Potential Behavioral and Physical Effects of Seismic Activities on Marine Mammals

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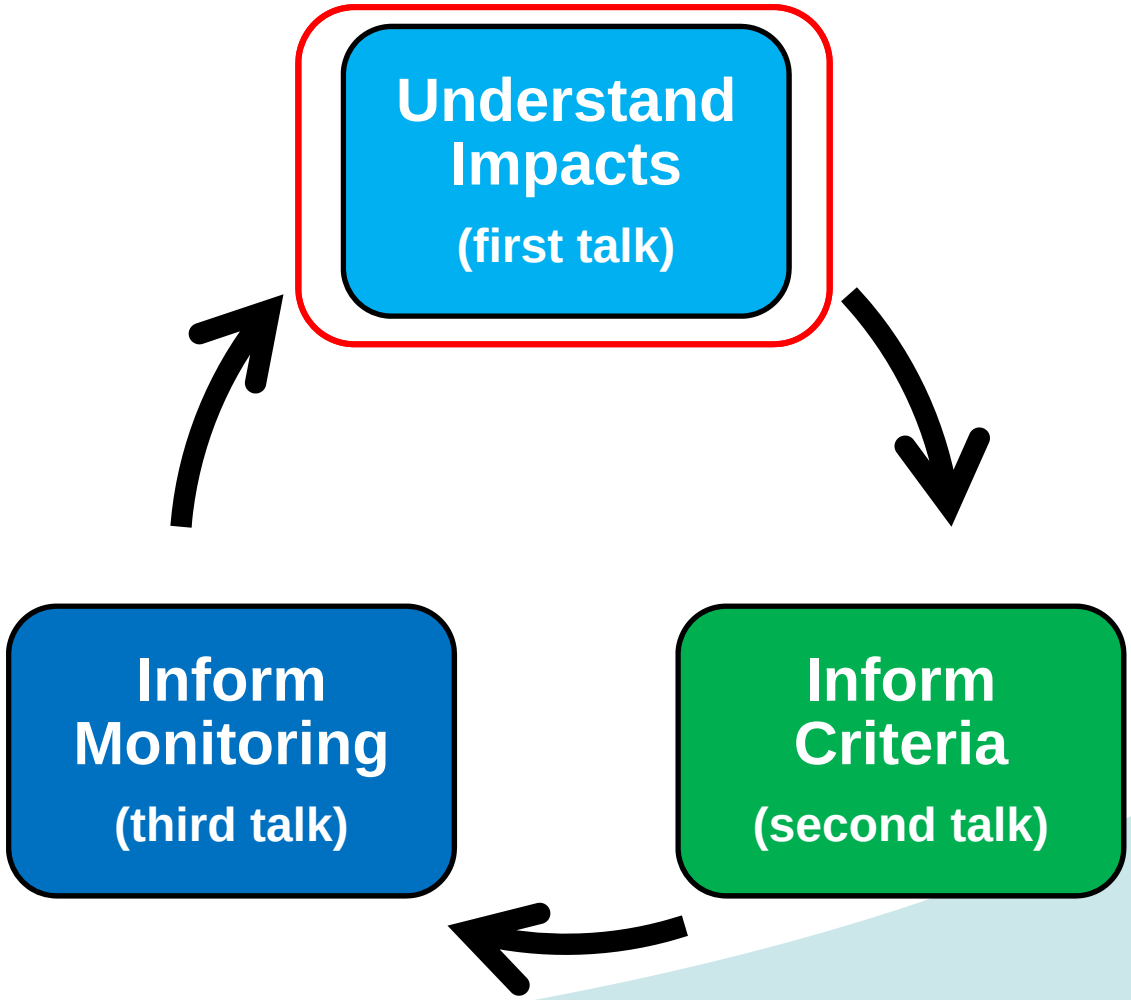
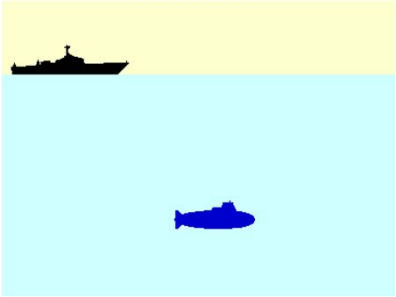
Presentation Overview
(Going to be hearing from me 3x!)



