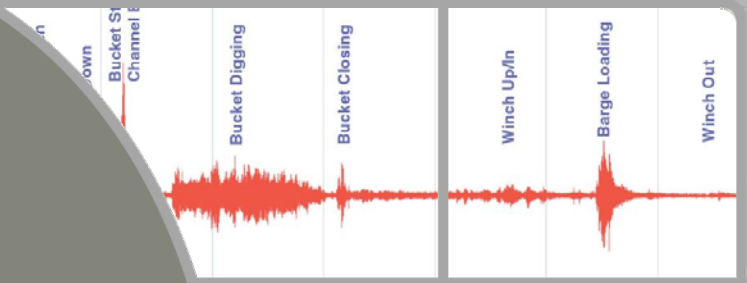
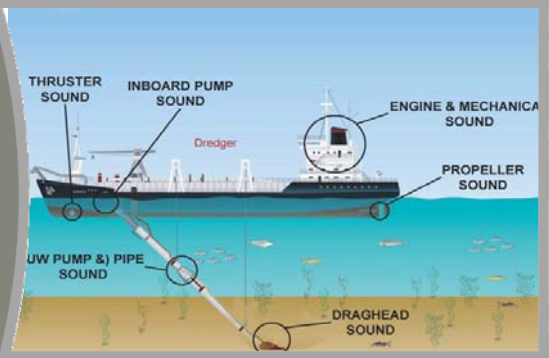
Biological Effects of Dredging-Induced Underwater Sounds

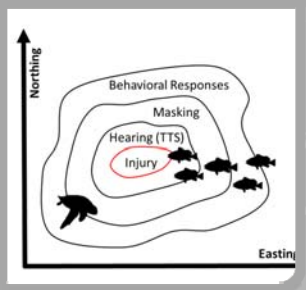
- **Andrew McQueen, PhD**
- Research Biologist
- US Army Engineer Research and Development Center

- **Burton Suedel, PhD**
- **Justin Wilkens**
- **Morris Fields**

21 March 2018







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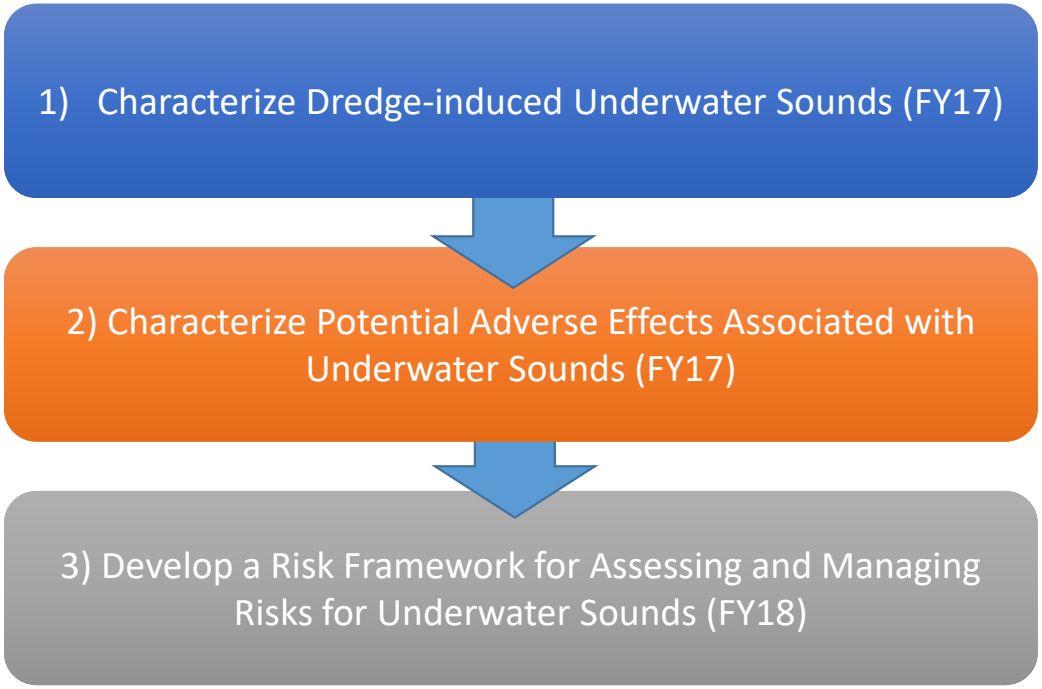
Introduction

- 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?

Outline


1) Characterize Dredge-induced Underwater Sounds (FY17)
2) Characterize Potential Adverse Effects Associated with Underwater Sounds (FY17)
3) Develop a Risk Framework for Assessing and Managing Risks for Underwater Sounds (FY18)

Approach

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

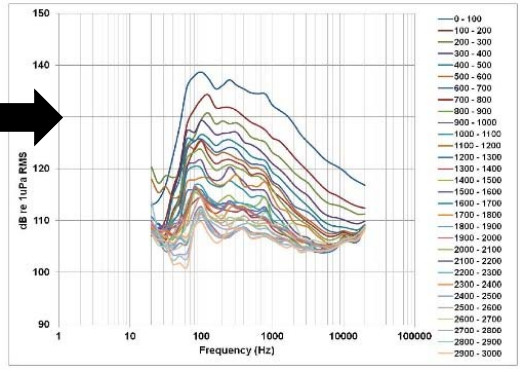
- Document adverse biological effects from dredging and other anthropogenic sources

Underwater Sound Metrics (Exposures)

