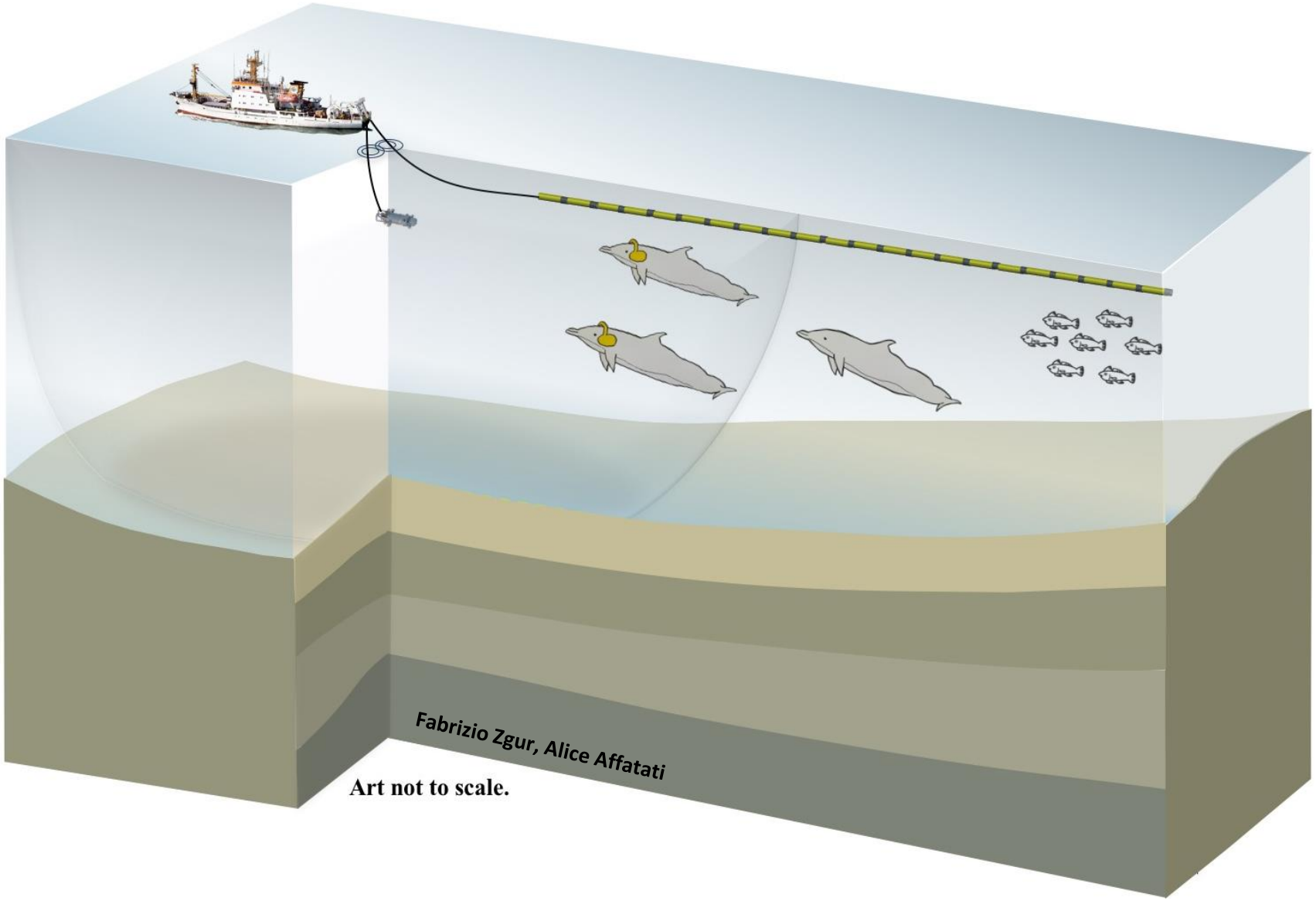
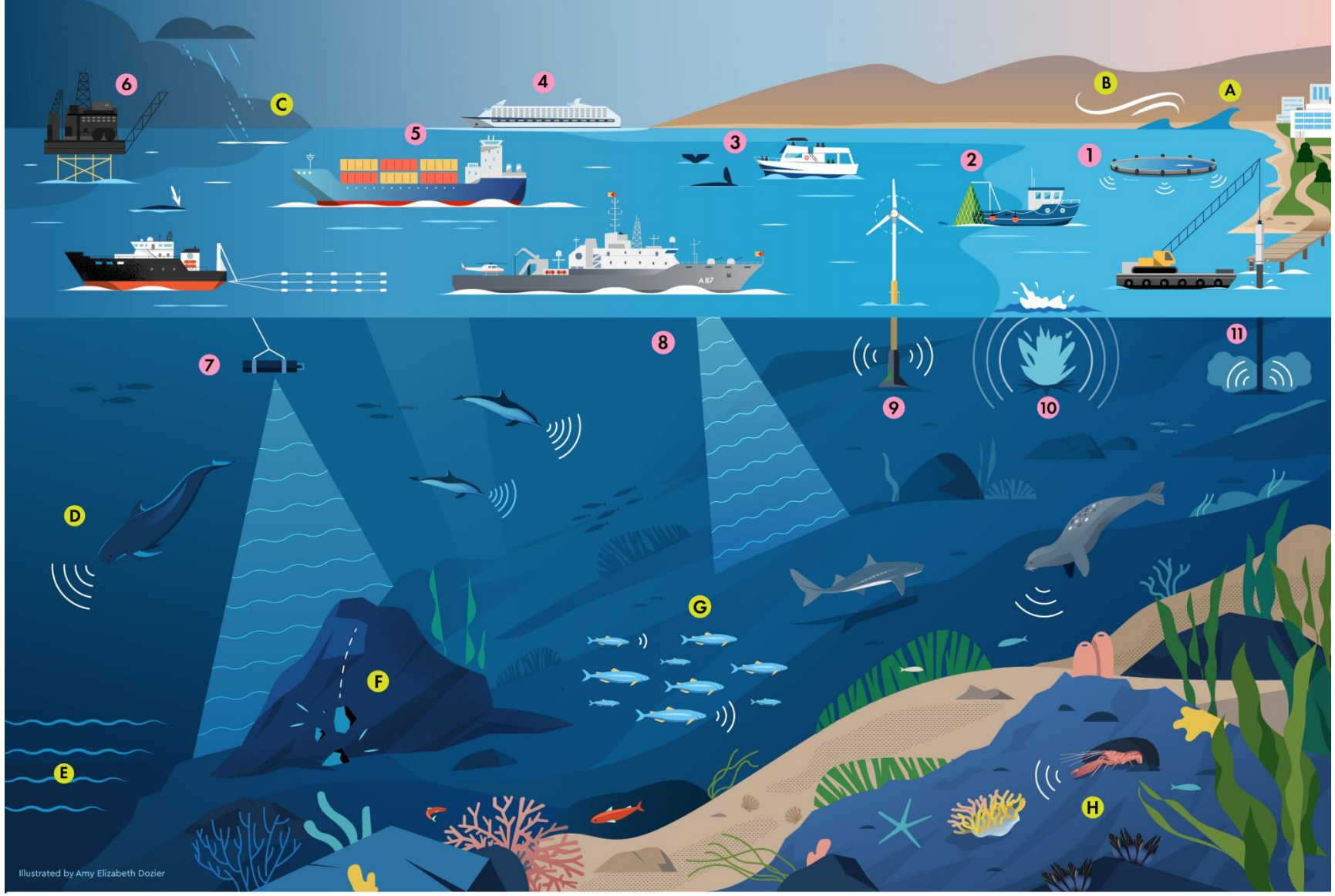
Sounds in the ocean and the effect of seismic surveys on marine fauna



Alice Affatati, aaffatati@ogs.it , December 19, 2022

Today's agenda

- **Sounds in the marine environment**
  geophony, biophony, anthropophony, soundscape
  how do cetaceans use sound?
- **Recording sounds at sea**
- **Effects of underwater noise on marine fauna**
  effects of seismic surveys
- **Mitigation measures**
- **Basic regulatory framework in EU and Italy**



TODAY'S OCEAN SOUNDSCAPE

including anthropogenic and natural sound sources, labelled anti-clockwise

European MARINE BOARD
Advancing Seas & Ocean Science

jonas
Joint Framework for Ocean Noise in the Atlantic Seas

ANTHROPOGENIC SOURCES

1 Acoustic deterrent devices
2 Fishing vessels
3 Recreational vessels
4 Cruise ships
5 Commercial shipping
6 Offshore oil & gas
7 Seismic airgun surveys
8 Military & civilian sonar
9 Offshore renewable energy
10 Underwater explosions
11 Construction and pile-driving

NATURAL SOURCES

A Waves
B Wind
C Rain
D Marine mammals
E Currents
F Underwater landslides, volcanos and earthquakes
G Fishes
H Invertebrates

Geophony

- Geophony – natural sounds

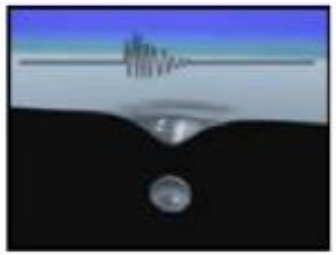
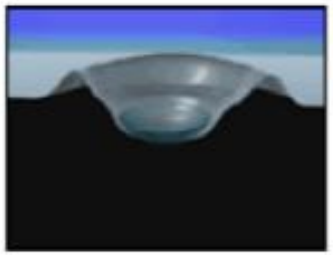
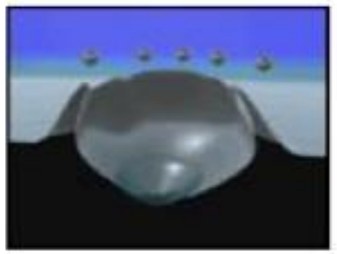
a. Geological processes – volcanoes, earthquakes…

b. Physical processes – wind, waves, rainfall…

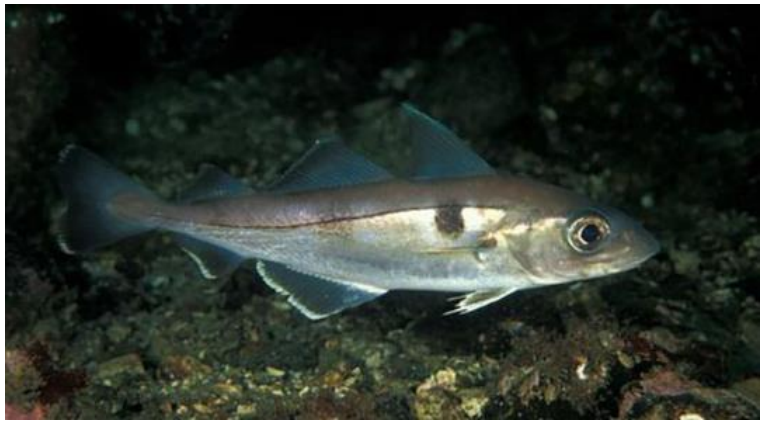
(https://dosits.org/galleries/audio-gallery/other-natural-sounds/)

