The Impact of Human-Caused Ocean Noise Pollution on Marine Animals and Ecosystems

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Impacts of Noise on Marine Animals

- Most marine animals use sound for vital functions
- So far, around 130 marine species shown to be impacted by underwater noise (practically all that have been examined)
  - 30 species of marine mammals
  - 66 species of fish
  - 36 species of invertebrates

Impacts of Noise on Marine Animals

- Development
  - Body malformations
  - Higher egg or immature mortality
  - Developmental delays
  - Delays in metamorphosing and settling
  - Slower growth rates
- Anatomy
  - Hearing loss (up to months or permanent)
  - Cellular damage to statocysts/neurons
  - Massive internal injuries
  - Disorientation and death

Impacts of Noise on Marine Animals

- Physiology (stress)
  - Increases in:
    - Stress hormones
    - Metabolic rate
    - Oxygen uptake
    - Cardiac output
    - Parasites
    - Irritation
    - Distress
    - Mortality rate (disease and cannibalism)
  - Worse/lower:
    - Body condition
    - Growth
    - Weight
    - Food consumption
    - Immune response
    - Reproductive rates
    - DNA integrity
    - Overall physiology

Impacts of Noise on Marine Animals

- Behavior
  - Avoidance of important habitat, days to years
  - Alarm responses, hiding, flight
  - Increased aggression
  - Decreased anti-predator defense
  - Decreased nest-digging and care
  - Decreased courtship calls, spawning, egg clutches
  - Decreased feeding
  - Distraction (food-handling errors, inefficiency)
  - Uncoordinated schooling

Impacts of Noise on Marine Animals

- Masking (obscuring, obliterating of sounds of interest)
- Commercial catch rates
  - Decreased landings (up to 80% drop)
  - Large fish leave area
  - Increased bycatch
  - Decreased abundance
- Ecological Services
  - Less water filtration
  - Less sediment layer mixing
  - Less bio-irrigation (key to nutrient cycling)

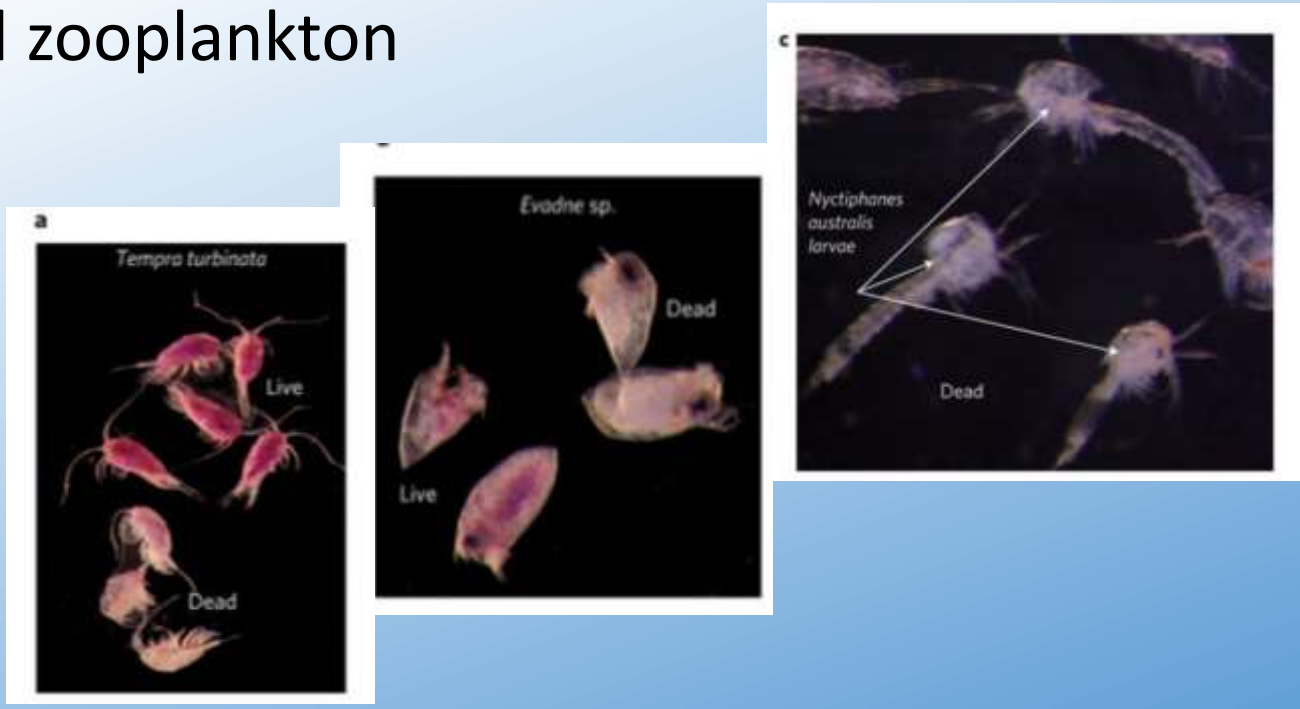
Noise Impacts on Ecosystem and Ecological Services

