Jun 21st, 2:30 PM - 2:50 PM

Determining potential functional connectivity of fish species with various life history traits

Andrew T.M. Chin
University of Toronto

Marie-Josée Fortin
University of Toronto

Carol Godin
Fisheries and Oceans Canada

Roland Cormier
Helmholtz-Zentrum Geesthacht

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Andrew T.M. Chin[1],
Marie-Josée Fortin[1],
Carol Godin[2],
Roland Cormier[3]

[1] University of Toronto, Toronto, Canada
[2] Fisheries and Oceans Canada, Moncton, Canada
[3] Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

atm.chin@mail.utoronto.ca

UNIVERSITY OF TORONTO

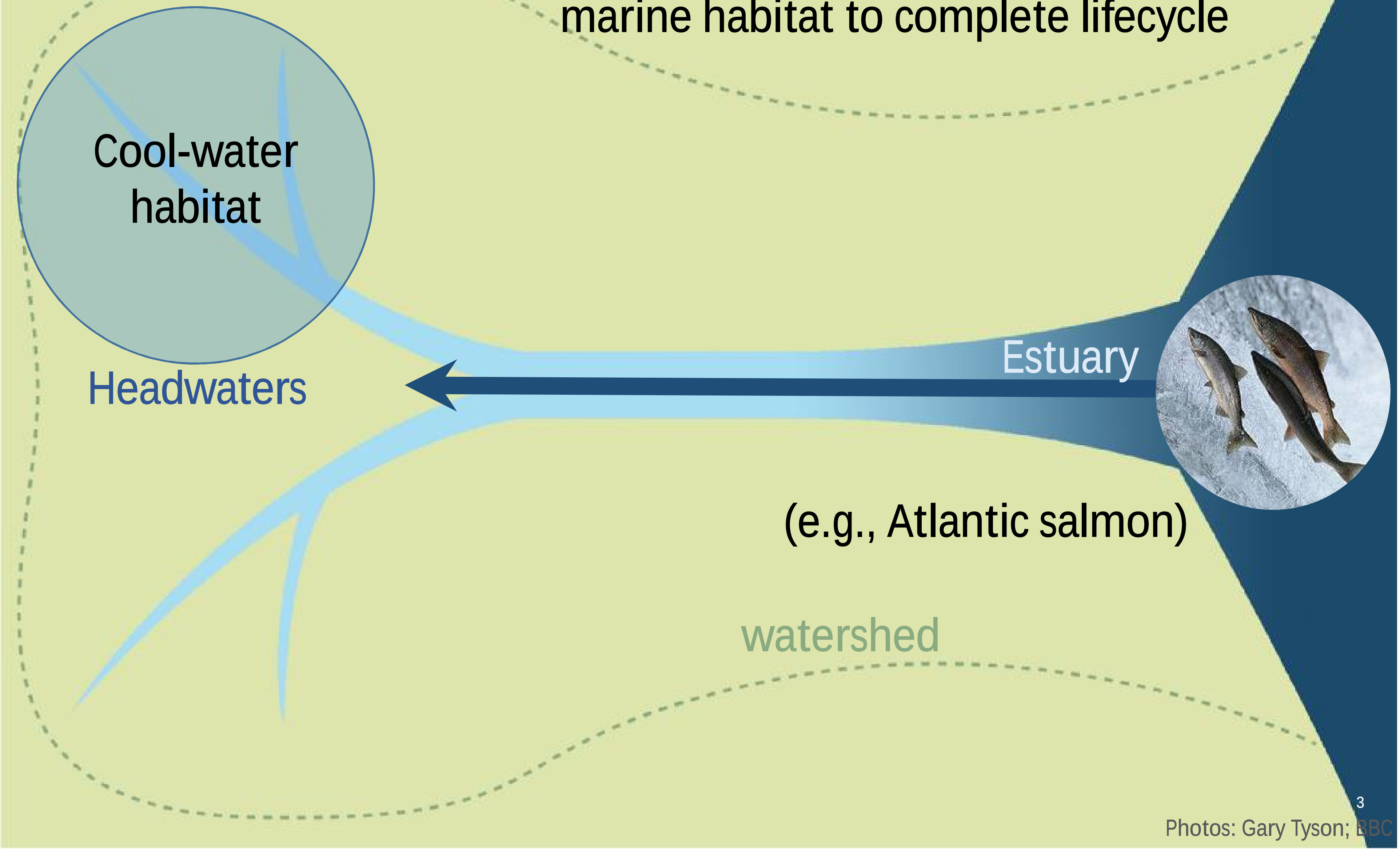
Photo: Andrew Chin

Stream Fragmentation

Intro

Migratory Fish

Diadromous species require both freshwater and marine habitat to complete lifecycle

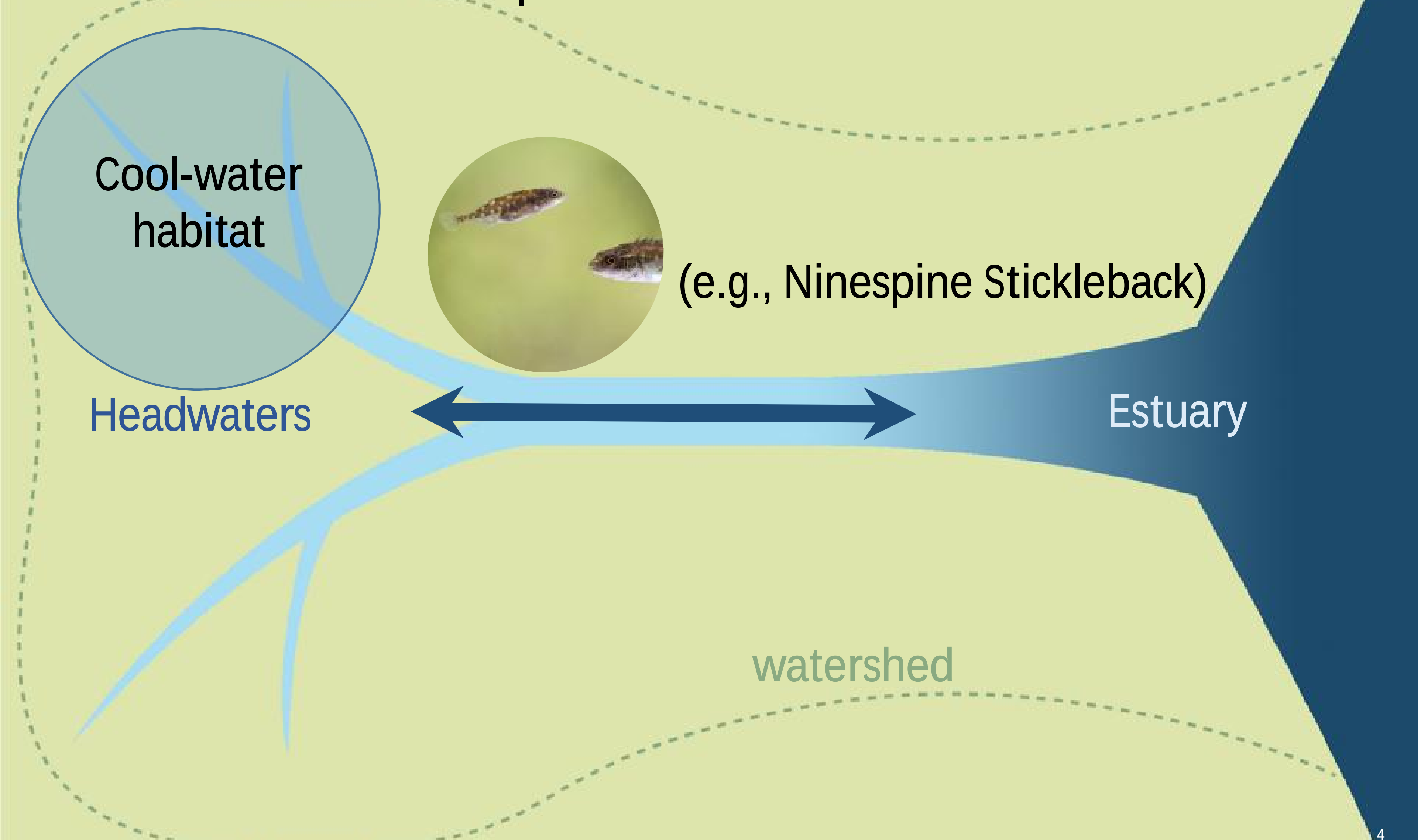


Photos: Gary Tyson; BBC

Intro

Non-Migratory Fish

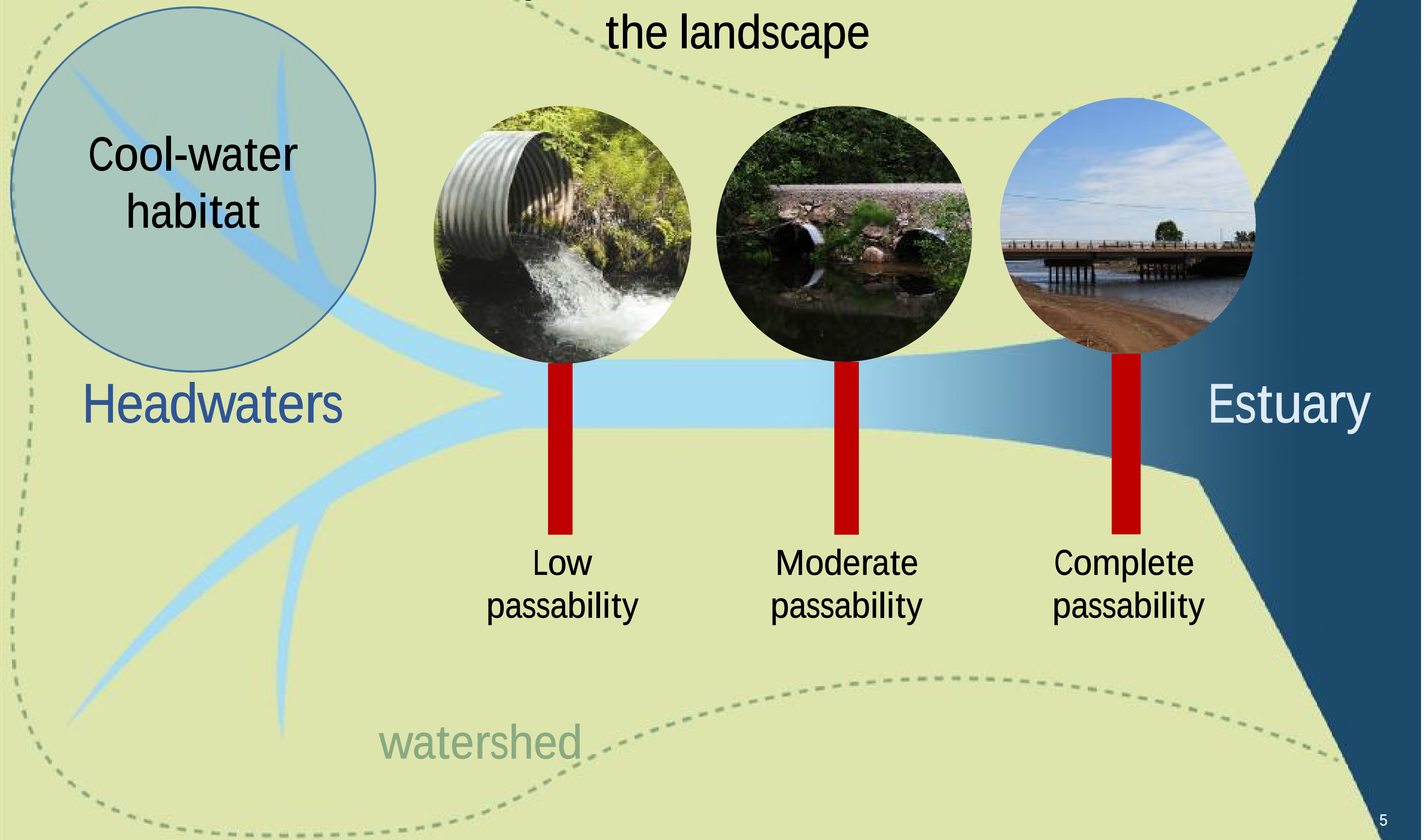
Non-diadromous species remain in freshwater



