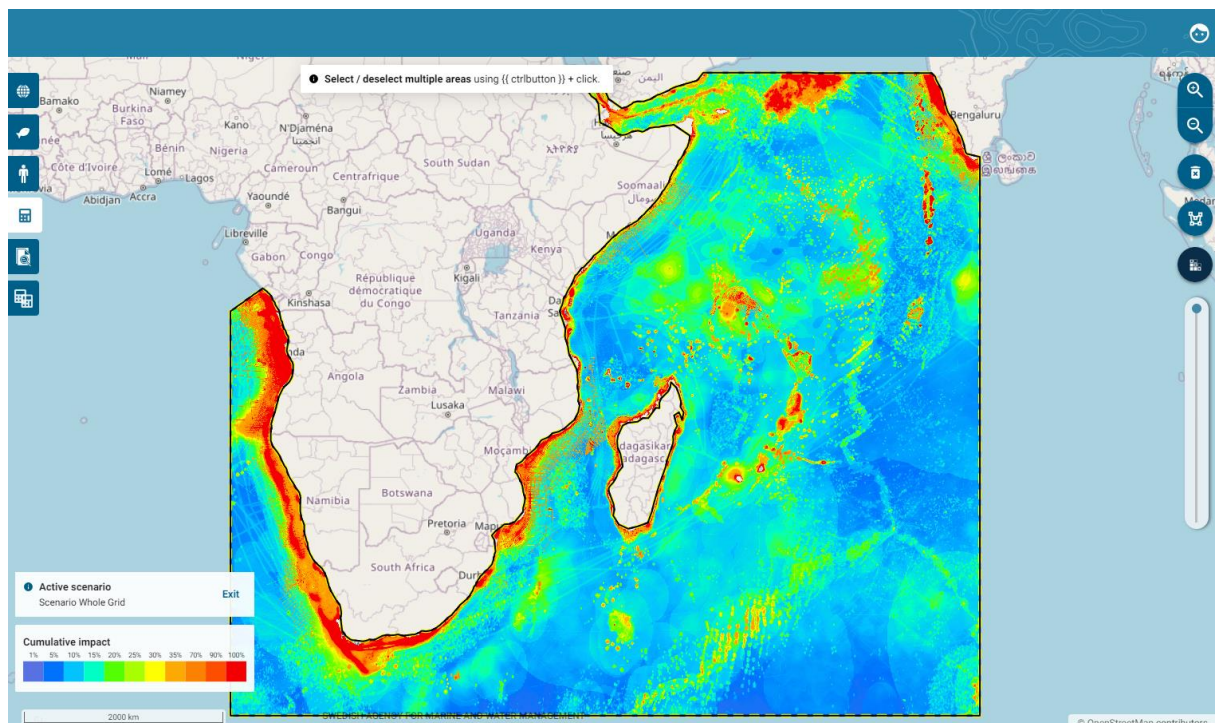


WIO Symphony user manual

Manual edition: 13 December 2023

WIO Symphony version: Symphony 1.14.2



WIO Symphony stands for **Western Indian Ocean Symphony**. It is a co-developed tool for the assessment of combined, or cumulative, environmental impact of different human activities across vast ocean spaces. This open-source tool is useful for MSP, marine spatial planning and other area-based management.

You can access the tool at <https://symphony.nairobiconvention.org>.

For **Quick Start**, move directly to **chapter 4**.

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This manual has been compiled by Linus Hammar and Eric Strömberg and edited by Wilhelm Gårdmark and Ann Ahlsten.

1. Purpose, principles, partnership

When marine spatial planners and managers work across large geographies, it becomes difficult to account for the full myriad of animals, plants, and human activities without help from data and computations. From a bird's eye perspective, the WIO Symphony tool serves as a vehicle for understanding the combination of many human activities affecting multiple parts of nature, all at the same time. This is called cumulative impact assessment.

Marine planners and managers who have access to the tool will obtain an overview of existing ecosystem components and pressures, as well as current environmental impact in their area of interest. This brings science closer to management and may support ocean governance, specifically ecosystem-based marine spatial planning (MSP).

The purpose of WIO Symphony is to facilitate informed and transparent decision-making that leads to sound and sustainable use of marine resources, and, in turn, support wealth and socio-economic development in the Western Indian Ocean region.

