    

Aquatic Noise 2025

A TRAIT-BASED FRAMEWORK TO IDENTIFY MARINE INVERTEBRATES VULNERABLE TO UNDERWATER NOISE

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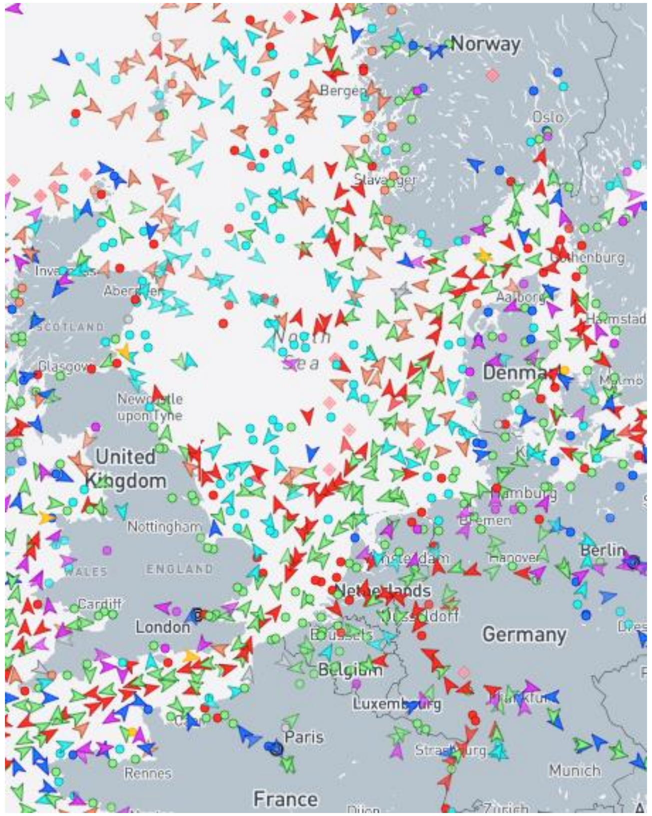
Interreg North Sea

Co-funded by the European Union

Challenge: noise pollution

The North Sea

Real-time ship traffic (2025-06-13)



MarineTraffic.com

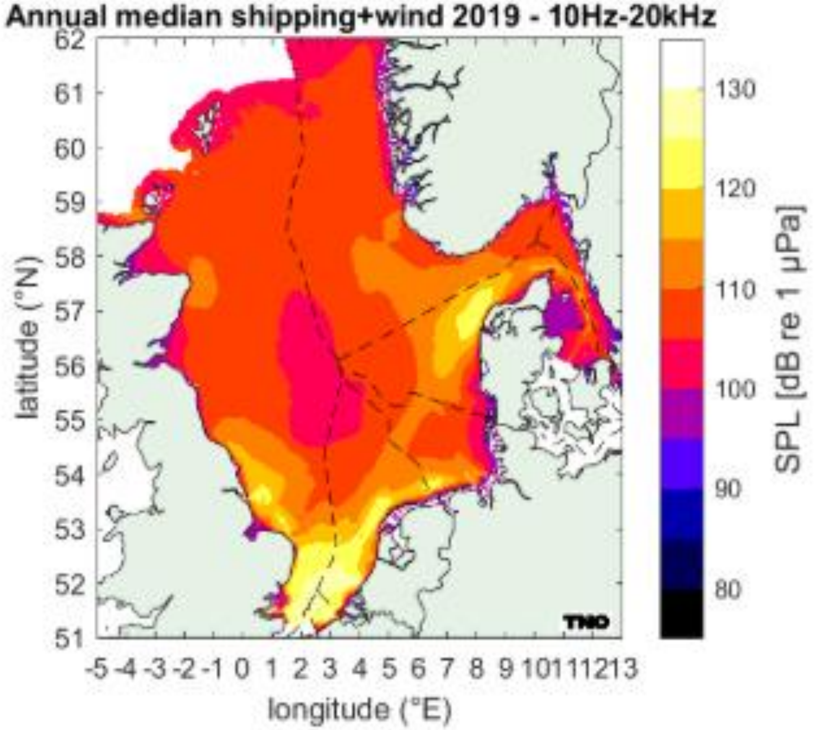


Fig. de Jong et al. (2022)

Challenge: noise pollution

The North Sea

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Risk assessment of noise pollution

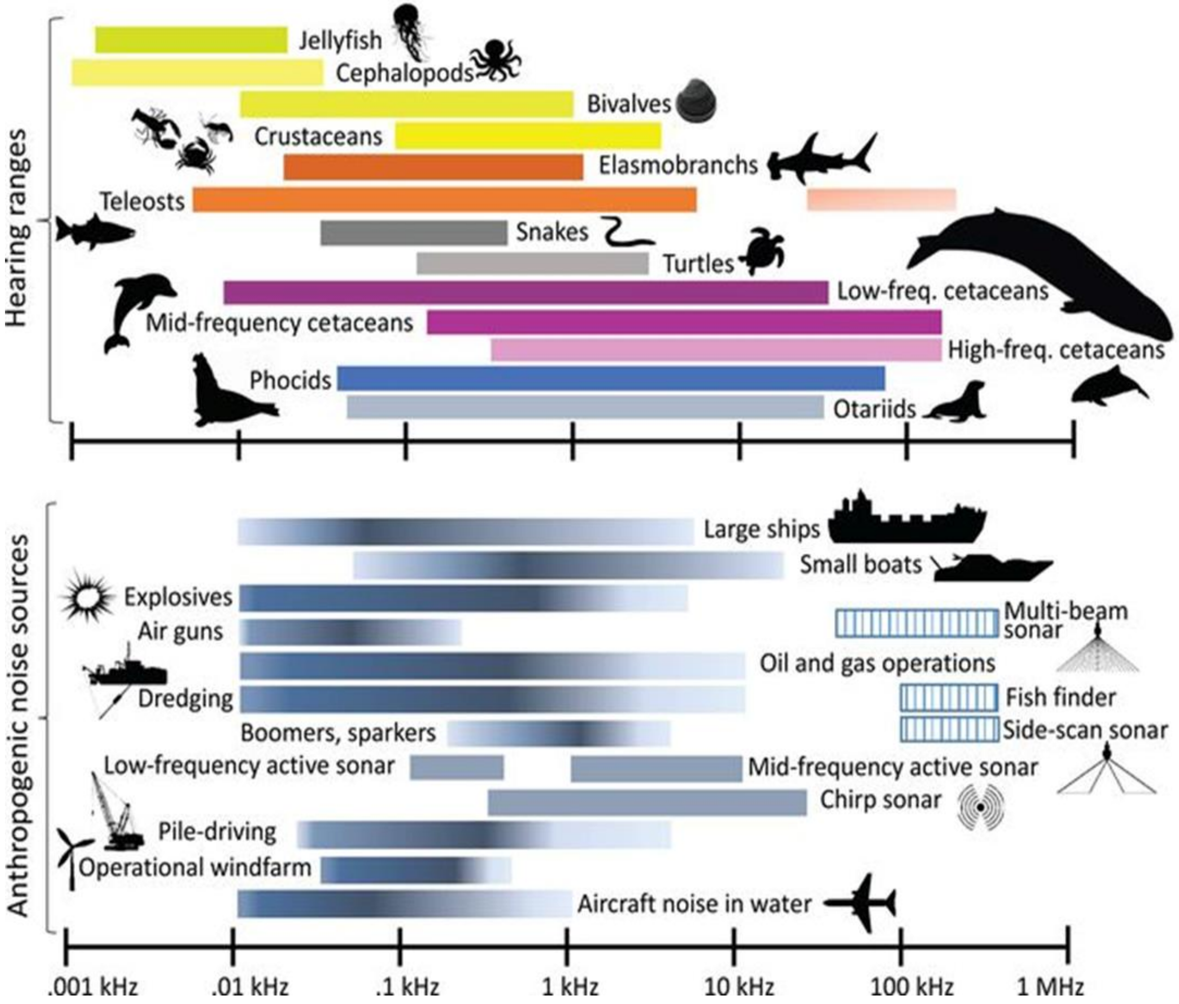

Fig. Duarte et al. (2021)

Risk assessment of noise pollution

Photo: Ecomare

Wikimedia Commons

Photo: Ove Glenjen(Creative Commons)

Photo: Piet Spaans

Risk assessment of noise pollution

EU's TG NOISE Assessment procedure

- Step 1. Define indicator species and their habitats
- Step 2. Define the level of onset of biologically adverse effects (LOBE)
- Step 3. Determine time periods for assessment
- Step 4. Assess the acoustic status by monitoring
- Step 5. Establish the reference condition
- Step 6. Establish the current condition
- Step 7. Evaluate the condition of the grid cells
- Step 8. Determine the status of the habitats
- Step 9. Assess the status of the marine reporting unit as being GES or not GES

Borsani et al. (2023)

Interreg
North Sea

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Contribute to a well-managed North Sea soundscape and protection of the marine environment

DEMASK - Development and evaluation of noise management strategies to keep the North Sea healthy (2024-2026)

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Ministerie van Infrastructuur en Waterstaat

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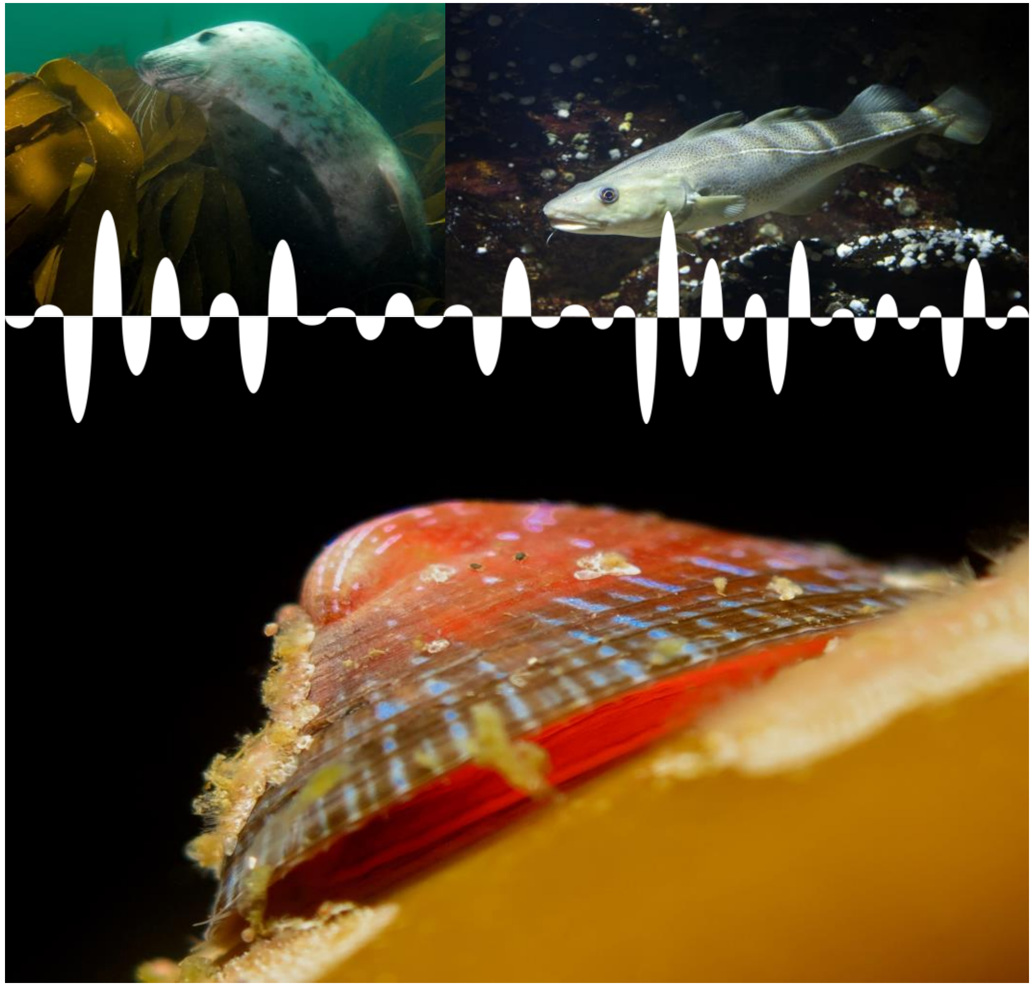
Identify and select indicator species