Photos: Gary Tyson; BBC

Stream Fragmentation and Connectivity

Functional Connectivity species ability to disperse through the landscape

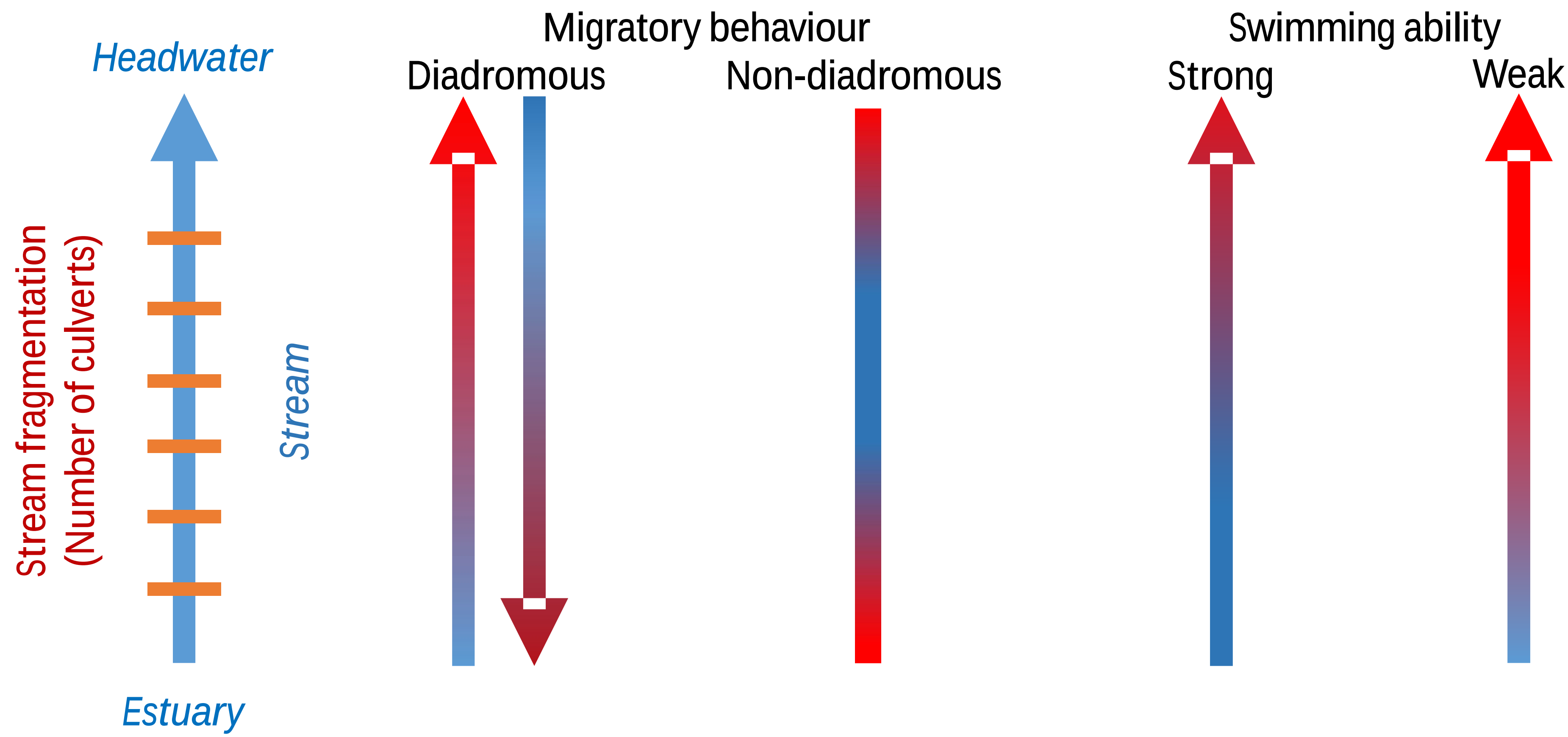


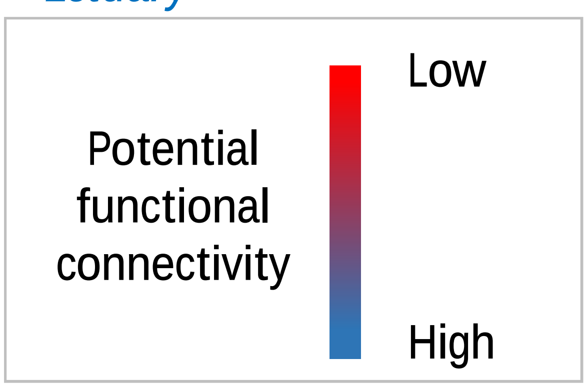
Photos: Andrew Chin

Question

Do culverts differently affect the potential functional connectivity of diadromous and non-diadromous species?

Hypothesis





Weak swimming diadromous species are most adversely affected by stream fragmentation

Methods

Study Area

Fisheries and Oceans Canada
Located culverts upstream from mouth of estuaries (2006-2008)

Culverts surveyed

- Length
- Diameter
- Slope
- Drop height
- Material

25 species in 3 watersheds

Methods

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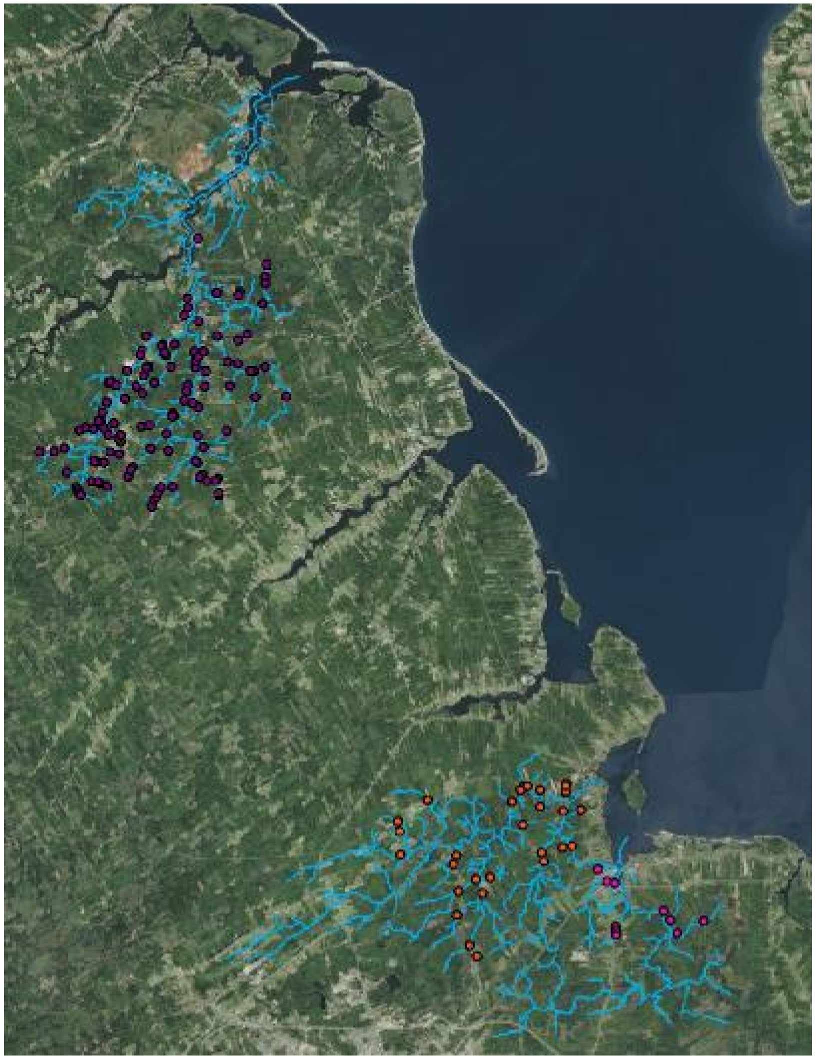
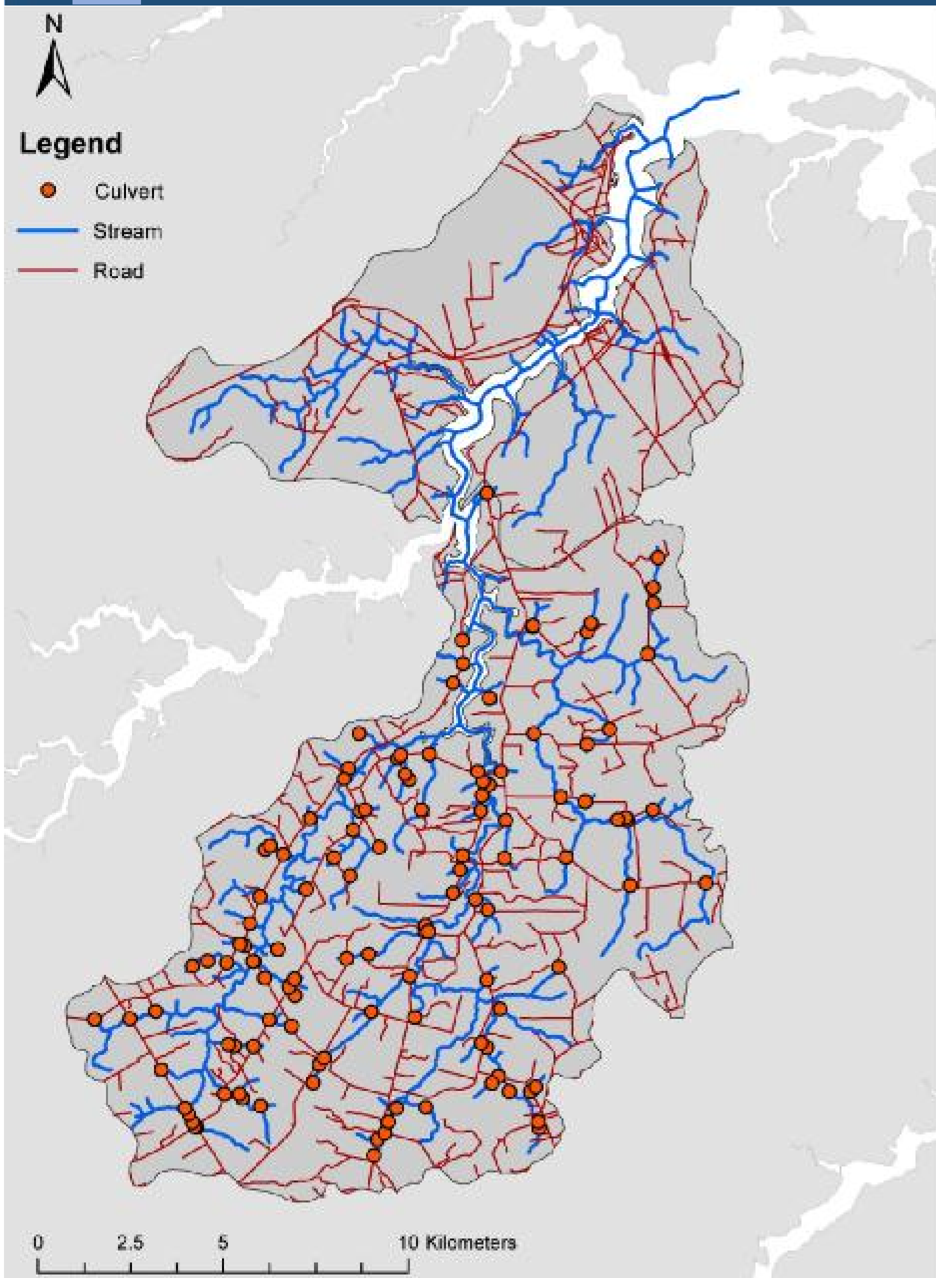
25 species in 3 watersheds



