MARIN

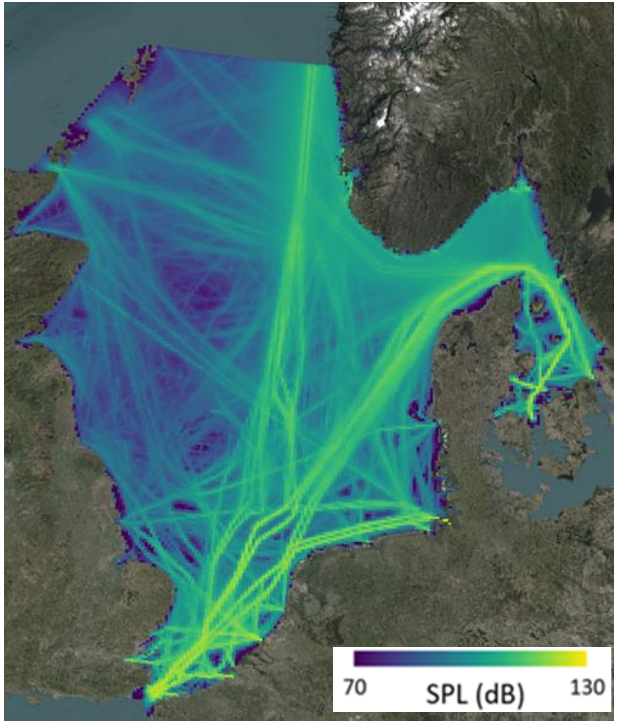
BETTER SHIPS, BLUE OCEANS

# Progress Underwater Radiated Noise studies

Johan Bosschers, Evert-Jan Foeth, Fernanda dos Santos, Marjolijn Hermans, Thomas Lloyd

# Background

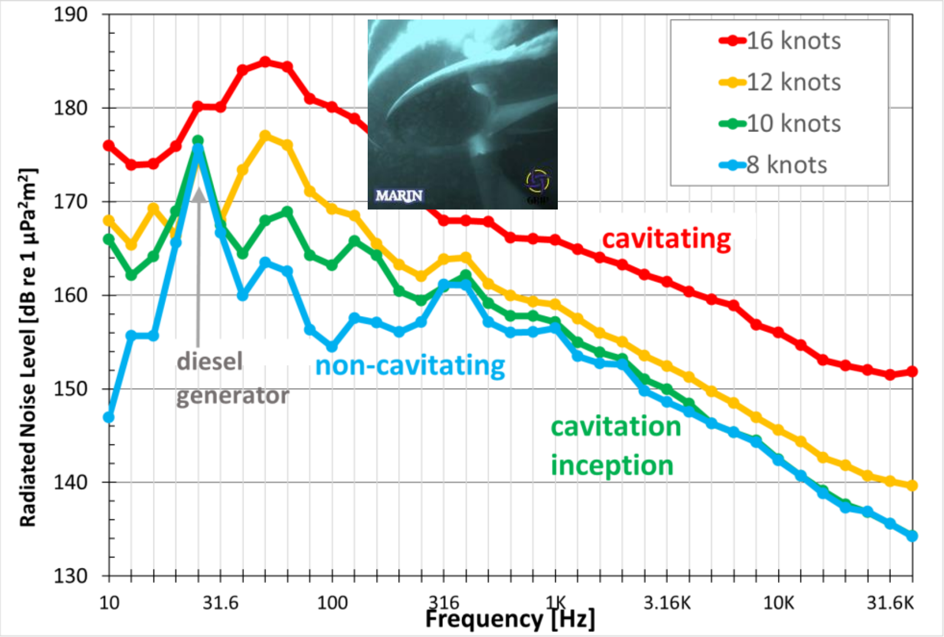
- Continuous underwater radiated noise (URN) of shipping affects marine life (masking, disturbance, …)
- Class rules for URN of single vessel exist
- Assessment methods for URN maturing, but still questions left
- Topic being addressed by IMO, currently in 'experience building phase'
  - Not clear how to apply regulation




EMSA Navison report (2024), 63 Hz

# Background: ship speed dependency

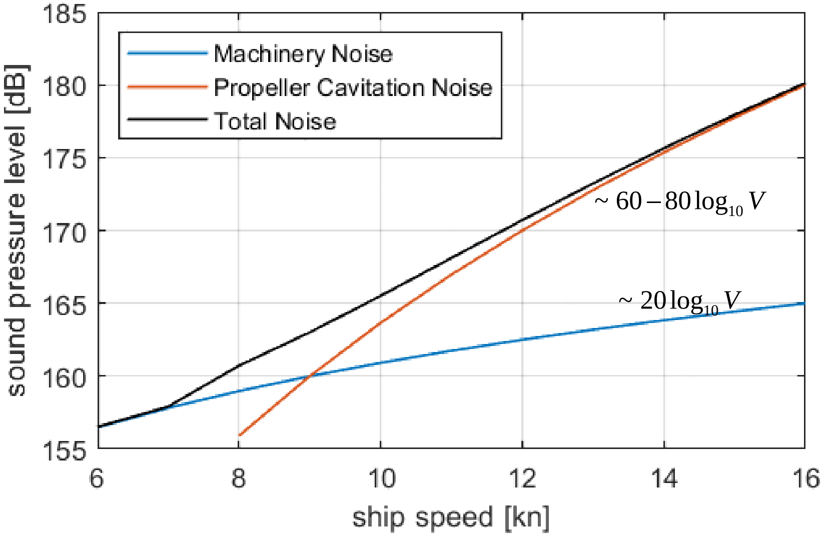
Slowing down typically reduces the radiated noise levels emitted by the ship




Data adapted from Arveson & Vendittis (2000), 173 m merchant vessel

$$L_p\left[dB, \text{re} 1\mu Pa^2 m^2\right] = 10\log_{10}\left(\frac{p_{rms}^2}{p_{ref}^2 R^2}\right)$$

$p_{rms}$ is root-mean-square pressure amplitude at certain frequency band measured at distance *R* from the ship

