Repairing Atlantic Rivers to Restore Diadromous Fishes

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Can a Resilience Approach Improve Anadromous Fish Restoration?

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**Diadromy 101 – The Freshwater-Sea Fishes**

- Uncommon; an evolutionarily convergence
- Regular movement between fresh water and salt water.
  - **Anadromy** – spawned in rivers, migrates to sea, returns to rivers to spawn
    - Salmons, shads, striped bass, sturgeons, sea lamprey
  - **Catadromy** – spawned at sea, migrates to fresh waters, returns to sea to spawn
    - Eels
The Atlantic Assemblage
The Atlantic Assemblage
More Diadromy 101 - The Migratory Imperative
Atlantic Salmon

Distributions – Large & Small

Atlantic Whitefish

Photo: Bob Sample
Costs and Benefits of Diadromy

**Benefits**
- Relative mortality differences between habitats
- Relative trophic resources between habitats

**Costs**
- Physiological adjustments
- Migration costs
  - Bioenergetics
  - Predation risk
- Suitability of *two* habitats

"Historical advantages have become contemporary curses"
Diadromous Species are Iconic

From Lossing 1886: The Hudson from the Wilderness to the Sea
Diadromy - Why “Home”?

- Certainty of habitat suitability – retained in memory through imprinting

- Fine-tuning to its own migratory circuit, e.g., seasonal timing, age at 1\textsuperscript{st} spawning, iteroparity vs. semelparity, morphological adjustments – populations and “races”
Life History Variation – Lost Anadromous Forms

• Shad
  – Hudson: yellowback, blueback, greenback, golden, pink, pink-faced, locust, chunker, chunk head
  – Potomac: May shad

• Atlantic salmon
More Subtle Anadromous Life History Variation

- Facultative Anadromy
  - e.g.,
  - Striped bass

Figure 2. Representative time series of salinity habitation for individual fish displaying (a) resident behavior, (b) a shift from high to low salinity, (c) a shift from low salinity to high salinity, and (d) resident behavior in saline waters with annual migrations to fresher waters
“Alewives came up to the fresh rivers to spawn in such multitudes it is almost incredible, pressing up such shallow waters as will scarce permit them to swim”

William Wood, New England’s Prospect, 1634

“. . . in April there is a fish much like a herring that comes up into the small brooks to spawn, and when the water is not knee deep they will presse up through your hands, yea, thow you beat at them with cudgels, and in such abundance as is incredible.”

Capt. Chartles Whitborne, 1616

“In a word, it is unbelievable, indeed, undescrivable, as also incomprehensible, what quantity is found there. One must behold oneself.”

William Byrd, Natural History of Virginia, 1728
Anadromy – An Overly Cooperative Life History?

Alewives

©Heather Perry
River Herring Today in the Northeast

MA – total closure since 2005
RI – total closure since 2006
CT – near total closure since 2002
NY – reduced in HR; closed elsewhere

American Shad & River Herring Commercial Landings
Source: Personal communication from NMFS Fisheries Statistics Division, Silver Spring, MD, 2013
A Week on the Concord and Merrimack Rivers
Henry David Thoreau (1849; trip made in 1839)

Who Hears the Fishes When They Cry?
Amoskeag Mills
What is the State of Our Anadromous Fishes?
Changes in Size

Oliver Hewitt, 1st row Right, Large Shad Catch, Fishs Eddy, NY

4 Fish Caught in the Oconee River at Nuledgeville GA. Weight 668
Species & Population Persistence
(Limburg & Waldman, Bioscience 2009)

• 22 Species found in Europe, NA, or both
  - Insufficient data on ½ (mainly lower value species)
• All others lost populations
  - American shad 70 of 138 lost (51%)
  - ~33% North American Atlantic salmon pops extirpated
Changes in Abundance

*Atlantic Salmon*

- Historical U.S. estimates 300,000 – 500,000 annually
- In 2014: <400!
- Federally endangered in Gulf of Maine rivers
Susquehanna River Shad

Lake Otsego

Lock Haven

Chesapeake Bay
Susquehanna River Shad

Goal = 750,000 past York Haven

<table>
<thead>
<tr>
<th>Location</th>
<th>Actual Counts 2014</th>
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<tbody>
<tr>
<td>Conowingo</td>
<td>10,425</td>
</tr>
<tr>
<td>Holtwood</td>
<td>2,528</td>
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<tr>
<td>Safe Harbor</td>
<td>1,336</td>
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<tr>
<td>York Haven</td>
<td>8</td>
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</table>
For 31 time series of N. Atlantic anadromous fishes, relative abundances:
- 98% decline from historic highs in 13,
- 90% in additional 11 (Limburg & Waldman: Bioscience 2009)
What Happened?