Richibucto estuary

Methods

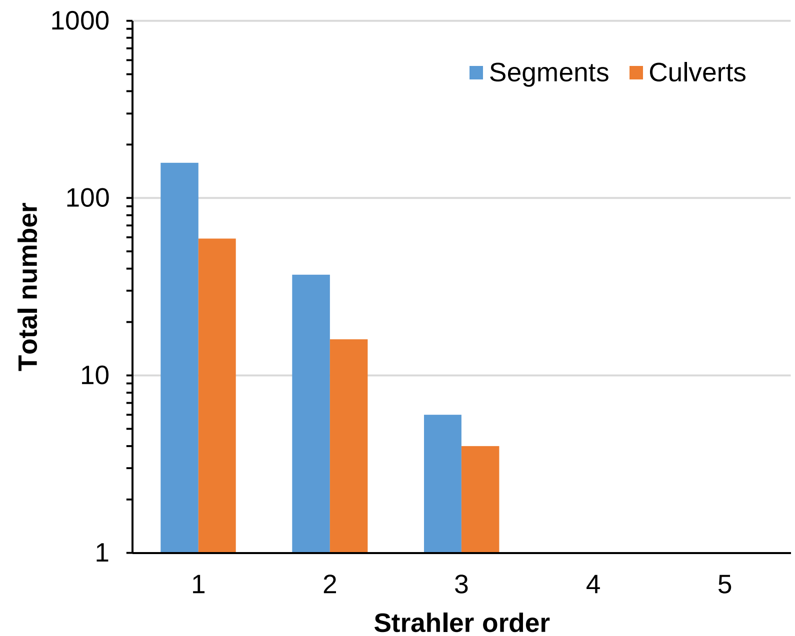
Study Area: Richibucto



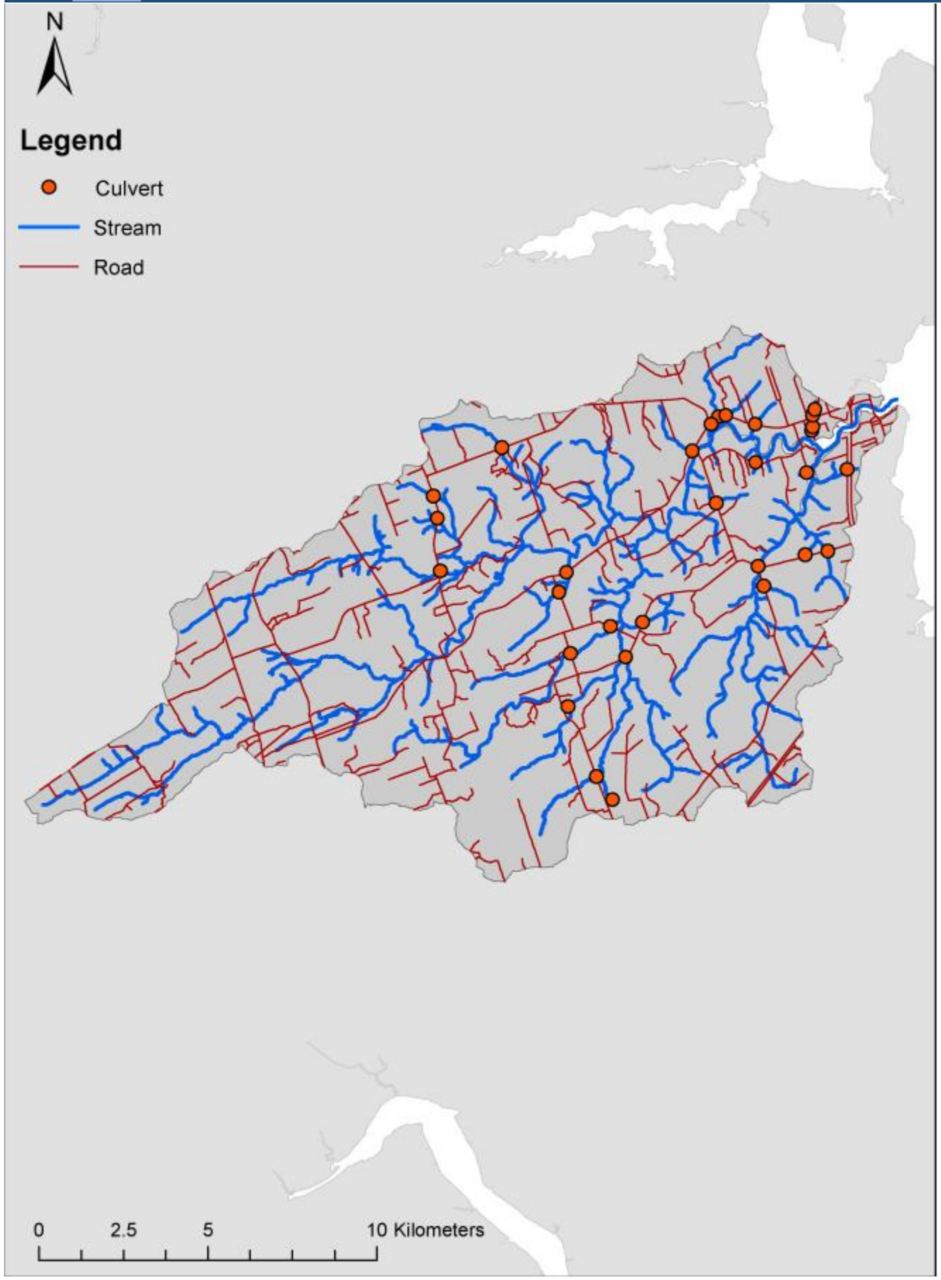
Richibucto (119 culverts)

