MARIN

BETTER SHIPS, BLUE OCEANS

Underwater radiated noise from ships: status review and related work at MARIN

Thomas Lloyd, Johan Bosschers and Frans Hendrik Lafeber

Sustainability in Ship Design (SISD) conference

Tuesday 8th November 2022

Sustainability and noise

Source: sustainableshipping.org

Sustainability and noise

- Environmental Performance Indicators

AQUATIC INVASIVE SPECIES

GREENHOUSE GAS EMISSIONS

OILY DISCHARGE

POLLUTANT AIR EMISSIONS NOX

POLLUTANT AIR EMISSIONS SOX & PM

SHIP RECYCLING

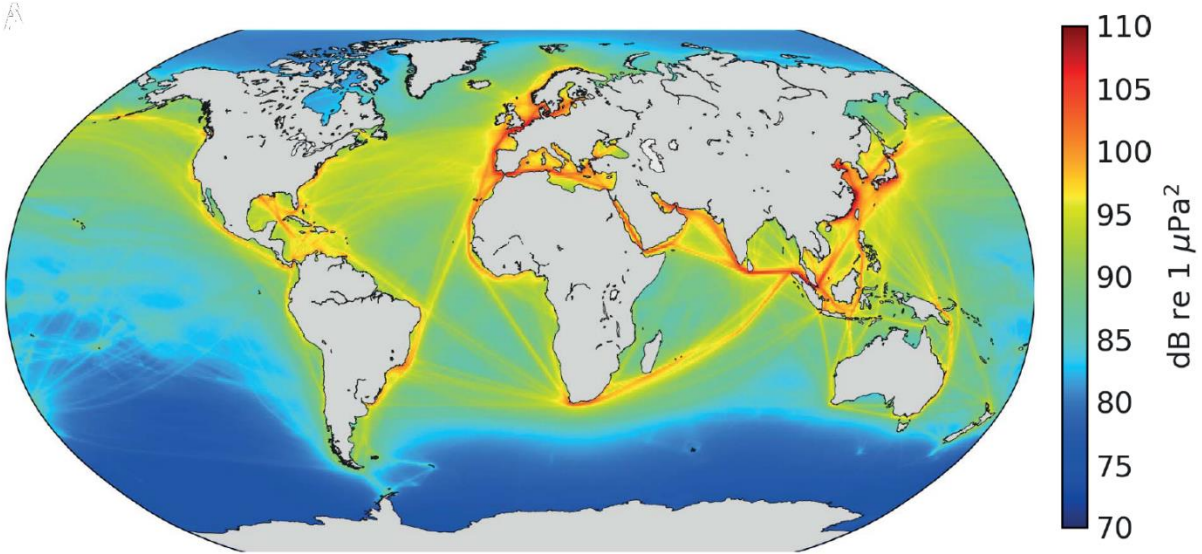
UNDERWATER NOISE

WASTE MANAGEMENT

Source: https://greenmarineeurope.org/en/

Sustainability and noise

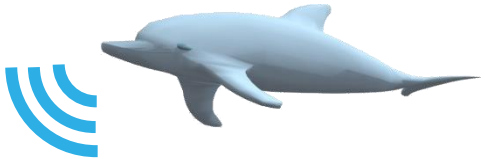
- Shipping recognised as one of the main contributors to anthropogenic underwater radiated noise (URN)



Average sound level due to shipping in 2014 at 100 Hz. Source: Duarte et al. (2021).

Sustainability and noise

- Increasing evidence of environmental impact on numerous marine species
- **Key difference compared to other pollutants**: noise reduction leads to immediate lowering of impact
- Currently there is no international mandatory regulation relating to URN of ships
- Numerous projects and initiatives ongoing at different levels



Talk outline

- State of play concerning underwater radiated (URN) noise of ships

- Overview of *SOUNDS* project (2021):
  - Noise sources
  - Environmental impact
  - Policy
  - Mitigation

- Other recent related projects and activities at MARIN

SOUNDS project

- Study initiated by European Maritime Safety Agency (EMSA)
- Work performed in 2021 together with WavEC (Portugal)
- Literature review and stakeholder questionnaire and interviews
- Publicly available to download: https://www.emsa.europa.eu/newsroom/latest-news/item/4569-sounds.html

SOUNDS project

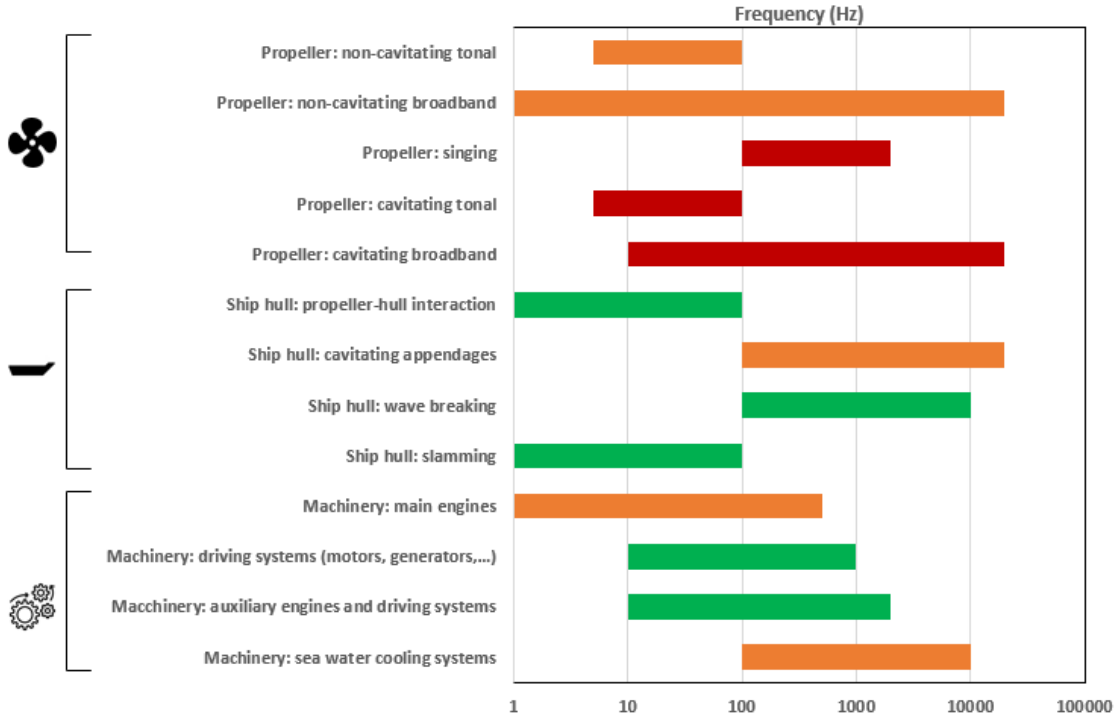
- Study divided into four main subject areas

Noise sources	Impacts	Policy	Mitigation
• Types of noise sources • Noise measurements • Noise modelling	• Different species • Relevant frequency ranges • Cumulative impacts	• Multiparty agreements • Regional and international • Certifications	• Technical measures • Operational measures • Management tools

- The first three areas inform appropriate mitigation.
- Main aim: to deliver recommendations to European Union

Ship noise sources

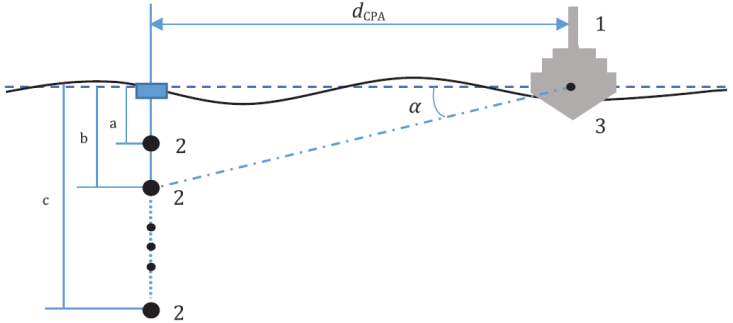
- Broadband propeller cavitation dominates at most frequencies
- Main engine noise is important at the low frequencies



Contribution of noise sources to continuous URN from ships. Source: Cruz et al. (2021).

