**Università di Trieste**
**LAUREA MAGISTRALE IN GEOSCIENZE**
**Curriculum Geofisico**
**Curriculum Geologico Ambientale**

**Anno accademico 2020 – 2021**

# Geologia Marina

Parte II

**Modulo 7.1 Effetti del rumore sull'ambiente marino**

**Angelo Camerlenghi**
acamerlenghi@inogs.it

# OUTLINE

Introduction
Sound in the marine environment
Anthropogenic Sound in the marine environment
- sources
- impacts
- mitigation

Legislation and policies

## Introduction

Noise has major negative impacts on

- Communication
- sleep and mood
- children's school learning skills
- cardiovascular system
- hearing loss.

## Introduction

The World Health Organization (WHO) has declared that in Europe traffic noise is an environmental problem second only to air pollution:

some 30 million Europeans would be exposed to decibel levels that are hazardous to their well-being.

living on busy streets or near an airport increases the risk of heart attacks and strokes by 20 to 25%

*"Un giorno, l'uomo dovrà combattere i rumori con la stessa tenacia con cui ha combattuto il colera e la peste"*

*(Robert Koch 1843-1910)*

1905 Nobel Price in Medicine

Introduction

# APPROACH

## RESEARCH


## THRESHOLDS

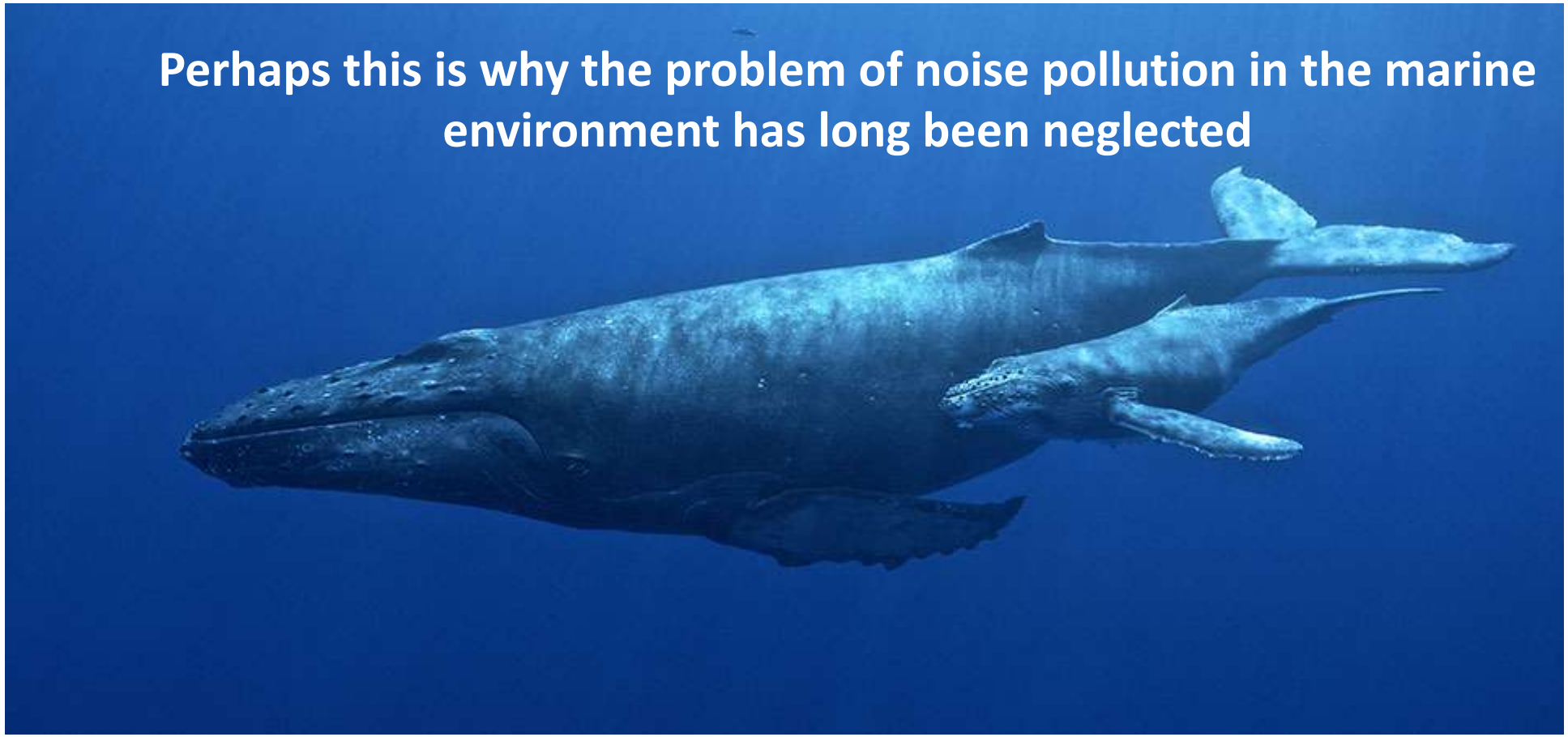

## MITIGATION MEASURES

ARPAT
Agenzia regionale per la protezione ambientale della Toscana
INSIEME PER UN FUTURO SOSTENIBILE

Sound in the marine environment

## And in the marine environment? (70% of the earth's surface)

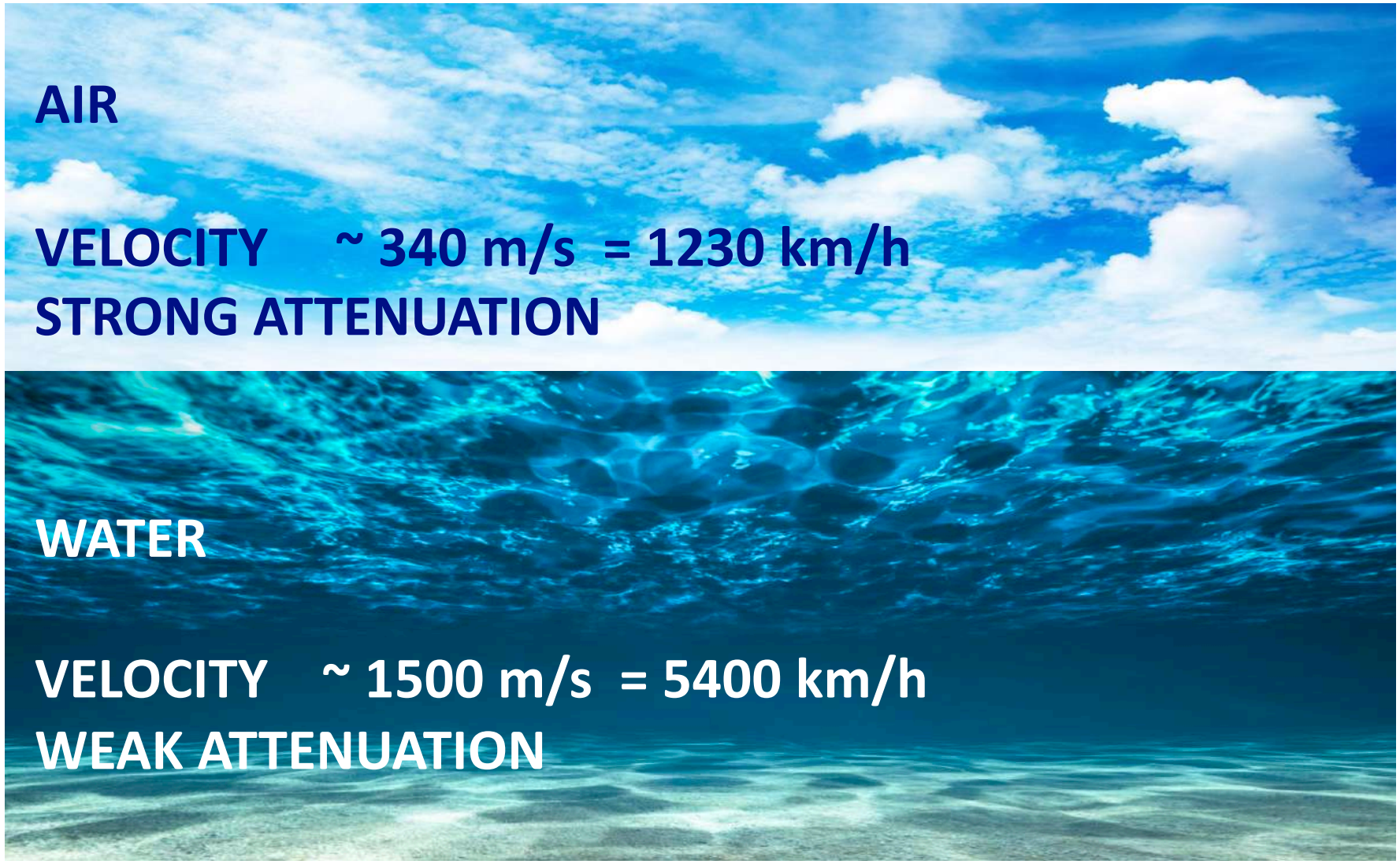
## No human beings live




Humpback whales swimming underwater. Photo credit: Ed Lyman/NOAA, under NOAA permit #14682

Sound in the marine environment

# SOUND PROPAGATION



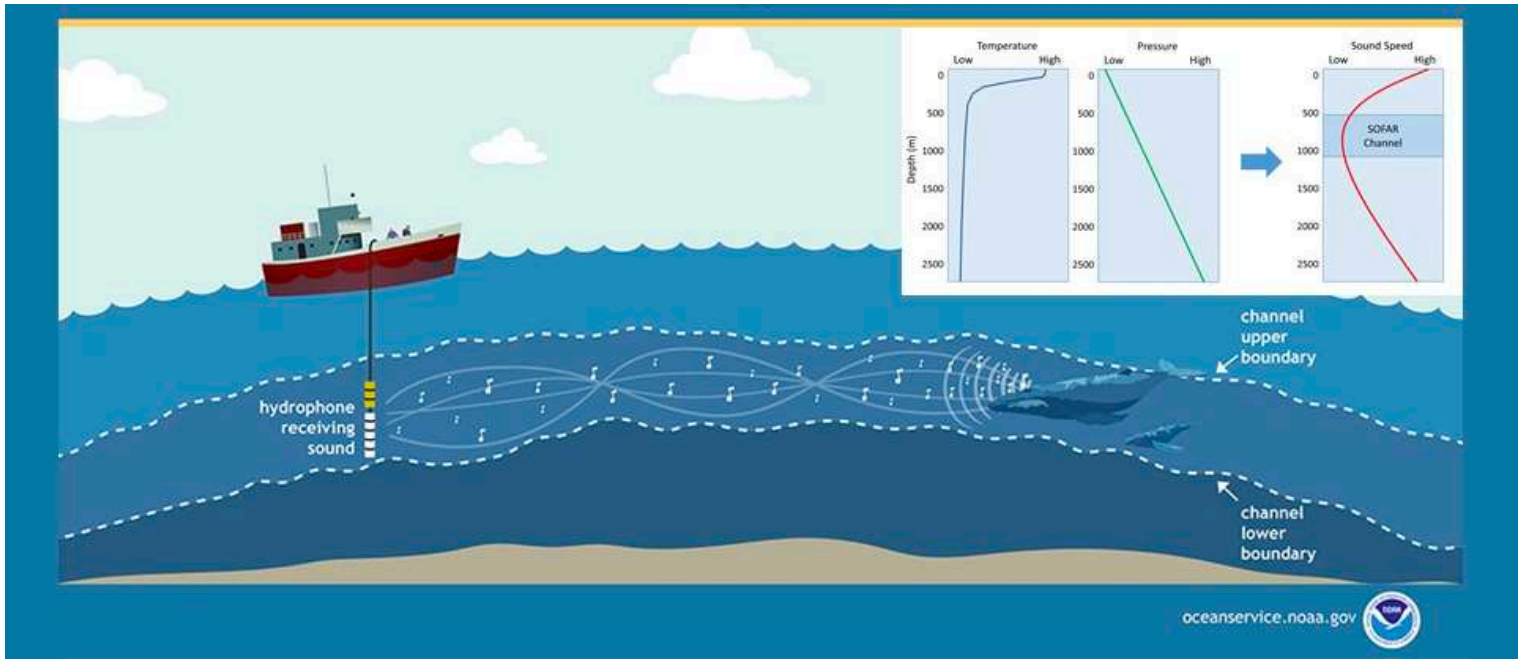

$$c = \sqrt{\frac{K}{\rho}} = \sqrt{\frac{1}{\chi\rho}}$$

*c = velocity*
*K = Bulk Modulus* $[N \cdot m\text{-}2]$
$\rho$ *= Density* $[kg \cdot m\text{-}3]$
$\chi$ = Compressibility = 1/K