Sound and Marine Life

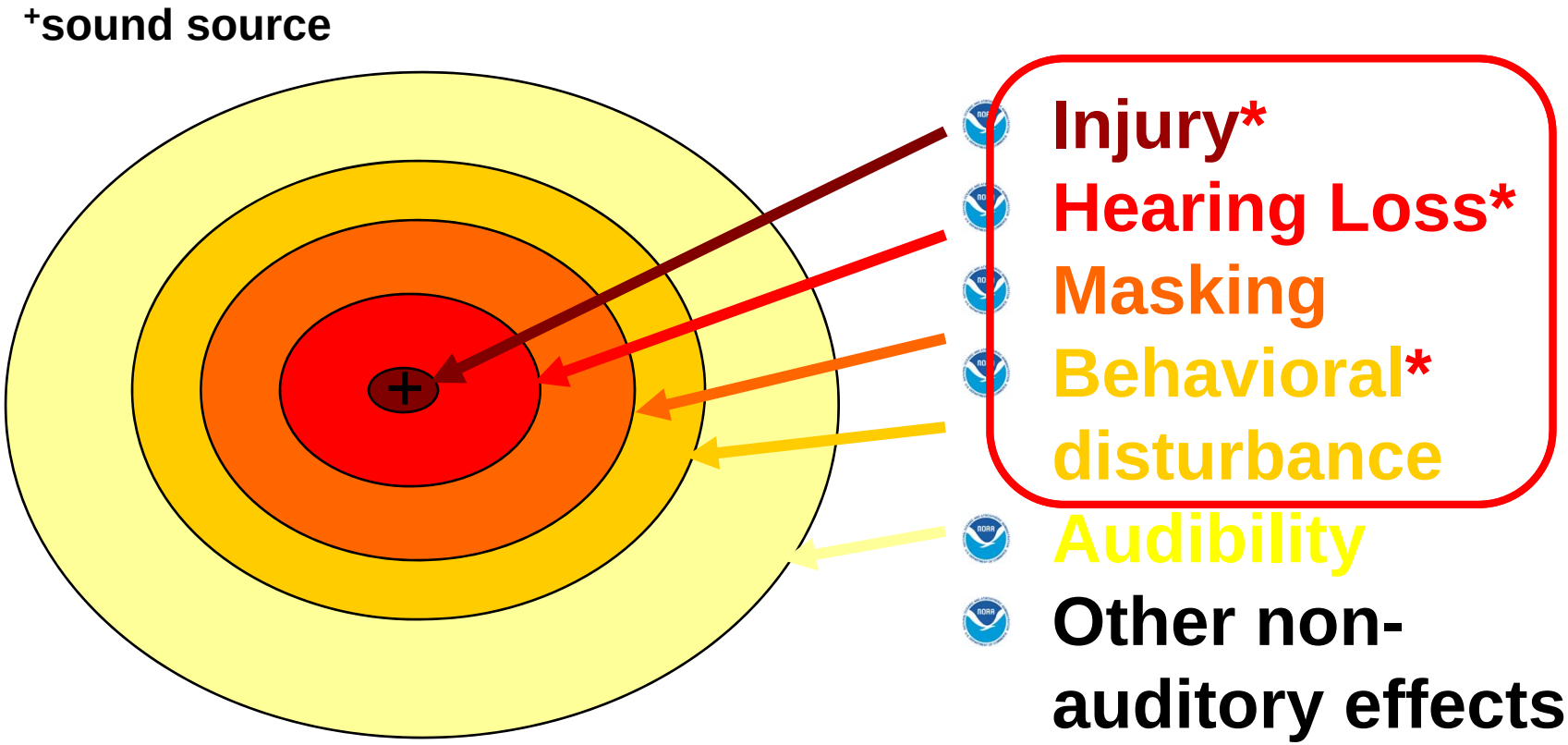


- **Ocean is inherently noisy (more than Navy sonar)**
  - Natural: wind, earthquakes, biologics
  - Anthropogenic: sound intentionally (sonar, seismic) or incidentally (construction, shipping)

- **Sound is important to marine species**
  - Communication, navigation, predator/prey detection

- **Outstanding questions (a lot of public interest)**
  - When is underwater sound a threat to marine life?
  - What can be done to mitigate effects while allowing activities vital to national security and economy?