Ship noise measurements

- Types of measurement:
  - Dedicated e.g. sea trials
  - Opportunistic e.g. monitoring
- Also important for development and validation of noise models
- Alternatives include on-board sensors and even drones!



Hydrophone array layout for ship noise measurements. Source: ISO 17208-2

Ship noise measurements

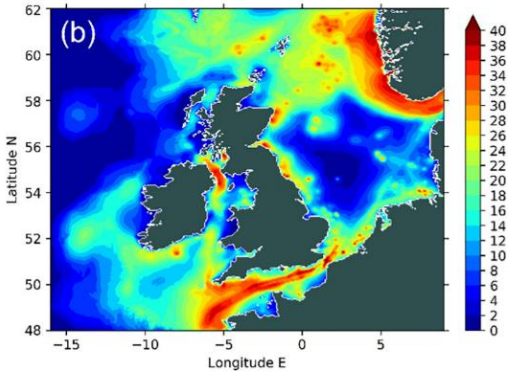
- Main standard is currently ISO 17208-2, which applies to deep water conditions
- Development of a standard for shallow water is ongoing

- Other procedures have been published by classification societies and ITTC

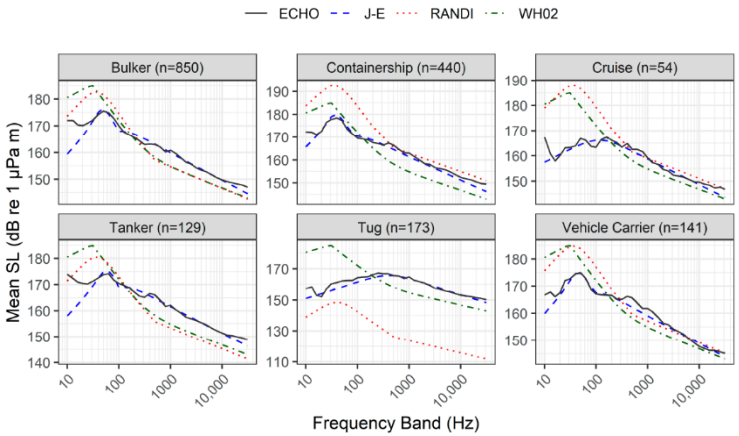
- Differences in procedures leads to high uncertainty, which has resulted in proposals for harmonisation (Ainslie et al., 2022)

Ship noise source models

- Simplified point source models
- Used to:
  - generate sound maps for marine spatial planning
  - assess noise performance in concept desig phase
- Make use of limited number of input parameters (speed, size,…)

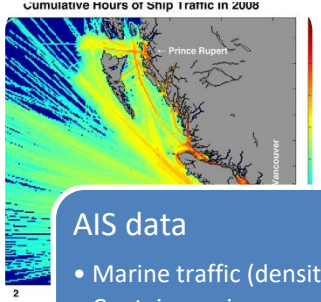


Example sound map. Source: Farcas et al., 2020



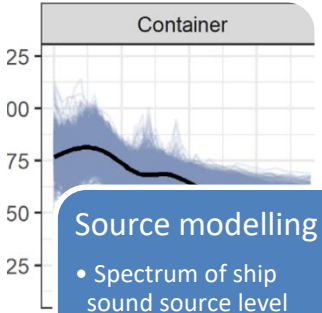
ECHO-JOMOPANS source model. Source: MacGillivray and de Jong, 2021

Sound mapping: process overview



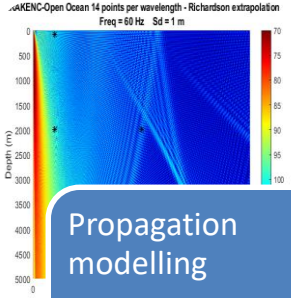
AIS data

- Marine traffic (density)
- Contains main parameters used by simple source models



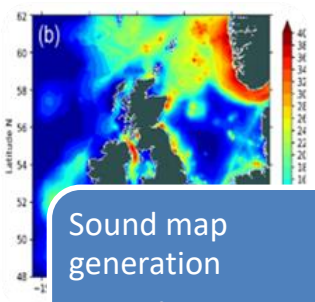
Source modelling

- Spectrum of ship sound source level
- Simple to apply, but accuracy may be limited



Propagation modelling

- Effect of environment on sound radiation
- Large number of source-receiver combinations!

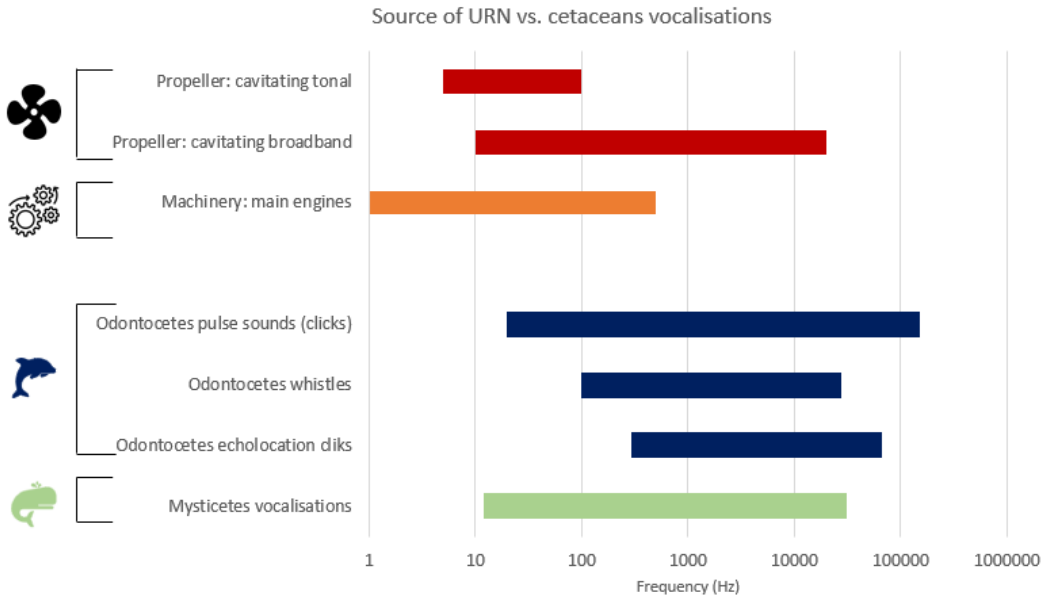


Sound map generation

- Noise footprint => total sound field
- Statistics can be determined

Environmental impact

- Different species:
  - Marine mammals
  - Fish
  - Invertebrates
- Types of impact:
  - Behavioural
  - Masking
  - Hearing loss



Overlap in frequency ranges of ship noise sources and cetaceans. Source: Cruz et al., 2021.