- Boat noise increased larval mortality and developmental failure in sea hare embryos *(Nedelec et al. 2014)*
  - Keep corals and algae in balance, graze on toxic bacteria
- Ship generator noise increases mussel biofouling but decreases size with "potential cascading ecological impacts" *(Jolivet et al. 2016)*
  - Vessel hull fouling responsible for 75% of invasive species brought in by ships *(McDonald et al. 2014)*
  - Costs U.S. Navy US$1 billion every year
- Noise causes confusion and disrupts orientation behavior at a critical (larval) stage in reef fish *(Simpson et al. 2010)*
  - Could affect population welfare, weaken connectivity between populations, reducing replenishment of fished species

Seismic Airgun Noise Kills Zooplankton

- Single airgun causes “hole” in zooplankton out to 1.2 km (max range examined) *(McCauley et al. 2017)*
  - Most seismic surveys consist of 18-48 airguns
- Numbers halved in most plankton species
- 1/3 of species almost entirely killed
- All krill larvae killed
- 2-3x more dead zooplankton

Healthy populations of fish and marine mammals are not possible without viable planktonic productivity



Seismic Airgun Noise Damages Sensory Organs and Reflexes in Lobster

- Extensively damaged hair cells in statocysts (for body positioning, gravity-sensing)
- Up to 157% longer righting time, even one year post-noise exposure and after moulting
- Critical reflex for predator avoidance *(Day et al. 2019)*

Noise Impacts on Ecosystem and Ecological Services

- 6 hrs of ship noise caused breaks in DNA of blue mussel, lower filtration (algal clearance), oxidative stress *(Wale et al. 2016)*
  - Mussels could not perform important ecological service of water filtration
- Scallop mortality increased with seismic survey, reflexes disrupted, immunocompromised, imbalanced electrolytes *(Day et al. 2017)*
  - Scallops improve water quality through bio-filtration, increase light for underwater plants, decrease eutrophication, feed bottom-dwelling organisms by depositing organic matter from water column
- Predator-prey interactions in fish changed with boat noise *(Sabet et al. 2015; Simpson et al. 2016)*
  - Food web dynamics, community structure and stability compromised

Noise Impacts on Ecosystem and Ecological Services

- Noise repressed burying and bio-irrigation behavior (or water circulation within lobster burrows) in Norway lobsters *(Solan et al. 2016)*
- Manila clams showed a stress response to noise, individuals relocated less, stayed on top of the seabed, and closed their valves, increasing lactate dangerously
  - Clams could not mix upper layers of sediment and could not feed
  - Noise changed the fluid and particle transport that invertebrates provide, key to nutrient cycling on the seabed

Impacts of Noise on Cetaceans

- Avoidance of important habitat, sometimes days to years
- Reduced feeding and feeding success
- Decreased reproduction
- Masking
- Change in calling rate, potentially affecting mating
- Disruption in migration
- Strong escape responses
- Hearing damage
- Stress (damage to immune and reproductive function)
- Death

Human-Caused Ocean Noise

Can prevent whales from:

- hearing prey or predators
- orienting, sensing the environment
- communicating with mates, group members, or young

