

Biological Effects of Dredging-Induced Underwater Sounds

Andrew McQueen, PhD

Research Biologist

Environmental Laboratory

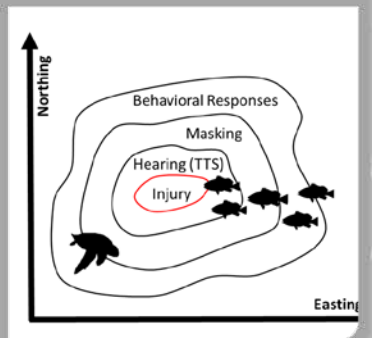
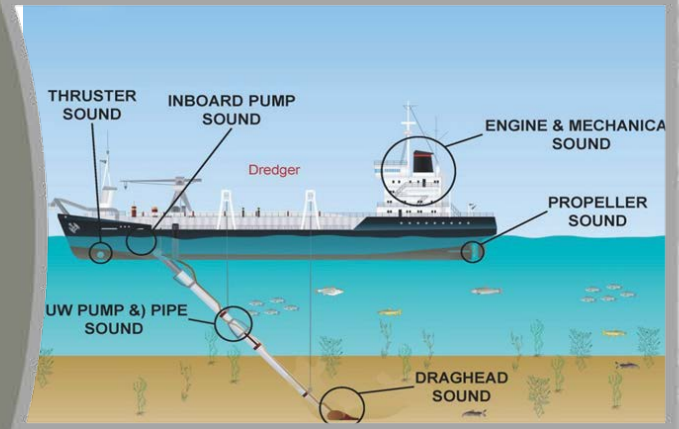
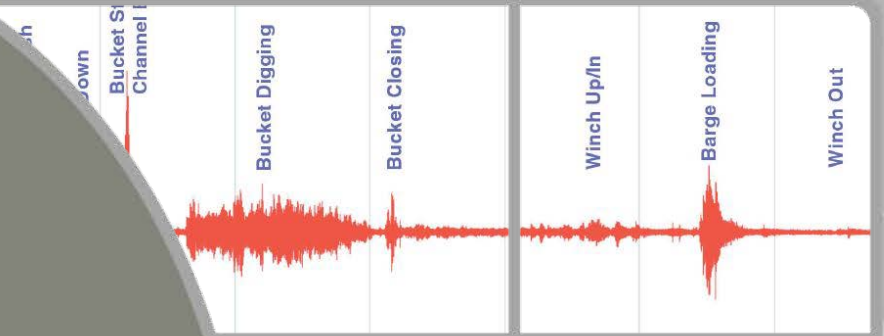
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Introduction

- 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?**

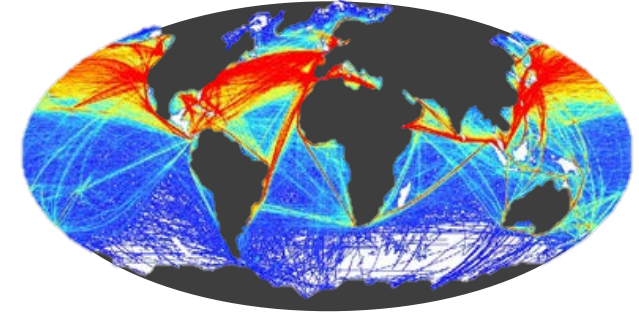


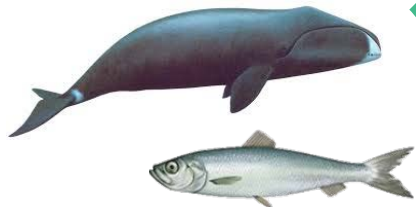
Image: Ocean Conservation Research (2018)



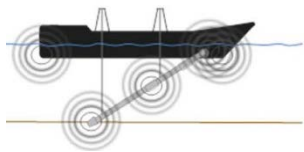
PRESENTAION OUTLINE



1) Characterize Dredge-induced Underwater Sounds (Exposures)