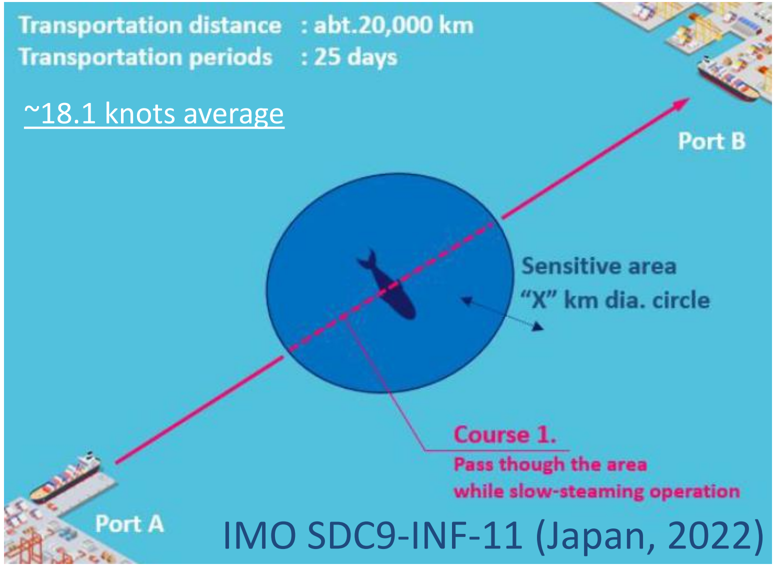



*Typical average ship speed dependency:*

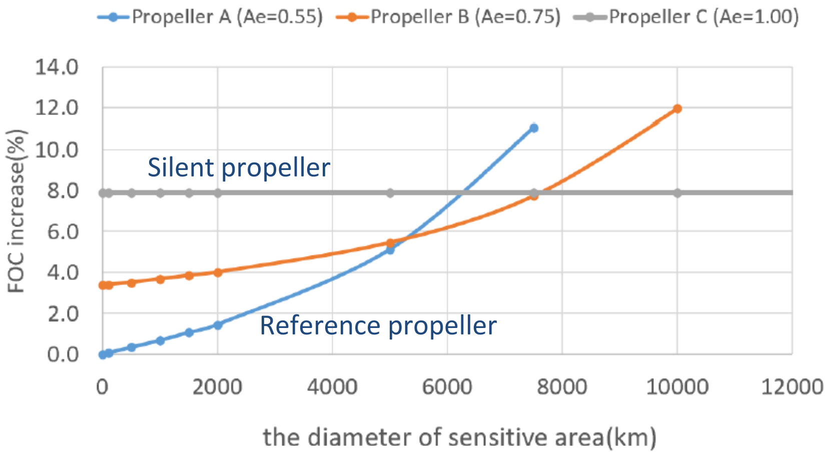
$$L_p\left[dB\right] \propto \sim 10\log_{10} V_{ship}^6 = 60\log_{10} V_{ship}$$

# Desk study #1: slowing down or a quiet propeller?

- Suppose a URN limit exists during part of the journey of a container vessel, does slowing down lead to an overall less fuel consumption than more silent propeller design? (no delay in time of arrival allowed!)




Change in Fuel Oil Consumption (FOC) vs area size

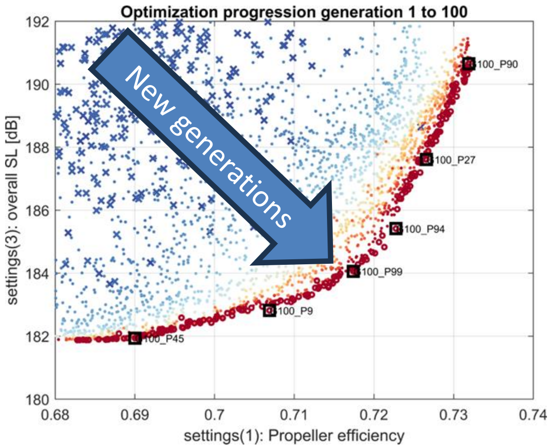



Rules of thumb used, does this also hold for 'real' propeller designs?

# Propeller design study using Propart

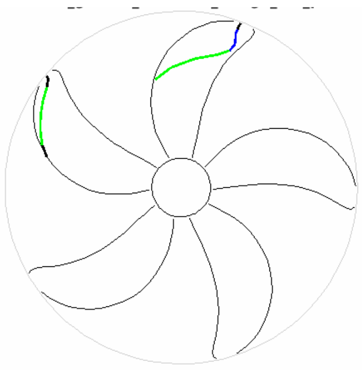
*By Evert-Jan Foeth*

- ~270 m Container ship, tested at MARIN
  - Ship geometry + ship wake available
  - Design conditions available (~9.5 m prop diameter, ship speed ~20 kn)
- Automatic propeller design tool PROPART (machine learning optimizers)
  - Automatic geometry generation
    - satisfy design criteria (thrust, rpm)
    - satisfy design constraints (strength, …)
  - Optimizes for efficiency and URN
  - Uses potential flow method PROCAL for hydrodynamic evaluation (efficiency, URN, …)

