The Effects of Road Culverts on Nekton in New England Salt Marshes: Implications for Tidal Restoration

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• **Decreased salinity**  
  (Roman et al. 1984; Burdick et al. 1999)

• **Colonization by invasive vegetation**  
  (Roman et al. 1984; Burdick et al. 1999)

• **Changes to infaunal communities**  
  (Fell et al. 1991)

• **Reduced habitat access and use by nekton**  
BENEFITS OF TIDAL RESTORATION

• Reestablishment of salt marsh vegetation
  (e.g. Roman et al. 1984, Barrett and Neiring 1993, Burdick et al. 1997)

• Increased soil salinity
  (Beefink 1979, Sincrope et al. 1990, Burdick et al. 1997)

• Colonization by macroinvertebrate and avifauna communities
  (Peck et al. 1994, Brawley et al. 1998)

• Restored habitat use by nekton
OBJECTIVES

1. Determine the effect of culverts on upstream nekton assemblages

2. Determine if culverts restrict the movements of the mummichog, Fundulus heteroclitus
FYKE NET SAMPLING SITES

Drake’s Island Marsh
Parson’s Creek
Awcomin Marsh
Bass Beach
Little River
Drakeside Road
Brown’s River
Reference

Culvert
- restricted
- restored

FYKE NET SAMPLING DESIGN
## RESULTS - NEKTON COMMUNITY

Contribution of each species to the total nekton community

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Reference (%)</th>
<th>Restoration (%)</th>
<th>Restricted (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alosa aestivalis</td>
<td>Blueback herring</td>
<td>—</td>
<td>5%</td>
<td>—</td>
</tr>
<tr>
<td>Anguilla rostrata</td>
<td>American eel</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Brevoortia tyrannus</td>
<td>Atlantic menhaden</td>
<td>2%</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Carcinus maenus</td>
<td>Green crab</td>
<td>10%</td>
<td>16%</td>
<td>1%</td>
</tr>
<tr>
<td>Crangon septemspinosa</td>
<td>Sand shrimp</td>
<td>—</td>
<td>26%</td>
<td>—</td>
</tr>
<tr>
<td>Cyprinodon variegatus</td>
<td>Sheepshead minnow</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>—</td>
</tr>
<tr>
<td>Fundulus heteroclitus</td>
<td>Mummichog</td>
<td>77%</td>
<td>32%</td>
<td>98%</td>
</tr>
<tr>
<td>Fundulus majalis</td>
<td>Striped killifish</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Hemigrapsus sanguineus</td>
<td>Asian shore crab</td>
<td>—</td>
<td>&lt;1%</td>
<td>—</td>
</tr>
<tr>
<td>Gasterosteus aculeatus</td>
<td>Threespine stickleback</td>
<td>—</td>
<td>&lt;1%</td>
<td>—</td>
</tr>
<tr>
<td>Menidia menidia</td>
<td>Atlantic silverside</td>
<td>9%</td>
<td>&lt;1%</td>
<td>—</td>
</tr>
<tr>
<td>Mugil curema</td>
<td>White mullet</td>
<td>&lt;1%</td>
<td>—</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Palaemonetes pugio</td>
<td>Daggerblade grass shrimp</td>
<td>1%</td>
<td>20%</td>
<td>3%</td>
</tr>
<tr>
<td>Peprilus triacanthus</td>
<td>Butterfish</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pungitius pungitius</td>
<td>Ninespine stickleback</td>
<td>—</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Pseudopleuronectes americanus</td>
<td>Winter flounder</td>
<td>&lt;1%</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Total number of species: 10

<table>
<thead>
<tr>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test for differences among sites</td>
</tr>
</tbody>
</table>

Pairwise comparisons between hydrology:

- Restricted versus reference: 1.000
- Restricted versus restored: 0.333
- Reference versus restored: 0.920
RESULTS - FISH DENSITY

(Repeated measures ANOVA)