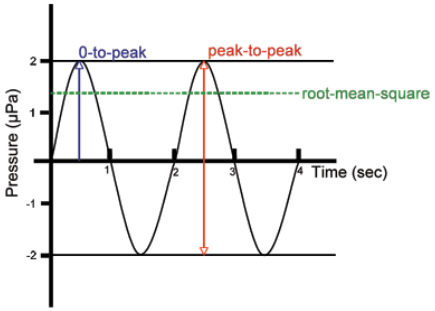
Dredging Operation

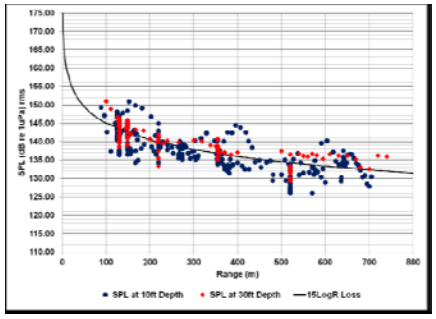
Complex Pressure Waveforms

Frequencies



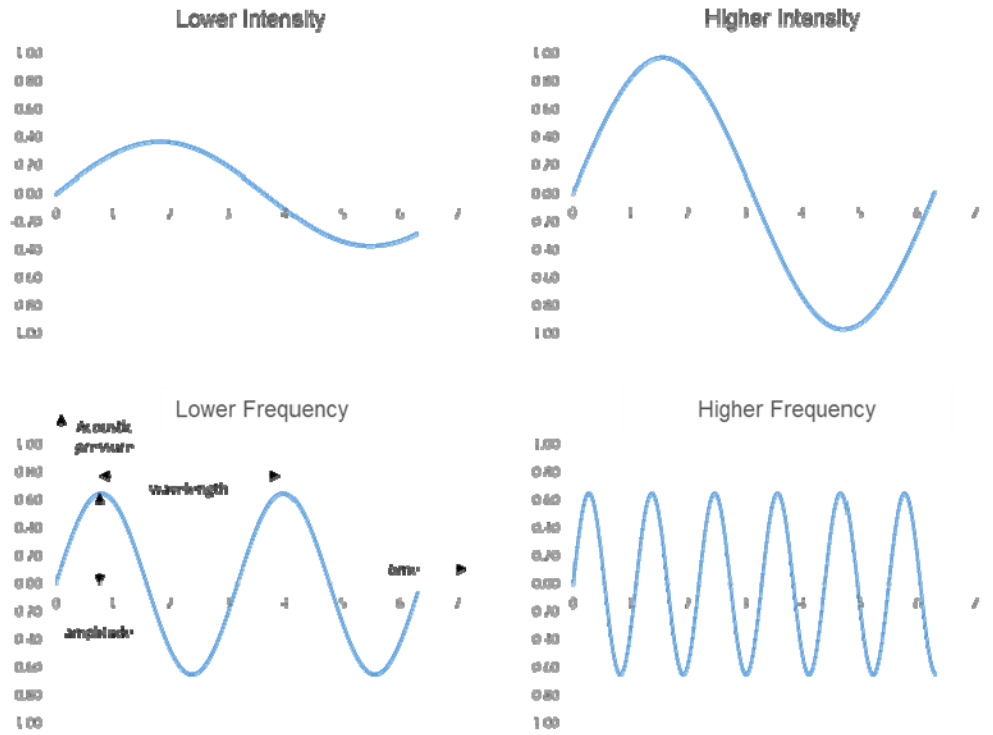
Sound Pressure Levels (SPLs)





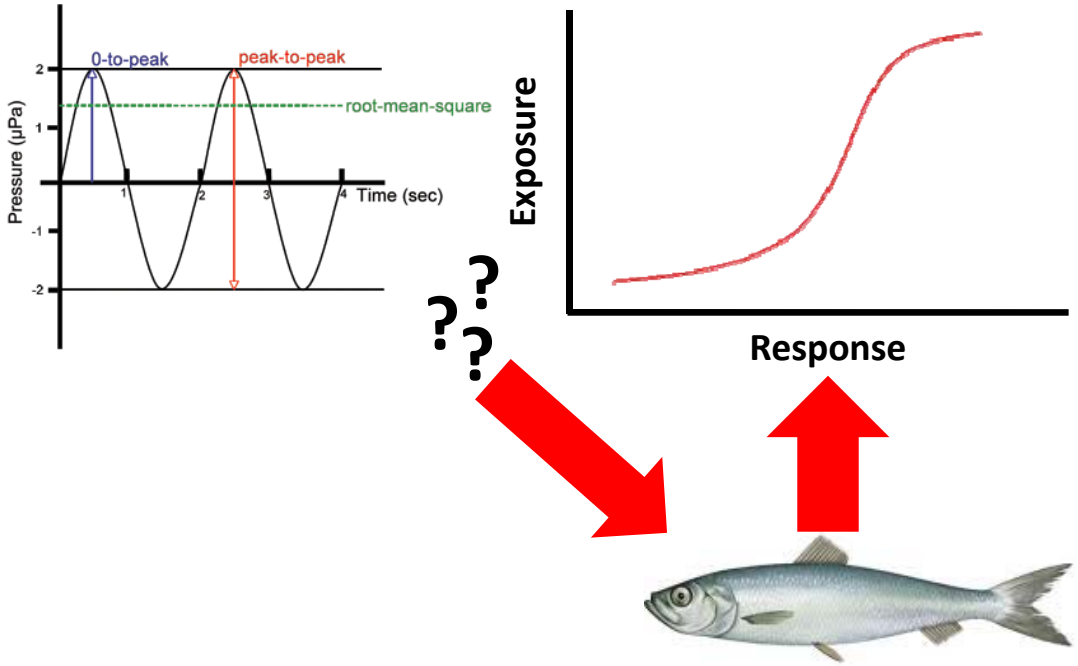
Underwater Sound Terminology

- Pressure (Pascal)
  - Sound Pressure Level (SPL)
  - Decibels (dB)
- Wavelength
  - Distance between pressure waves
- Frequency
  - Hertz (Hz); wavelengths per second



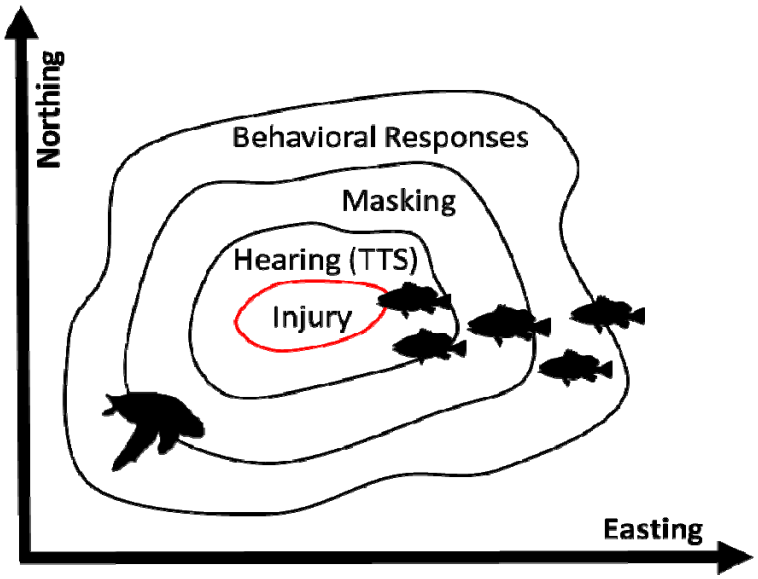
Underwater Sound Metrics (Exposures)