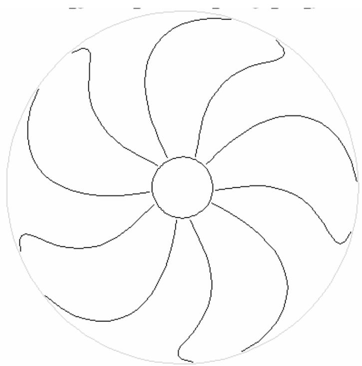



# Results of design study: URN versus efficiency

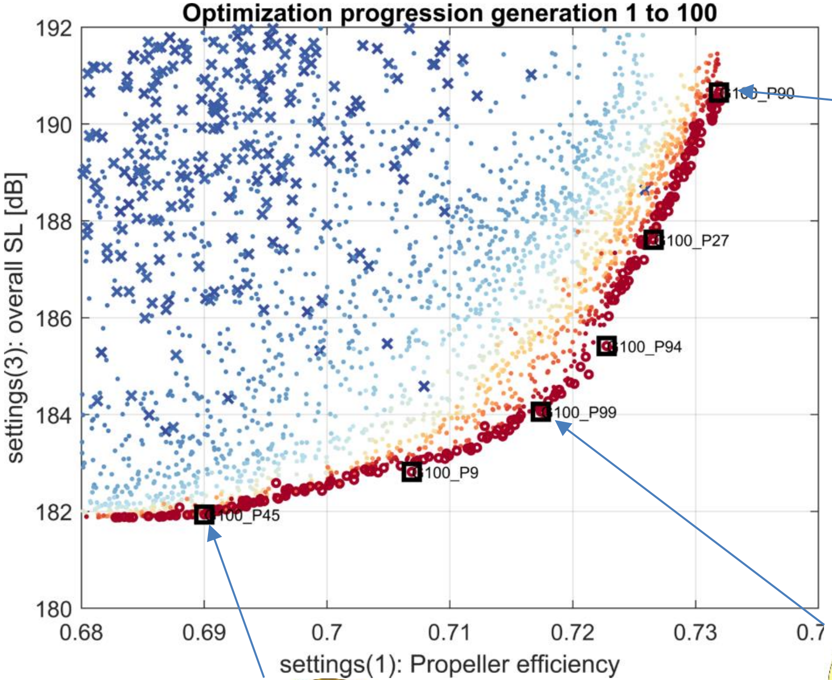
cavity extents

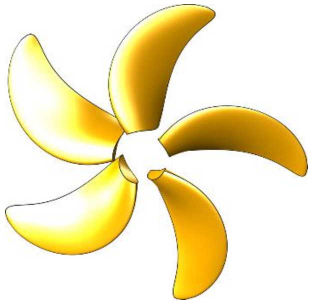


Most efficient

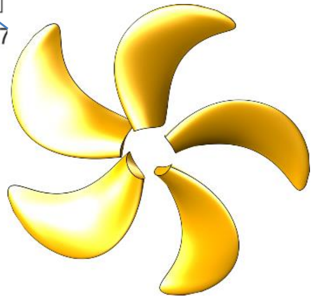


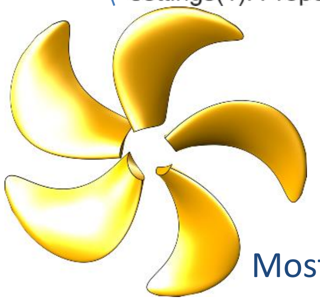
Most quiet



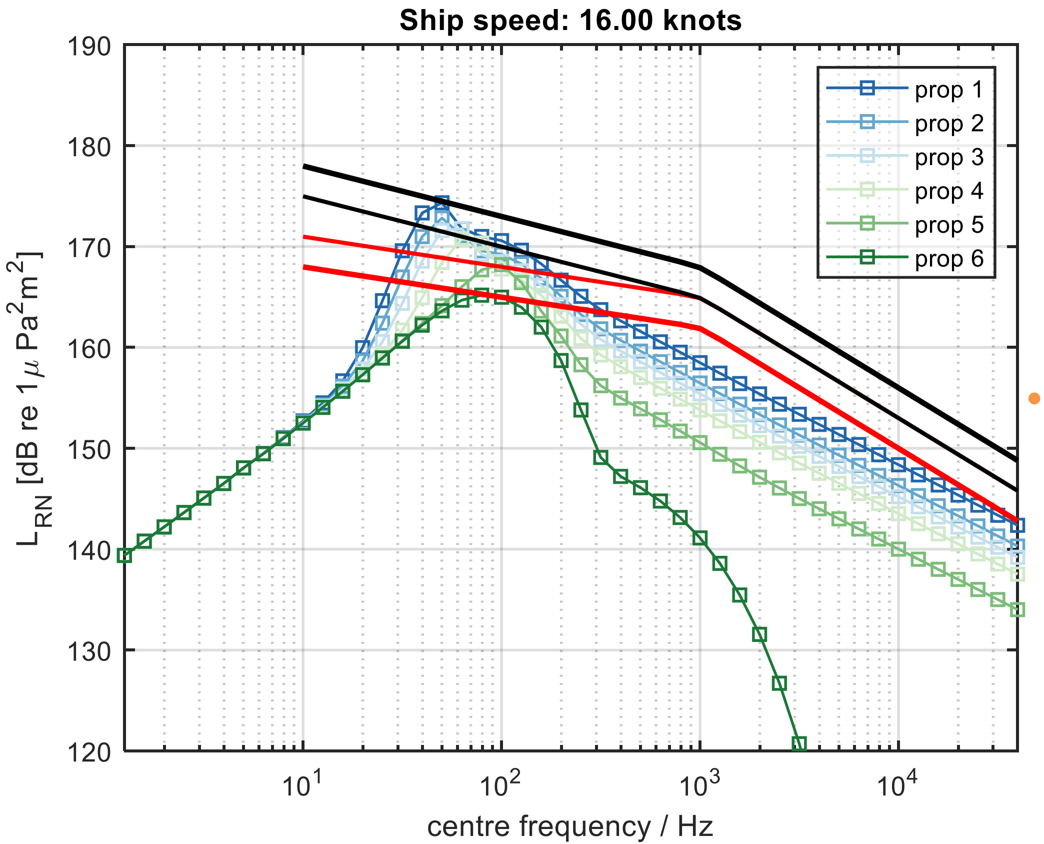
Most efficient





Most quiet

# Radiated Noise Levels for six propeller designs, reduced ship speed

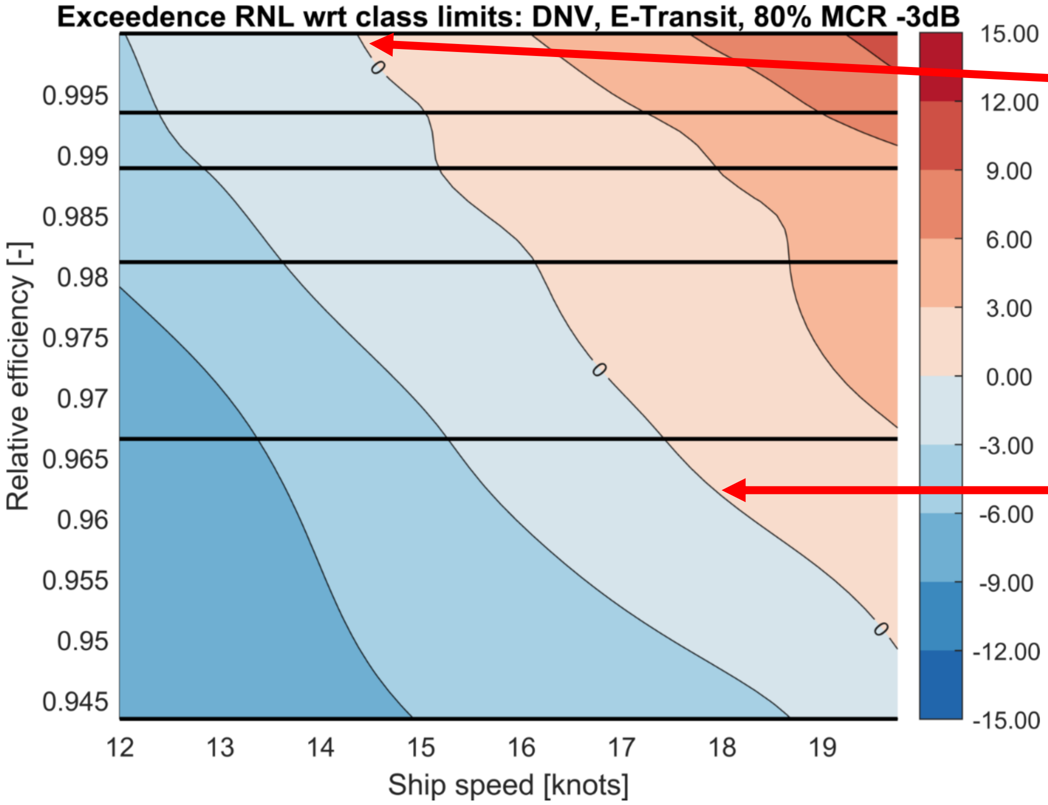



- Noise limits DNV Environmental class:
  - Transit (80% MCR= ~20 kn)
  - (Transit – 3 dB)
  - Quiet (11 kn)

