Evaluating Biological Effects of Dredging-Induced Underwater Sounds
Burton Suedel, Andrew McQueen, Justin Wilkens, and Morris Fields
Introduction

• Increasing national and international regulatory focus on adverse impacts from anthropogenic underwater sound

• Potential impacts to aquatic organisms:
  • Mammals
  • Fish
  • Turtles
  • Benthic fauna

• NOAA NMFS (2016): Advisory Acoustic Thresholds for Marine Mammals
  • Impulsive Sounds – Blasting, Pile-driving, Sonar, Geophysical Surveys
  • Non-impulsive Sounds – Shipping, Windfarms, Dredging?
PRESENTATION OUTLINE

1) Characterize Dredge-induced Underwater Sounds (Exposures)

2) Characterize Potential Adverse Biological Effects Associated with Underwater Sounds (Responses)

3) Identification of Mitigation Approaches
Approach

- Focused literature review to characterize dredging sounds in context to other relevant underwater sounds

- Document adverse biological effects from dredging and other anthropogenic sources and potential mitigation approaches
Dredging Sound Studies

USACE
• Dickerson et al. 2001
• Clarke et al. 2002
• Reine et al. 2012
• Reine and Dickerson 2014

The Netherlands
• Maasvlakte 2 Studies

United Kingdom
• Nedwell et al. 2008
• Robinson et al. 2011
Underwater Sound Metrics (Exposures)

• Impulsive Sounds:
  • Rapid rise and decay
  • E.g., blasting, pile-driving
  • Metrics:
    • SPL “Peak” intensity

• Non-Impulsive Sounds
  • “Broadband”, continuous
  • E.g., shipping, dredging
  • Metrics:
    • SPL Root Mean Square (RMS)

• Sound Exposure Level (SEL)
  • Incorporates intensity and duration of sound event
Biological Endpoints (Responses)

- **Endpoints**
  - Mortality
  - Tissue injury
  - Auditory system damage
    - Threshold shifts:
      - Permanent (PTS)
      - Temporary (TTS)
  - Masking
  - Behavioral changes
    - Schooling, feeding, etc.

(Based on Richardson et al. 1995)
Spatial and Temporal Scales

- Hydraulic dredge (Reine and Dickerson 2014)

Distance from Dredge

Time/ Operation

US Army Corps of Engineers • Engineer Research and Development Center
Sound Pressure Levels (SPLs)

Sound Intensity

SPL (dB re 1 µPa at 1 m)

Dredging

Hydraulic

Mechanical

Shipping  CSD  TSHD  GD  BHD  Wind Turbine  Ambient Harbor

US Army Corps of Engineers • Engineer Research and Development Center
Summary: Exposures

• Dredging-induced sounds:
  • < 190 dB re μPA at source
  • Non-impulsive and intermittent

• Predominate sound sources:
  • Propulsion, machinery, pumping, aggregate
  • Greatest SPLs often associated with transit at speed
  • Intensity (SPL) and frequency (Hz) similar to shipping

• Mechanical dredging generally lower SPLs versus hydraulic dredging

• Cavitation from propulsion often cited as the predominate sound intensity
## Biological Responses to Dredging-induced Sounds: Fish

<table>
<thead>
<tr>
<th>Sound Source</th>
<th>Exposure Level</th>
<th>Species</th>
<th>Effect</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping + Dredging</td>
<td>186 SEL (db re 1µPA/s); 24 hrs</td>
<td>*Modeled fish exposure</td>
<td>No TTS risk fish &gt;2g; Risk for TTS with fish &lt;2g</td>
<td>Heinis et al. 2013</td>
</tr>
<tr>
<td>Dredging</td>
<td>190 SPL (dB re 1µPA RMS)</td>
<td>Atlantic salmon</td>
<td>No significant behavioral effects</td>
<td>Nedwell et al. 2008</td>
</tr>
<tr>
<td>Dredging</td>
<td>163 SPL (dB re 1µPA RMS)</td>
<td>Atlantic salmon</td>
<td>No significant behavioral effects</td>
<td>Nedwell et al. 2008</td>
</tr>
<tr>
<td>Dredging</td>
<td>117-122 SPL (dB re 1µPA at 50 m)</td>
<td>Clupeidae (herring, shad, etc.) and flat fish</td>
<td>No auditory risk</td>
<td>DEFRA 2003</td>
</tr>
</tbody>
</table>
## Biological Responses to Dredging-induced Sounds: Mammals

