CEDA Webinar Series

Underwater sound in relation to dredging

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DHI Group

Underwater sound and dredging

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Central Dredging Association

Underwater Sound
In Relation To Dredging

The Central Dredging Association is committed to environmentally responsible management of dredging activities and this paper – produced by the CEDA Environment Commission – seeks to inform those parties concerned about sounds produced by dredgers

Dredging is an activity that is carried out for many purposes. The dredging process can simplistically be described as the excavation of sediment from a sea, river or lake bed and the handling and transport of the excavated sediments and soils to a placement site elsewhere. Dredging is commonly applied for:

- Construction and maintenance of ports and waterways, dikes and other infrastructures
- Reclamation of new land
- Flood and storm protection and erosion control by maintaining river flows and by nourishing beaches
- Extraction of mineral resources from underwater deposits, particularly sand and gravel, to provide raw materials for the construction industry, and
- Environmental remediation of contaminated sediments.

Thus dredging provides many benefits to society with the goal of sustainable development while protecting natural resources and quality of life.

Objectives

Like many other activities, dredging produces underwater sound. Recently, the issue of effects of underwater sound on aquatic life has received broader attention within the scientific community, with stakeholders and the general public.

In this paper we will:

1). Summarise the effects of sound on aquatic life to set the scene
2). Describe in detail the underwater sounds generated by various components of the dredging process
3). Summarise what is known about potential effects of dredging sounds
4). Identify options for managing dredging-related sound, and
5). Provide conclusions and an outline of future areas of research.

Effects Of Sound On Aquatic Life

What is sound? – It can be described as a moving wave in which particles of the medium are forced together and then apart. This creates changes in pressure that propagate with the speed of sound.

The speed of sound in water is more than four times faster than in air and attenuation is also much less in water compared to air. Thus, water is an ideal medium for sound propagation.

Sounds can be described in terms of their intensity, which is measured or expressed in decibels (dB), pitch or frequency (in Hertz or kilohertz) and their duration (in seconds or milliseconds).

Sources of underwater sound – Both the natural environment and man can produce underwater sound. Natural sources of sound can be vocalisations of marine life – eg the elaborate songs of humpback whales or the snapping of shrimp. Wind, rain, waves, and subsea volcanic and seismic activity all contribute to ambient sounds in bodies of water.

Human-induced sound comes from construction of marine infrastructure (including dredging) and industrial activities such as drilling or aggregate extraction (including dredging); shipping; military activities using various types of sonar; geophysical exploration using seismic surveys, and a variety of other activities.

Anthropogenic sound sources can be broadly divided into high intensity impulsive sources, such as pile driving, and less intensive but more continuous sources like shipping and dredging. It has to be noted here that the dredging fleet represents 0.5% of the world total shipping fleet.

Human activities in the aquatic environment have intensified since the last century and research has indicated that ambient sound has been increasing in some regions too. While ambient sound levels are the result of both natural and anthropogenic sources, it is the latter we have control over since these can be managed.

Use of sound by aquatic life – As sound transits very well underwater, many marine species use it for a variety of purposes.

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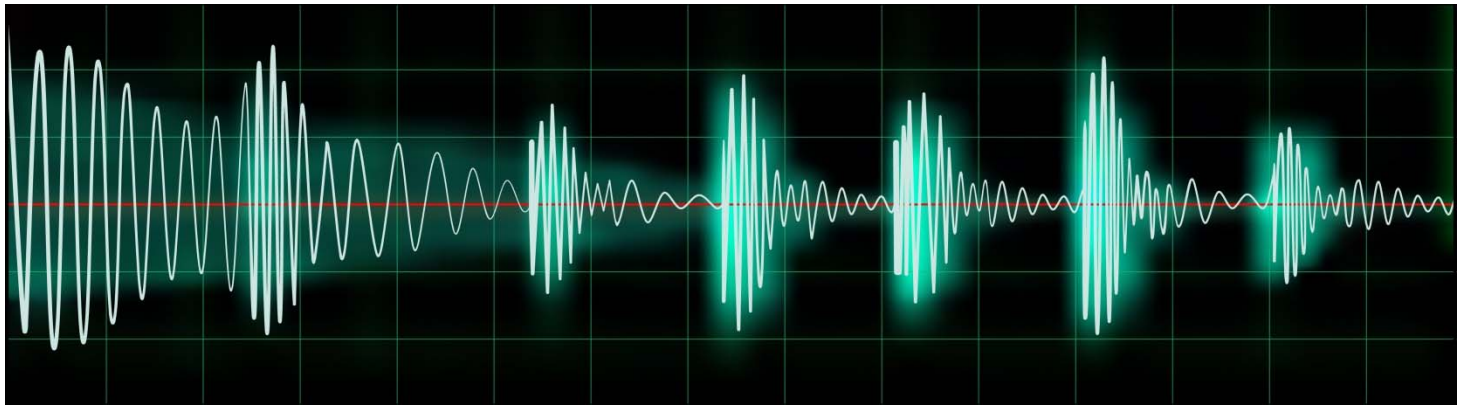
http://www.dredging.org/, special thanks to Anna Csiti

Outline

- Sound and marine life
- Effects of sound on marine life
- Mitigation
- Policy
- Conclusions

Sound

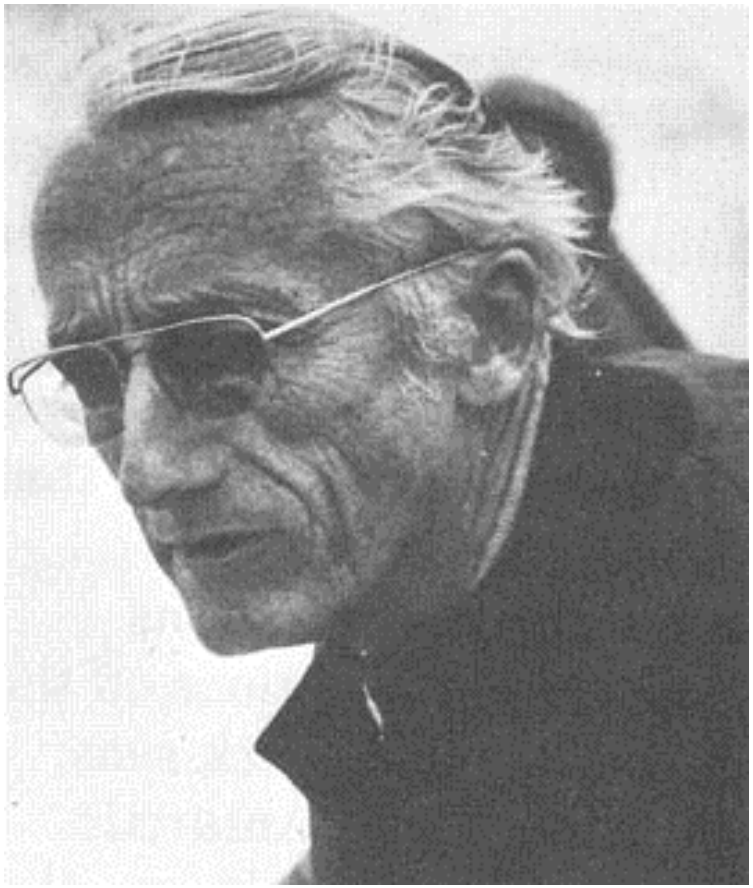


Acoustic pressure: SPL (dB) = 20 $\log_{10}$ (P/P_0)

P_0 underwater = 1 µPa; P_0 air = 20 µPa

Pitch: Hz = cycles / s (pitch)