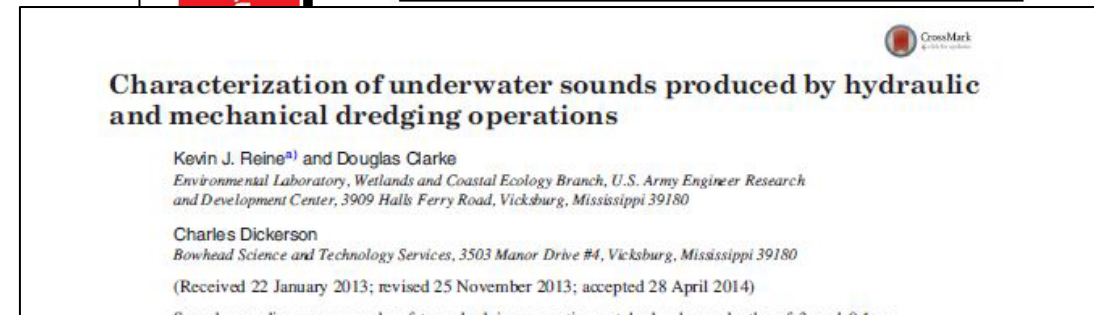
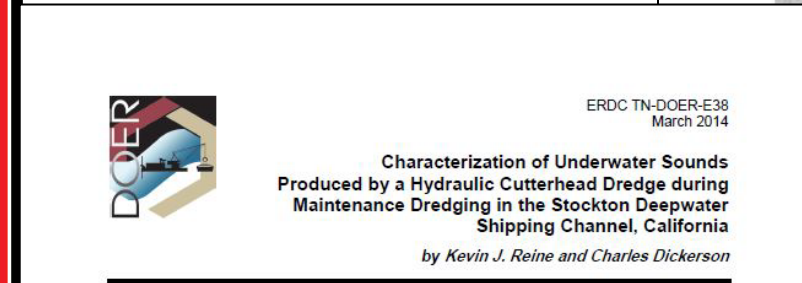
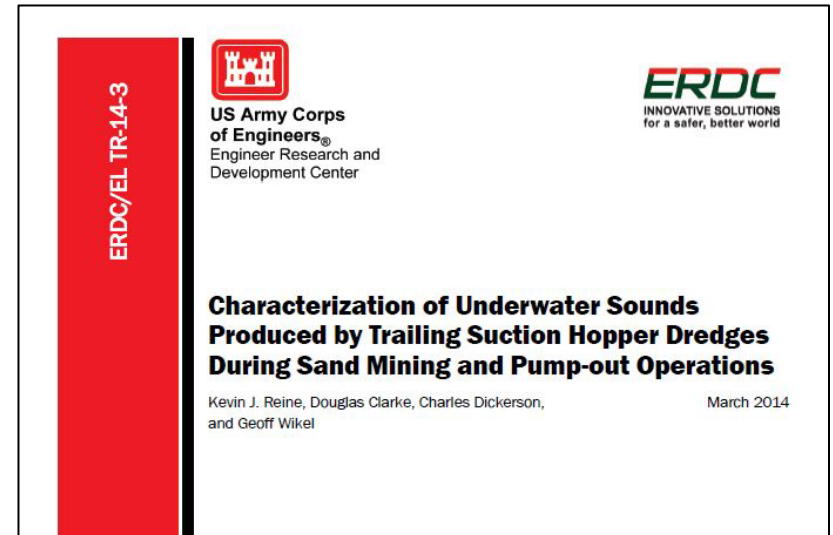
2) Characterize Potential Adverse Biological Effects Associated with Underwater Sounds (Responses)