198 km^2

143 road crossings
= 83.2% culverts



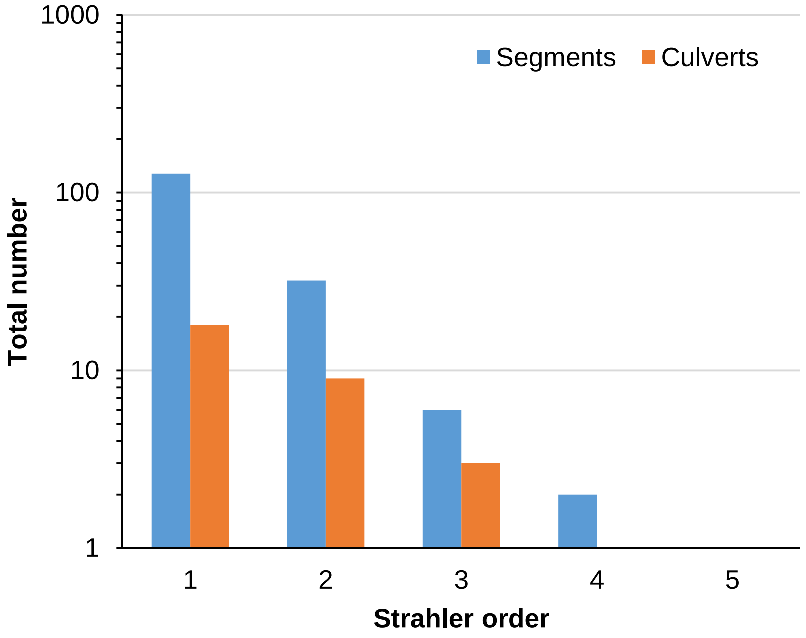
Study Area: Shediac



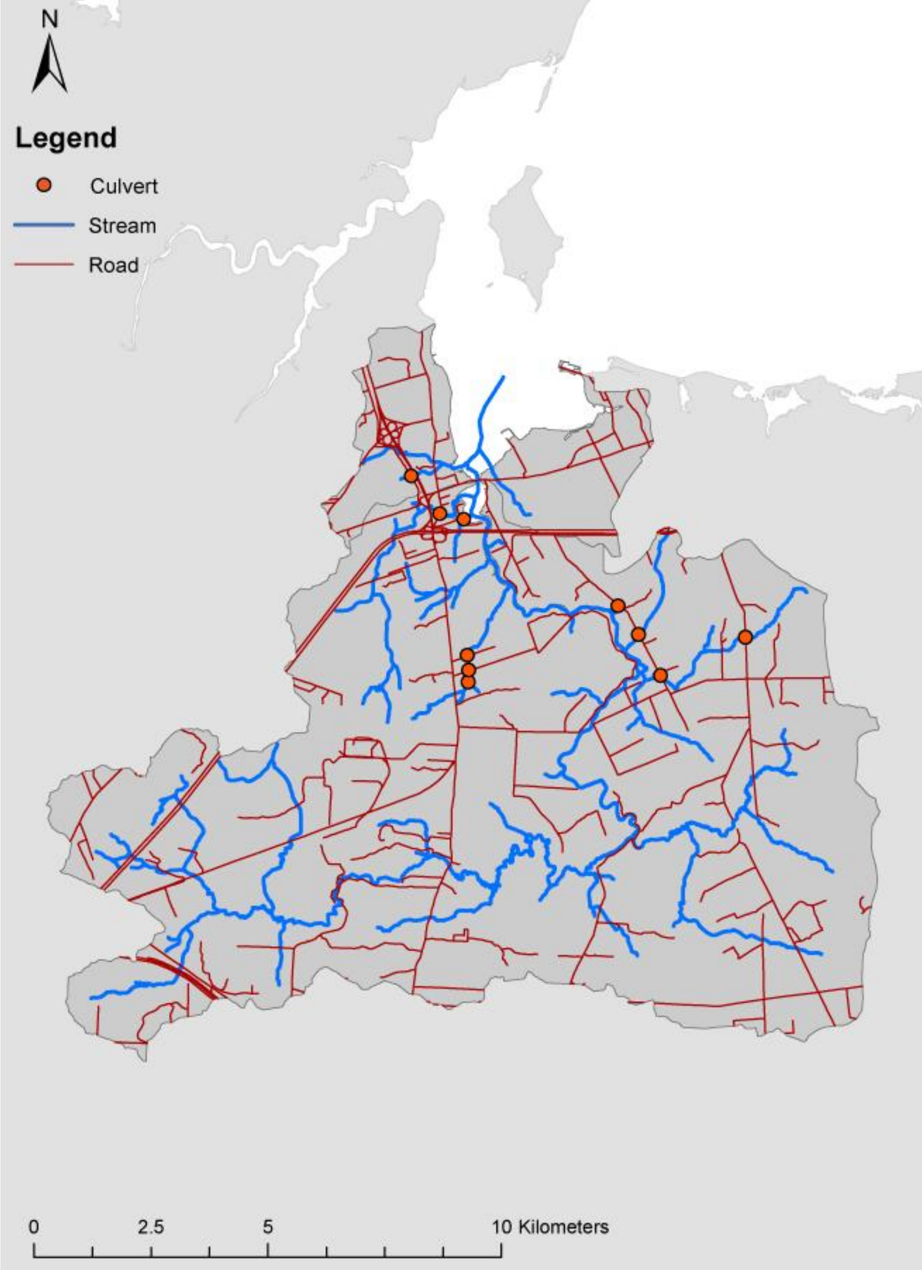
Shediac (30 culverts)

221 km^2

107 road crossings
= 28.0% culverts



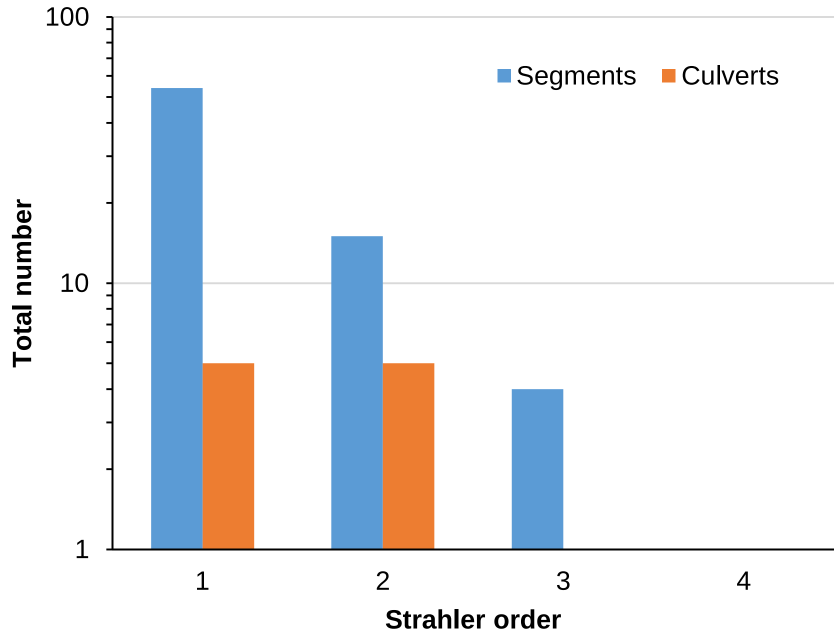
Study Area: Scoudouc



Scoudouc (10 culverts)

144 km^2

71 road crossings
= 14.1% culverts



Methods

Morphometrics

Use morphological traits to imply the swimming strength

Adult fish length

Total length

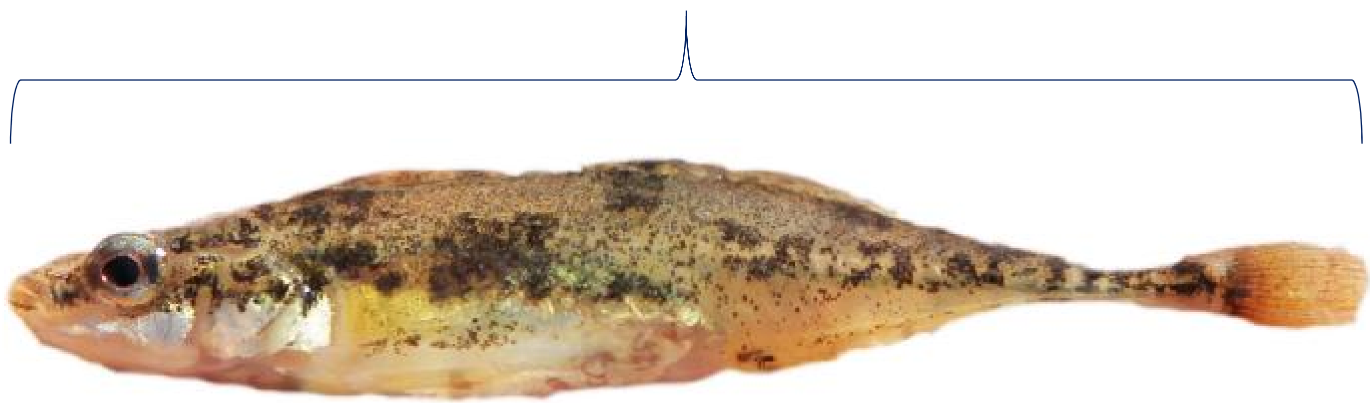


Photo: Andrew Chin

Swimming Strength

Stronger Swimmer = Higher Connectivity

- Rainbow Smelt*
- Atlantic Tomcod
- Alewife*
- Striped Bass*
- American Shad*
- Brook Trout*
- Atlantic Salmon*
- White Perch

- Banded Killifish
- Central Mudminnow
- Mummichog
- Pearl Dace
- Common Shiner
- Lake Chub
- Creek Chub
- American Eel*
- Sea Lamprey*

Weaker Swimmer = Lower Connectivity

- Fourspine Stickleback
- Northern Redbelly Dace
- Ninespine Stickleback*
- Fathead Minnow
- Finescale Dace
- Threespine Stickleback*
- Slimy Sculpin
- Blacknose Dace

*diadromous

Focal Species

NON-DIADROMOUS

Ninespine Stickleback
(Pungitius pungitius)

Alewife
(Alosa pseudoharengus)

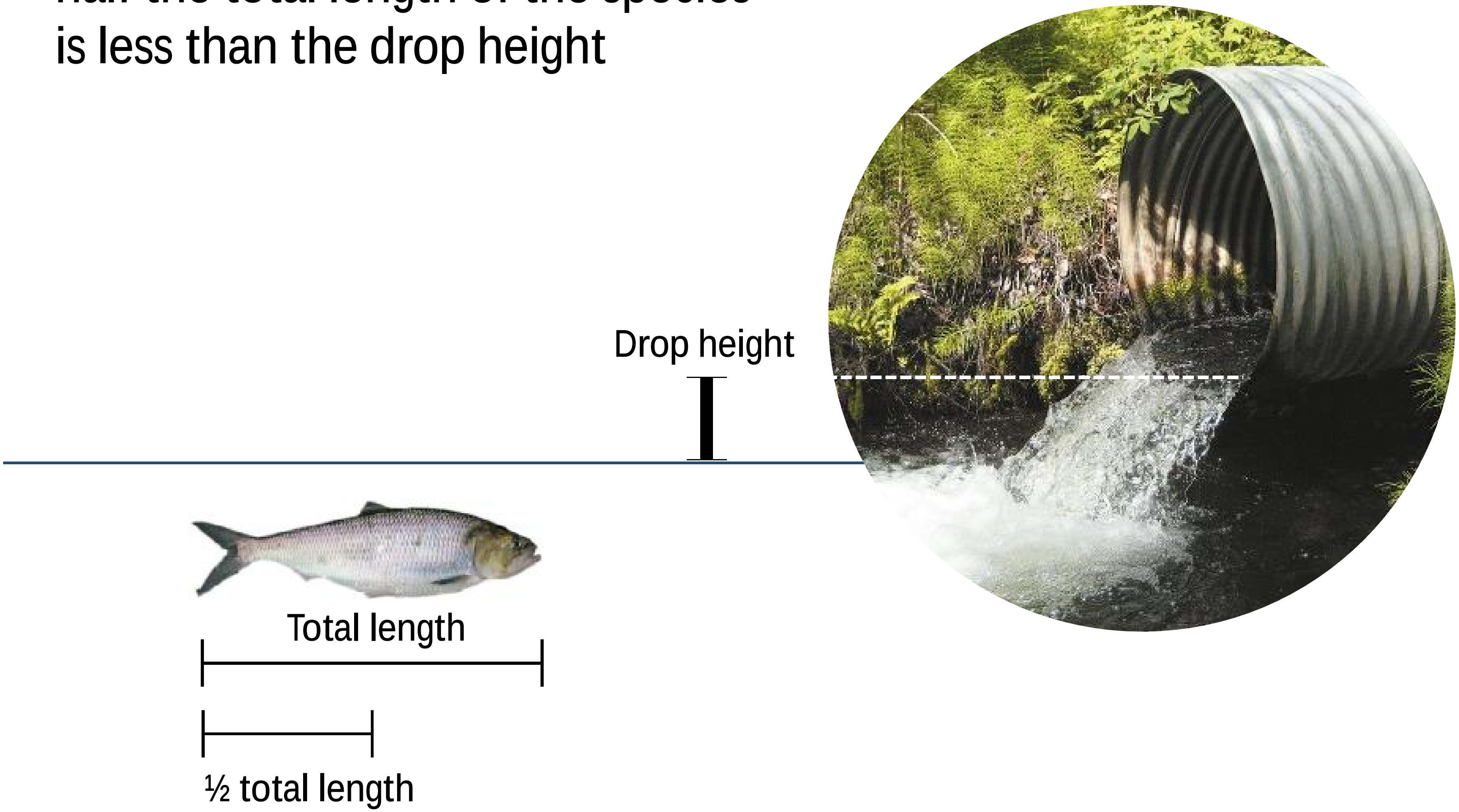
Fourspine Stickleback
(Apeltes quadracus)

American Shad
(Alosa sapidissima)