Sound in the marine environment

# SOund Fixing And Ranging Channel

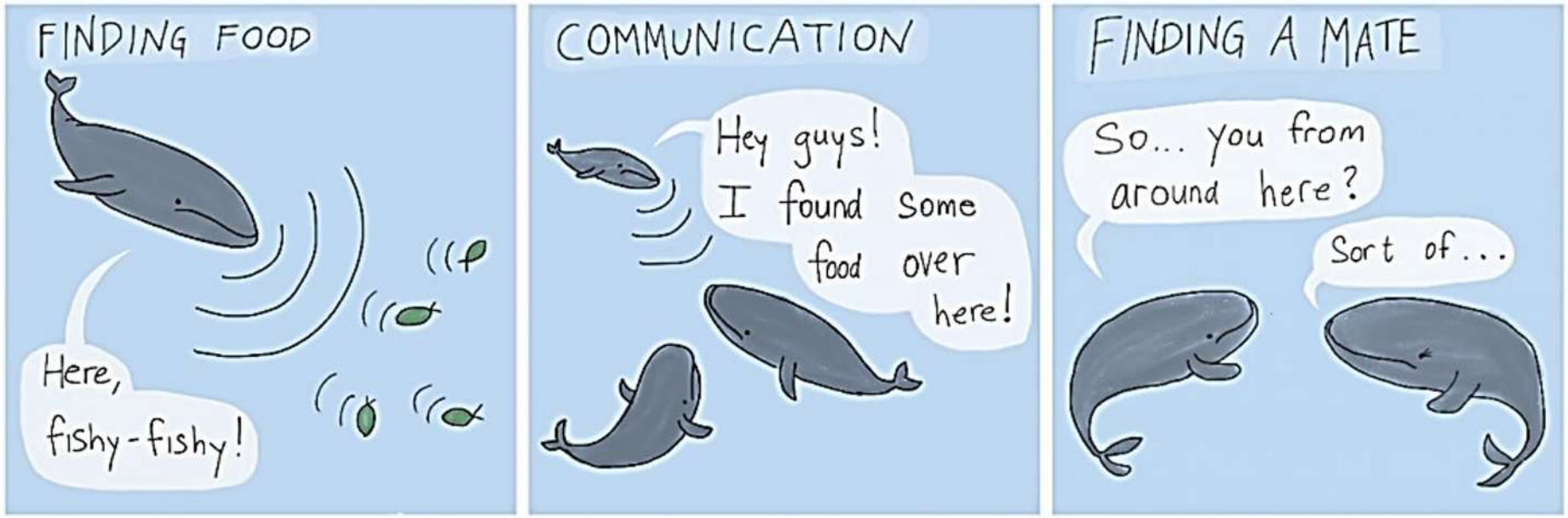
Low-frequency sound waves within the channel can travel thousands of miles before dissipating




SOFAR CHANNEL

Sound in the marine environment

# USE OF SOUND BY MARINE ANIMALS




"CLICKS" Odontoceti (Orcas, Dolphins, Porpoises, Sperm Whales) to detect the size and nature of objects

“MOANS”, “TONES” - communication, navigation mysticetes (Fin Whales, Humpback Whales)

“VOCALIZATIONS” Humpback whales only by males and only during the mating season

**Communication, Find food, Find a mate**

https://dosits.org/galleries/audio-gallery/marine-mammals

Sound in the marine environment

# Whales and dolphins

**Odontocetes –** whales and dolphins with teeth

impulsive clicks – echolocation

whistles + other sounds – communication

**Mysticetes** – whales with baleen moans and tones – communication and navigation

Sound in the marine environment

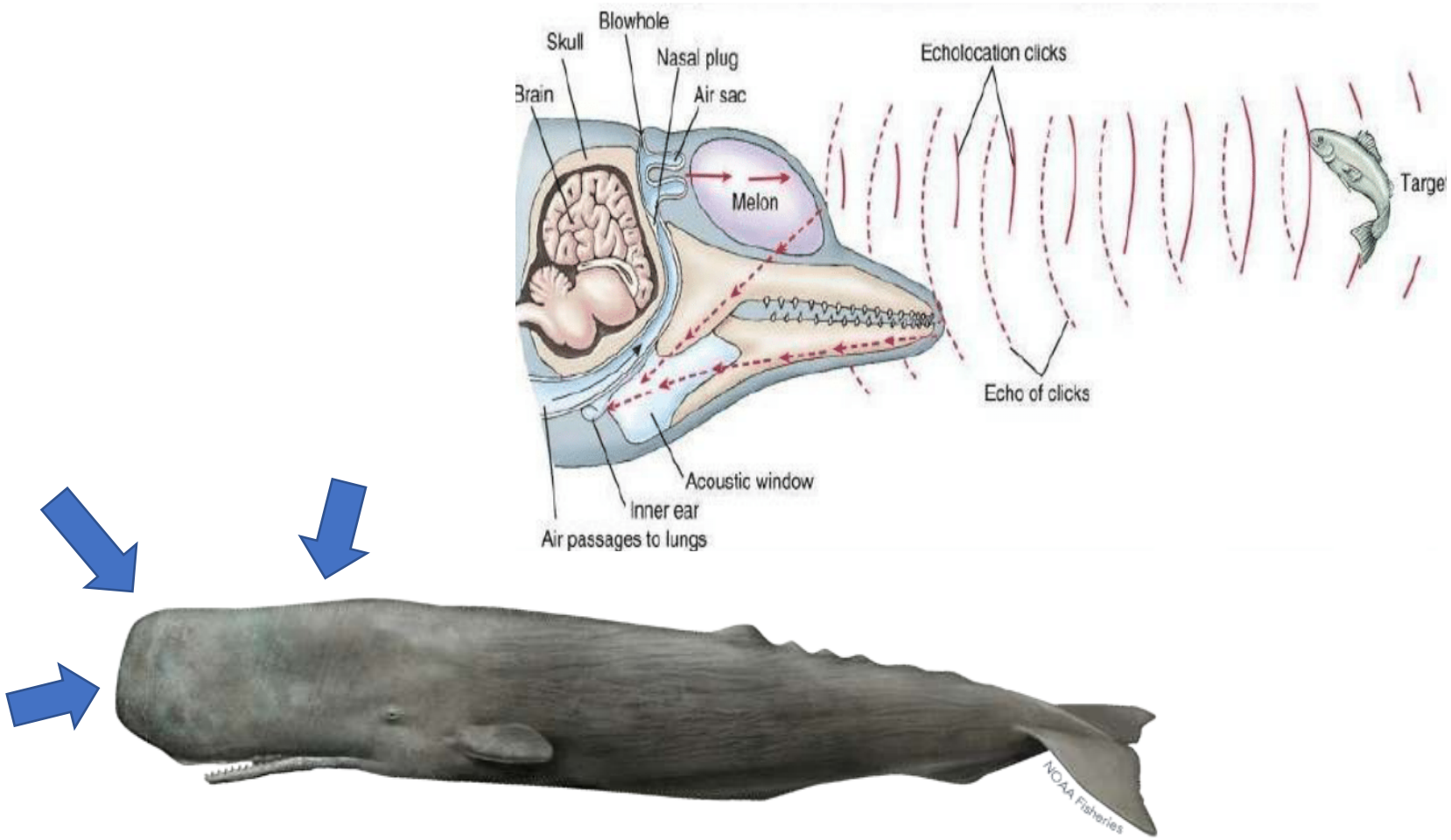
## OTHER ANIMALS

INVERTEBRATES

FISH !

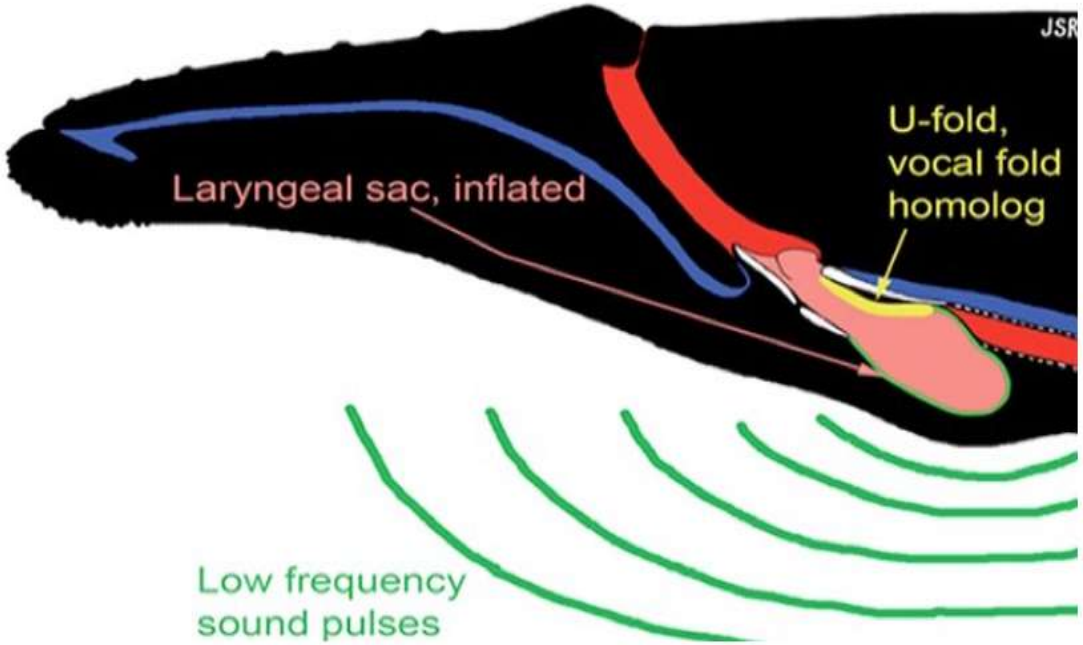
# Sound production

## Odontocete head anatomy and acoustic beam



# Sound production

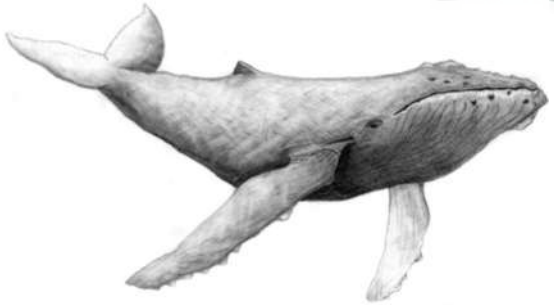
## Mysticete head anatomy



# Sound in the marine environment

Balenottera azzurra

Balenottera comune



Megattera

Balena della Groenlandia

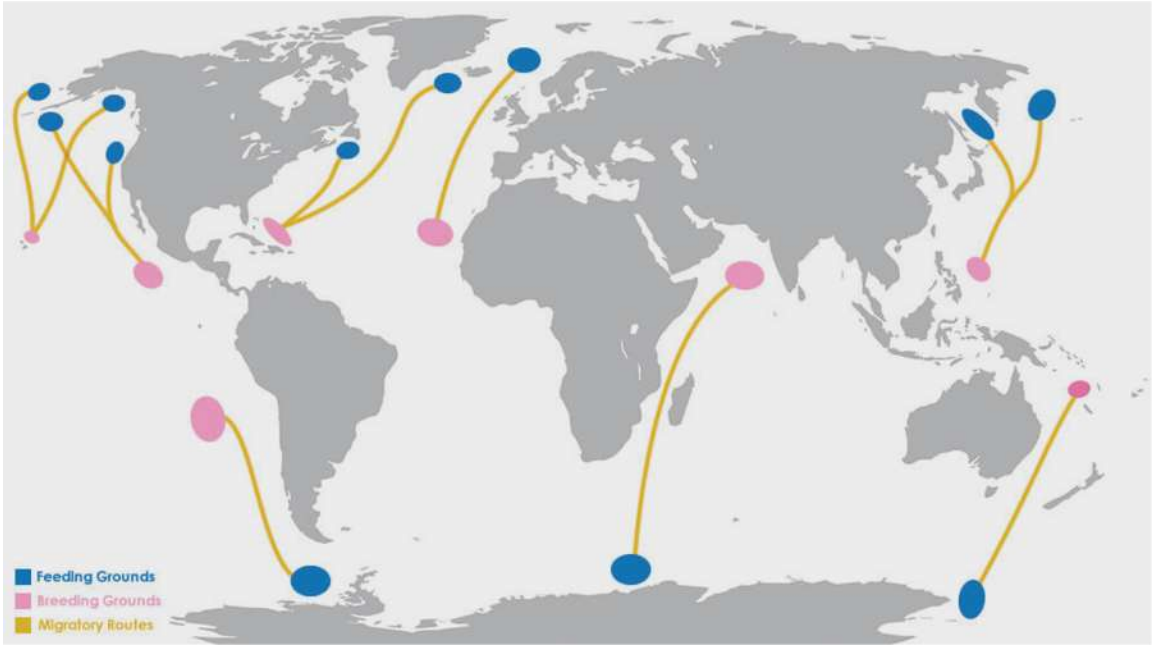
Balenottera minore

## Mysticetes

Sound in the marine environment

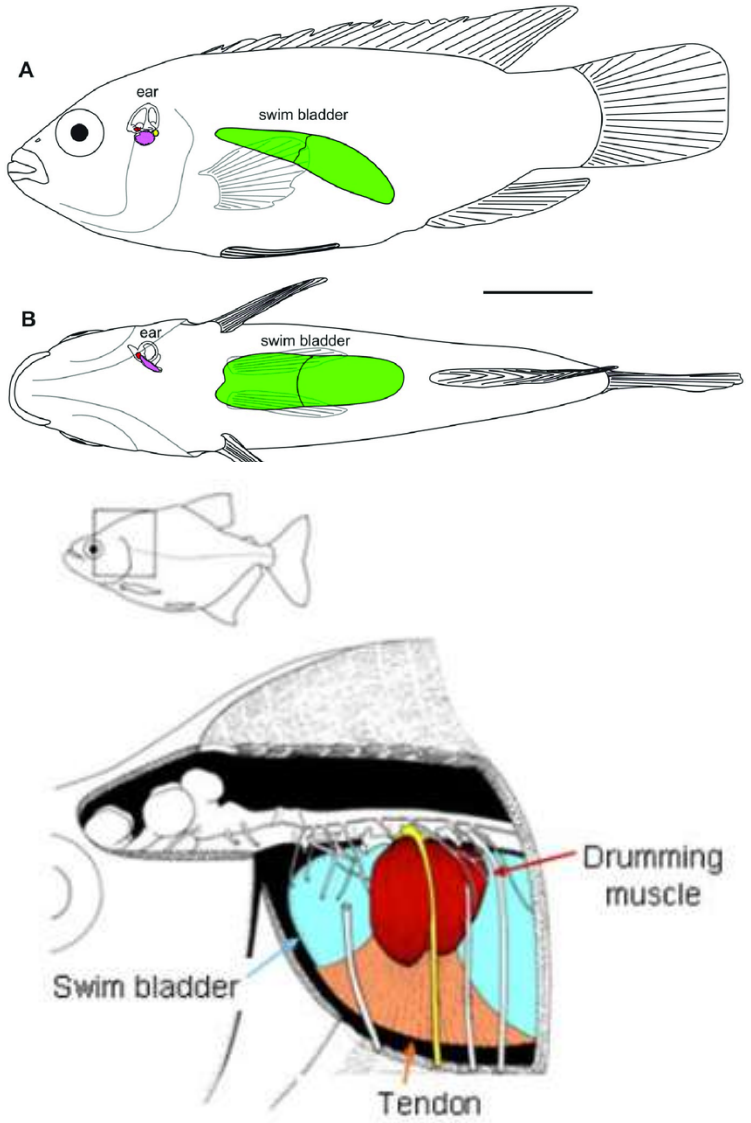
## Why do whales sing?