Objective

- Develop a framework for assessing the relative vulnerability of species to underwater noise
- Identify and select species in the North Sea that are most vulnerable to underwater noise, to be used as indicator species for environmental risk assessment



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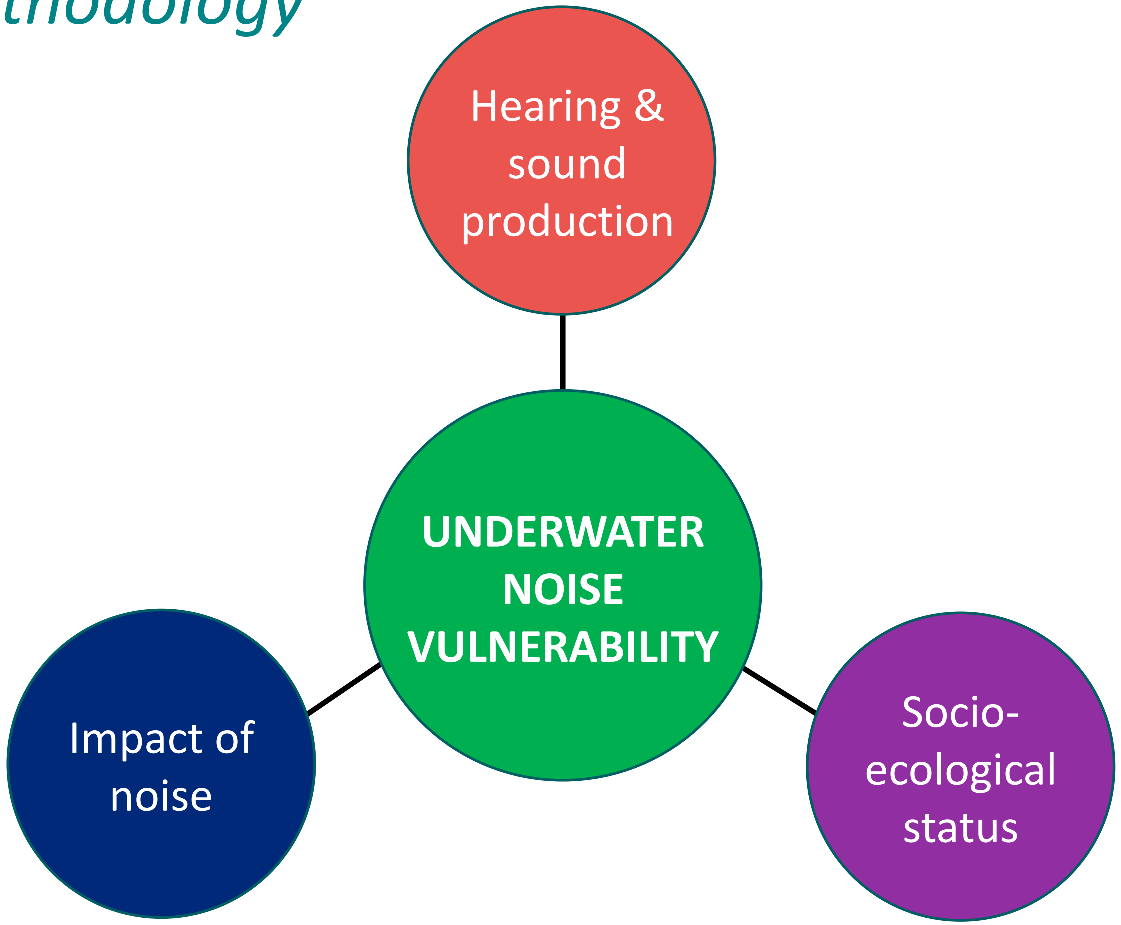
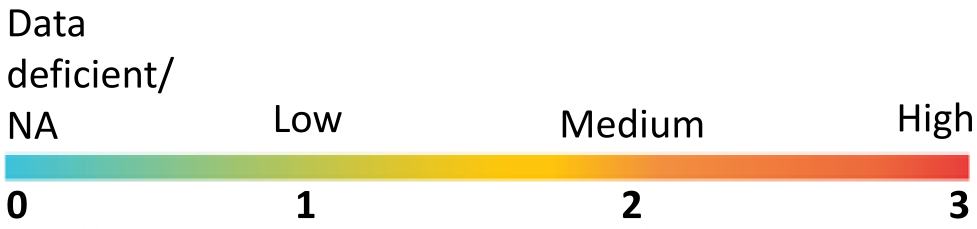
Identify and select indicator species

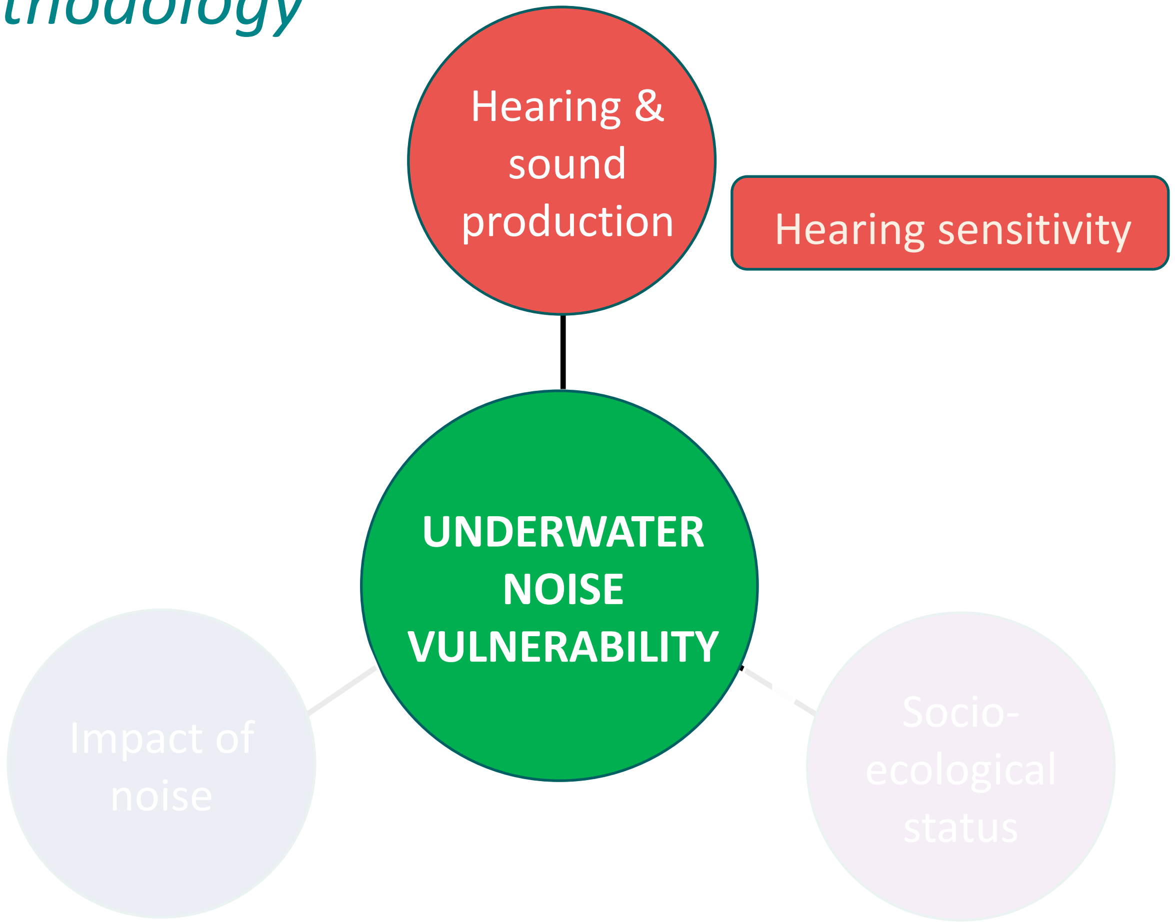
Methodology

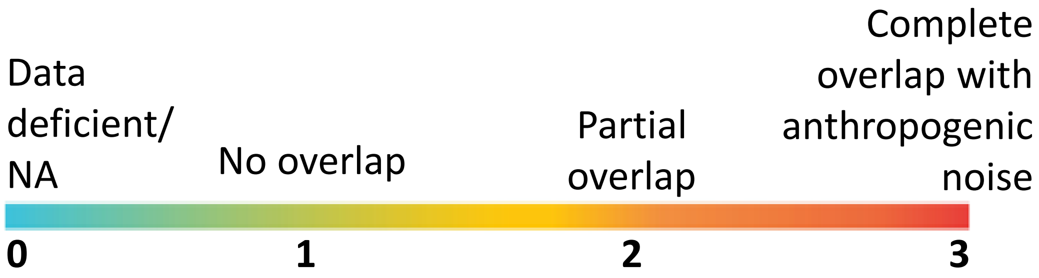




Identify and select indicator species

Methodology





- Primarily sensitive to low-frequency sounds <500 Hz (up to a few kHz)

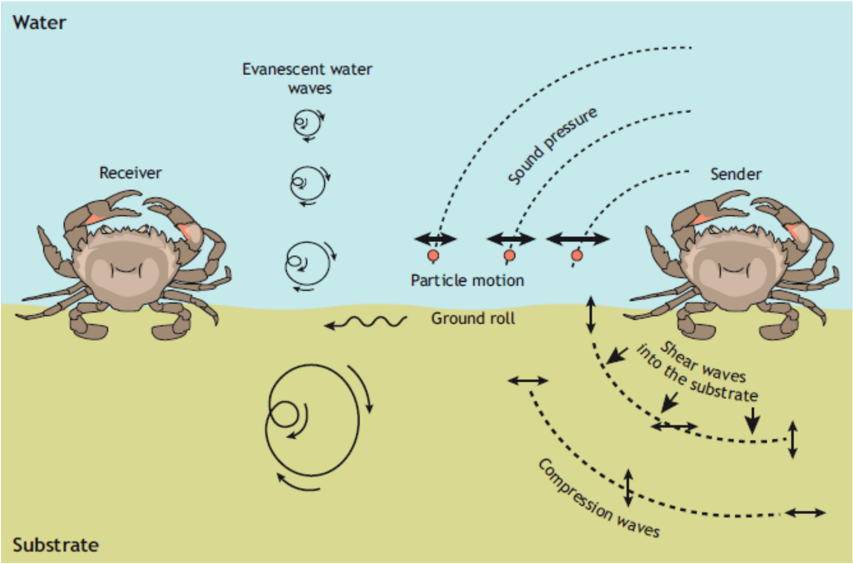


Fig. Radford & Stanley (2023)

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Identify and select indicator species