Methods

Passability

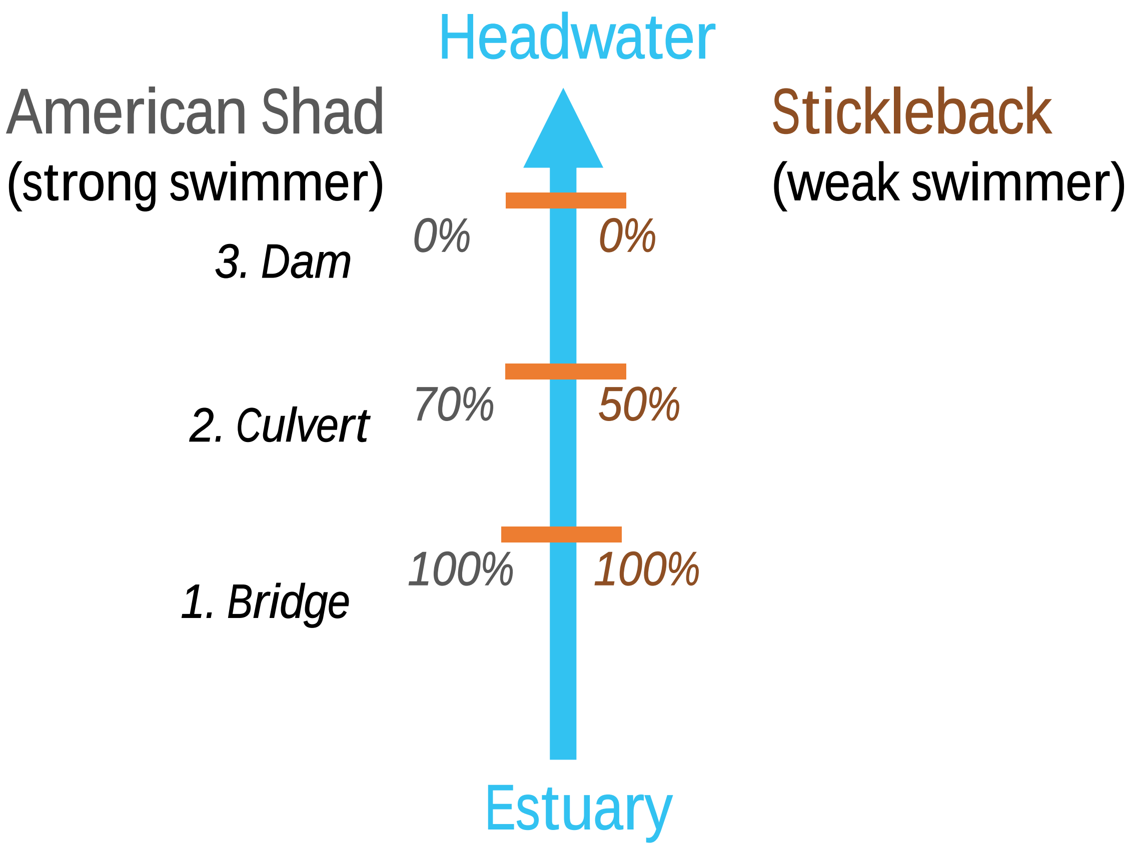
For each culvert, it is impassable if half the total length of the species is less than the drop height



Methods

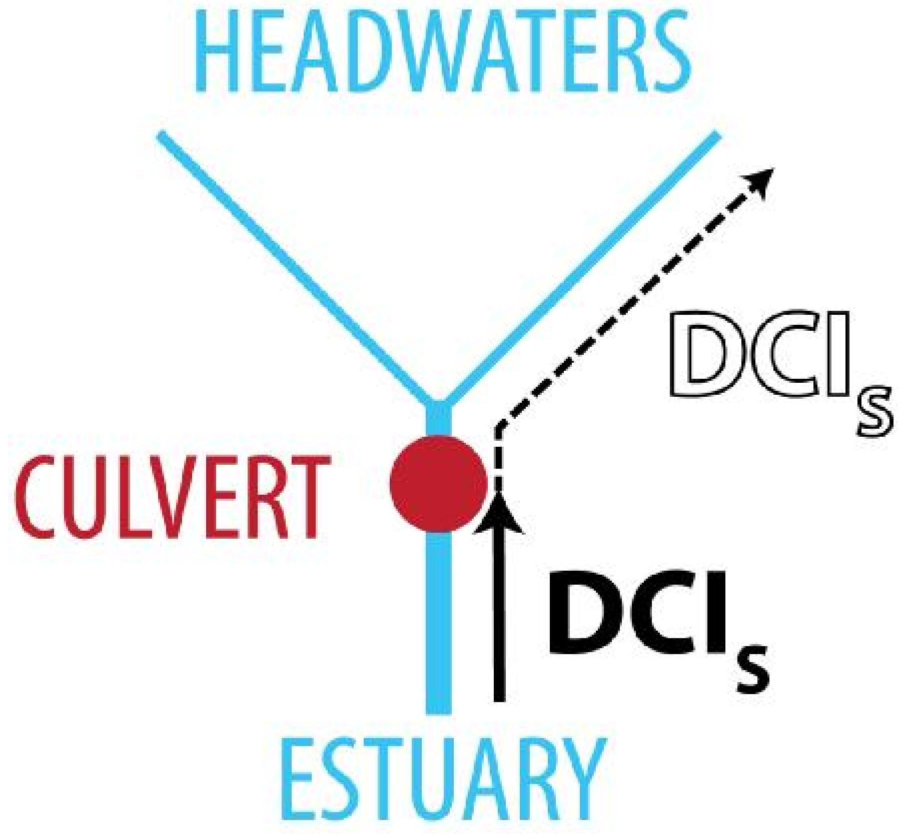
Connectivity Index

Each particular obstacle (e.g., road culvert, bridge, etc.) will have a different probability of passage

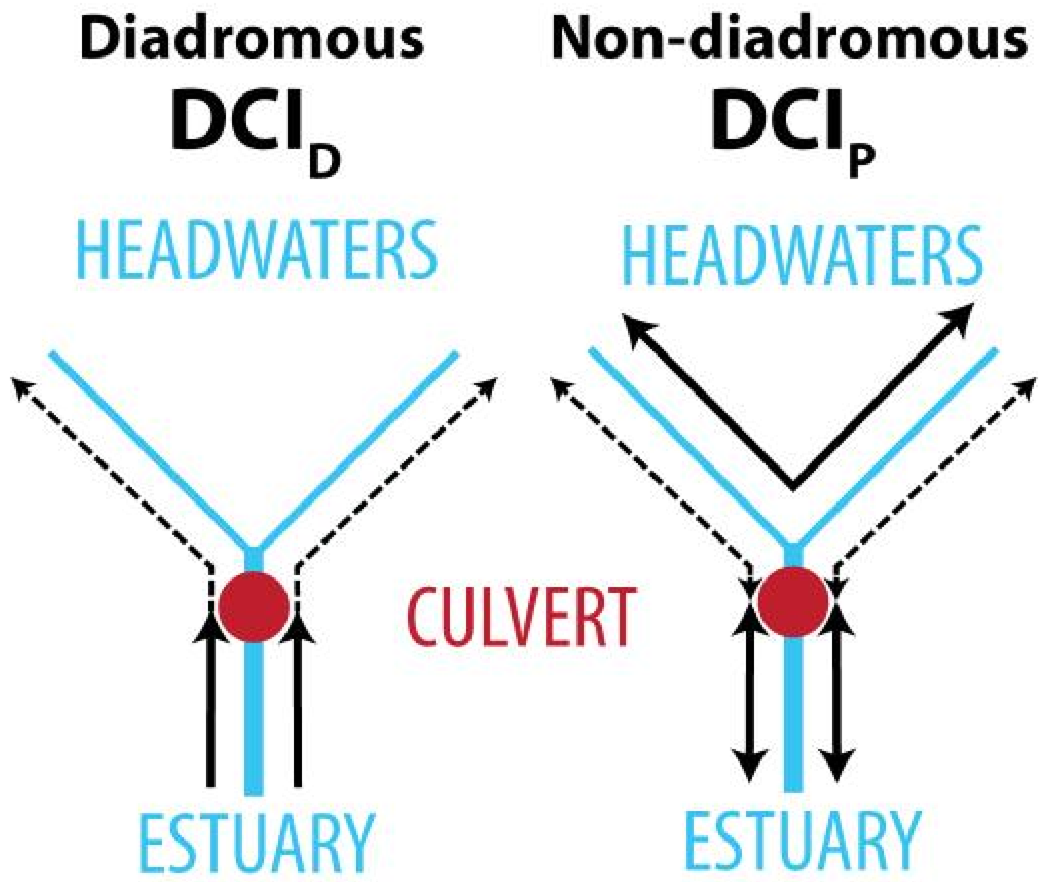


- Dendritic Connectivity Index (DCI) (Cote et al. 2009)

Potential Connectivity Index



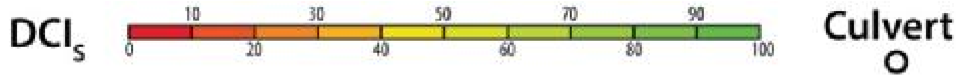
Potential Connectivity Index



High fragmentation

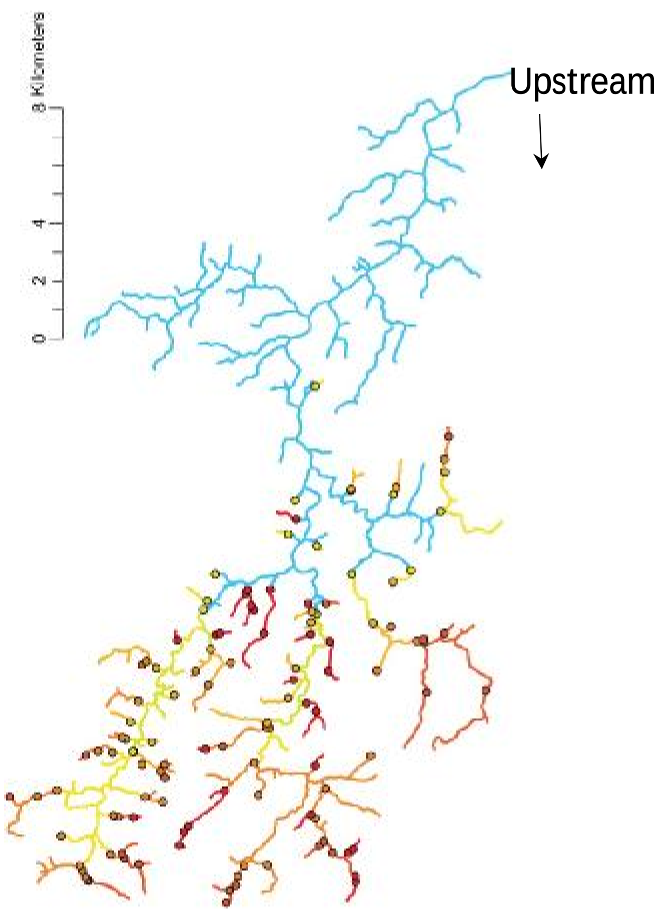
Results

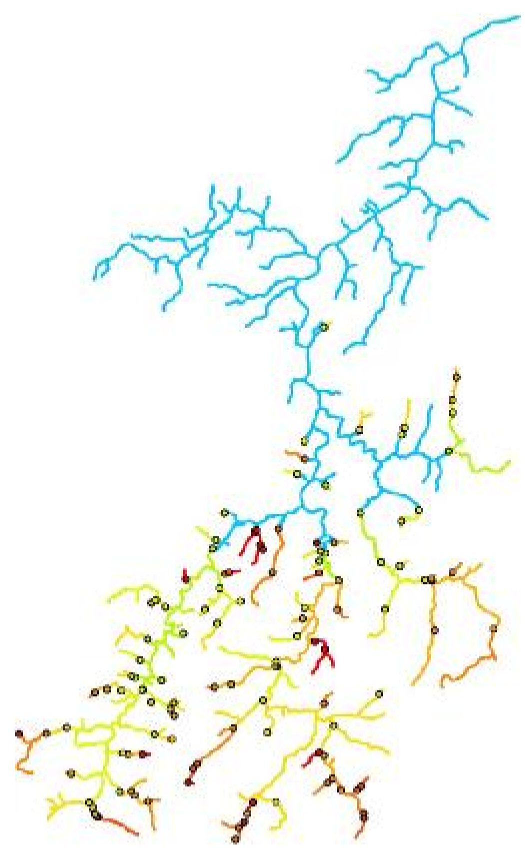
Richibucto (*n* = 119 culverts)