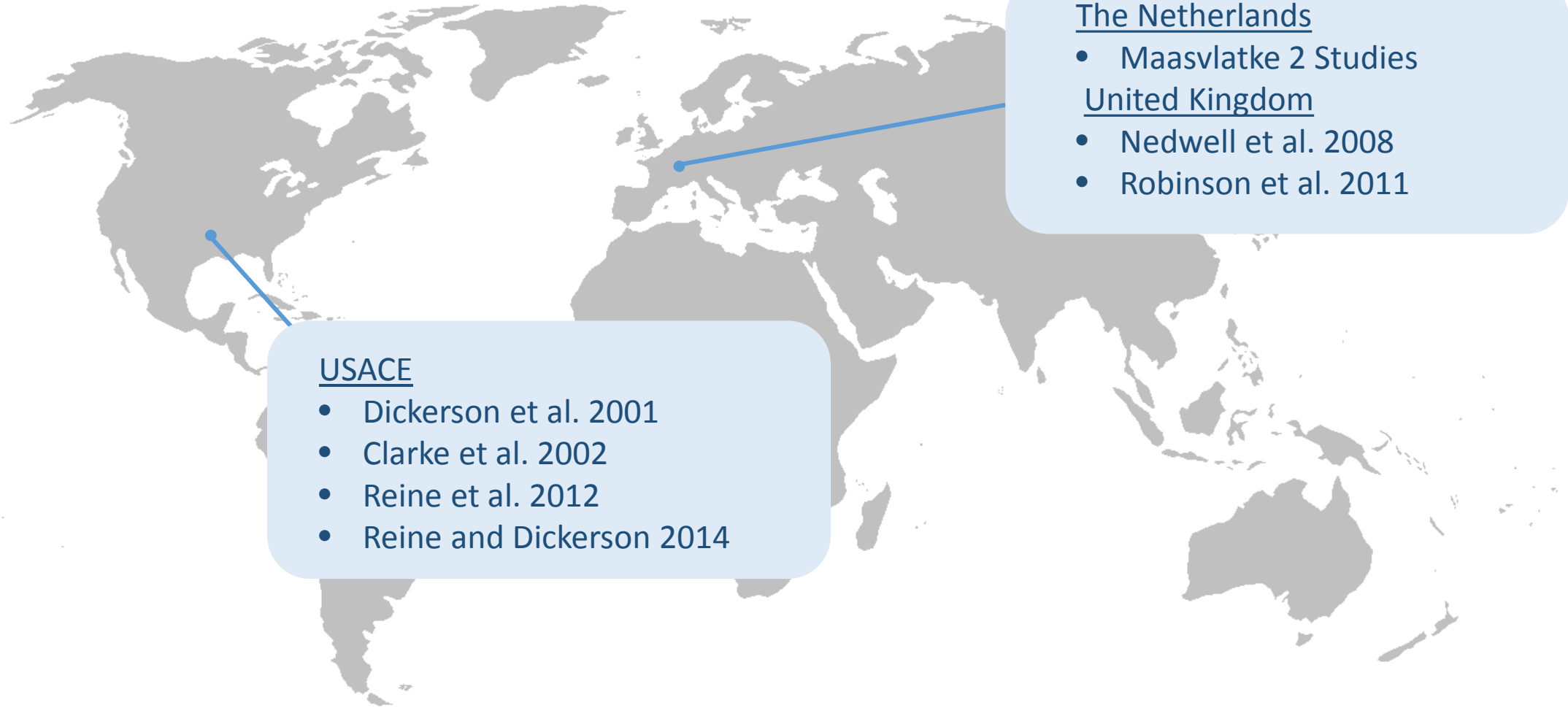
3) Implications to Dredging Operations

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



Dredging Sound Studies



The Netherlands

- Maasvatke 2 Studies

United Kingdom

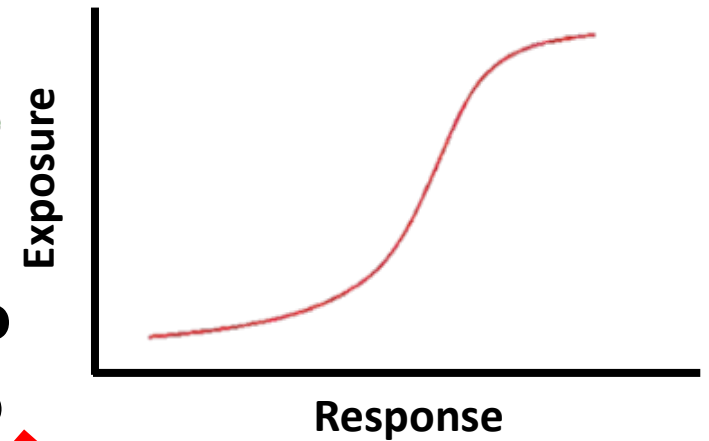
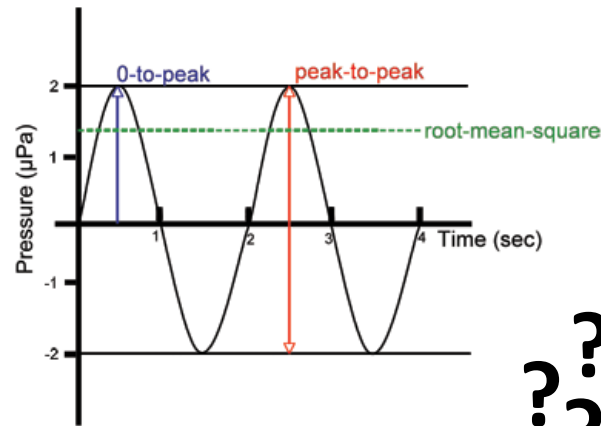
- Nedwell et al. 2008
- Robinson et al. 2011

USACE

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

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

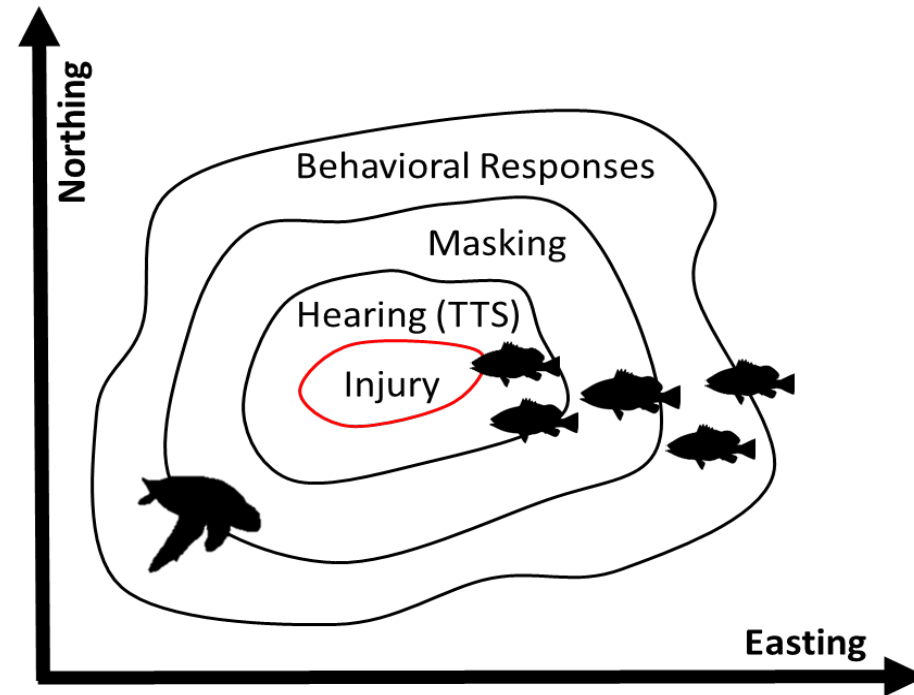


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Biological Endpoints (Responses)