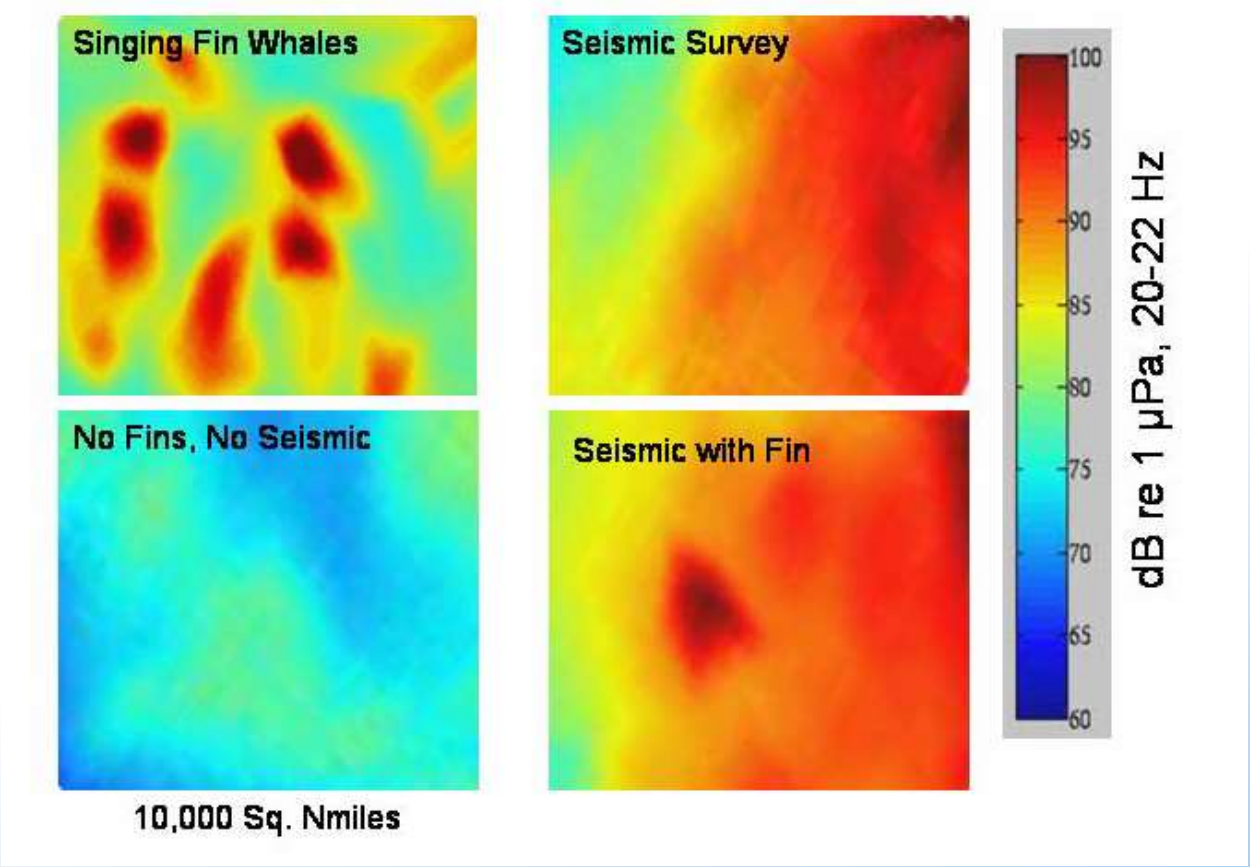
Masking

Before Noise

After Noise

From C.W. Clark

Loss in whale communication range



Clark & Gagnon 2006

Raises background 10-30 dB (ten-fold or thousand-fold) over 35,000-70,000 sq km (area of Switzerland-Ireland) for months; finbacks stop singing, most likely population impact

- Military sonars (and some seismic surveys) can cause fatal mass strandings, esp. in beaked whales
- Hemorrhages around vital organs like brain, heart
- Death within 4-24 hrs.

(Fernández et al. 2005)

Special Noise-Sensitivity of Beaked Whales

- During multi-day naval exercises with sonar, Blainville's beaked whales stopped vocalizing and feeding, moved tens of km away, returning 2-3 days after exercises stopped *(McCarthy et al. 2011, Tyack et al. 2011)*

- With naval sonar, Cuvier's beaked whales stopped normal feeding and swimming, moving rapidly and silently away in longer dives, responding for 3-4 hrs. Energetic costs, increased stranding and decompression sickness risk *(DeRuiter et al. 2013)*