- We don't know for sure
- To mark the territory
- To communicate with the little ones
- To coordinate the migration
- To attract females
- Why do they have fun (?)



# Fish bioacoustics

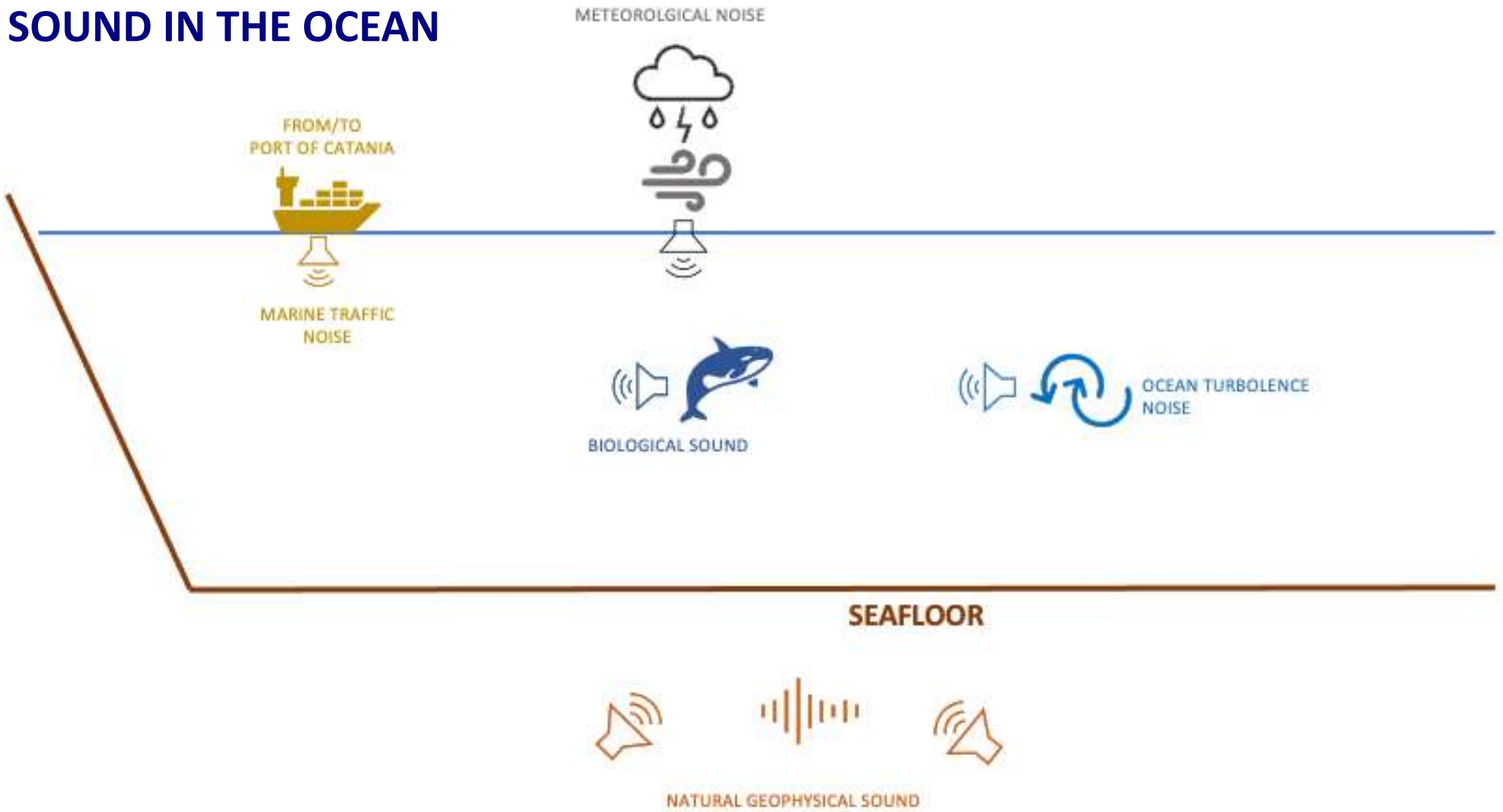
- Fishes produce different types of sound.
- Sounds can be produced as signals to predators, to attract mates, as a fright response.
- Ways to produce sound: drumming, stridulation, hydrodynamics.




Schulz-Mirbach et al., 2012

Sound in the marine environment

# NATURAL SOUND IN THE OCEAN



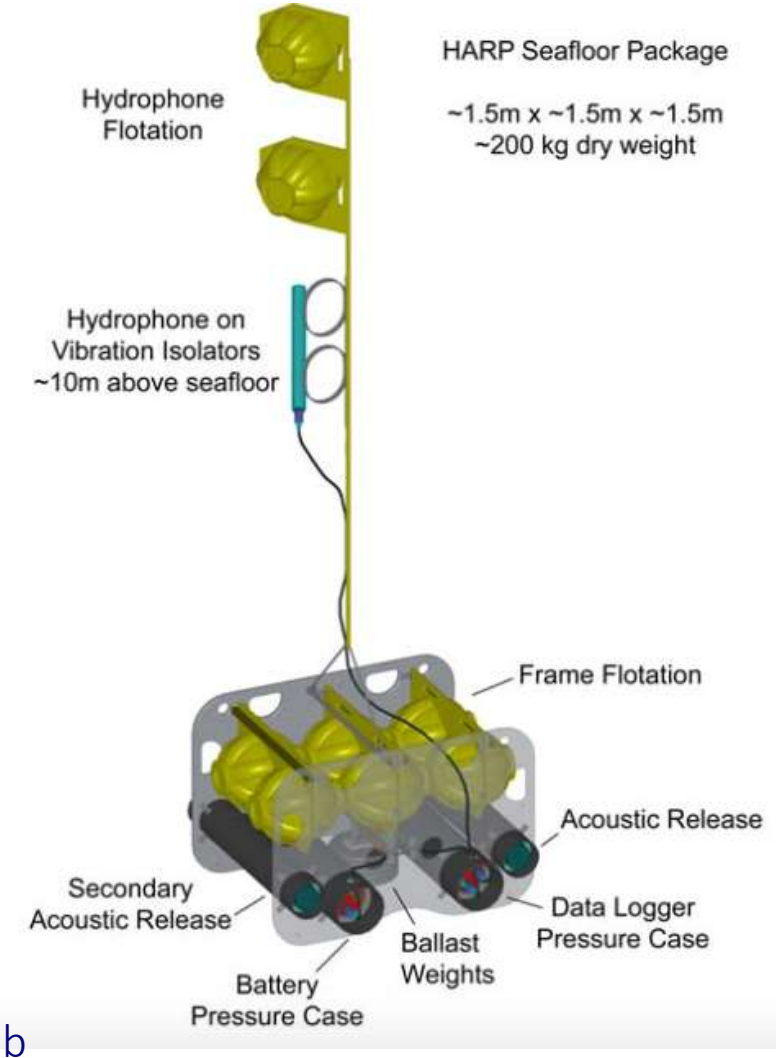
Sound in the marine environment

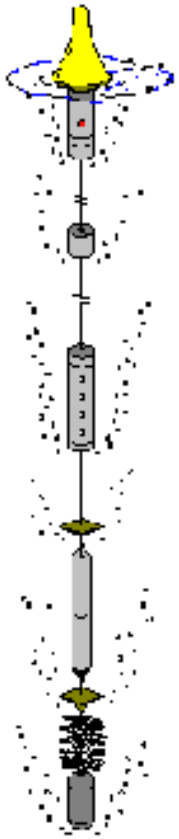
# MEASURING UNDERWATER SOUND

Deployment of an acoustic recorder in Florida Keys National Marine Sanctuary. NOAA