Environmental impact

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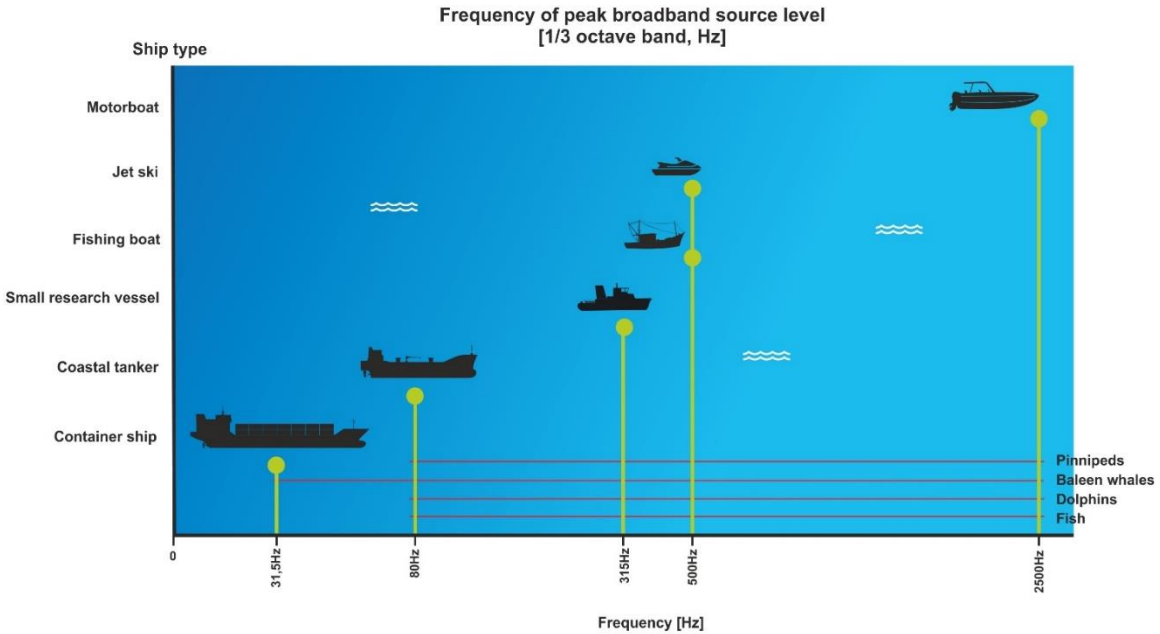


Overlap in frequency of peak noise from different vessel types and hearing ranges of several species. Source: Cruz et al., 2021.

Policy

- Multiparty agreements
- Working groups

CMS

Convention on Biological Diversity

HELCOM

OSPAR COMMISSION

IMO INTERNATIONAL MARITIME ORGANIZATION

Working groups	
ASCOBANS	Working Group on the Assessment of Acoustics Disturbance
European Commission	TG-Noise working group
HELCOM	HELCOM EN-Noise working group
ICES	Working Group on Shipping Impacts in the Marine Environment
IMO	Sub-Committee on Ship Design and Construction

Policy: European Union

- The EU Marine Strategy Framework Directive (MSFD) is the only binding agreement

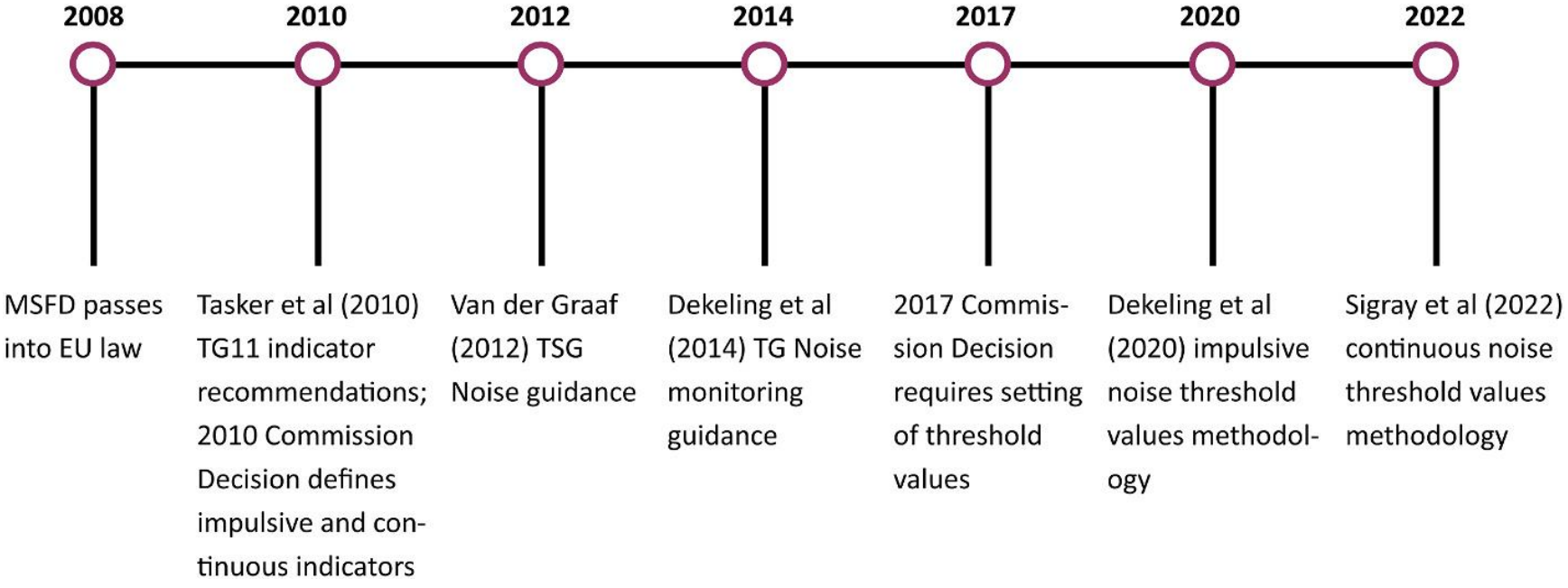
Descriptor 11

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

- Frequencies of interest are 63 and 125 Hz
- Focus on monitoring of ambient noise
- Achieved through combination of measurement and modelling (e.g. JOMOPANS and JONAS projects)

Policy: European Union

- Currently working towards setting threshold values



MSFD Descriptor 11 timeline and technical guidance published by scientific advisory groups. Source: Merchant et al. (2022)

Policy: European Union

- European Green Deal (2020)
- Noise not mentioned explicitly
- “A zero pollution Europe”
- “Sustainable Transport”

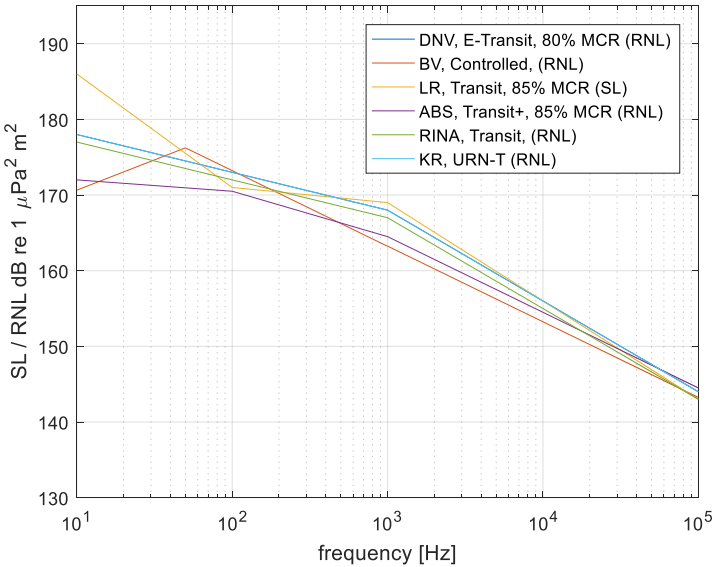
The European Green Deal objectives. Source: https://www.weforum.org/agenda/2020/05/the-european-green-deal-must-be-at-the-heart-of-the-covid-19-recovery/

Policy: International Maritime Organisation

- First guidelines published in 2014: MEPC.1/Circ.833
- Recommendations for noise reduction of commercial ships
- Currently being revised and extended: initiative from Canada
- New version to be discussed at Ship Design Committee SDC 9 meeting (January 2023)
- GHG emissions have received more attention so far.

