Noise dosage regimens: Can physiological noise impacts on North Atlantic right whales be managed temporally?

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Changes to the temporal structure of noise production (i.e., the noise dosage regimen for exposed animals) may help alleviate impacts of noise on North Atlantic right whales (NARW) and other marine mammals. However, we know little about how the resulting trade-offs affect individuals (e.g., slowing ships reduces peak noise levels, but prolongs transit time). Accordingly, we reviewed available literature on physiological effects of noise exposure in model laboratory species (e.g., rats). Many generalized aspects of stress responses were noted, including periods of heightened activity of the Sympathetic Nervous System, Hypothalamic-Pituitary-Adrenal axis, and other stress-related neuropeptide signalling systems, such as corticotrophin-releasing hormone. Importantly, each of these systems exert broad, immediate influences on behaviour and physiology of the organism (e.g., reduced social and sexual behaviour), while also contributing to long-term adverse health consequences (e.g., disruptions in cognitive or affective function). Many classic effects of chronic stress were reported following days to weeks of exposures, including alterations in hippocampal function (reduced dendritic branching and spines, reduced neurogenesis, etc.) that contribute to cognitive dysfunction (e.g., impaired learning and memory). Reported metabolic changes escalated with the duration of noise exposure and behavioural indices of increased anxiety. Elsewhere, increased tau phosphorylation in the prefrontal cortex may contribute to noise-related vulnerability to neurodegenerative processes. Similarly, inflammatory processes in the Central Nervous System likely contribute to enhanced pain sensitivity (hyperalgesia). Although, a broad spectrum of behavioural and neural alterations were evident in models exposed to noise on an acute, subacute, or chronic basis, studies examining long-term chronic noise exposure at more moderate sound levels were lacking. This gap limits the use of terrestrial models to inform effective management decisions for NARWs and other marine mammals. However, repeated acute and subacute exposures over even relatively brief periods of days would be expected to have enduring physiological and cognitive impacts.

Noise Dosage Regimens: Can Physiological Noise Impacts on North Atlantic Right Whales be Managed Temporally?

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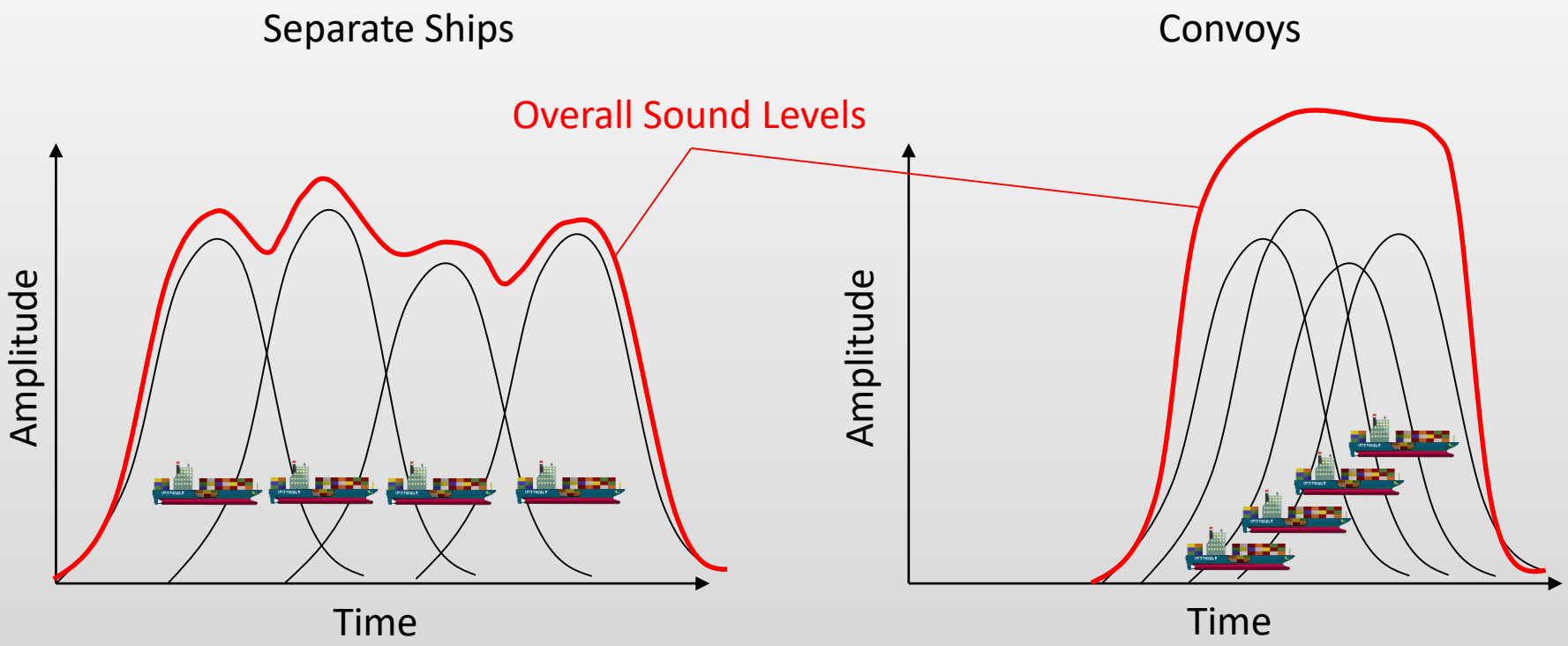
North Atlantic right whales
Photo credit: DFO's Team Whale