Ice cracking in Cambridge Bay

https://earthobservatory.nasa.gov/features/Rain/rain_2.php

Biophony – organisms produce sounds

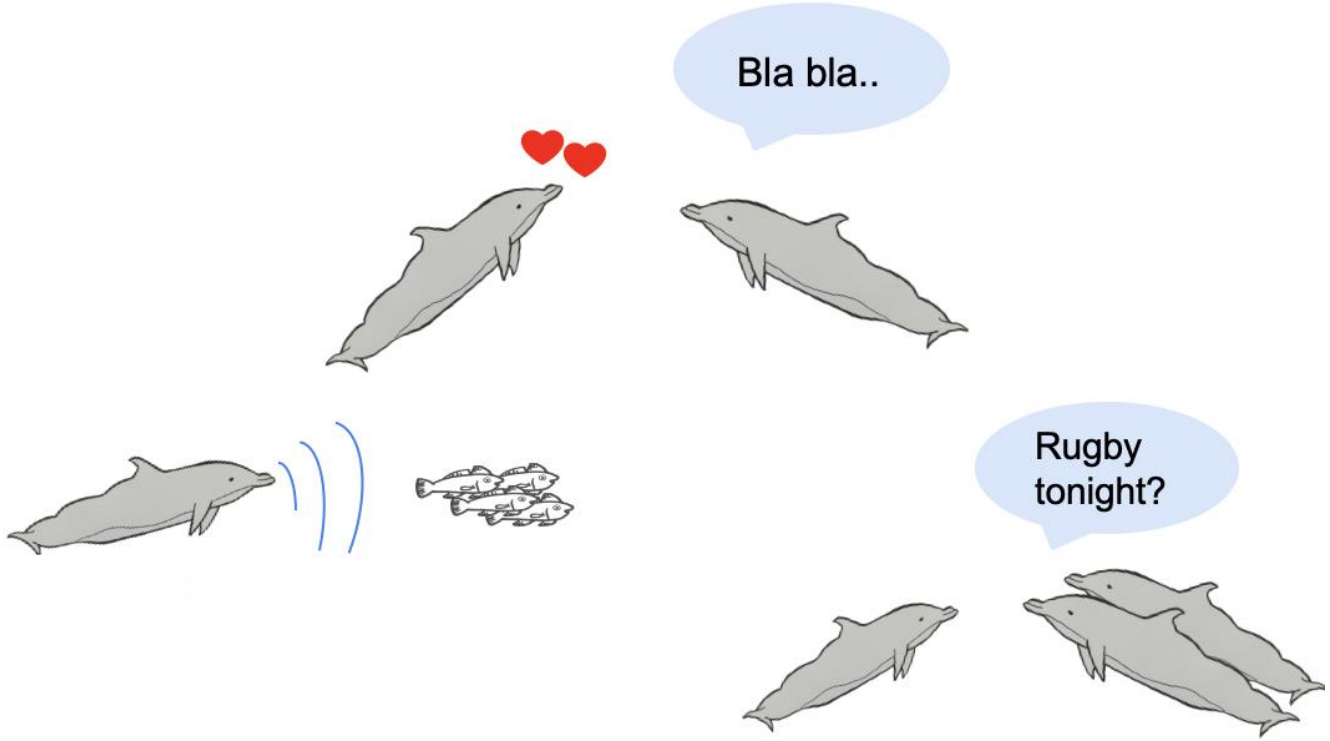


Fishes
e.g, Haddock

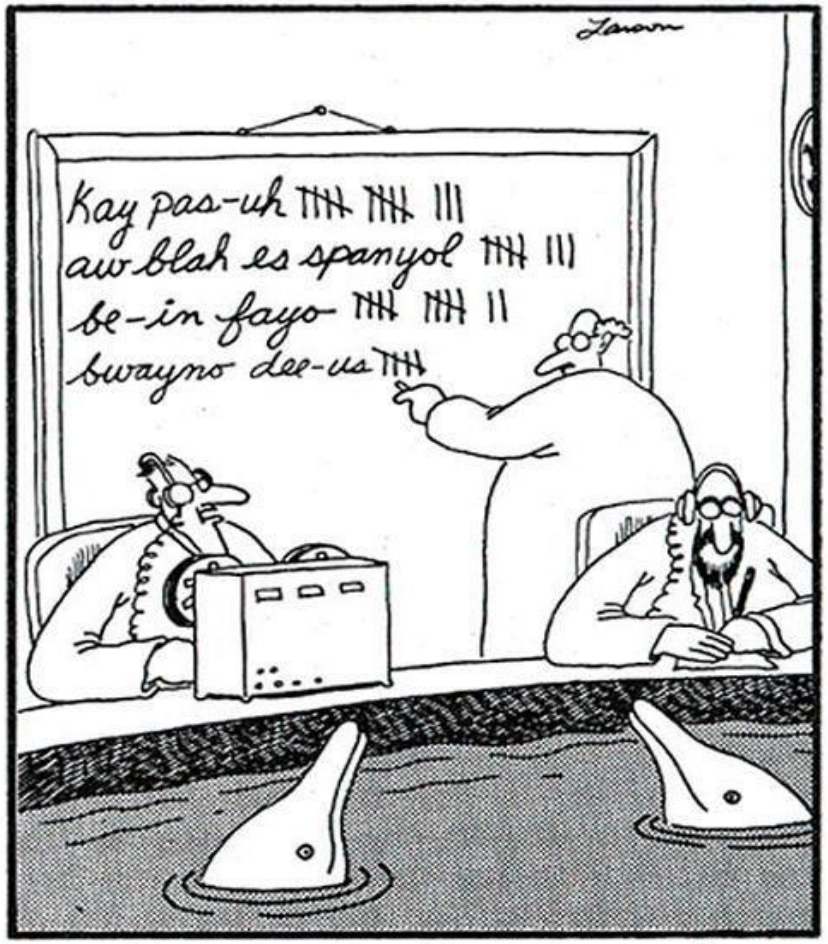
mammals
e.g., killer whale

Invertebrates
e.g., Snapping shrimps

Why do cetaceans produce sounds?



Alice Affatati



"Matthews ... we're getting another one of those strange 'aw blah es span yol' sounds."

- Identify individuals
- Hunting preys
- Reproduction
- Communication – group structure, mother-calf…

- Imaging
- Aggressions /territoriality

Sound production

Odontocetes: hunters

clicks

Ecolocalization

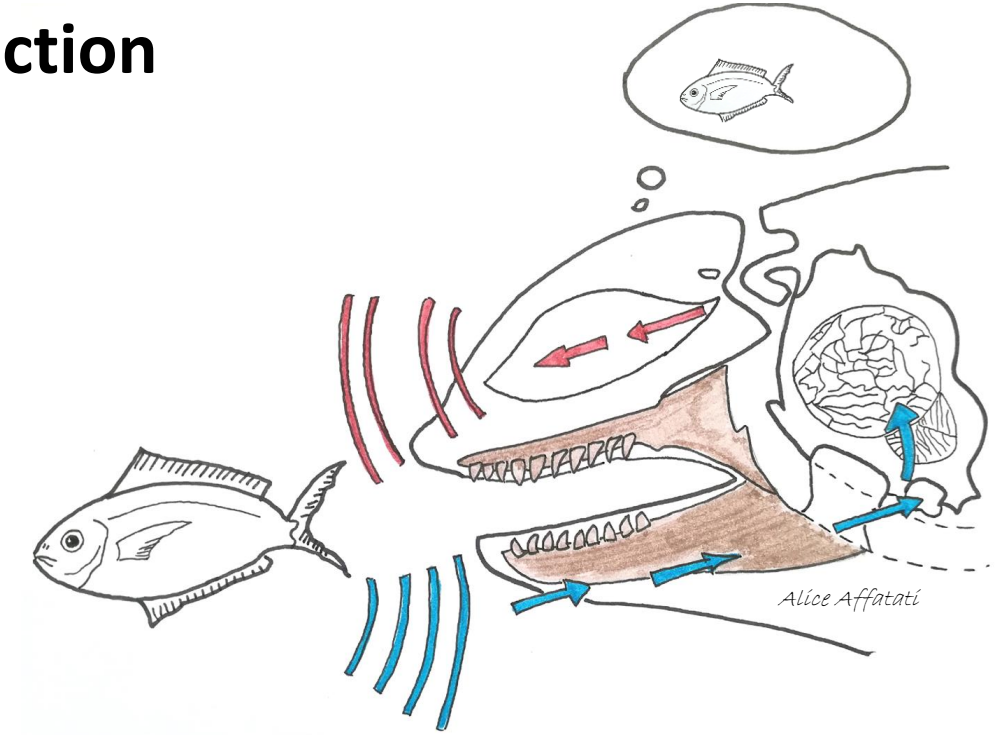
Sperm whale Clicks

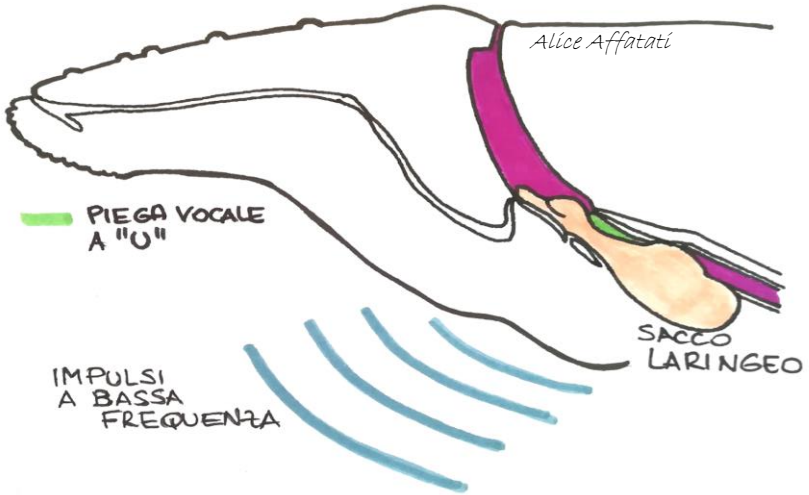
whistles

Dolphin whistles

Mysticetes: filter feeders/gatherers

Humpback whale song



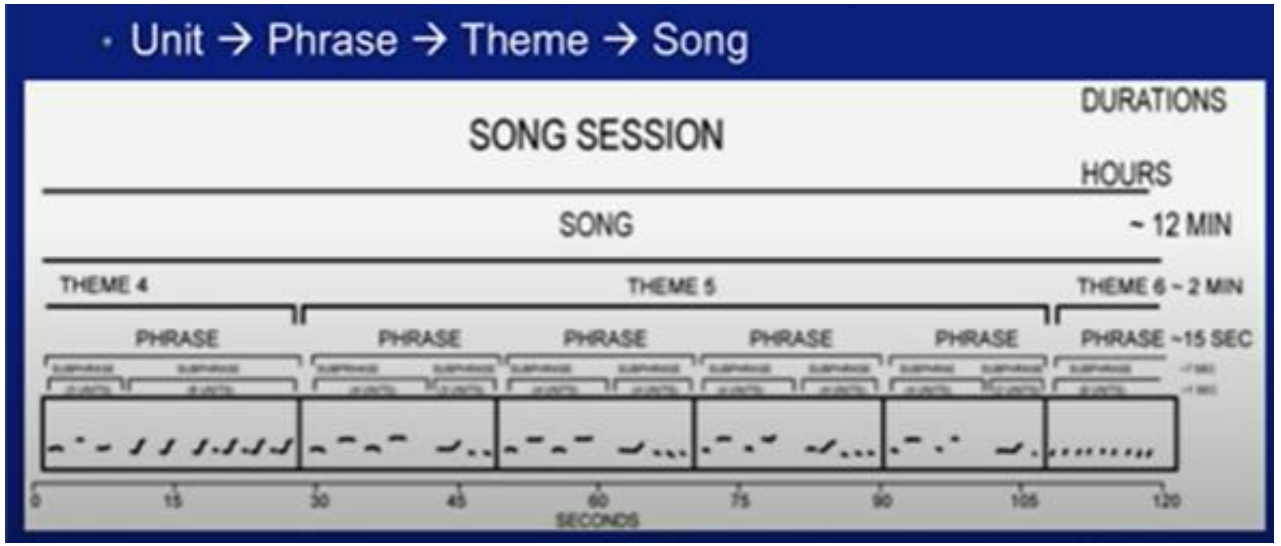


Humpback whale (*Megaptera novaeangliae*)

