Modeling underwater soundscapes of shipping in the Baltic Sea

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Why modeling underwater sound?
Modeling in the BIAS project
Understanding the structure of ambient noise
Maps of the soundscape in the Baltic Sea
✓ Why modeling underwater sound?
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 Descriptor 11.1.2: Continuous Noise

Recommendations formulated by EU/Technical Sub-Group Noise on noise monitoring (Dekeling R. et al., 2014)

- Combined use of measurements and models
- Member States within a sub region to work together in setting up ambient noise monitoring systems
- Initial set of guidelines for placement of measurement devices
- Objectives of measurements should be:
  - to establish information on the ambient noise in a location and to ground truth noise prediction,
  - to reduce uncertainty on source levels to be used as the input for modelling.
What does modeling bring?

- Enhances the local measurement by providing a basin-scale description over the full area of interest.
- Allows to understand the geographical structure of the noise.
- Allows to isolate the several types and origin of noise.
- Allows to track, understand and interpret substantial changes in the soundscape that may be caused by:
  - modifications of the nature of the maritime activities,
  - new routes, deserted routes, etc.
  - spatial planning actions,
  - or the implementation of maritime regulation.
- Allows to establish representative trends in considering a relevant area instead of a single point.
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Maps of the soundscape in the Baltic Sea
The modelling task in the BIAS project

- Field survey
- Environmental data
- Maritime data

Modelling of soundscape

GIS Planning Tool
Predicting noise in a similar matter as weather forecast systems does.
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Ambient noise from several prospectives

Series of Instant Deterministic Maps @ fixed depth

Field measurement @ fixed point
Stochasticity of the noise chorus

- **Biological noise**: Seconds
- **Wind-wave noise**: Hours-Days
- **High intensity anthropogenic events**: 30-60min
Percentile or “exceeding levels” of noise is used to quantify the noise despite its variability. The $n\%$ exceeding level represent that noise level value, at which $n\%$ percentage of data exceed that noise value. In other terms, it represent the noise level reached for a given proportion of time during the period of interest.
Stochasticity of the noise chorus

Most intense but less frequent noise

Less intense but most frequent noise
Stochasticity of the noise chorus

- **Anthropophony**: Human related sound
- **Geophony**: Earth & Weather related sound

- **Loudness**
  - Most intense
  - Less intense

- **Occurrence**
  - Most frequent
  - Less frequent
✓ Why modeling underwater sound?
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✓ Understanding the structure of ambient noise
✓ **Mapping of the soundscape in the Baltic Sea**
Modelling the stochasticity of the noise chorus

- **Modelling Geophony**
- **Modelling Anthropophony**

**Total Ambient Noise**
Modeling Geophony
Modeling Anthropophony: noise sources
Modeling Anthropophony: noise sources
Modeling anthropophony: propagation

- Noise propagation is affected by
  - the bathymetry
  - the nature of the bottom
  - the temperature and density of the water column

![Bathymetry](image1)
![Bottom density](image2)
![Surface sound speed](image3)
✓ Allowed for two degrees of freedom
  - On vessel source levels
  - On bottom geoacoustic properties
✓ Automatic algorithm

Calibration of noise maps
More than 364 800 km²

3 frequency bands: 63 Hz, 125Hz and 2kHz
  - 63Hz and 125Hz as defined in the MSFD
  - 2kHz to (somehow) address Harbor Porpoise issue

3 depth-layers
  - Surface – 15m
  - 30m – bottom
  - Full depth

12 months and one year maps
7 percentiles
4 people involved
64 CPU for approx. 1800 hours of parallell computing
756 maps
Noise Maps – 125 Hz band

« Occasionnal » noise
- is the most intense
- is largely correlated with maritime activities

« Regular » noise
- is the less intense
- shows less spatial dynamics

Bathymetry and bottom type plays an important role

« Regularly »  
« Half of the time »  
« Occasionnaly »
Mapping the most intense noise occurring « occasionally »
- 10% of the month, e.g. 3 days per month
- Most intense noise is concentrated along shipping routes
- Limited variability along shipping routes, variability away from shipping routes due to oceanography
- Noise at 2kHz do not propagate well in the Baltic: anthropogenic along routes, natural at distances of major shipping routes
Noise Maps – 75th percentile

✓ Mapping the most intense noise occurring « regularly »
  o Natural noise is *regularly* dominated by shipping noise along major routes and choke-points
  o Bay of Finland is *mostly* dominated by natural noise, especially the northern area
  o Large seasonnality of the *regular* noise

1/3 octave centered @ 63Hz  
1/3 octave centered @ 125Hz  
1/3 octave centered @ 2kHz
Conclusion

✓ **BIAS has achieved the modeling of soundscape**
  o which covers the full Baltic Sea
  o across one full year
  o takes into account major environmental parameters that influence the propagation of sound in the marine environment
  o includes (most of) geophony and antropophony
  o calibrated using multiple sensors spread across the full area

✓ **Modeling has brought to the project a georeferenced and statistical description of noise, a baseline for the whole region**

✓ **BIAS has demonstrated that mapping such a large area is feasible, operational, and can be included into a GIS decision aid tool**
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