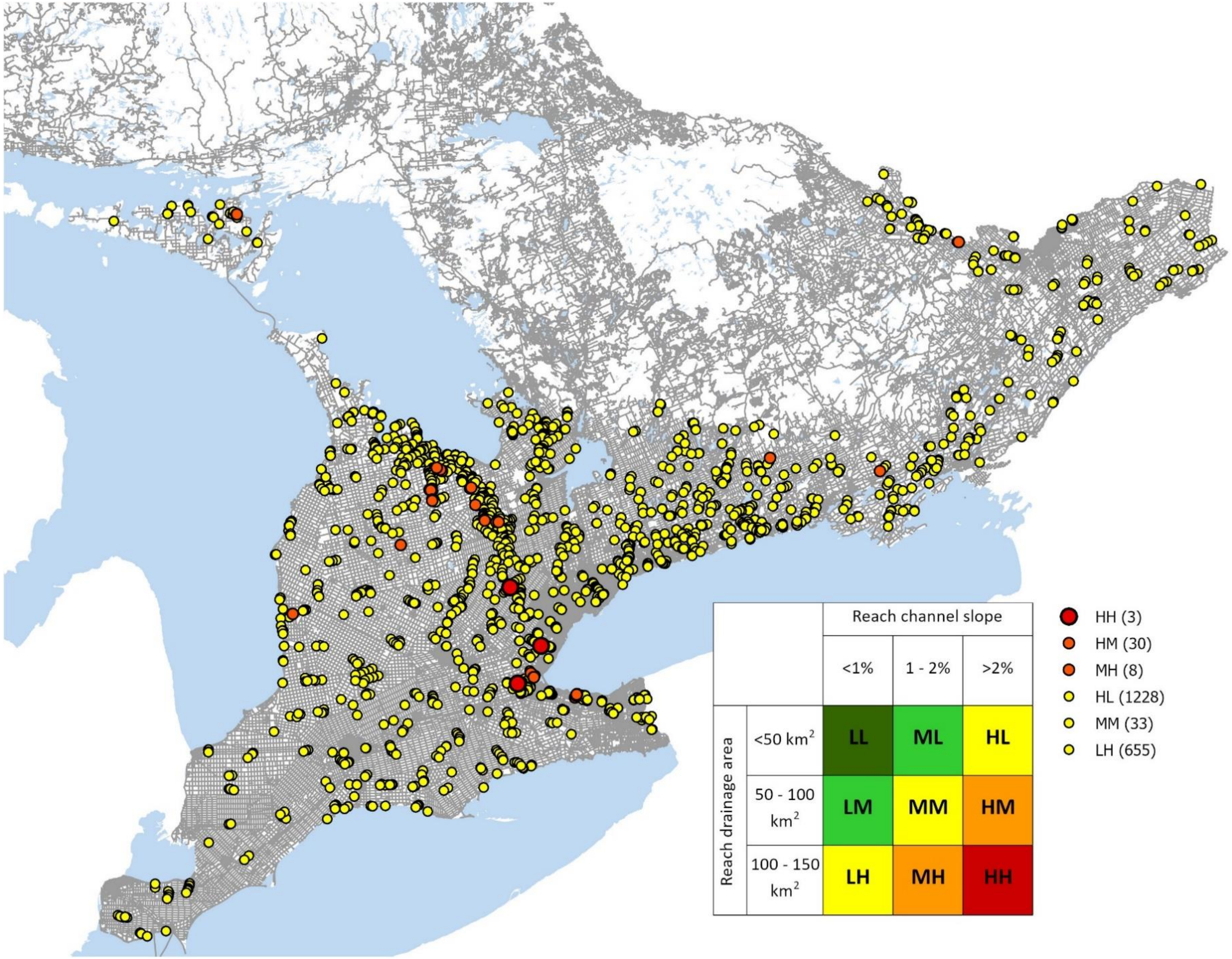
Notice the escarpment.

Lots of yellow coloured crossings.



Increased likelihood of being a barrier

With the green (low risk) crossings removed.