Policy: classification societies

- Seven class societies have published noise limits
- “Transit” and “Quiet” conditions
- Calls for alignment of definitions
- And distinction between ship types, sizes and speeds (Ainslie et al., 2020)



Example classification society limits for “transit” condition

Policy: classification societies

- Most vessels to obtain notation are cruise vessels; the first being *Celebrity Eclipse*.

https://www.portvancouver.com/wp-content/uploads/2017/03/Cruise-Update-Issue-2017-Silence-is-golden.pdf

- *ONEX Peace* was the first cargo vessel, in 2021.

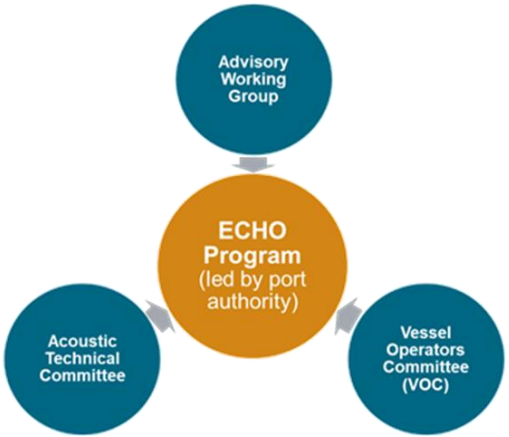
https://www.dnv.com/news/dnv-awards-first-merchant-vessel-silent-e-notation-200156

Policy: voluntary certification

- Means of demonstrating environmental credentials
- Can be used to comply with incentive schemes e.g. port dues discounts (ECHO Program)
- Green Marine is only organisation to include noise in such a scheme
- Active in North America and Europe (since 2019)

The ECHO Program

- Resulting from national legislation for protecting killer whales
- To date the largest and most successful such initiative
- Voluntary slowdown trial: ~ 3dB reduction in 2020.
- Incentives



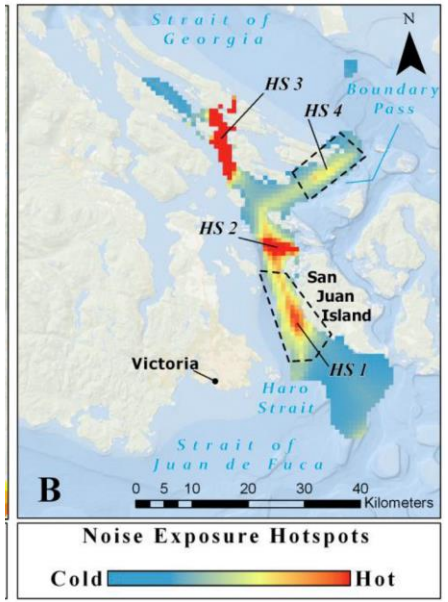
Level	Discount (%)	Criteria	Examples
Gold	47	Quiet Class notation	ABS, BV, DNVGL Silent Class, LR, RINA
Silver	35	Voluntary certification	Green marine
Bronze	23	Cavitation-reducing technologies	Pre-swirl stator, Wake equalising duct, Propeller boss cap fins, Twisted rudder

ECHO PROGRAM

PORT of vancouver | Vancouver Fraser Port Authority

Mitigation measures

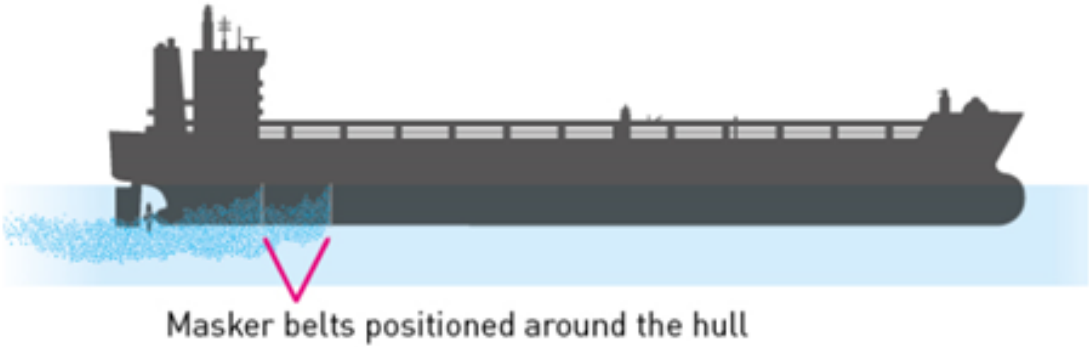
- Appropriate solution(s) depend on species present, vessel type(s), etc.
- Decision support tools are not widely available.
- Trade-off with GHG emissions also needs to be considered!
- Split into technical and operational measures.



Example result from geovisualisation tool. Source: Cominelli et al., 2021.

Technical mitigation measures

- Propeller design
- Hull design (wake field improvement)
- Isolation of machinery
- Air injection

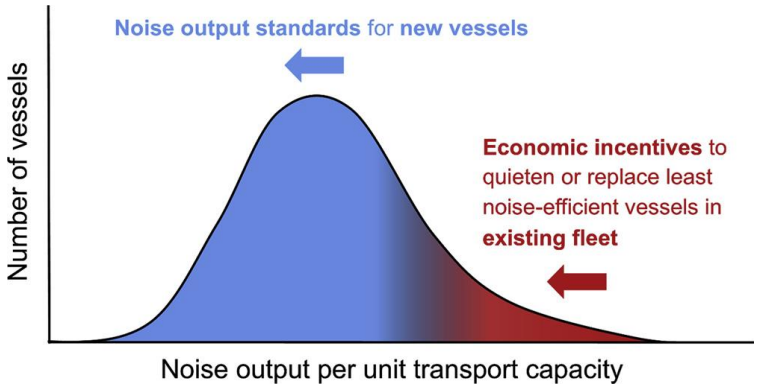


Schematic of "Masker" system designed to reduce machinery noise.