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert presence/absence</td>
<td>F=0.045;</td>
<td>F=1.67;</td>
</tr>
<tr>
<td></td>
<td>p&lt;0.844</td>
<td>p&lt;0.253</td>
</tr>
<tr>
<td>Hydrology (restricted or restored)</td>
<td>F=0.009;</td>
<td>F=0.720;</td>
</tr>
<tr>
<td></td>
<td>p&lt;0.935</td>
<td>p&lt;0.444</td>
</tr>
</tbody>
</table>
**RESULTS - CRANGON SEPTEMSPINOSA DENSITY**

<table>
<thead>
<tr>
<th>Location</th>
<th>Restricted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awcomin</td>
<td>0.00</td>
</tr>
<tr>
<td>Bass Beach</td>
<td>0.00</td>
</tr>
<tr>
<td>Brown's River</td>
<td>0.10</td>
</tr>
<tr>
<td>Drake's Island</td>
<td>0.15</td>
</tr>
<tr>
<td>Drakeside Road</td>
<td>0.10</td>
</tr>
<tr>
<td>Little River</td>
<td>0.05</td>
</tr>
</tbody>
</table>

(Number of *C. septemspinosa* per m²)

(Repeated measures ANOVA) 2003

Culvert presence/absence: F=11.4; p<0.020
CONCLUSIONS - DRAKE'S ISLAND MARSH

Photo: http://maps.google.com; 2 Nov 2010
Fish communities upstream of tidally restricted and restored culverts are similar to communities in reference systems.

Culverts may inhibit sand shrimp (Crangon septemspinosa) access to upstream areas.

Ponds upstream of undersized culverts may retain fish at all tidal stages, deterring downstream movement.
OBJECTIVES

1. Determine the effect of culverts on upstream nekton communities

2. Determine if culverts restrict the movements of the mummichog, *Fundulus heteroclitus*
CROSSING SIZE

- Restricted
- Restored
- Reference

Crossing size

- Brown's River
- DIM Culvert
- Huckleberry Road
- Wentworth Road
- Drakeside Road
- Locke Road
- Parson's Creek
- Wallis Road
- Little River Reference
- DIM Reference
RESULTS - FISH PASSAGE

Restrictive Restored Reference

Brown's River 0.00
DIM Culvert 0.05
Huckleberry Road 0.10
Wentworth Road 0.15
Drakeside Road 0.20
Locke Road 0.25
Parson's Creek 0.30
Wallis Road 0.35
Little River Reference 0.40
DIM Reference 0.45

Passage rate

Restricted

Restored

Reference
RESULTS - FISH PASSAGE

\[ y = 0.268 + 0.046 \log x, \quad r^2 = 0.604589 \]

\begin{align*}
X & \text{ restricted} \\
+ & \text{ restored} \\
\blacksquare & \text{ reference}
\end{align*}

Wentworth Rd
RESULTS - FISH PASSAGE

\[ y = 0.229 - 0.045x, \quad r^2 = 0.875921 \]

- \( \times \) restricted
- \( + \) restored
- ■ reference

Wentworth Rd
Increasing the size of tidally restrictive culverts will result in increased passage of *F. heteroclitus*; full hydrologic restoration can increase passage to reference levels.

The accelerated water velocity caused by undersized culverts inhibits the movement of *F. heteroclitus* between upstream and downstream areas.
TROPHIC RELAY MODEL

- young resident nekton
- adult resident nekton
- young transient nekton
- adult transient nekton

Adapted from Kneib 1997
CONCLUSIONS

Similar communities measured in upstream areas of tidally restricted, restored and reference marshes indicate that culverts may not prevent fish from reaching upstream areas.

The increased water velocity as well as the presence of upstream subtidal habitats due to undersized culverts may decrease the rate at which nekton move between upstream and downstream areas.

Decreased passage rates may reduce the rate at which marsh derived production is exported out of the system to coastal waters.