- 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)

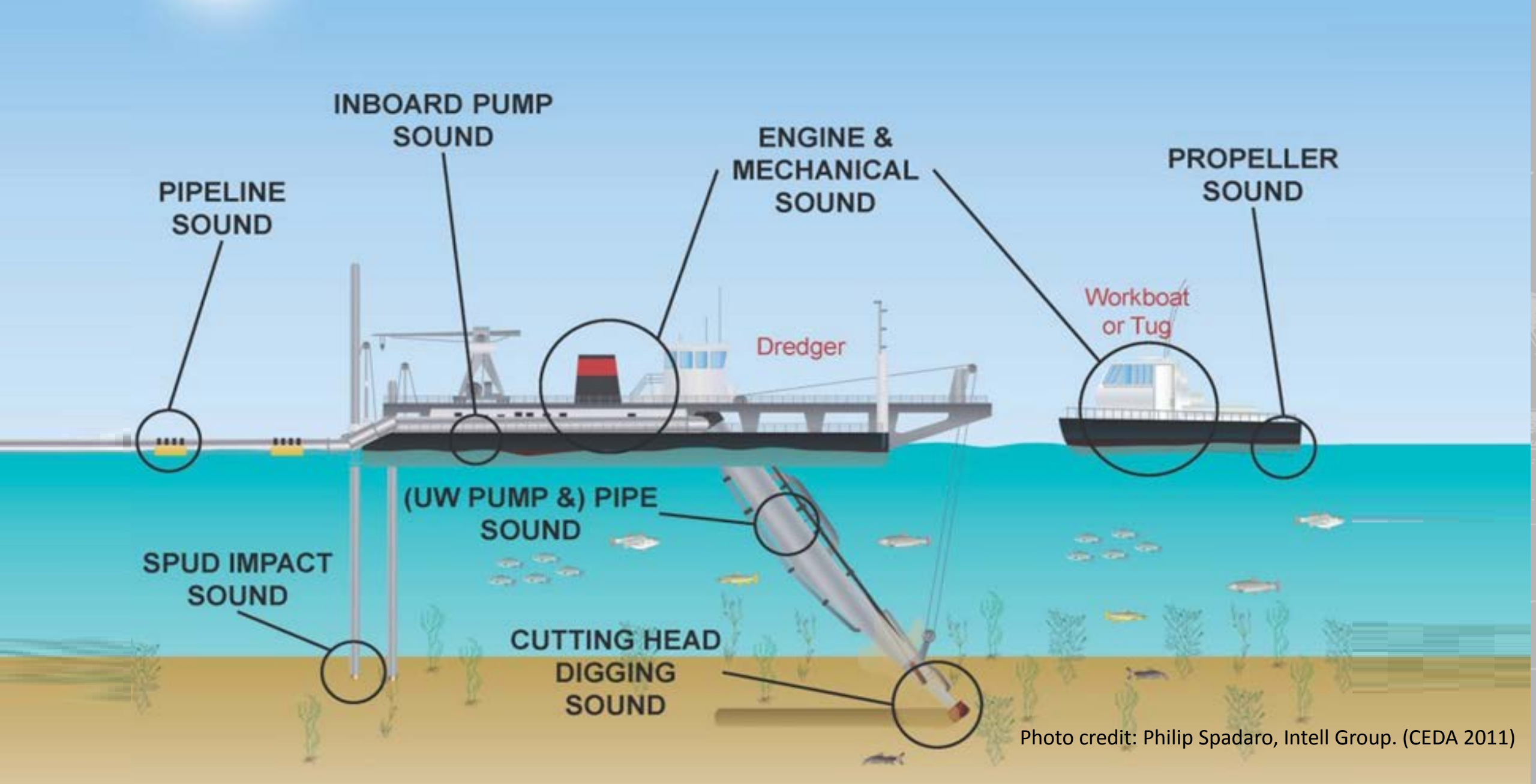