The Traditional “Unholy Trinity”:

- Dams, Dams, and More Dams
- Overfishing
- Pollution
Swimmable Distance,” American Shad

- Originally: 11,221 km
- In yr 2000: 6,856 km
- Net Loss: 4,364 km (~40%)
Pollution
Newer Threats

• Non-Native Species
Rainbow smelt *Osmerus mordax*

Climate Change (i.e., Warming)

J. Waldman – Hudson River
Somewhat Forgotten Threats
What Does a Natural River Look Like?

Single Channel Meandering?
Or Braided?
Maybe the Biggest Threat – Loss of Memory

*The Shifting Baseline Syndrome*

- “Each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes. When the next generation starts its career, the stocks have further declined, but it is the stocks at that time that serve as a new baseline.”

- *Daniel Pauly (1995)*
Shad Landings (millions/kg)
What Can Be Done?

Clue:

*What did the fish say when it swam into the wall?*
Answer: Oh Dam!

Conowingo Dam, Susquehanna River
Looking Forward on Salient Drivers

Largely Rectified
- Pollution

Essentially Untractable
- Non-native Species
- Climate

Tractable & Applied
- Overfishing

Tractable but Unrectified
- Dams
Dam Removal

“Every Dam Should Have an Existential Crisis”

Edwards Dam, Kennebec River, built 1837
(Augusta, Maine)

July 1, 1999
Another Option, Use a Ladder
Another, Take the Elevator
Finally, Take a Truck
Looking Forward – Two Divergent Pathways

Smaller Rivers
(*River Herring*)

Larger Rivers
(*Especially shad & salmon*)
River Herring – Pre-adapted to Ladders
Smaller Rivers
Coalitions: Grassroots Efforts are Essential, but Combined with Agency & NGO Expertise
Nature-Like Fishways
Why Isn’t Restoration Working (mostly) for Large Rivers?  
*Countervailing Forces of Resilience?*

**(Positive)  
“Anti-Allee Effects”**

- Allee effects are depensatory, accelerate declines
- Compensation: Truncation of spawning in time and space

**(Negative)  
Loss of “Storage Effect”**

- Storage effect is conservation of biomass so that fecundity is adequate to compensate for lean years
- One-way trips of small, 1st time spawners counteracts storage effect – ratchet downwards
Three Large Atlantic Rivers - The Record of Hydro Fish Passage

Brown et al. 2013
Number of Fish Passed as Percent of Target

- **Merrimack**
- **Connecticut**
- **Susquehanna**
Passage Efficiencies

- Merrimack R.: The graph shows the passage efficiency between dams on the Merrimack River. The red line represents the 1st to last dam, while the blue line represents the 1st to 2nd dam. The efficiency varies over time with some periods of higher efficiency and others of lower efficiency.

- Connecticut R.: This graph displays the passage efficiency between dams on the Connecticut River. The efficiency remains consistently high throughout the years, with minor fluctuations.

- Susquehanna: The graph for the Susquehanna River shows the passage efficiency between dams. It also depicts fluctuations over time, with periods of higher and lower efficiency.
Is it a Question of Scale?

Rainbow Dam on Farmington River, CT
Shad - An Interesting West Coast Exception

Bonneville Dam
Columbia River
Some West Coast vs. East Coast Shad Rivers

Is there Enough Water for Fish and Hydropower?

Columbia River

- Bonneville Dam Ladder = 2,000 – 3,000 cfs
- Columbia R. flow 275,000 cfs!

East Coast Rivers

- Avg. ladder flow = 30-50 cfs
- Connecticut 17,000 cfs
- Delaware 11,700 cfs
- Kennebec 9,100 cfs
- Pawcatuck 675 cfs
What Can Be Done?

Ultimately - Need to Free Rivers in Space & Time!

“Healthy River”

Does Habitat Diversity = Life History Diversity = Resilience?
Now is a Potentially Transformative Time for Large Hydro Dams

--Time to “Make Fish”

- Recognition that traditional engineered fishways haven’t succeeded in restoring stocks
- The energy mix is rapidly changing
  - e.g., Industrial scale solar and wind power
  - Smart homes
- Dams don’t last forever - aging and sedimentation
- Many dams are coming up for FERC relicensing
Let the River Run Wild

By JOHN WALDMAN, KARIN E. LIMBURG and AMY ROE  SEPT. 7, 2014
SHARED RIVER CONCEPT
""Poor shad! Where is thy redress? . . . Still wandering the sea in thy scaly armor to inquire humbly at the mouths of rivers if man has perchance left them free to enter . . . Armed with no sword . . . But mere shad armed with only innocence and a just cause . . . Who knows what may avail a crow-bar against that Billerica Dam?"

"Keep a stiff fin then, and stem all the tides thou mayst meet."