Alewife DCI_D = 69.69

American Shad DCI_D = 74.28





High fragmentation

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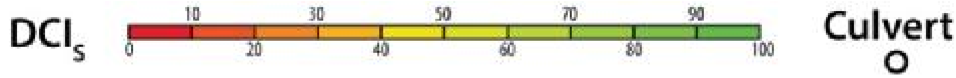
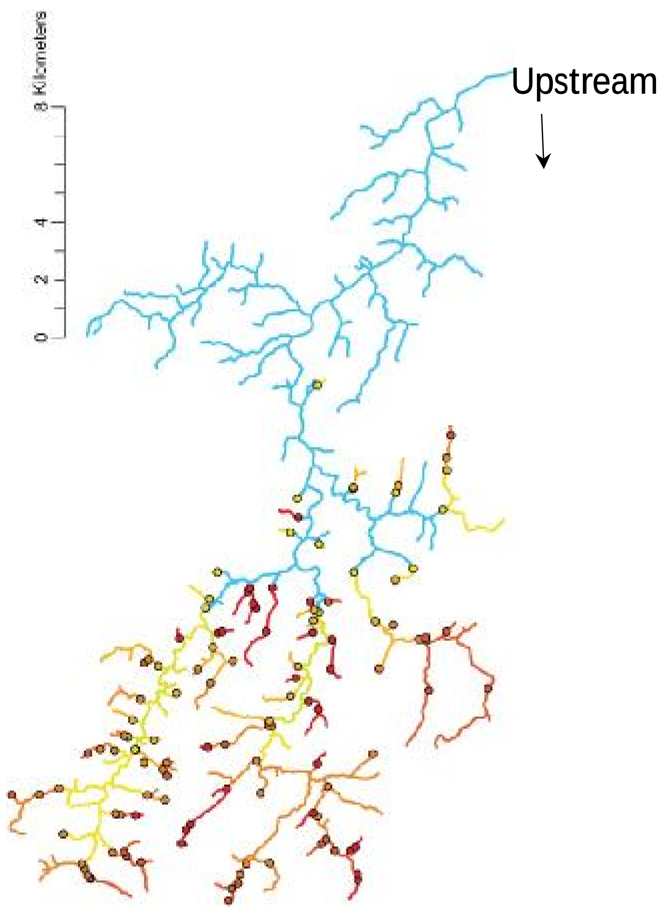
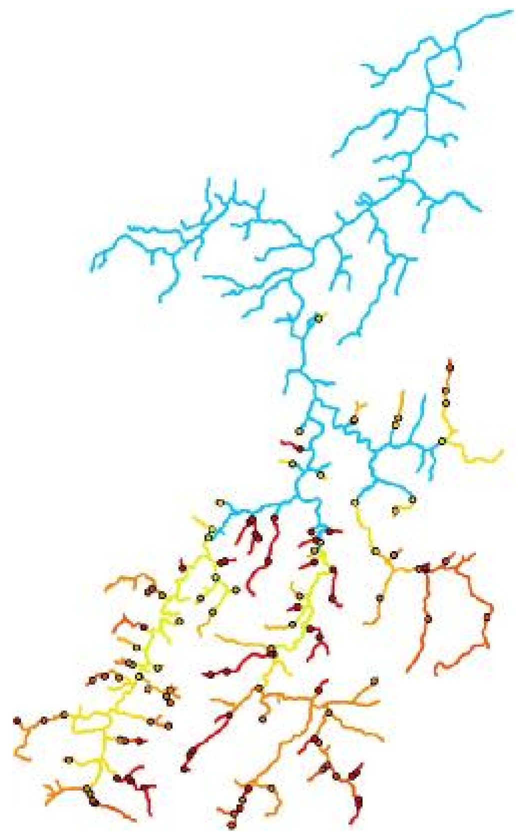


Ninespine Stickleback DCI$_P$ = 45.45



Fourspine Stickleback DCI$_D$ = 65.62

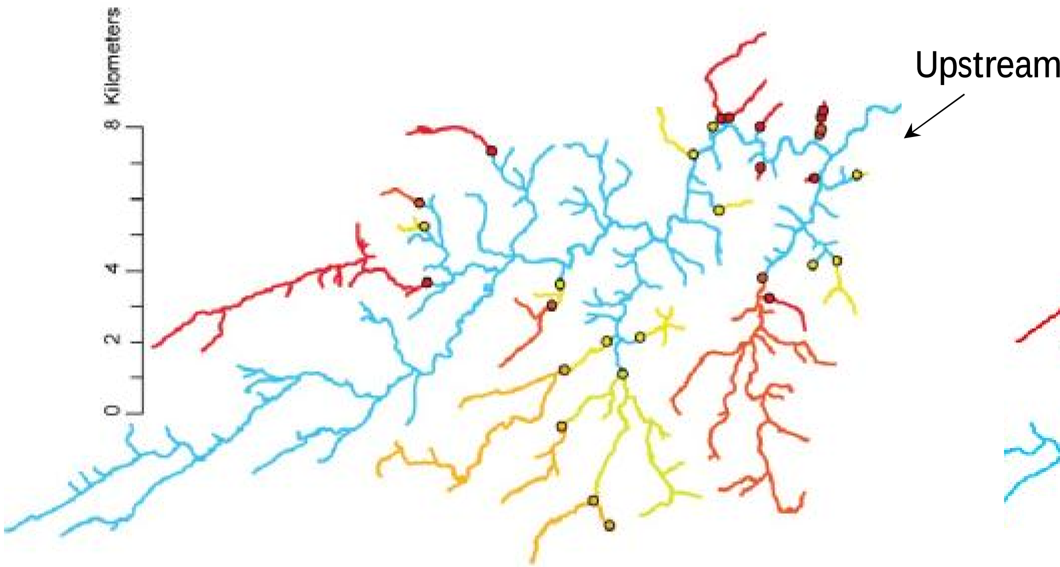


Results

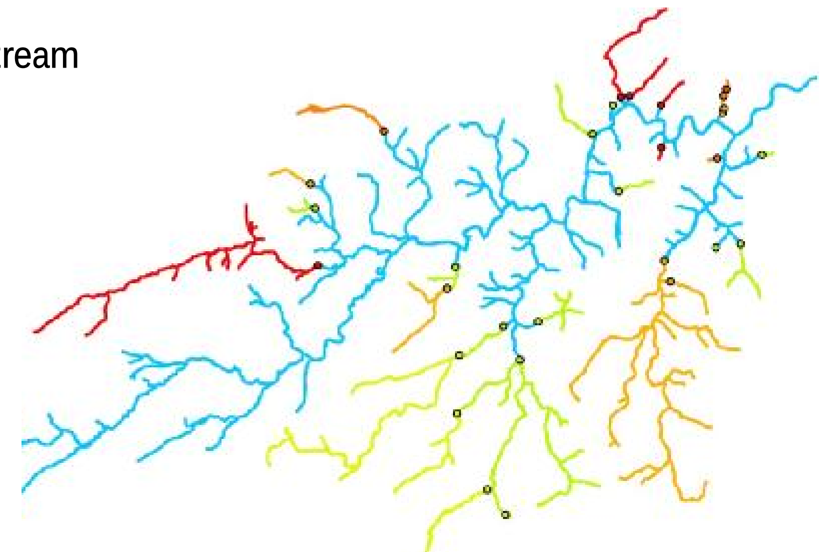
Moderate fragmentation

Shediac (*n* = 30 culverts)

Alewife DCI$_D$ = 69.69



American Shad DCI$_D$ = 75.18



Moderate fragmentation

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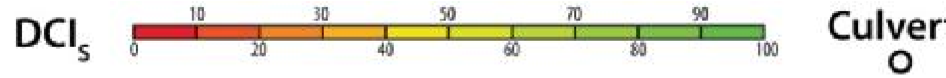
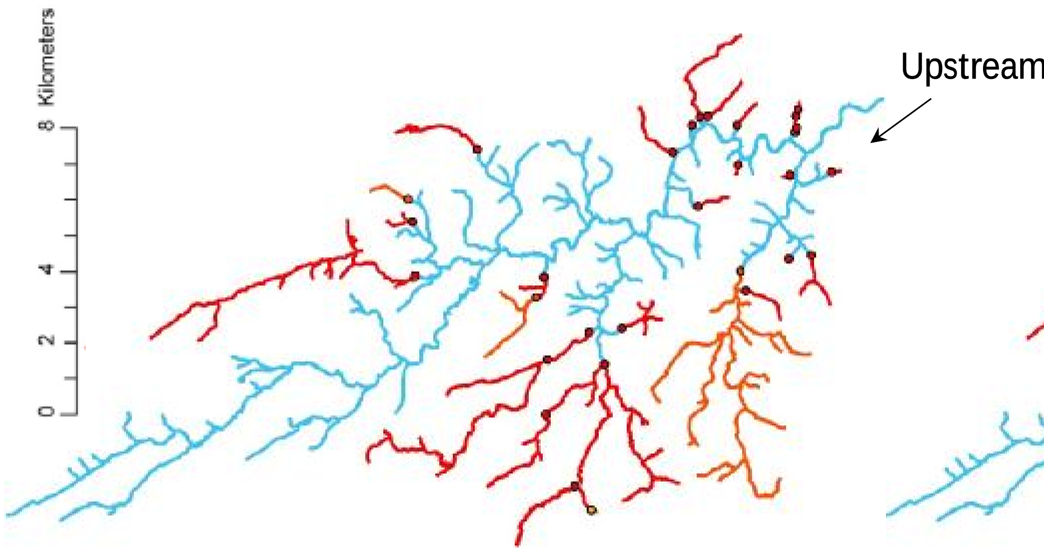
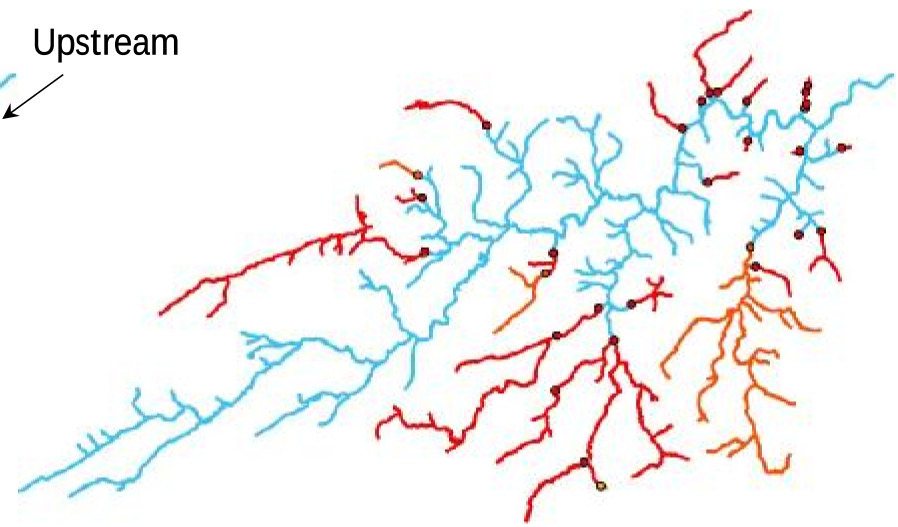