Bird models and whale songs

Watkins on review for JASA of McDonald et al. 1995

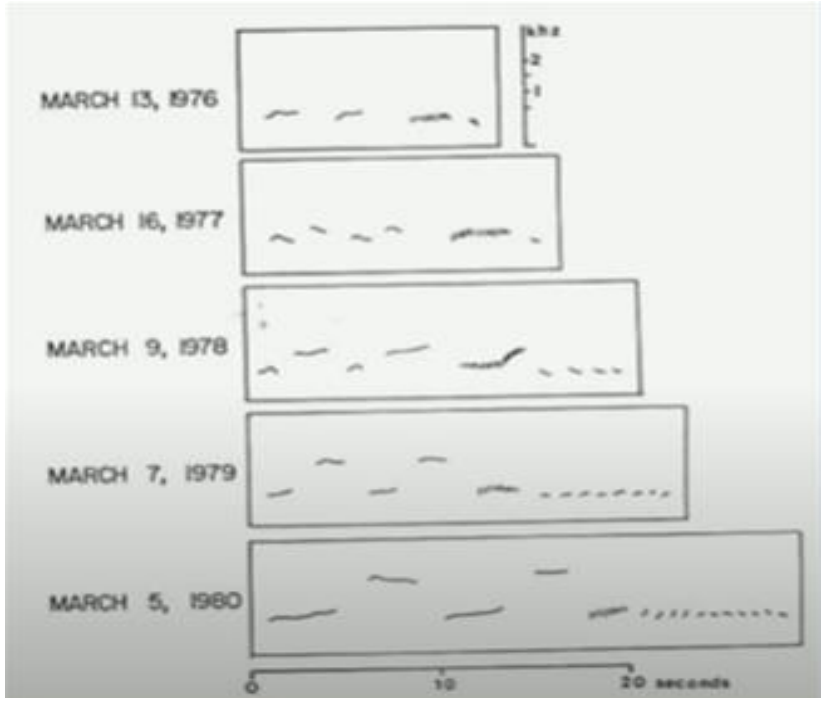
- Produced by males
- Territorial
- Stereotyped
- Seasonally produced
- Involved in reproductive displays



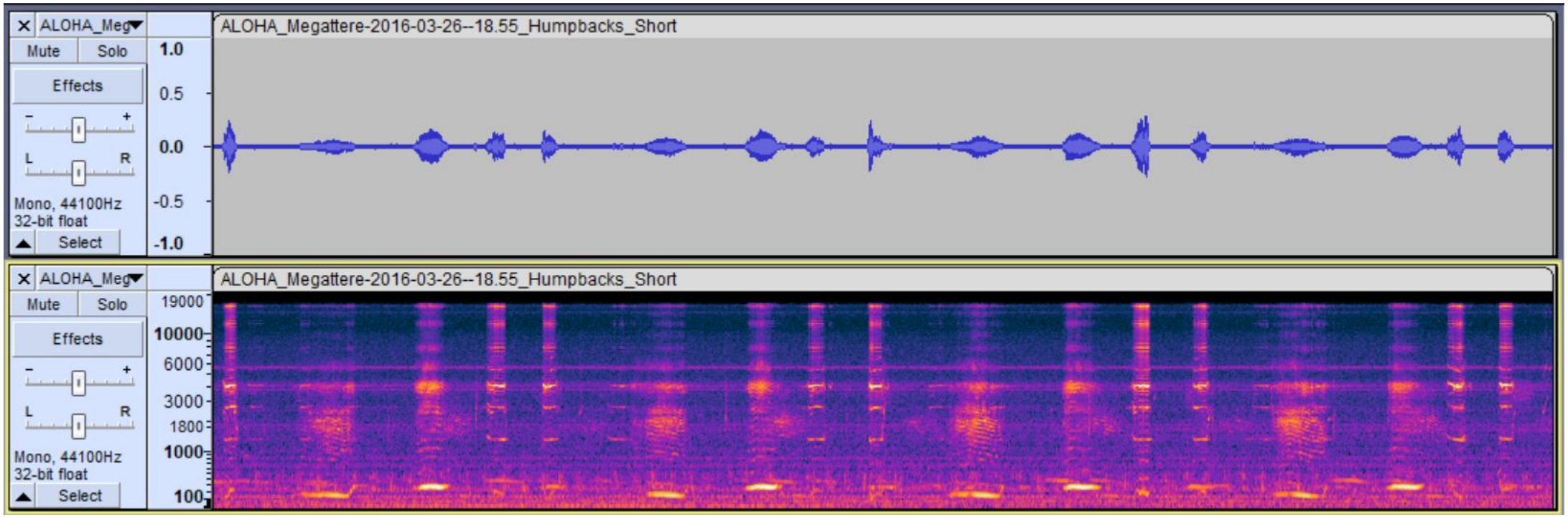
Modified from Payne and McVay (1971)

Evolution of Humpback whale themes

- Songs are changed during each annual cycle

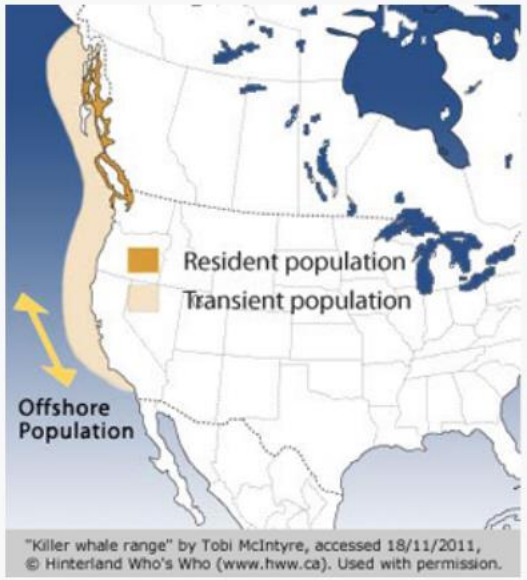


How do we look at sound?

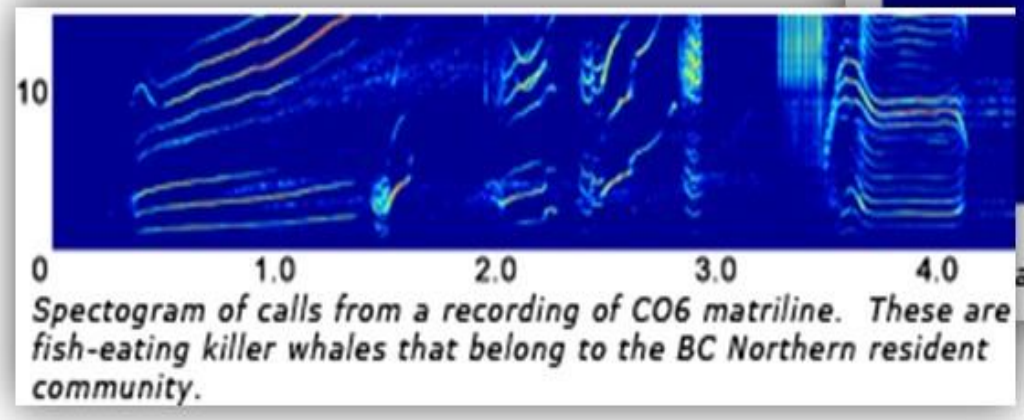


“There is culture in the ocean” -Hal Whitehead

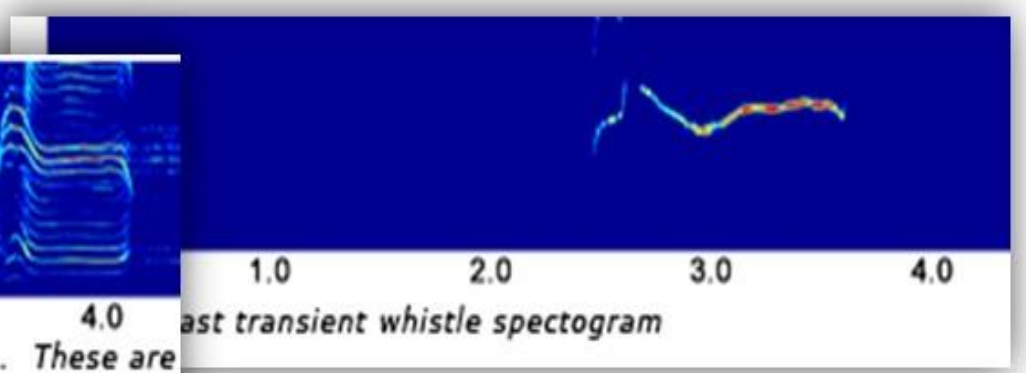
Resident (fish-eating) Orcas



Transient (mammal-eating) Orcas



Spectogram of calls from a recording of CO6 matriline. These are fish-eating killer whales that belong to the BC Northern resident community.