- Impulsive Sounds:
  - Rapid rise and decay
  - Metrics:
    - SPL “Peak” intensity
- Non-Impulsive Sounds
  - SPL at “source” (at 1 meter)
  - SPL Root Mean Square (RMS)
  - SPL 1/3 Octave Bands
- Sound Exposure Level (SEL)
  - Incorporates intensity and duration of sound event



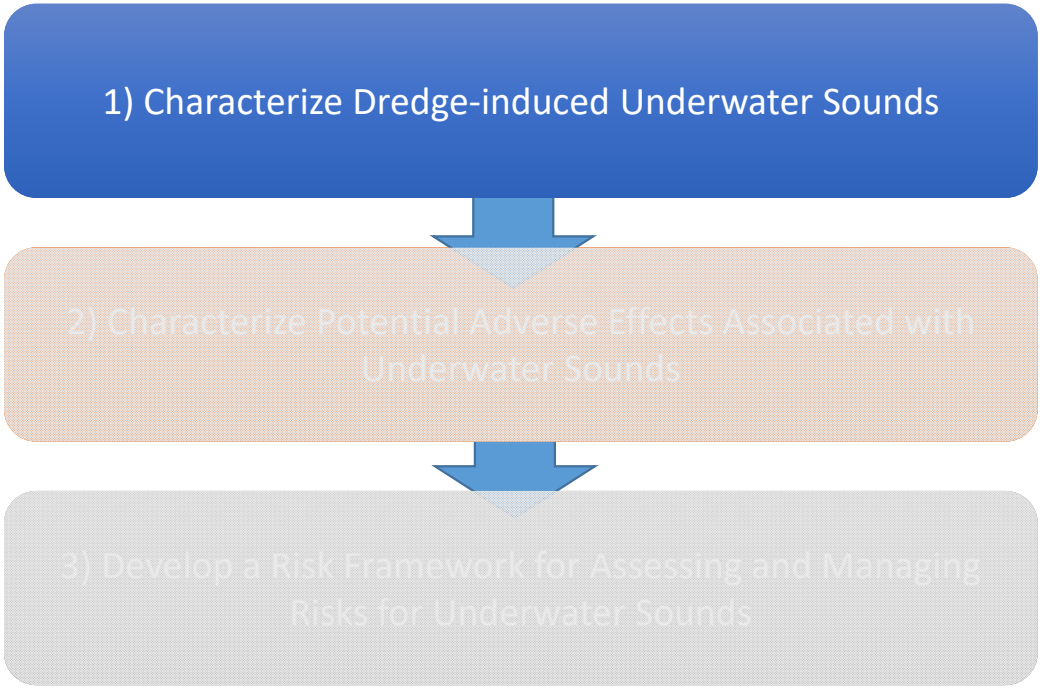
Biological Endpoints (Responses)

- 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)

Outline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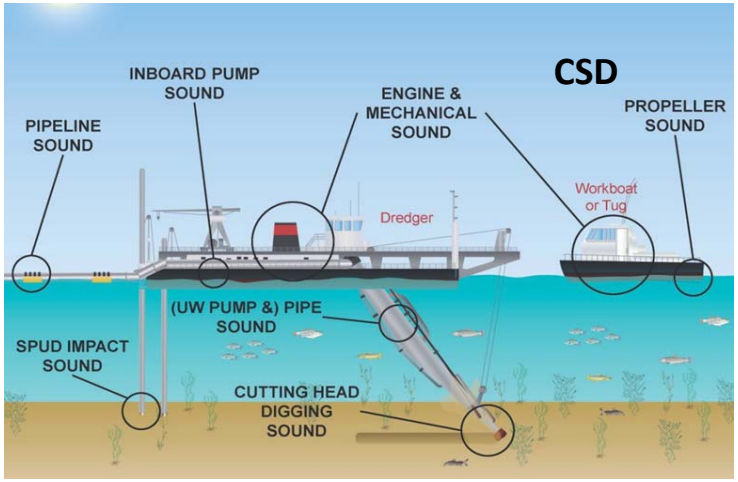
Hydraulic Dredges

Cutter Suction Dredge (CSD)

- Most widely used dredge type in US
- Multiple sources of sound
- Propulsion, cutting head, pumping



Trailing Suction Hopper Dredge (TSHD)

- 2nd most used dredge type
- Multiple sources of sound
- Propulsion, draghead, pumping

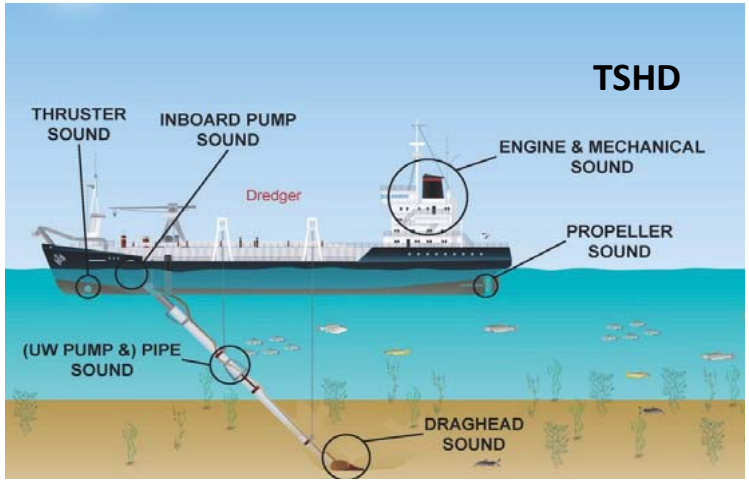


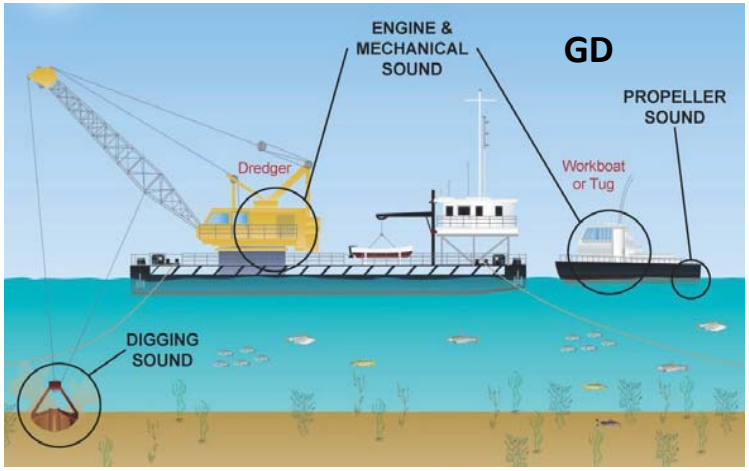
Photo credit: Philip Spadaro, Intell Group. (CEDA 2011)

Photo credit: Philip Spadaro, Intell Group.

