Lock and Dam #1, Asian carp barrier alternatives analysis; the known unknowns

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Lock and Dam #1
Fish Deterrence Barrier Alternatives Analysis

Ron Koth and Jeff Lee
Barr Engineering Company

2014 International Engineering Ecohydraulics and Fish Passage Conference
Original Project Scope

Contract with MNDNR August 2012

**Phase 1**
Alternatives Evaluation Report

**Phase 2**
IEPR review assistance
  Design
  Permitting
USACE Section 408 EA and approval
Construction Plans

**Phase 3**
Bid and Award
Construction Admin and oversight
Completion of construction by April 15, 2014
O&M manual
Lock and Dam #1
Fish Barrier Alternatives Analysis

It is the goal of the MNDNR to design and construct a safe and effective fish deterrence barrier at Lock and Dam #1.
Barrier Alternatives Evaluation Criteria

- All life stages Asian carp deterred > 90%
- Safety concerns must be mitigated
- Authorized uses maintained
- No adverse impacts to structure
- Construction start: fall 2013
- Protection of active lock only
- 100-year design event
Project Site and Uses

2,000,000 annual park visitors
2,495 3-yr avg. # lockages
Important Water Elevations at the Lock and Dam
Lock and Dam #1
Fish Passage Routes

- Drain tubes/discharge manifold
- Miter gates
- Water levels
Known and Unknown

**Known**

- Tight timeline
- High use area at/near lock
- 100-yr flood risk
- Multiple passage pathways
- USACE facility

**Unknown**

- Technologies available
- Technology effectiveness for bigheaded carp
- Viable ways to protect lock
- Scope of safety mitigation
- Lock infrastructure affected
LEVEL 1 SCREENING: IS FISH DETERRENCE > 90%?

THE CONTENDERS

**Downstream**
- **D1**: Electric
- **D1a**: Sweeping
- **D1b**: Suspended Electrodes
- **D1c**: Graduated Field (GFFB)
- **D2**: Strobe Lights
- **D3**: Air Bubble Curtain (BAFF)
- **D4**: Sound Projection Array (SPA)
- **D5**: Acoustic Air Bubble Curtain (SPA/BAFF)
- **D6**: Combination: Sweeping Electric & Non-electric
- **D7**: Combination: Graduated Field & Non-electric
- **D8**: Combination: Suspended Electrodes & Non-electric
- **D9**: Chemical Treatment

**In-lock**
- **I1**: Electric
- **I1a**: Sweeping
- **I1b**: Suspended Electrodes
- **I1c**: Graduated Field (GFFB)
- **I2**: Strobe Lights
- **I3**: Air Bubble Curtain (BAFF)
- **I4**: Sound Projection Array (SPA)
- **I5**: Acoustic Air Bubble Curtain (SPA/BAFF)
- **I6**: Combination: Sweeping Electric & Non-electric
- **I7**: Combination: Graduated Field & Non-electric
- **I8**: Combination: Suspended Electrodes & Non-electric
- **I9**: Cease Operation of the Lock
- **I10**: Chemical Treatment

**Downstream**
- **D2**: Strobe Lights
- **D3**: Air Bubble Curtain (BAFF)
- **D4**: Sound Projection Array (SPA)

**In-lock**
- **I2**: Strobe Lights
- **I3**: Air Bubble Curtain (BAFF)
- **I4**: Sound Projection Array (SPA)

**Moving on. Further consideration...**

resourceful. naturally.
## Literature review of non-physical deterrence barriers

The table below summarizes the effectiveness of various non-physical deterrents, along with key factors influencing their effectiveness, limitations, and reference studies.