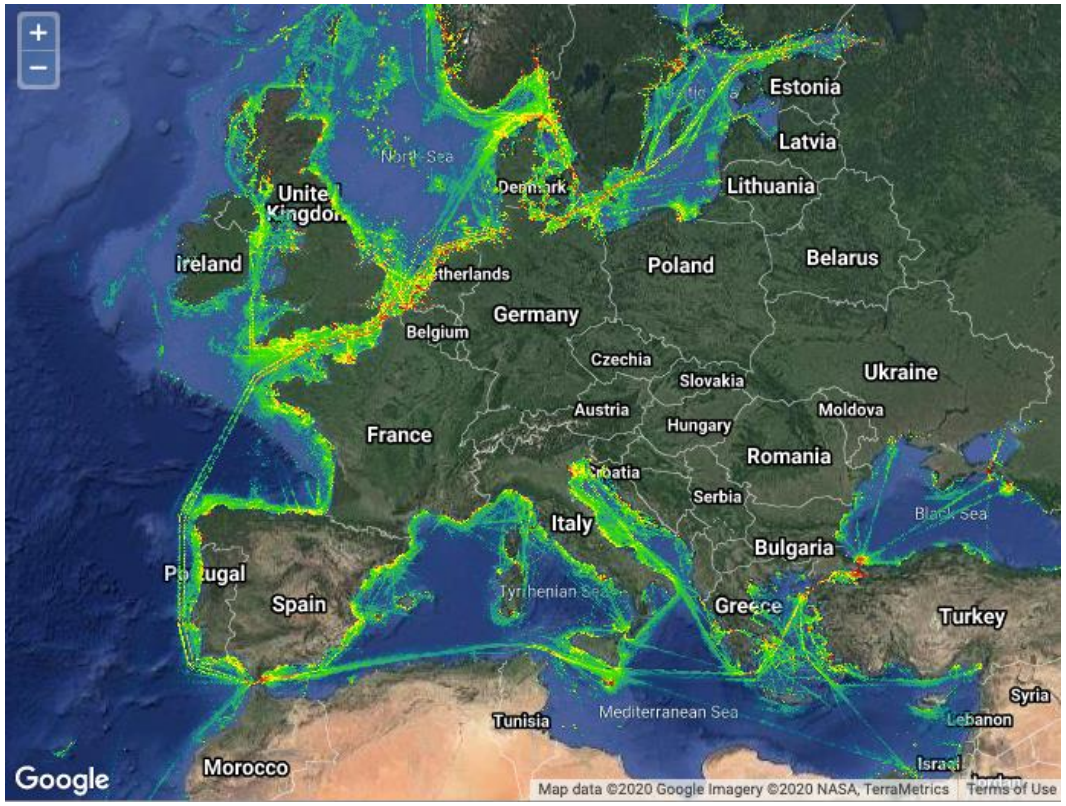
ast transient whistle spectogram

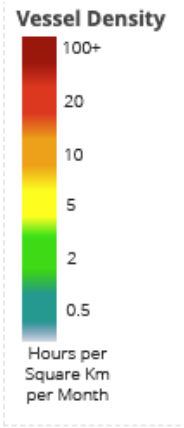
https://ptmsc.org/programs/investigate/citizen-science/completed-projects/orca-project/resident-and-transient-orcas

Marine Traffic

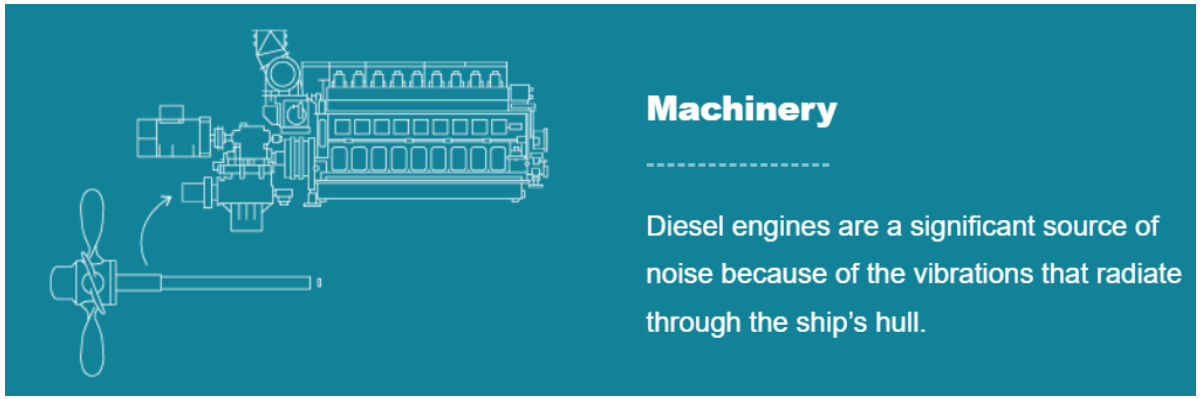
Mediterranean Sea: highest shipping traffic in the EU (27% % of its area subject to shipping).
https://environment.ec.europa.eu/news/

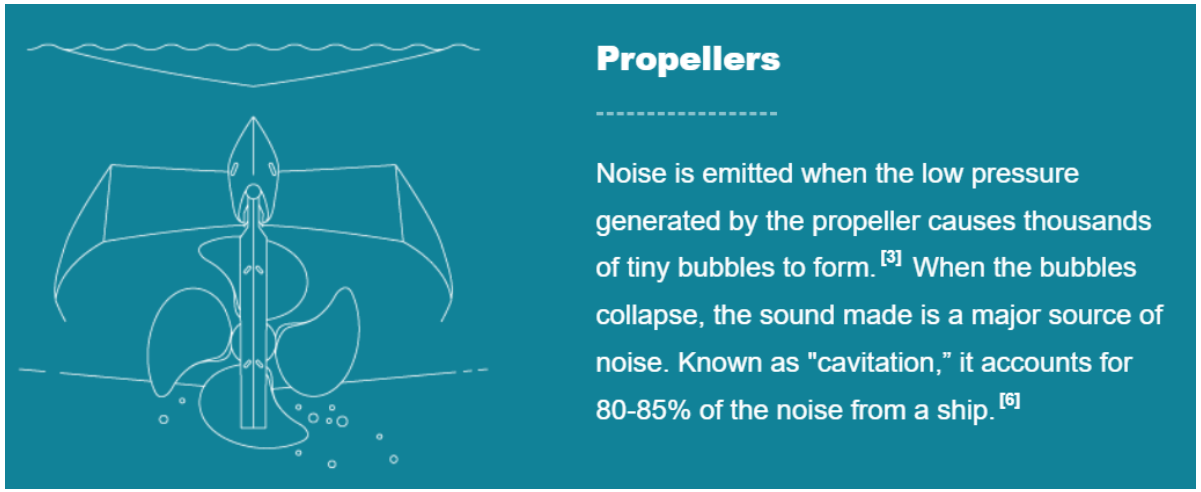
Marine Traffic





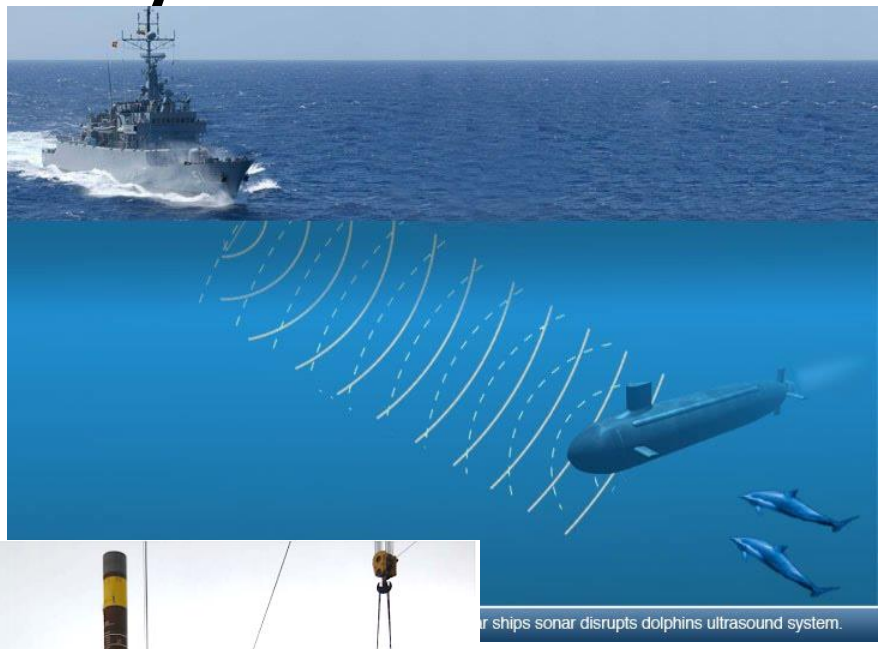
European Marine Observation and Data Network
Emodnet



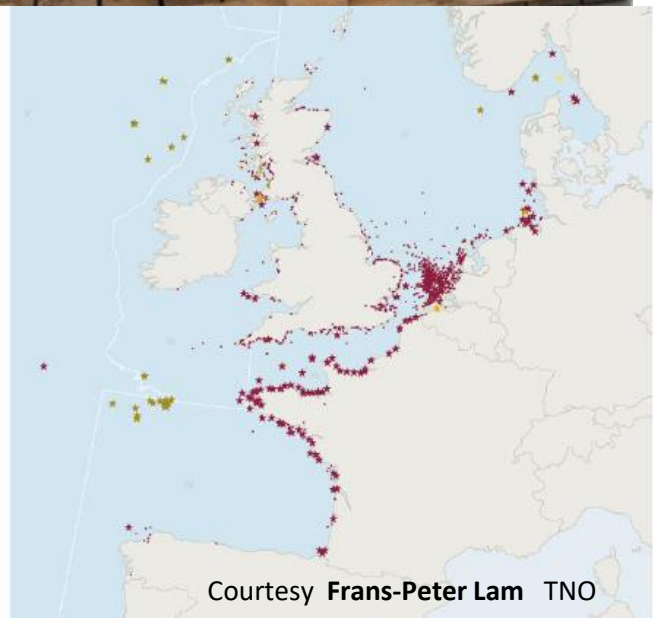


Clear seas

Military sonar

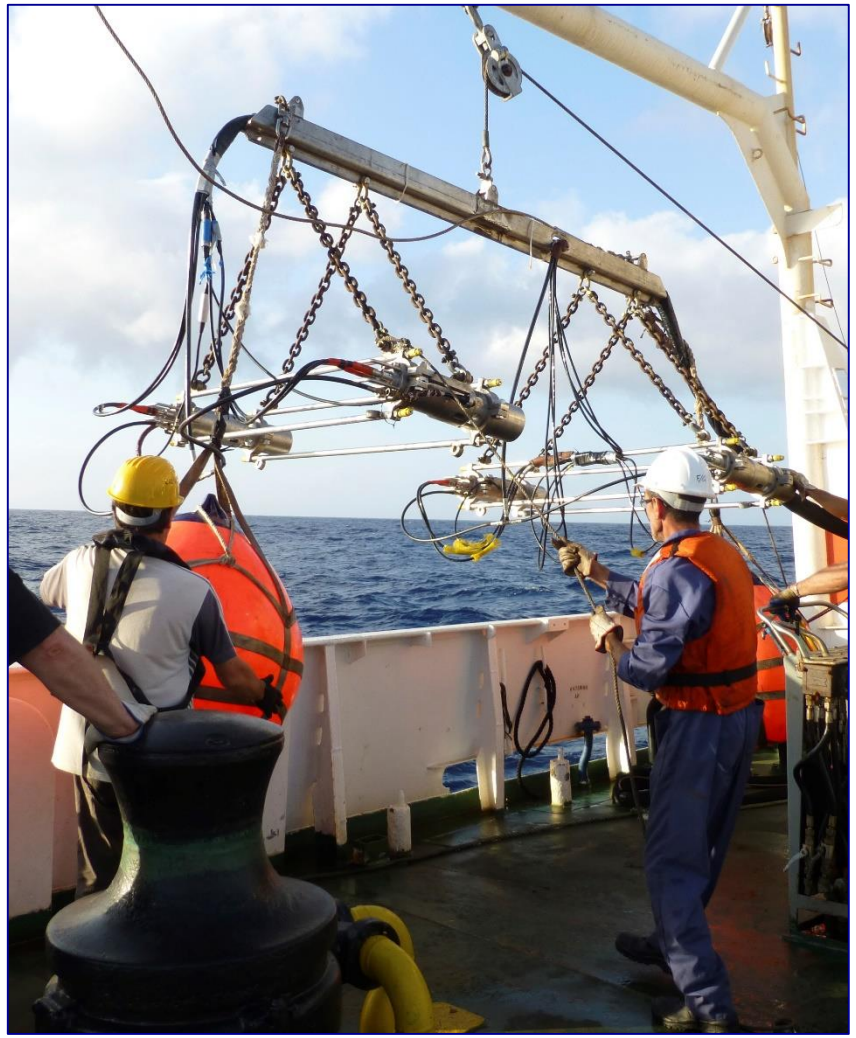


Explosions



Pile driving

Marine Seismic surveys



A typical element ranges in size/volume:

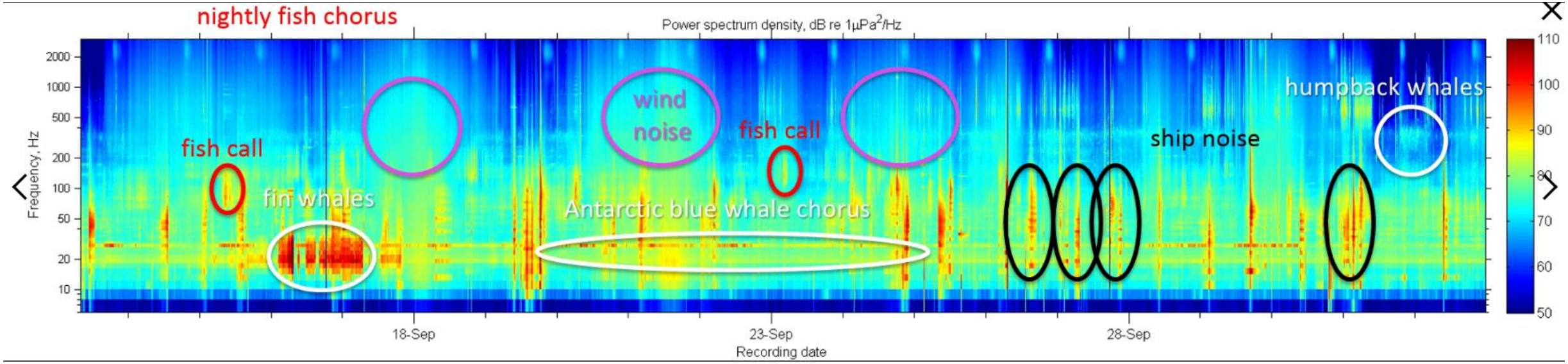
- 10 – 800 cubic inches or …..
- 0.15 – 13 liter or ……..
- A disappointingly small beer to a daypack

Typical air pressure is

- 2000 psi or 14 Mpa or 140 Bar or ……..
- Somewhere between a household pressure washer (1500 psi) and a scuba tank (3000 psi)

https://dosits.org/decision-makers/webinar-series/webinars-2019/seismic-sources/

Soundscape



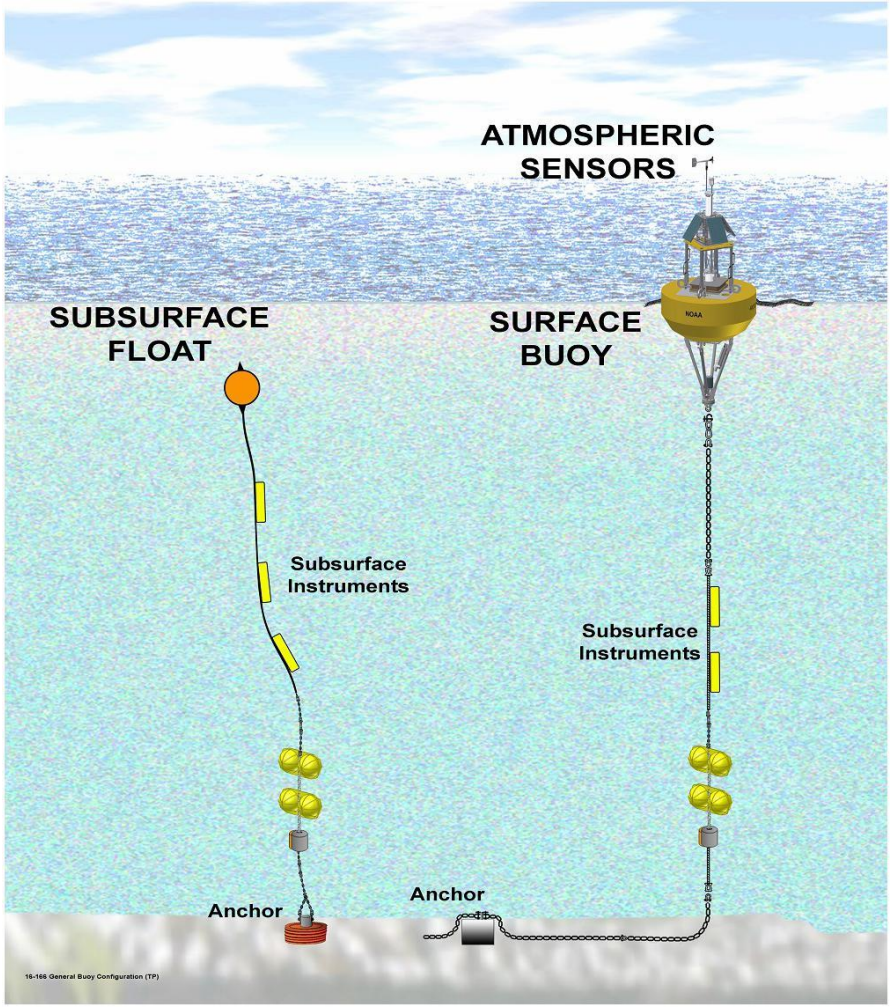
Spectograph showing the marine soundscape of Perth Canyon, Australia
Erbe, C, et al, The Marine Soundscape of the Perth Canyon published 2015 in Progress in Oceanography

https://soundscape.world/play/swamp

Passive acoustic monitoring

- Cabled hydrophones: permanent installations, expensive, near-real time, continuous rec
- Autonomous recordings: on the seabed, fixed, buoys

ONC Canada



Pros

- Detect animal presence also at night and in bad weather
- Long-term monitoring, less expensive
- Large spatial scale covered
- Non-invasive

Cons

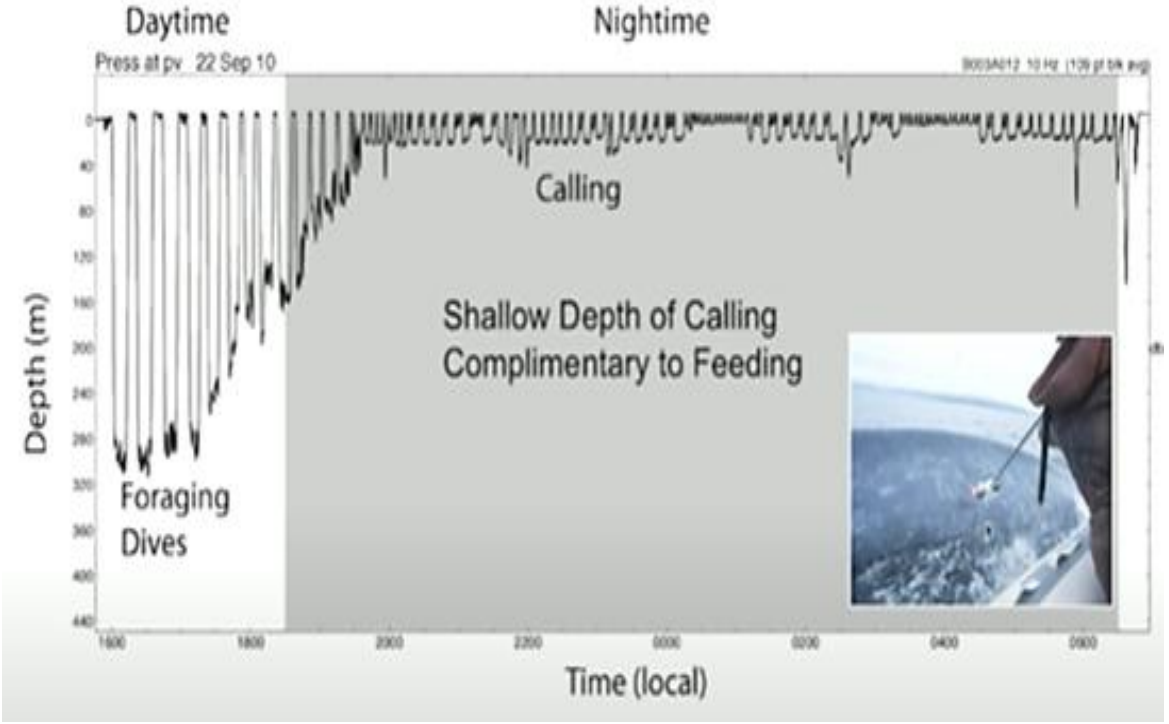
- Absence of sounds ≠ absence of animals
- Number of individuals present (?)
- Many unknown sounds

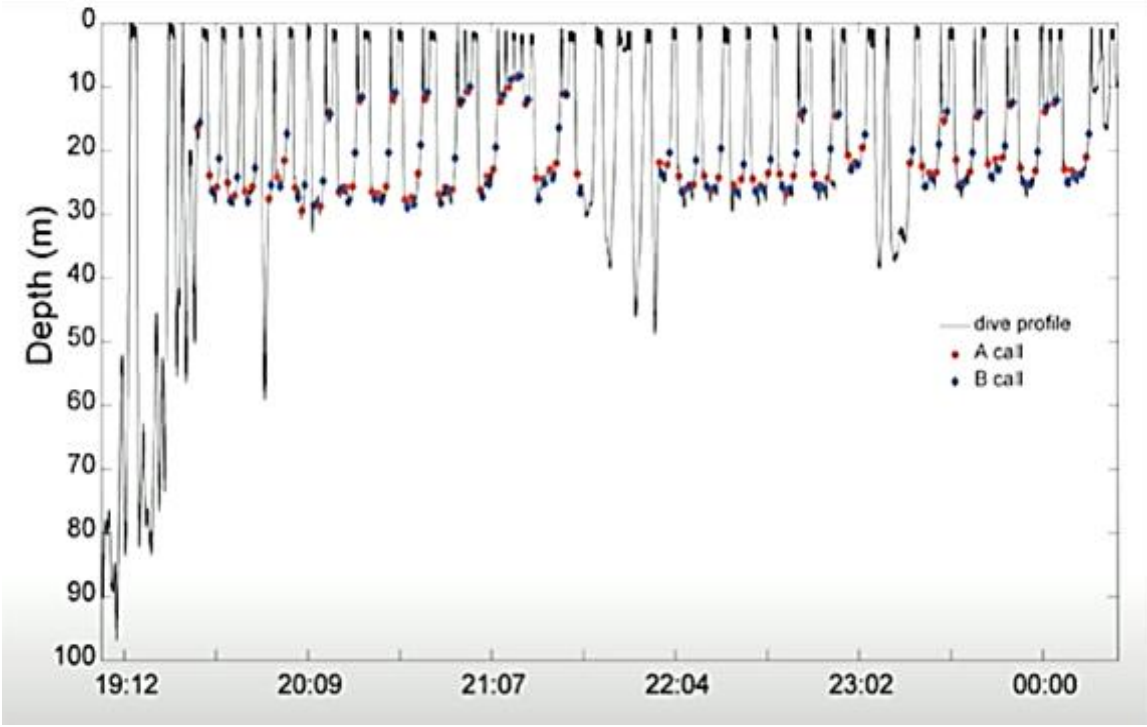
Mellinger et al., 2007; Bailey et al., 2019