Spatial Zones of Sound Influence



* NMFS has acoustic criteria

Adapted from Richardson *et al*., 1995

What We Know?
(and don't know!)

- **Mortality**
  - MFA sonar: beaked whales
  - Explosives

- **Hearing loss**
  - Laboratory studies
- **Masking**
  - Adjustments associated with noise

- **Behavioral disturbance**
  - None to avoidance or changes in vocalization, respiration, foraging, distribution
  - Highly variable
- **Stress & Other Effects?**

Seismic Activities: Potential Physical Effects

- **Mortality?**
  - Concern over seismic & potential for stranding events
- **Injury (Permanent Threshold Shift)**
  - Danger from impulsive sources (high peak pressure, rapid rise time)
  - No direct data on marine mammals (estimate from terrestrial mammal data)
- **Temporary Threshold Shift (Laboratory Studies)**
  - Seismic watergun (Finneran et al. 2002): Bottlenose dolphin (n=1); Beluga (n=1)
  - Single airgun (Lucke et al. 2009): Harbor porpoise (n=1)
  - Arc-gap transducer (sparker) (Finneran et al. 2003): California sea lion (n=2)

Marine Mammal TTS Specifics

- **Seismic watergun (Finneran et al. 2002)**
  - Source: broadband (up to 40 kHz, most energy below 1 kHz)
  - Bottlenose dolphin: no incidents of TTS (i.e., above 6 dB)
  - Beluga TTS: 186 dB cSEL (unweighted) & 224 dB_{pk}

- **Single airgun (Lucke et al. 2009)**
  - Source: broadband (up to 20 kHz, most energy below 500 Hz)
  - Harbor porpoise TTS: 164 dB cSEL (unweighted) & 195 dB_{pk}
  - Findings: Indicate HF cetaceans have a lower TTS onset than MF cetaceans (Dall's porpoise similar trend?)
    - Confirmed by other studies (Kastelein et al. 2012: OBN)

Marine Mammal TTS Specifics (cont'd)

- **Arc-gap transducer (Finneran et al. 2003)**
  - Source: broadband (up to 40 kHz, most energy below 10 kHz)
  - California sea lions: no incidents of TTS (i.e., above 6 dB) with exposures up to 163 dB cSEL (unweighted)

- **Current research (Finneran Laboratory)**
  - Bottlenose dolphins & multiple shots (unpublished)

What We Know About TTS: General Trends

- **Duration (metric considerations)**
  - Intermittent exposures: Recover faster (compared to continuous exposures of the same duration)
  - Exposures of longer duration & lower levels: More TTS (onset at lower level; amount of TTS higher) than those exposures of higher level & shorter duration with the same cSEL
  - Recovery: Longer exposures = longer durations to recover (compared to shorter duration exposures with the same cSEL)

- **Frequency (weighting considerations)**
  - Sound in regions of highest hearing sensitivity: Greater TTS, including higher growth rates (dB TTS/dB noise)

Seismic Activities: Potential Behavioral Effects

- **General**
  - Further from source: Lose impulsive characteristics
    - o Longer pulse duration (reverberation); masking?

- **Mysticetes (most data)**
  - Changes: Vocalization, Distribution, Respiration, & Foraging
  - Avoidance & Attraction
  - Aberrant behavior? (increased breaching): Gray whales
  - Most data: Bowhead whales; various contexts (other species)

Seismic Activities: Potential Behavioral Effects

- **Odontocetes (fewer data, especially with RL)**

  - Changes: Vocalization, Distribution, & Foraging
  - Avoidance & Attraction
  - Aberrant behavior? (erratic locomotion & unusual posture): Pantropical spotted dolphin
  - Ice entrapment (3 instances: narwhals): causally linked to seismic
  - Most data: Sperm whales; Delphinids

- **Pinnipeds (even fewer data, especially with RL)**

  - Changes in density
  - Localized avoidance
  - Alterations in laboratory setting
  - Most data: Arctic seals (ringed, bearded, spotted)