Sound in the marine environment

# Recording equipment



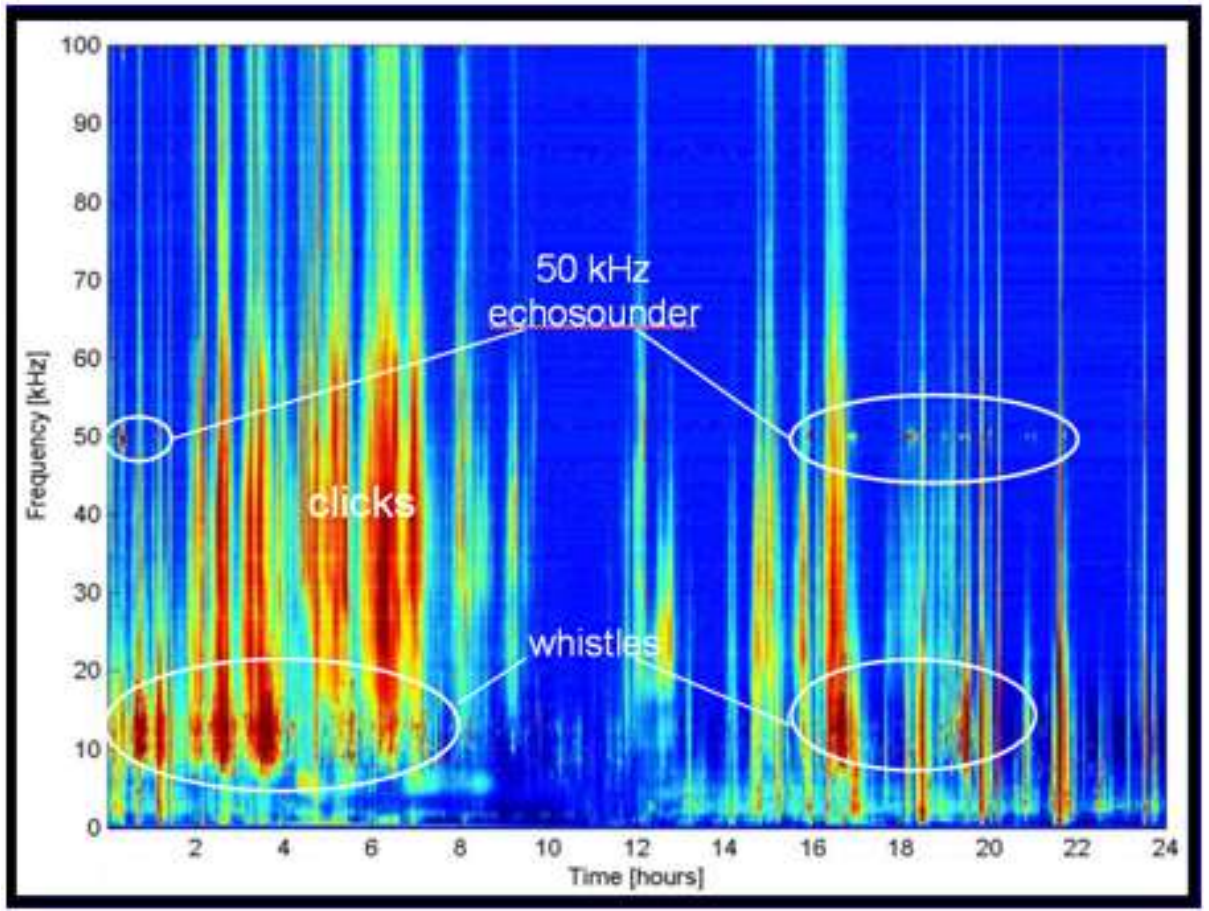



Scripps whale acoustic lab
Sonobuoy.crane.navy.mil

Sound in the marine environment

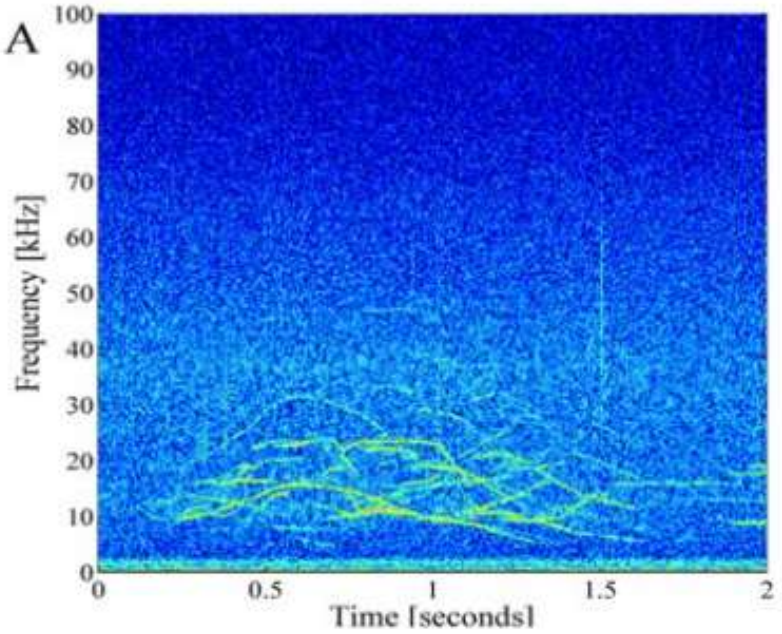
# Sound spectral analysis -LTSA

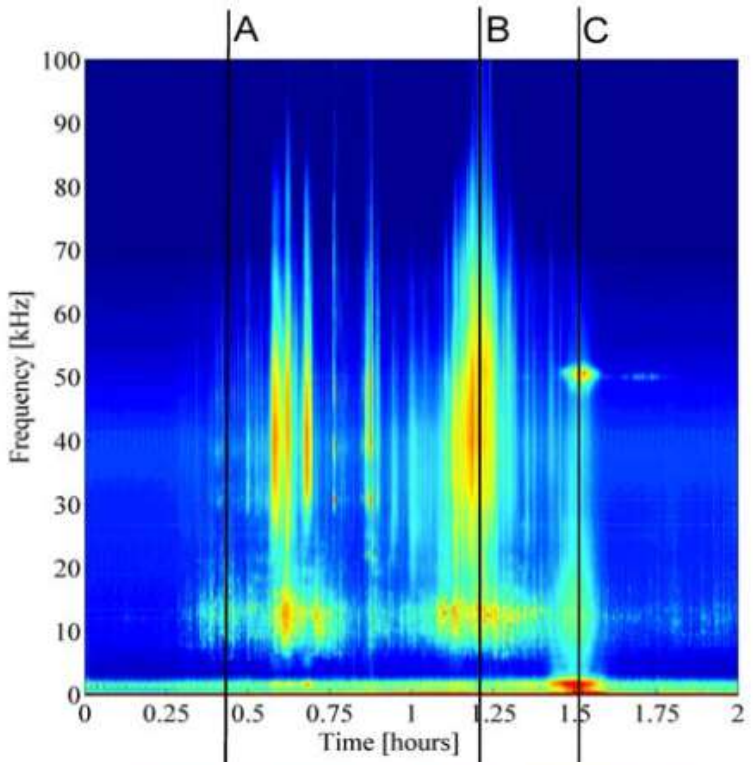
- Visual representation of sound.
- Horizontal dimension is time, vertical dimension is frequency.
- Intensity of the sound is the colour.