Tags

Can record acoustic data, behaviour, seawater physical properties

Holt et al. NOAA

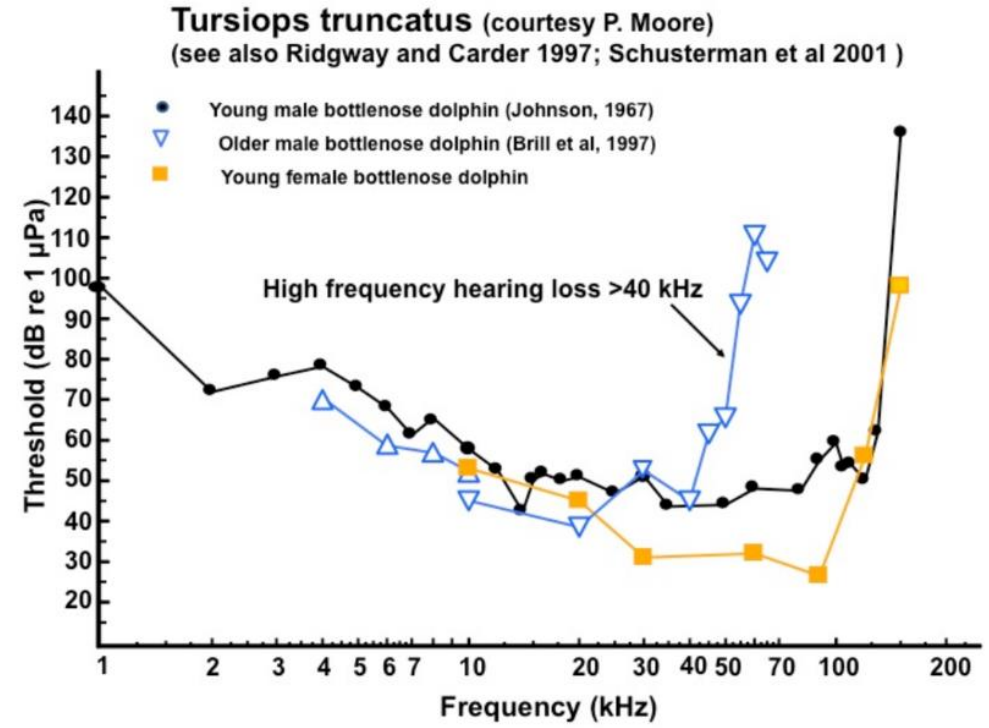




Scripps Whale Acoustic Lab, Data collected Sept. 22, 2010 – Palos Verdes Peninsula, California

Effects of underwater noise on marine fauna

1. **Injuries**: damages on tissues, gas embolism/decompression syndromes (Fernàndez et al., 2017)
2. **Permanent/Temporary Threshold Shifts** (PTS, TTS)



Hearing threshold curves of three bottlenose dolphins showing the range of natural variability in hearing sensitivities, as well as the loss of high frequency hearing that can occur with age. Figure courtesy of Darlene Ketten, Harvard Medical School.

https://dosits.org/decision-makers/tutorials/effects/mammals-hearing-loss/

Richardson et al., 2013

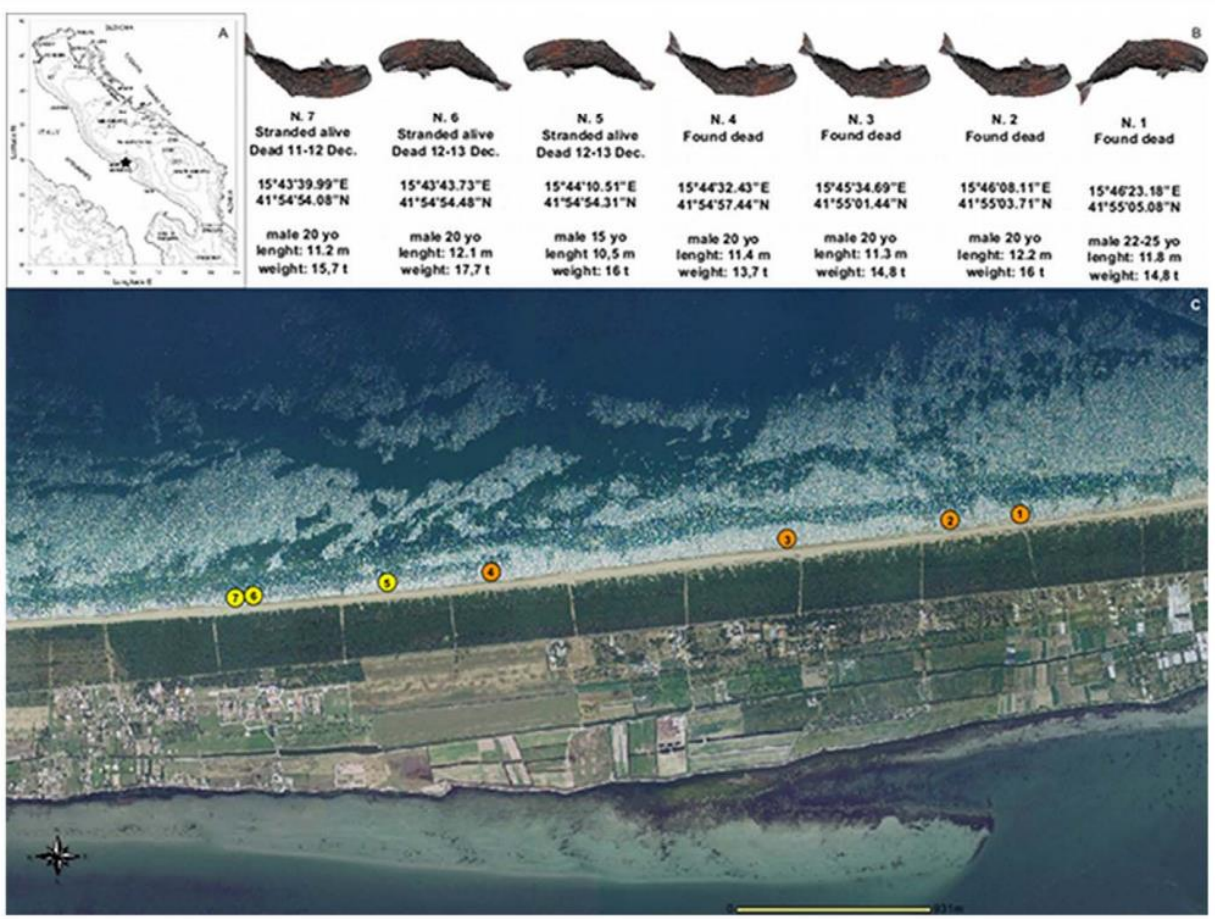
Effects of underwater noise on marine fauna

3. **Communication Masking** intraspecific, interspecific, interferences (audio)
4. **Behavioral modifications**
    - Temporary interruptions of behaviors
    - Partial modifications of natural behavior and vocalizations
    - Area avoidance
5. **Indirect effects**
    - Decrease in prey availability
    - Increase in vulnerability to predation and other risks (e.g., strandings)
    - Changes in behaviors leading to injuries (e.g., ship strikes)

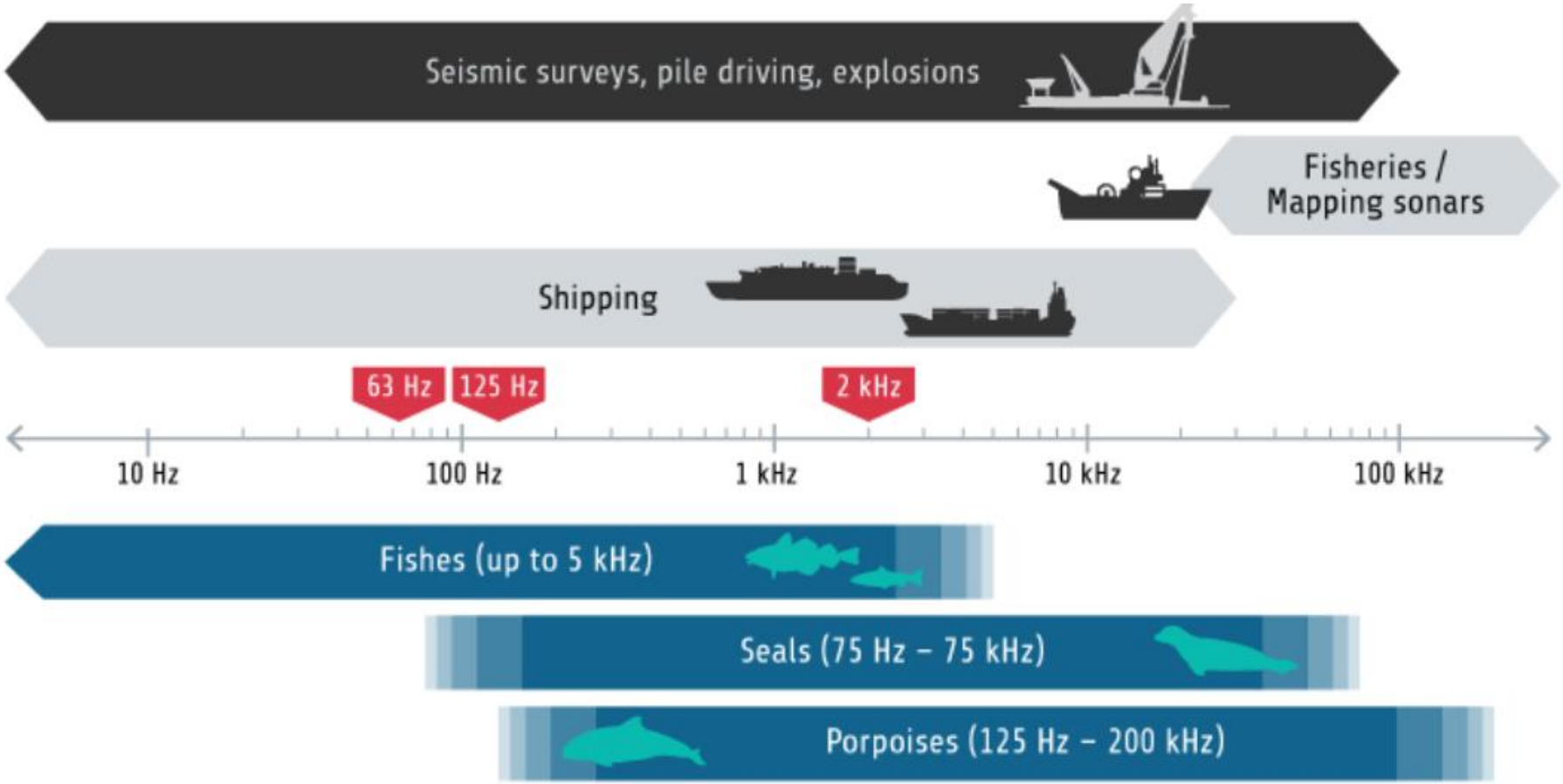
6. **Stress**

“In December 2009, a pod of seven male sperm whales stranded along the Adriatic coast. The animals were part of the same group and the Mediterranean population. Causes of death did not include biological agents, or the ‘‘gas and fat embolic syndrome’’, associated with direct sonar exposure. Environmental pollutant tissue concentrations were relatively high. prolonged starvation. Chemical compounds subsequently entered the blood circulation and may have impaired immune and nervous functions. A multi-factorial cause underlying this sperm whales’ mass stranding is proposed herein based upon the results of postmortem investigations. The seven sperm whales took the same ‘‘wrong way’’ into the Adriatic Sea, a potentially dangerous trap for Mediterranean sperm whales.”