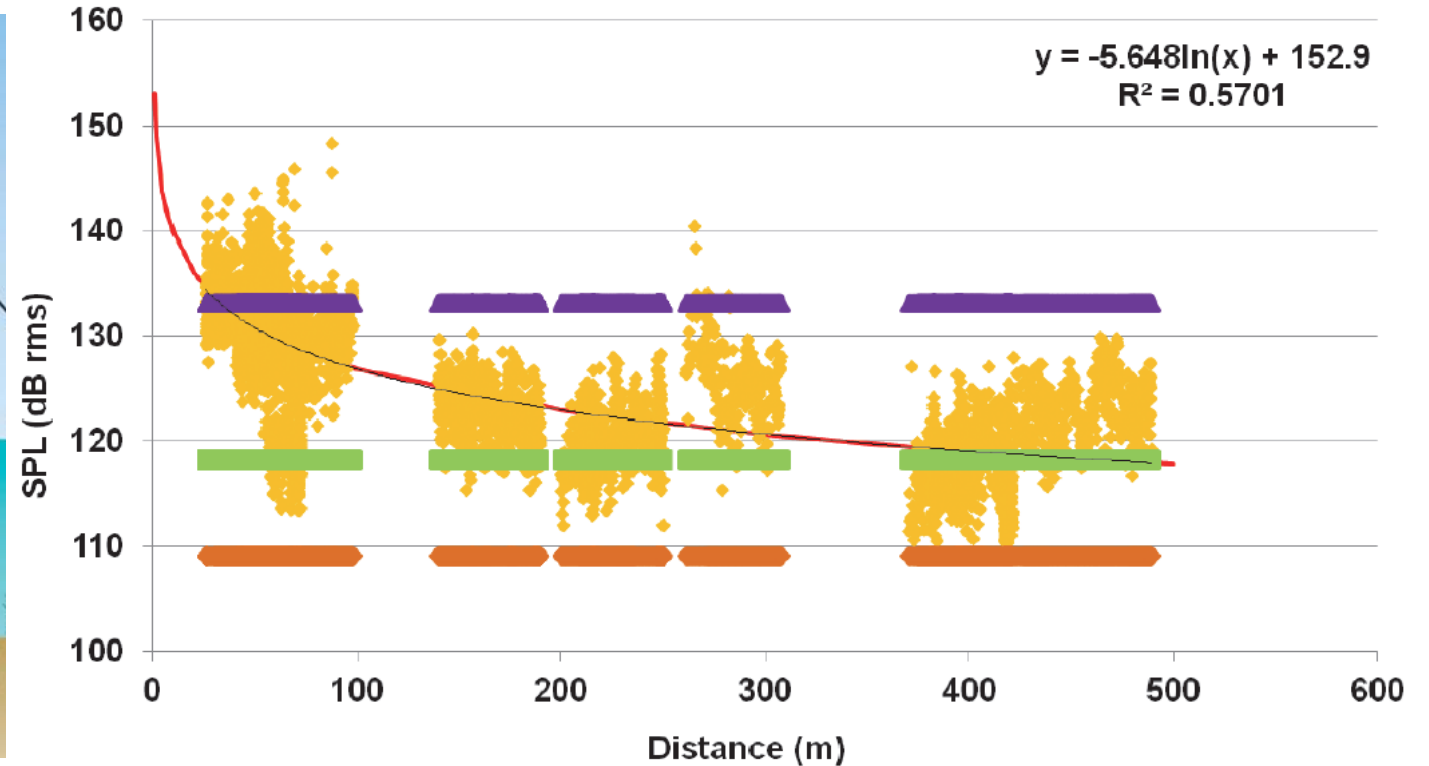
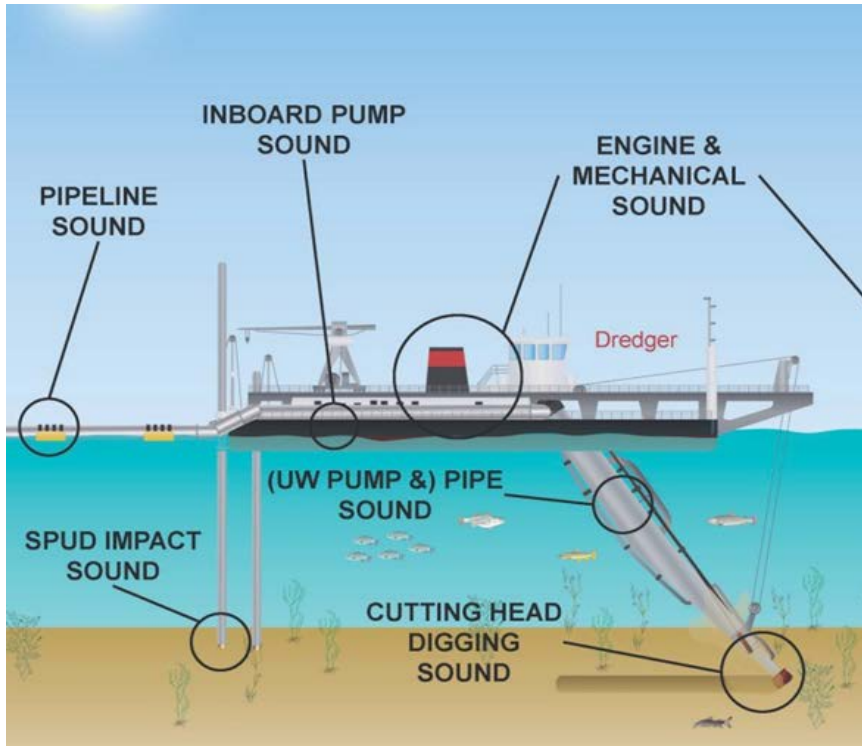


