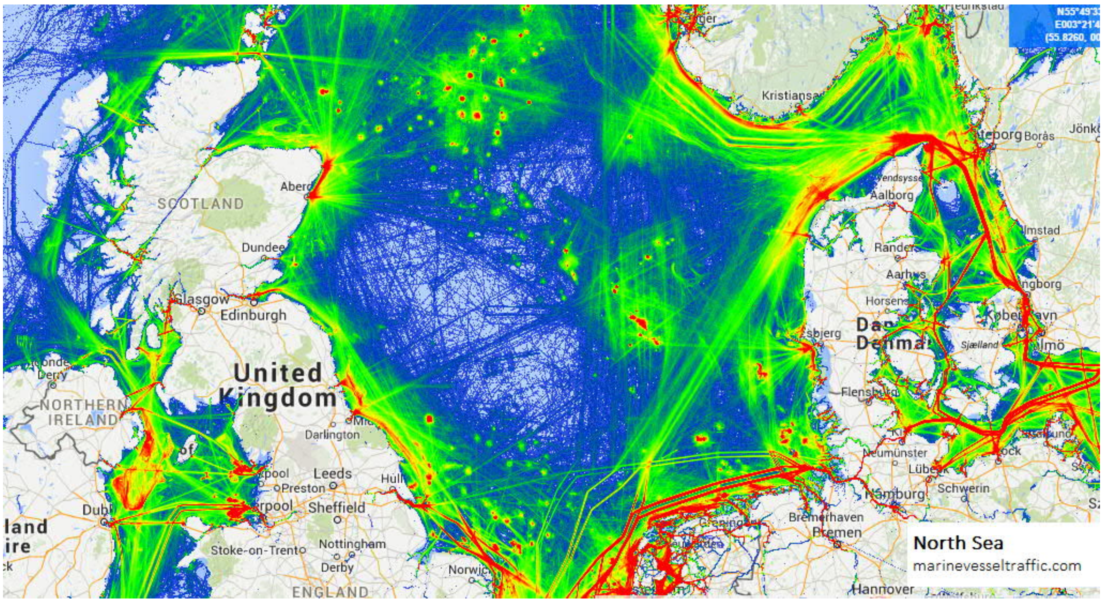
Joint Monitoring Programme for Ambient Noise North Sea

2018 – 2020

Specifications for GES Tool

WP 7, Task 7.4.1



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Summary

The aim of the JOMOPMANS project is to develop a framework for a fully operational joint monitoring programme for ambient noise in the North Sea. A key output will be an online tool for managers, planners and other stakeholders, which will provide access to the data and results of the project and allow assessments of Good Environmental Standard (GES) within the North Sea area with basis in the results of JOMOPANS.

The online GES tool will be based on input from the JOMOPANS project in the form of summary statistics of measurements and maps of modelled underwater noise in the North Sea. In addition will be biological information about distribution and sensitivity of key (indicator) species. Based on these inputs the tool will provide graphical display and quantitative assessments of risk of impact on the indicator species, providing regulators and other stakeholders with geographically explicit information about the GES in the North Sea waters with respect to continuous low frequency underwater noise.

1 OVERALL OBJECTIVE OF THE GES TOOL

The JOMOPANS GES tool (the GES tool in the following) is intended to be the primary method for accessing the results of JOMOPANS and a key legacy of the project. It should serve three main purposes:

- Allow the user to display, explore and export measurements made as part of JOMOPANS WP5 and the soundscapes modelled under JOMOPANS WP4
- Evaluate the soundscapes by one or more pressure indicators derived by JOMOPANS WP6 for spatially and temporally restricted subsamples.
- Evaluate species-specific indicators of risk of impact from the noise, and likewise for spatially and temporally restricted subsamples.

It is important for the success of JOMOPANS that data are widely accessible after the end of the project and the tool should be the preferred method for users to access these data. It is thus also important that a framework be established within JOMOPANS that will maximise the likelihood that the tool can continue to develop beyond the JOMOPANS project period.

1.1 Predecessors and inspiration

Two existing mapping tools have provided important inspiration to the specifications for the GES tool.

1.1.1 BIAS soundscape planning tool

The EU-LIFE project BIAS conducted sound measurements and modelling in the Baltic Sea (HELCOM area)(Sigray et al., 2016). An important part of the BIAS project was the soundscape planning tool, which was designed with the same three objectives mentioned above. Screenshots from the tool are shown in Figure 1 and Figure 2, illustrating a modelled noise map and statistics from the measured data, respectively.