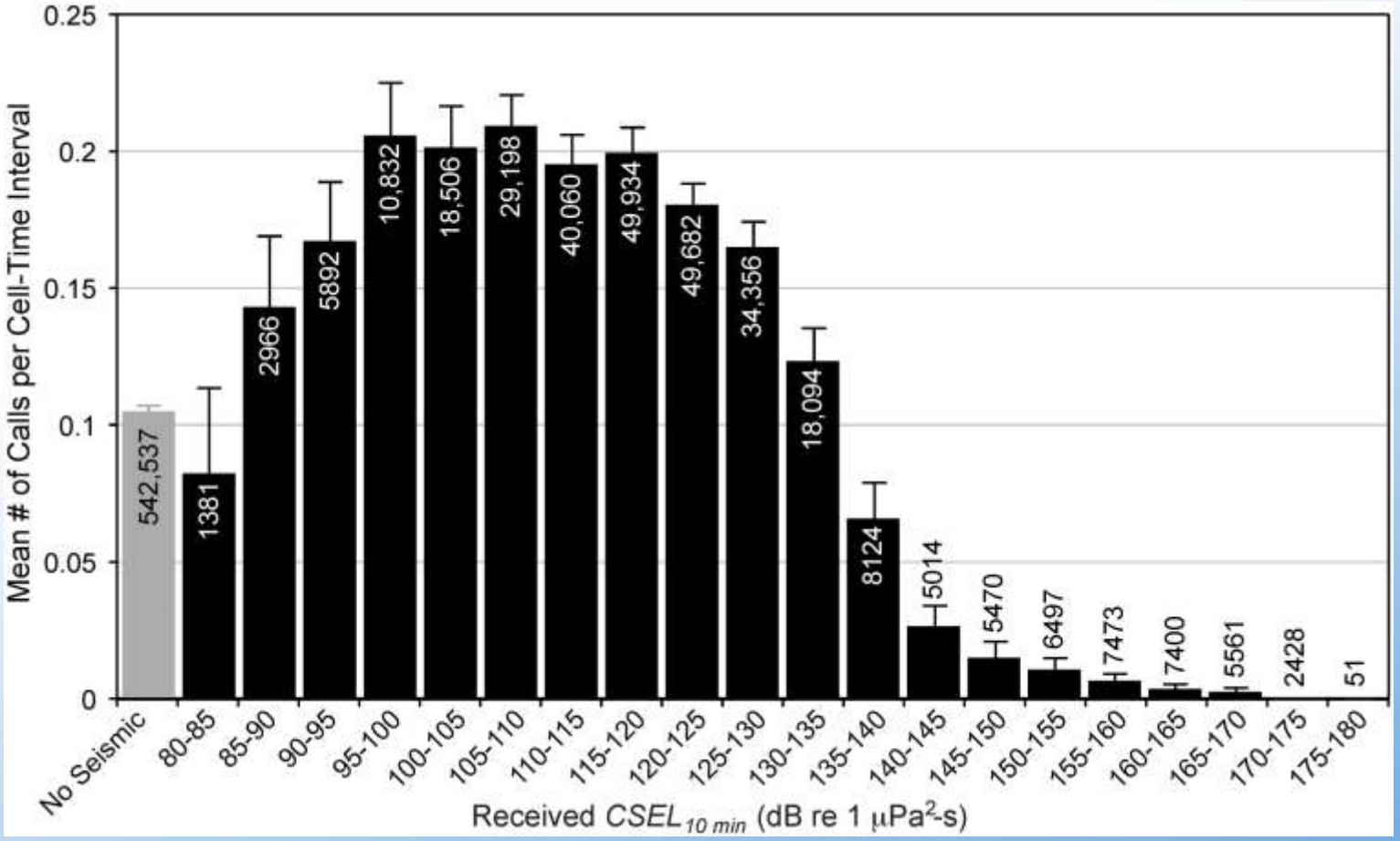
- Ship noise caused significant decrease in foraging movement of Blainville's up to at least 5.2 km away from vessel *(Pirotta et al. 2012)*

- Ship noise reduced foraging efficiency by > 50%, communication range reduction to 1/5 in Cuvier's *(Aguilar Soto et al. 2006)*