Une prodigieuse revelation...
LE MONDE DU SILENCE

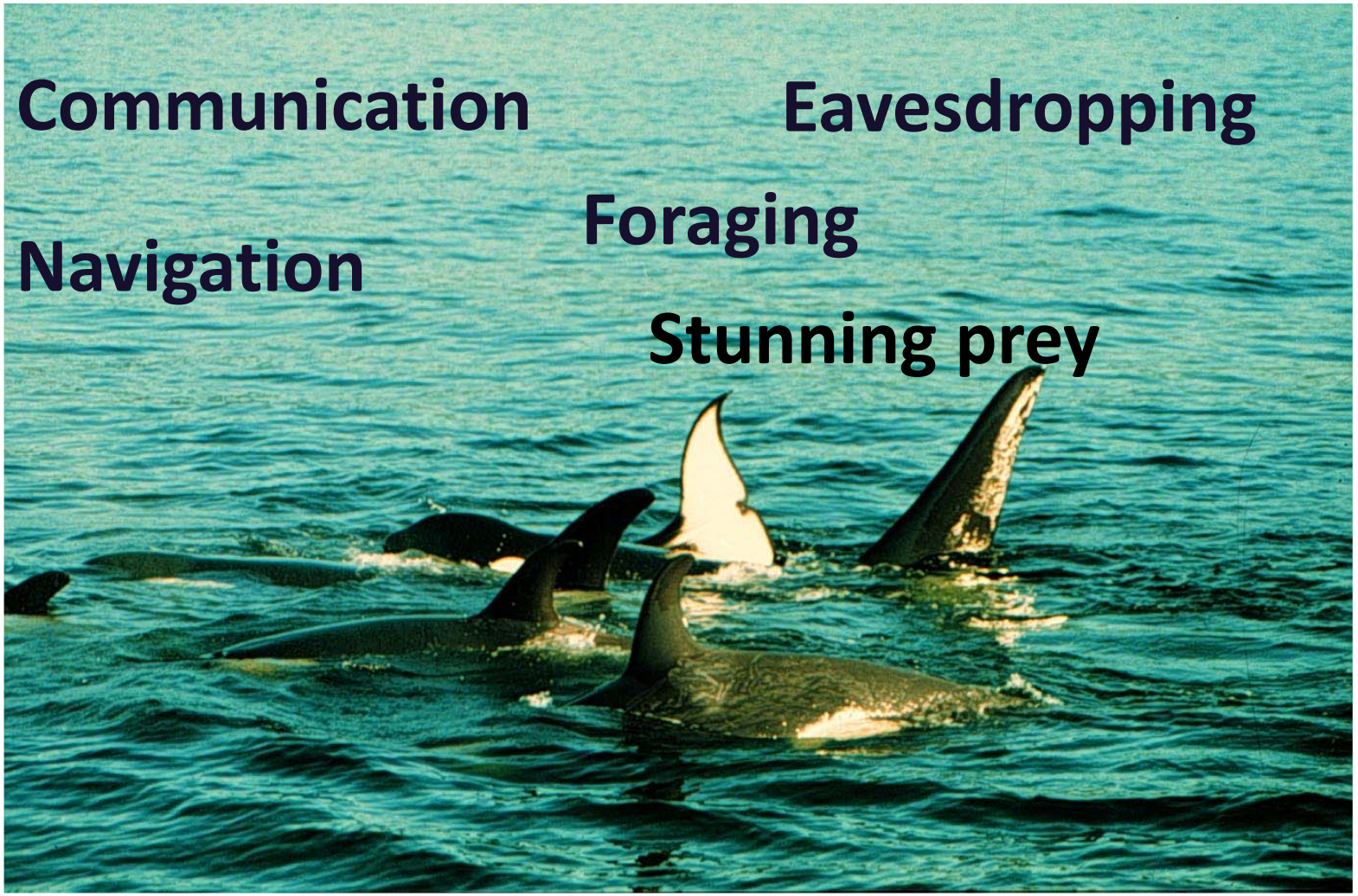


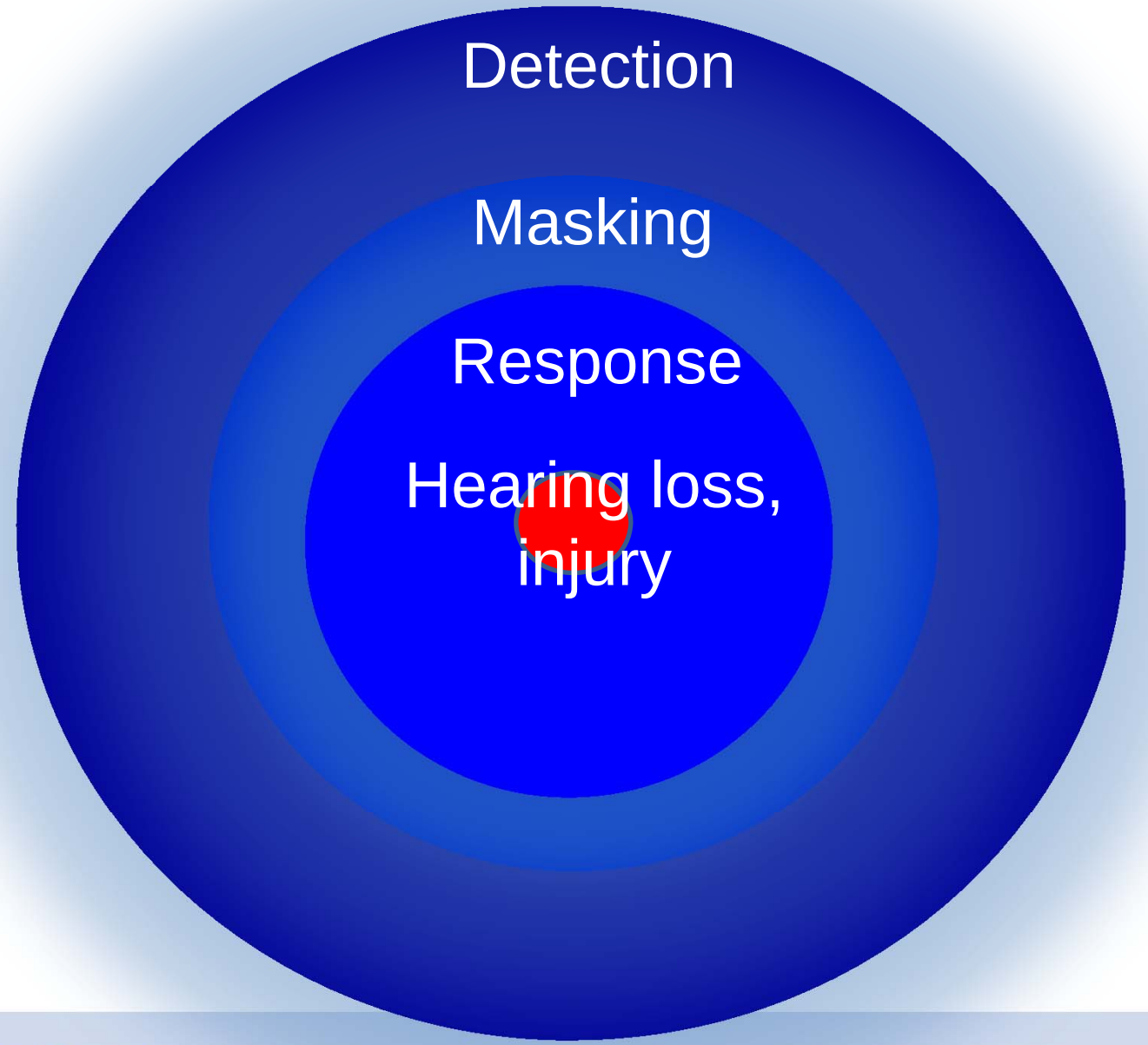
Water is an ideal medium for sound

Sound is more than four times faster underwater compared to air and there is less attenuation

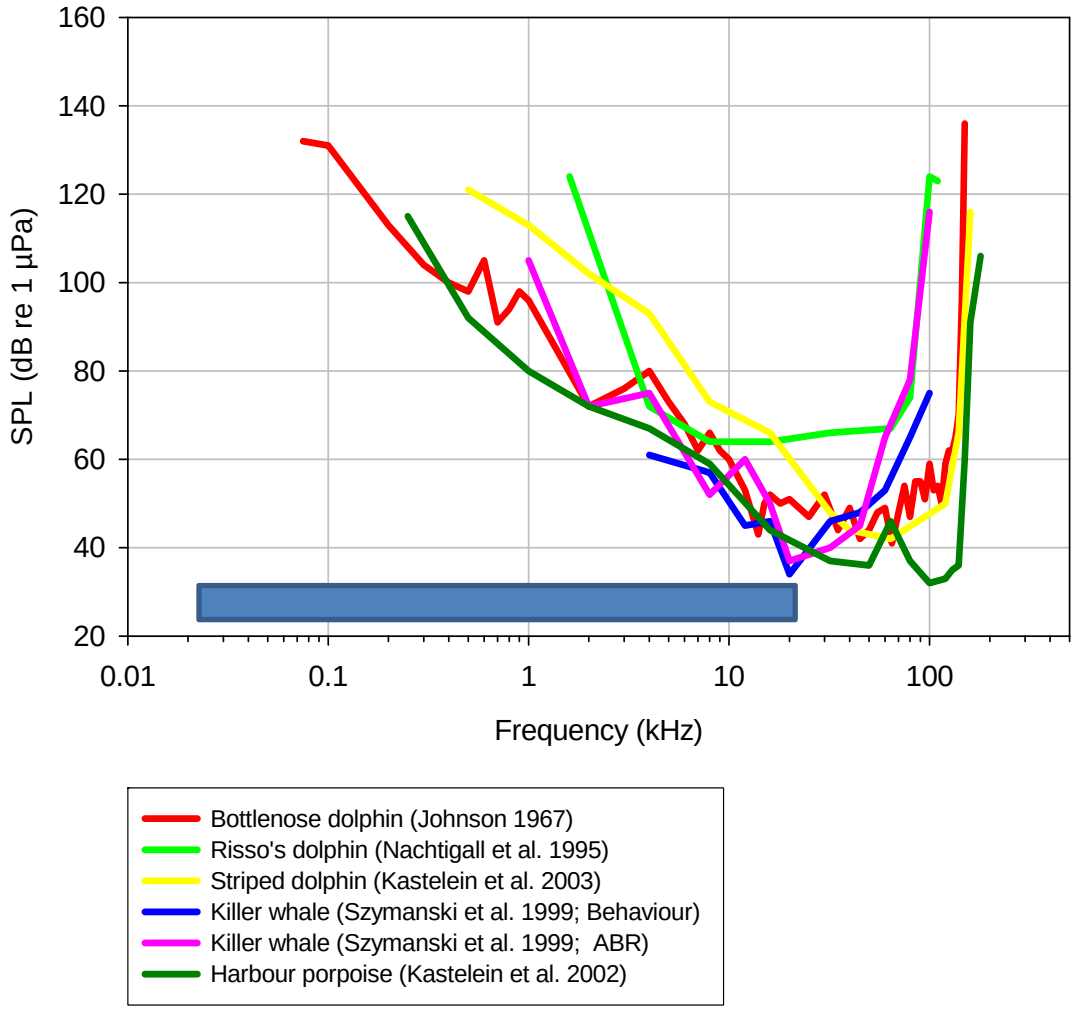
Marine life is noisy!