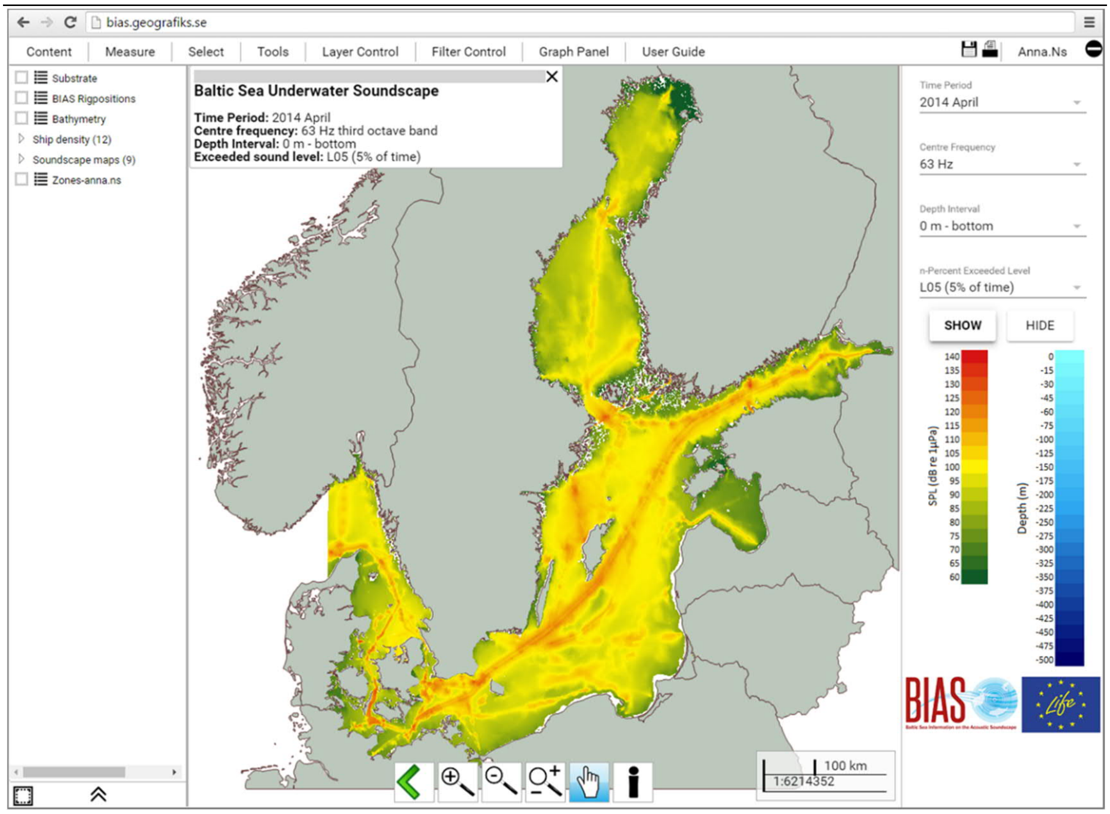

Figure 1. Screenshot from BIAS soundscape planning tool. The map shows the modelled monthly upper 5% percentile (L_5) of the 63 Hz 1/3-octave band noise for April 2014.

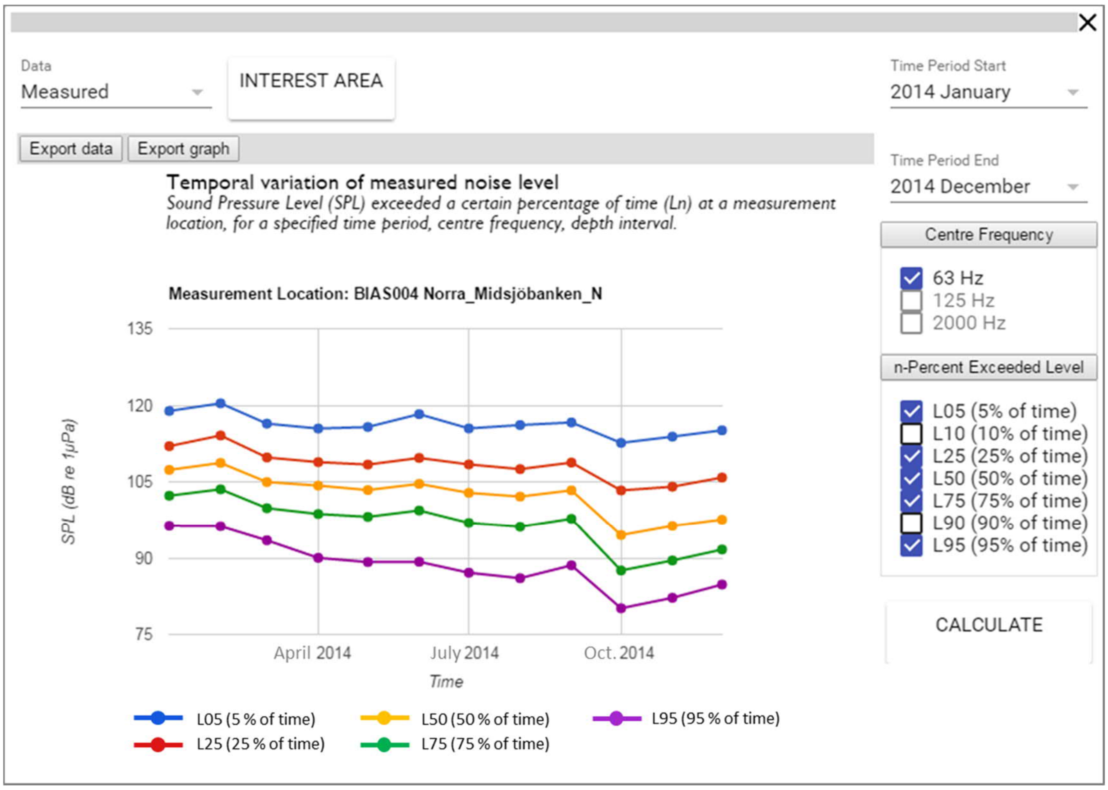

Figure 2. Screenshot from BIAS soundscape planning tool. The graph shows monthly percentiles of the 63 Hz 1/3-octave band noise derived from measurements at the measurement station North Midsjö Banks.