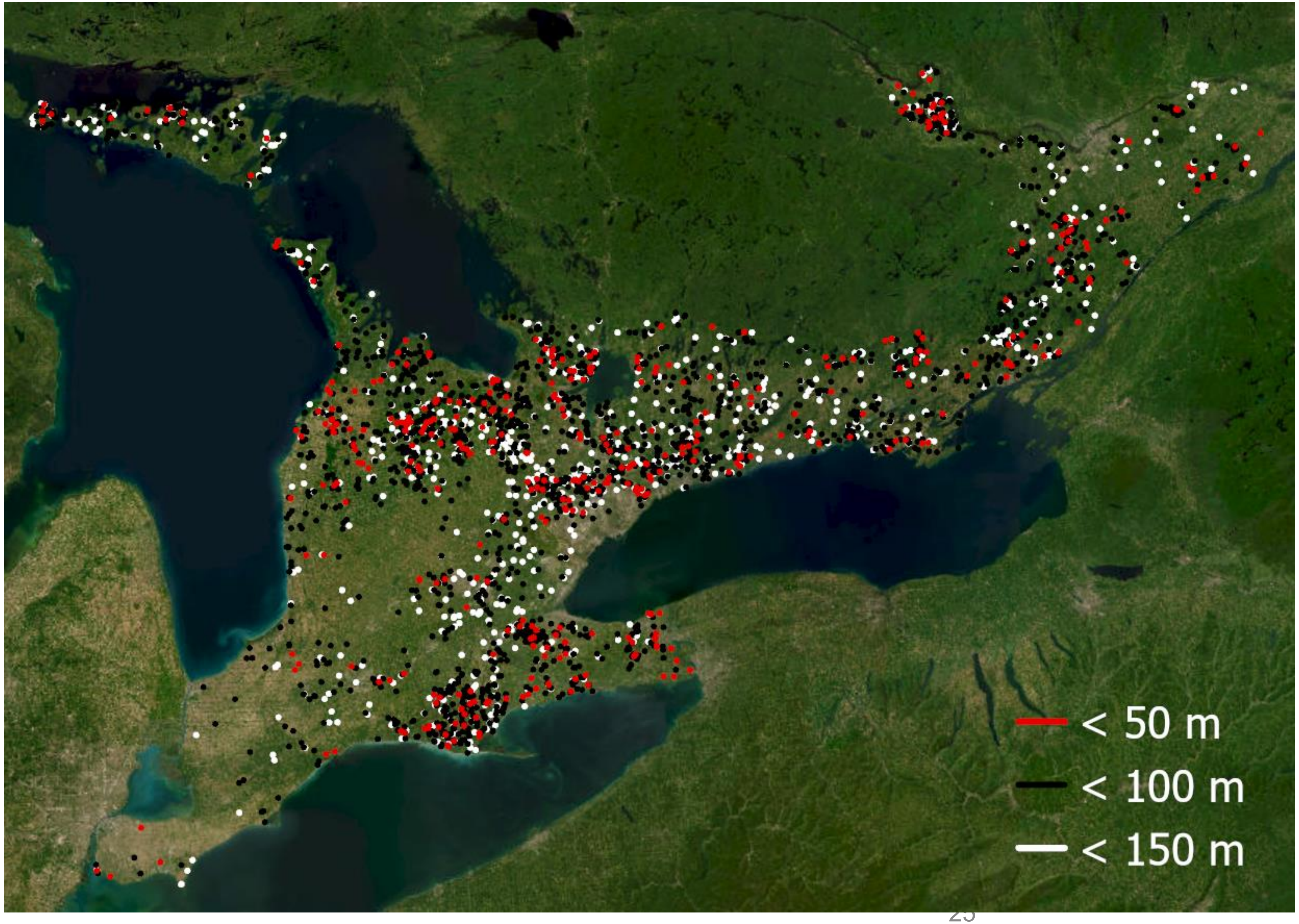


Other Barriers

Road crossing might be largely public, but there are many ponds on private land.

Selection criteria:
UCA < 50 km2
Confluence type = outlet
Virtual reach length:

<50m = 422 ponds
<100m = 2630 ponds
<150m = 3635 ponds



Other methods: using lidar enforced hydrology

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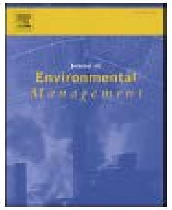


A machine learning approach to identify barriers in stream networks demonstrates high prevalence of unmapped riverine dams

Brian P. Buchanan[a,*], Suresh A. Sethi[b], Scott Cuppett[c], Megan Lung[d], George Jackman[e], Liam Zarri[f], Ethan Duvall[f], Jeremy Dietrich[g], Patrick Sullivan[g], Alon Dominitz[h], Josephine A. Archibald[a], Alexander Flecker[f], Brian G. Rahm[i]

- Unmapped dams were prevalent throughout the two test watersheds. In fact, existing dam inventories underestimated the true number of dams by ~80–94%.
- Accounting for previously unmapped dams resulted in a 62–90% decrease in dendritic connectivity indices for migratory fishes.