Notable Behavioral Effects

- **Many situations: No dramatic effects observed**

- **Mysticetes**
  - Vocalize: more or less
  - Avoidance: short-term, localized → entire groups leaving area
  - Changes in distribution
  - Sensitive periods/contexts/habitats (e.g., resting)

- **Odontocetes (fewer data)**
  - Subtle effects on foraging (SWSS Study)
    - Delay & lower buzz rate
  - Changes in distribution
  - Laboratory TTS studies

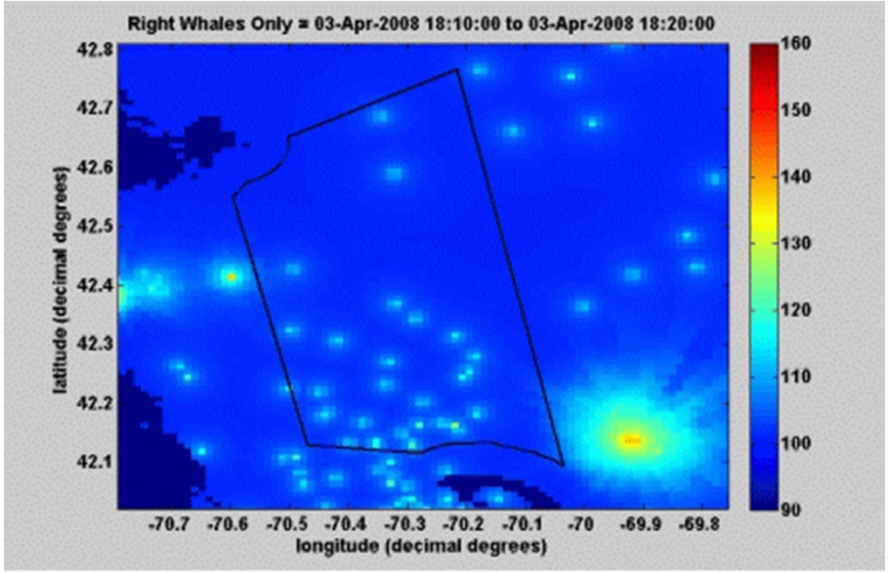
Masking & Effects on Acoustic Habitat

- **Ocean noise, especially commercial shipping, is a growing global problem for marine ecosystems**

- **Acute sources**
  - Intense events that can have adverse physical & behavioral impacts that can affect health & fitness

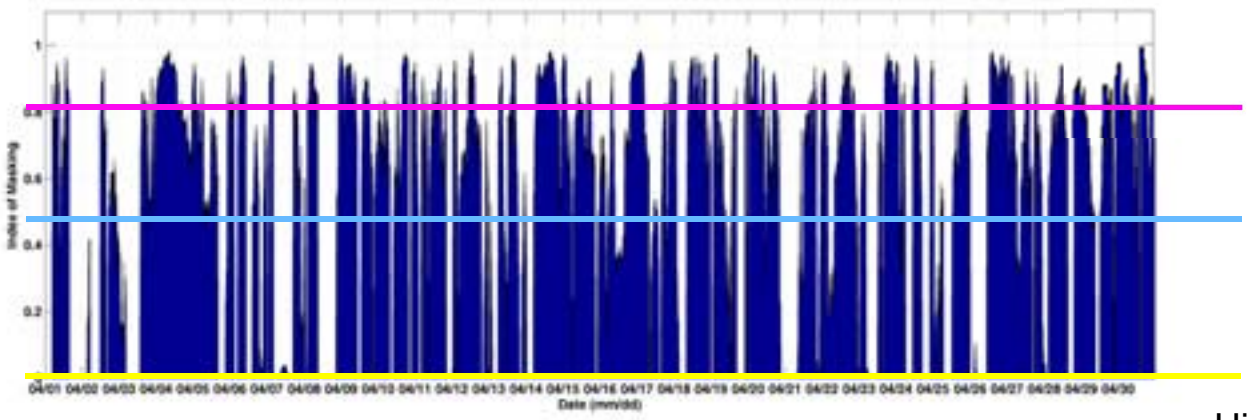
- **Chronic sources**
  - Rising background noise limits marine animals' communication range & ability to sense their environment
  - Can affect animals over broad temporal & spatial scales, especially mysticetes (e.g., long distances at low received levels)

Masking: Stellwagen Bank NMS



An example of predicted received levels (71-224 Hz, dB re 1µPa, scale far right) produced by calling right whales, large commercial ships and wind-dependent background noise within the study area (boundaries of the SBNMS outlined in black) calculated every 10-min over a 9-hr period.