The BIAS soundscape planning tool overall works as intended, and provides means of exploring the measured and modelled data, as well as allowing spatially explicit analyses of the data. However, a number of shortcomings were realized after end of the project. These can be rephrased into desired new features of the GES tool:

- **Separation of natural and anthropogenic noise**. Modelling in BIAS was on total noise, i.e. the sum of modelled natural ambient (wave generated) noise and anthropogenic (ship) noise. As these are modelled separately in the first place, it is technically simple to keep them separate all the way to the tool. The layers can then be added for the total noise, or otherwise manipulated within the tool, as the ratio of anthropogenic to the natural noise is most often more relevant to animals than the absolute level of noise.
- **Derivation of indicators of pressure and risk**. Rather than assessing the pressure of anthropogenic noise in a given area directly through the (percentile) sound pressure levels, as done in the BIAS soundscape planning tool, it is the goal of JOMOPANS to derive indicators of pressure, which are more indicative of potential impact than sound pressure levels on their own. It is the task of WP6 to develop such pressure indicators. In the same way, it is desirable to be able to combine such pressure indicators with spatially explicit information about animal abundance, in order to assess potential risk of impact.
- **Embedding into institution or organisation**. The future of the BIAS soundscape planning tool was not guaranteed after the end of the BIAS project. Subsequently, HELCOM countries have agreed to support a continued operation and further development of the tool, although the practical decisions on how this should be done have not been settled. These circumstances have created a delay and thus an unfortunate gap in the availability of data for the HELCOM area in the years following the BIAS modelling year (2014). For the GES tool it is therefore desirable to have agreements about the continued operation and update of the tool in place before JOMOPANS concludes by the end of 2020, such that a smooth transition is possible. Actual decisions about such a continuation cannot be made within JOMOPANS, as they extend beyond the JOMOPANS project period, but must instead be coordinated with relevant bodies, most importantly OSPAR. It is thus also a requirement that the design of the GES tool is portable, such that the possible transition of the tool to a new location can be as fast and smooth as possible.

1.1.2 ICES impulsive noise register

The ICES impulsive noise register has been established at the initiative of OSPAR and later also adopted by HELCOM and serves as the main source of information about impulsive anthropogenic noise ((as defined in the MSFD criteria D11C1, European Commission, 2017) in the North Sea and the

Baltic Sea. The database contains records of impulsive events compiled and reported by national agencies to ICES. Figure 3 shows a screenshot from the online database interface.

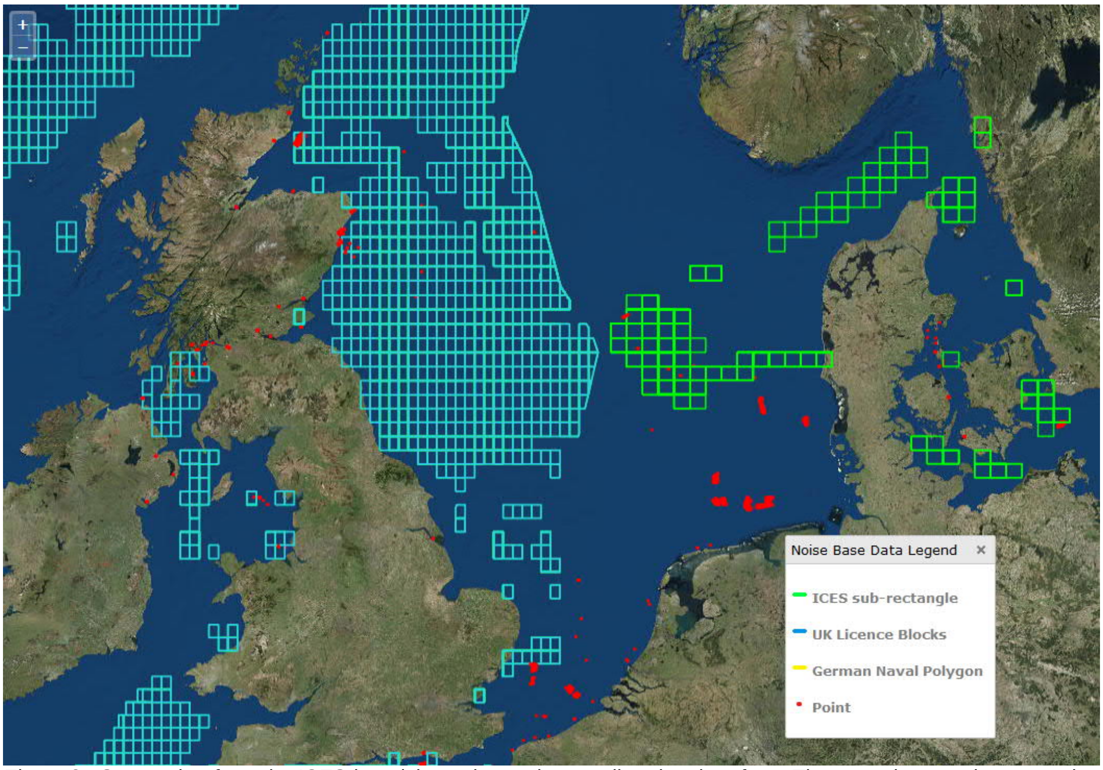

Figure 3. Screenshot from the ICES impulsive noise register, online data interface. The map shows polygons and points where impulsive noise sources have been reported by the HELCOM and/or OSPAR member states.

While the database does little more at the moment than offering display and export of the data, two important features, desirable also for the GES tool, are evident:

- **Open access**. It is very easy for users (agencies) to upload new data to the database and anyone can access the data, explore them on the map and export them for further analysis. This maximises the possibilities for using the data beyond the narrow purpose for which it was originally designed (providing data for the regular assessments of OSPAR and HELCOM, as well as national reporting in accordance with the MSFD requirements.
- **Embedding in ICES**. The fact that the database is hosted by an established organisation and paid for through committed contributions from the HELCOM and OSPAR member states is the best guarantee that the database will continue to be updated and developed.

2 Overall structure of the tool

The suggested components of the tool are outlined in Figure 4 and described in details in section 3 below. The tool operates on large amounts of input data, most of which is static and only a little fraction is user-specified at run-time. Based on the user-specified data, the static data is evaluated by the processing engine and displayed or exported, either as maps, or as graphs/tables.