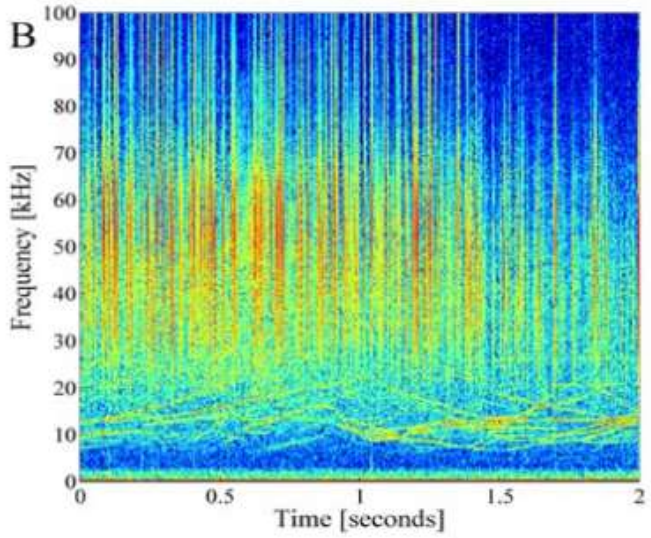


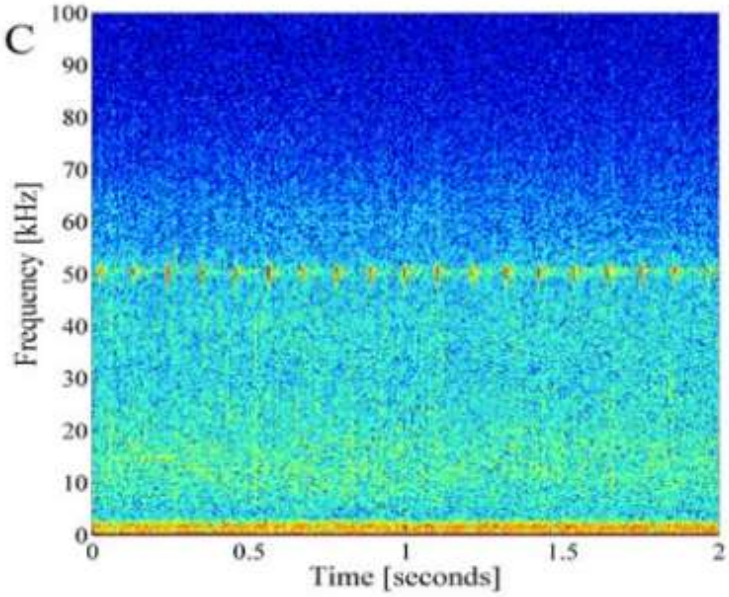

Courtesy of Scripps Whale Acoustic Lab

# Sound in the marine environment

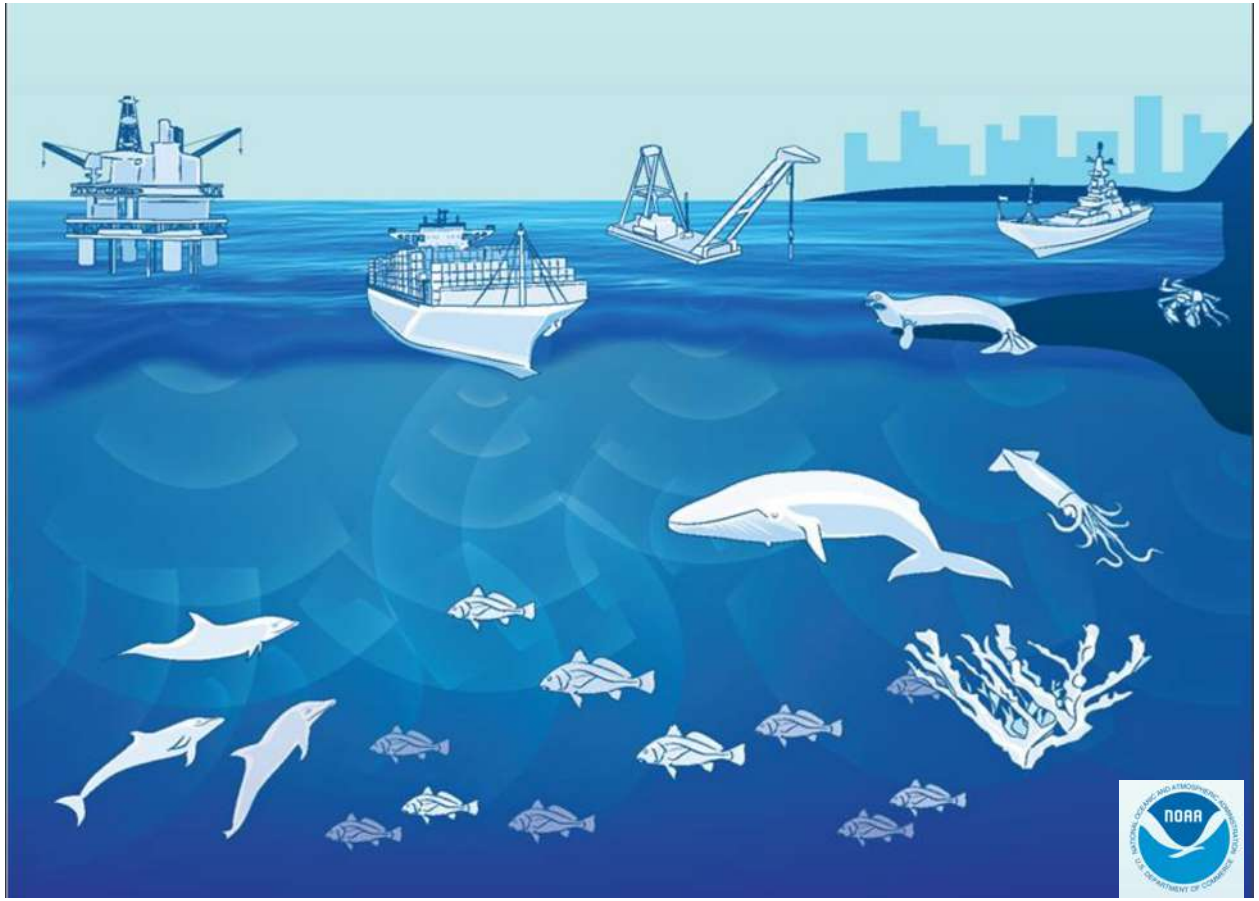


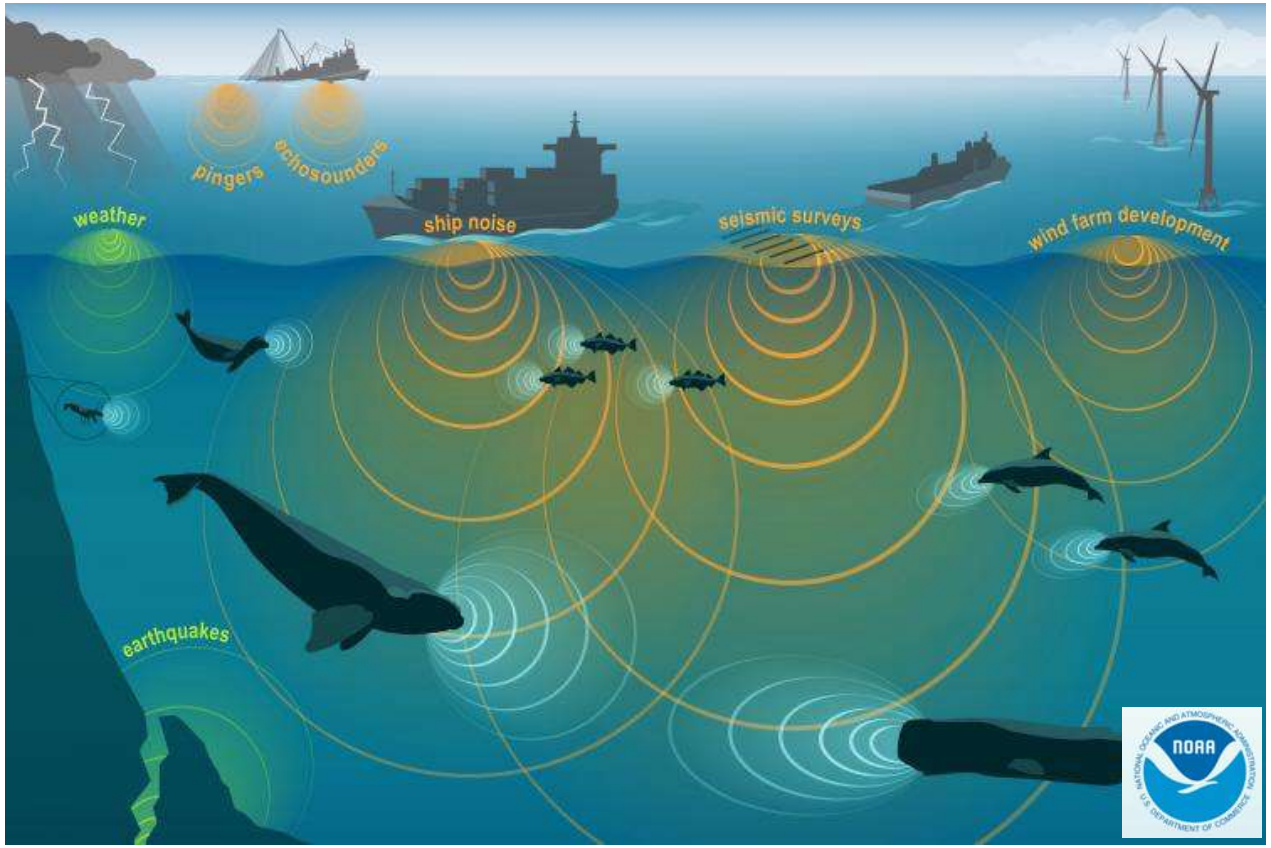



# Anthropogenic Sound in the marine environment
## Sources

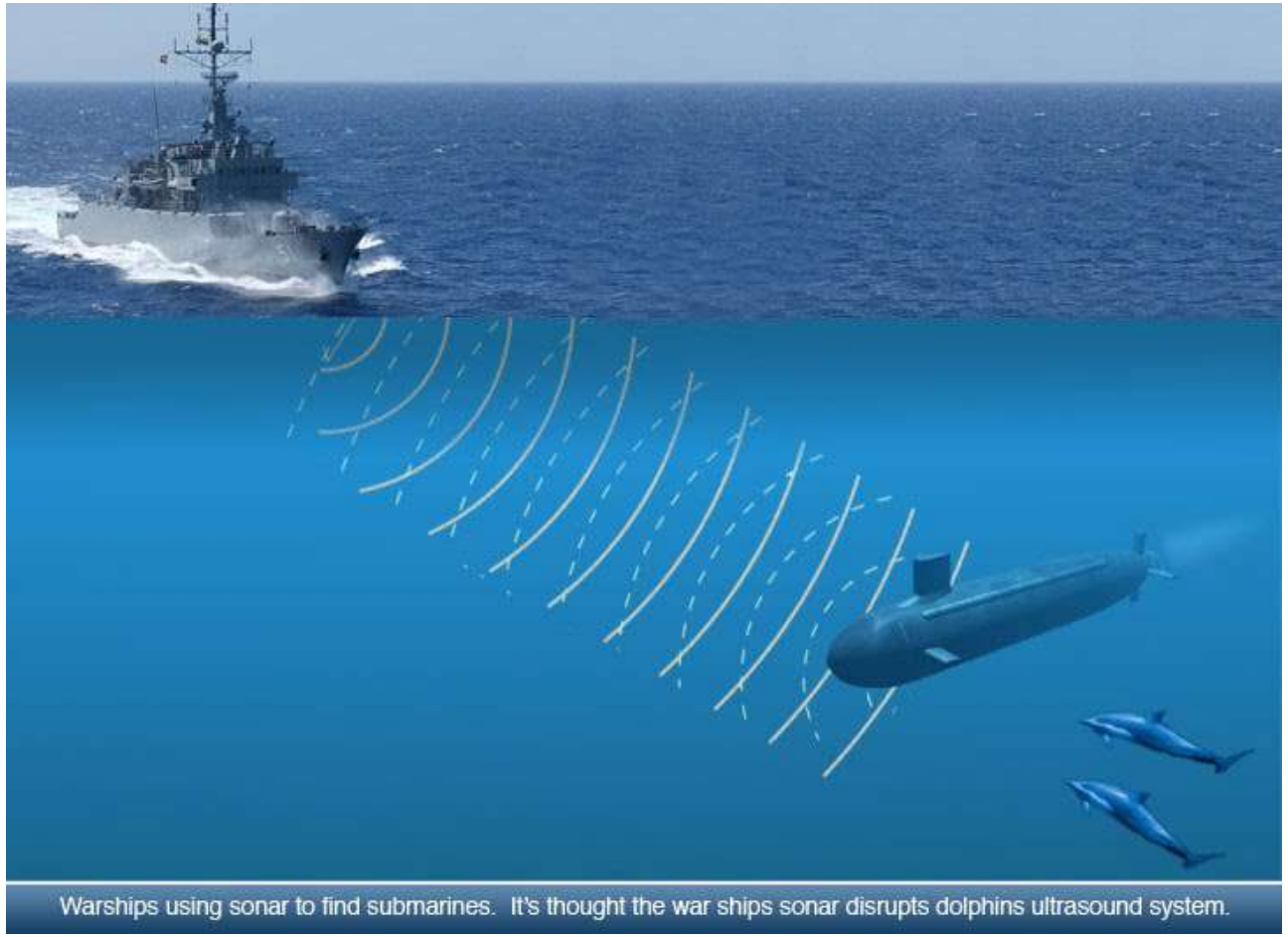





**THE BIG FIVE!**

Anthropogenic Sound in the marine environment
Sources

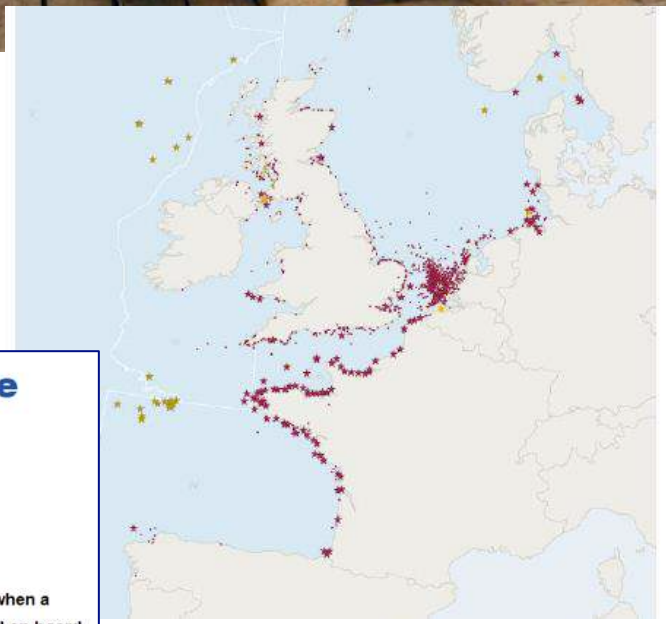
# 1.(military) Sonar



Warships using sonar to find submarines. It's thought the war ships sonar disrupts dolphins ultrasound system.

# Anthropogenic Sound in the marine environment
## Sources

## 2.Explosions



**World War II bomb kills three fishermen**

AFP

Friday, April 08, 2005

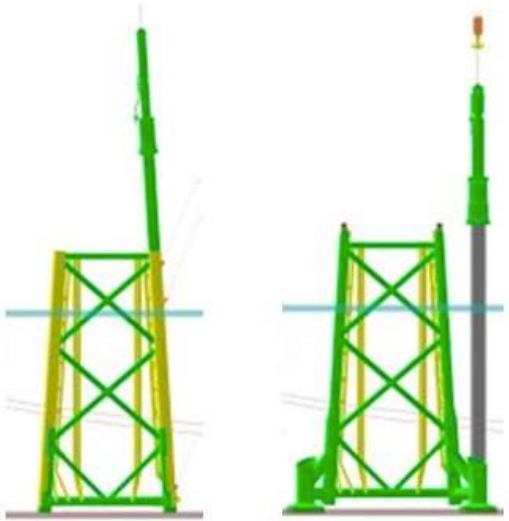
Like Share 0 Tweet

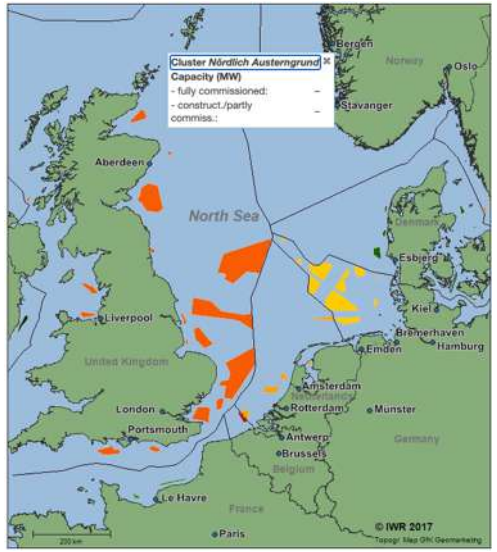
THE HAGUE (AFP) - Three Dutch fishermen were killed yesterday when a suspected World War II bomb they picked up in their nets exploded on board the vessel, the ANP news agency reported.

Courtesy **Frans-Peter Lam** TNO

Anthropogenic Sound in the marine environment
Sources

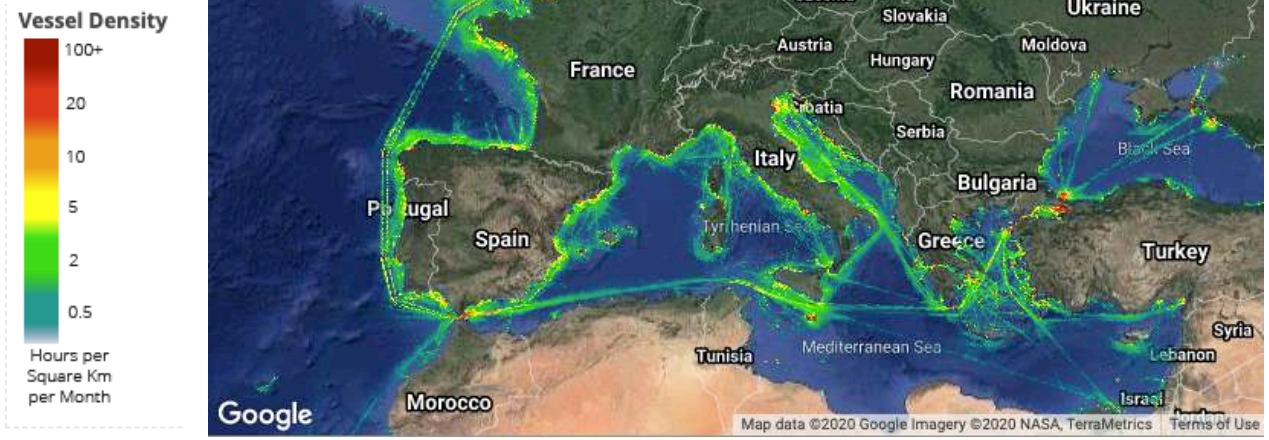
# 3.Offshore activities, pile driving (offshore wind farms)



Anthropogenic Sound in the marine environment
Sources

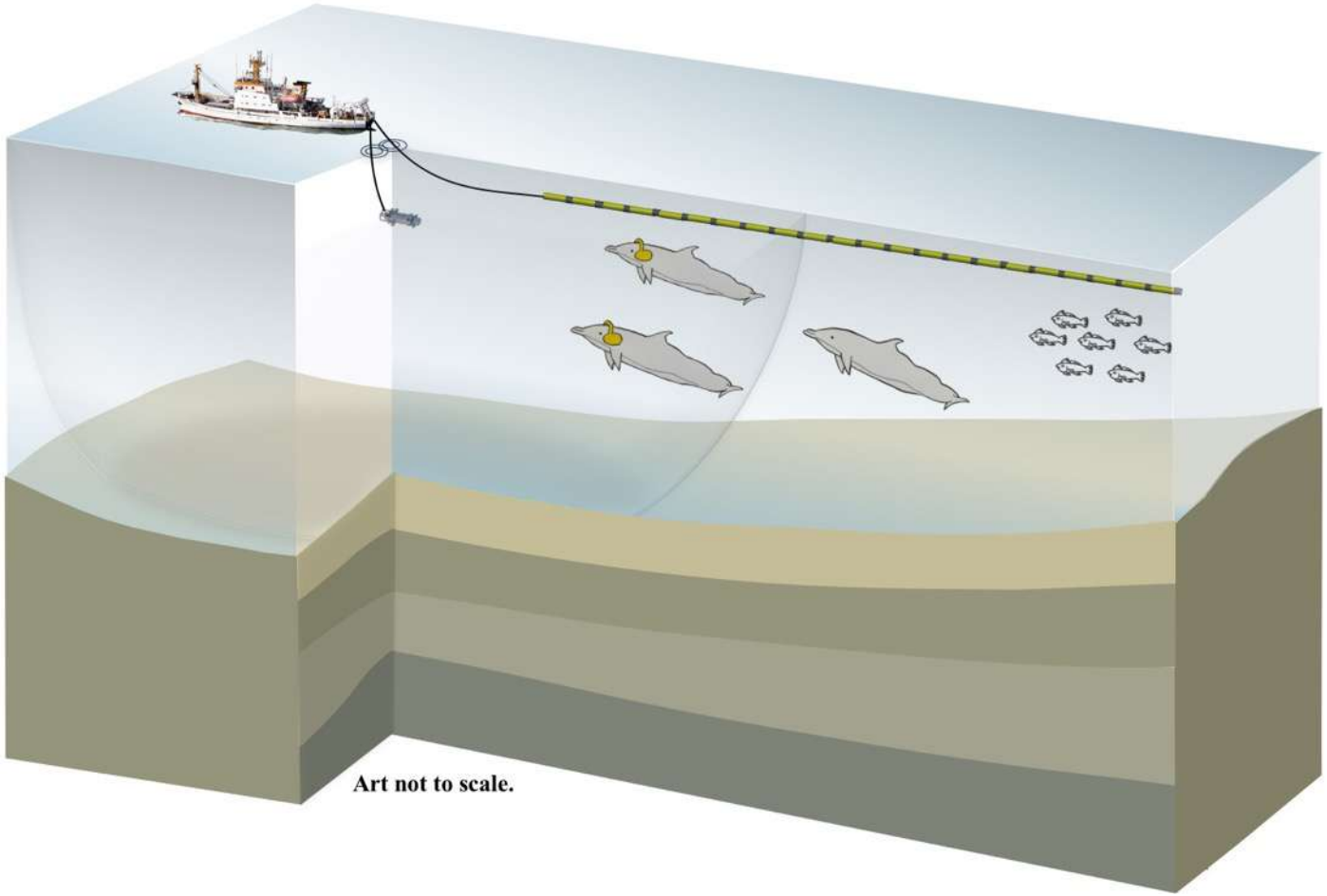
# 4. Shipping




EMODnet HUMAN ACTIVITIES
*Making use of our oceans*

Anthropogenic Sound in the marine environment
Sources

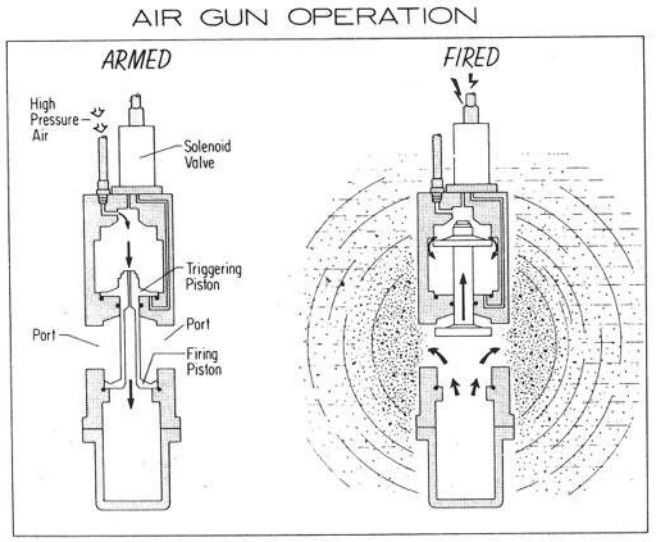
# 5. Seismic exploration



# Anthropogenic Sound in the marine environment
## Sources

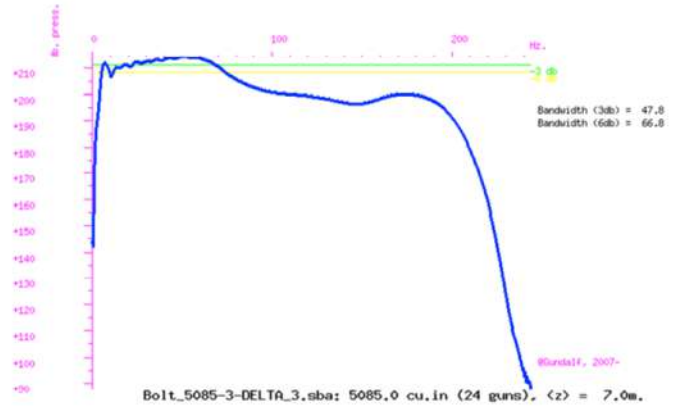
# Anthropogenic Sound in the marine environment
## Sources