Photo credit: Philip Spadaro, Intell Group. (CEDA 2011)

Results: Cutter Suction Dredge SPLs (Reine and Dickerson 2014)

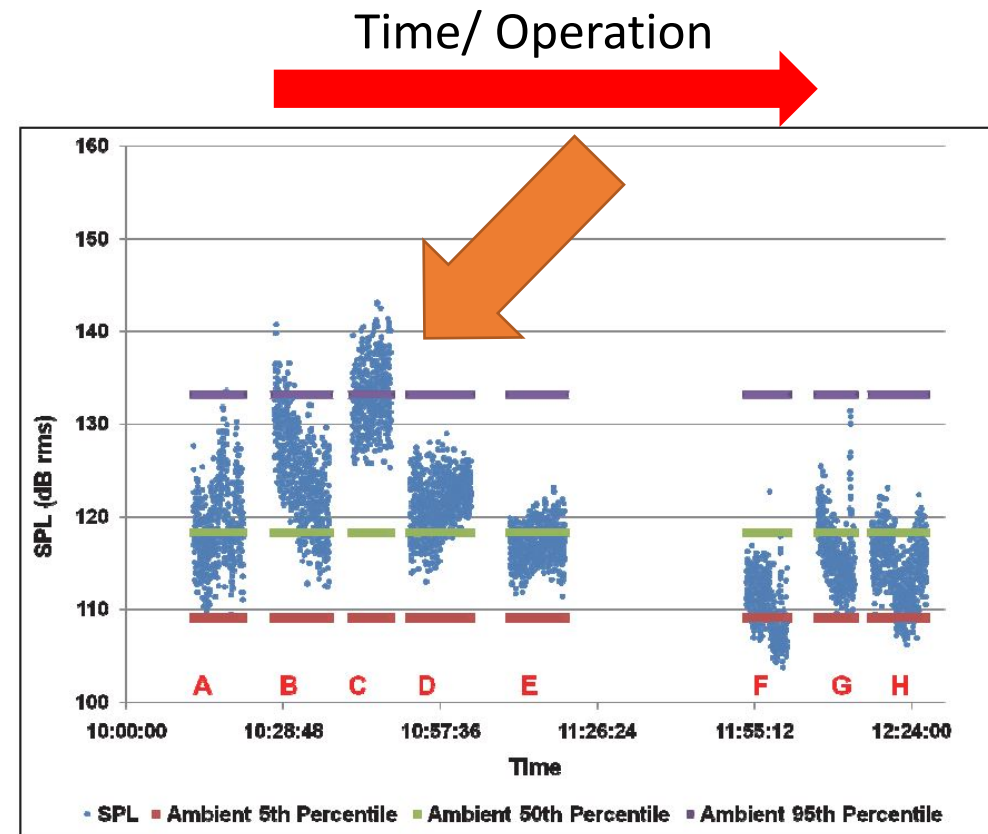
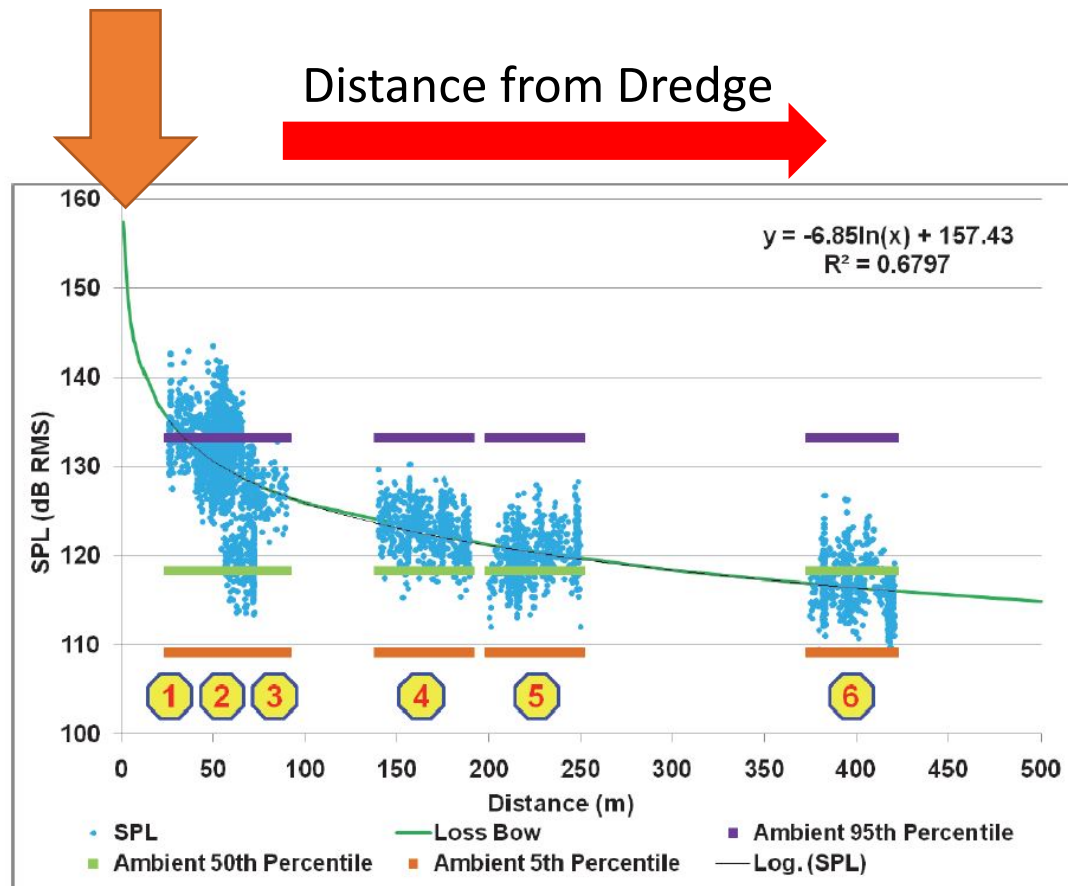