Ninespine Stickleback DCI$_P$ = 47.00

Fourspine Stickleback DCI$_D$ = 66.54

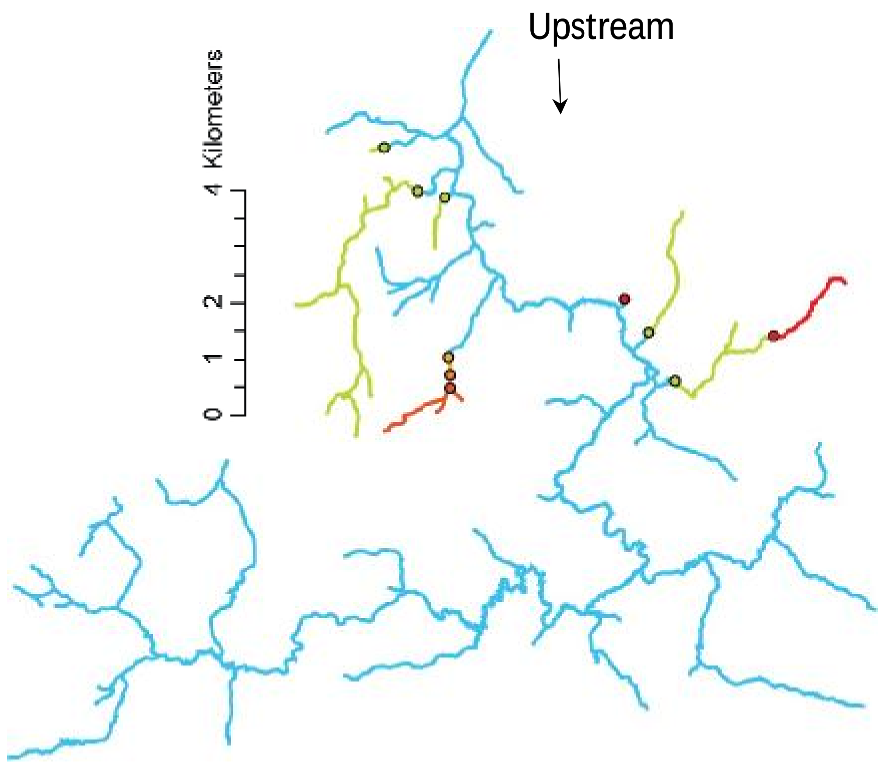




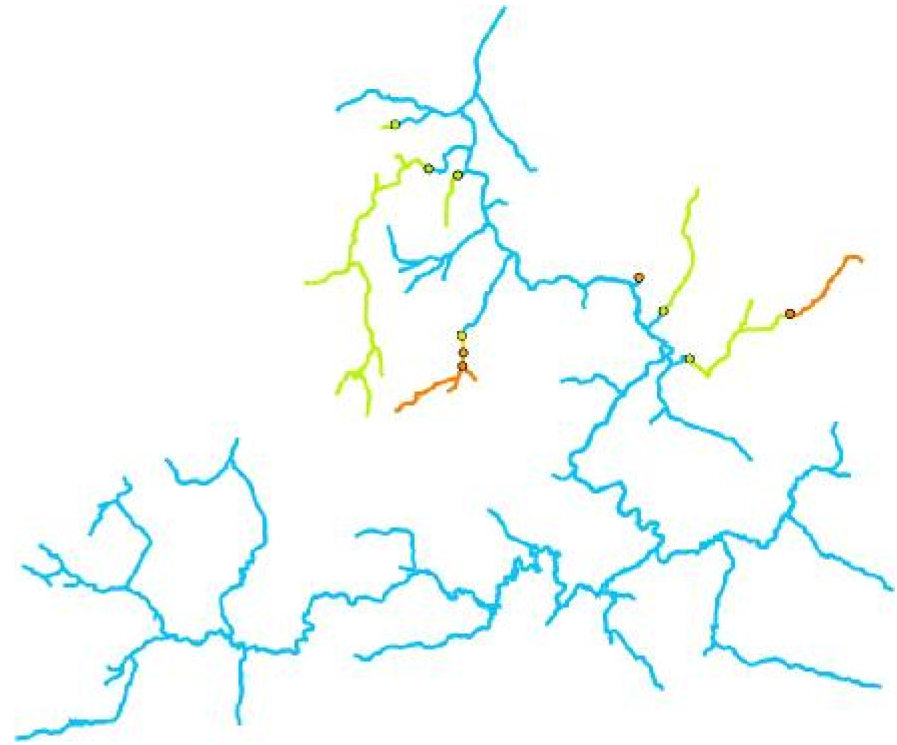
Low fragmentation

Scoudouc (*n* = 10 culverts)

Alewife DCI$_D$ = 92.70



American Shad DCI$_D$ = 93.22

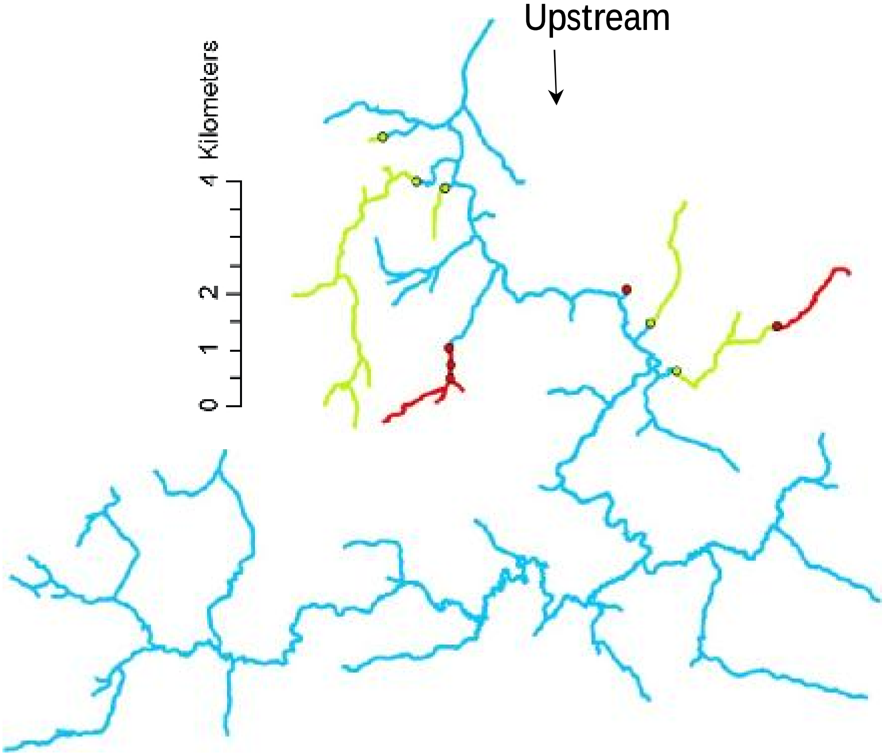


Results

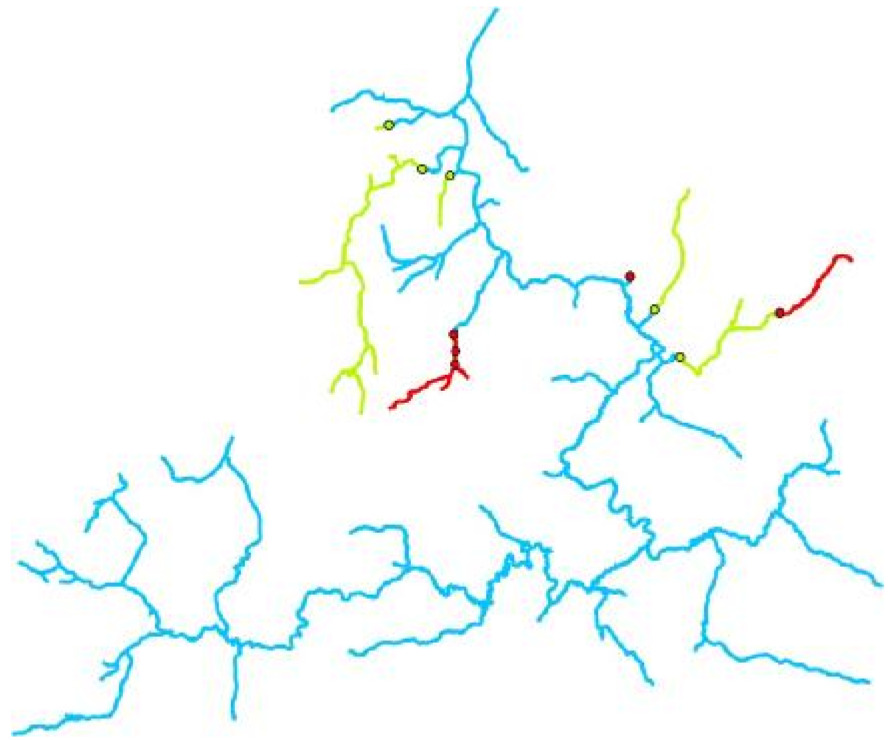
Low fragmentation

Shediac (*n* = 10 culverts)

