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River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Fish Passage and River Connectivity Barriers

• Anything that hinders any life stage of fish and other aquatic organisms, energy and inert matter from moving through a waterway.
  • Cultural
  • Physical barriers: dams and deteriorating culverts.
  • Environmental / biological barriers: water velocity, temperature, quality, predators, upstream habitat.
  • Technical barriers: materials, engineering and know-how

• Restoration of connectivity of freshwater habitats throughout the historic range of anadromous fish requires a coordinated approach.
Technical Developments in Materials and Designs for Improved River Connectivity

Guidance, Collection, Exclusion, Separation of Fish, Debris & Water Quality
River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
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Man has been trapping fish throughout our recorded history.

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Heart shape trap, Marshal Islands ....(note the long “lead”)
Man has been trapping fish throughout our recorded history.

Double heart shape trap west of Taiwan

(note the lead and exclusion barrier)
Man has been trapping fish throughout our recorded history.

Ancient “V” shaped trap
Teifi Estuary in Wales.
Over the years...

Wood  Rocks

Hemp  Jute

Romans made concrete by mixing lime and volcanic rock to form a mortar.
Synthetics Fiber: 1st invented in the mid 1800’s as filament for a light bulb.
Nylon and Polyesters during the 2nd World War

Source: National Science and Technology Centre, Australia
Todays Materials

**UHMWPE**
- Ultra-High Molecular Weight Polyethylene
- Invented in 1963 (Albert Pennings)
- Commercially available in 1990 (DSM).
- Brand Names: Dyneema, Spectra, Plasma
- *The* material for netting, ropes, anchor lines

**HDPE**
- High Density Polyethylene
- Invented in 1953 (Karl Ziegler, Nobel Prize, Chemistry 1963)
- First commercial use in 1955 as pipe.
- *The* material for booms, flotation, docks.
Key Features

Allows facilities a solution for fish guidance previously unachievable

- Does not decay or absorb water
- Excellent UV resistance
- Excellent fatigue and predator resistance
- Excellent material for lowest adhesion of zebra mussels and other marine growth
- Smooth to the touch
- Durable, Reliable
- High abrasion resistance
- Low drag
- Greatly reduce surface area
- Long lifespan
Custom Extruded HDPE

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A different kind of material

Material Benefits

- Can be used to construct a variety of marine structures
- Capacity for high deformation without fracture (great for ice, or impacts)
- Long services life, low maintenance
- Very adaptable
Benefits of both materials combined

In aquatic environments these materials used to:

- Guide
- Collect
- Exclude
- Transport
- Attenuate
- Separate
- Float
Downstream Fish Passage

Full exclusion guide net allows only one way out for downstream migrating fish.

Guide net acts “as an extension of the shoreline”.

Currents guide fish to net transition structure (NTS) and floating surface collector (FSC) for site specific handling.

Full exclusion net prevents entrainment and impingement.

Installation fits bathymetry of specific site.

Guidance and Collection

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Guidance and Collection

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FSC
1,000 cfs
Est. Fall 2015

Spillway exclusion net
Est. 2013

Migrant Collector
250 cfs
Est. 1958

Guidance and Collection

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Guidance and Collection
Guidance and Collection

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Not passage, but exclusion...

Longest Full Exclusion Net in the world

- 2.5 mile long, 55 ft. average depth 650,000 sq. ft.
- 2 billion cubic ft. of water per hour flow through it during operation.
- Seasonally deployed, continuously cleaned during deployment, and 20% of net replaced annually to maintain effectiveness.

Exclusion

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Designed for:

- Ocean-like conditions, rolling surf and winds and high water flow velocity
- Bi-directional currents with water flow velocities up to 5.0 fps
- With net floats that reduce load while still maintaining shape, position and effectiveness.

Exclusion
Prevents entrainment and impingement

▪ Full Exclusion Net, Ameren UE Bagnell Dam
▪ Designed to protect adult paddlefish and other critical species from passing through facility turbines.
▪ Fail-safe deployment as close as 10 feet from the nearest turbine intake.
▪ 1,200 ft. long / 120 ft. deep
▪ Designed for periodic reverse directional currents
▪ Water flow velocities: 1.0 to 3.4 fps

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Exclusion
Invasive Species

Fish exclusion barrier to prevent downstream migration of non-native species
Consisting of both a MultiFunction Boom™ for protection from debris and ice boom and an exclusion net.
Invasive Species

Elkhead Lake, Colorado.
Boom: 800 feet of 24inch Class 1 Material
Exclusion net: ¼ inch Dyneema fiber, 540 feet long, 31 feet deep
Head of Reservoir Fish Collection

- Portable and seasonally deployable.
- Nets reels ease set and retrieval, cleaning and maintenance.
- Effective at different sites.
- Debris controlled by a boom incorporated in design or placed up river.

Fish Collection doesn’t have to be at the dam

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Head of Reservoir Fish Collection

- Biological platform for fish assessment, agency or stakeholders needs.
- Attraction flow via river current.
- Transportable, floating fish pens, built of HDPE pipe and Dyneema netting.
- Cost effective, efficient and portable.