# Ship speed in noise-restricted region

- Ship must meet DNV TRANSIT - 3dB

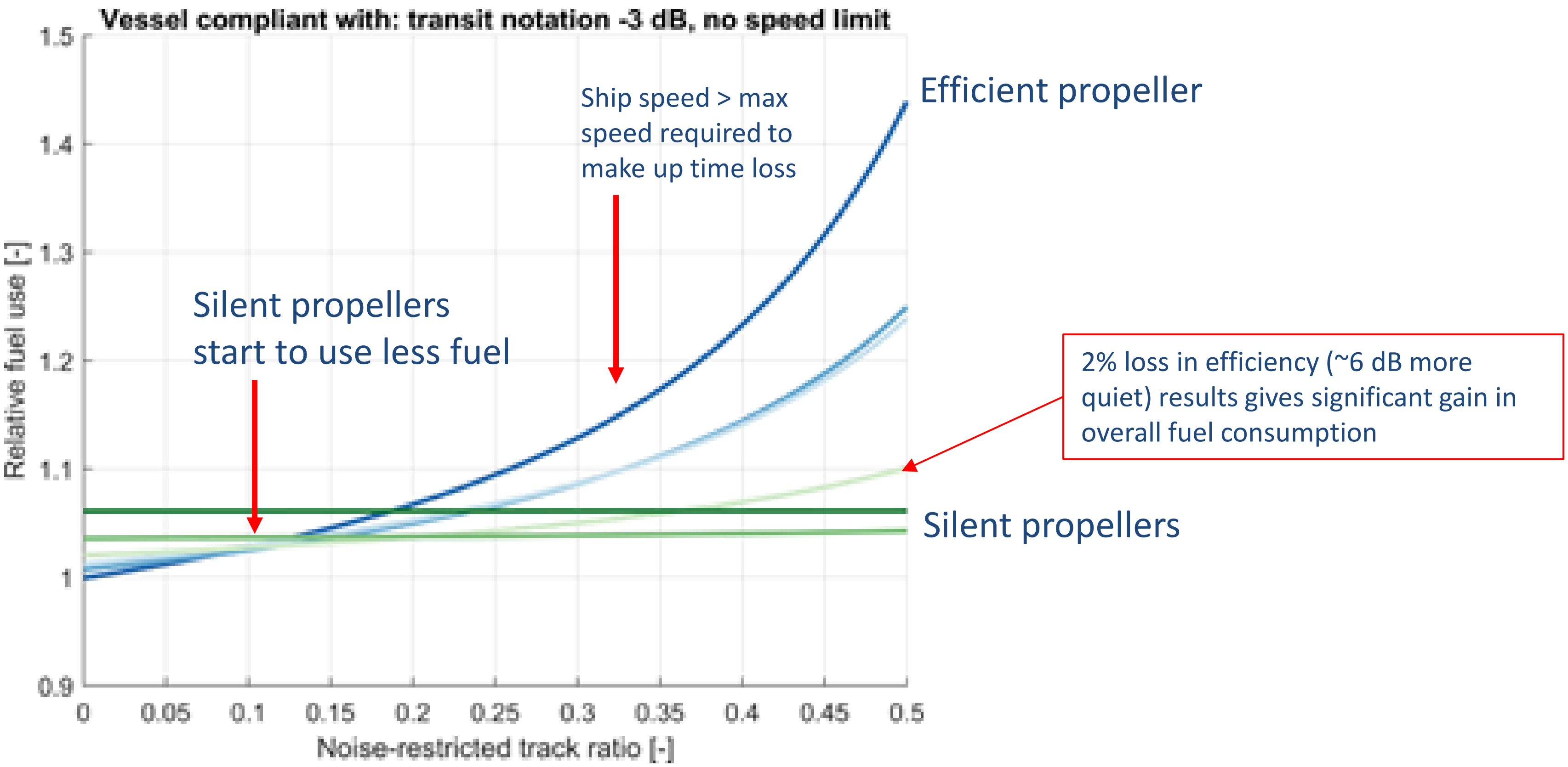
Six propeller designs, less efficient, more silent




Most efficient design must slow down to 14.5 knots

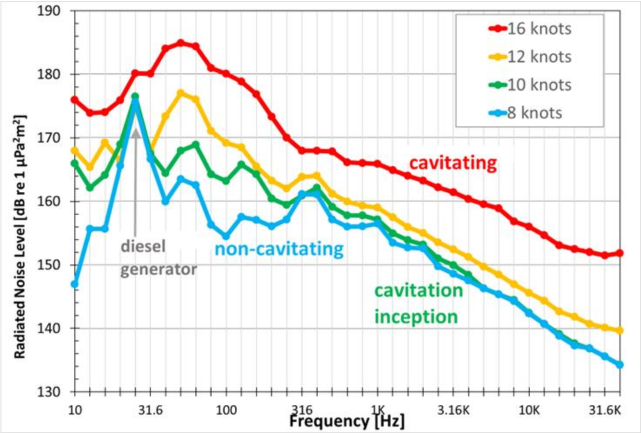
Silent design sailing at 18 kn

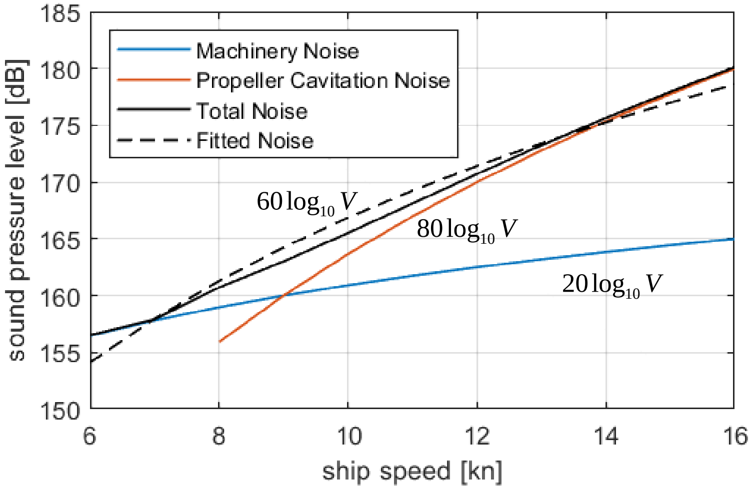
# Change in relative fuel consumption during journey



# Desk study #2: Slowing down North-Sea shipping

- All studies of impact of slow-down have used a $V^6$ ship speed dependency of URN
  - But this is a gross simplification: averaging over ship speed and frequency!
  - What is the situation if more accurate data from literature is used?