Ninespine Stickleback $DCI_P = 85.37$



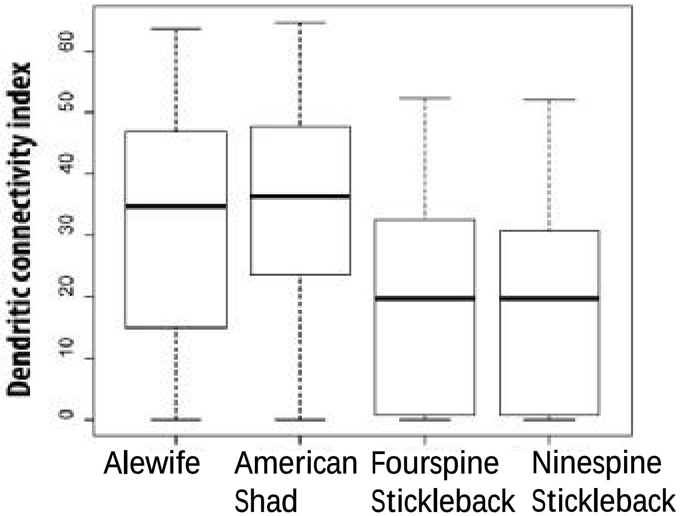
Fourspine Stickleback $DCI_D = 92.17$



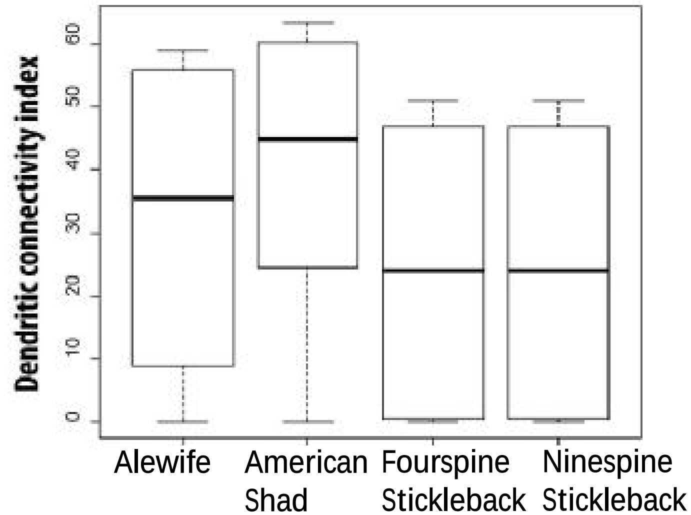
Results

Connectivity within streams

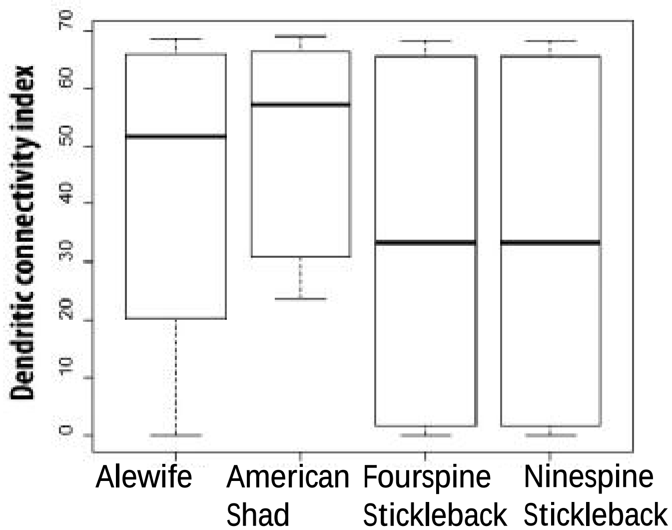
Richibucto
(n = 119 culverts)



Shediac
(n = 30 culverts)



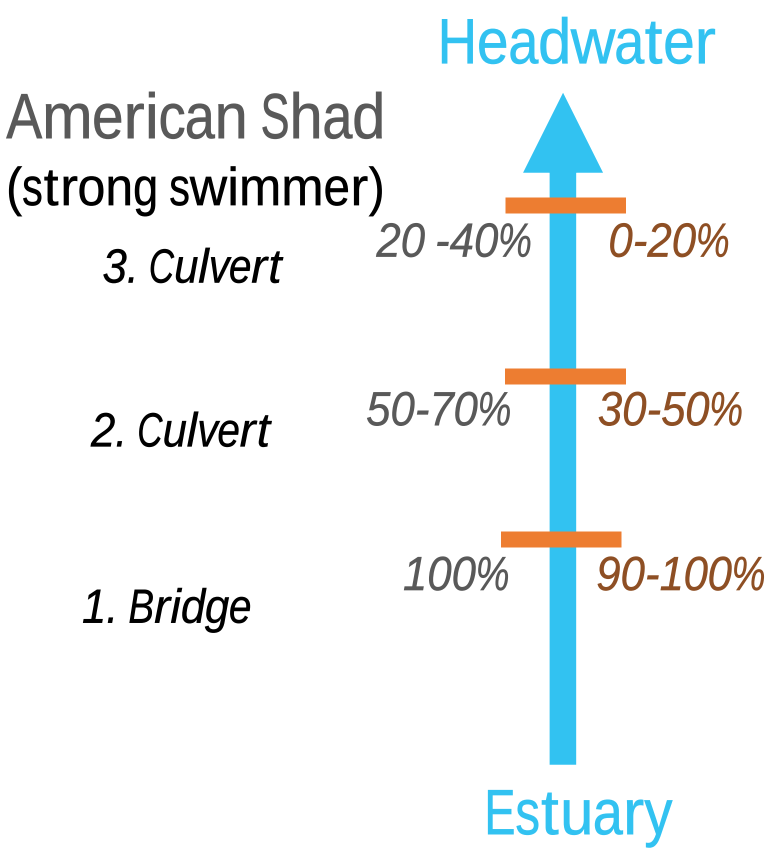
Scoudouc
(n = 10 culverts)



Sensitivity Analysis

Varying cost values for obstacles

(Rayfield et al., 2010)



Sensitivity analysis of fish passage:

- species traits
- culvert features

Significance

- Morphological trait-based analysis is a surrogate for functional connectivity
- Species-based approach is necessary to consider for functional connectivity and species persistence in stream networks
- Sensitivity analysis of passage will provide insights on which combination of species traits and culvert features affect potential functional connectivity
- Findings will inform policy and management

Acknowledgements

Supervisor
Marie-Josée Fortin
PhD Committee
Donald Jackson
Keith Somers

Fortin's LE Lab

Jackson Lab

Ecorisk
Roland Cormier

Fisheries Oceans Canada
Carole Godin

CNAES

NSERC Canadian Network for Aquatic Ecosystem Services

NSERC CRSNG

UNIVERSITY OF TORONTO

Email:
atm.chin@mail.utoronto.ca




Potential Connectivity Index

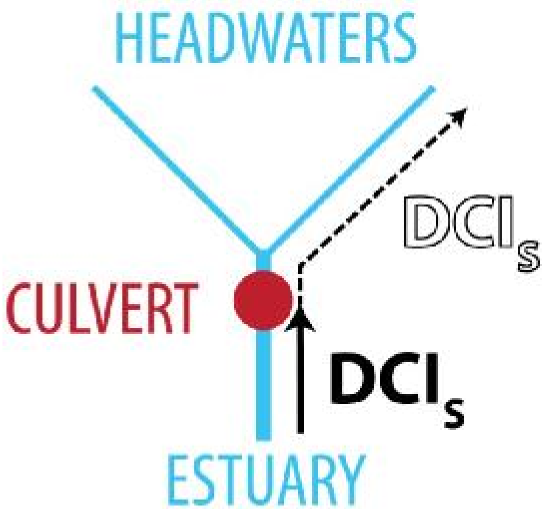
$$c_{ij} = \prod_{m=1}^{M} p_m^u p_m^d$$

C_{ij} : connectivity

M : number of barriers

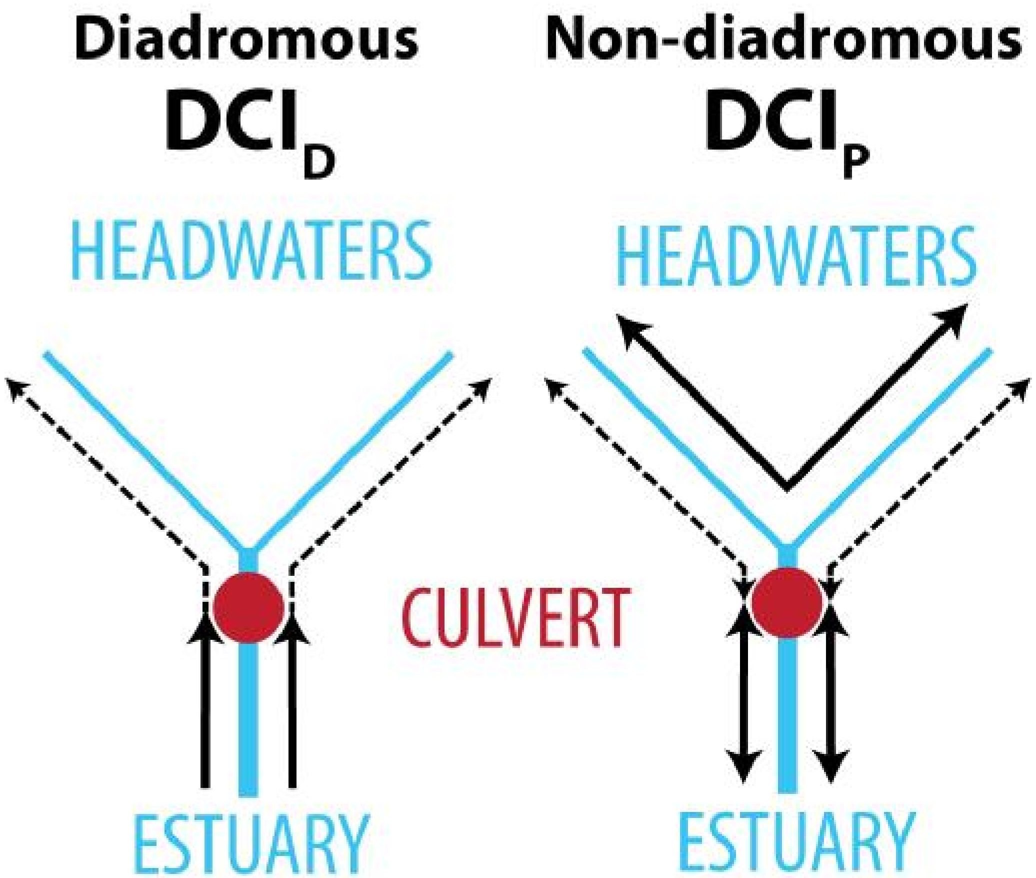
p_m^u : upstream passability

p_m^u : downstream passability



Potential Connectivity Index

$$DCI_D = \sum_{i=1}^{n} c_{ij} \frac{l_i}{L} \times 100 \qquad DCI_P = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} \frac{l_i l_j}{L\,L} \times 100$$



C_{ij} : connectivity between segment *i* and *j*

L : total length of all segments

l : length of segment between *i* and