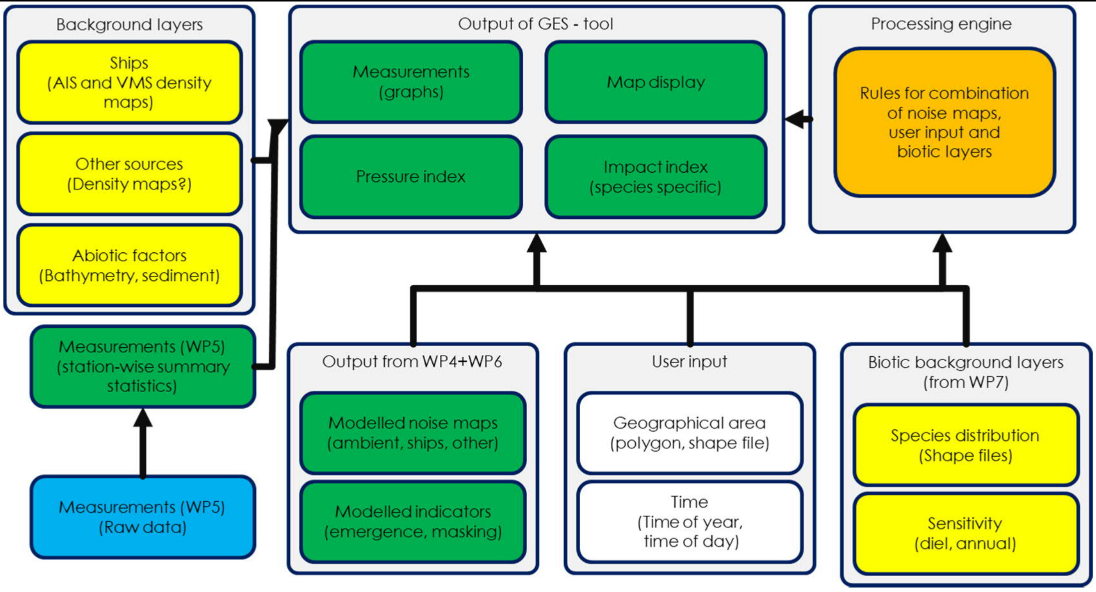

Figure 4. Overall suggested structure of the GES tool. See text for explanation.

Inputs to the tool are of different types and come from different sources. All input layers, except for the user input, will be provided by JOMOPANS (WP5, WP6 and WP7).
The tool should allow the user to access and manipulate the JOMOPANS results in three different ways.

1. **Display measurements data**. The measurements themselves will be in the form of huge binary files (.wav-files) and should be stored and managed by the national partners. WP5 will provide suitable summary statistics, which should be available for display within the GES tool. As measurements are restricted to isolated points in space, the display shall be in the form of graphs and/or tables, not maps. Simple queries should be possible (selection of station and time period) and adjustment of display (type of display, averaging periods etc.).
2. **Display modelled noise.** WP4 will model noise from AIS and VMS sources, propagated out to extend into the entire project area. These modelled noise levels will be represented as map surfaces by means of a suitable acoustic metric, developed as part of WP6. Such maps should be displayable in the tool and it should be possible to investigate them by zooming in on selected subregions.
3. **Display risk indicators**. The core of the tool will be the ability to combine the maps of the noise metrics with distribution and sensitivity information about key marine species of the North Sea. In this way maps representing risk of impact can be generated and displayed.

3 Input to the tool

The majority of the inputs to the tool are static and only a small fraction is to be supplied by the user at run-time. The primary reason is to avoid computer-heavy processing when the program is running, but also to ensure consistency. It is important for the success of the tool that users can reproduce output generated by other users, ensuring that assessments of pressure and GES is consistent between users. This is to be achieved by relying on minimal processing at run-time and allowing only limited user-supplied information at run-time. The primary user input should thus be restricted to specifying geographical areas and periods for the evaluation, likely supplemented by simple measures of sensitivity of key species.

3.1 Measurements from WP5

The actual recordings obtained in WP5 will be far too large to store and access through the tool and run-time processing would be prohibitively long for any meaningful analyses to be performed at run-time[1]. Thus, the tool should only store and display processed versions of the recordings. These processed data will be supplied by WP5 and is suggested to consist of third-octave levels of the noise rms-averaged over a suitable, short time interval (1 second). These third-octave levels should be displayable as summary graphs over selected time intervals, expressed as selectable percentiles of the intensity distribution. Also total sound pressure level, unweighted and by application of appropriate auditory frequency weighting functions (e.g. National Marine Fisheries Service, 2016; Tougaard and Beedholm, 2019) should be selectable, and possibly also time series of short-time averaged third-octave levels (as for example long-time spectrograms).

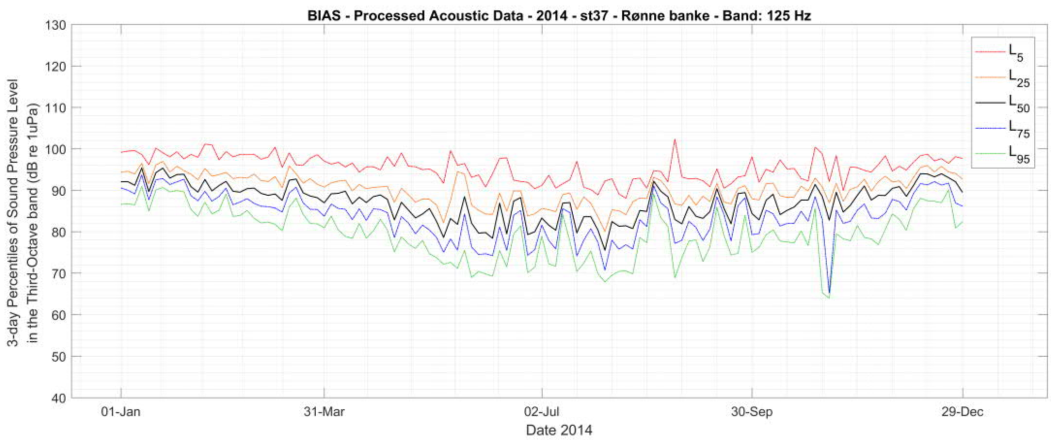

Figure 5. Example of display of noise monitoring data from actual measurements. From BIAS/the national Danish continuous noise monitoring program. Shown are exceedance levels for consecutive 3-day periods.