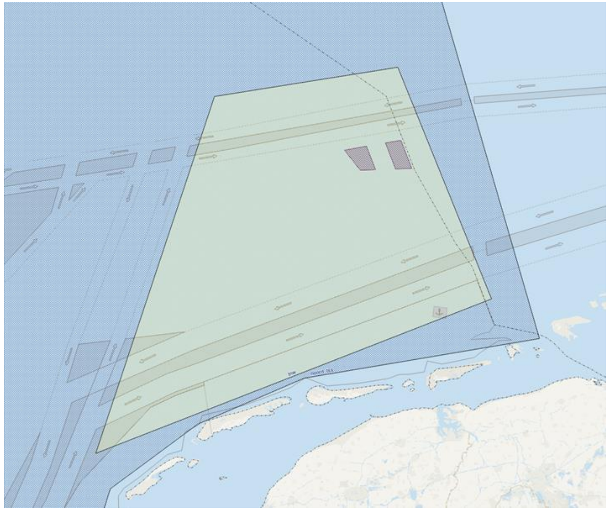


# North-Sea shipping analysis

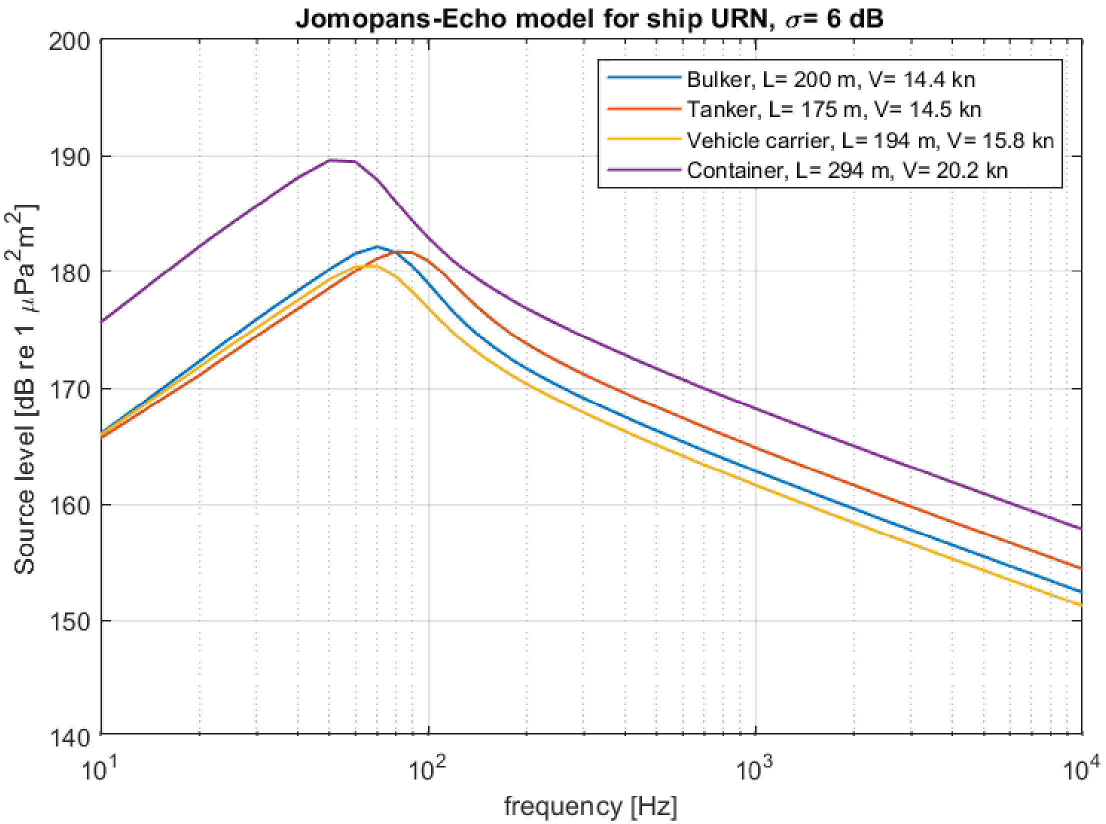
*By Fernanda dos Santos, Marjolein Hermans, et al.*

- Analyze ship speeds in North sea using AIS data
  - Ship types as used by MacGillivray et al. (2022)
    - *defined (and limited) by AIS data*
  - Filter: std dev. of speed < 10% and speed > 3 kn
  - Compare with estimated service speed (fitted curves per ship type)
  - Compare with estimated inception speed (simple empirical formulation)
- URN analysis (empirical formulations, to be done)
- Slow down analysis (still to be defined and done)
  - Consequence of speed limits on individual ship noise levels
    - e.g. Echo Slow-Down study: 11 kn for slow sailing ships, 14.5 kn for fast sailing ships
  - (Consequence of imposing URN limits on ship speed)