Methodology

Hearing & sound production

UNDERWATER NOISE VULNERABILITY

Impact of noise

Socio-ecological status

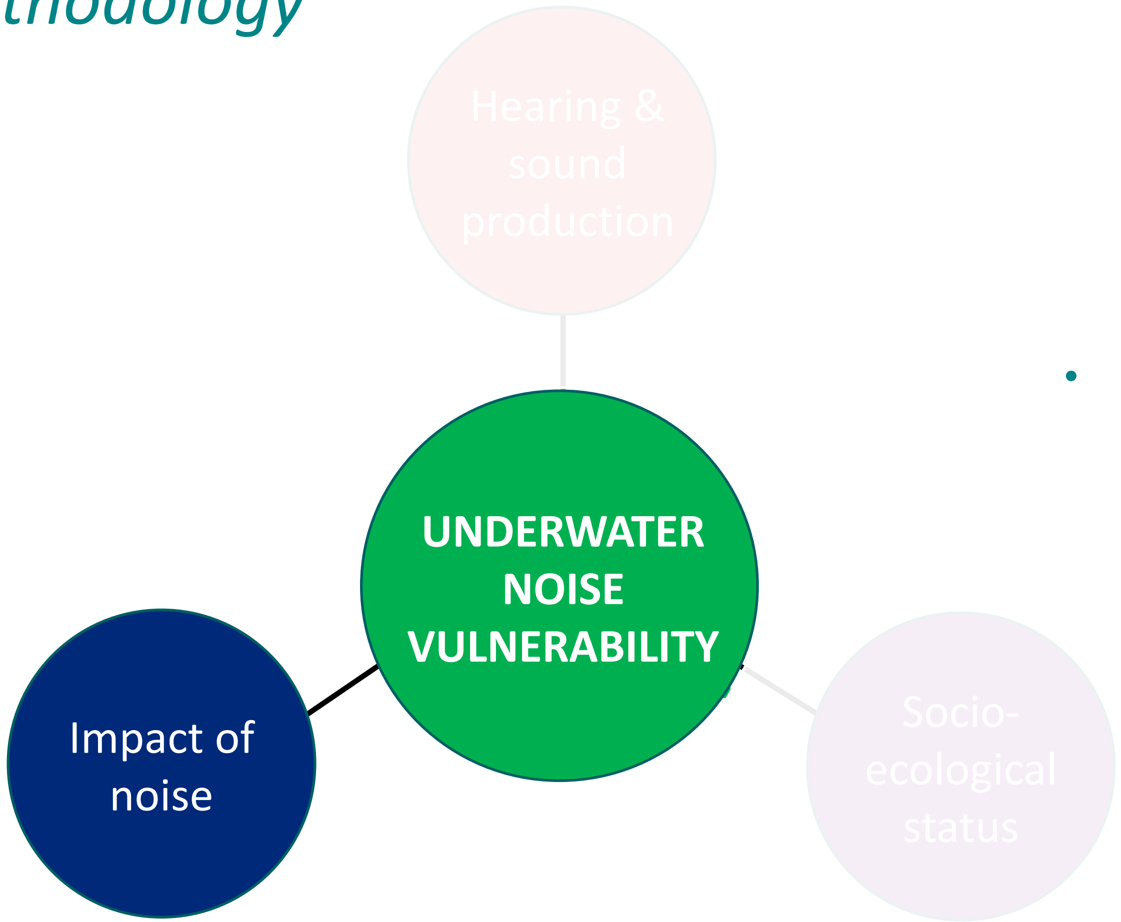
Sound production

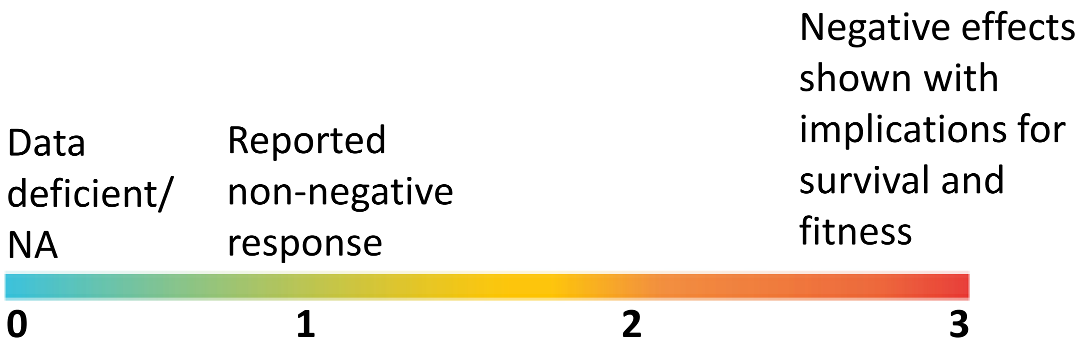
Unlikely /Data deficient/ NA	Passive/ Likely but unconfirmed	Active but unconfirmed for signalling	Active and used for signalling
0	**1**	**2**	**3**

The capacity to produce sounds is only known in 3 groups of marine invertebrates: crustaceans, bivalves and echinoderms

Identify and select indicator species

Methodology





- **Acoustic masking:** Increased number of agonistic sounds when high levels of vessel noise (*European lobster*) (Jezequel et al. 2021)

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Identify and select indicator species

Methodology

Hearing & sound production

Impact of continuous noise

UNDERWATER NOISE VULNERABILITY

Impact of noise

0	1	2	3
Data deficient/ NA	Reported non-negative response		Negative effects shown with implications for survival and fitness

- **Acoustic masking:** Increased number of agonistic sounds when high levels of vessel noise (*European lobster*) (Jezequel et al. 2021)
- **Behavioural effects:**

  - Triggered larval settlement (*barnacles, blue mussel, oyster, scallop, sea squirt*) (e.g. Stanley et al. 2014, Jolivet et al. 2016)





  - Impaired shell-quality assessment (*hermit crab*) (Tidau & Briffa, 2019)
  - Impaired mating behaviour (*shore crab*) (Rising et al. 2022)

- **Changes in morphology:**
  - Reduced ability to camouflage by change of shell colour (*juvenile shore crab*) (Carter et al. 2020)

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Identify and select indicator species

Methodology

Hearing & sound production

UNDERWATER NOISE VULNERABILITY

Impact of impulsive noise

Impact of noise

Socio-ecological status

Data deficient/ NA	Reported non-negative responses		Negative effects shown with implications for survival and fitness
0	**1**	**2**	**3**

- **Acoustic trauma:** Physical damage to the auditory system (*cuttlefish, octopus, squid*)

  (André et al. 2011, Solé et al. 2013, 2022)



- **Mortality** of crustacean zooplankton (*krill, copepods*)

  (McCauley et al. 2017, Vereide et al. 2023)


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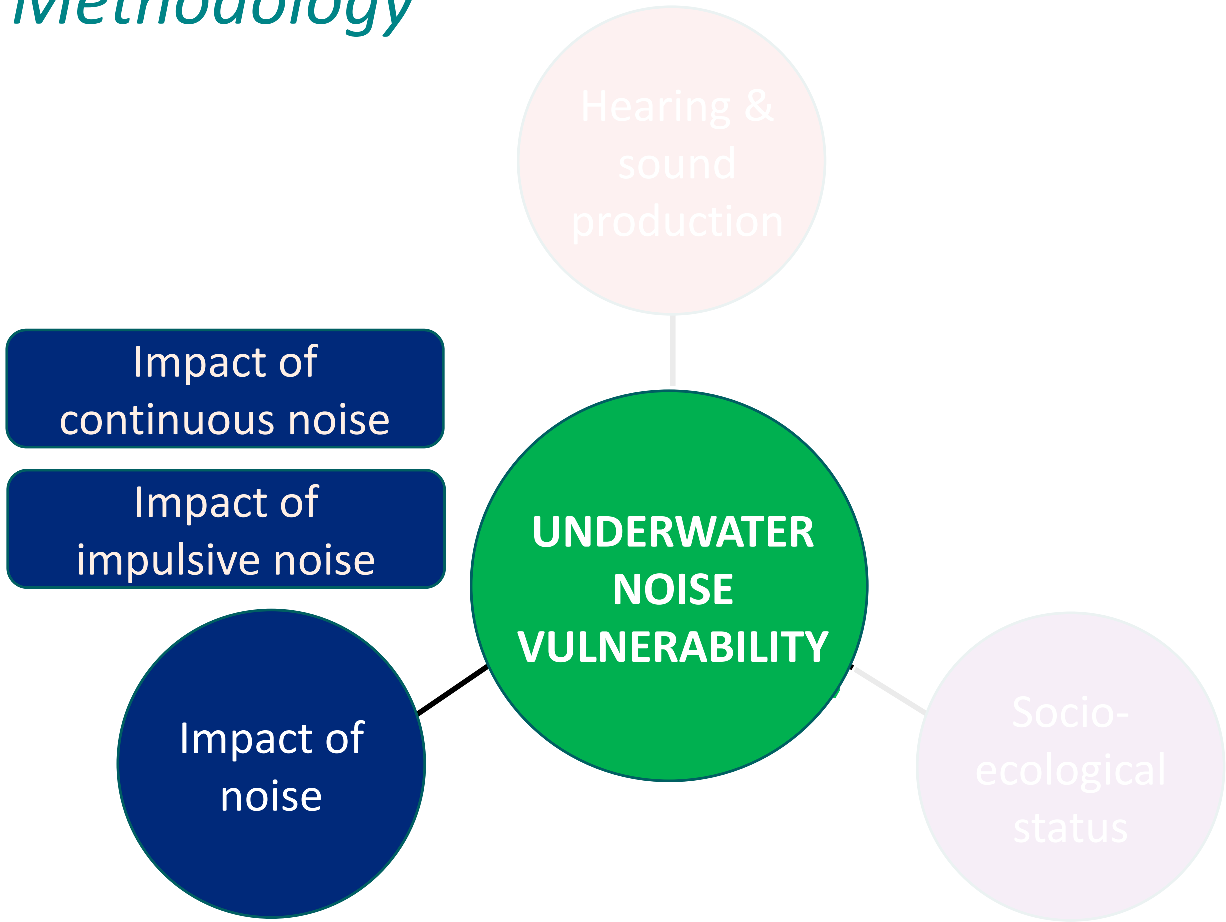

Data deficient/ NA

No negative effects indicated to noise exposure

Negative effects shown with implications for survival and fitness

- **Behavioural effects:**
  - Impaired/induced anti-predator responses (*cuttlefish, European lobster juveniles, shore crab*)
  - Impaired foraging (*shore crab, prawn, copepod, blue mussel*)
  - Reduced burrowing and bioturbation (*Norway lobster, amphipods, brittle star, lugworm*)