Dosing Noise



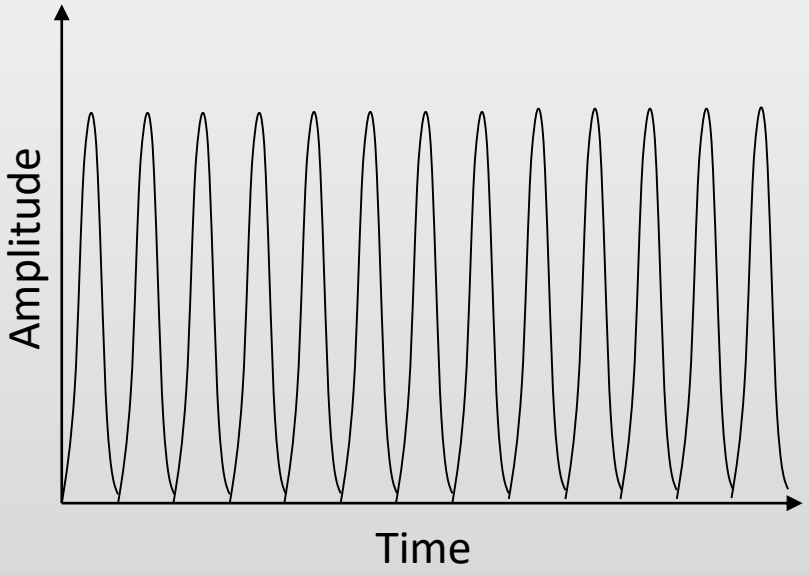
- Longer exposure
- Lower sound pressure levels