Use of sound


Communication
Eavesdropping
Foraging
Navigation
Stunning prey

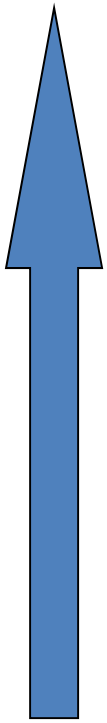

Detection
Masking
Response
Hearing loss, injury

Marine mammal hearing



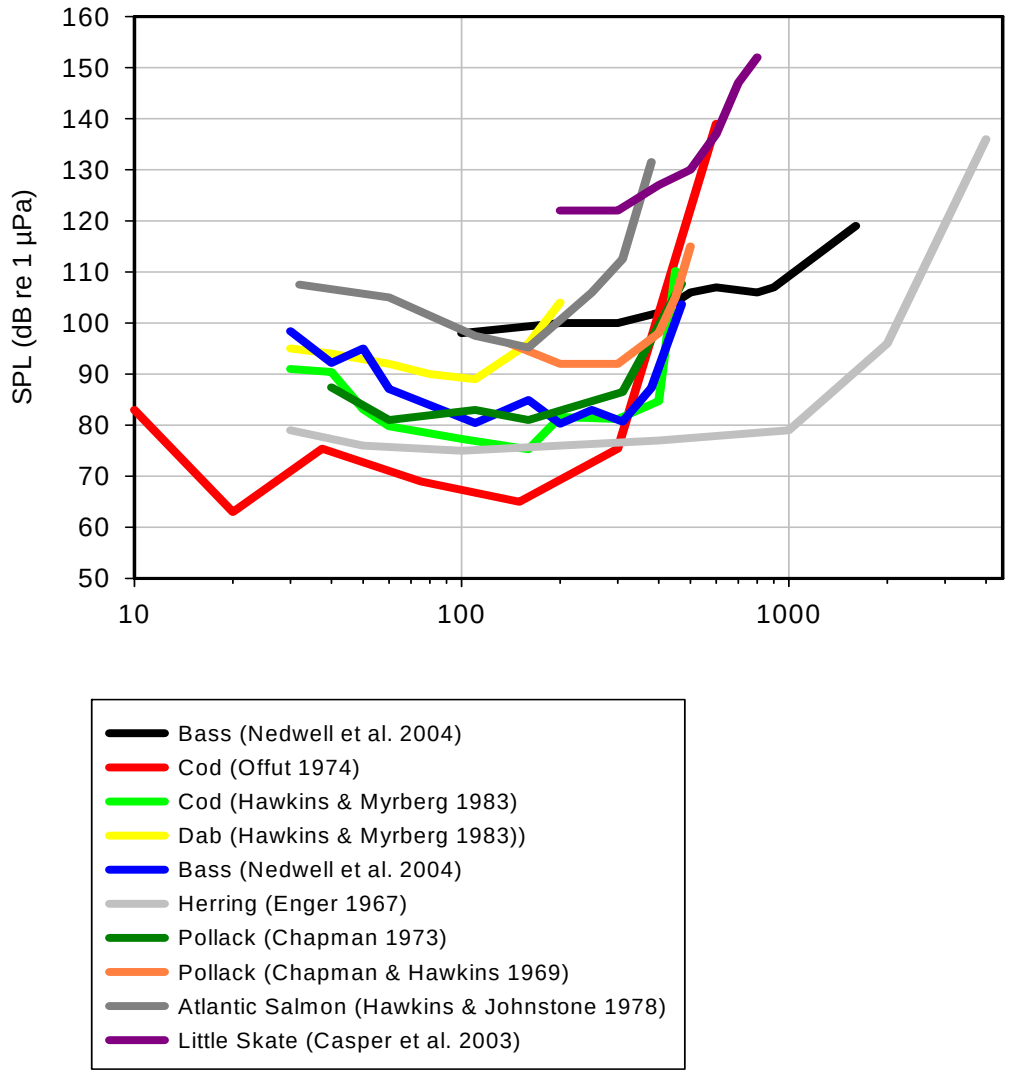
Fish hearing

Pressure Detection



Particle Motion Detection

Fish hearing



Marine sound sources

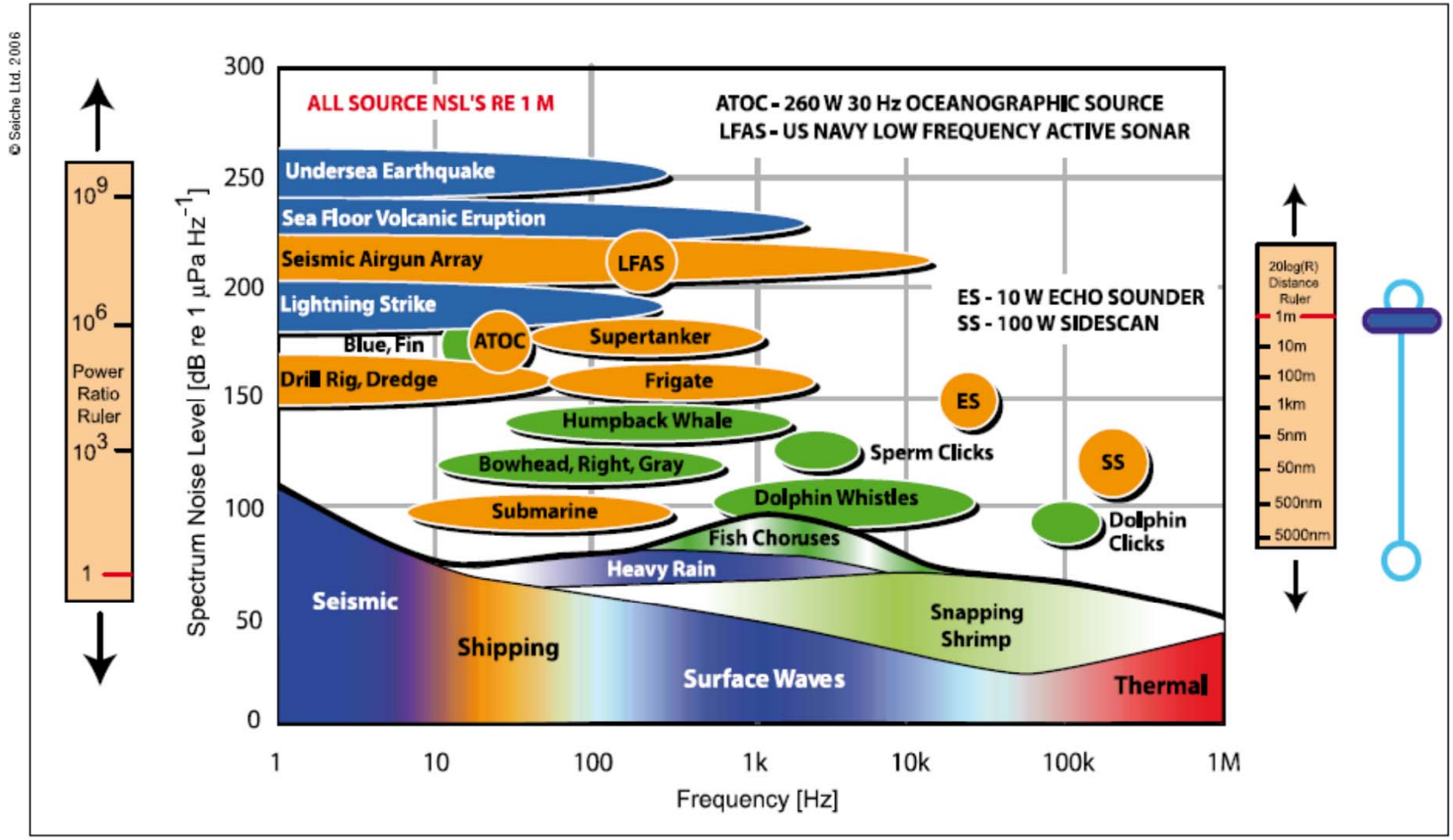


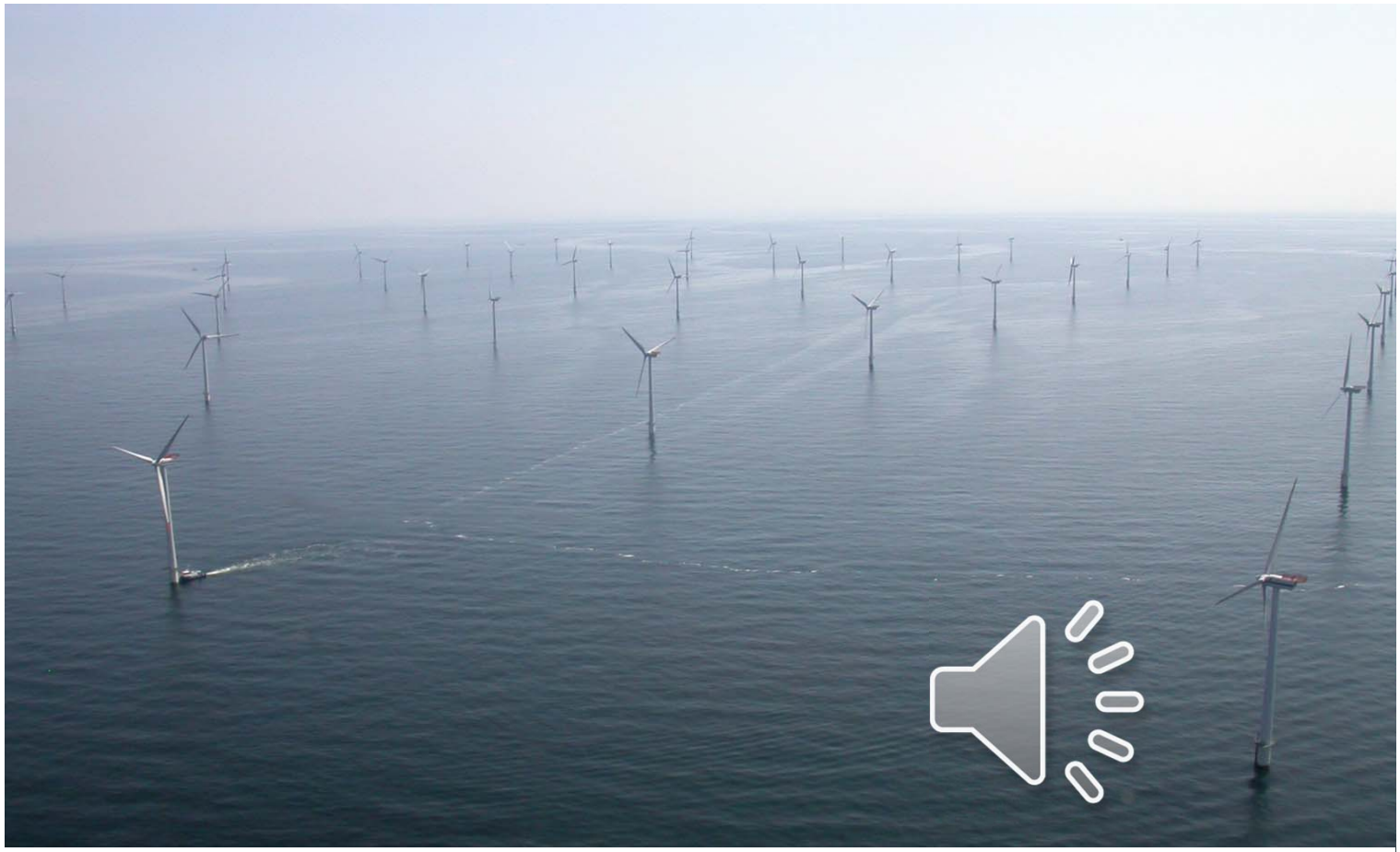
Figure 4. Noise levels and frequencies of anthropogenic and naturally occurring sound sources in the marine environment

Boyd et al. 2008

Seismic surveys

- > 256 dB re 1µPa (peak to peak) at 1 m
- < 1 kHz (see OSPAR 2009)