1.1 Co-developed widely

The WIO Symphony tool was co-developed on the request by the Nairobi Convention. The work was initiated in 2019 and the tool is available since the end of 2022. The co-development was led by a Swedish team in partnership with the MSP technical working group (TWG) of the Nairobi Convention, including two representatives from each of the 10 member states (Comoros, France, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, Tanzania, and South Africa). The Swedish team was led by the Swedish Agency for Marine and Water Management (SwAM), in partnership with the Geological Survey of Sweden (SGU), the Swedish University of Agricultural Sciences (SLU), and Gothenburg University (GU). The co-development got technical support of a large group of experts from the region and internationally. Approximately 100 professionals from 14 countries have contributed to the development of WIO Symphony.

1.2 Open and transparent

All components of the WIO Symphony tool are based on the principles of transparency and open data sharing.

- The tool's software code is published and available on [GitHub: MSP Symphony](#).
- Data layers and metadata is available for download at the [Nairobi Convention](#) and [GitHub: WIO Symphony](#).
- Links to underpinning data and models is freely available at [GitHub](#).
- WIO Symphony is also described at [SwAM's web page](#) and discussed at [GitHub Wiki](#).

Summary of metadata is also displayed in the tool, as well as contributor acknowledgements.

1.3 The Nairobi Convention manages and updates

Although all components of the tool are open access, the WIO Symphony is implemented on the server of Nairobi Convention, who is also the acting owner of the WIO Symphony application. The Nairobi Convention Secretariat is responsible for tool management plan and updating procedures.

1.4 Financed by Sida, SEPA, GEF, and in-kind

The bulk of finances behind the WIO Symphony development have been provided by the Swedish Development Cooperation Agency (Sida) through the SwAM Ocean program, the Swedish Environmental Protection Agency through the bilateral program for environment and climate collaboration, and the Nairobi Convention, in turn, supported by the Global Environment Facility, especially the SAPPHIRE project.

Numerous institutions have contributed in-kind with expert staff and some individuals have contributed on voluntary basis.

2. WIO Symphony method and analyses

2.1 Method

Rationale for cumulative impact assessment

The rationale behind cumulative impact assessment is to emphasize the combined effect of many different sources on many different parts of the environment. Cumulative impacts – positive or negative, direct and indirect, long-term and short-term – arise from a range of activities throughout an area or region, where each individual effect may not be significant if taken in isolation (EEA 1999). However, the cumulative impact calculated in WIO Symphony does not explicitly consider temporal, time-dependent, aspects. Nor does it explicitly consider positive impacts. These and other caveats are discussed in this manual.

Symphony is used for ecosystem-based MSP in Sweden

The WIO Symphony tool is directly based on the Swedish Symphony tool used within Swedish MSP (Hammar *et al.* 2020, SwAM report 2018:1). Being responsible for ecosystem-based MSP in Sweden, the Swedish Agency for Marine and Water Management (SwAM) developed and used Symphony as a tool for integrating cumulative impact assessment in the planning process. In Swedish MSP, Symphony was used for:

- (i) planning-integrated comparison of environmental impact of different planning alternatives,
- (ii) identification of areas in need of measures for environmental precaution, and
- (iii) as a basis for the Strategic Environmental Assessment (SEA) of the MSP.

It has also been used in support of marine protected areas (MPA).

*Methods originates from Halpern *et al.* 2008*

The method originates from the previous work by Halpern *et al.* (2008). Halpern presented a transparent and useful way of estimating cumulative impacts on global scale, based on maps representing marine ecosystems, pressures from human activities, and sensitivity scores indicating how sensitive each ecosystem is to each pressure.

Method expansions: scenario comparisons and specific taxa

This basic method has been adopted for WIO Symphony, which differs from the original work in two essential ways:

1. WIO Symphony is a more dynamic tool that allow scenario comparisons. This means that the tool can produce assessments of planned activities, which is at the core of MSP and may also be useful for other marine management. Scenario comparisons in cumulative impact assessments are distinctive for the Symphony applications.
2. WIO Symphony includes representation of both marine habitats/ecosystems and individual marine taxa/species, whereof only the former was included in the original method by Halpern *et al.* To include both specific taxa and general habitats/ecosystems in the same analysis can be difficult to interpret, like comparing apples and pears. Therefore, to be considerate, the default setting in WIO Symphony is to include only

habitats/ecosystems. Yet often there is merit to include individual taxa in the same analysis, or study the cumulative impact on a single taxon alone. It gives you more details on specific animals. Inclusion of taxa are common in cumulative impact assessments applications.