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</tr>
</thead>
<tbody>
<tr>
<td>Shipping + Dredging</td>
<td>180 - 182 SEL (db re 1µPA/s) for 24 hrs</td>
<td>*Modeled seal and porpoise exposure</td>
<td>Did not exceed PTS or TTS risk threshold</td>
<td>Heinis et al. 2013</td>
</tr>
<tr>
<td>Dredging</td>
<td>115-117 SPL (dB re 1µPA)</td>
<td>Bowhead whales (field observations)</td>
<td>No adverse behavioral response</td>
<td>Richardson et al. 1990</td>
</tr>
<tr>
<td>Dredging</td>
<td>94-122 SPL (dB re 1µPA)</td>
<td>Bowhead whales (dredge sound playback)</td>
<td>Inconclusive behavioral response</td>
<td>Richardson et al. 1990</td>
</tr>
<tr>
<td>Dredging</td>
<td>NA (field observations &amp; impact assessment)</td>
<td>Beluga whales</td>
<td>No adverse effects reported</td>
<td>Hoffman 2010</td>
</tr>
<tr>
<td>Dredging</td>
<td>NA (field observations)</td>
<td>Bottlenose dolphins, harbor porpoises</td>
<td>Avoidance behavior, short-term avoidance</td>
<td>Pirotta et al. 2013; Diederichs et al. 2010</td>
</tr>
</tbody>
</table>
Summary: Biological Responses

• No direct evidence of mortality or tissue injury due to dredge-induced underwater sound

• Non-lethal effects:
  • Potential risks for altering hearing thresholds for fish
    • Temporary threshold shift (TTS) for fish < 2 g; Heinis et al. 2013
  • Observed behavioral effects
    • e.g., avoidance (harbor porpoises); Diederichs et al. 2010

• Limited exposure-response data
# Mitigation Approaches

<table>
<thead>
<tr>
<th>Mitigation Options</th>
<th>Comment</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Exclusion Zones</td>
<td>Defined area excluding animals during noise emissions</td>
<td>ACCOBAMS 2013</td>
</tr>
<tr>
<td>Spatial and temporal restrictions</td>
<td>Minimizing or excluding operations to biologically sensitive areas or times</td>
<td>Convention on Biological Diversity 2012</td>
</tr>
<tr>
<td>Acoustic damping</td>
<td>Mitigating transmission of sounds</td>
<td>ACCOBAMS 2013</td>
</tr>
<tr>
<td>Equipment design and retrofit</td>
<td>Altering the source level/ frequency</td>
<td>IMO 2014</td>
</tr>
<tr>
<td>Equipment operation and maintenance</td>
<td>Altering the source level/ frequency</td>
<td>IMO 2014; WODA 2013</td>
</tr>
<tr>
<td>Reduction in power levels</td>
<td>Altering the source level/ frequency</td>
<td>ACCOBAMS 2013</td>
</tr>
</tbody>
</table>
Conclusions

• Mortality or injury of aquatic biota from dredge-induced sounds have not been documented
• Effects are likely limited to non-lethal effects:
  • Hearing threshold shifts
  • Behavioral
• Mitigation approaches need to be informed by ecological risk
• A broader risk framework is being developed for assessing and managing underwater sounds
Discussion Points

• Are there district dredging projects where underwater sound as a source of risk has been identified?
• Are there research needs to help develop the science needed to address risk concerns?
• Do you anticipate underwater sound concerns to increase in the future?