- Shorter exposure
- Higher sound pressure levels

“EQUAL” SOUND EXPOSURE LEVELS

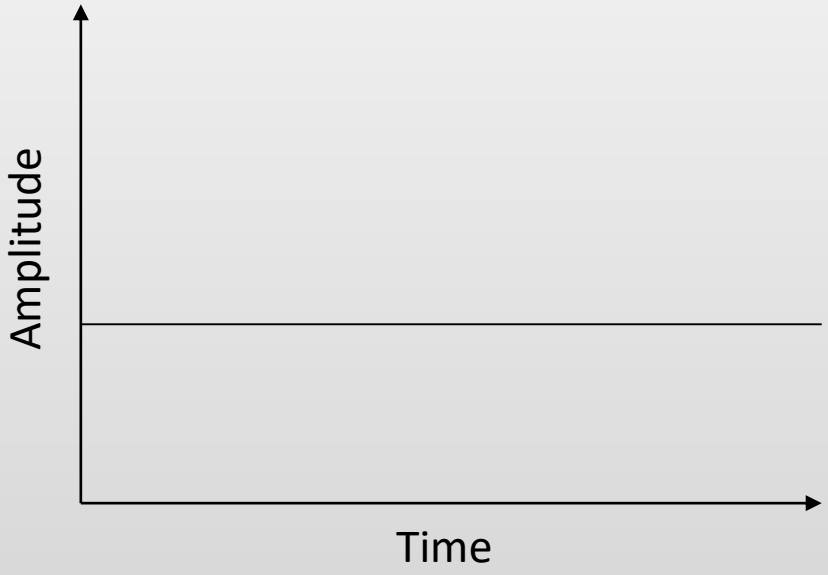
Dosing Noise

Airguns



- Periods of low/no exposure
- Higher sound pressure levels

Vibroseis



- Constant exposure
- Lower sound pressure levels

"EQUAL" SOUND EXPOSURE LEVELS

Available Data

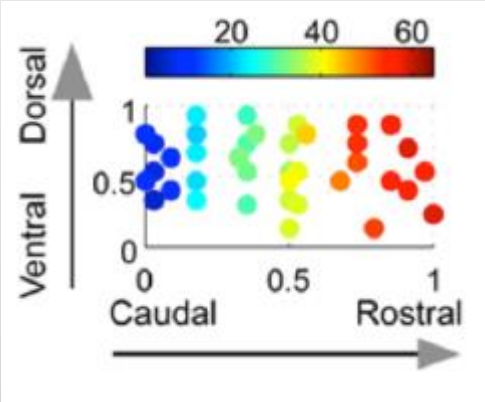
- Whales…?
- Terrestrial models?

Review

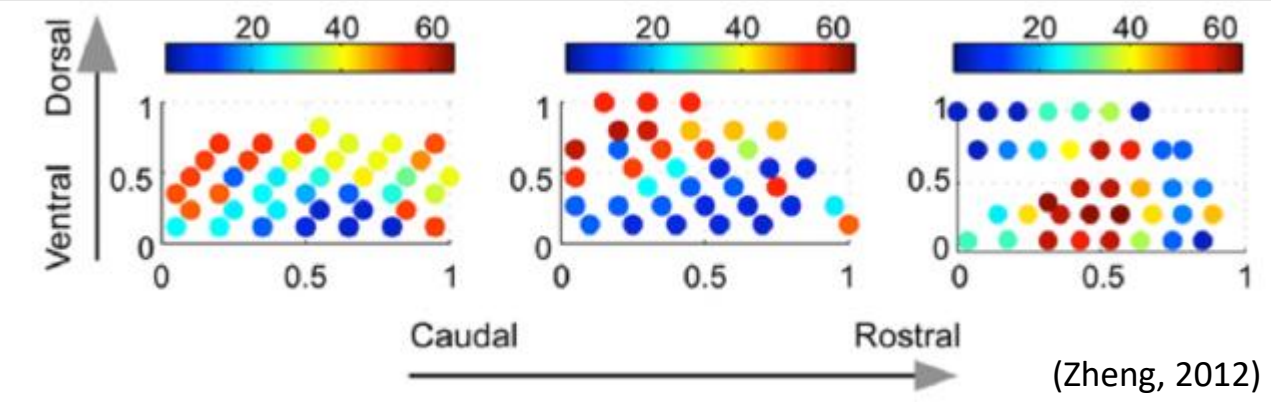
- Noise elicits response from stress neural circuits that are universal to most threats.
  - Stress response cascade will proceed following initiation of stress response: sympathetic nervous system and hypothalamic-pituitary-adrenal (HPA) axis
  - Increase in CRF (corticotropin-releasing factor) expression in hippocampus and paraventricular nucleus of the hypothalamus (via activation of the stress responsive HPA axis).

- Neurological plasticity – adaptation to noise?
  - Tonotopic map in primary auditory cortex dramatically remapped after consistent chronic, low-level noise exposure in rats (60-70dB re: 20µPa for 30 days).

Pre- & unexposed



Three examples of post-exposure



(Zheng, 2012)

  - **SUGGESTED** link to communication attempts during auditory exposure and brain plasticity.

Review

- Pain and hearing threshold shifts
  - Primary pain (the response to the stimulus) typically precedes and predicts damage.
  - Once the damage threshold is crossed, the threshold for future pain is reduced, leading to hyperalgesia (sensitization to pain) and/or chronic pain.