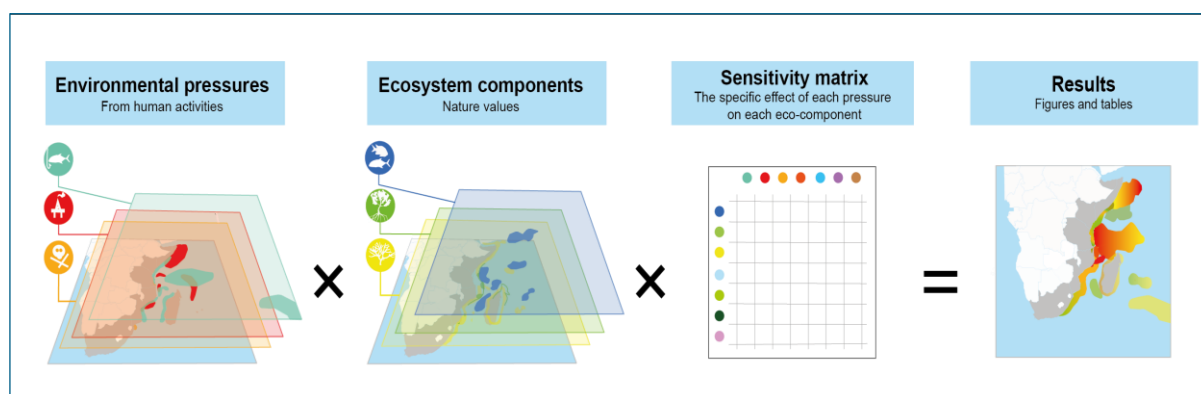
The Halpern method for cumulative impact assessment has also been implemented by the Helsinki Commission (HELCOM 2018), for environmental status assessment and other means of marine planning and management. Several independent reports and scientific studies have applied the same method (Korpinen & Andersen 2016; Depellegrin *et al.* 2017; Fernandes *et al.* 2017; Andersen *et al.* 2020).

2.2 Basic equation

Cumulative impact (I) is calculated by:

Eq. 1:
$$I_{sum} = \sum_{i=1}^n \sum_{j=1}^m P_i \times E_j \times S_{i,j}$$

where E is ecosystem components, P is pressures from human activities, and S denotes the sensitivity score. The numbers of ecosystem components and pressures are derived from the underpinning data layers (maps), which are all scaled between 0 and 100. The sensitivity score is derived from a sensitivity matrix scaled between 0 and 1. See figure below.



Calculation of cumulative impact is the default setting in the WIO Symphony tool, and it represents the straightforward estimate of how all human activities affect all of the marine environment. Very abundant ecosystems and species will hence have a strong influence on the results, if they are at least somewhat sensitive to pressures in the area. See chapter 5.5.

A meaningful aspect is that the cumulative impact result is broken down into flow charts indicating how each pressure contributes to the impact of each ecosystem component. See chapter 5.6.

2.3 Further analyses: rarity, one-over-many, and scenario comparisons

The WIO Symphony tool enables the comparison of different scenarios, showing how environmental impact increase or decrease at each location based on the changes simulated from marine management measures or marine planning priorities. See chapter **5.8** and **5.9**.

WIO Symphony is not restricted to estimates of full cumulative impact. It also enables tailor-made analyses of how selected pressures impact one or several selected ecosystem components, or vice versa – these one-over-many analyses are called MINISYM. These can be meaningful for understanding the threats to particular species and ecosystems, or for learning how a particular pressure or sector impact the environment in different areas. See chapter **6.1** and **6.2**.

Moreover, it is also possible to calculate rarity-adjusted cumulative impact, which means that the impact on each ecosystem component is divided by the commonness of the same ecosystem component, defined as the total sum of the ecosystem component in the area of interest. The rarity-based cumulative impact is interesting from an ecological and conservation-oriented perspective, as it highlights impacts on rare species or ecosystems. See chapter **6.3**.

3. Main ingredients: ecosystem components, pressures, sensitivities

The main contents of WIO Symphony are ecosystem components (nature values), pressures from human activities, and sensitivity scores. These have been selected by the regional and national expertise from the Western Indian Ocean through processes of workshops and questioners.