Offshore wind



- 228 dB re 1µPa peak – 257 dB re 1µPa (peak to peak) at 1 m
- < 1kHz

©Werner Piper

Military activities

- Military, private and research
- > 220 dB re 1µPa at 1 meter
- LF, MF and HF
- Activities classified

Shipping

Small leisure crafts and boats < 50 m

- Variable output: 160-175 dB re 1µPa at 1 m
- < 1kHz - > 10 kHz

Medium sized ships 50 -100 m

- 165 – 180 dB re 1µPa a 1 m
- < 1 kHz

Large vessels > 100 m

- 180 - > 190 dB re 1µPa a 1 m
- < 200 Hz

(see OSPAR 2009)

Dredging

Excavation of sediment from a sea, river or lake bed and the handling and transport of the excavated sediments and soils to a placement site elsewhere

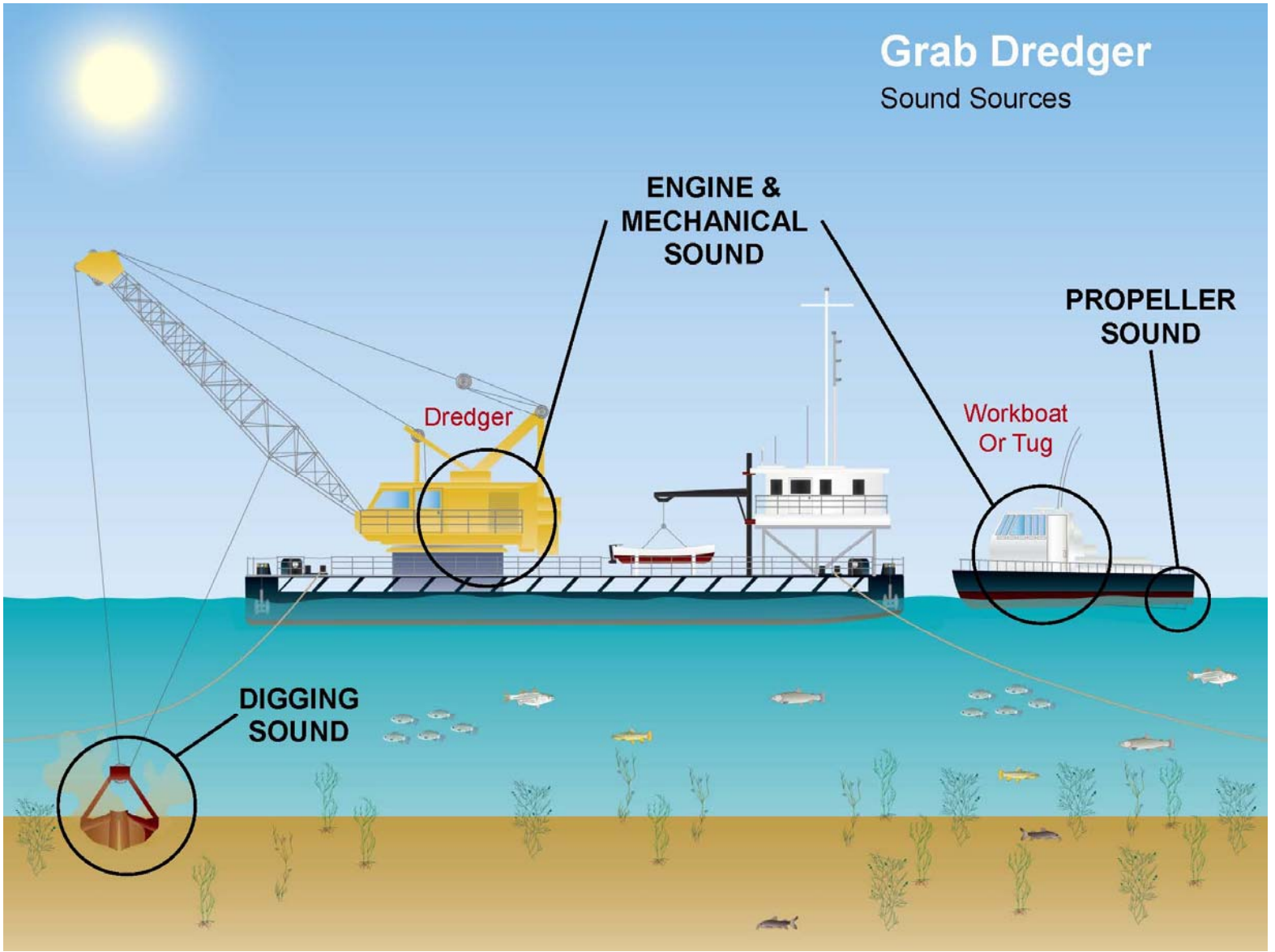
- Construction and maintenance of ports and waterways, dikes and other infrastructures
- Reclamation of new land
- Flood and storm protection and erosion control by maintaining river flows and by nourishing beaches
- Extraction of mineral resources from underwater deposits, particularly sand and gravel, to provide raw materials for the construction industry
- Environmental remediation of contaminated sediments.

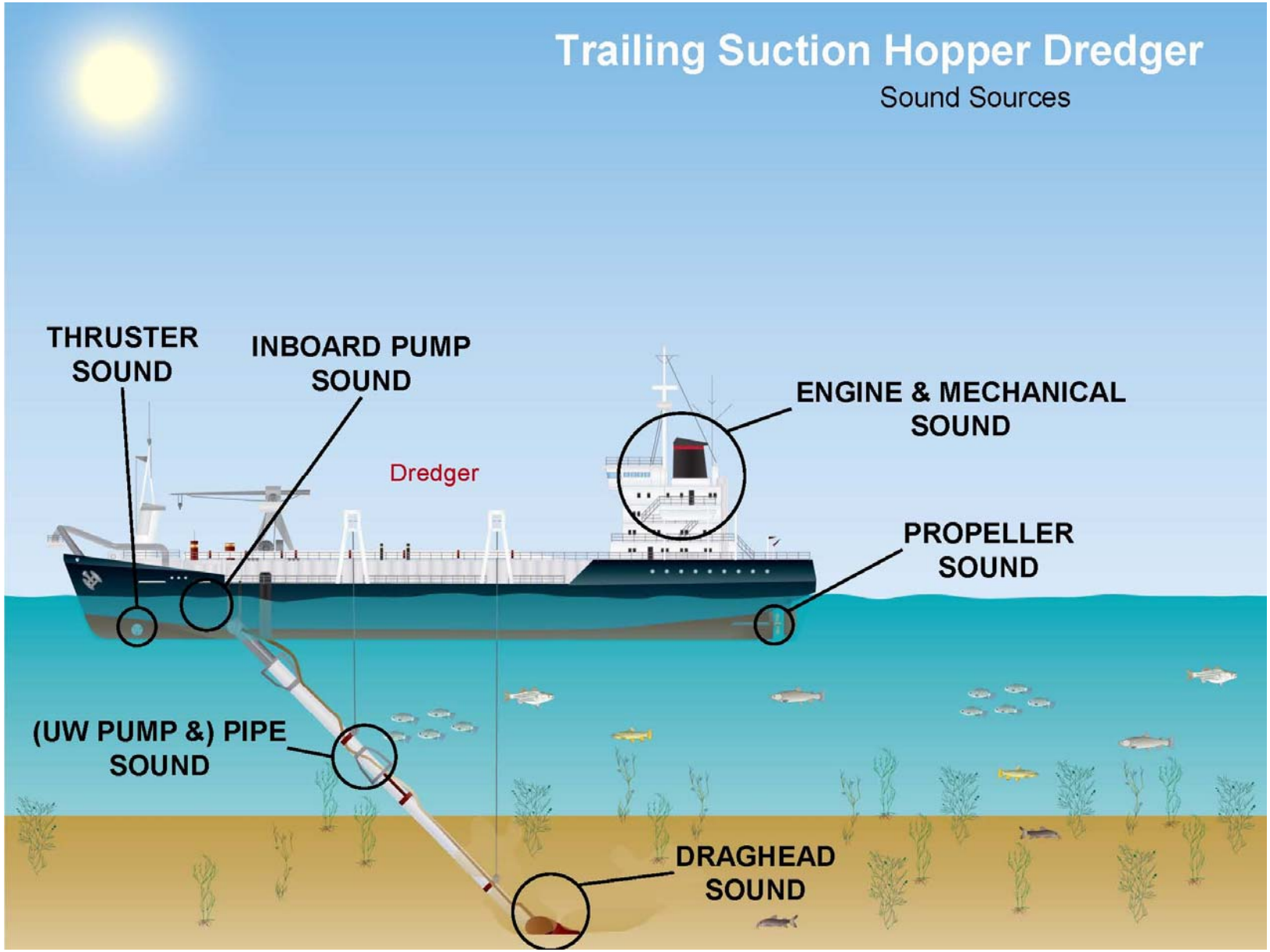
Dredger types and noisy activities

- Cutter suction dredgers (CSD),
- trailing suction hopper dredgers (TSHD),
- grab dredgers (GD)
- backhoe dredgers (BHD)