3.2 Abiotic background layers

These layers form important input to the noise modelling in WP4, but do not feed into the processing engine. They are thus included for reference only. The layers are geographically explicit and cover the entire project area.

3.2.1 Ship density

These layers should express the density of ships in the project area, with a unit of for example average number of ship passages per raster rectangle per day. They are derived from AIS and VMS positions and supplied to the tool from WP4 or WP5. It may be useful to allow for display of only data from the period selected by the user. An example of a ship density map, from the BIAS soundscape planning tool, is shown in Figure 6.

3.2.2 Other sources of underwater sound

If other sound sources than large ships are included in the modelling in WP4, then appropriate layers for these sources should be available for display in the tool as well. Such sources could be offshore wind farms, pile drivings, seismic surveys and explosions.

[1] In addition, there may also be other complications related to sharing actual recordings, related to possible matters of national security preventing sharing actual recordings through the tool.

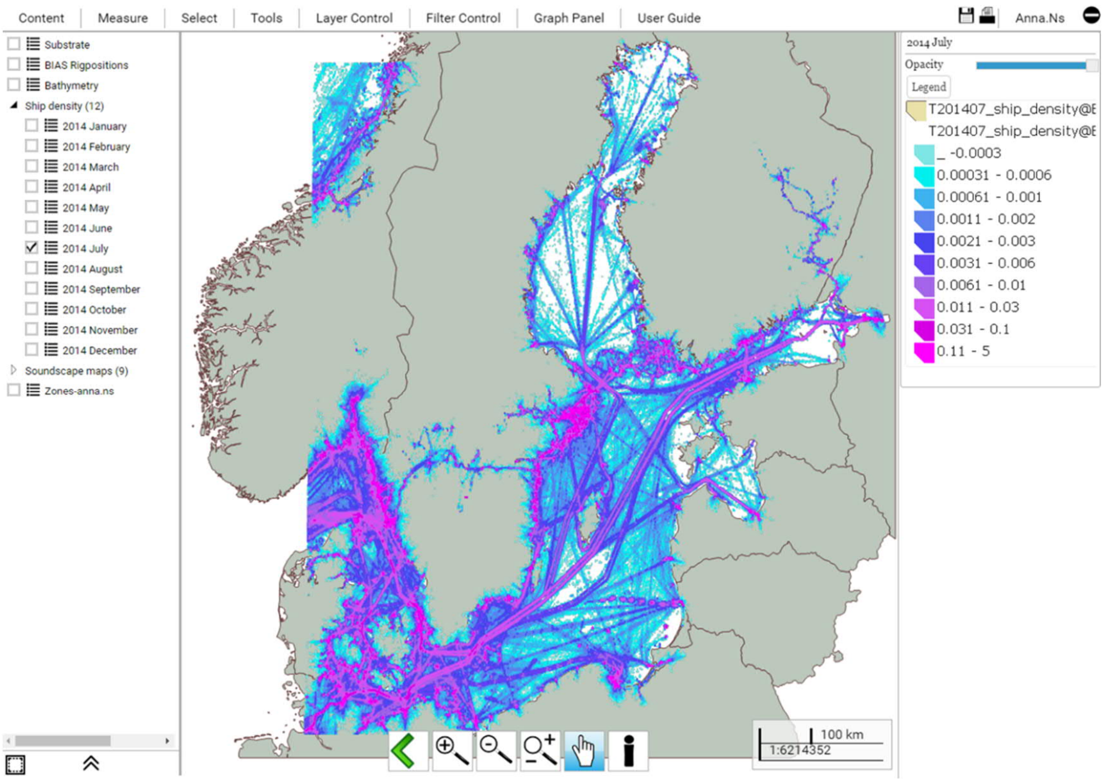

Figure 6. Example of ship density, from the BIAS soundscape planning tool.

3.2.3 Abiotic factors used in modelling

Layers expressing static factors of importance for the sound propagation modelling, such as bathymetry and bottom sediment properties, should be available for display. Bottom sediment could be as sediment type or directly as a map of the acoustic properties of the seabed, used in propagation modelling.

Additional dynamic factors, such as sea surface roughness and hydrography, should also be included by means of appropriate statistics (measures of mean/median and variance), if these factors are included in the modelling performed in WP4.

3.3 Maps of modelled noise

These maps are produced and delivered by WP4, based on input from WP6. Together with the maps of risk indicators (see section 5.4 below) this is the main output of the tool. Maps must be delivered by WP4 with a resolution high enough to allow for the desired processing within the tool, yet be sufficiently pre-processed not to slow down the tool beyond what is acceptable.