3.1 Ecosystem components

Ecosystem components represent value

Ecosystem components represent valuable parts of the marine environment. Each ecosystem component is a map in WIO Symphony. The map indicates the distribution or potential distribution of the corresponding ecosystem component. Pixels of the map have values from 0 to 100, where 0 means that the pixel is not important for the ecosystem component and 100 means that the pixel is fully covered with, or in other ways highly important for the ecosystem component.

0 = not important

100 = fully covered or highly important

WIO Symphony includes 52 ecosystem components, available as modelled data layers (maps) in the tool. They are split into two categories: *habitats* and *taxa*.

Habitats represent environments - taxa represent important animals

Habitats refer to environments and include all animals and plants typically associated with this environment. For instance, seagrass meadows with all associated invertebrates, fish, turtles, birds, and mammals. The original method by Halpern *et al.* (2008) includes only habitats. Likewise, in WIO Symphony only habitats are included by default.

Taxa refers to groups of animals (or other organisms). It can be types of fish or mammals who are considered important from a social, economic, cultural or ecological perspective and which needs to be addressed separately. Taxa are not pre-selected for cumulative analyses in the default mode of the WIO Symphony, but can be easily added either together with the habitats, creating a mixed model, or in isolation for studies on the impact on those specific taxa.

Tropical and temperate ecosystem components

Some ecosystem components are also divided into tropical and temperate habitats. This is because tropical and temperate environments may differ considerably in their sensitivity to various pressures. When using the tool, it is often reasonable to include both categories since solely tropical areas will not contain any data of temperate habitats, and vice versa. In transition areas, both tropical and temperate ecosystem components are present.

3.2 Pressures

Human pressures are emissions, harvest, or changes caused by human activities. Each pressure is a map in WIO Symphony. The map indicates the intensity of the pressure, such as fishing intensity or underwater noise level. Values range from 0 to 100 in each pixel, where 0 indicates zero or insignificant levels of the pressure, whereas 100 indicates very high intensity.

0	= zero or insignificant
100	= defined maximum intensity or highest plausible intensity

Typically, pressure value 100 is equivalent to a defined and quantifiable level of pressure, such as “a day-frequent exposure to 140 dB re 1 μ Pa underwater noise level at 200 Hz”. WIO Symphony contains 48 different pressures, whereof most, but not yet all, are represented as pressure data layers (maps) in the tool.

3.3 Sensitivity scores

Sensitivity scores denote how sensitive each ecosystem component is to each pressure. The sensitivity is a scale from 0 to 1 with six pre-defined categories. Value 0 indicate no or insignificant effect, while 1 means complete destruction of the habitat or taxa individuals. Between these extremes are stress, injury and occasional death or partial destruction.

0	= insignificant effect
1	= complete destruction

With 52 ecosystem components and 48 pressures, a total of nearly 2 500 sensitivity scores are needed ($52 \times 48 = 2\,496$). With such a great number of sensitivities, judgement of experts is needed as it is not deemed possible to rely solely on published literature.

The sensitivity scores are derived from an expert panel of the Western Indian Ocean including around 50 scholars and managers, whereof about half have contributed more actively.

3.4 Uncertainties

The WIO Symphony tool is meant for use at screening level and for strategic decision making. The uncertainties in data and limitations of the method should always be remembered.

The underpinning models, currently 88 pieces, are based on open-source data. The basic method (chapter 2) does not account for:

- temporal variation
- connectivity
- food-web interactions

WIO Symphony is not suitable for use at high spatial resolution and does not replace the need for detailed mapping and in-depth studies.

3.5 Tool implementation and access

WIO Symphony tool is implemented in Nairobi, Kenya, at the server of the Nairobi Convention. All member states of the convention, and invited partners, have access to the tool and data. Temporary or permanent log-in to the implemented tool can be achieved by the Nairobi Convention Secretariat, and underpinning data are open-source and accessible. The tool software code is also open source and available for anyone at GitHub.

4. Before using the tool

4.1 Use WIO Symphony alongside other methods

WIO Symphony is one tool of many, and only addresses environmental impact. It does not include socio-economic parameters or sector conflicts. It also does not replace or reduce the need for ordinary environmental impact assessments (EIA) and scientific studies. It solely gives you a valuable overview, to better see the bigger picture and to frame more detailed studies.

The smaller area you choose to analyse, the less accurate overview you get from the analysis, due to the very large grid spanning approximately 9 percent of the world's ocean and the pixel size of 1 x 1 km. This should be remembered in relation to the scale you are working with. For example, a result from a small bay should be interpreted with high caution.