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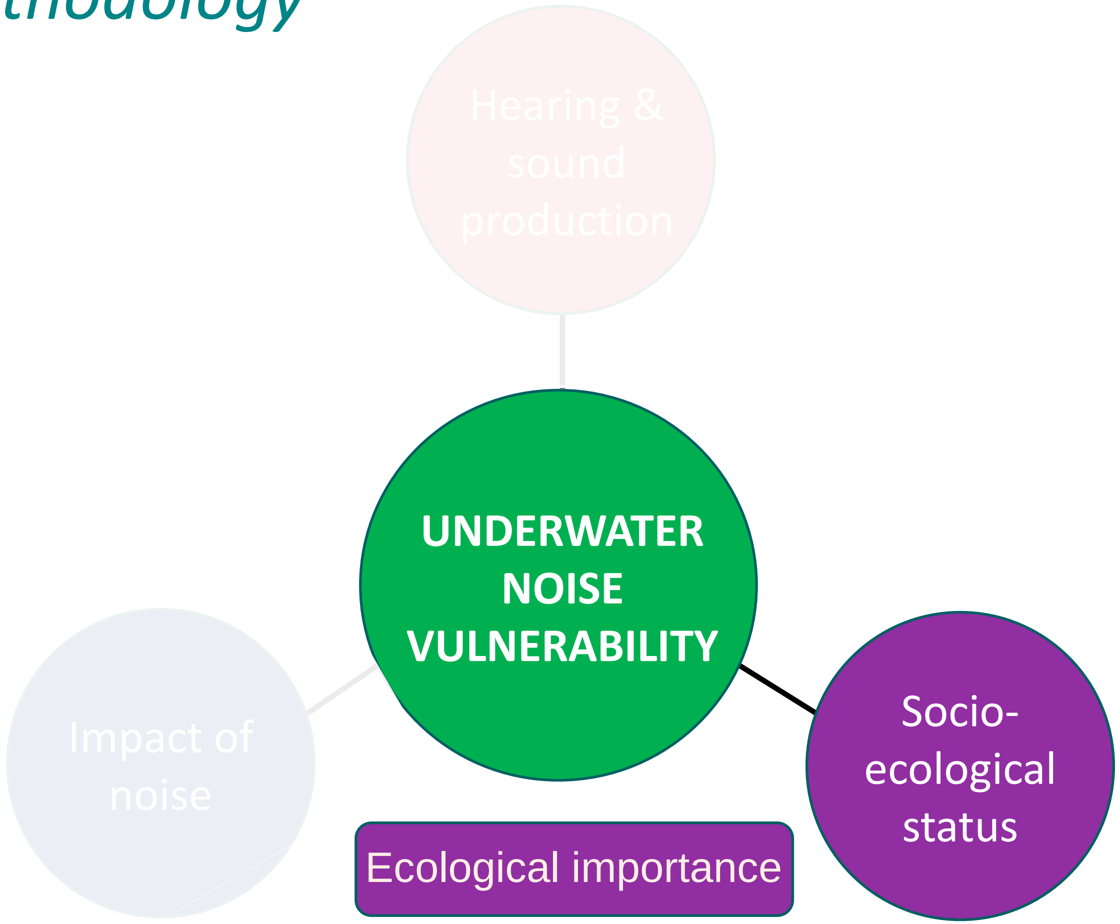

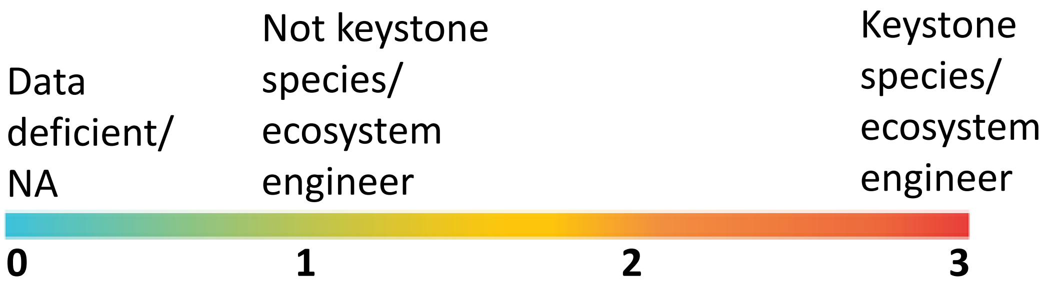

Keystone species

- Dominant food source
- Important predators


Ecosystem engineers

- Efficient filtrators, reducing the nutrient load
- Offering habitats for increased biodiversity
- Bioturbate and oxygenate the seafloor


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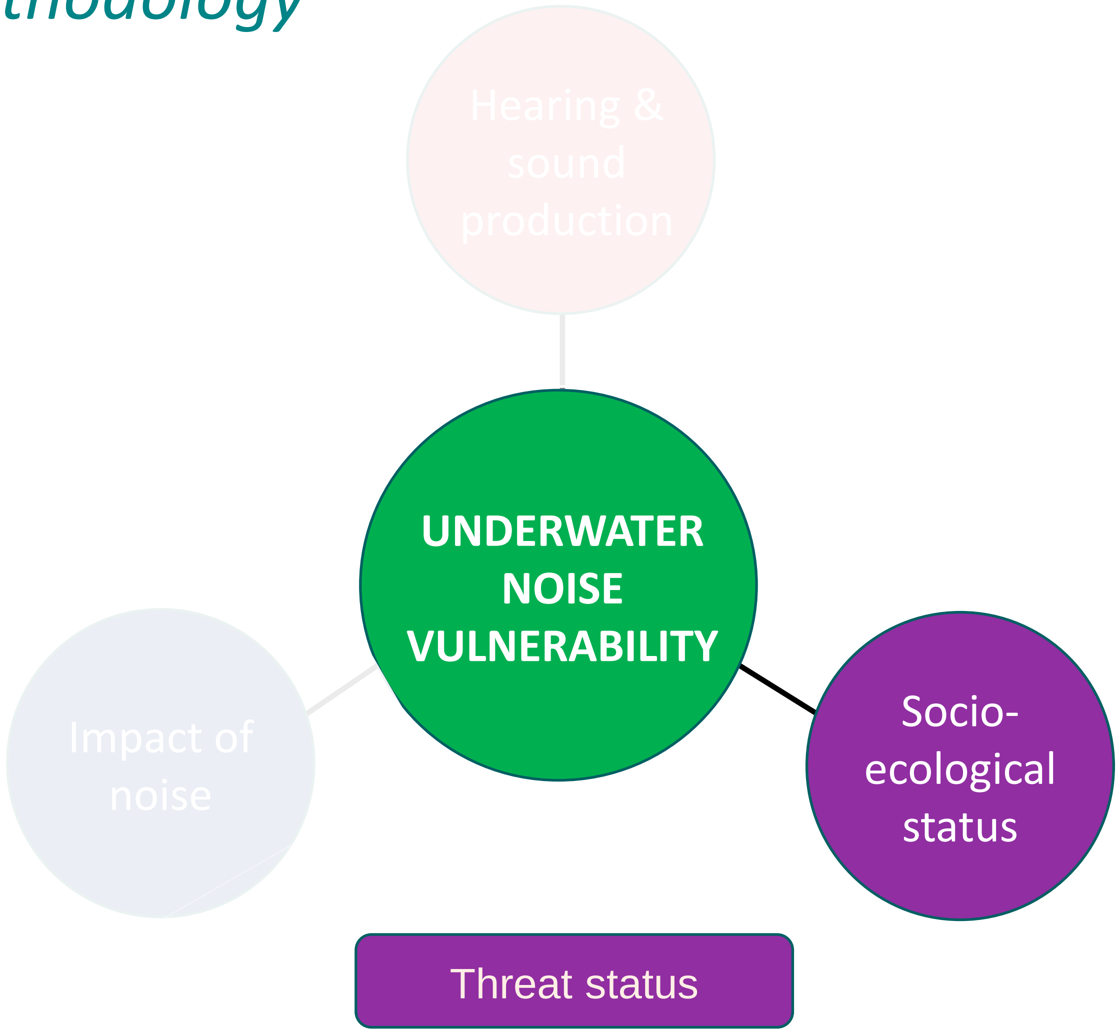

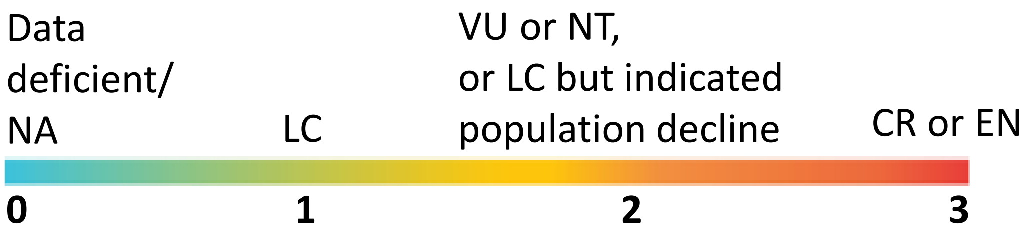

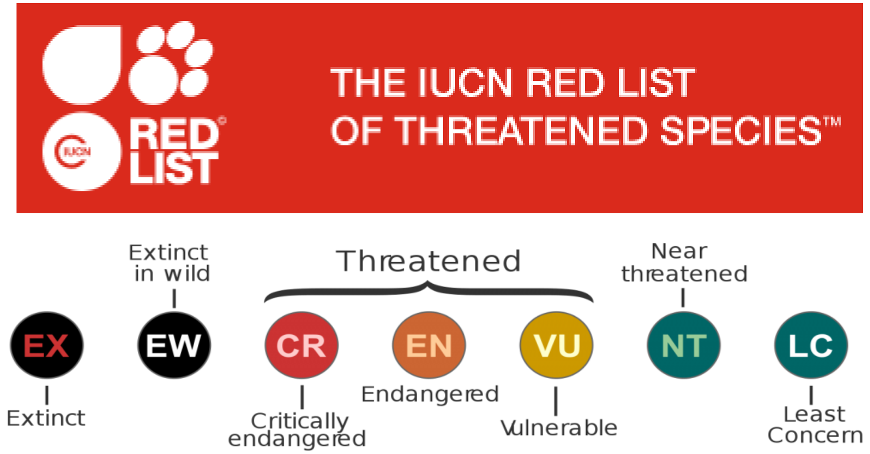

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UNDERWATER NOISE VULNERABILITY

Impact of noise

Socio-ecological status

Commercial value

Data deficient/ NA	Low	Medium: more prominent in local commercial fisheries, or recreational fishing but high price	High
0	**1**	**2**	**3**

Norway lobster (*Nephrops norvegicus*)

Shore crab (*Carcinus maenas*)
Common hermit crab (*Pagurus bernhardus*)
Purple acorn barnacle (*Amphibalanus amphitrite*)
Brittle star (*Amphiura filiformis*)

Sea squirt (*Ciona intestinalis*)
Copepod (*Acartia tonsa*)

Krill (*Euphausia spp.*)
Lugworm (*Arenicola marina*)

European squid (*Loligo vulgaris*)
European lobster (*Homarus gammarus*)
Common prawn (*Palaemon serratus*)
Blue mussel (*Mytilus edulis*)
Pacific oyster (Magallana gigas)
European/Flat oyster (*Ostrea edulis*)
Great scallop (*Pecten maximus*)

Edible crab (*Cancer pagurus*)
Brown shrimp (*Crangon crangon*)
Common cuttlefish (*Sepia officinalis*)
Common octopus (*Octopus vulgaris*)