Other methods: using lidar enforced hydrology

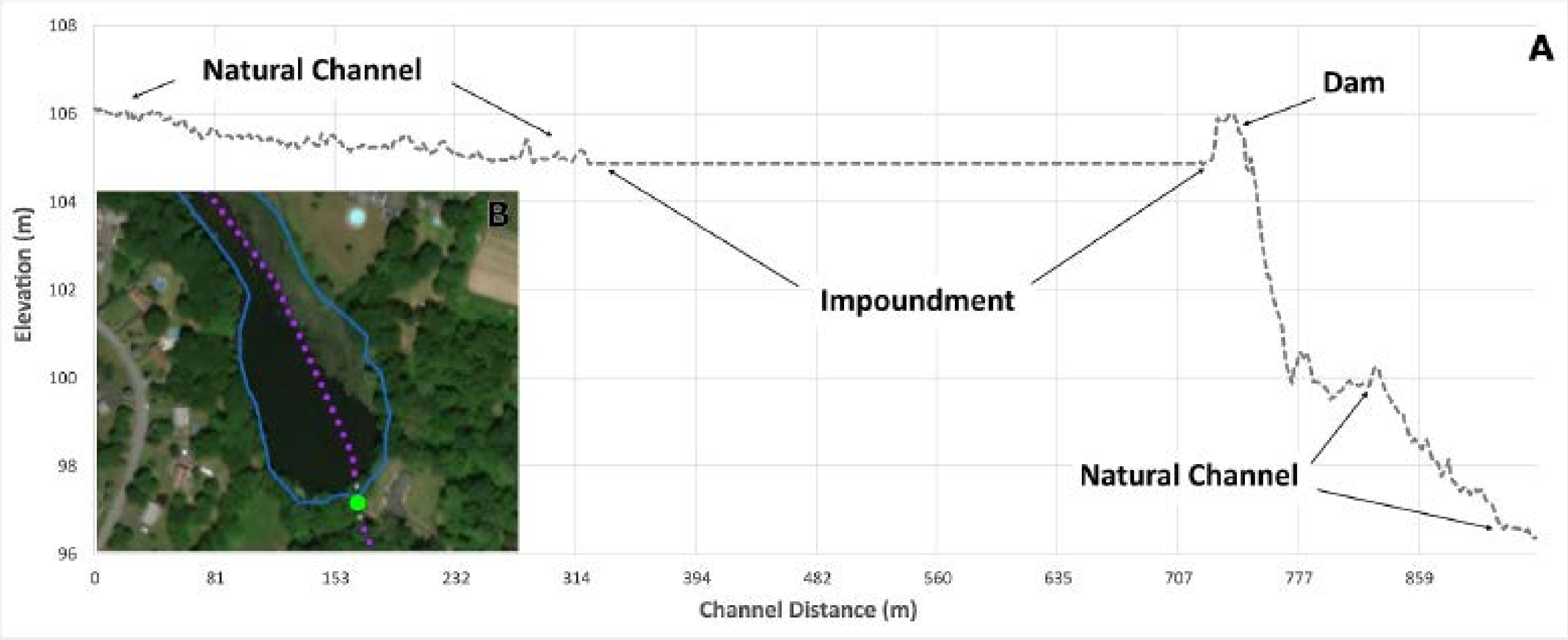
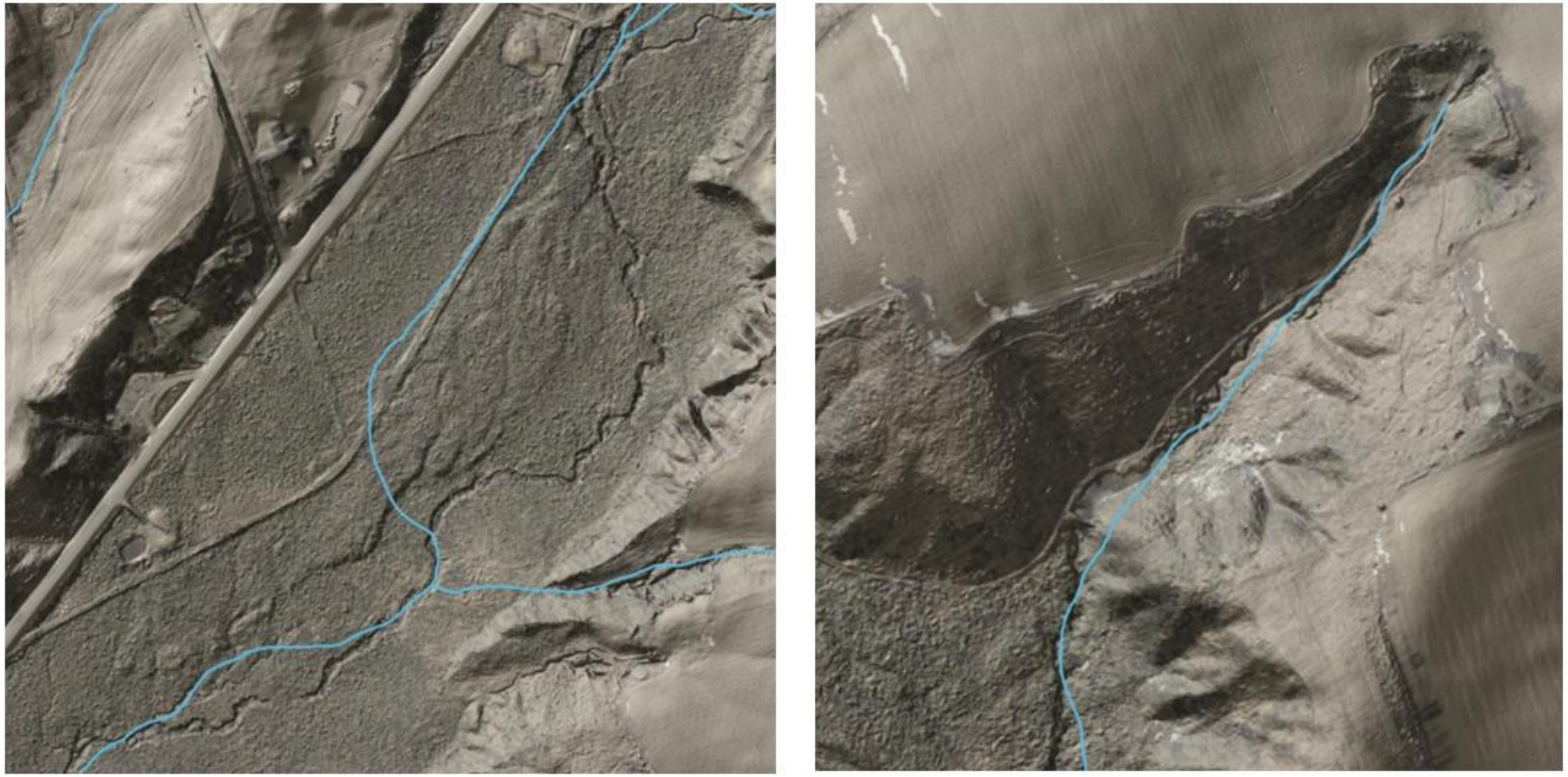