4.2 Carefully consider what to analyse: Kind of analysis and what to include

Before analysing, prepare carefully for which pressures and ecosystem components you wish to include. Default is a good start, but you may wish to tailor make the analysis in some cases. Also, consider what sort of alternative analysis you may wish to conduct. You can choose between different algorithms and you can make full cumulative analysis or focus on one-over-many (MINISYM). You may also search for more suitable locations by adding specific pressures everywhere and see where it makes less harm. Most probably, if you work on MSP, you may want to compare different scenarios that you first carefully simulate on the basis of your planning framework. Additionally, several kinds of well-organised analyses will often improve understanding. Make sure to re-name your scenarios to keep track of them along the way.

4.3 Constructive critique

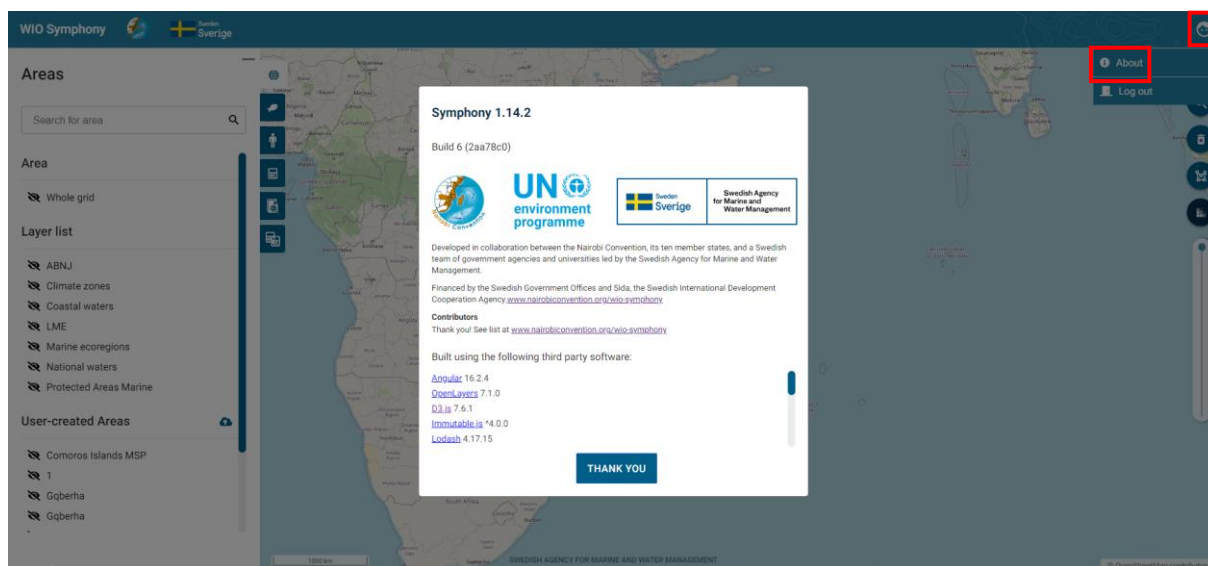
Constructive critique improves the quality and transparency of WIO Symphony. Data layers in the tool will always have **room for improvement**. The WIO Symphony team urge you as users of the tool to come with input on improvements, whether it is something specific such as a data layer within your expertise, or improvement of the tool itself. Several data layers were constructively criticised during first tests and tutorials. See the table below of examples of critique that have been revised.

Data layer	Critique	Action
Algae farming	Data accidentally include both algae farms and mariculture	Revised in April 2023
Mariculture	Not populated with data (see above)	Revised in April 2023
Cold coral reef	Depth limit is currently too shallow (40 m), to be moved to deeper colder water	Revised in April 2023
Penguin feedground and fur seals	Models erroneously extend far into tropical waters	Revised in April 2023
Whale shark	Unreliable peak by Cape town	Revised in April 2023
Baleen whales	Missing available data	Revised in April 2023

5. User manual

This manual version (November 20, 2023) is based on the software *version 1.14.2*. This manual is an updated version of the previous one from November 30, 2022, which was based on the software *version 1.6.0*. This manual will be updated over time alongside the development of the tool.

You find the information of the current software version under the **About** tab, located under the user symbol.