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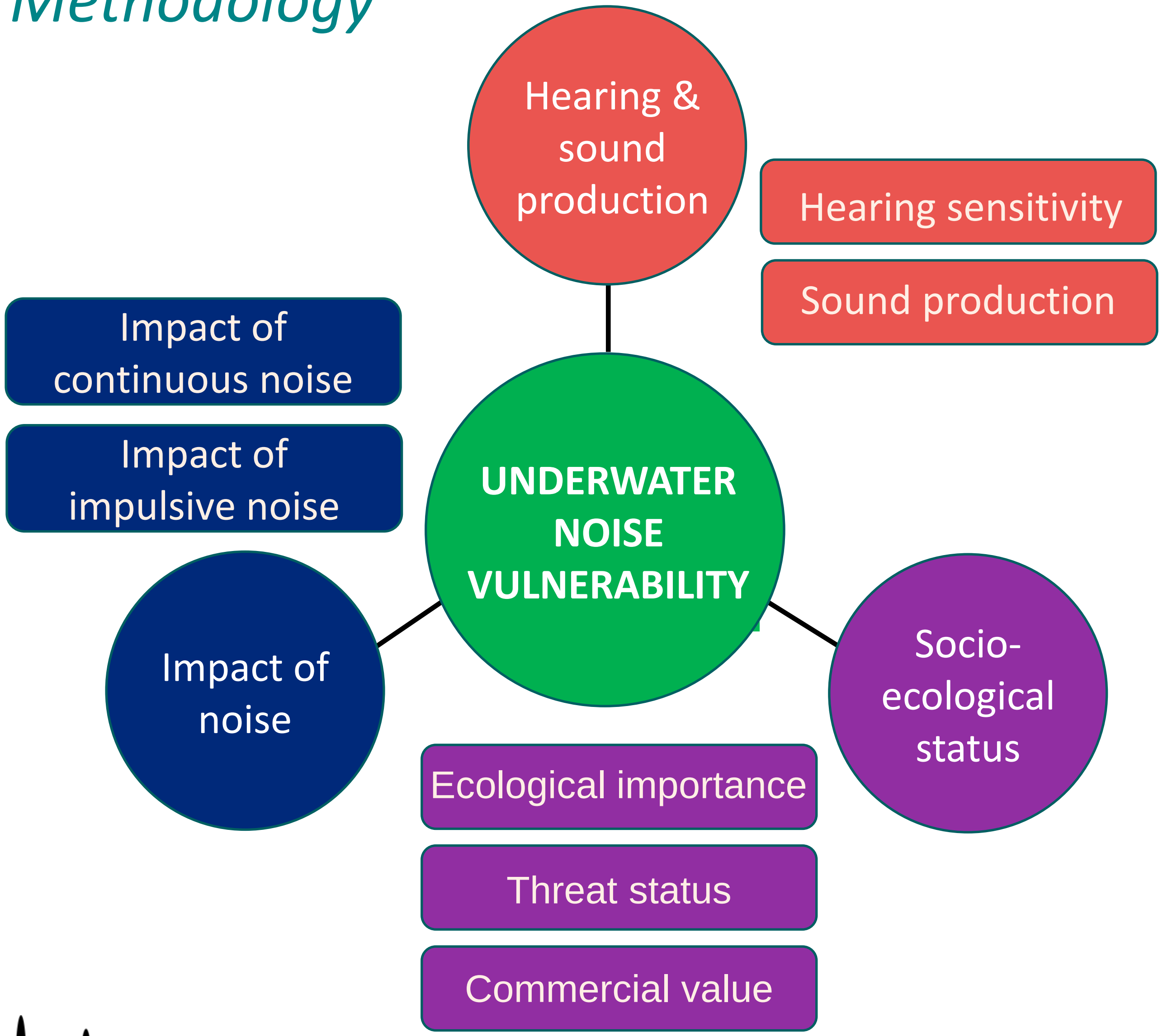

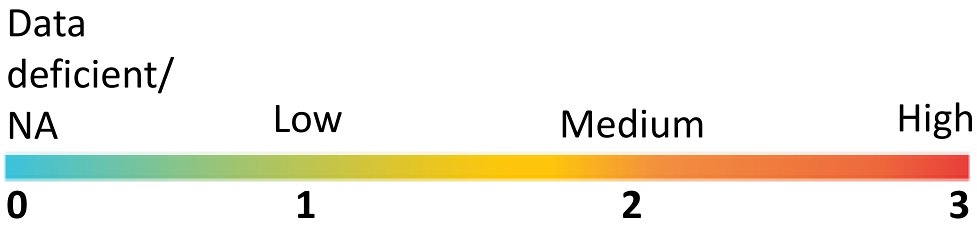

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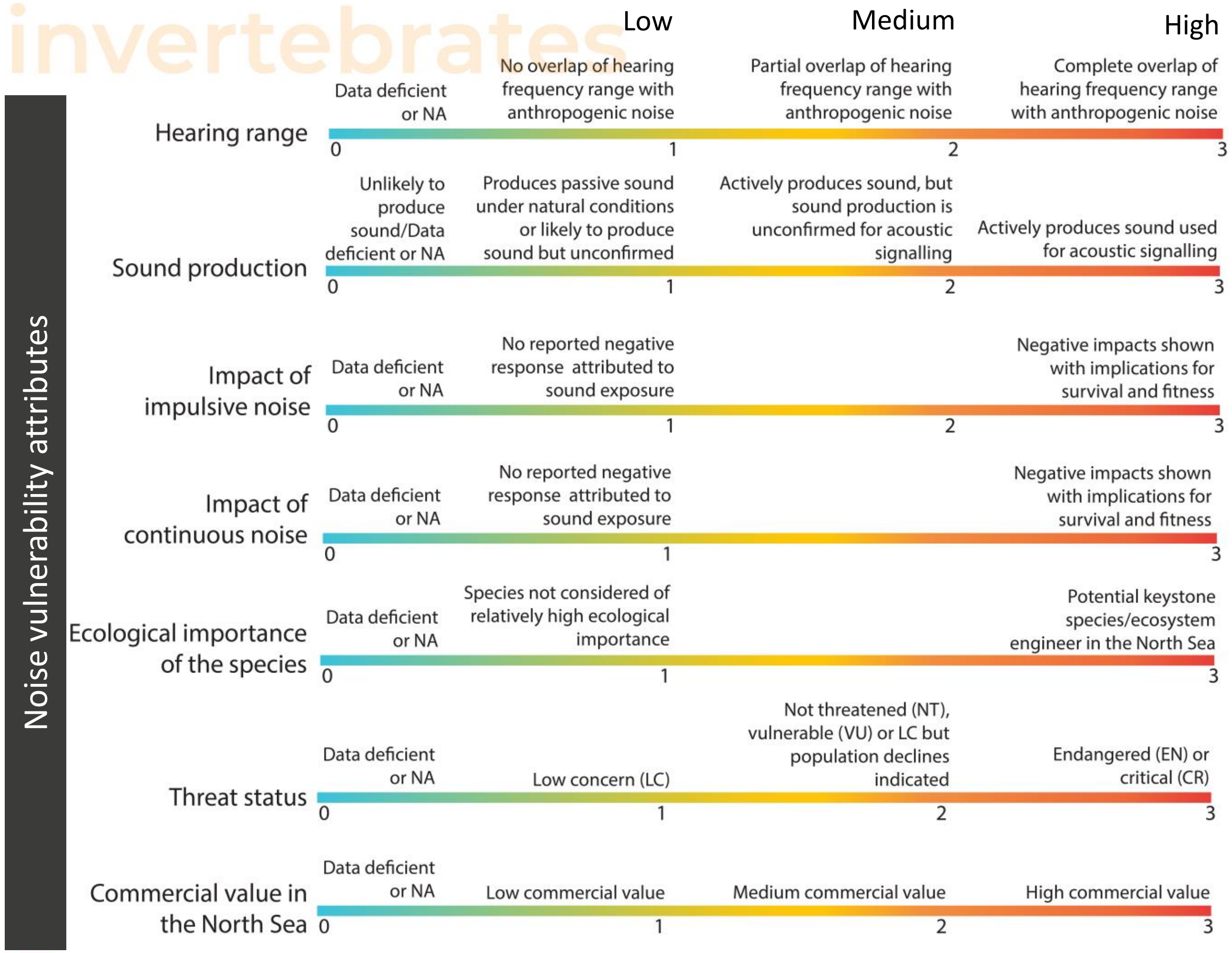
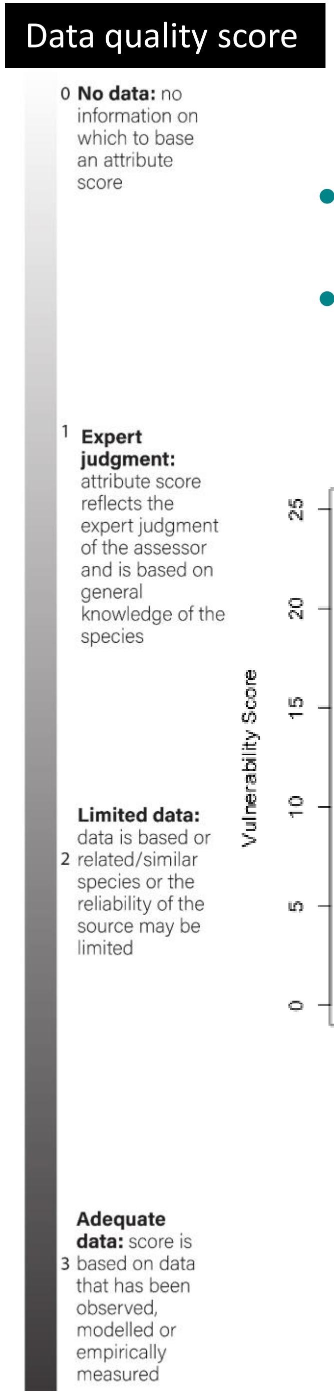
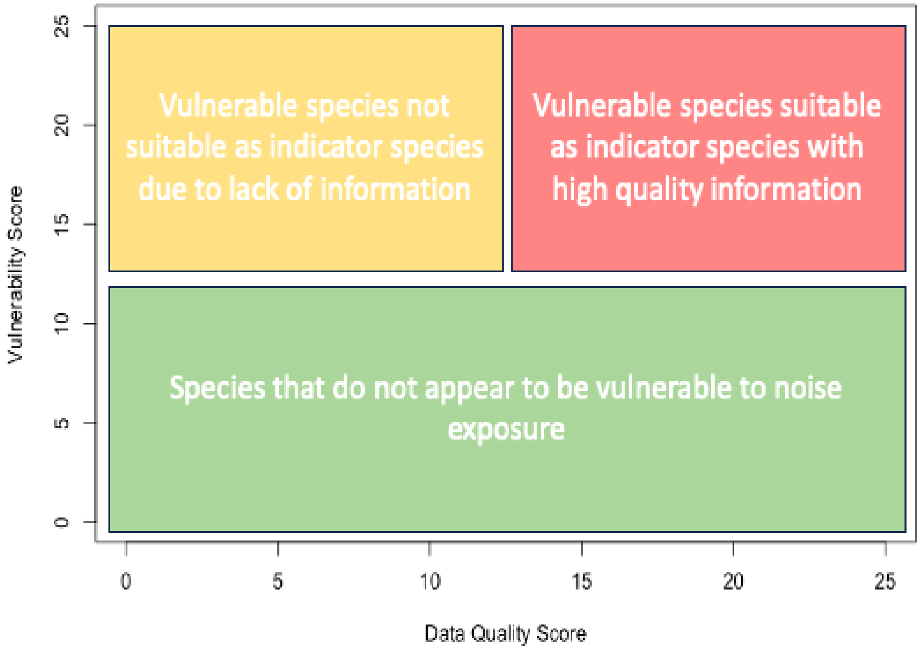
Identify and select indicator species

Methodology





- For each vulnerabity attribute, species were assigned a score from low to high
- Combined with a data quality score estimating the reliablity of the data used for vulnerability scoring



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Identify and select indicator species