3.3.1 Modelled natural ambient and anthropogenic noise

Rasters of the modelled noise, separated into sources (wind, ships and possibly other anthropogenic sources), should be accessible for the tool with a resolution that allows spatial and temporal aggregation and derivation of summary statistics for the selected area and period, as well as plotting selected noise statistics, such as percentiles, in the map display. The noise should also be separable into different frequency bands as well as weighted levels, where the auditory sensitivity of key indicator species (or species groups) is factored in (see National Marine Fisheries Service, 2016 for examples for marine mammals). An example of noise modelled in the BIAS project is shown in Figure 7.

Of considerable interest for the purpose of display and combination with biotic layers are different measures of the ratio between anthropogenic and natural noise. Such measures, referred to as “emergence” of the anthropogenic noise, are likely good indicators of the potential for masking by the anthropogenic noise.

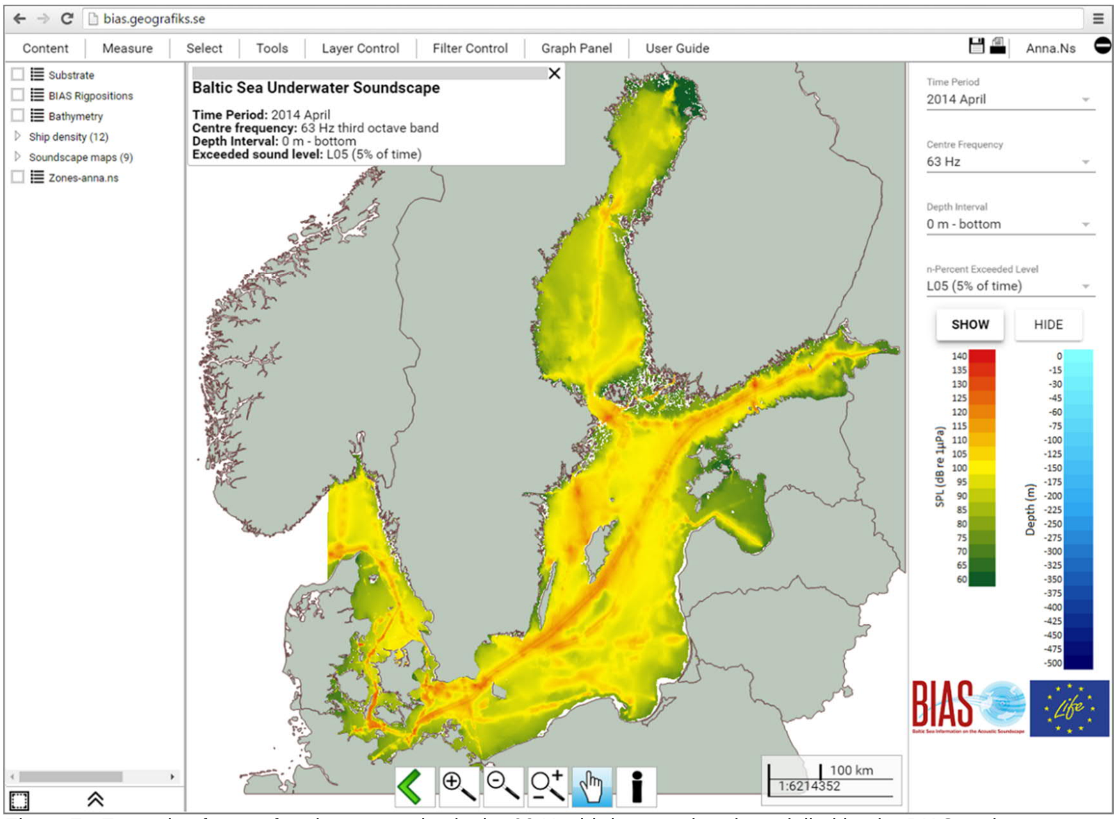

Figure 7. Example of map of underwater noise in the 63 Hz third-octave band, modelled by the BIAS project. Shown is the 5% exceedance level (L_5) for the total noise (sum of wind and wave generated noise and ship noise) for the months of April 2014.

3.4 Biotic background layers

A number of animal species will be selected and data on their distribution in space and time will be included for derivation of risk indices. These background layers are supplied by WP7 for a number of selected indicator species. The exact species are to be decided, but should as a minimum include both marine mammals and fish species for which reliable information on distribution is available.

3.4.1 Species distribution

This information should be available to the tool in the form of map rasters covering the entire project area. At least one map must be supplied per species, but if sufficient information about seasonal occurrence is available, the rasters should be split into appropriate time periods. An example of a possible distribution map is shown in Figure 8.

For other species, most notably fish, it may not be possible to obtain reliable density surfaces, not even relative measures, and instead a binary map would be used, i.e. strictly presence/absence. All distribution maps are to be supplied as static maps/rasters by WP7, but the architecture should allow for later updating of existing maps and amendment of maps for additional species, as this information becomes available. At some future point, it may be desirable to allow users to upload at runtime their own maps for species distribution, but such a capability is not envisioned to be part of the tool at the present stage.

3.4.2 Species sensitivity

Animals are not equally sensitive throughout the year and throughout the day and not all areas are equally important. To the extent that such information is available this should be included as input to the tool in the form of geographical layers and/or functions expressing change in sensitivity with time of the year and time of the day. This information is supplied by WP7.