Mechanical Dredges

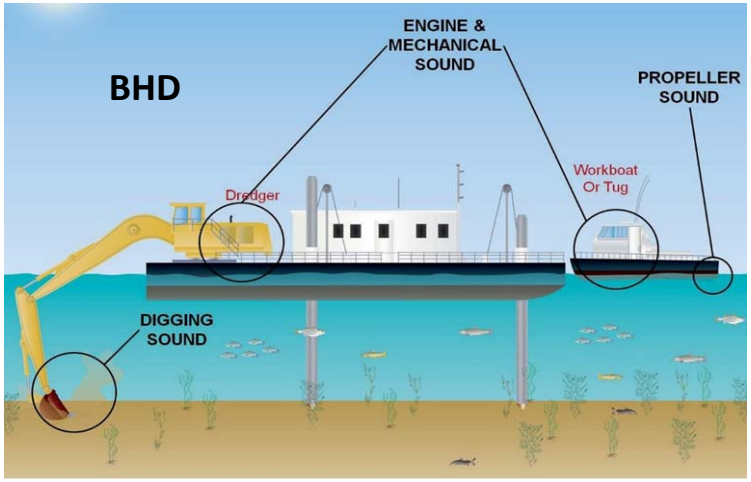
Grab Dredges (GD)

- Multiple sources of sound
- Cyclical, discontinuous
- Propulsion, machinery, digging



Backhoe Dredges (BHD)

- Multiple sources of sound
- Cyclical, discontinuous
- Propulsion, machinery, digging



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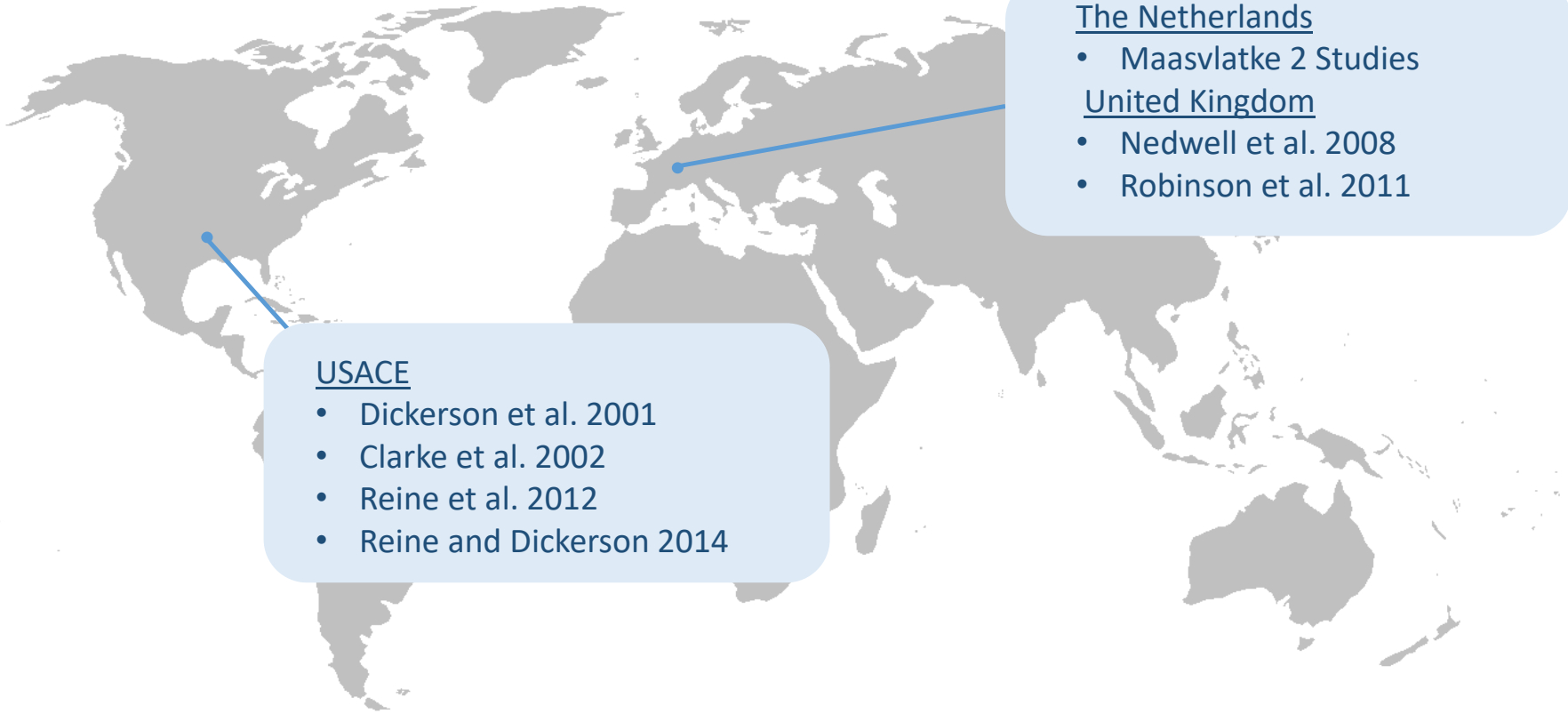
Dredging Sound Studies