Mazzariol et al., 2011



https://us.whales.org/2018/10/15/whales-dolphins-and-the-climate-all-win-if-we-slow-down-our-ships-please-take-action/



Modified from Scholik-Schlomer (2015) and BIAS (2017)

http://stateofthebalticsea.helcom.fi/pressures-and-their-status/underwater-sound/

ZONES OF INFLUENCE

Sound detection:

Behavior modification, vocalization, food search.

'Masking’:

sound interferes with biological signal detection. Communications, echolocation, navigation.

Reactivity:

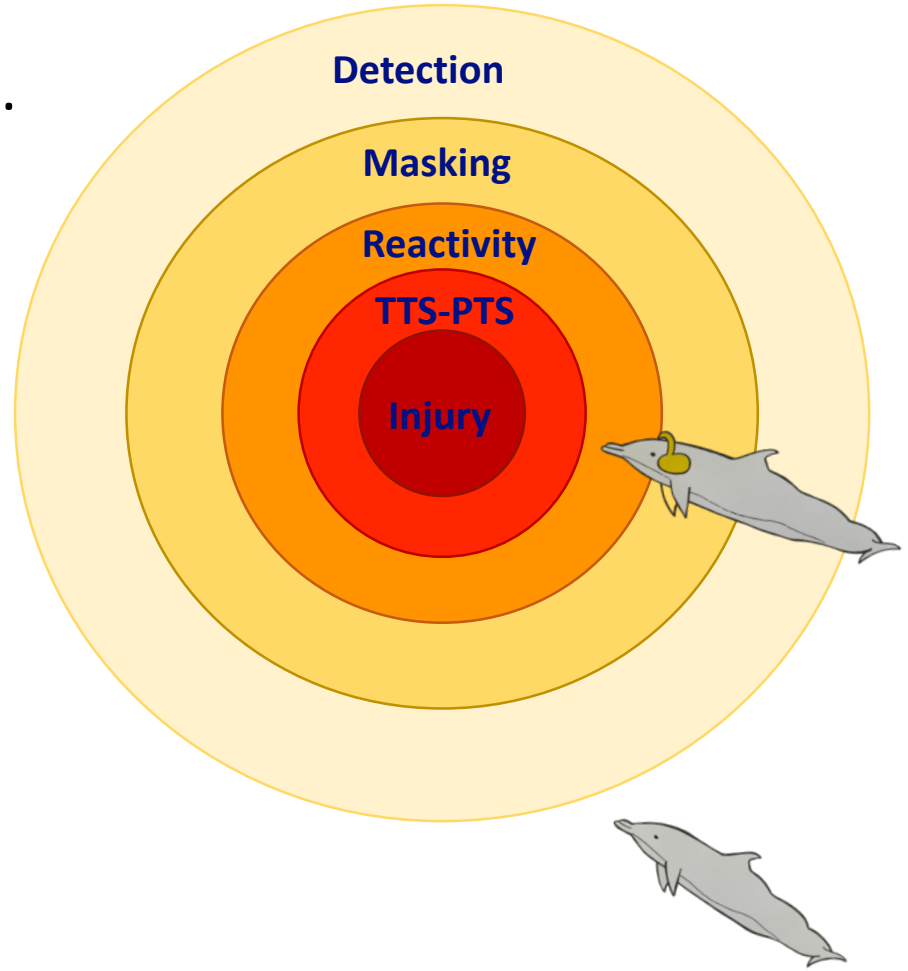
behavioral changes (avoidance or flight).

TTS, PTS:

hearing damage. Permanent / temporary lowering of the hearing threshold.

Injury:

physical effects (tissue damage, decompression symptoms)



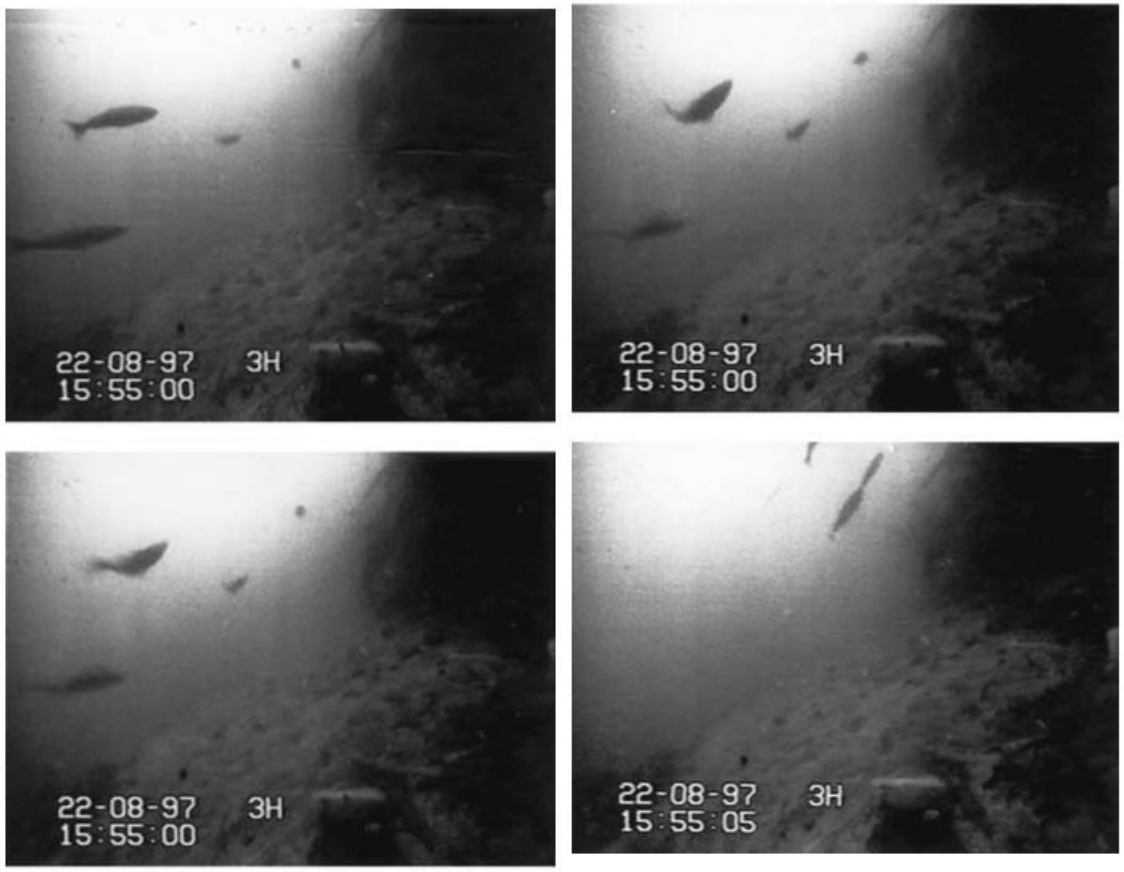
Modified after Richardson et al., 1995

Seismic surveys - responses to low frequency sound

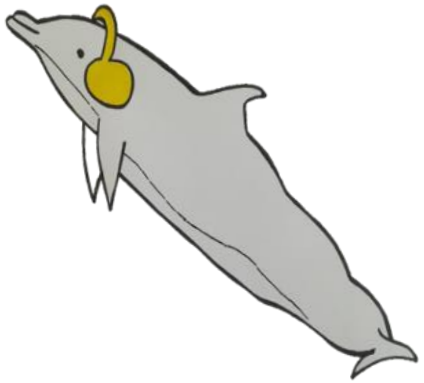
- **Fish**: high-intensity of airgun emissions may damage hair cells and cause changes in associated hearing capabilities (McCauley et al., 2003) **vs** other studies: no evidence of hearing damage.
- **Whales**: no evidence of distress (McCauley et al., 1998) vs vessel avoidance (Richardson et al., 1995)
- **Male humpbacks** attracted to single air gun – similarity to breaching sounds?