AIS data of year 2023 + Jan-Jun 2024

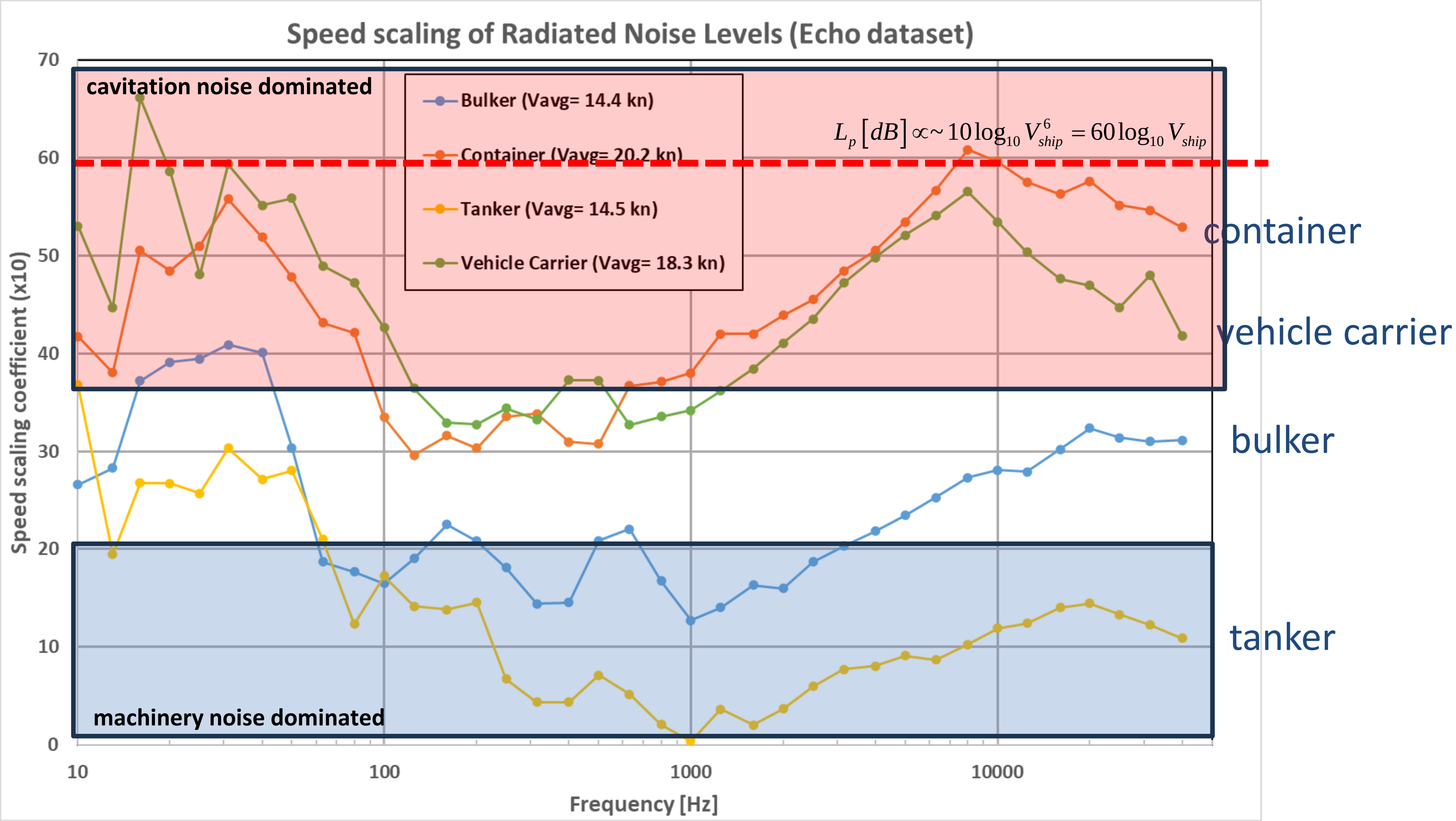
# Empirical ship source level spectra (Echo project)




- function of ship speed, ship length, (draught), …

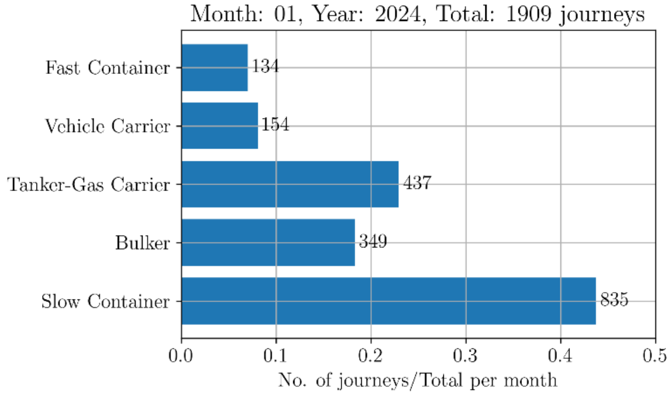
MacGillivray & de Jong (2021), MacGillivray et al. (2022)

# Speed scaling: Hannay et al. (2019), MacGillivray et al. (2022)

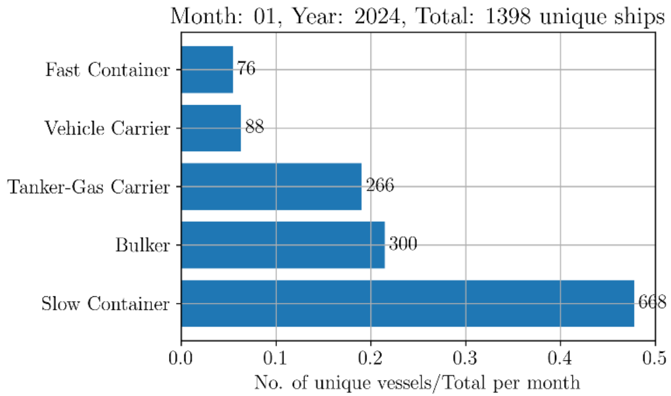


# Statistical distribution of ships (Jan. 2024)

## Number (No.) of journeys

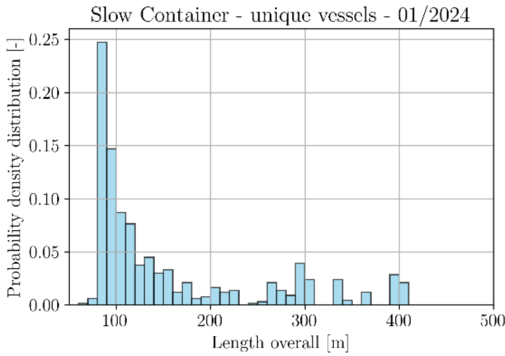


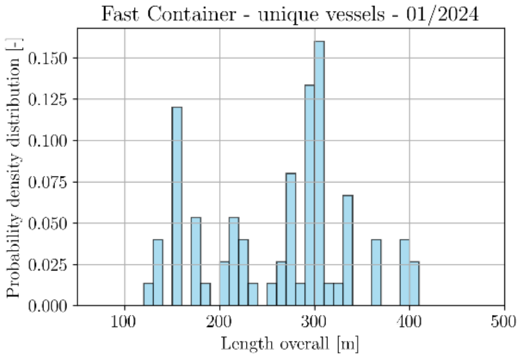

## Number (No.) of unique vessels




### Jomopans-Echo model*

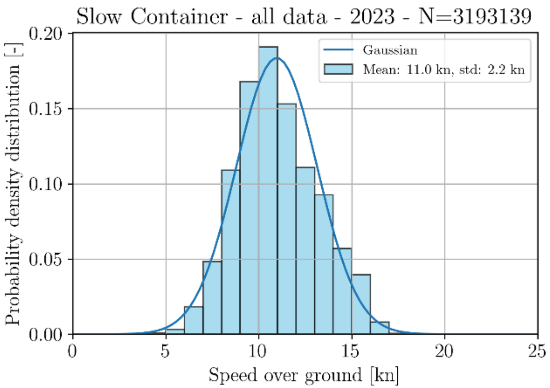
| Vessel Class | AIS SHIPTYPE ID | Lloyd's List (MMSI) |
|---|---|---|
| Container Ship | 71-74 (all speeds)<br>70, 75-79 (speed $V > 16$ kn) | Unitised |
| Bulker | 70, 75-79 (speed $V \leq 16$ kn) | Bulk; (Misc.) General Cargo |
| Tanker | 80-89 | Tank; Gas tanker |