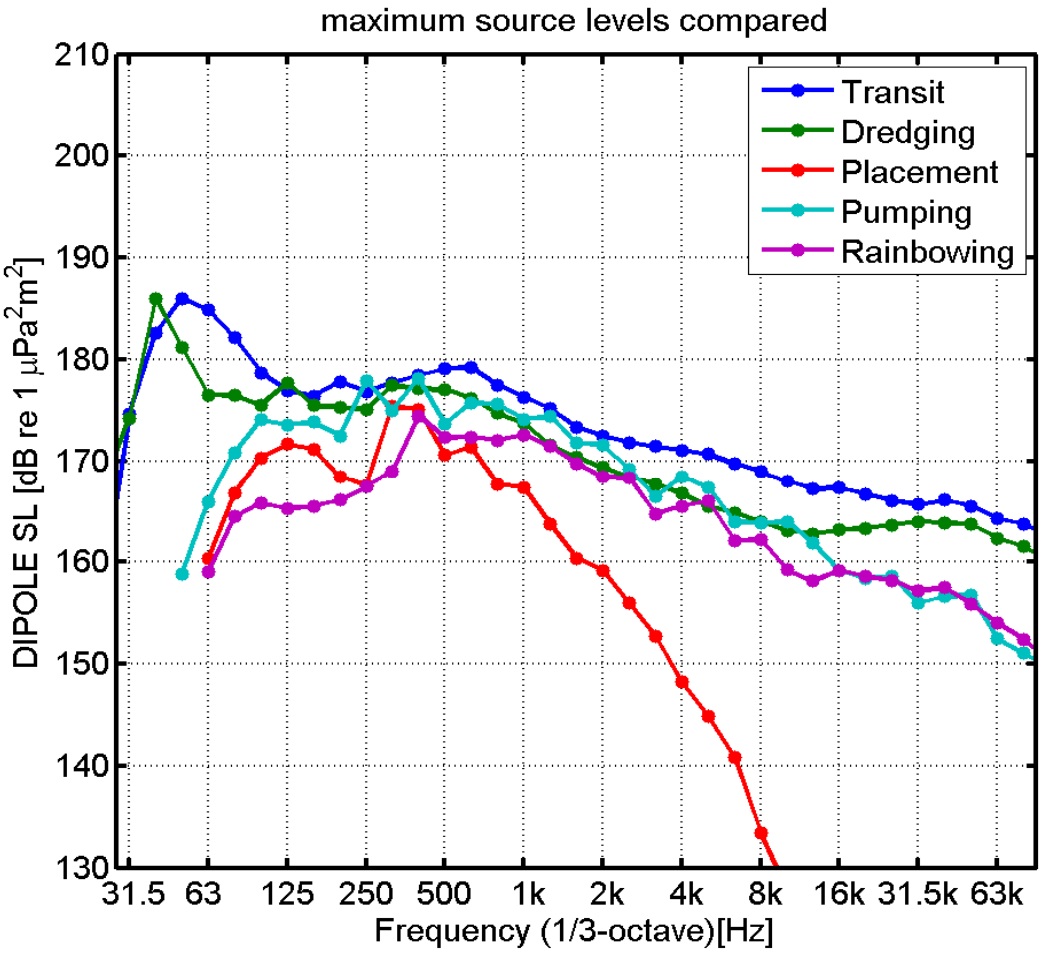
Activities generating sound:

- Dredging excavation
- Dredging vessels during transport
- Dredged material placement


Grab Dredger
Sound Sources
ENGINE &
MECHANICAL
SOUND
PROPELLER
SOUND
Dredger
Workboat
Or Tug
DIGGING
SOUND

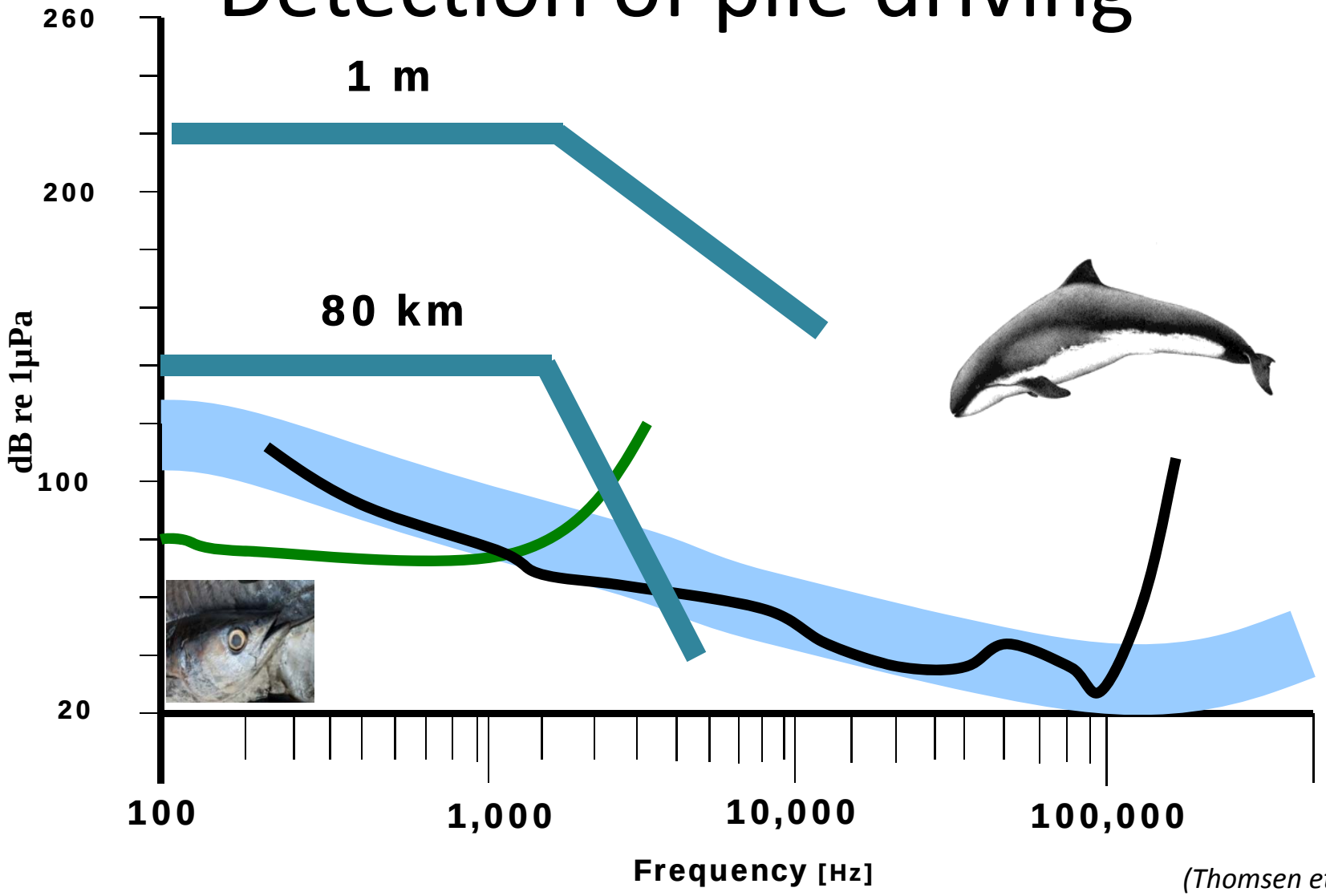

Trailing Suction Hopper Dredger
Sound Sources
THRUSTER SOUND
INBOARD PUMP SOUND
ENGINE & MECHANICAL SOUND
Dredger
PROPELLER SOUND
(UW PUMP &) PIPE SOUND
DRAGHEAD SOUND

New TSHD investigations -1



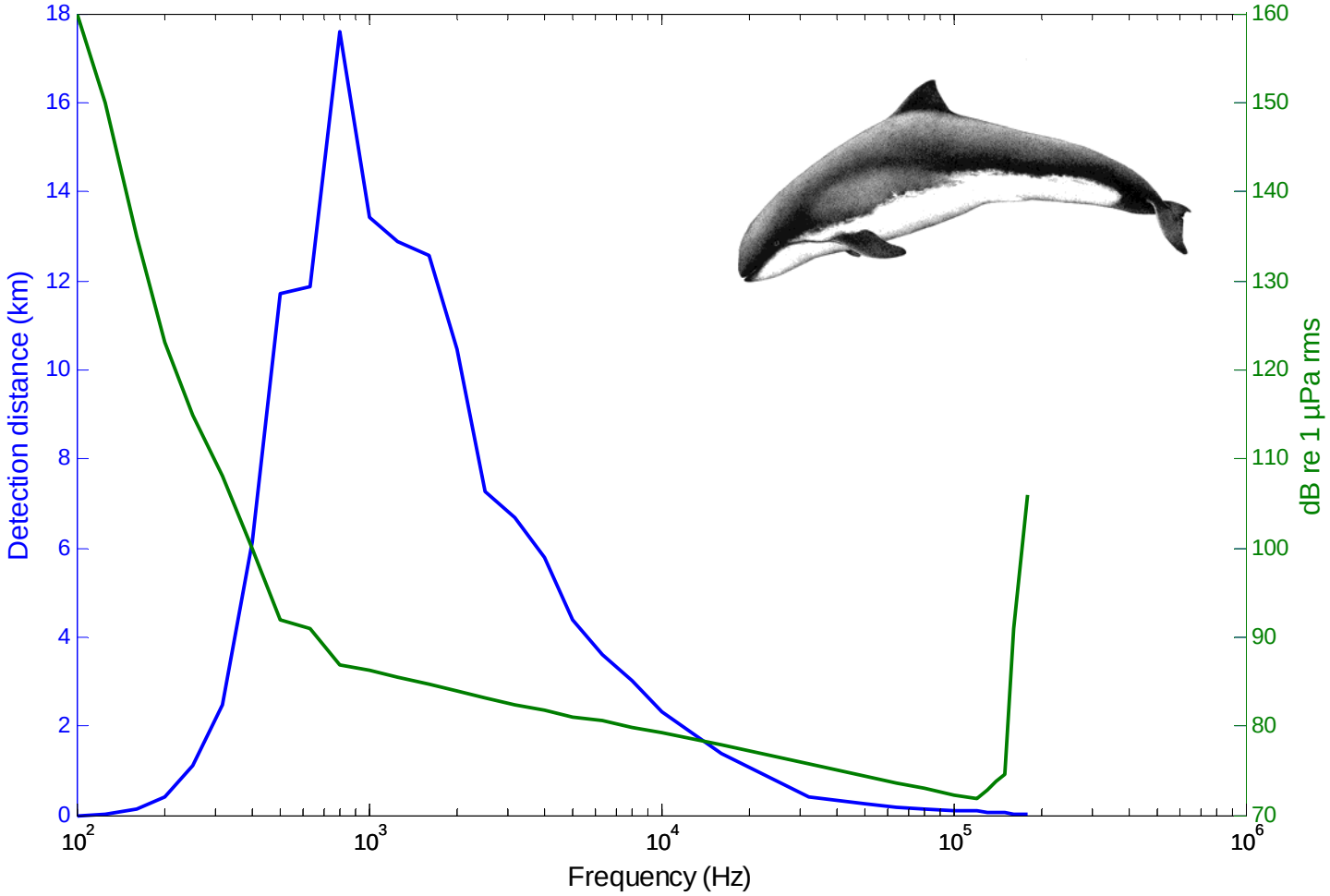
De Jong et al. 2009 Maasvlakte 2, Port of Rotterdam