North Atlantic Right Whale Masking



Right whale communication masking index calculated every 10-minutes for a month, where 0 indicates no masking relative to historic levels and 1 indicates 100% masking as a result of modern-day levels of noise in the study area. These calculations suggest significant loss of communication capabilities for right whales in the SBNMS.

Seismic Activities & Impact on Vocalizations

- **Blue whales (Di Iorio & Clark 2009)**
  - Whales vocalize more when sparker activity was occurring
- **Bowhead whales (Blackwell et al. 2013)**
  - Fewer calls detected near seismic activities
- **Fin whales (Clark & Gagnon 2006)**
  - Ceased vocalizing through entire seismic operation (weeks)
- **Airgun sounds have been recorded up to 4000 km from vessel (Nieukirk et al. 2012); Can be a chronic source**
- **What are energetic consequences of vocal adjustments?**

Behavioral Effects: Bigger Picture Issues

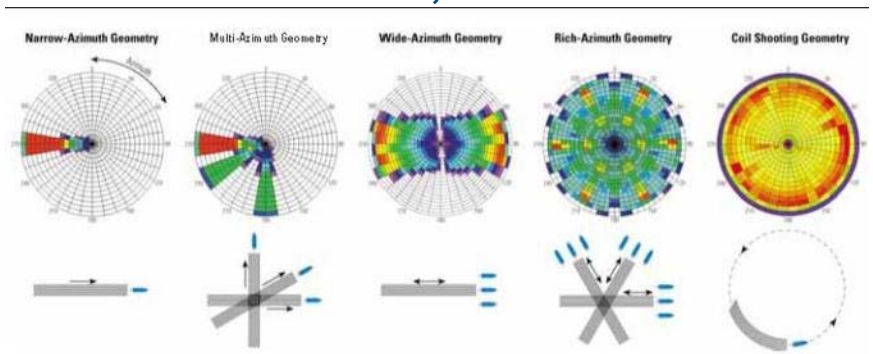
- **Most significant issue: Potential fitness consequences**
  - Reproduction: Mating behavior
  - Survival: Stranding events, Separation of calf/pup
  - Growth: Feeding & Energetics

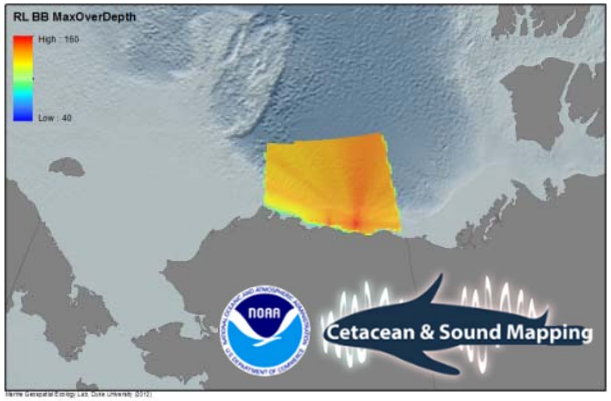
- **Cumulative Impacts**
  - Multiple sound sources or with other stressors
- **Population-Level Impacts**
  - How do effects to individuals translate to higher level effects?

Appropriate Metrics for Each?

Source Considerations

- **What is the typical "soundscape"?**
  - 2D, 3D, 4D, WAZ, MAZ, RAZ, coil
  - Multiple vessels
  - Other sources beyond airguns: boomers, sparkers, side-scan sonars, echosounders





- **Spatial-Temporal-Spectral**
  - Spatial: Horizontal & long-distance propagation
  - Spectral: Higher frequency components? Other Sources?

Thanks for listening!

Any questions?

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