Operational mitigation measures

- Owner/operator:
  - Real-time monitoring[1]
  - Maintenance (hull and propeller cleaning)
- Authorities:
  - Marine spatial planning
  - Speed limits
  - Incentives
  - Noise labels

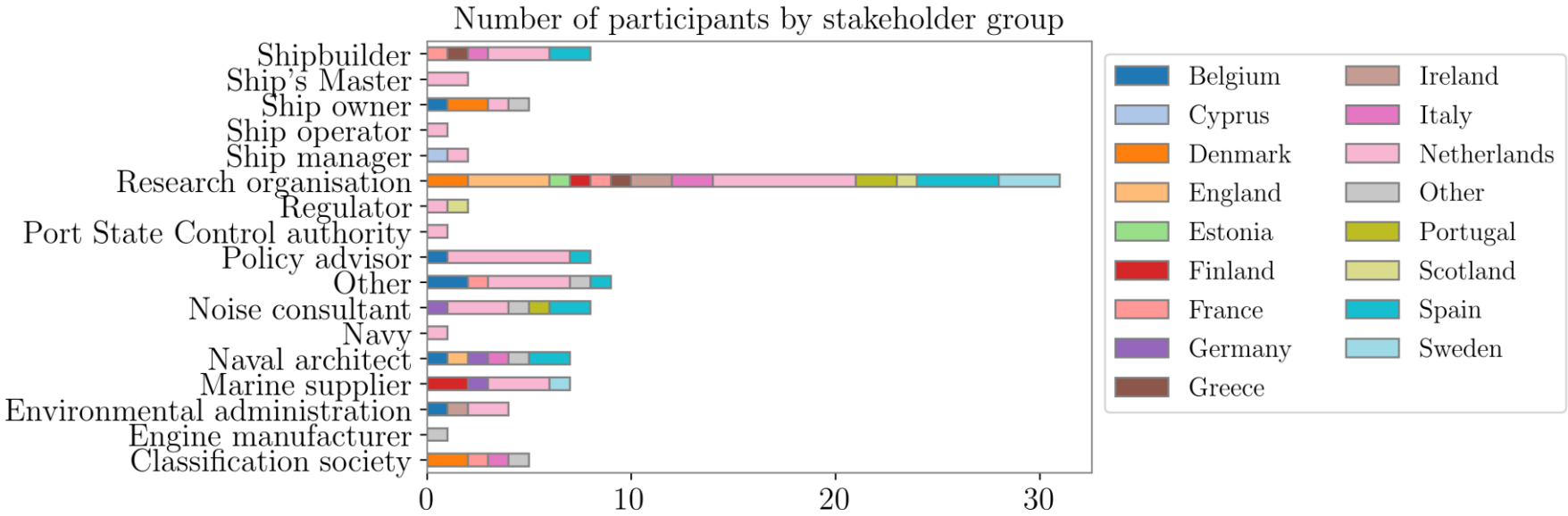
1: being addressed in the LIFE-PIAQUO project: http://lifepiaquo-urn.eu/en/home/



Possible ship noise abatement strategy. Source: Merchant (2019).

Stakeholder engagement: survey

- 100 participants representing a wide range of stakeholder groups and geographical distribution.

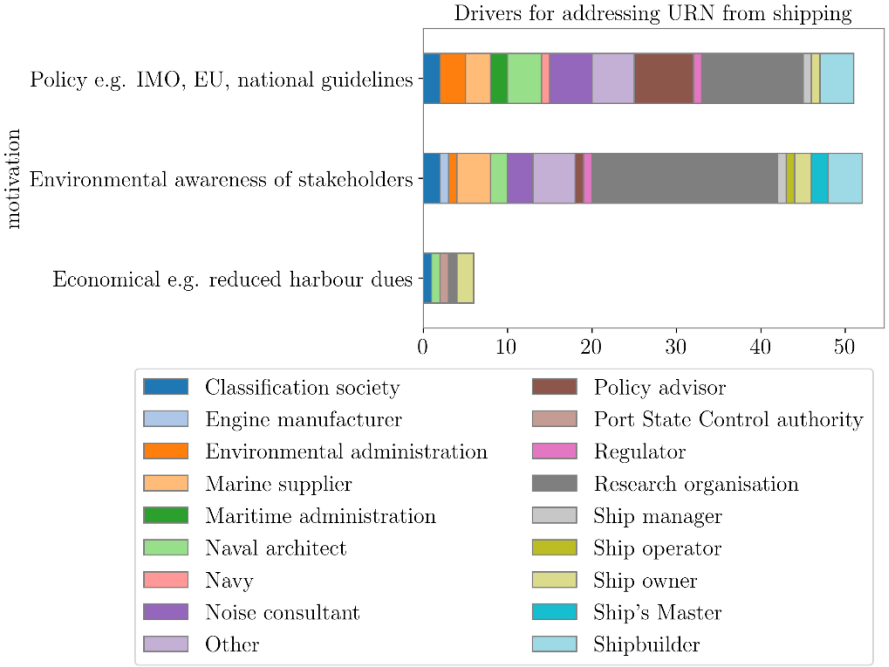


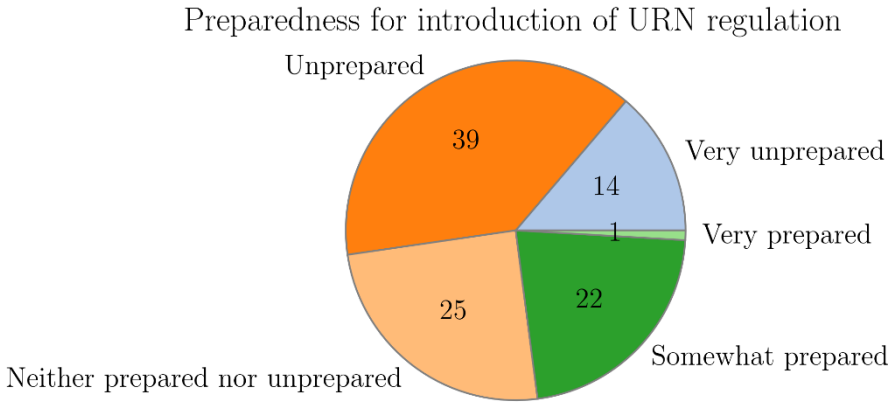
Stakeholder engagement: survey

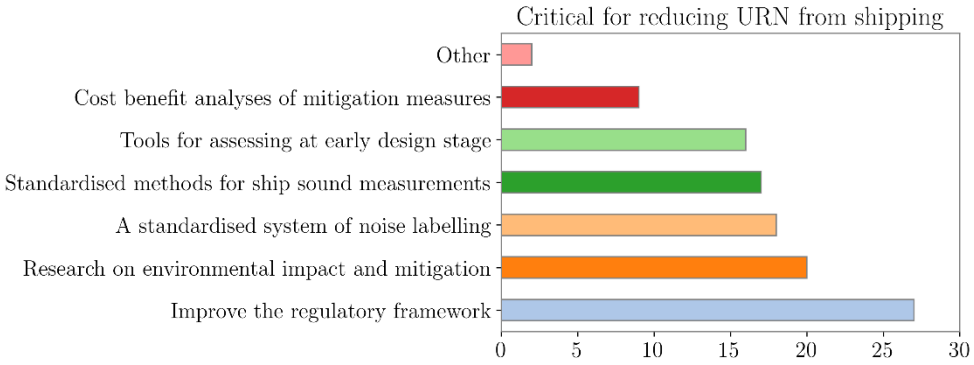
- 100 participants representing a wide range of stakeholder groups and geographical distribution.