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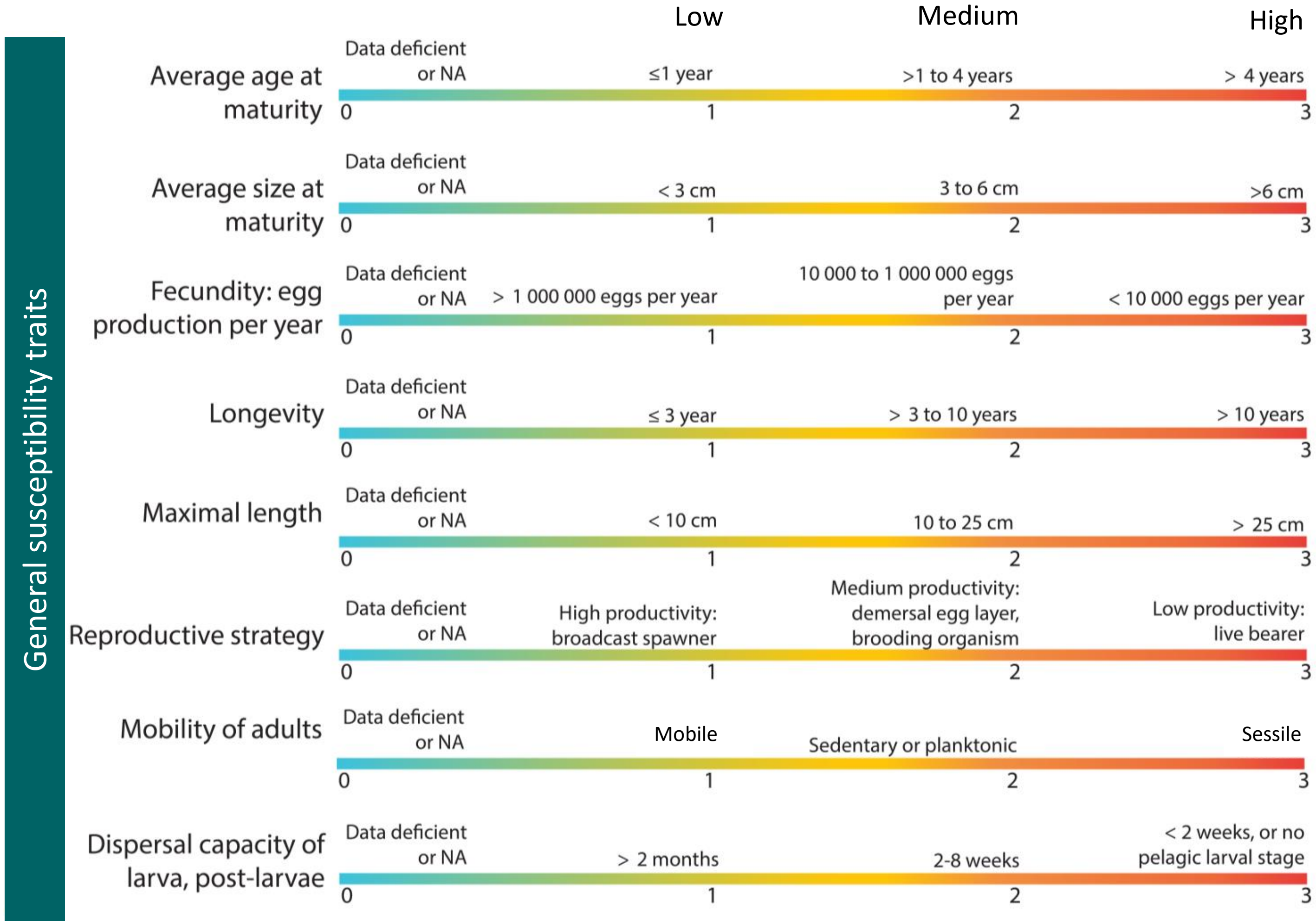

Basic life-history traits related to **PRODUCTIVITY** and **MOBILITY** for estimation of species' general susceptibility

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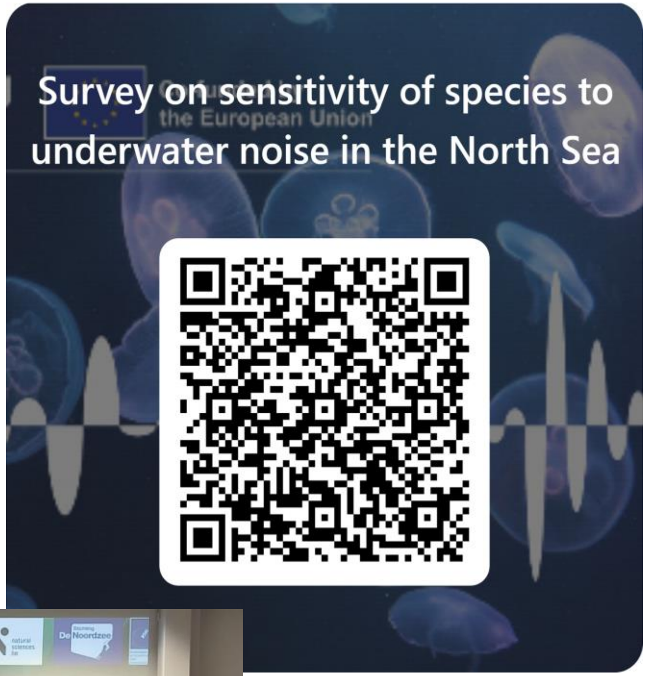
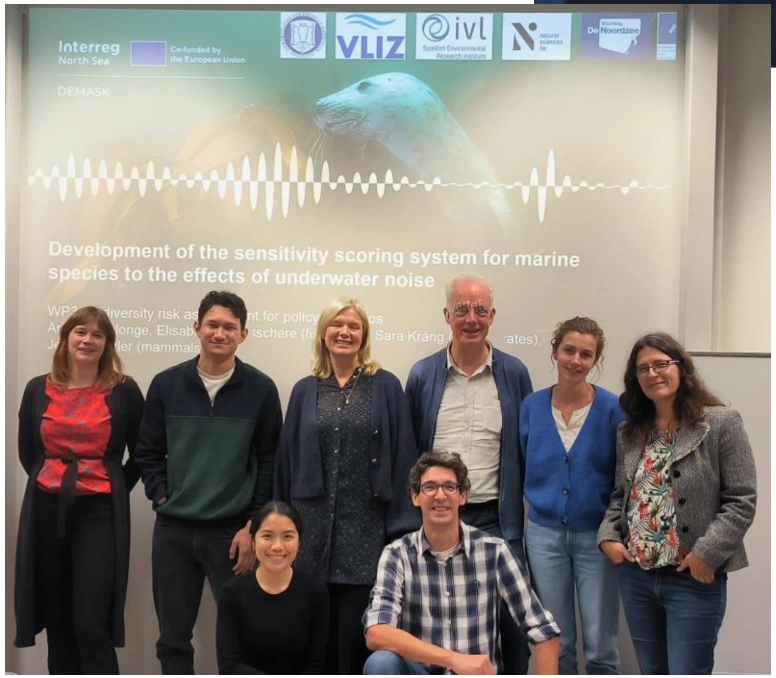
Identify and select indicator species
Methodology

1. **Literature review** identified 20 invertebrate species from the North Sea region where data was available for vulnerability scoring
(3 cephalopods, 10 crustaceans, 4 bivalves,
1 Ascidia, 1 Annelida, 1 Echinodermata)

2. **Literature-based scoring** of noise vulnerability, data quality and general susceptibility

3. **Vulnerability scoring by experts, via**
    a. **Online survey**
    b. **DEMASK workshop** – Bioacoustics Day, Oct 2024





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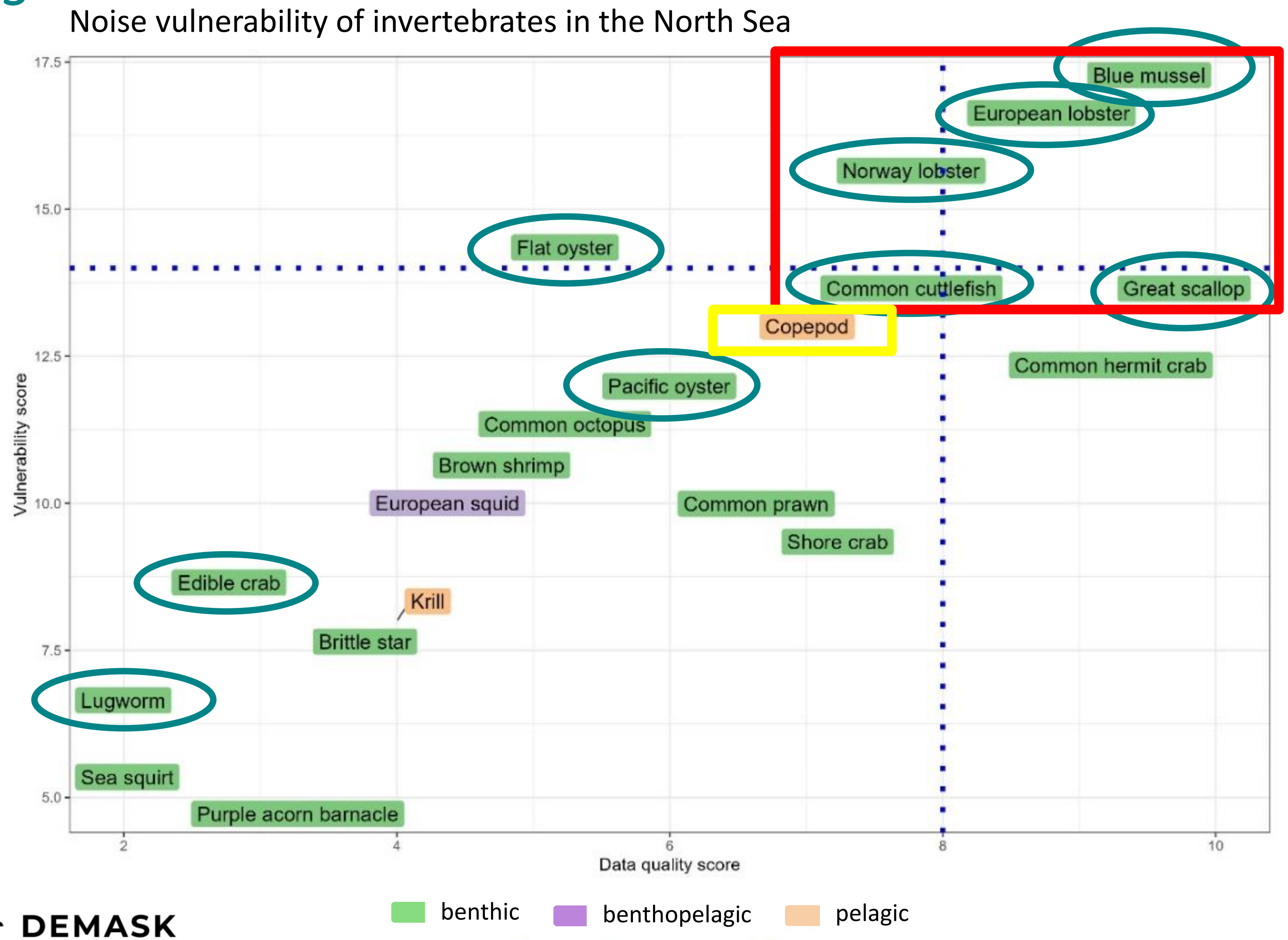
Identify and select indicator species

Results



species that scored high for general susceptibility

- **Blue mussel, European lobster** and **Norway lobster** received the highest noise vulnerability and data quality scores
- Also **common cuttlefish** and **great scallop** received high noise vulnerability and data quality scores
- All five species also received high score for general susceptibility