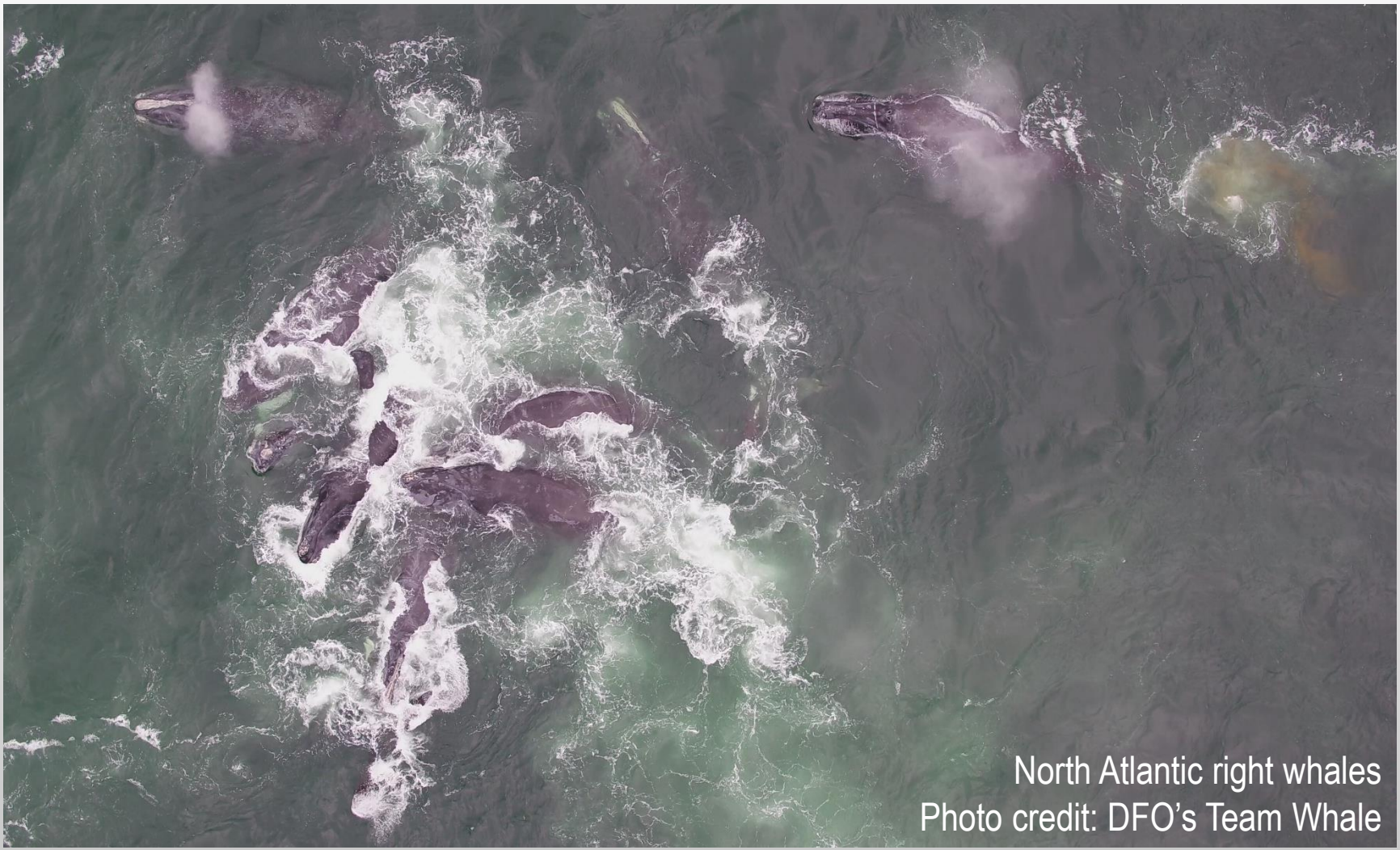
What about the whales?

North Atlantic right whales
Photo credit: Jolinne Surrette

What about the whales?

- Extrapolating
  - Natural exposures less constant and predictable than laboratory exposures.
  - Air/water difference may restrict applicability of human/ rodent model research to aquatic environments.
  - Few studies on noise exposures of medium levels and durations:
    - No insight into ship convoys.
  - BUT chronic, low-level noise may potentially be less harmful than intense, intermittent noise:
    - Vibroseis may be less impactful than airguns.

Any questions?



North Atlantic right whales
Photo credit: DFO's Team Whale