Fish Collection doesn’t have to be at the dam

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Control Temperature, Algae, Silt

- When stratification results in isolated, warmer, less dense surface waters
- A barrier curtain can effectively isolate and segregate the near-surface waters from the deeper waters.
- Downstream waters can be similar to deeper water upstream
- Demonstrated in an installation at the Iron Gate dam on the Klamath River
Curtain Design

- 798 Feet at High Pool
- 83 foot Max Depth
- 747 Feet at Low Pool
- 70 foot Min Depth
- Adjustable Depth
- Pool Fluctuation 16 ft.
- Frame Construction
- Contoured to Reservoir Bathy

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Vinyl Curtain

Continuous Section

Heavy Chain

Attached To Chain

Stainless D Ring

Winch Line Through D Rings

Hand Winch To Lift Vinyl To Desired Height

Winch Plate/Support

16" Diameter HDPE Foam Filled Pipe

Typical Barrier layout
Strength and Shape:
Polyester Net, 6 Inch mesh

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Impervious Surface

Seaman Corp. XR-5
- Synthetic reinforced geomembrane
- High Puncture Resistance: 30 mil thick 868lbs
- Fabric inhibits damage spread if torn or punctured
- Flexible, prefabricated panels (15,000+ square feet) practical.
- Material is not subject to environmental stress cracking

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Flotation and Anchoring

- Rigid float system.
- Each section flange bolted to the next to form a continuous boom
- Securely anchored in place.
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- Each section flange bolted to the next to form a continuous boom.
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River Connectivity: Technical, cultural, and biological aspects of fish passage and reintroduction.
Cyanobacteria & Microcystin consistently higher upstream of the curtain than those downstream of the curtain.
Thermograph shows less stratification downstream of the curtain.

**River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction**
### Design and Construction

**Typical Frame Section of a guidance structure**

<table>
<thead>
<tr>
<th>UHMWPE Fiber Mesh</th>
<th>Boat Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square Orientation</td>
<td>Collection Gate</td>
</tr>
<tr>
<td>Standard Openings as small as 3.175 Mm</td>
<td>Pool Fluctuation</td>
</tr>
<tr>
<td>Vertical &amp; Horizontal Frame Lines</td>
<td>Strength &amp; Effectiveness</td>
</tr>
<tr>
<td>Lighter Weight Materials</td>
<td>Reduced Operations / Maintenance Costs</td>
</tr>
</tbody>
</table>
Net design and construction

Regulatory
Environmental
Operational

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Net design and construction

Design and engineering
✓ Flow and velocity of water
✓ Debris; type, size, management
✓ Type of fish
✓ Guidance, collection or exclusion objectives
✓ Types of aquatic growth and maintenance procedures
✓ Weather, environment, ice, wind, waves
✓ Dam & Public Safety

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Pool Fluctuation

High Pool

Low Pool

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Shape of Forebay and Net
Net Orientation

Rigid but flexible wall:
- To maintain mesh opening size
- To provide strength for anticipated loads
- To allow for changes in pool level

Square Mesh

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Debris Control

- Exclusion
- Collection
- Guidance

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Reducing Debris Loading Fish Collection Facilities
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MultiFunction Boom™

DEBRIS | DEMARCATION | DAM SAFETY | FISH PASSAGE | ICE | SECURITY | ENVIRONMENTAL

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Custom Boom to Protect Fish Screens

Alameda Creek Watershed

- 121 feet length.
- Depth 4 foot under floatation
- 6 debris barrier panels
- Floated by 30 in class 3/ MultiFunction Booms™
- Galvanized steel frame
- HDPE Pile Sliders to reduce friction and moving parts
- Anchored by wall beam slider and piles sliders
Custom Boom to Protect Fish Screens

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Custom Boom to Protect Fish Screens
Alameda Creek Watershed

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Custom boom to prevent plant shutdown during debris and ice events

Brookfield, Lower Saint Anthony’s Falls

- 225 feet length overall
- 36 inch Class 1 Boom
- 9 sections, “V” Shape
- Main sections flange bolted with articulated sections on dam end
- Debris skirt / splashguard
- Swimmer ladder / emergency exit
- Walkway grate
- Designed for 10 feet sec flow
- Anchored by in river cored concrete pile, flush to river bed, connected by chain to 8ftx16ft anchor buoy
Custom boom to prevent plant shutdown during debris and ice events

Brookfield, Lower Saint Anthony’s Falls

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Material Features

☑ Not vulnerable to biological attack
☑ Exceptional resistance to fouling
☑ Smooth, non-stick surface
☑ Excellent Bending Radius
☑ 2% carbon black and/or ultraviolet stabilizer for UV

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Debris Overtopping Guard (DoG)

- Prevents debris overtopping boom
- On upstream side of the boom, works like the bow of a boat
Boat Gates

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River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Security

River Connectivity: Technical, cultural and biological aspects of fish passage and reintroduction
Conclusions

Barriers to river connectivity:
- Physical
- Environmental
- Political
- Technical
- Social

...are complex and interdependent

We humans have been building things for a long time to collect or guide or exclude fish from moving through a waterway.
Conclusions

Modern materials, UHMWPE and HDPE, engineering and design have opened new opportunities that benefit efforts for collection, exclusion and guidance of fish and debris and the restoration of freshwater habitats connectivity throughout the historic ranges of anadromous fish.

So my question to you is “Now which barriers do we need to overcome?”