Fig. 2. A longitudinal profile reflecting the typical topographic signature of a dam in the Lattintown Creek study watershed (A). The river upstream the dam is characterized by a rugged and steep natural channel that transitions to a flat impoundment, followed by a pronounced dam structure and dramatic slope break immediately downstream. Finally, the channel returns to a rugged and steep natural channel as distance downstream the dam structure increases. The dam impoundment is clearly visible from aerial imagery (B); points represent the network sampling interval corresponding to channel distances from panel A; the green dot indicates the dam location; the blue polygon represents the National Hydrography Dataset Plus High Resolution Waterbody layer.

Current situation in Ontario

Figure 1. Two examples of southern Ontario Hydrographic Network stream channels (blue lines) shown in context of the hill shaded LIDAR elevation surface (0.5m resolution, hill shade z-factor = 3).

Notice the misalignment between the mapped lines and their valley bottoms even in areas of high topographic relief.



Current situation in Ontario

Figure 2. Example A) shows a southern Ontario Hydrographic Network stream channel misalignment (blue line) shown in context of the hill shaded LIDAR elevation surface.

Example B) shows how the misalignment with the valley bottom is most pronounced under tree cover, but the road crossing location is spot on.

The Plan

Visit many higher risk (red, orange, and yellow) crossings to evaluate whether the matrix is correct.

Requires an assessment method. Should be relatively quick. It will never be absolute.

Share maps and assessment method with others interested in helping. On-line portal.