- Questions focused on:
  - Understanding relationships between stakeholders
  - Gauging perceptions of possible mitigation measures
  - Assessing readiness and needs for the future

Stakeholder engagement: survey



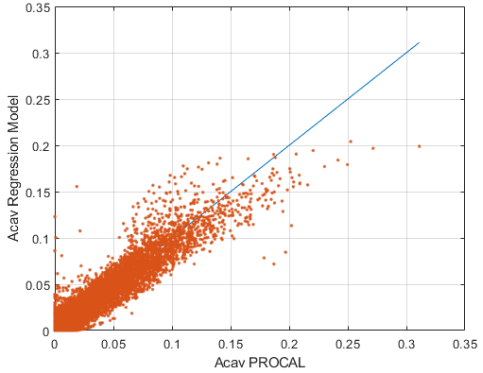




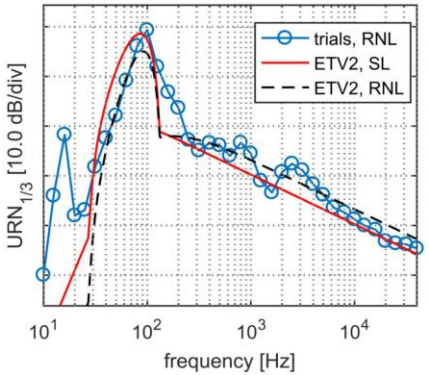
Key recommendations

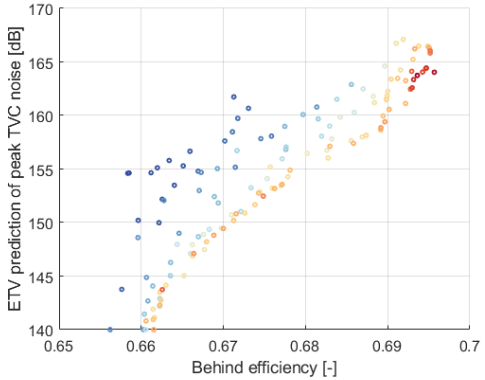
- Increase standardisation of procedures and terminology
- Development of measurement standards for shallow water
- Improve modelling techniques for management tools
- Definition of thresholds for environmental impact
- Expand class society notations leading to “achievable” limits
- Increase stakeholder engagement for effective mitigation
- Develop a quiet ship demonstrator using ambitious reduction targets
- Learn from the experiences of developing GHG regulations
- **Some of the above are already being addressed in ongoing work!**

Noise-related work at MARIN

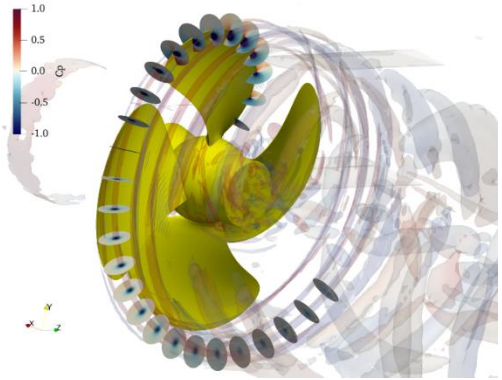


Simplified regression models for early design stage estimations.





Semi-empirical models for detailed design predictions and propeller optimisation.

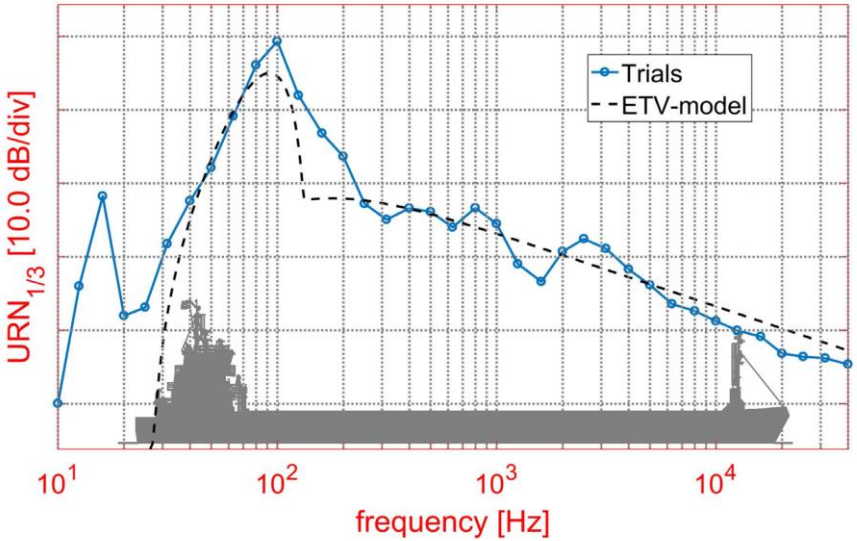


High-fidelity CFD computations for broadband noise prediction.

Model-scale noise measurements in Depressurised Wave Basin using silent towing carriage

Noise-related work at MARIN

- Performed through various internal and collaborative projects and initiatives, both national and international
- Cooperative Research Ships (CRS) has supported development of several numerical tools including validation data.
- https://www.crships.org/



ETV model result compared to sea trials data

Recent and ongoing work at MARIN: example EU projects

NAVAIS
New Advanced Value Added Innovative Ships

https://www.navais.eu/

- Recently-completed H2020 project on modular ship design
- MARIN led work package on low-impact design, including noise

Saturn
Developing Solutions for Underwater Radiated Noise

https://www.saturnh2020.eu/

- Ongoing H2020 project
- Main activities:
  - Standardisation
  - Biological thresholds
  - Assessment of mitigation measures -> MARIN involved.

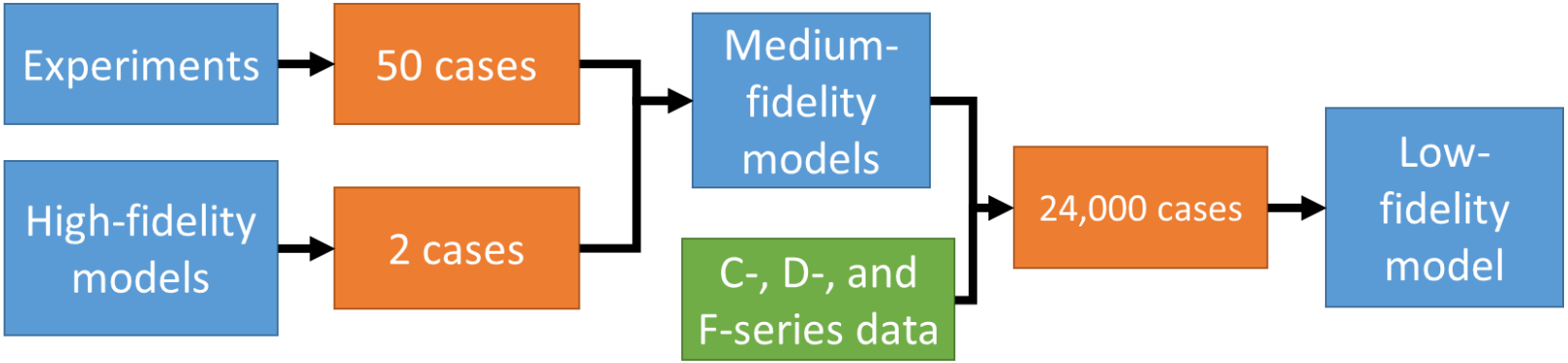
NAVAIS: Introduction

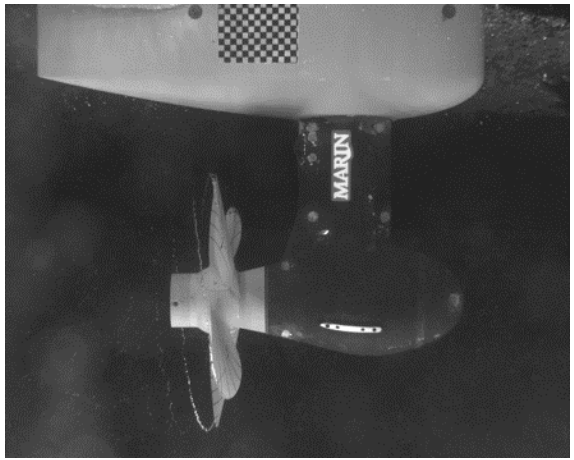
NAVAIS
New Advanced Value Added Innovative Ships