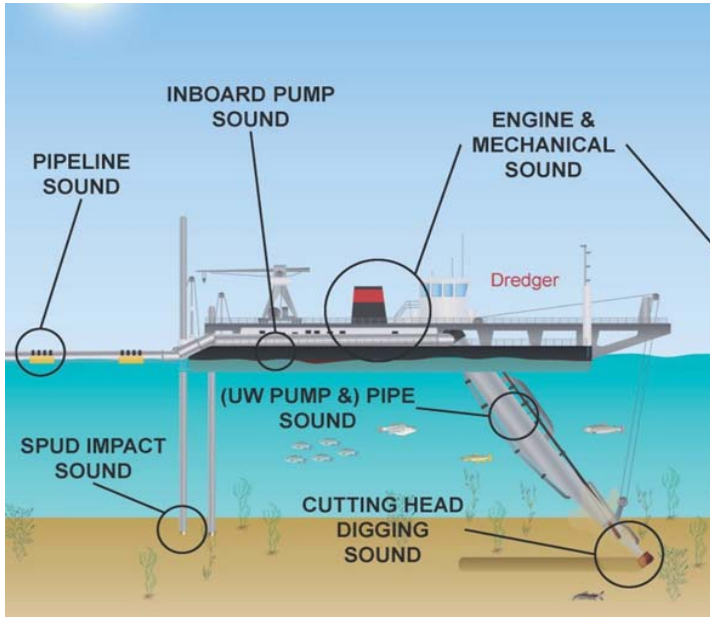


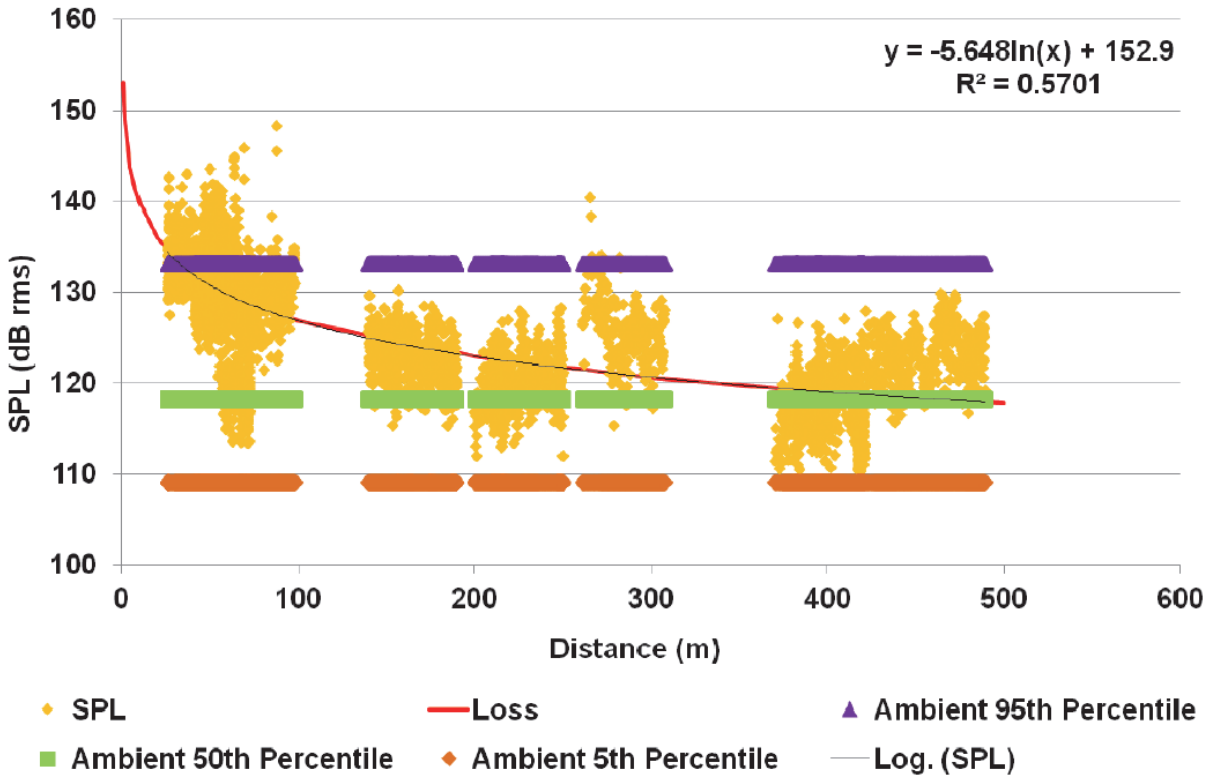
The Netherlands
- Maasvlatke 2 Studies

United Kingdom
- Nedwell et al. 2008
- Robinson et al. 2011

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

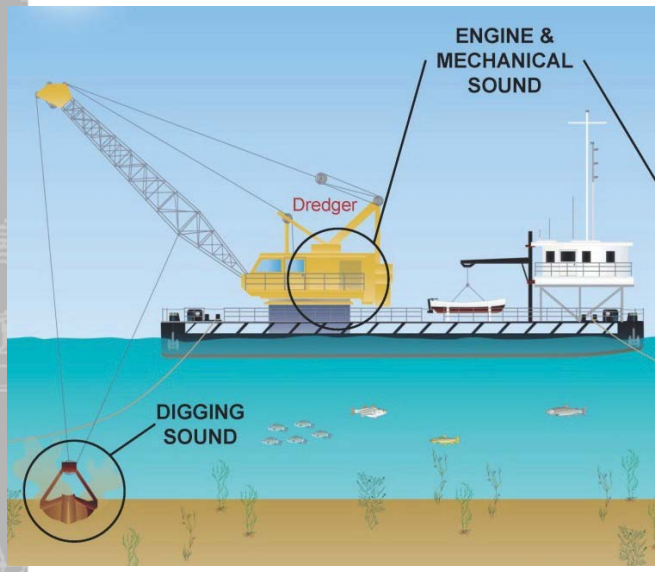
Cutter Suction Dredge SPLs (Reine and Dickerson 2014)





Stockton Deepwater Shipping Channel, California

Grab Dredge SPLs (Dickerson et al. 2001)