## Cannoni ad aria (*air guns*)





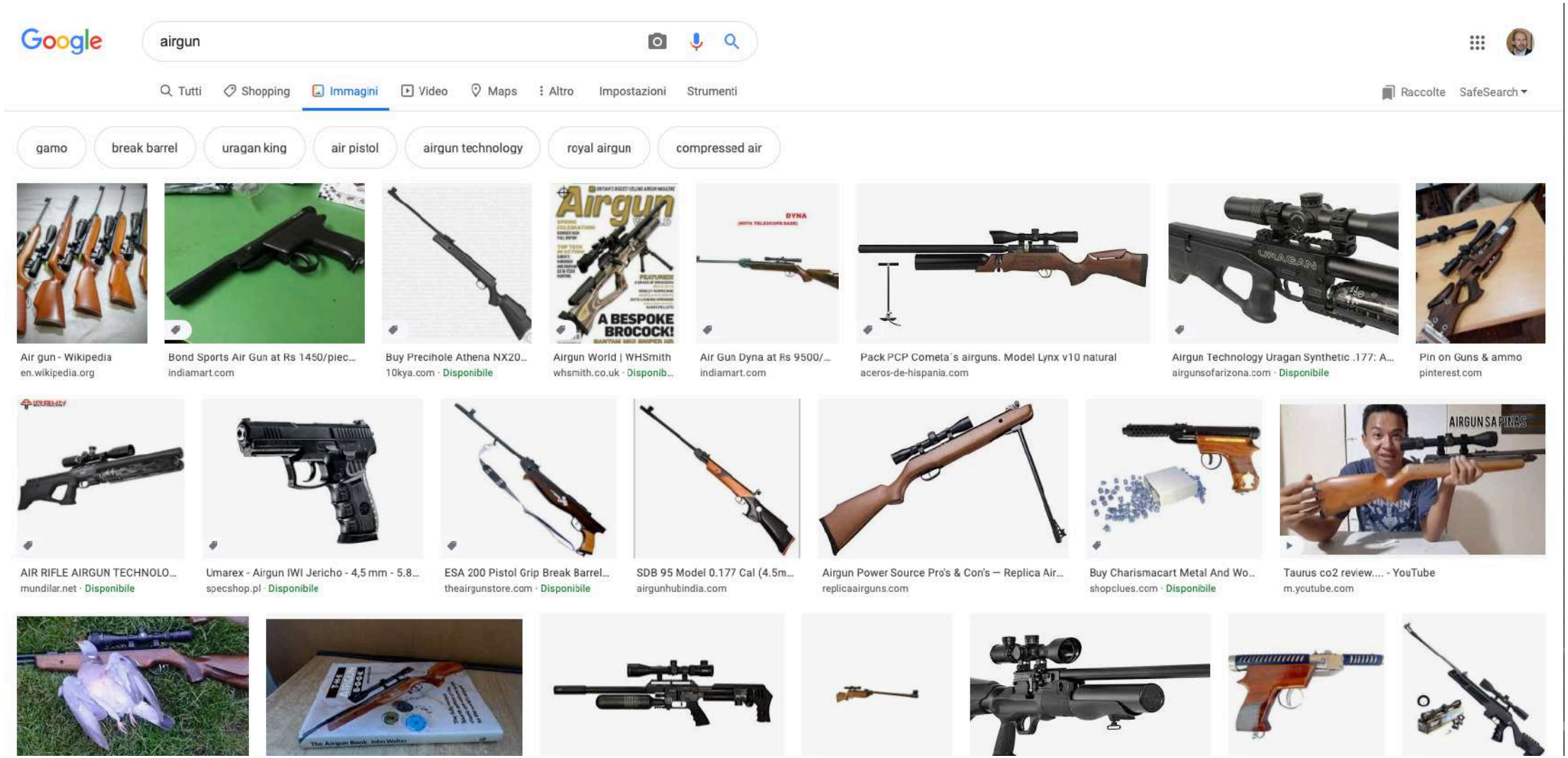
| | intervallo di frequenza |
|---|---|
| **Sismica naturale** | 0.1 - 5 Hz |
| **Sismica convenzionale a bassa frequenza** *Deep scientific / industrial exploration* | 5 - 80 Hz |
| **Sismica ad alta risoluzione** *Fluid escape, gaz hydrates, reservoir modelling* | 50 - 400 Hz |
| **Sismica a risoluzione molto alta** *Site survey, sedimentary models, reservoir modelling* | 300 - 2000 Hz |




Spettro di frequenza (near field) di un array industriale

# Anthropogenic Sound in the marine environment
## Sources

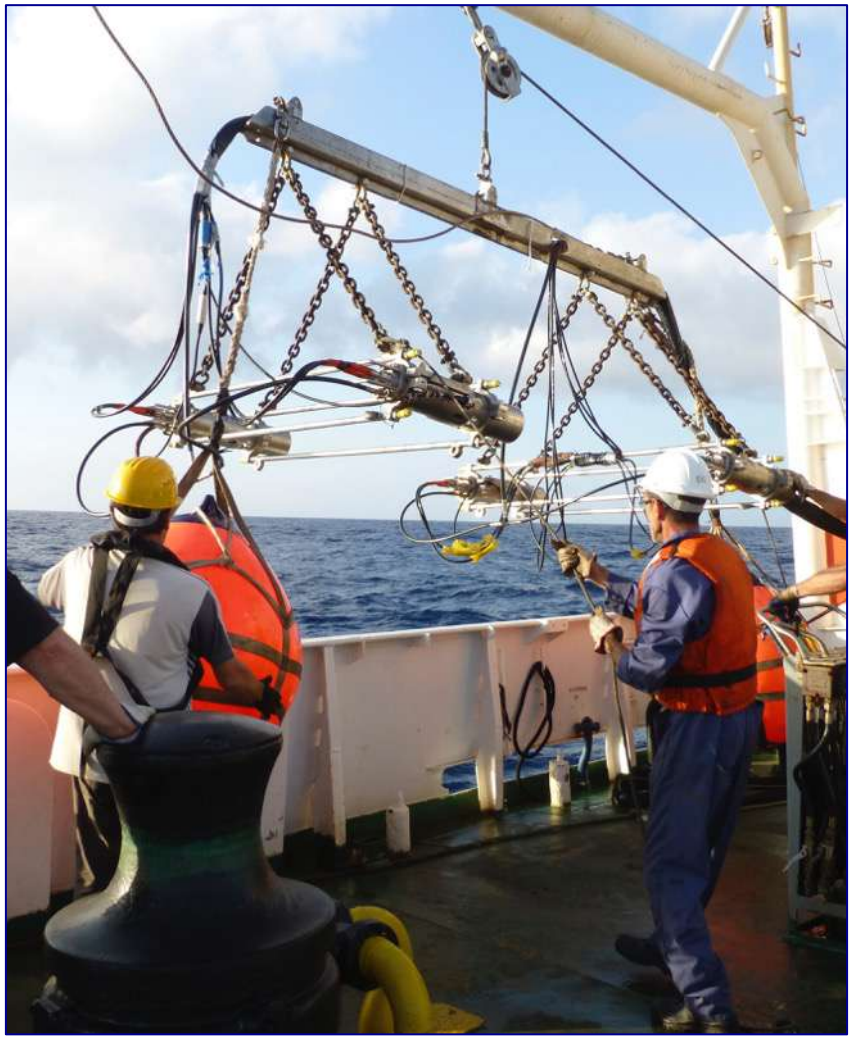
## Google Search: airgun



# Anthropogenic Sound in the marine environment

## Sources

### Airguns



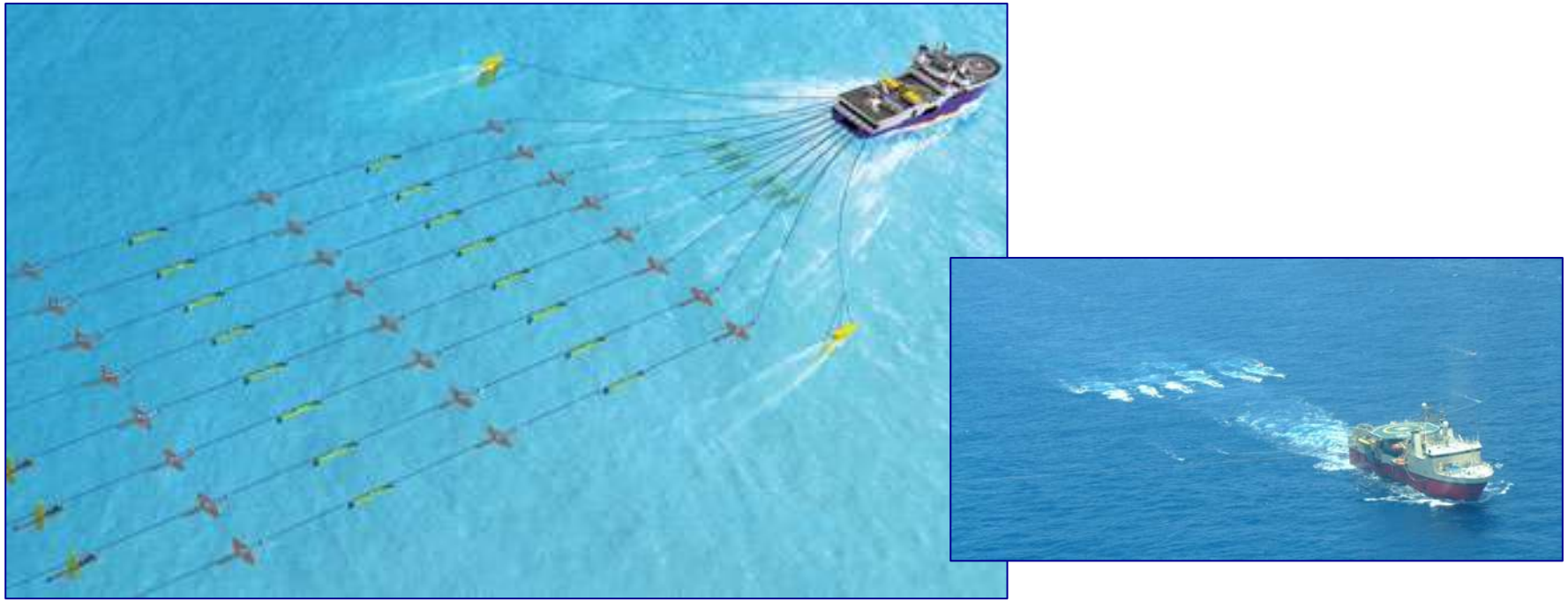
# Anthropogenic Sound in the marine environment
## Sources

### Seismic streamer

# Anthropogenic Sound in the marine environment

## Sources

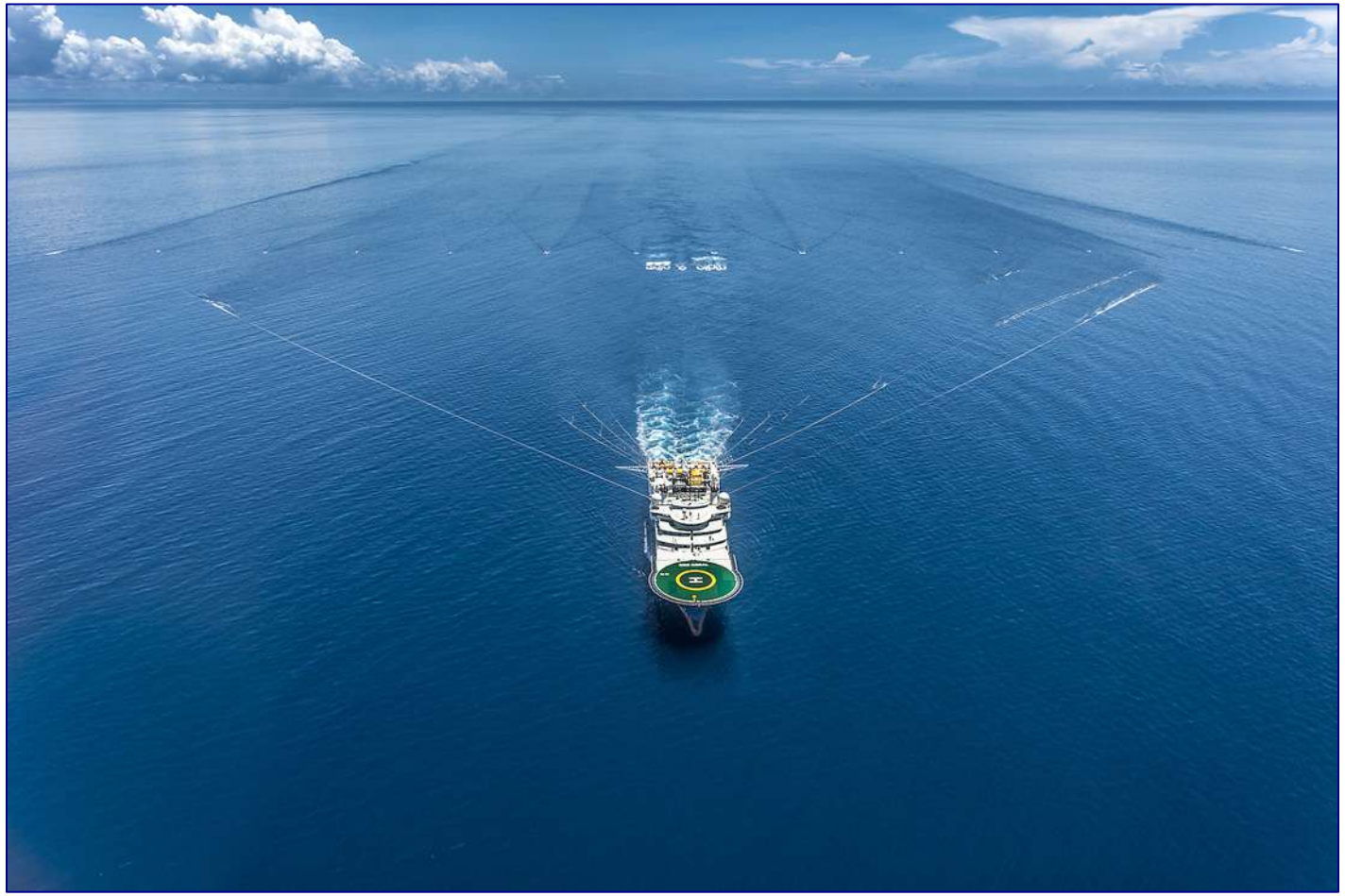

# Anthropogenic Sound in the marine environment
## Sources



BGP, TGS Sign Seismic Data Acquisition Contract for East Africa. http://subseaworldnews.com/2013/05/23/