Detection of pile driving

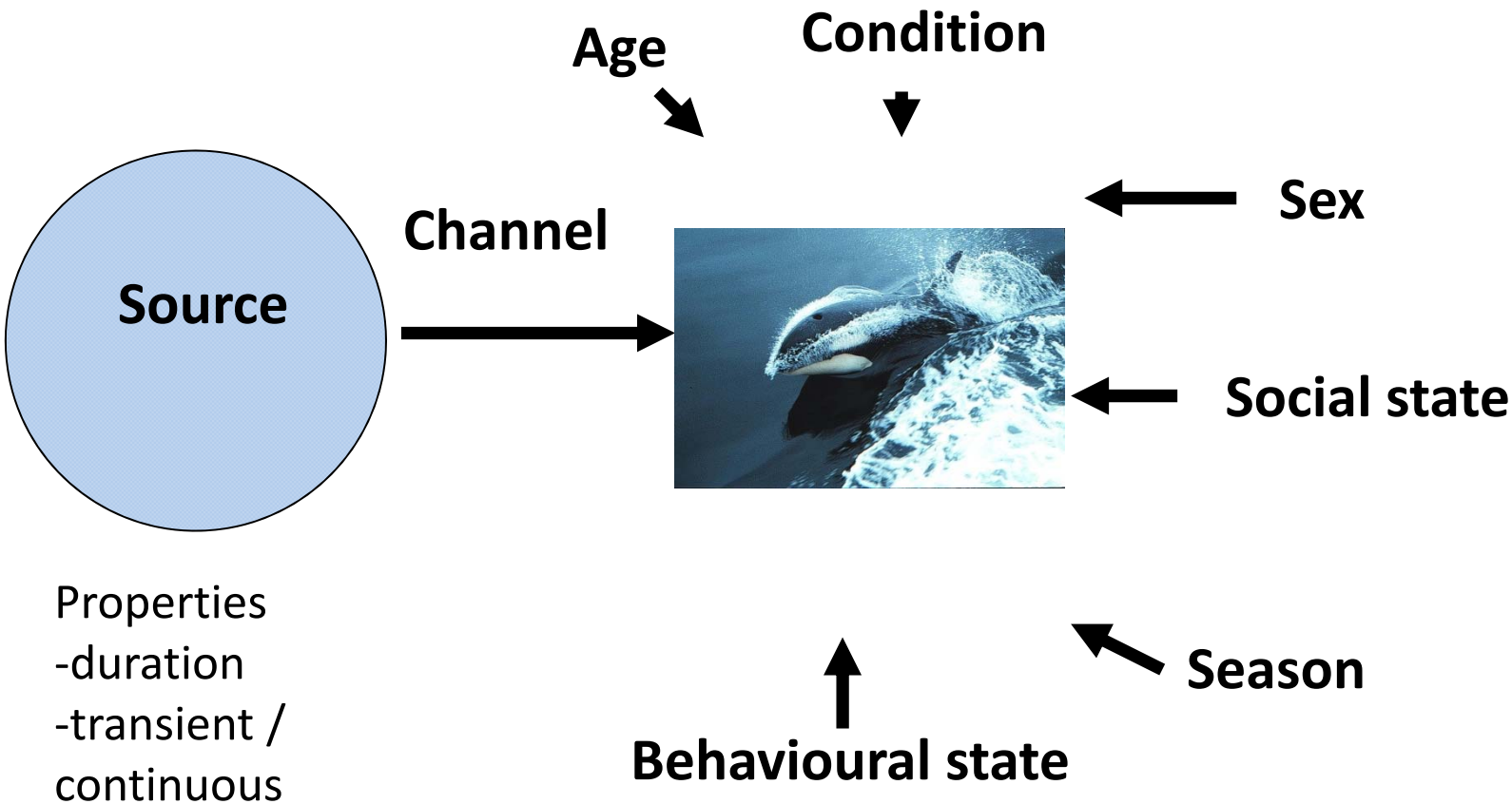


(Thomsen et al. 2006)

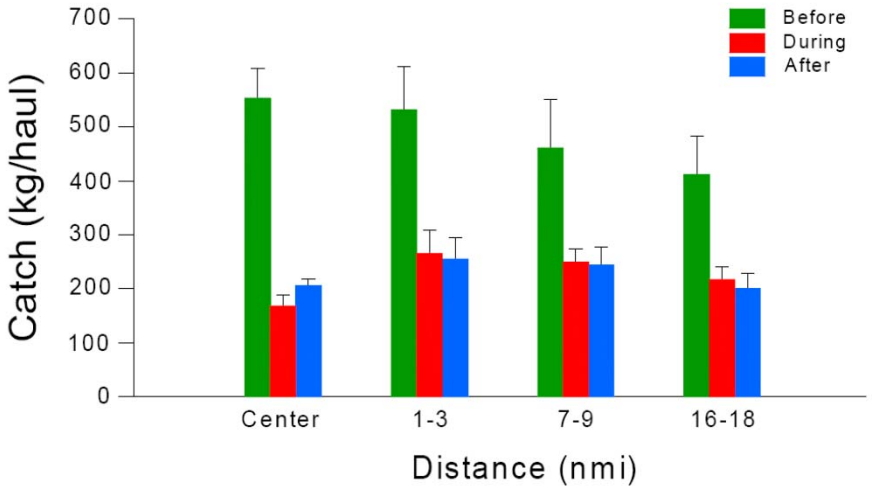
Detection of dredging sound



Response


Age
Condition
Source
Channel
Sex
Social state
Season
Behavioural state
Properties
-duration
-transient /
continuous

Response of fish to seismic surveys



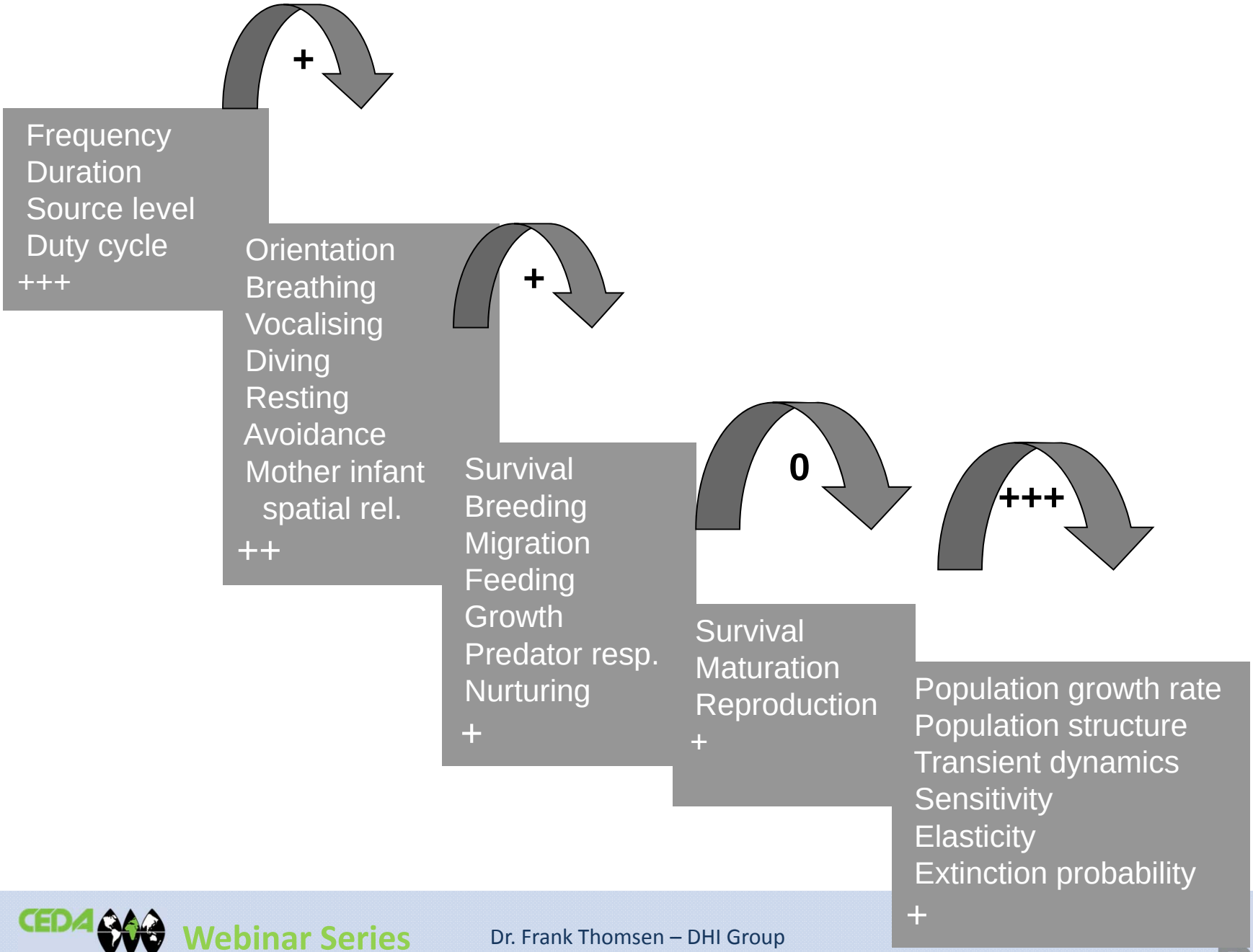
- Significant decline in herring catch rate during and after seismic exposure
- 5 days to recover
- Effects 20 nm
- Vertical movement in some species