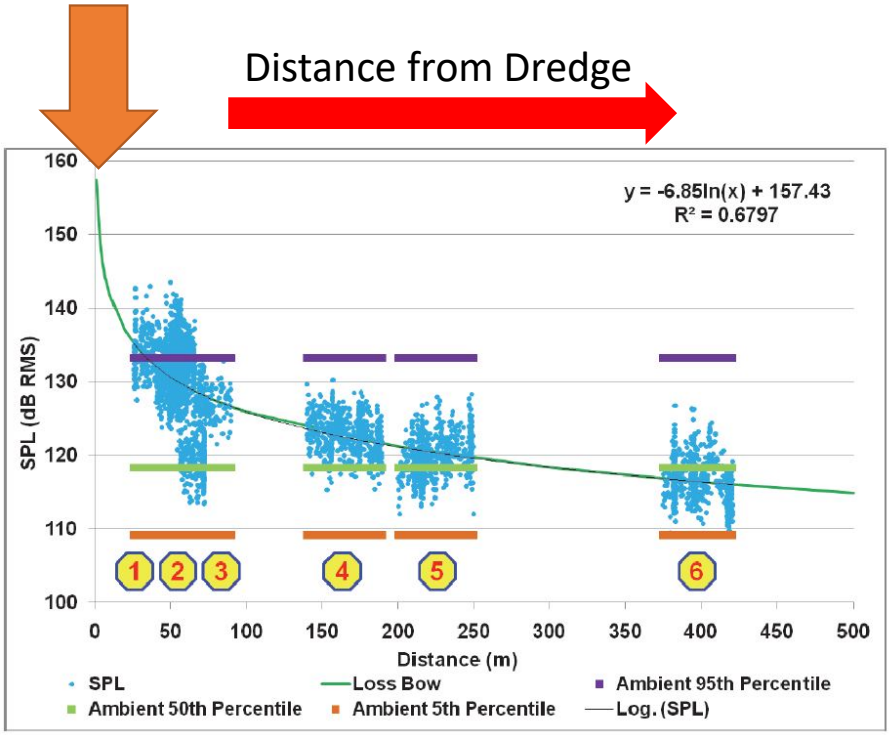
Dredge Activity	SPL at 150 m (dB re 1µPa RMS)	Peak Frequency (Hz)
Bucket striking bottom	124	162
Bucket digging	133	40
Bucket closing	99	316
Winch-in out	116	35
Dumping material into barge	108	82
Emptying barge at placement site	108	45

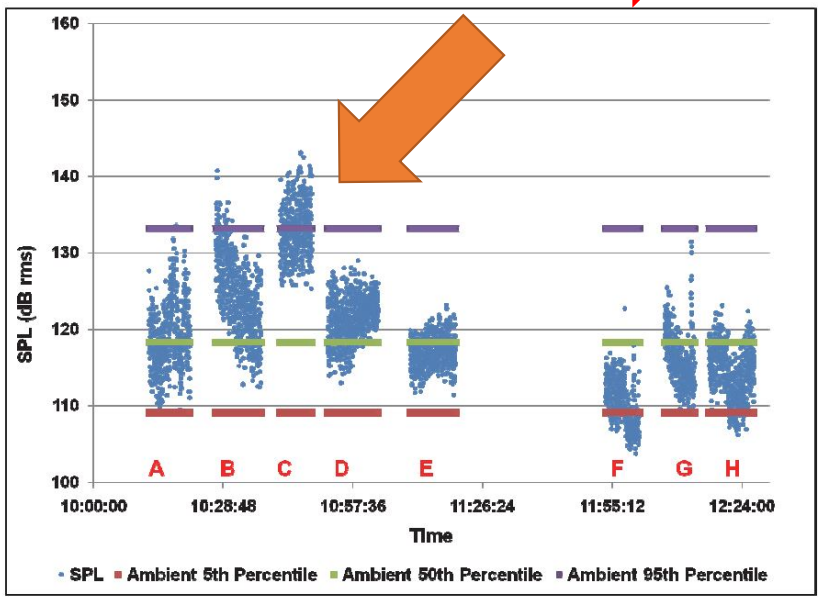
Dredging-induced Sounds

- Intermittent sounds
  - Depending on operational mode
    - Extraction, transiting, pumping, depositing
- Predominate sound sources:
  - Propulsion, machinery, pumping, aggregate
  - Greatest SPLs often associated with transit at speed
- Non-impulsive