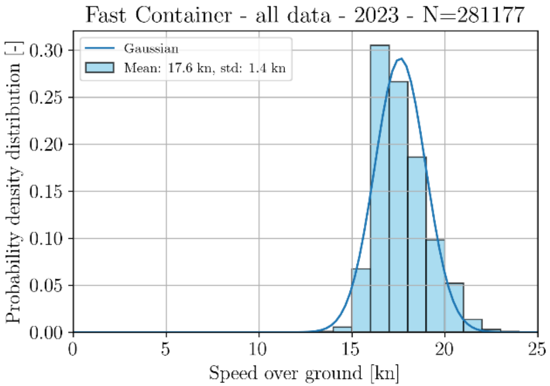


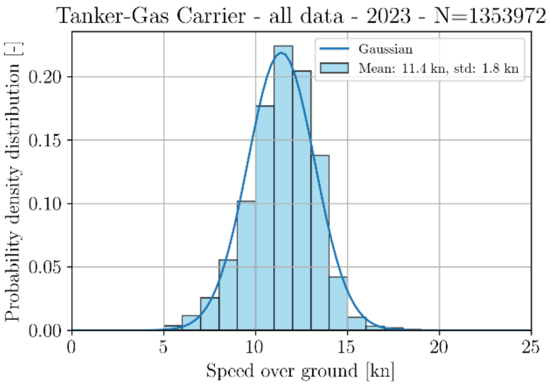



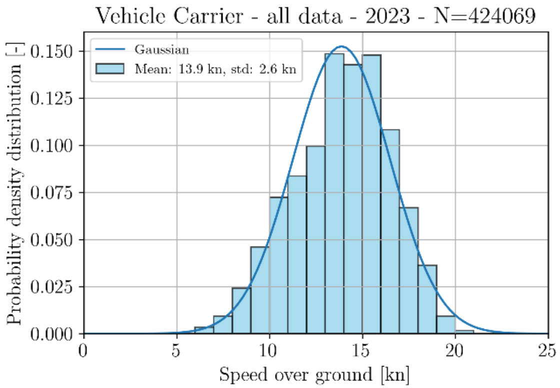

*: MacGillivray & de Jong (2021), MacGillivray et al. (2022)

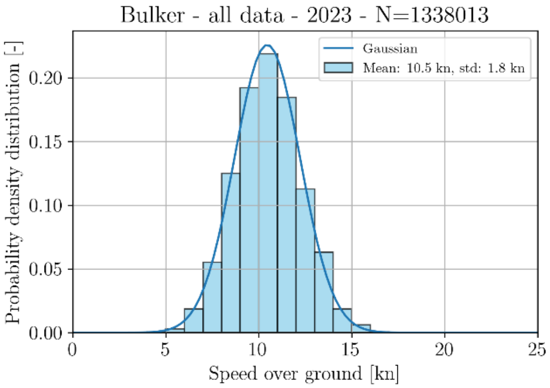
# Probability density functions of Speed over ground



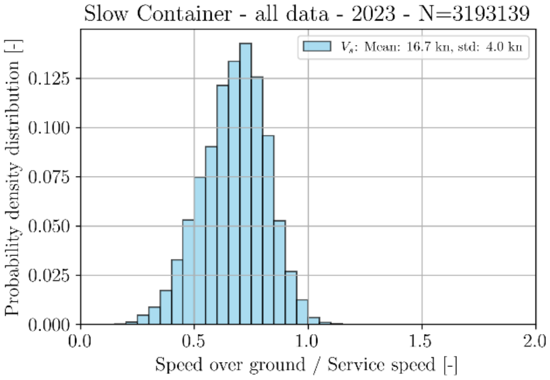




Echo Slow-Down study: 11 kn for slow sailing ships, 14.5 kn for fast sailing ships

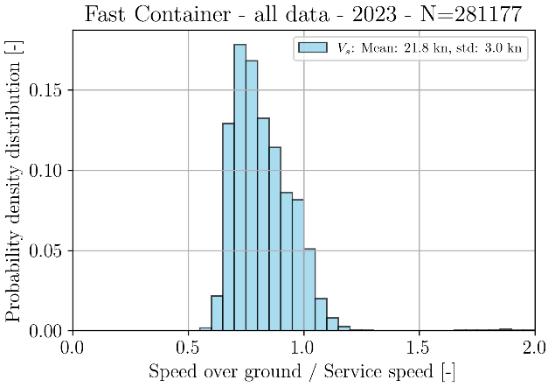
# pdf of speed over ground / service speed

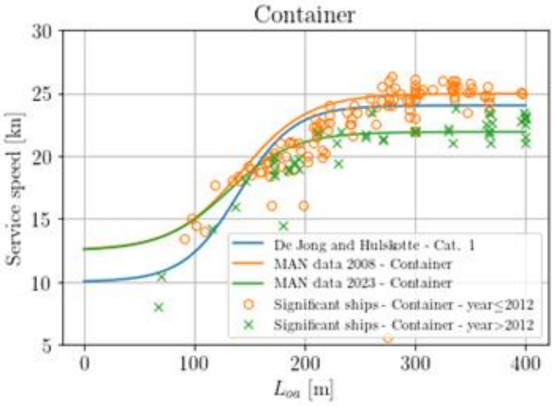
## Service speed function of ship type and length