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Identify and select indicator species

Results

Noise vulnerability of invertebrates in the North Sea

species that scored high for general susceptibility

- **Blue mussel, European lobster** and **Norway lobster** received the highest noise vulnerability and data quality scores
- Also **common cuttlefish** and **great scallop** received high noise vulnerability and data quality scores
- All five species also received high score for general susceptibility
- Potentially vulnerable species could not be fairly assessed due to limited data

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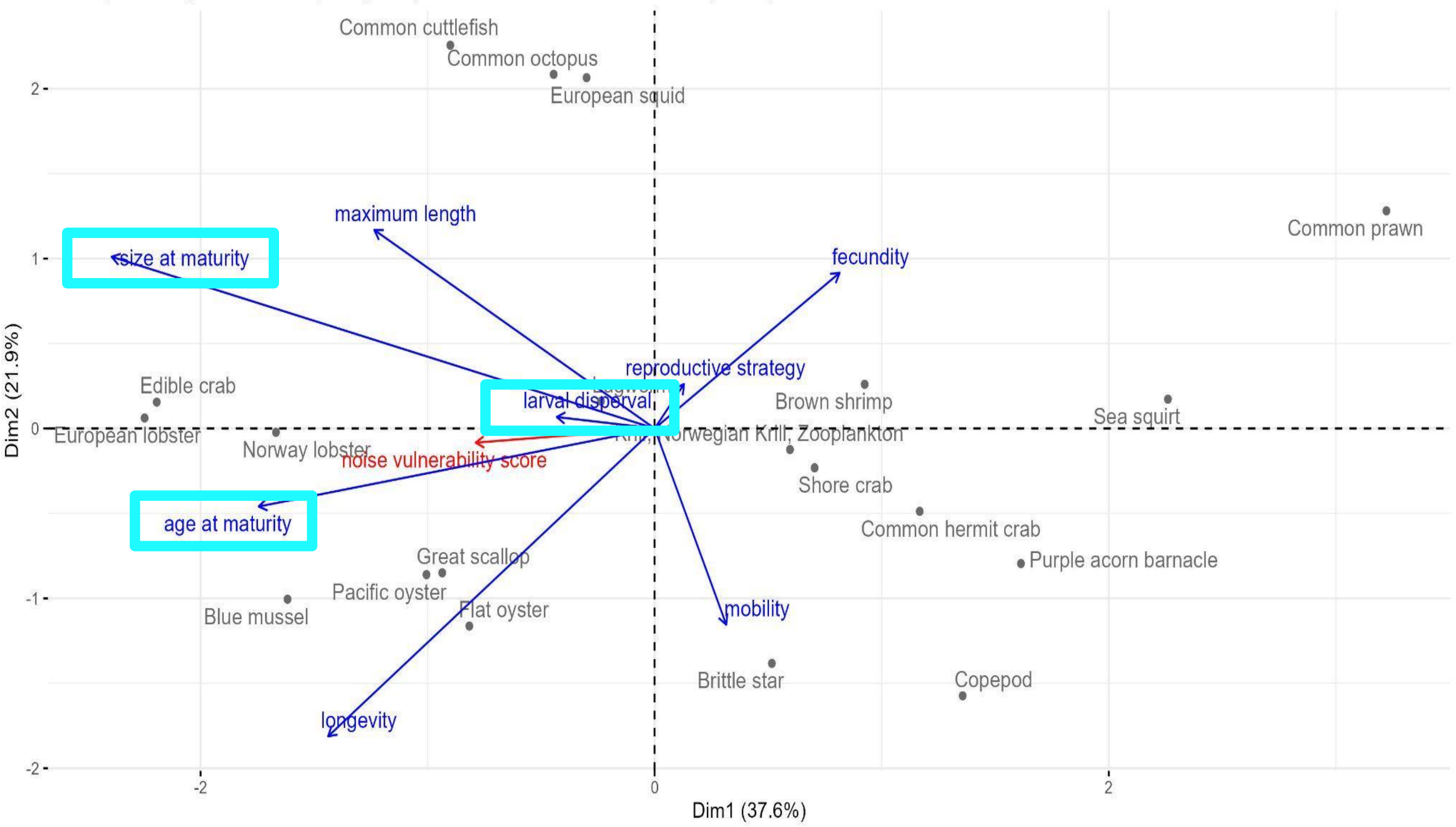
Identify and select indicator species
Results

Principal Component Analysis relating noise vulnerability
to the different life-history traits used to assess general susceptibility



Noise vulnerability foremost correlated with:

- high age at maturity
- large size at maturity
- low larval dispersal ability

But also:

- large size
- longer lifespan

Not correlated with:

- fecundity
- reproductive strategy
- mobility of adults

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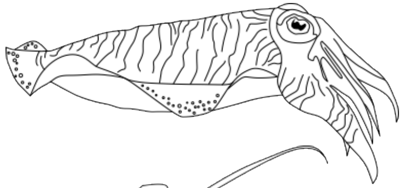
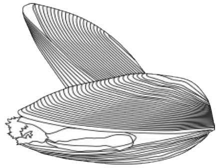
Identify and select indicator species
Results

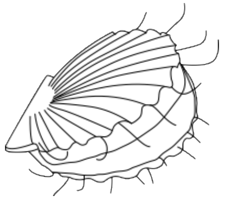
Low	Medium	High
< 1	≥ 1 to < 2	≥ 2

Summary of all score categories

Species group	Species	pelagic or benthic (adults)	Average Noise Vulnerability Score	Average Data Quality Score	Average General Susceptibility Score
Cephalopoda	**Common cuttlefish (*Sepia officinalis*)**	benthic	2.00	2.00	2.25
	Common octopus (*Octopus vulgaris*)	benthic	1.57	1.25	1.88
	European squid (*Loligo vulgaris*)	benthopelagic	1.43	1.25	1.75
Crustacea	**European lobster (*Homarus gammarus*)**	benthic	2.43	2.25	2.50
	Norway lobster (*Nephrops norvegicus*)	benthic	2.29	2.00	2.50
	Edible crab (*Cancer pagurus*)	benthic	1.29	0.75	2.13
	Shore crab (*Carcinus maenas*)	benthic	1.29	1.75	1.63
	Common prawn (*Palaemon serratus*)	benthic	1.43	1.50	1.13
	Common hermit crab (*Pagurus bernhardus*)	benthic	1.71	2.25	1.63
	Brown shrimp (*Crangon crangon*)	benthic	1.57	1.25	1.88
	Krill (*Euphausia spp.*)	pelagic	1.14	1.00	1.38
	Purple acorn barnacle (*Amphibalanus amphitrite*)	benthic	0.71	1.00	1.75
	Copepod (*Acartia tonsa*)	pelagic	1.86	1.75	1.50
Bivalvia	**Blue mussel (*Mytilus edulis*)**	benthic	2.43	2.25	2.13
	Pacific oyster (*Magallana gigas*)	benthic	1.71	1.50	2.13
	Flat oyster (*Ostrea edulis*)	benthic	2.00	1.25	2.25
	Great scallop (*Pecten maximus*)	benthic	2.00	2.50	2.00
Ascidia	Sea squirt (*Ciona intestinalis*)	benthic	0.71	0.50	1.88
Annelida	Lugworm (*Arenicola marina*)	benthic	1.00	0.50	2.13
Echinodermata	Brittle star (*Amphiura filiformis*)	benthic	1.14	1.00	1.63







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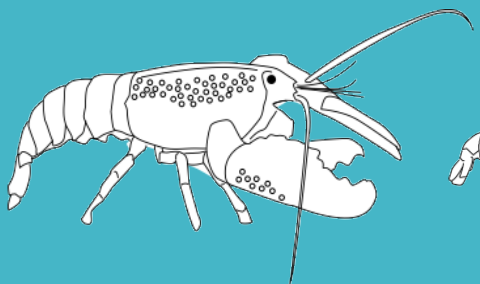
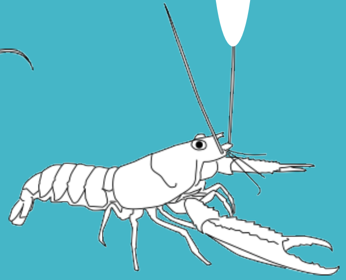
Potential invertebrate indicator species

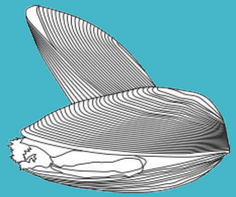
For the North Sea



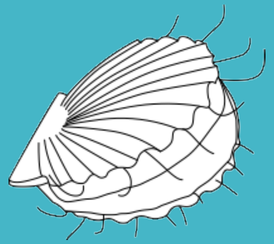
European lobster
Homarus gammarus



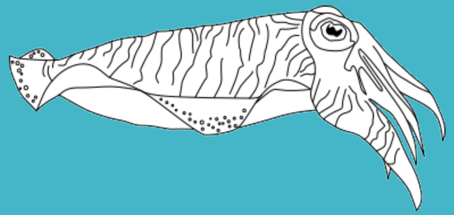
Norway lobster
Nephrops norvegicus



Blue mussel
Mytilus edulis



Great scallop
Pecten maximus



Common cuttlefish
Sepia officinalis

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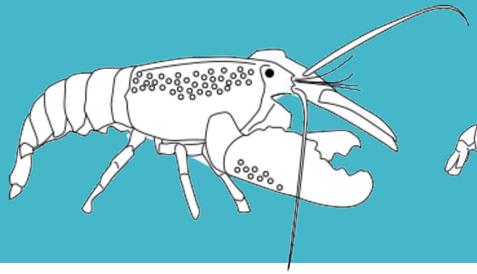
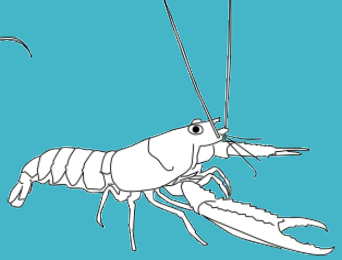
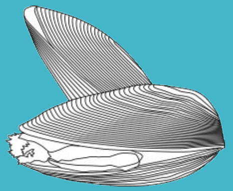