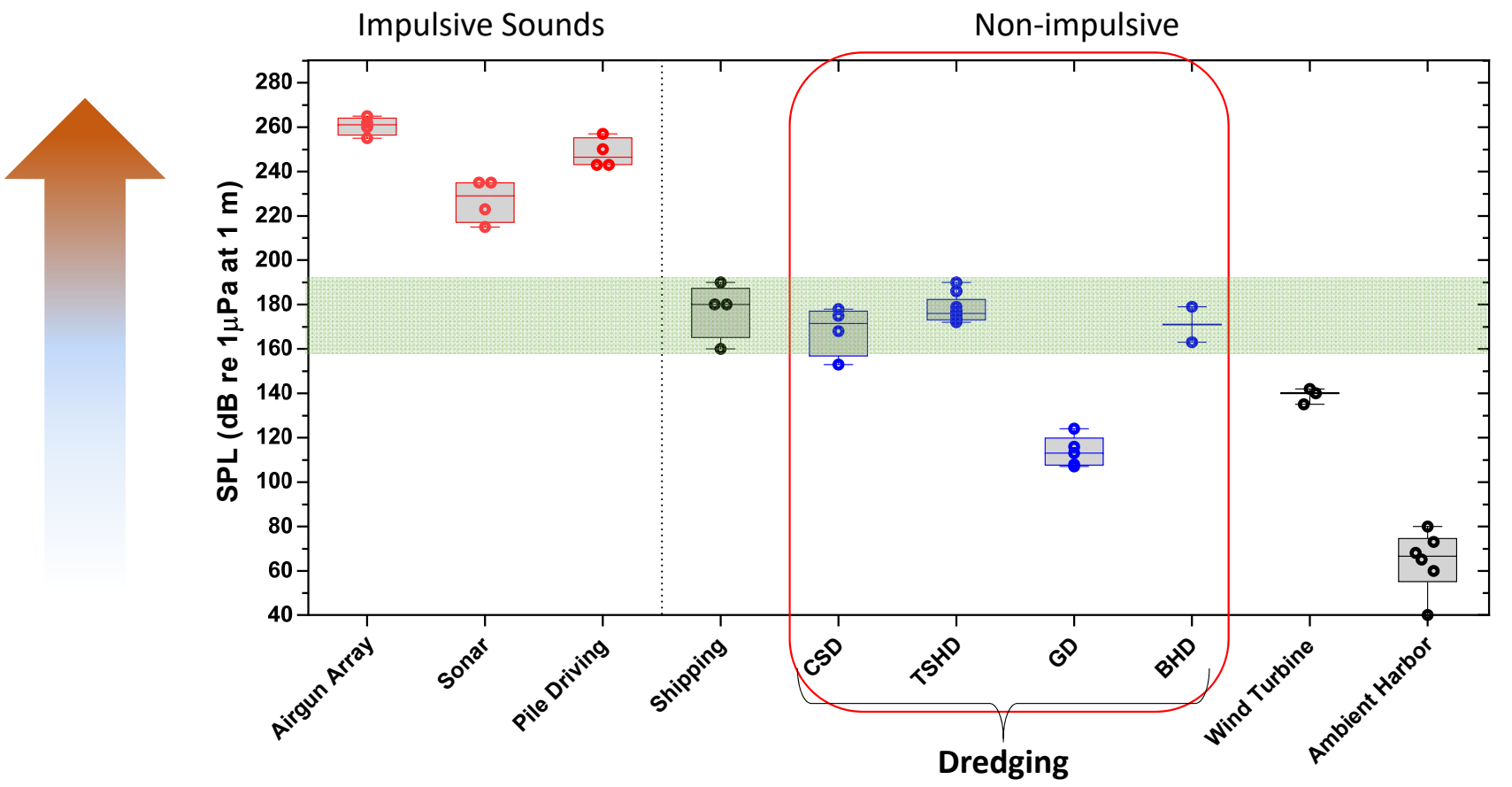
Spatial and Temporal Scales

- Hydraulic dredge (Reine and Dickerson 2014)





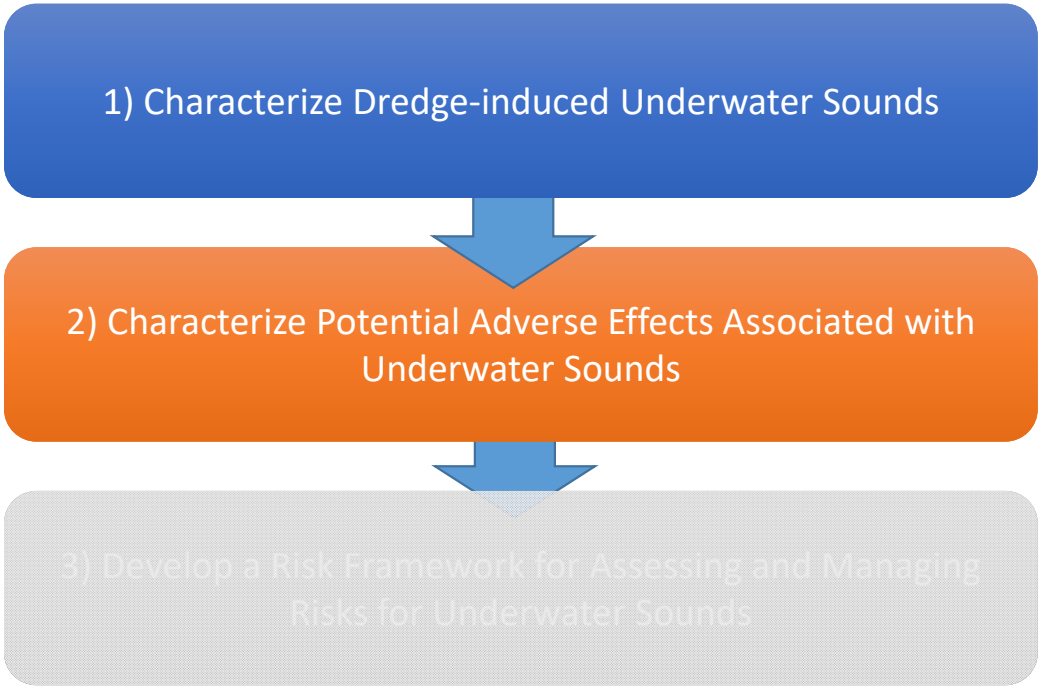
Sound Pressure Levels (SPLs)



Summary: Exposures

- Dredging-induced sounds:
  - < 190 dB re µPA at source
  - Non-impulsive and intermittent
  - Intensity and frequencies similar to commercial shipping
  - Mechanical dredging generally lower SPLs versus hydraulic dredging
  - Cavitation from propeller and thrusters often cited as the predominate sound source and intensity

Outline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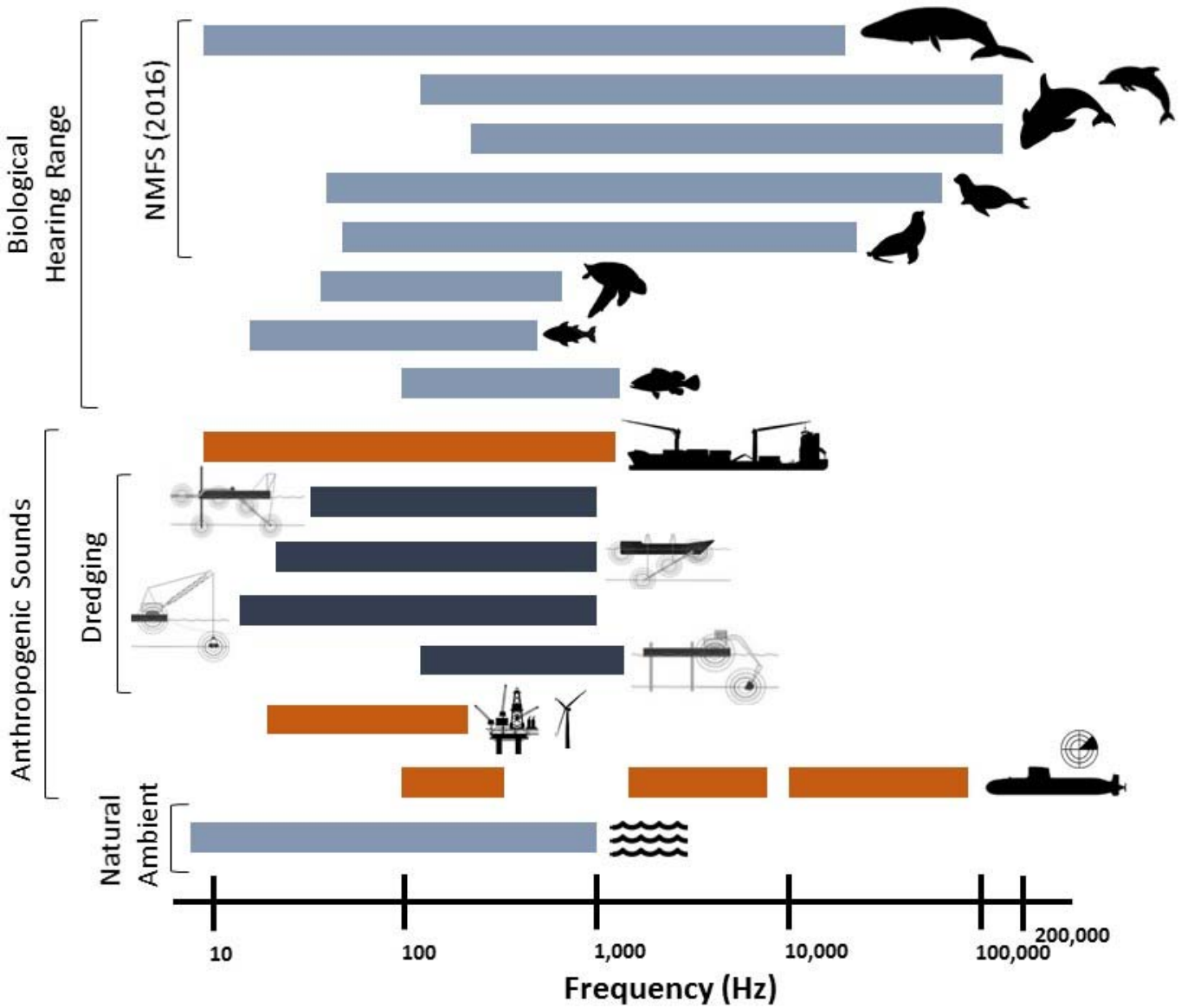
Biological Responses to Dredging-induced Sounds: Fish