Pearson *et al.* 1992; Engas *et al.* 1996; Slotte *et al.* 2004

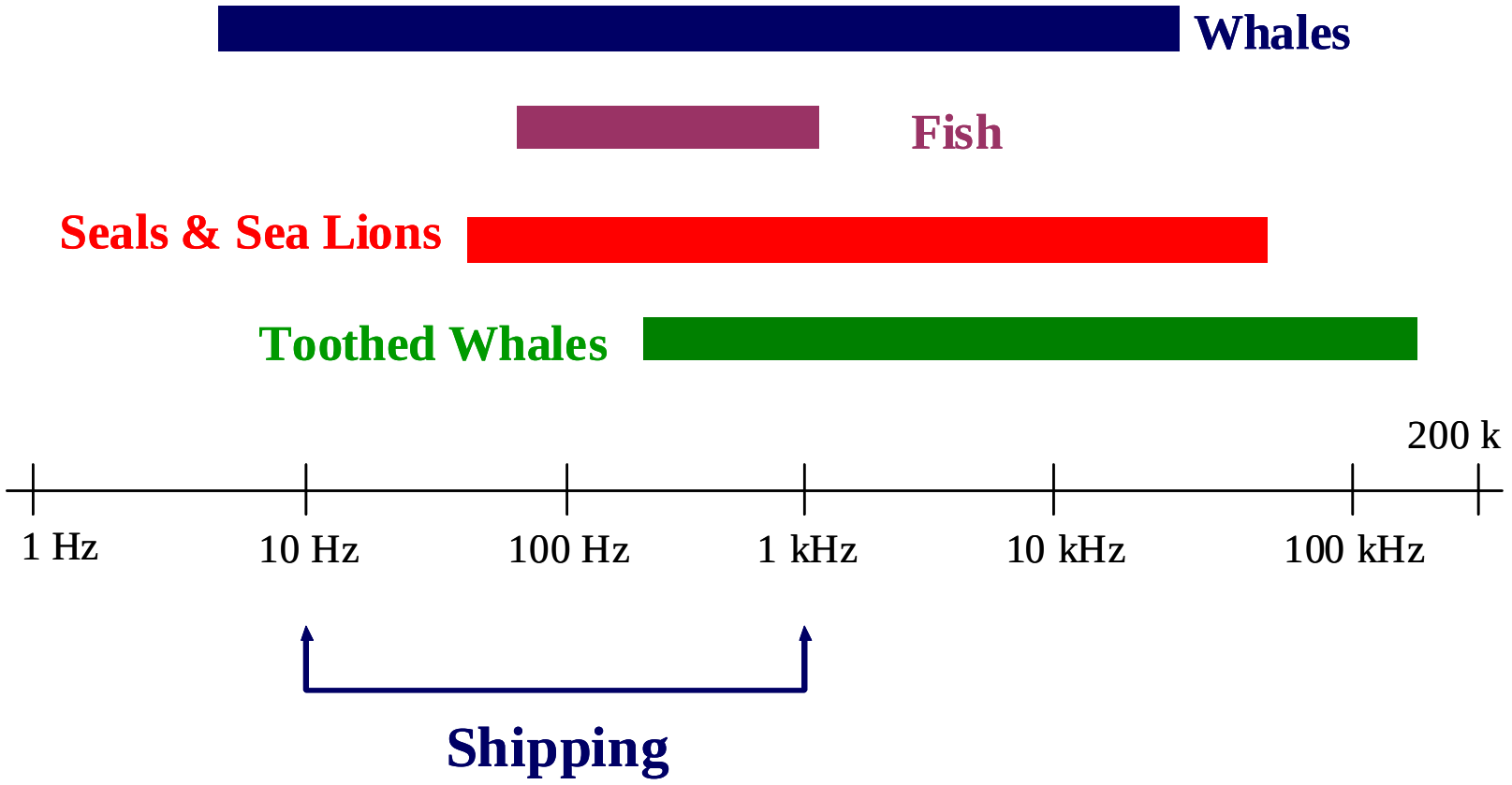
Documented effects of dredging

- Gray and bowhead whales avoid areas of dredging activity (reviewed by Richardson et al. 1995)

- Harbour porpoises leave areas during sand extraction. The reactions were relatively short term however (Diederichs et al. 2010)

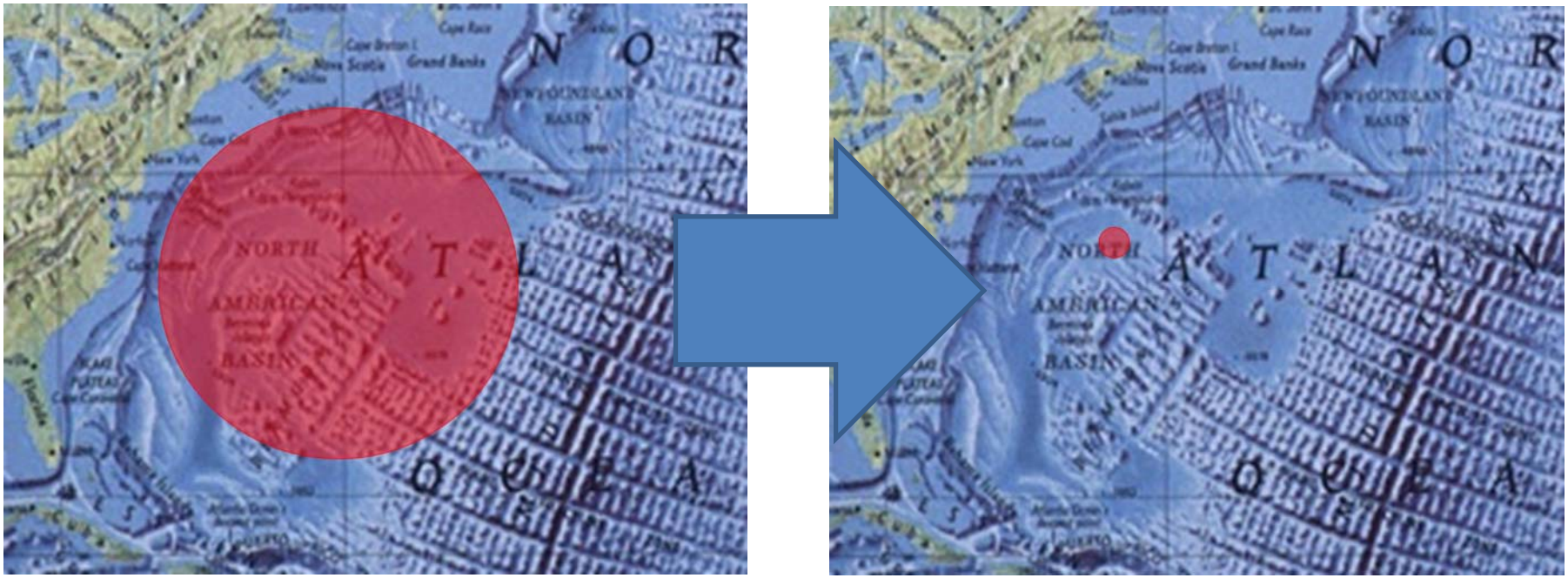

+
Frequency
Duration
Source level
Duty cycle
+++
+
Orientation
Breathing
Vocalising
Diving
Resting
Avoidance
Mother infant
spatial rel.
++
0
Survival
Breeding
Migration
Feeding
Growth
Predator resp.
Nurturing
+
+++
Survival
Maturation
Reproduction
+
Population growth rate
Population structure
Transient dynamics
Sensitivity
Elasticity
Extinction probability
+

Masking potential of shipping sound



Southall & Hatch in OSPAR 2009

Theoretical consequences of masking

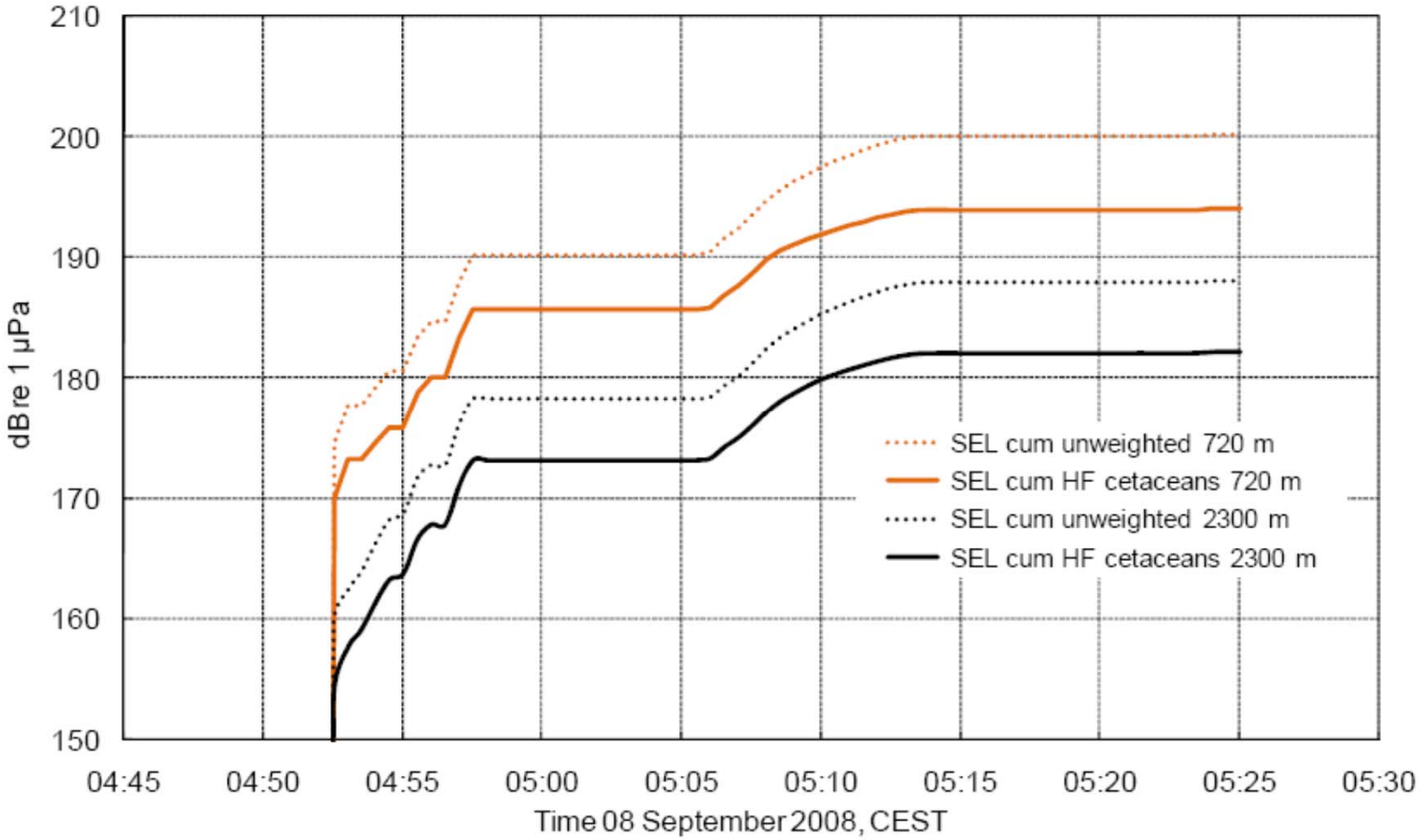


Southall & Hatch in OSPAR 2009

Hearing loss, injury

- TTS studies in a few marine mammal and fish species
- Depending on sound type, duration and pressure
- Cumulative exposure important