- ◆ SPL
- ◆ Ambient 5th Percentile
- Loss
- Log. (SPL)
- ▲ Ambient 95th Percentile

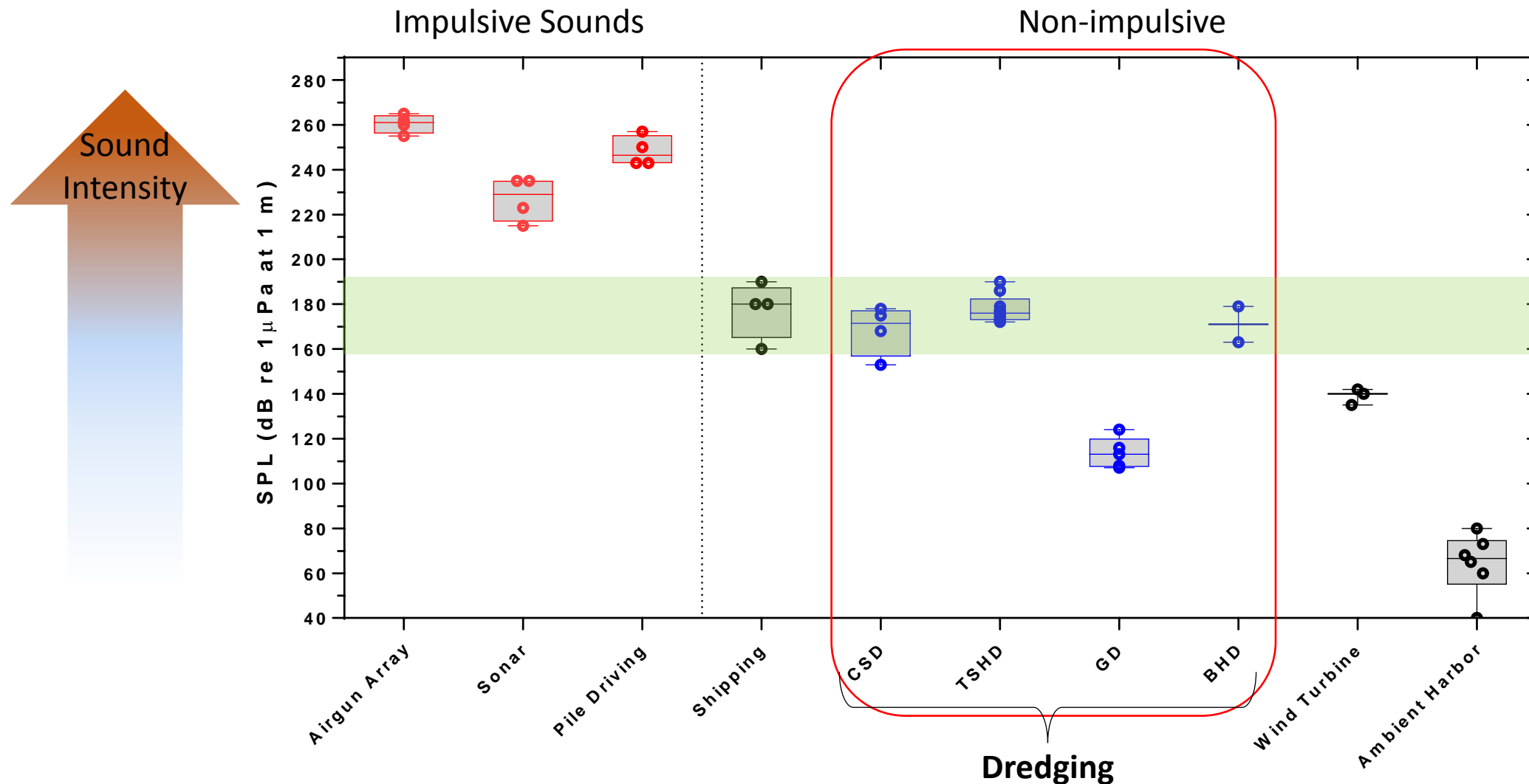
Stockton Deepwater Shipping Channel, California

Spatial and Temporal Scales

- Hydraulic dredge (Reine and Dickerson 2014)



Sound Pressure Levels (SPLs)



Summary: Exposures

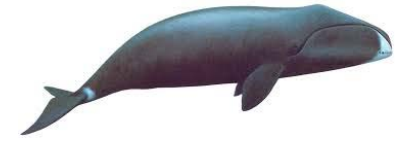
- Dredging-induced sounds:
 - < 190 dB re μ PA at source
 - Non-impulsive and intermittent
- Predominate sound sources:
 - **Propulsion**, machinery, pumping, aggregate
 - **Greatest SPLs often associated with transit at speed**
 - Intensity (SPL) and frequency (Hz) similar to shipping
- Mechanical dredging generally lower SPLs versus hydraulic dredging
- **Cavitation from propulsion often cited as the predominate sound intensity**