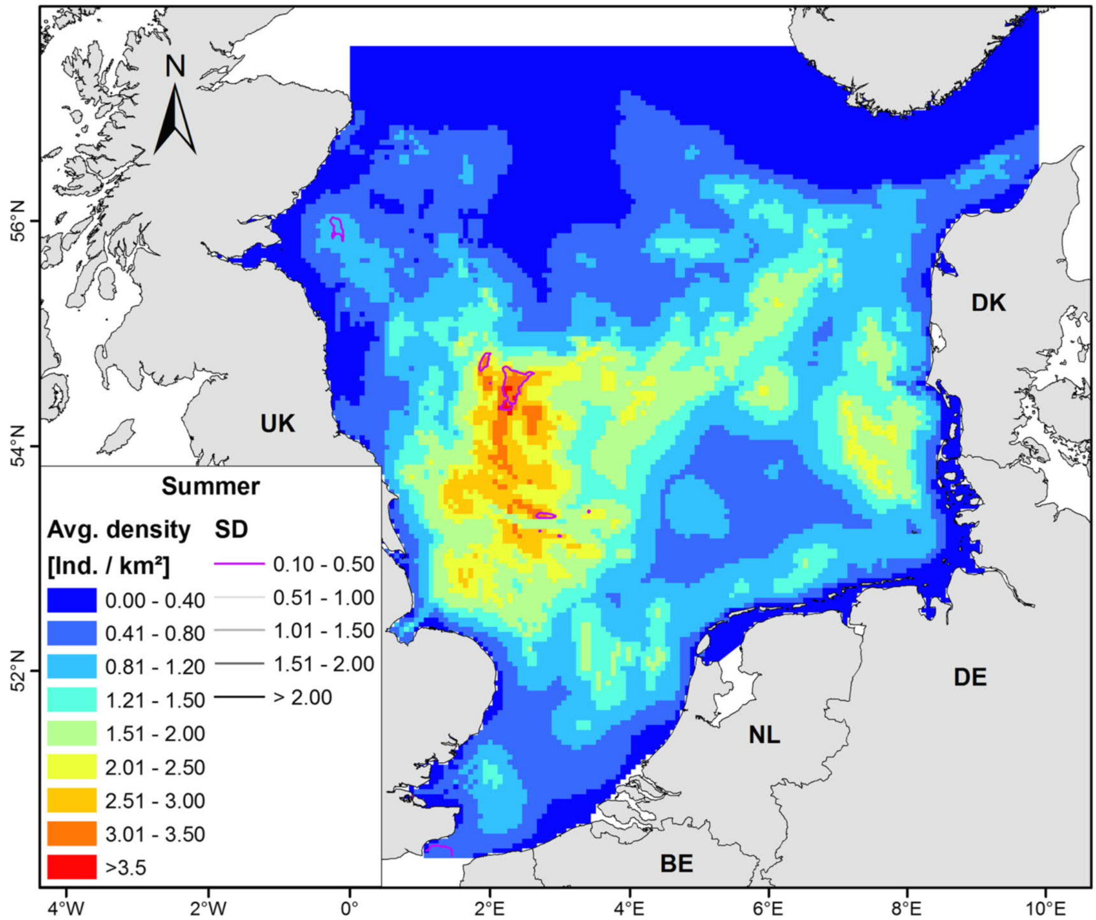

Figure 8. Example of animal distribution map: modelled density of harbour porpoises, based on aerial and ship survey observations. From Gilles et al. (2016).

3.5 User input

3.5.1 Geographical area

The user should have the possibility to focus analysis on a specified geographical sub-region of the project area. This could be in the form of selection of one or more of a number of pre-defined subareas of the North Sea, such as ICES statistical rectangles, national EEZs, designated Natura2000 areas, or could be selectable by the user as a simple polygon. It would be preferable if coordinates for such polygons could be not only selectable on a map, but could be uploaded in a standard format (ESRI shape file or similar).

3.5.2 Time period

Likewise, the user should be able to select a time interval for evaluation. As a minimum, this should allow for selection of a fraction of the year. Resolution is to be determined, but minimum requirement would be displays and analyses by season and/or month, possibly down to custom date ranges. Ultimately, the resolution is determined by the resolution of the noise rasters and the resolution of the animal distribution rasters. With these constraints, it appears unlikely that much will be gained in quality of the output with a resolution finer than month by month.
It is to be discussed whether a capability to stratify across the hours of the day would be worth implementing in the tool. This would allow a comparison of for example day vs. night, which would be relevant for areas with high diel variation in either animal abundance or anthropogenic noise (typically areas with many ferries).

4 Processing capabilities (run-time processing)

This is the heart of the tool, where the sound maps, animal abundance information and user input are combined at run-time. User input will be specification of a geographical area A, a time interval T, a suitable representation of the noise, in the form of a noise raster $P_{i,j}$, and a receptor (indicator species or species group). Three types of derived outputs are presently envisioned, based on these input selections.

4.1 Area-specific pressure index

This index should provide a single measure (with possible indication of variance and/or uncertainty) intended to describe the antropogenic noise pressure on the area. It is generated from the noise rasters $P_{i,j}$, by means of a function f, yet to be specified:

$$P(A,T) = f\left(P_{i,j}(A,T)\right)$$

An example of such a pressure index could be the calculated fraction of time and space where anthropogenic noise exceeds natural ambient noise by X dB (emergence). Such an index would be between 0 and 1, where 0 would mean that anthropogenic noise never exceeds natural ambient in any part of the area and 1 would indicate that anthropogenic noise exceeds natural ambient everywhere and always. Intermediate values, such as 0.1, would mean that emergence exceeds X dB all the time in 10% of the area, exceeds X dB in 10% of the time across the entire area, or (much more likely) some combination of exceedance in time and space.