Repeated exposure

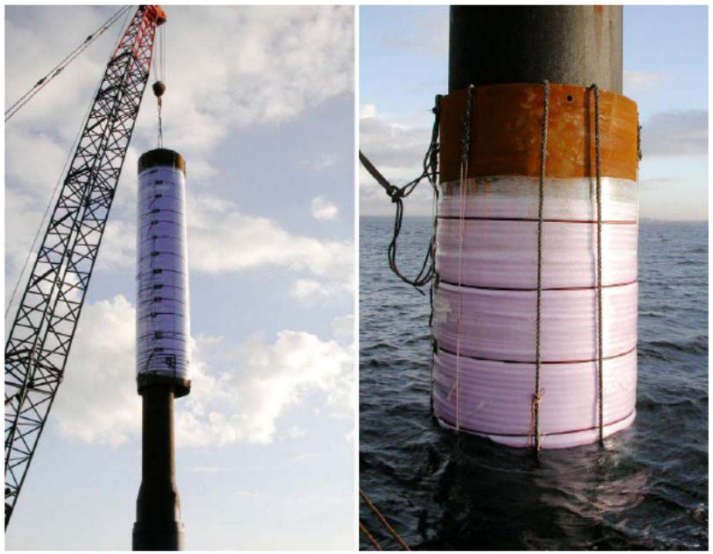


BioConsult / Itap 2008

Mitigation

Acoustic devices (e.g. Pinger)

Equipment Design (e.g. pile sleeves)



Timing

Bubble curtain

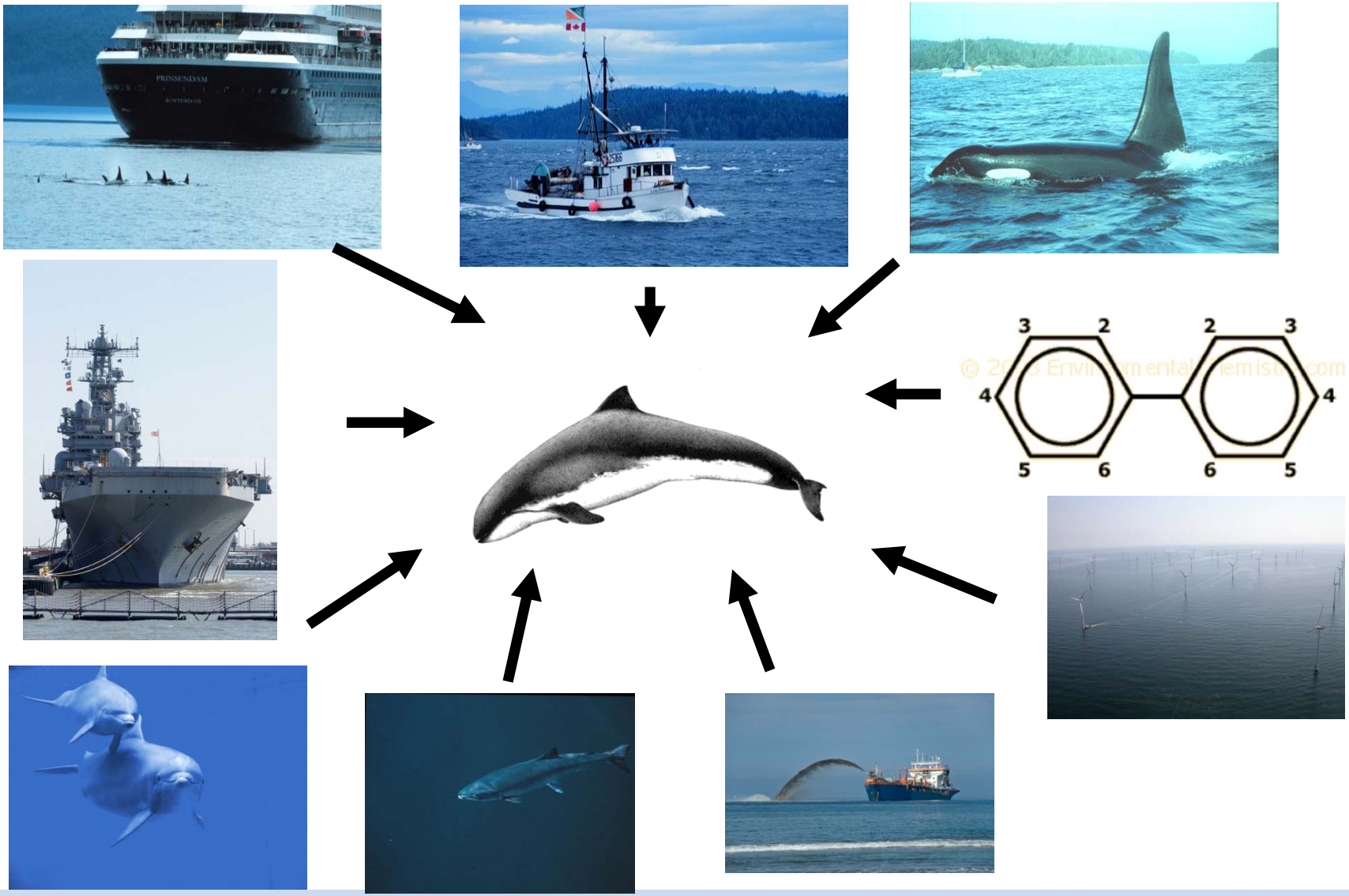
Monitoring of safety zones (visual and acoustic)

Ramp up / soft-start

Research

Nehls *et al.* 2007

Cumulative impacts

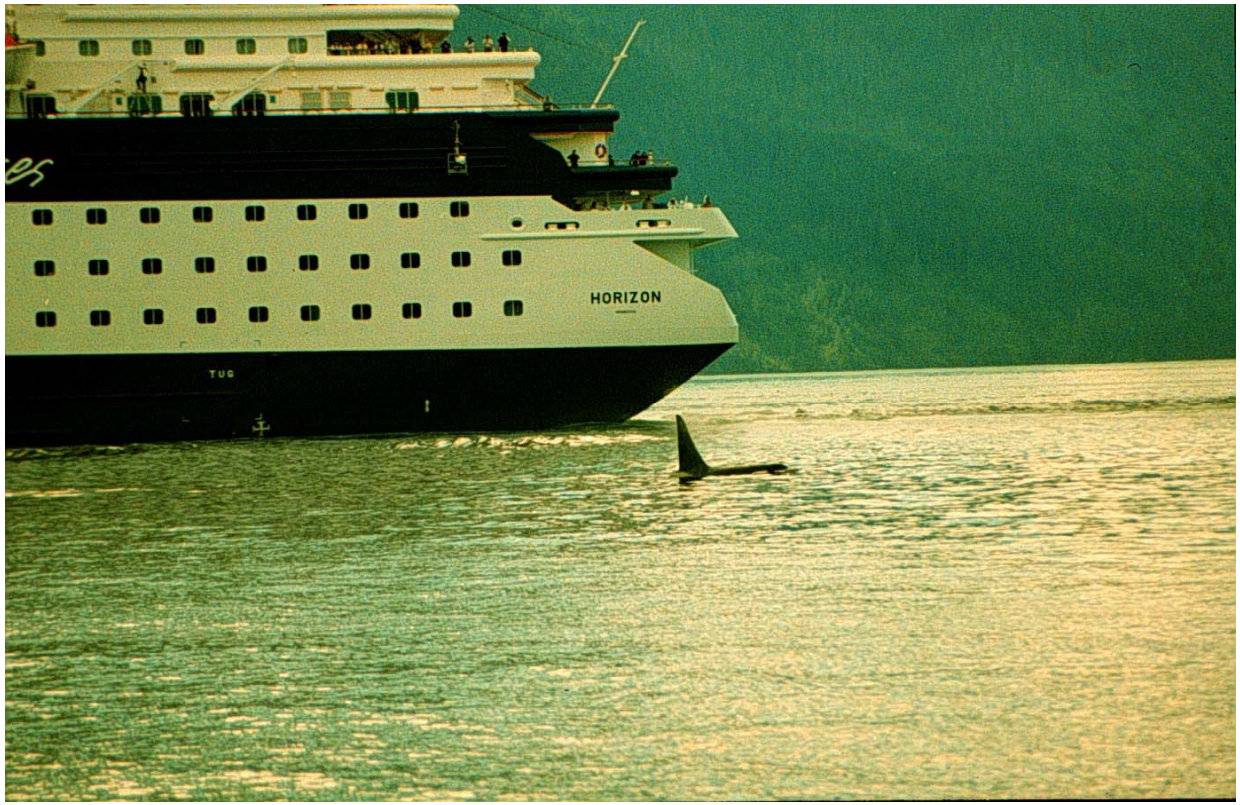


Marine Strategy Framework Directive

Chronic exposure to continuous low frequency sound

- Masking and potentially stress in marine mammals and fish

MSFD Indicator 11.2.1



Trends in the ambient noise level within the 1/3 octave bands **63 and 125 Hz** (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by **observation stations** and/or with the use of **models** if appropriate

Conclusions -1

- Underwater sound is important for many marine life
- Man-made underwater sound can impact marine life in various ways and over various spatial scales
- A lot of gaps still exist on impacts of underwater sound on marine life
- Mitigation measures are being developed and policy has picked up the issue

Conclusions -2

- Dredging comes with lower sound pressure levels compared to other activities (e.g. pile driving)
- Behavioural impacts and masking possible
- TTS to consider at long exposures
- Injury unlikely
- More studies on dredging sounds and effects on marine life are needed

Thanks to:

Fabrizio Borsani, Douglas Clarke, Anna Csiti, Christ de Jong, Pim de Wit, Frederik Goethals, Martine Holtkamp, Astrid Kramer, Helmut Meyer, Kevin Reine, Frederik Roose, Elena San Martin, Philip Spadaro, Gerard van Raalte, George Yesu Vedha Victor, Anders Jensen.