Biological Responses to Dredging-induced Sounds: Fish



Sound Source	Exposure Level	Species	Effect	Reference
Shipping + Dredging	186 SEL (db re 1 μ PA/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 1 μ PA RMS)	Atlantic salmon	No significant behavioral effects	Nedwell et al. 2008
Dredging	163 SPL (dB re 1 μ PA RMS)	Atlantic salmon	No significant behavioral effects	Nedwell et al. 2008
Dredging	117-122 SPL (dB re 1 μ PA at 50 m)	Clupeidae (herring, shad, etc.) and flat fish	No auditory risk	DEFRA 2003

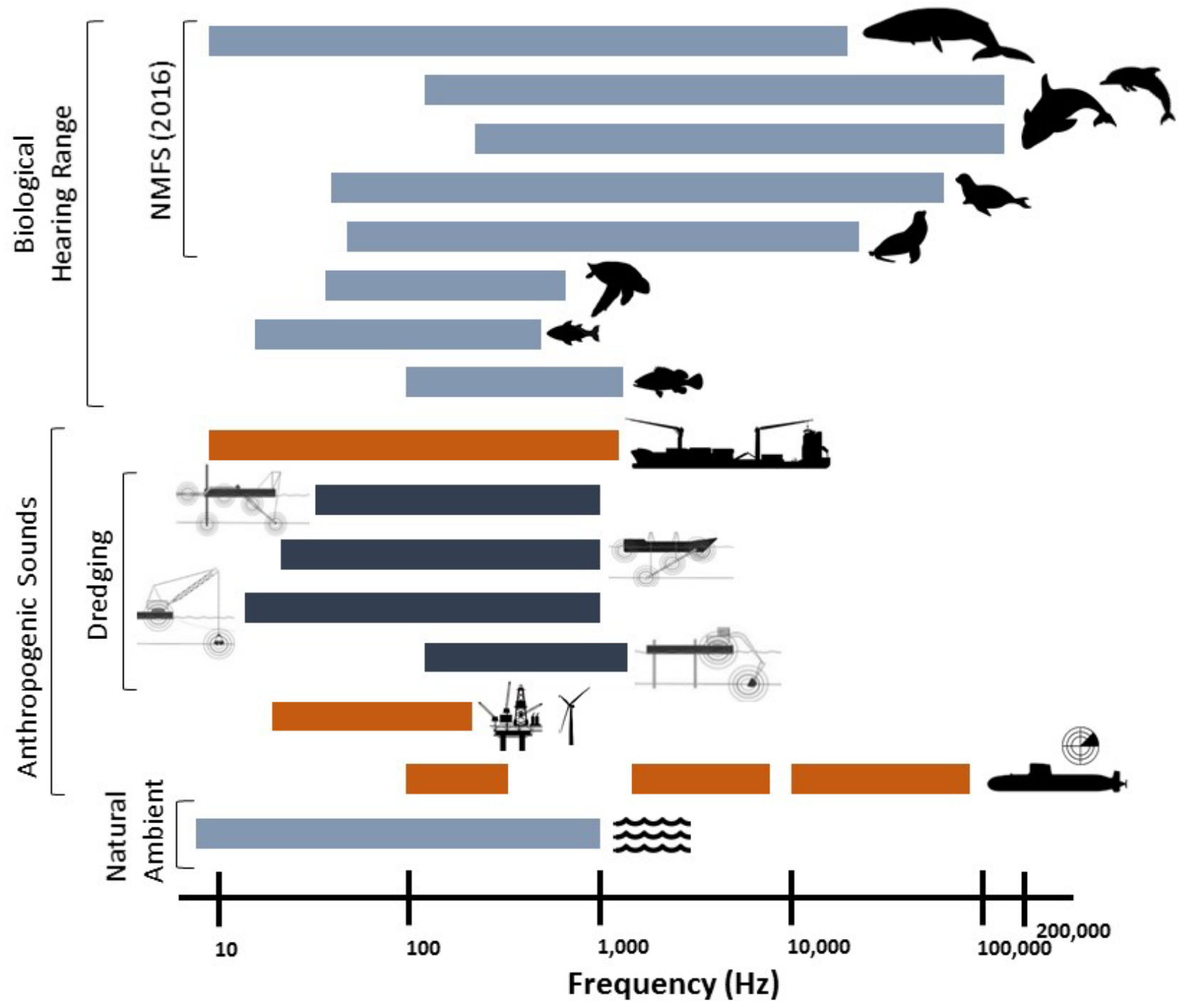
Biological Responses to Dredging-induced Sounds: Mammals



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

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



NOAA Technical Guidance

- The NOAA (2018) guidelines does not identify or address dredging sounds:
 - Sound metrics are not broadly applicable/ comparable to reported dredge exposures
 - SEL to accounts 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).

“We recommend its use but note that user groups/stakeholders are not required to use the Technical Guidance; **other scientifically rigorous methods are acceptable.**” (NMFS 2018)

Path Forward – Need for Risk-based Framework

- 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**
- Goal is to be comprehensive

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
- NOAA (2018) guidelines are not directly applicable for dredging sounds
- A broader risk framework is being developed for assessing and managing underwater sounds

THANK YOU!

QUESTIONS?