max at 73%

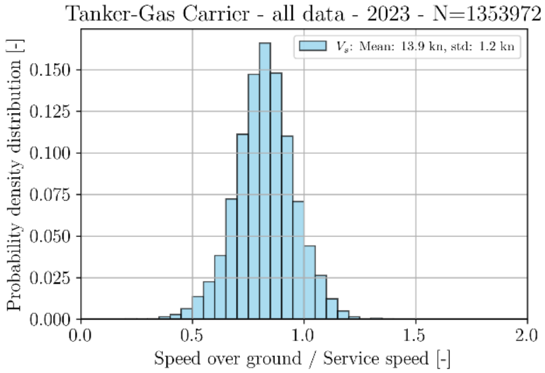



max at 73%

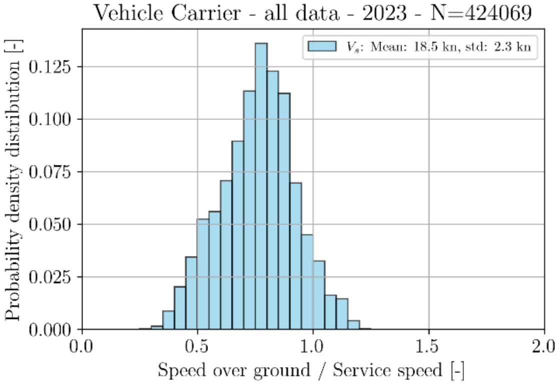


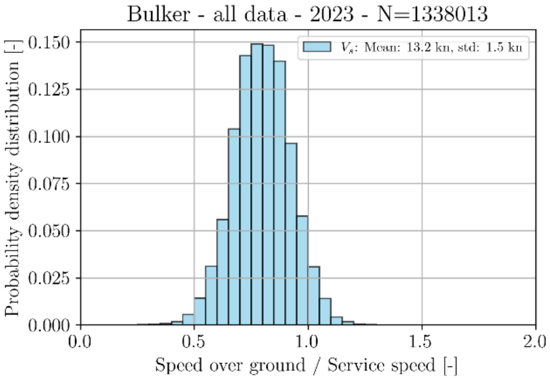

max at 82%




max at 77%

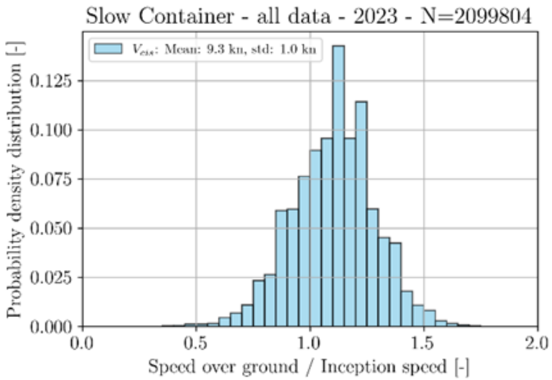


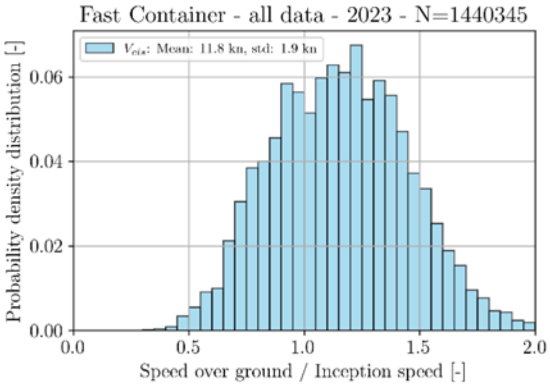

max at 80%

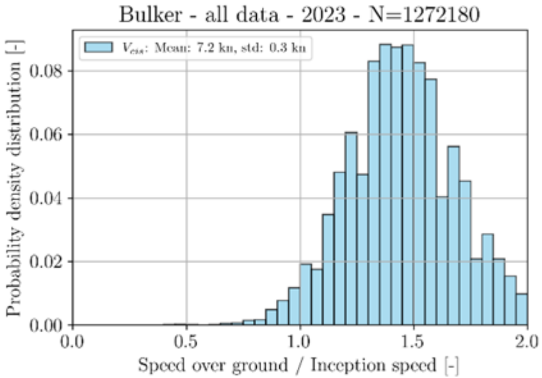


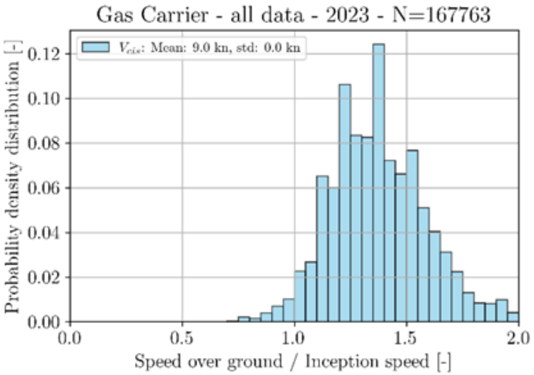
# pdf of speed over ground / inception speed (rough estimate)

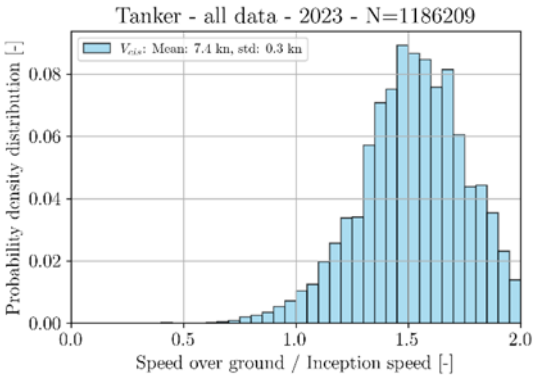
$$V_{CIS} = \min\{\max[(1.42 - 1.2C_B)V_S; V_{lower}]; 14\}^*$$

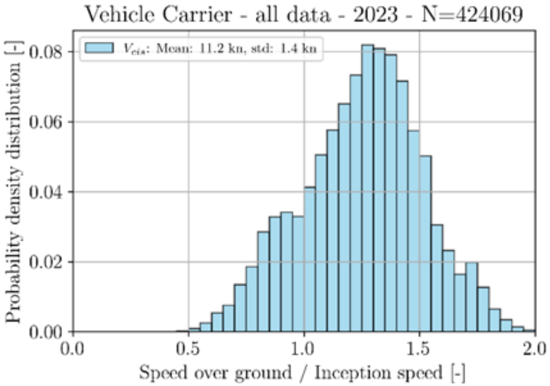



* adapted from Jalkanen et al. (2018)

Updated sheet after presentation

# Concluding remarks

- Slow down or more silent propeller design ?
  - A more silent propeller design for fast container reduces overall fuel consumption if URN limits apply on a track larger than ~15% of the journey
- Does slow down reduce URN in North Sea?
  - Speed limits as in Echo project might affect ~50% of the ships
  - But slow-down much less effective URN mitigation mechanism than commonly assumed (depends on frequency and ship type)
    - Largest benefits expected for fast sailing ships
    - Quantitative data will be generated in next weeks.
  - Need for more knowledge on cavitation inception speeds and cavitation status of merchant ships