Possible Population-Level Effect of Sonar Use at a Navy Range

- Lower Blainville's beaked whale abundance at naval range vs. Abaco, Bahamas, based on 15-yr. field study *(Claridge 2013)*
- Fewer births (calf:female ratio) at naval range likely reason for fewer animals *(Claridge 2013)*
- Long recoveries after deep (1,600 m), long (80 min.) dives, more vulnerable to higher energetic costs of displacement and lower feeding rates during noise exposure; mechanism for fewer calves? *(Claridge 2013)*
- Adult females show high residency at navy ranges, putting them at special risk, esp. when pregnant and lactating *(Claridge 2013)*

Bowhead Whale Calling Affected by Seismic Noise



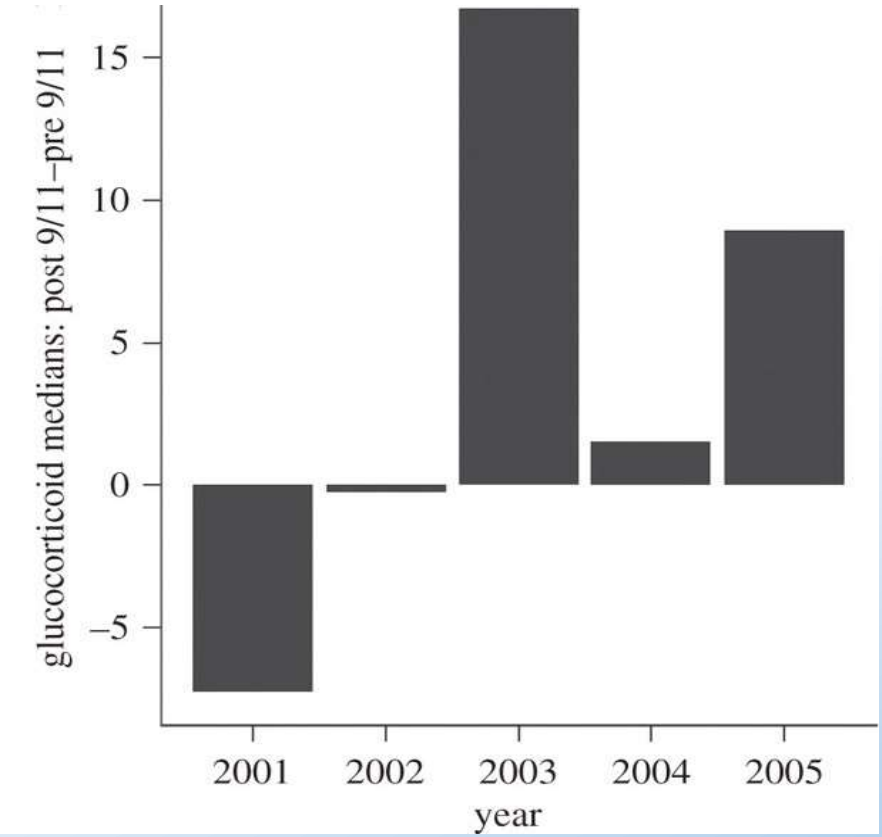
Blackwell et al. 2015

Bowhead Whale Calling Affected by Seismic Noise

- Calls increased as soon as seismic detectable
- Calling rates leveled off at RLs of 94 dB
- >127 dB, whale calling rates began decreasing
- With noise >160 dB, whales fell silent
- Calling repressed within 50–100 km radius (8,000-30,000 sq km)
- Within 10–40 km (300–5,000 sq km), calling almost absent

Blackwell et al. 2015

Right Whales Stressed from Ship Noise



Yearly difference in fecal glucocorticoid levels post 9/11, associated with less underwater low-frequency noise resulting from less ship traffic *(Rolland et al. 2012)*

Summary

- At least 130 marine species shown to be impacted by noise
- Cetaceans: avoid important habitat, reduced feeding and reproduction, call less or fall silent, experience stress, masking, fatal strandings, and, in some cases, likely population impacts due to noise
- Fish and invertebrates: impacts on development, immune responses, stress, reflexes, feeding, reproduction, predator defense, mortality, catch rates, and damage to sensory organs, which can persist at least one year post-noise exposure
- Noise can increase invasive species on ship hulls, weaken connectivity between fish populations, change predator-prey interactions and community structure, compromise food web dynamics and stability, and risk ecosystem productivity
- Studies on fish and invertebrates show impacts extend beyond *individual* species to now include *communities* of species and how they interact; the ecosystem, and ecological services