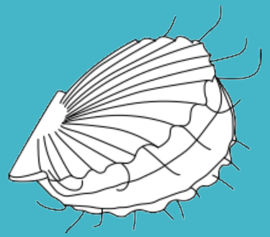
European lobster
Homarus gammarus



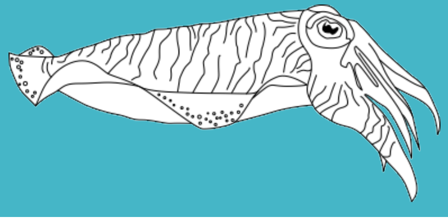
Norway lobster
Nephrops norvegicus



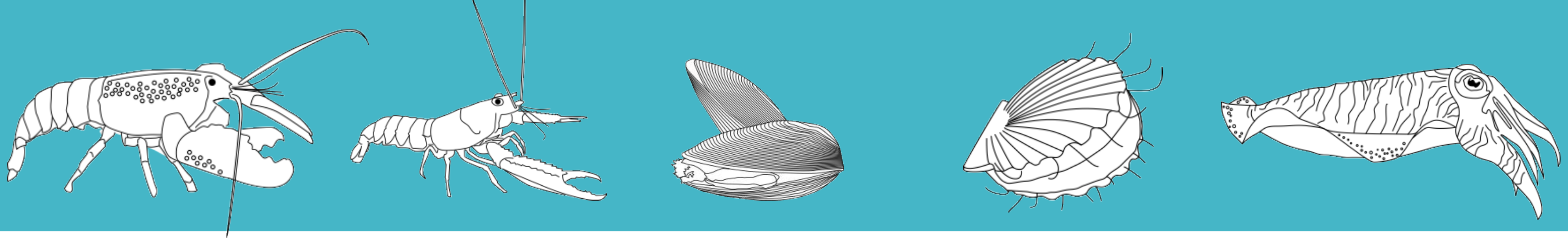
Blue mussel
Mytilus edulis



Great scallop
Pecten maximus



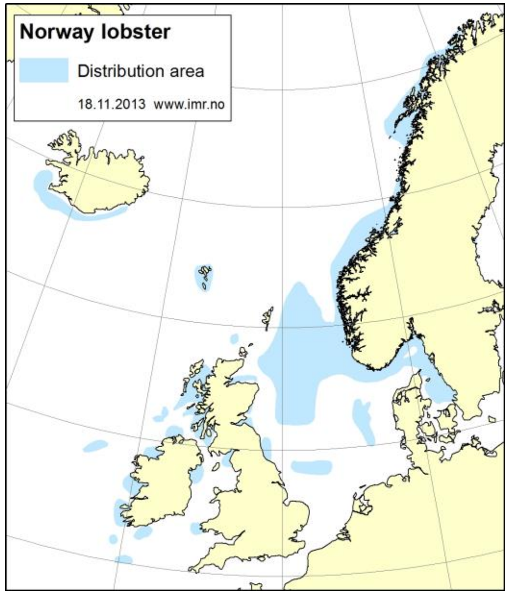
Common cuttlefish
Sepia officinalis



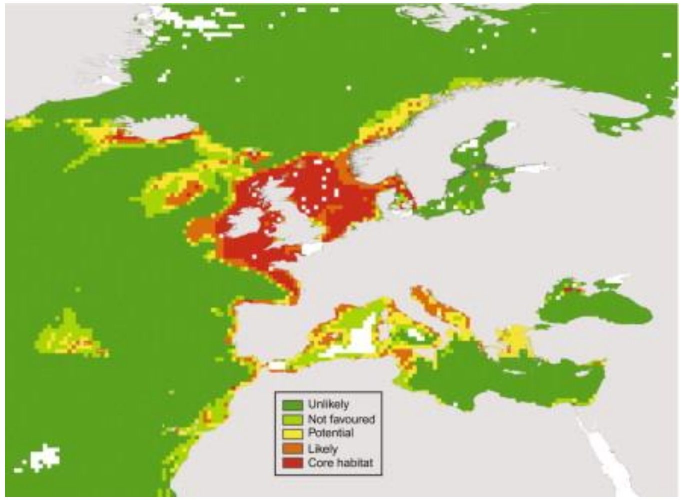
	European lobster *Homarus gammarus*	Norway lobster *Nephrops norvegicus*	Blue mussel *Mytilus edulis*	Great scallop *Pecten maximus*	Common cuttlefish *Sepia officinalis*
Hearing sensitivity	80 to 250 Hz*	20-180 Hz	5 - 410 Hz	20 - 1000 Hz*	<400 Hz
Sound production	55-180 Hz agonistic behaviour	Likely but unconfirmed	Likely but unconfirmed	20–27 kHz valve movements	No studies available
Impact of impulsive noise	Physiological*	Behavioural, Physiological, Larval development	Behavioural, Physiological*	Physiological, Larval development	Acoustic trauma, Behavioural, Egg & larval development
Impact of continuous noise	Masking, Behavioral	Behavioural	Behavioural, Physiological	Physiological, Larval development & survival	Acoustic trauma, Behavioural, Egg & larval development
Ecological importance	Less	Yes ecosystem engineer	Yes ecosystem engineer	Less	Less
Threat status	Least concern (LC) but high fishing pressure & depleted popuations	Least concern (LC)	Least concern (LC) but declining populations & habitats	Least concern (LC)	Least concern (LC)
Commercial value	Medium, high price, mainly recreational fishing	High	Medium, commercially cultured	Medium, high price, locally fished & cultured	High

Outlook

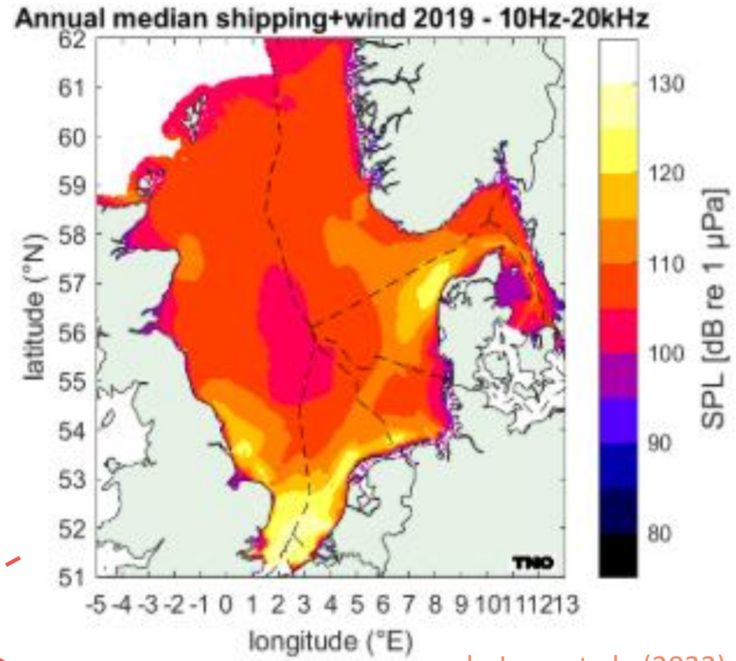
- **Distribution/habitat maps** for indicator species
- Overlaid with **sound level maps** for baseline and future policy scenarios
- Identify **threshold values** for biologically significant adverse effects
- Evaluate the fraction of habitats where thresholds are exceeded
- Assess the effects of noise on indicator species for different management strategies



www.imr.no



Johnson et al. (2013)



de Jong et al. (2022)

underwater noise risk assessment & management

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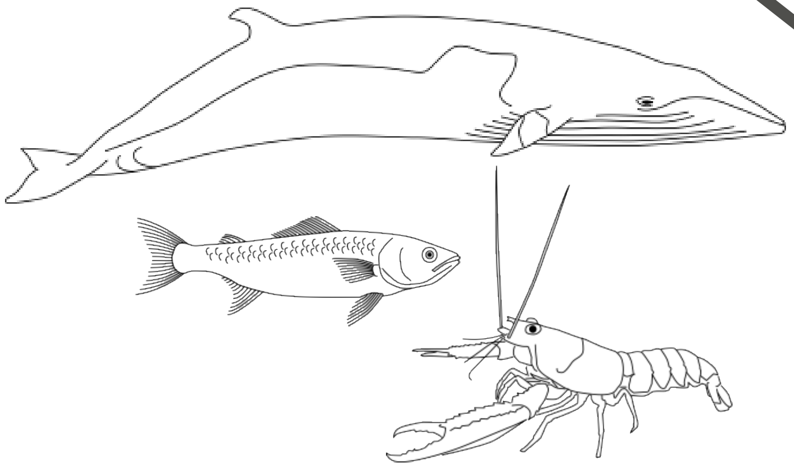
Final remark and overall goal

impact-based



adaptive

The vulnerability scoring system serves as a framework

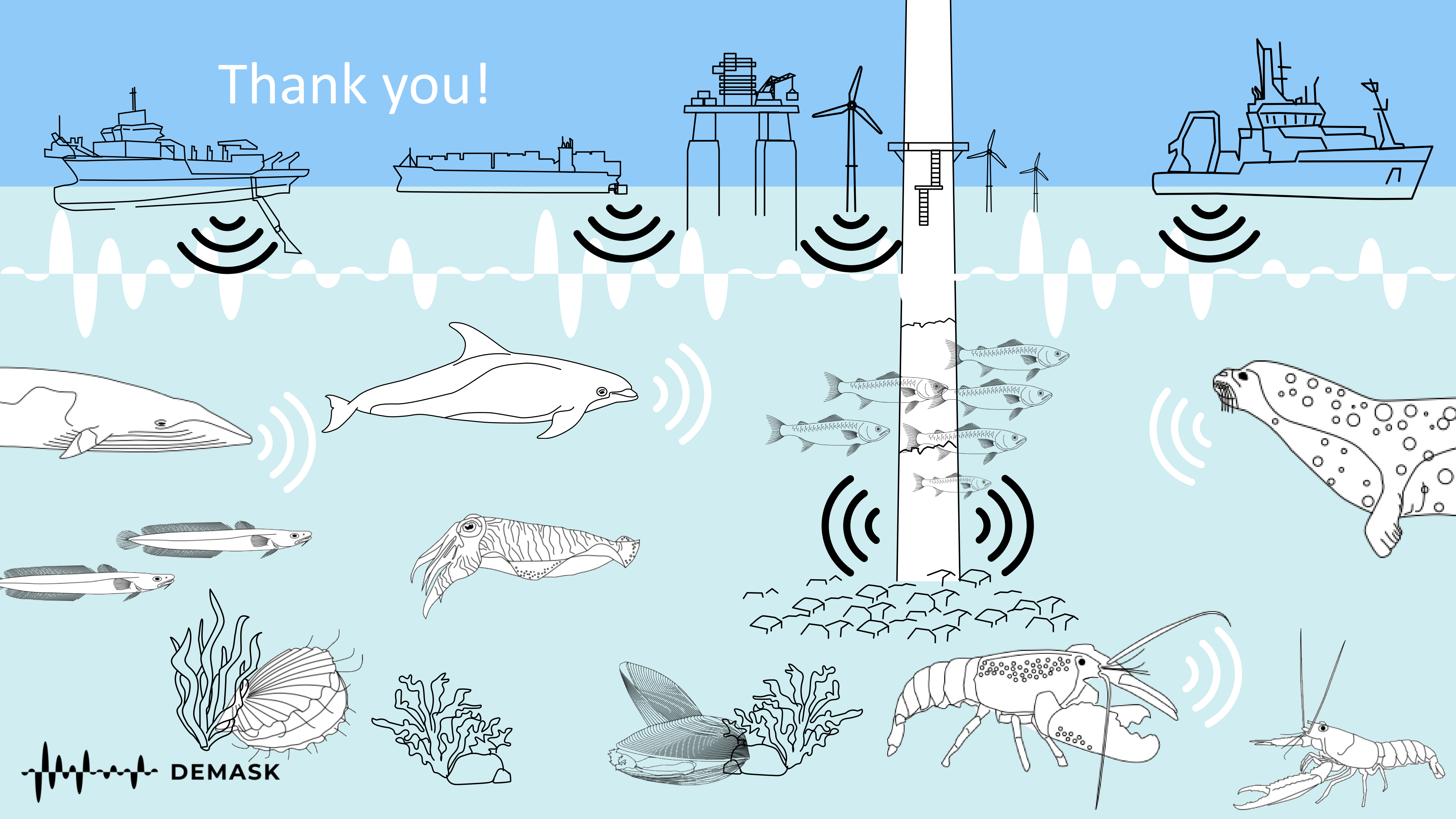
Ecosystem-based underwater noise risk assessment & management

comprehensive

holistic

DEMASK

ivl Swedish Environmental Research Institute


Thank you!
DEMASK