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Species</th>
<th>Deterrence Effectiveness</th>
<th>Factors Influencing Effectiveness</th>
<th>Limitations</th>
<th>Reference Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFFB</td>
<td>Chinook salmon</td>
<td>84.7%</td>
<td>Water conductivity, size of fish, attunement of electric field or placement of electrodes</td>
<td>Power outages, maintenance issues, human error, size-selective effectiveness</td>
<td>Palmisano and Burger 1988; Macelina et al. 1999a,b; Hallman 2011</td>
</tr>
<tr>
<td></td>
<td>Grass carp</td>
<td>98.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silver carp, bighead carp</td>
<td>63% - 99%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPA/BAFF</td>
<td>Silver carp, bighead carp</td>
<td>60-99.7%</td>
<td>Ambient light and turbidity (strobe portion)</td>
<td>Lack of Asian-carp-specific testing on large scale</td>
<td>Taylor et al. 2005; Rubelush et al. 2012; Pegg and Chick 2004</td>
</tr>
<tr>
<td>Sweeping</td>
<td>Goldfish</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unpublished data Smith-Rood</td>
</tr>
<tr>
<td>Suspended electrodes</td>
<td>Bleak, asp, common carp, rainbow trout, catfish</td>
<td>93.98%</td>
<td>Water conductivity, size of fish</td>
<td>Water velocity; only downstream applications to date</td>
<td>Unpublished and mostly Polish Journals</td>
</tr>
<tr>
<td>Air Bubble Curtain</td>
<td>Gizzard shad, alewife, rainbow smelt</td>
<td>70-95%</td>
<td>Turbidity, water velocity, bottom geography, light penetration</td>
<td>Not easily noticed from a distance</td>
<td>Patrick et al. 1985; McNinch and Hocutt 1987</td>
</tr>
<tr>
<td>SPA</td>
<td>Alewife, Atlantic herring, European sprat, river lamprey, flat fish</td>
<td>60-96%</td>
<td>Bottom morphology, hydrology, angle of sound waves</td>
<td>Sound waves are less effective in shallow waters and across hard substrates</td>
<td>Ross et al. 1993; Maes et al. 2004</td>
</tr>
<tr>
<td>Strobe Lights</td>
<td>Rainbow smelt, Atlantic menhaden, spot, white perch</td>
<td>8-100%</td>
<td>Turbidity, ambient light</td>
<td>Reduced effectiveness during daylight hours and in high-turbidity conditions</td>
<td>Sager et al. 1987; Hamel et al. 2008</td>
</tr>
<tr>
<td>BAFF</td>
<td>European silver eels, alewife, silver carp, bighead carp</td>
<td>57.99%</td>
<td>Bottom morphology, hydrology, angle of sound waves</td>
<td>Less effective in shallow waters and across hard substrates</td>
<td>Haynes and Patrick 1986; Sand et al. 1998; Pegg and Chick 2004</td>
</tr>
</tbody>
</table>

### Decision to use only Bighead and Silver carp specific research

The decision to focus on Bighead and Silver carp specific research is based on the observed effectiveness and specific deterrent requirements of these species.
Bighead and Silver carp specific peer reviewed studies 2012


Level 2 Screening: Site-Specific Considerations

- Lock structure modifications
- Lock and dam operational modifications
- Public and operator safety
- Ice and cold weather
- Flood flows
- Damage by commercial vessels
- Fish behavior
- Recreational traffic impacts
- Sedimentation and/or scour
Electrical Effects on Fish and Humans

- CSSC operations
- NAVSEA report

Voltage known to deter Asian Carp of any life stage:

- 2.3 Volts/inch

Voltage level that can cause fibrillation and involuntary loss of muscular control in humans:

- 0.08 Volts/inch
LEVEL 2 SCREENING: SITE SPECIFIC CONSIDERATIONS

THE SEMI-FINALISTS

<table>
<thead>
<tr>
<th>Downstream</th>
<th>FAIL</th>
<th>PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1: Electric</td>
<td>D1a: (High Potential, but not ready to implement)</td>
<td>D1a: (High Potential, but not ready to implement)</td>
</tr>
<tr>
<td>D1a: Sweeping</td>
<td>D1b: (potential for entanglement)</td>
<td>D1b: (potential for entanglement)</td>
</tr>
<tr>
<td>D1b: Suspended Electrodes</td>
<td></td>
<td>D1b: (potential for entanglement)</td>
</tr>
<tr>
<td>D1c: Graduated Field (GFFB)</td>
<td></td>
<td>D1c: (not recommended)</td>
</tr>
<tr>
<td>D5: Acoustic Air Bubble Curtain (SPA/BAFF)</td>
<td></td>
<td>D5: (not recommended)</td>
</tr>
<tr>
<td>D6: Combination: Sweeping Electric &amp; Non-electric</td>
<td>D6: (should be evaluated separately)</td>
<td>D6: (should be evaluated separately)</td>
</tr>
<tr>
<td>D7: Combination: Graduated Field &amp; Non-electric</td>
<td>D7: (should be evaluated separately)</td>
<td>D7: (should be evaluated separately)</td>
</tr>
<tr>
<td>D8: Combination: Suspended Electrodes &amp; Non-electric</td>
<td>D8: (should be evaluated separately)</td>
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<table>
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<tr>
<th>In-lock</th>
<th>FAIL</th>
<th>PASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1: Electric</td>
<td>I1a: (not recommended)</td>
<td>I1a: (not recommended)</td>
</tr>
<tr>
<td>I1a: Sweeping</td>
<td>I1b: (not applicable)</td>
<td>I1b: (not applicable)</td>
</tr>
<tr>
<td>I1b: Suspended Electrodes</td>
<td></td>
<td>I1b: (not applicable)</td>
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<tr>
<td>I1c: Graduated Field (GFFB)</td>
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<td>I1c: (not recommended)</td>
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<td>I6: (should be evaluated separately)</td>
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<tr>
<td>I7: Combination: Graduated Field &amp; Non-electric</td>
<td>I7: (should be evaluated separately)</td>
<td>I7: (should be evaluated separately)</td>
</tr>
<tr>
<td>I8: Combination: Suspended Electrodes &amp; Non-electric</td>
<td>I8: (should be evaluated separately)</td>
<td>I8: (should be evaluated separately)</td>
</tr>
<tr>
<td>I9: Cease Operation of the Lock</td>
<td>I9: (public decision process required)</td>
<td>I9: (public decision process required)</td>
</tr>
</tbody>
</table>

THE FINALISTS

ELECTRIC: GFFB
NON-ELECTRIC: SPA / BAFF
Known and Unknown

**Known**
- Limited technologies applicable
- USACE concerns about structural changes to lock
- Safety mitigation for electric required
- Very limited species specific research
- Limited understanding of how research results apply in operational use

**Unknown**
GFFB Locations and Specific Site Issues

- Short and long-term structural impacts
- Construction methods
- Construction schedule
- Operational changes
SPA/BAFF Location and Site-Specific Issues

- Operational changes
- Construction methods
SPA/BAFF was the Recommended Alternative

- Potentially up to 99+% effective for all life stages of Asian carp
- No lock operational changes
- Meets public safety needs
- Location may enhance effectiveness
Sweeping Barrier Concept and Location

- SRI design contract
- Electrical parameter validation study May 2014
Upper St. Anthony Falls to be closed within one year of signature of the legislation.
Questions
Barrier Overview

Sweeping Field/Diffuser/Terminal

No installations of these combined technologies at this time anywhere.

May 2014 validation study to provide guidance on parameter settings required for Asian carp.

<table>
<thead>
<tr>
<th>Barrier Type</th>
<th>Voltage Gradient at Surface**</th>
<th>Voltage Gradient near electrodes at (12’ water depth)**</th>
<th>Pulse Rate/ Frequency**</th>
<th>NAVSEA report max safe voltage gradient humans</th>
<th>CSSC canal electric barrier operational parameters (surface)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusers</td>
<td>.004V/in - .014V/in</td>
<td>1.6-1.7V/in</td>
<td>3Hz/2ms</td>
<td>≤0.05V/in</td>
<td>NA</td>
</tr>
<tr>
<td>Sweeping</td>
<td>≥1.08V/in</td>
<td>&lt;2.0V/in</td>
<td>3Hz/2ms</td>
<td>≤0.05V/in</td>
<td>NA</td>
</tr>
<tr>
<td>Terminal</td>
<td>≥1.08V/in</td>
<td>6.0V/in</td>
<td>3Hz/2ms</td>
<td>≤0.05V/in</td>
<td>2.3V/in, 30Hz, 4ms</td>
</tr>
</tbody>
</table>

** hypothetical optimums Smith Root 99% design report 2014
NAVSEA Report 2008