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

Biological Responses to Dredging-induced Sounds: Mammals

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

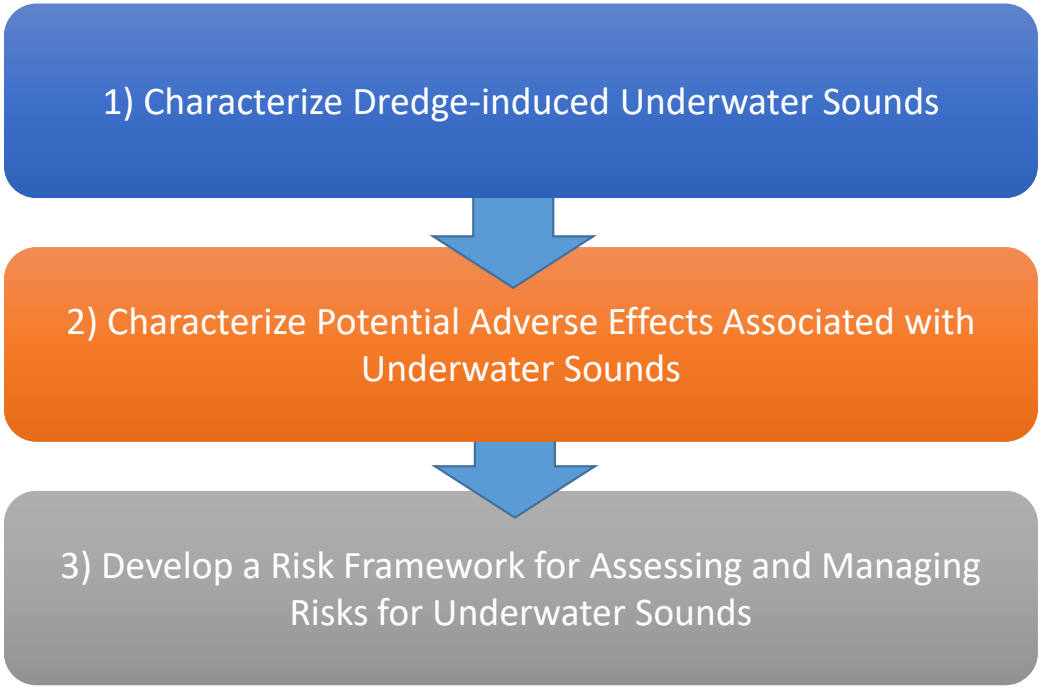


Suedel et al. (In Review)

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

Outline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NOAA National Marine Fisheries Service Technical Guidance

- July 2016 NOAA released guidance for assessing effects of anthropogenic sound on marine mammal hearing
- Focused on 5 marine mammal groups
  - Low- Mid- and High-Frequency cetaceans (whales & dolphins)
  - Otariid pinnipeds (sea lions and fur seals)
  - Phocid pinnipeds (true seals)

"…identifies the received levels, or acoustic thresholds, at which individual marine mammals are predicted to experience changes in their hearing sensitivity (either temporary or permanent) for acute, incidental exposure to underwater anthropogenic sound sources." (NMFS 2016)

NOAA National Marine Fisheries Service Technical Guidance

- Two groups of exposures:
  - **Impulsive** – brief, broadband, and consist of high peak sound pressure with rapid rise time and decay
    - "Peak" SPL and Cumulative Sound Exposure Level (SEL)
  - **Non-impulsive** – brief or prolonged, continuous or intermittent, do not have high peak sound pressure with rapid rise time and decay
    - **Cumulative Sound Exposure Level (SEL)**
- Biological Response Metrics:
  - Auditory Responses:
  - **Temporary Threshold Shifts (TTS)**
  - **Permanent Threshold Shifts (PTS)**

NOAA Technical Guidance: Summary

- The NOAA (2016) guidelines does not identify or address dredging sounds:
  - Sound metrics are not broadly applicable/ comparable to reported dredge exposures
  - NMFS intends for the SEL to account for 24hrs of exposure
  - No guidelines for intermittent periods of no sound production

> "Current data available for deriving acoustic thresholds using this metric are based on exposure to only a single source and may not be appropriate for situations where exposure to multiple sources is occurring." (p. 28; NMFS 2016).

> "It is not intended for accumulating sound exposure from multiple activities occurring within the same area or over the same time or to estimate the impacts of those exposures to an animal occurring over various spatial or temporal scales." (p. 28; NMFS 2016).

Path Forward (2018)

- Developing a risk-based framework for assessing and managing risks from underwater sound originating from dredging and other anthropogenic sources.
- Framework designed to be flexible so that it will consider the recently released NOAA noise guidance.
- Goal is to be comprehensive

Developing Underwater Sound Risk Framework

WODA (2013)

Summary

- 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
- NOAA (2016) guidelines are not directly applicable for dredging sounds
- A broader risk framework is being developed for assessing and managing underwater sounds

QUESTIONS?

A. Use Chat Feature; send to Everyone
B. Select *6 on your phone to unmute your line and ask verbally
C. After the meeting, email:
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   - Burton.Suedel@usace.army.mil
   - Joseph.R.Wilson@usace.army.mil
D. Webinar suggestions, email:
   - Courtney.E.Chambers@usace.army.mil

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