Barrier-free watersheds – Parks

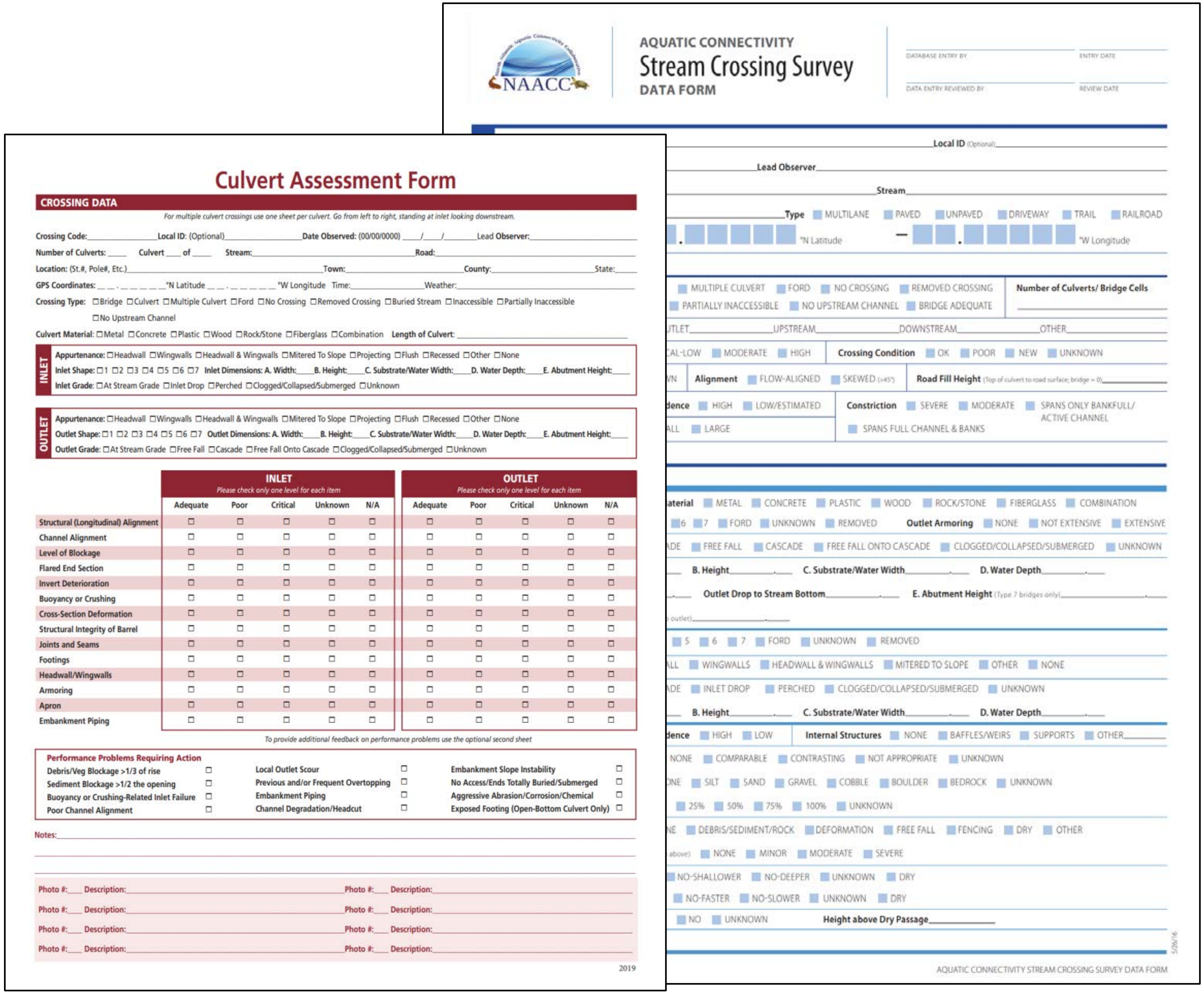
Closing thoughts

North Atlantic Aquatic Connectivity Collaborative

https://streamcontinuity.org/naacc/assessments/documents

SOUTHEAST AQUATIC RESOURCES PARTNERSHIP
SARP

https://southeastaquatics.net/



Summary

Species distributions and habitat suitability can be used to decide which barriers should stay and which could be removed.

While the probability of any particular culvert being impassable is low, the vast number of culverts means that they could pose a greater challenge to migratory fish than dams.

Field work and research is required. Online portal and standardized assessment could help collaborate efforts

The End