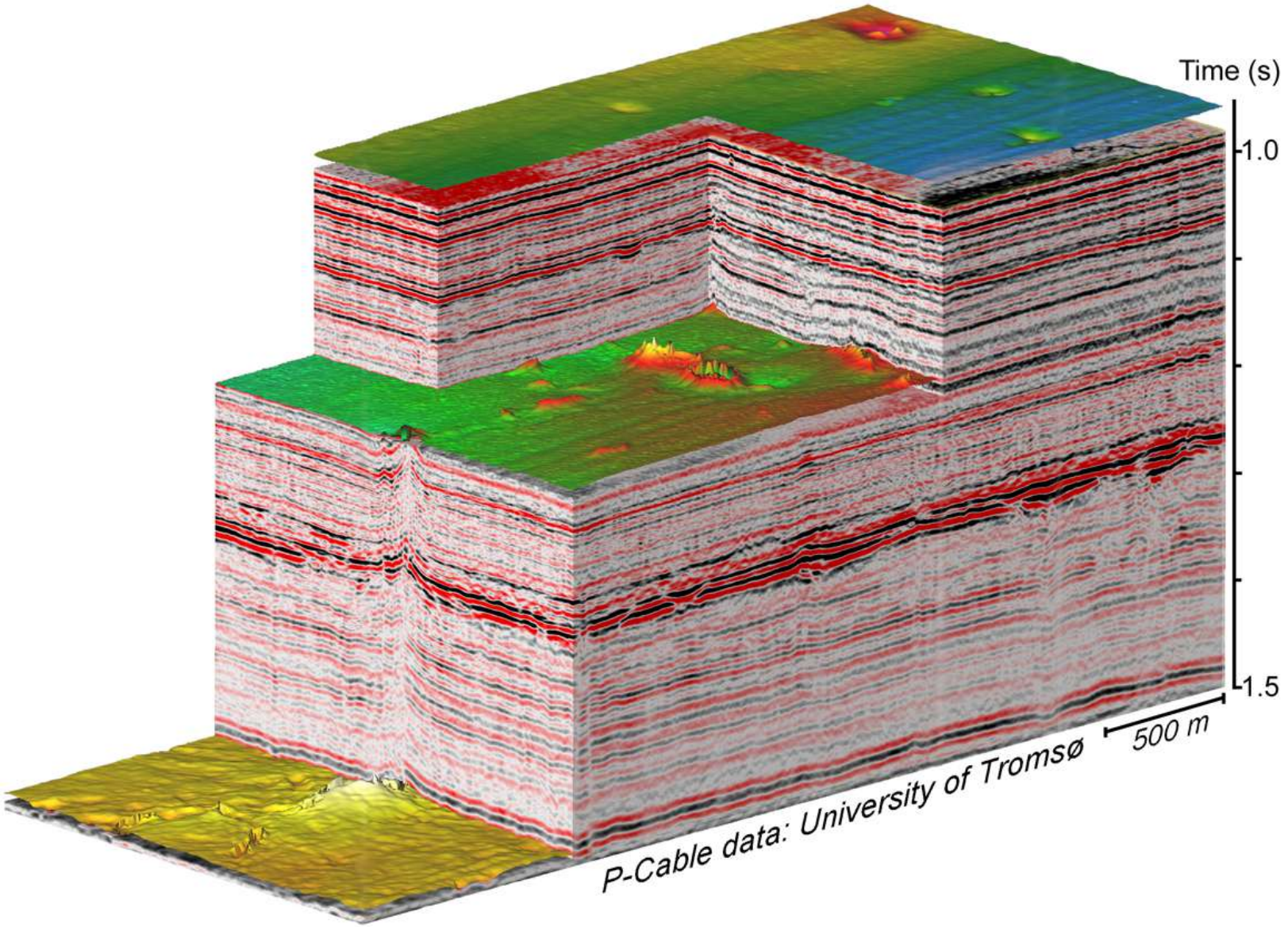
# Anthropogenic Sound in the marine environment

## Sources



Geophysical Surveys - International Association of Geophysical ...
www.iagc.org1100 × 733Search by image

# Anthropogenic Sound Sources




http://www.geometricspcable.com

# Anthropogenic Sound in the marine environment
## Sources

Early phase of geophysical prospecting at sea: Explosives were commmonly ised.

**Today, this is fobidden**

Airguns are pneumatic impulsive seismic sources

They do not generate any explosion underwater

www.cgg.com

1958 CGG's first dual vessel marine survey, with one boat as source, initially using an underwater dynamite charge. A second boat towed the streamer recording the seabed reflections.

Anthropogenic Sound in the marine environment
Sources

# Airguns - 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?

Airgun discharges: startle and alarm responses in fish, C-starts

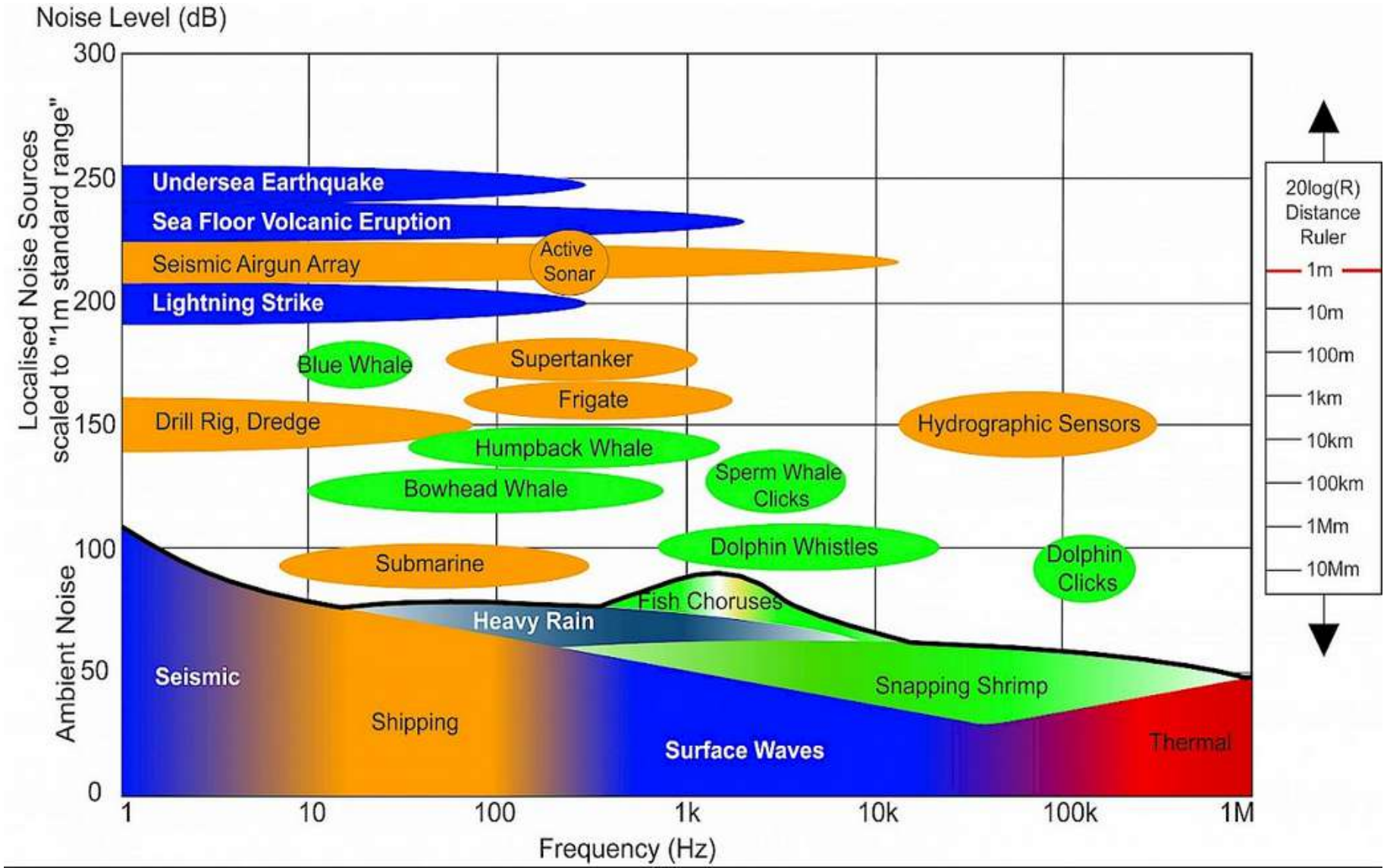

Twardle *et al.,* 2001

**Double, double toil and trouble;**
**Air guns fire and ocean bubble.**
(with apologies to Shakespeare's witches)
- W. H. Dragoset

Anthropogenic Sound in the marine environment

Sources

# Underwater sound sources



Anthropogenic Sound in the marine environment
impacts

# 5 EFFECTS ON MARINE FAUNA

- ✓ Injury
  - Damage to tissues (rupture, internal bleeding)
  - Gas embolism or decompression symptoms
- ✓ Hearing Loss
  - Irreversible damage to the hearing apparatus
  - Permanent lowering of the hearing threshold (PTS)
  - Temporary lowering of the auditory threshold (TTS)

Richardson et al., 1995

Anthropogenic Sound in the marine environment
impacts

# 5 EFFECTS ON MARINE FAUNA

✓ Masking

*Masking of intraspecific communications*
*Masking of interspecific communications*
*Interference with the ability to analyse the environment*

✓ Behavioural Disturbance

*Temporary Interruption of normal behaviour*
*Partial modification of natural behaviour*
*Moving from an area normally occupied (for short or long term)*
*Temporary interruption of social ties*

Anthropogenic Sound in the marine environment
impacts

# 5 EFFECTS ON MARINE FAUNA

✓ Other indirect effects

*Less availability of prey*

*Increased vulnerability to predation or other risks (eg stranding)*

*Behavioral changes that cause physical damage (eg collisions with boats)*

Anthropogenic Sound in the marine environment impacts

# Zones of influence

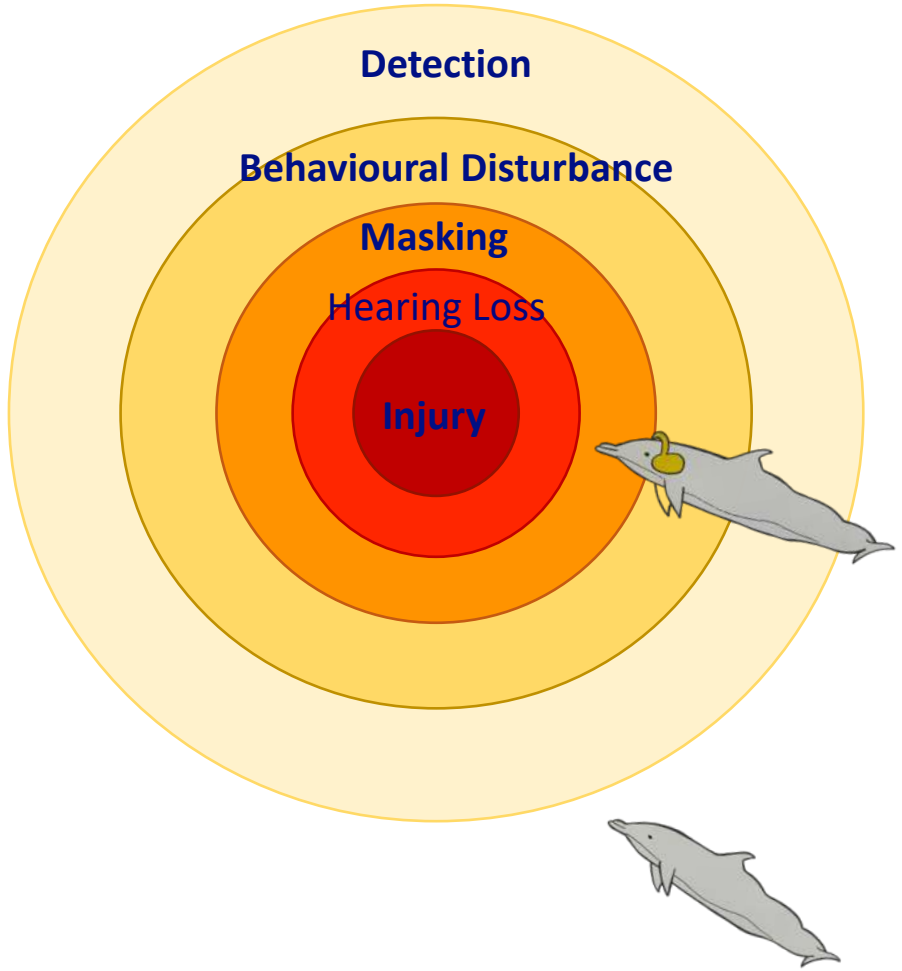
**Rilevamento sonoro:**
Modifica comportamento, vocalizzazione, ricerca di cibo.