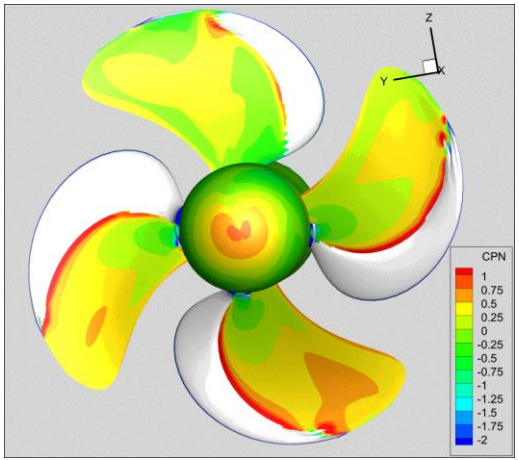
- Deceleration: pressure-side cavitation
- Dynamic Positioning: ducted propellers in bollard pull
- Goals:
  - Develop cavitation noise models for off-design conditions
  - Develop an easy-to-use model for concept design phase

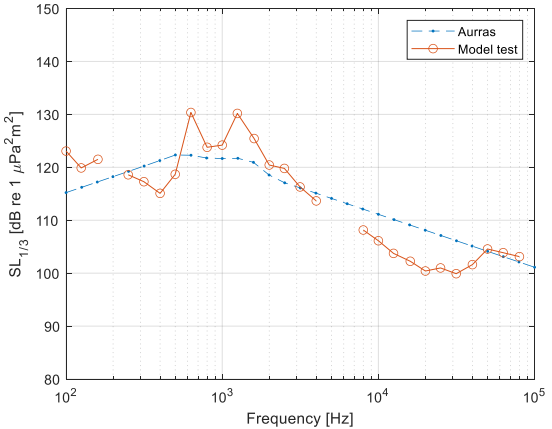
The NAVAIS project was funded by the European Union Horizon 2020 programme (Contract No.: 769419)