4.1 Map of impact risk index

Once an indicator species, Y, has been selected, it is possible to create a raster expressing impact risk for that particular species. The underlying logic of the risk index is that risk can be expressed as a combination of the pressure (the magnitude of the anthropogenic noise in the area), the animal density, and the sensitivity of the animals towards the noise:

$$Risk = pressure \times density \times sensitivity$$

The key logic is that if only one of the three inputs is very small, then the risk is small, irrespective of the value of the others, and if all three inputs are large, the risk is large.
Derivation of the risk index is done over the selected time period T by combining the appropriate noise raster $P_{i,j,}$ expressing for example exceedance level, with the distribution raster for species Y, $D_{i,j}$, and possibly also factoring in the sensitivity raster $S_{i,j}$, also for species Y:

$$R_{i,j}(Y,T) = P_{i,j} \cdot D_{i,j}(Y,T) \cdot S_{i,j}(Y,T)$$

This raster can be displayed in the map display, providing a graphical representation of the areas assessed to have the highest risk of an impact, but can also be used to derive an area specific impact risk index (GES-index).

4.2 Area-specific impact risk index

The impact risk index for area A and time period T is derived from the corresponding impact risk index raster by means of a yet undefined function g:

$$I_{GES}(Y,A,T) = g\left(R_{i,j}(Y,T),A\right)$$

This function is a key element of the tool as the output index I is intended to be useful as a measure of Good Environmental Standard (GES) of the area A. A high value of I would indicate that the risk of impact (from the risk index above) is high in large parts of the area A over a considerable fraction of the time and thus low likelihood that GES is achieved in the area. Considerable work will undergo within WP7 to develop this particular indicator.

5 Output interface

The actual implementation of the GES tool and the interface will depend to a large degree on the choices of the developer. Some general comments can be made, however. The output interface should consist of a number of channels by which the user can access the input data and the processed results. Some important decisions on the balance between ease of use and possibilities for customisation of output must be made. This discussion is tightly coupled to the choices made regarding capabilities for exporting the results. Some users prefer an ability to export as many details as possible, in order for them to work independently with data and display in other software (such as GIS) and can live with very limited options for adjusting the display in the tool. Other users prefer more options for adjusting the display in the tool itself, allowing export of publication-ready figures and tables, removing the need for transfer into other software.

5.1 Measurements

Minimum capabilities should be ability to plot and compare statistics and distributions from multiple recording stations and across time periods.

5.2 Map display

This should be the core output display of the tool and should be in the form of a scalable map, where selected rasters (noise statistics, derived parameters etc.) can be inspected and possibly overlays of background layers (AIS, animal distribution etc) should be selectable. It is preferable that contributions from different source types (ships, impulsive noise etc.) can be identified individually, limited by the degree this information is available in the modelled maps.

5.3 Pressure index

In the simplest form the area and time specific pressure index is a single number and thus simple to display. It is to be discussed whether there should be possibilities for displaying additional information, such as temporal variation of the index

5.4 Impact risk index

In the simple form (4.1 above) the impact risk index is a raster and can be displayed directly in the map interface. In the area and time specific version the index is a single number as the pressure index, but additional information can be provided as well.

5.5 Comparison between areas and across time periods

Some effort will have to go into considering how summary statistics can be displayed in ways that allows for comparison between different areas of interest and/or different time periods. As the indices derived are relative measures of risk of impact and GES, the true value lies in a comparison between different areas, not in a direct interpretation of the absolute values.

5.6 Export capabilities

Dissemination of the results is central to the success of JOMOPANS and the GES tool is one possible way of achieving this. Exporting can be achieved at many levels, from simple export of map windows as image files, across export of processed layers as shape files or similar, to allowing export of entire or selected portions of the input data (noise rasters and measurements). This is up for discussion and depends to a large degree also on the way the tool is implemented and data is stored within (or accessible to) the tool.

6 Further considerations

A number of additional issues are relevant for design of the tool and will be discussed during early phases of development.

6.1.1 Open access, open source and portability

It is important for the success of JOMOPANS that results are widely disseminated, which is why the tool should be accessible to all interested parties. Whether this should be realised by a web interface open to everyone without login (such as the ICES impulsive noise register) or via a user registration (such as for the BIAS soundscape planning tool) is of lesser importance.
It is also important that the tool is transparent, which means that all processing algorithms should be openly documented. It is not a requirement that the software code itself is open, but it is important that it is portable, i.e. that the processing capabilities of the tool can be transferred from one operator to another, in order to secure the continual availability of the tool and the data of JOMOPANS. In this respect, we draw on the lessons learned from the BIAS soundscape planning tool (see 1.1.1 above).

6.1.2 Anchoring in institution and/or organisation

Following from this comes also the desire to have the tool anchored in an institution or organisation which can help secure the long-time operation (and hopefully also further development) of the tool. This will be a key point for the decision of which technical solution to choose for the tool.

6.1.3 Continued addition of data beyond JOMOPANS

Although completely outside the hands of the JOMOPANS project, it is a desired wish that the tool can continue to be operational beyond the end of JOMOPANS. This most importantly includes the ability to add new monitoring data and modelled maps, as they become available, and update and amend information about indicator species. Realisation of this vision clearly depends on decisions taken outside JOMOPANS (by OSPAR, or one or more North Sea states), but has implications for the design and development of the tool, which is why it is expressed in this context.

6.1.4 Modelling of scenarios

It is a desired wish from several potential future users of the tool (regulators and industry) that the ability to model different future scenarios for shipping routes and offshore development is built into the tool. Such a capability however, has very large implications for the way the tool should be designed, as it will require capability for performing the actual acoustic modelling within the tool itself, or a capability to request such modelling automatically from a separate online tool. This is clearly beyond the current scope for the GES tool, but mentioned as a possible future extension of the tool.

6.1.5 Coordinate system, map datum and map projection

Although not of critical importance for the function of the tool itself, some decisions have to be made early on regarding geographical coordinate system, map datum and map projection to use in the tool. This should be decided together with especially WP4 (modelling of sound). For now it is suggested to adopt a latitude/longitude grid based on the WGS84 datum and map projections consistent with current use in OSPAR assessments.

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