startle and alarm responses in fish, C-starts

Twardle *et al.,* 2001



MITIGATION MEASURES
basic principles



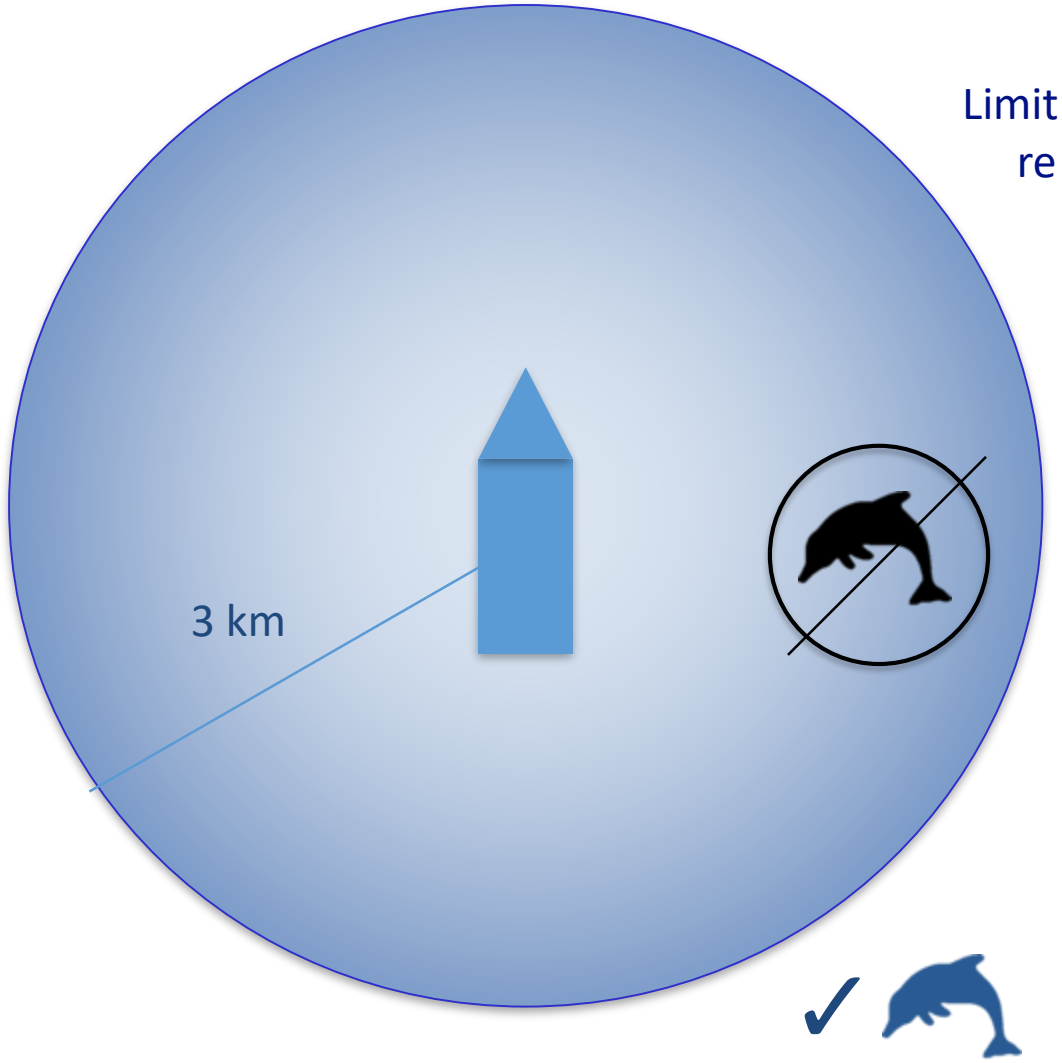
Planning:
avoid sensitive areas, exclusion zone.

Animal Detection:
passive visual monitoring (MMO)
passive acoustic monitoring (PAM)
interruption of operations

Operating procedures:
'Ramp up' = gradual increase in the sound pressure level.

Exclusion zone

- Defined with numerical modeling before the survey
- Acoustically and visually monitored during the survey (MMO e PAM).



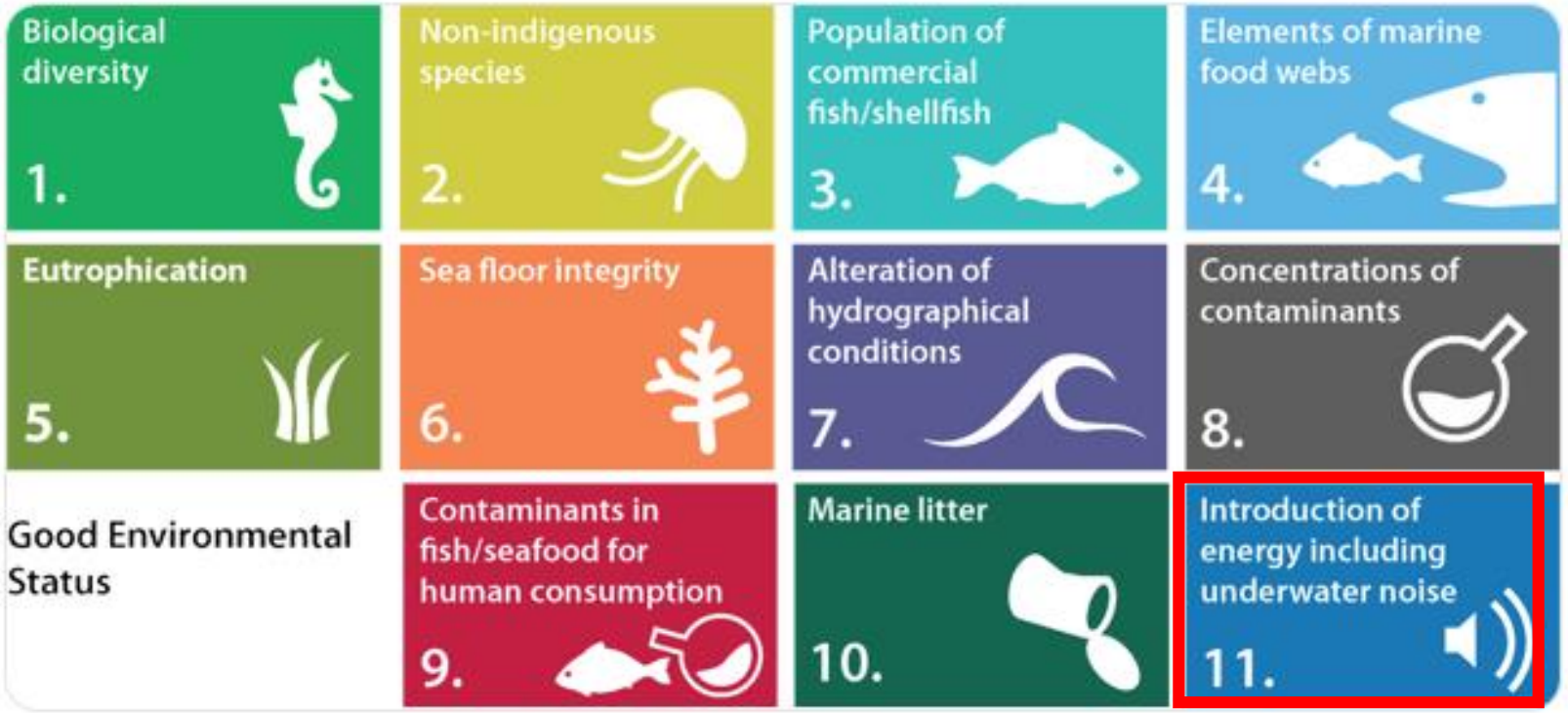
MARINE MAMMALS OBSERVERS (MMO)

https://www.mmo-association.org/

PASSIVE ACOUSTIC MONITORING (PAM)

Basic regulatory framework – European Union

MARINE STRATEGY FRAMEWORK DIRECTIVE - MSFD



Aim: to achieve the 'GOOD ENVIRONMENTAL STATUS' of seas and ocean

Descriptor 11. "**Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment**"

EU Zero Pollution Action Plan

- “The new limits mean, that to be in tolerable status, no more than 20% of a given marine area, can be exposed to continuous underwater noise over a year. Similarly, no more than 20% of a marine habitat can be exposed to impulsive noise over a given day, and no more than 10% over a year. ”

- “EU Member States will now need to take these threshold values into account when they update their marine strategies and eventually take actions in their programmes of measures.”

https://environment.ec.europa.eu/news/zero-pollution-and-biodiversity-first-ever-eu-wide-limits-underwater-noise-2022-11-29_en

https://www.snpambiente.it/wp-content/uploads/2020/05/Linee_Guida_SNPA_LLGGVIA_28_2020.pdf

ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Maggio 2012

Rapporto tecnico

Valutazione e mitigazione dell'impatto acustico dovuto alle prospezioni geofisiche nei mari italiani

Sistema Nazionale per la Protezione dell'Ambiente

VALUTAZIONE DI IMPATTO AMBIENTALE. NORME TECNICHE PER LA REDAZIONE DEGLI STUDI DI IMPATTO AMBIENTALE

Approvato dal Consiglio SNPA. Riunione ordinaria del 09.07.2019

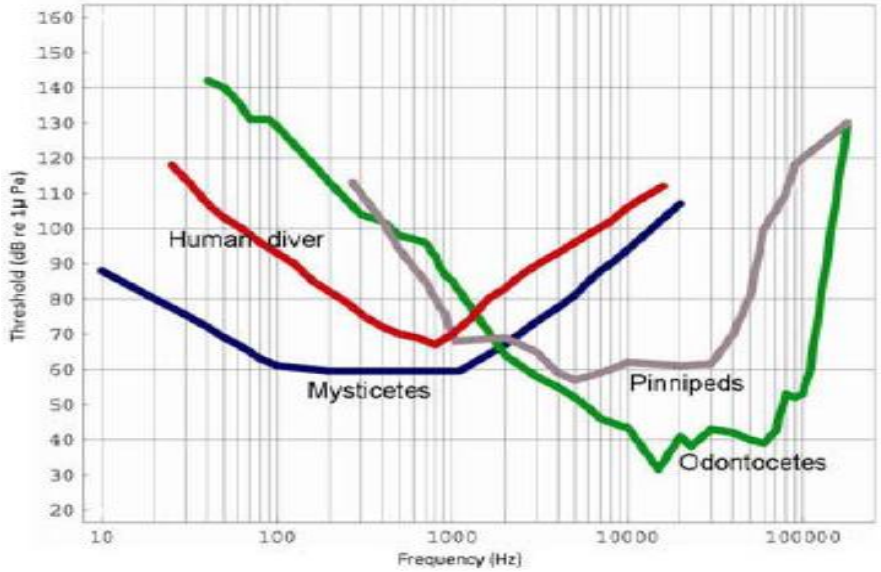
LINEE GUIDA
SNPA | 28 2020

Environmental Impact Assessment

1. **Define the area: geography, acoustical characterization of emissions**
2. **Study sensitive receptors and hearing thresholds** (Southall et al., 2007; 2019; 2021)

https://www.geoexpro.com/articles/2010/06/marine-seismic-sources-part-v-the-hearing-of-marine-mammals

Air Guns frequency band : 2-200 Hz



3. **Pressure analysis:** source and models used
4. **Define impacts** (and monitor before, during, after)
5. **Cumulative impacts**

Joint Nature Conservation Committee (JNCC) - UK

Pianificazione Monitoraggio pre-attività di 3 o più anni. Evitamento aree sensibili.

Appropriate Zone di sicurezza: Esame di un'area raggio di 500m dal centro dell'array per 30 min prima dell'inizio del *soft-start* (JNCC, 2010).

Zone di sicurezza: *Marine Mammal Observers* possono solamente raccomandare + PAM

ACCOBAMS The Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area

Pianificazione, Utilizzo sorgente meno potente possibile
Modellazione campo sonoro in relazione alle caratteristiche oceanografiche
PAM e MMO con operatori specializzati; Ramp up (30 min, 120 min per *Ziphius cavirostris*)
Mitigazioni aggiuntive per le acque profonde (*Ziphius cavirostris*)

ASCOBANS Agreement on the Conservation of Small Cetaceans of the Baltic & North Seas

Pianificazione: Aree di esercizio. Monitoraggio visivo 30 min.

Mitigazione in tempo reale: Zona di esclusione f =(caratt. fonte sonora, caratt. propagazione). PAM, Ramp-up

Monitoraggio post-esercizio: Relazionare alle autorità nazionali. Definire modellazione del campo sonoro generato e *background noise*.

Take home message

- Underwater sound is a big part of marine life
- Studying these topics requires multidisciplinarity
- If you work in the marine field, you will probably introduce noise. The goal is to be aware and try to conduct your experiments with minimum impact.