NAVAIS: Approach



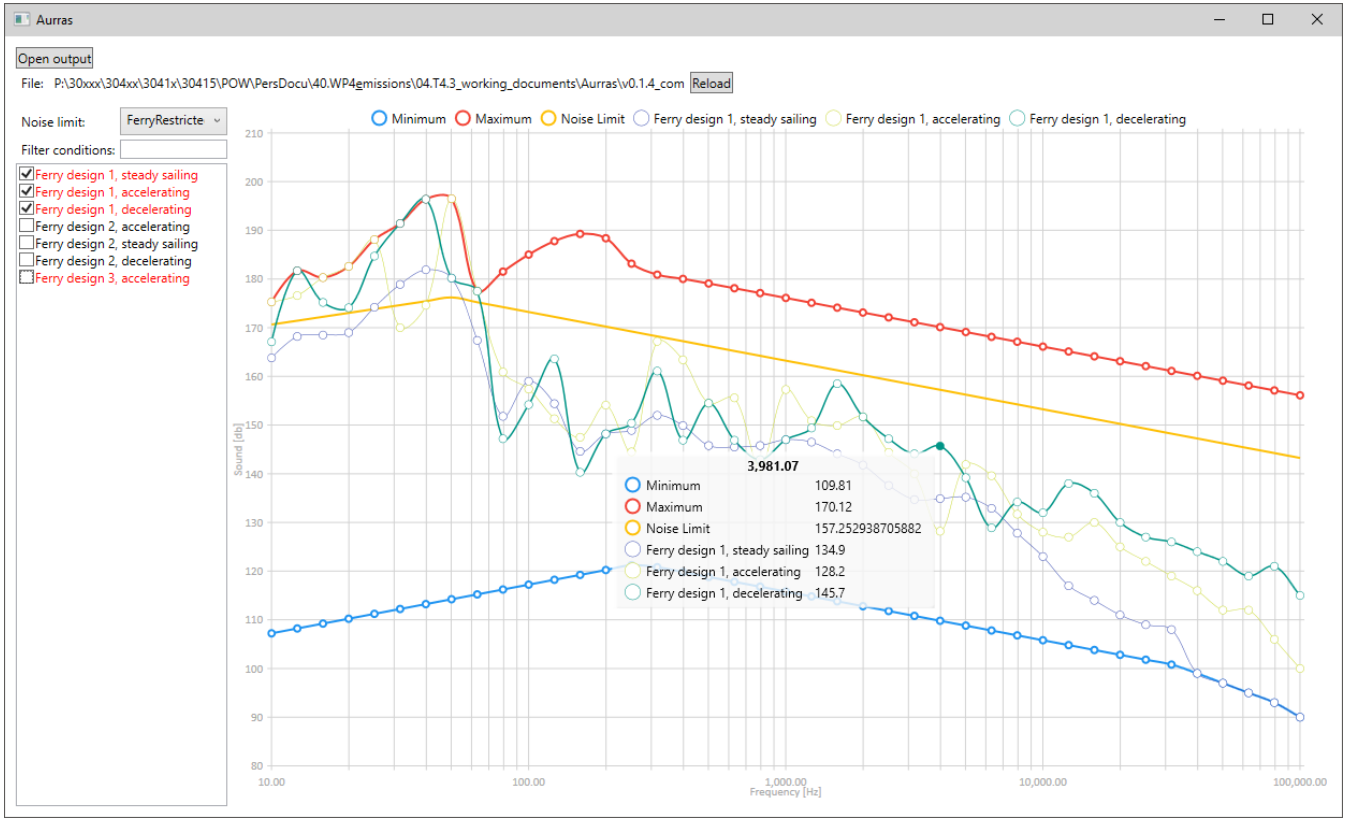






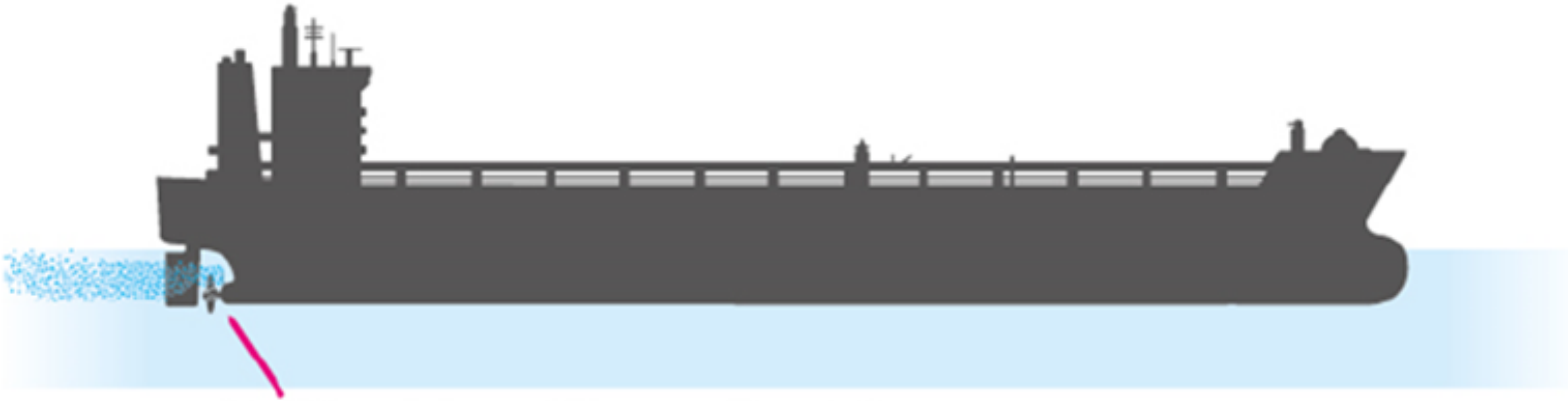
NAVAIS: AURRAS tool

- Low-fidelity model for concept design



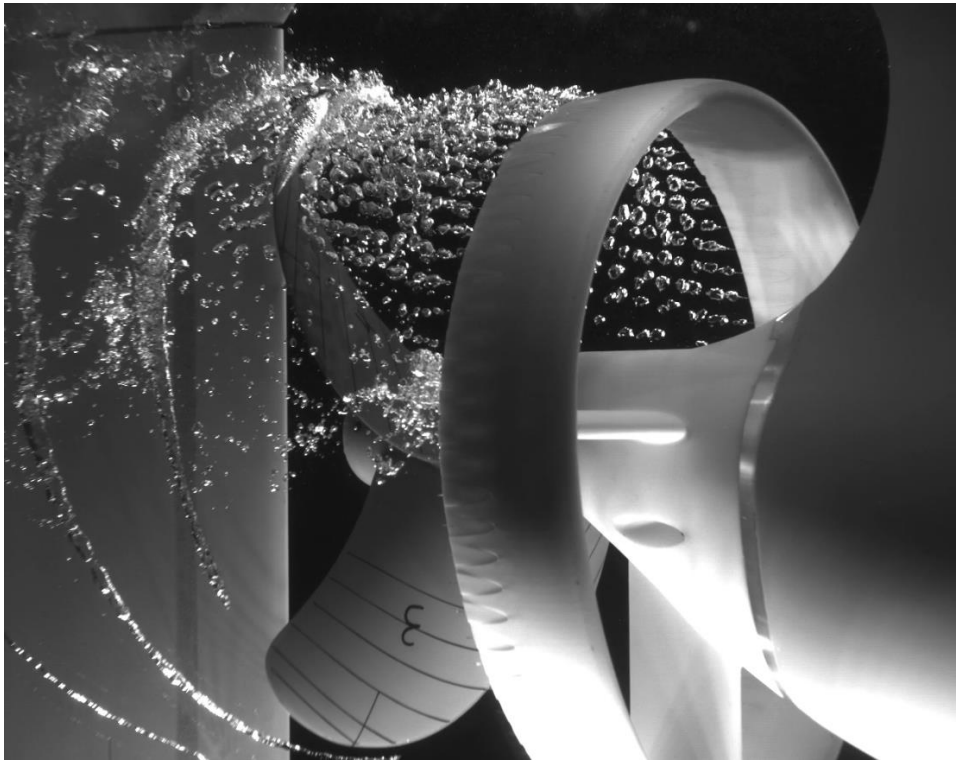
SATURN: “Prairie” system tests (preliminary results)

- Air bubbles injected into propeller disc to mitigate cavitation noise
- Air dampens cavity dynamics and noise generation
- Already applied to naval ships (injection through propeller leading edges)



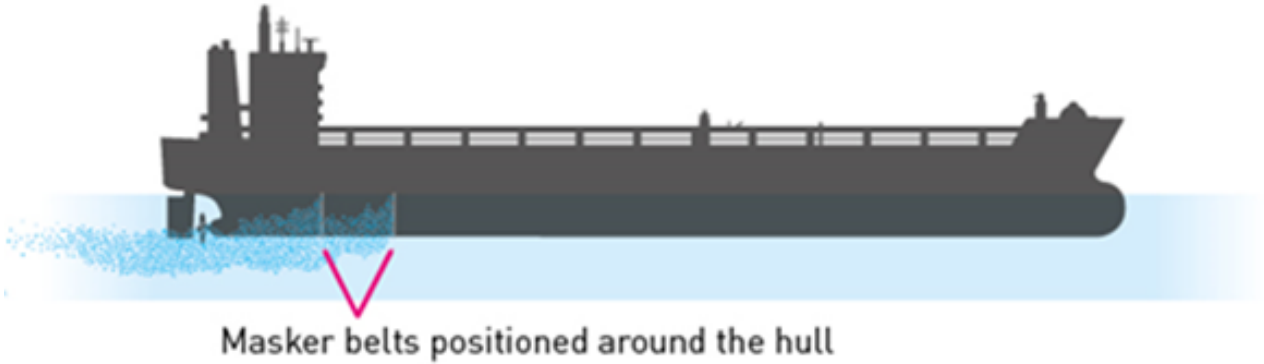
SATURN: “Prairie” system tests (preliminary results)

- Up to 7 dB noise reduction
- System effective above 4th blade passing frequency harmonic
- Noise increase at lower frequencies also found in literature



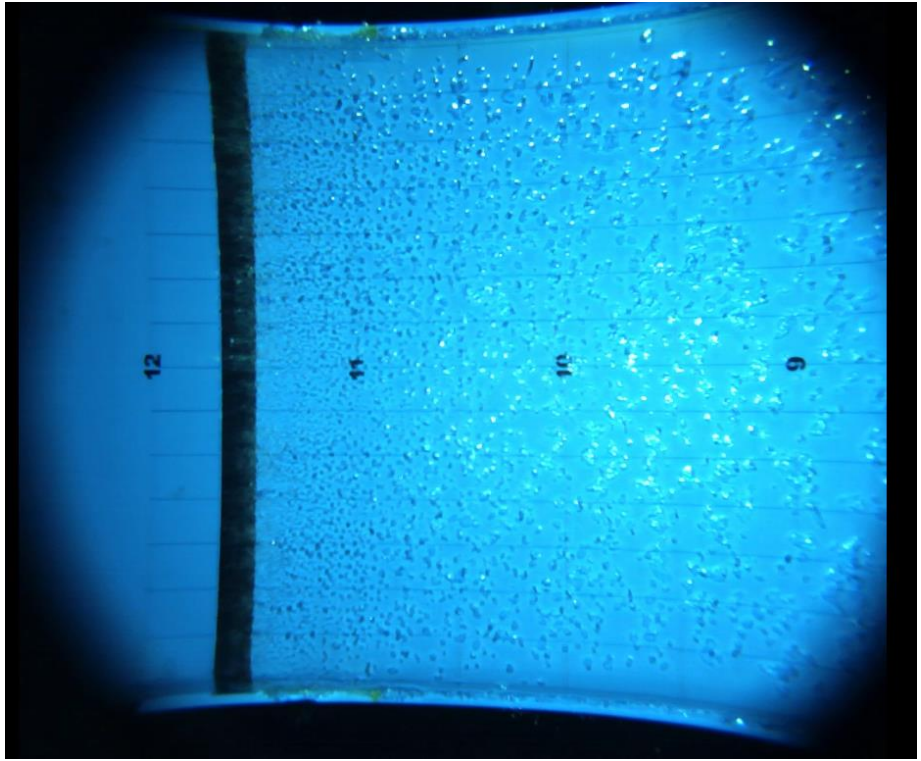
SATURN: “Masker” system tests (preliminary results)

- Air bubble layer around ship hull to mitigate machinery noise
- Measured in terms of “insertion loss”: difference in sound level with system switched on and off.
- Metal hull section excited using shaker



SATURN: “Masker” system tests (preliminary results)

- Large insertion loss measured across broad frequency range
- Up to 20 dB reduction in sound level
- The insertion loss depends on the air flow rate and ship speed.



Concluding remarks

- URN from ships is a very active field involving numerous actors!
- The current focus is on:
  - Determining thresholds for impact
  - Standardisation of measurement procedures and extension to shallow water
  - Cost-benefit analyses of mitigation measures in relation with EEDI/EEXI

- MARIN is engaged in numerous activities to support the shipping and shipbuilding industry:
  - Concept design phase for effective inclusion of noise requirements
  - Design phase verification and optimisation
  - Background research on mitigation measures

- Special thanks to Erica Cruz (blueOasis, formerly WavEC)

Sources used

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