**'Masking':** suono interferisce con rilevamento segnali biologici. Comunicazioni, ecolocalizzazione, navigazione.

**Reattività:** modifiche comportamentali (evitamento o fuga).

**TTS, PTS**: danno udito. Abbassamento permanente/temporaneo della soglia uditiva.

**Lesioni:** effetti fisici (danni ai tessuti, sintomi di decompressione)




modificato da Richardson et al., 1995

Anthropogenic Sound in the marine environment
Mitigation

# Airgun Mitigation

**Planning:**

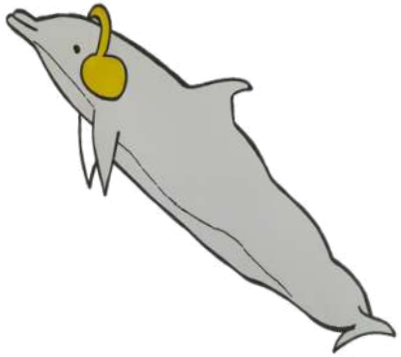
avoid sensitive areas, exclusion zone.

**Animal Detection:**

passive visual monitoring (MMO)

passive acoustic monitoring (PAM)

interruption of operations



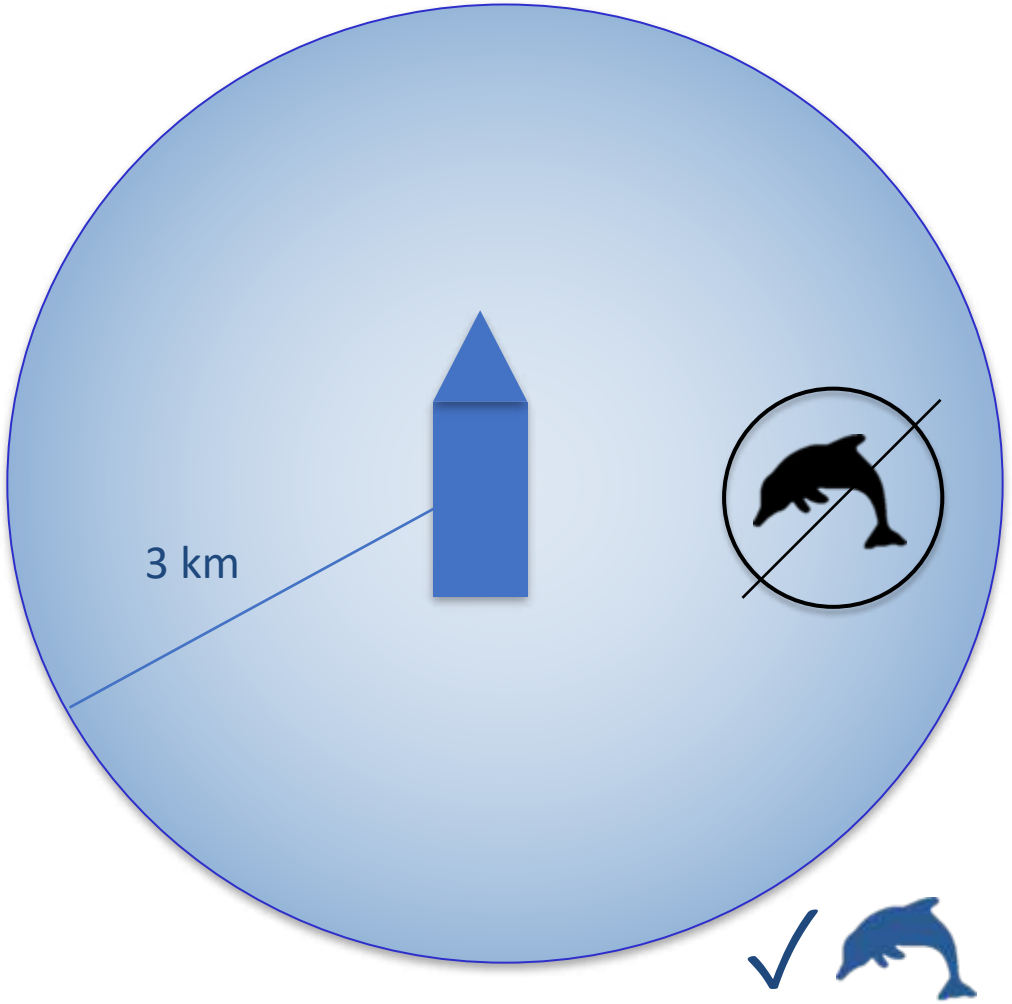
**Operating procedures:**

'Ramp up' 'soft start' = gradual increase in the sound pressure level.

Anthropogenic Sound in the marine environment
Mitigation

# Exclusion Zone

- Liit of 180 dB - 160 dB re 1µPa RMS
- To be defined before the survey using a sound propagation modelling software
- To be monitored and verified during the survey with Marine Mammal Observers (MMO) and Passive Acoustic Monitoring (PAM)



Anthropogenic Sound in the marine environment
Mitigation

# MARINE MAMMALS OBSERVERS (MMO)


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

Anthropogenic Sound in the marine environment
Mitigation

# PASSIVE ACOUSTIC MONITORING (PAM)


# EU INTRODUCES MARINE STRATEGY FRAMEWORK DIRECTIVE


To maintain the good environmental status of our seas member states should guarantee that

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

# Concerns for UW sound impacts

- Lack of standardized methodologies to measure and analyse UW noise
- Difficult to compare results
- Need for policy for standardised emissions
- **Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) proposes guidelines**
  - Environmental impacts to sea creatures
  - Noise thresholds
  - Mitigation measures

ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale

# Rapporto tecnico

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

## Maggio 2012

# 7. Raccomandazioni e conclusioni

Servirsi di personale tecnico altamente specializzato, in particolare per ricoprire il ruolo di osservatore-*Marine Mammal Observer* (MMO) e di tecnico per il PAM - monitoraggio acustico passivo;

assicurarsi che tutti i dati validi dal punto di vista scientifico derivanti da linee sismiche esistenti vengano, quando possibile, riutilizzati;

pianificare almeno una visita ispettiva a bordo della nave sismica (il numero di controlli può variare in base alla durata dell'attività di prospezione) da parte del Ministero vigilante o di ISPRA;

assicurarsi che il *reporting* di fine attività sia propriamente svolto e spedito al Ministero vigilante e ISPRA. Ciò può rivelarsi estremamente utile per l'individuazione di eventuali *lessons learnt* circa le misure di mitigazione adottate ed il loro possibile perfezionamento.

Documenti:

EUROPEAN PARLIAMENT

2004 2009

*Session document*

**B6-0089/2004**

**European Parliament resolution on the environmental effects of high-intensity active naval sonars**

JOINT NATURE CONSERVATION COMMITTEE

**Address:** JNCC, Marine Advice, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ, United Kingdom
**Telephone:** +44(0)1224 655720
**Email:** seismic@jncc.gov.uk

**ANNEX A - JNCC guidelines for minimising the risk of disturbance and injury to marine mammals from seismic surveys**

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Documenti:

**16th ASCOBANS Advisory Committee Meeting**
Brugge, Belgium, 20-24 April 2009

Document AC16/Doc.47 (O)
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Agenda Item 5.5.1

Implementation of the ASCOBANS Triennial Work Plan (2007-2009)

Review of New Information on Pollution, Underwater Sound and Disturbance

Anthropogenic noise

**Document 47**

# Noise Pollution

# Essenza dei documenti internazionali:

- L'utilizzo degli Air Guns deve essere strettamente regolamentato
- l'utilizzo deve essere approvato dall'autorità competente dietro presentazione di dettagliato rapporto di impatto ambientale
- a bordo devono essere presento MMO e PAM
- deve essere definita una Distanza di Esclusione sulla base del livello degli impulsi acustici
- l'inizio delle operazioni deve essere effettuato con modalità ramp-up

## Future European Policy

According to the **Mission Board Healthy Oceans, Seas, Coastal and Inland Waters (2020)** one of the four targets to achieve a status of Zero Pollution of the sub-aquatic environment is to reduce underwater acoustic emissions by at least 50% by the year 2030 and to define noise impact mitigation measures in each European marine region. The approach to this challenge is two-fold: 1) reduce the emissions at the source; 2) implement impact mitigation measures.

The **Technical Group on Underwater Noise (TG Noise) of the European Union** has the task to facilitate the development by Member States of their own strategies and regulations for the mitigation of impacts, always in order to achieve the Good Environmental Status (GES) addressed by the EU Marine Strategy Framework Directive (MSFD).

## Future European Policy

the **Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans),** an intergovernmental platform with the objective to promote coordination on marine and maritime research activities, launched a new Joint Action “Underwater Noise in the Marine Environment” (https://www.jpi-oceans.eu/underwater-noise-marine-environment) with Italian and German coordination, with the overarching objective to decrease the high level of uncertainty about the impact of noise through the promotion of specific lines of scientific research at regional and sub-basin scale. Among the urgent actions needed are the implementation of deep-sea sound observing systems and new numerical modeling tools for prediction of the anthropogenic sound propagation in the near and far field.

## Present policy in Italy

In Italy, the relevant authority for the implementation of the MSFD is the **Ministry of the Environment (MATTAM)**, in collaboration with other national and local authorities. The scientific and technical support is provided by the **Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA),** who is also co-leading the European Union TG-Noise. Both the MATTAM and the **Ministry of Economic Development (MISE)** have created technical committees to address the effect of the noise by seismic exploration on the marine ecosystems. In 2015 the MATTAM created a Working Group with the task of monitor and collect all available information about national and international initiatives aiming at understanding the impact of '*airguns*' on marine ecosystems, and suggest initiatives to contribute to the implementation of guidelines at a national level. In 2017, in the framework of the implementation of the European Directive 2013/30/UE for the safety of offshore oil and gas operations created a Working Group with the task of releasing, in 2018, a Report on Eco-Sustainable Techniques for Seismic Exploration Offshore (TESEO).

## Present policy in Italy

The **National Institute of Oceanography and Applied Geophysics (OGS)** has published in 2020 a Decalogue stating the institutional position with respect of the noise in the marine environment emitted during oceanographic expeditions, including research vessel's noise and sonars, stating the ethical necessity to reduce the impacts and to promote new scientific and technological research aimed at an environmentally sustainable use of oceanographic instruments for scientific research (Affatati, 2020).

# Un caso italiano: proposta di emendamento al ddl sugli Eco-reati (2015)

Marzo 2015. approvazione in Senato di un emendamento al ddl sugli ecoreati proposto da Gal e Fi che introduce il divieto di esplosioni in mare per attività di ricerca e ispezione dei fondali: «Art. 452-*undecies. - (Ispezione fondali marini)* - **Chiunque, per le attività di ricerca e di ispezione del fondali marini finalizzate alla coltivazione di idrocarburi, utilizza la tecnica dell'*air gun*, o altre tecniche esplosive è punito con la reclusione da uno a tre anni**».

Dalla trascrizione del dibattito in Senato:

*Si tratta di una tecnica **esplosiva**, per la quale noi riteniamo di dover prevedere la pena della reclusione da uno a tre anni. Altrimenti non si spiegherebbe come mai tutti coloro che utilizzano **sistemi di esplosione** per la pesca vengono condannati e perseguiti dalla legge e non lo si fa per questa che sostanzialmente è sovrapponibile.*

*…Attenzione, l'utilizzo di queste tecniche potrebbe **creare dei terremoti** pari al grado 3,6 della scala Richter. In un territorio vicino alla Sicilia o in altri luoghi dove già si è soggetti normalmente a processi di movimento del terreno, questo potrebbe costituire*
*un rischio.*

*L'emendamento ha provocato una risposta di Assomineraria ed una di tutti gli Enti Pubblici di Ricerca che si occupano di Oeanografia (OGS, CNR, INGV, Stazione Zoolgica di Napoli, INFN) CONISMA, Società Geologica Italiana, ISPRA Sezione Italiana*
*EAGE/SEG* (Geofisica Applicata)

Quest'ultima ha generato una replica da parte di WWF, Greepeace e Legambiente.

**L'emendamento è stato cancellato in Senato durante l'approvazione finale della legge**.

## Attualmente in Italia

L'utilizzo di «airguns» prevede l'autorizzazione tramite una procedura di VIA
Valutazione di Impatto Ambientale

Dal 2017 di fatto, qualsiasi attività di prospezione geofisica in mare, sia per scopi industriali che scientifici è stata azzerata

Serve una disciplina dettagliata che valuti non solo la tipologia dell'emissione sonora, ma l'energia e la modalità di emissione

Sorgenti *Sparker* e *Watergun* non sono considerate
Il volume e la durata temporale delle sorgenti non sono considerate

**Reading**:
Review by Alice Affatati: Rumore subacqueo in ambiente marino:fonti, effetti sulla fauna e misure di mitigazione. Bollettino di Geofisica teorica ed applicate, Vol. 61 – Supplemento 1 Marzo 2020.

and references herein