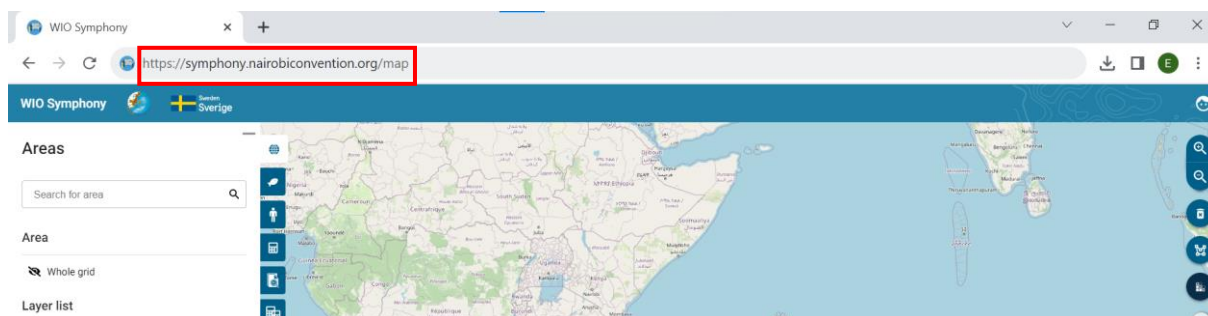
5.1 Important notes before composing Symphonies

Web browser can matter

The web browser can matter for the tool's performance. If your screen or the functionality appears wrong or incomplete, please **try another browser**. Google Chrome typically works.

Refresh page cache can help

Whenever something does not work, try to refresh the web page with deleted cache. Refresh the page, either by **ctrl + shift + R** or **ctrl + F5**. This is always recommended when using WIO Symphony again after periods of inactiveness. By doing this, you make sure recent updates to the tool are incorporated to your analysis. This is especially important when you want to start over or begin a new analysis.



Smaller areas – better when you practice

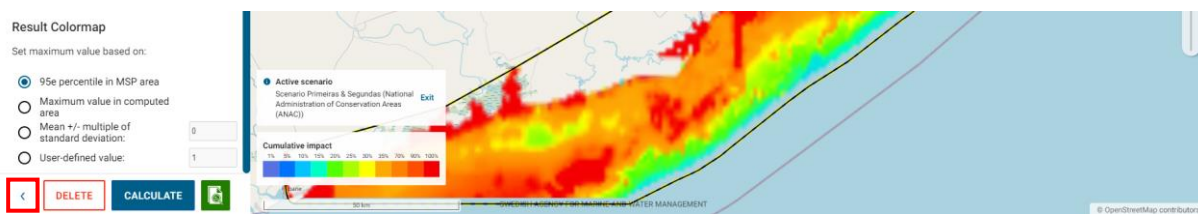
Analysing the *Whole grid* or other very large areas takes time and the results occupy disk space. Stay with **smaller areas when practicing**.

Customize colour scale for clarity

The colour scale for cumulative impact goes from transparent and blue to orange and red. The default setting is that red colour corresponds to 90-100% of the maximum cumulative impact value in your analysis. If you analyse across a large area containing both coastal and offshore water, it is likely that much of the area will remain transparent. This is because more happens in coastal shallow water and the combined scores are high compared to far offshore. You can get a more interesting image by **customizing the colour scale**. The colour scale is relative and will not affect your results. See chapter 5.5 for further details of you customization options.

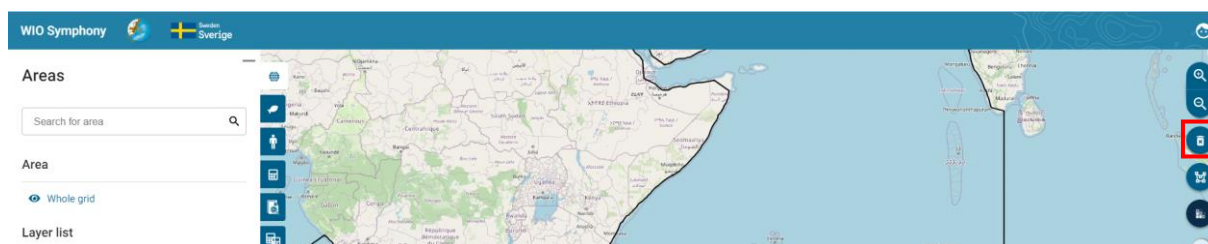
The return symbol takes you to main menu

When working in a scenario or calculation, you sometimes might feel stuck to those menus. The blue left-pointing arrow in the bottom left corner will **take you back to the main menu**.



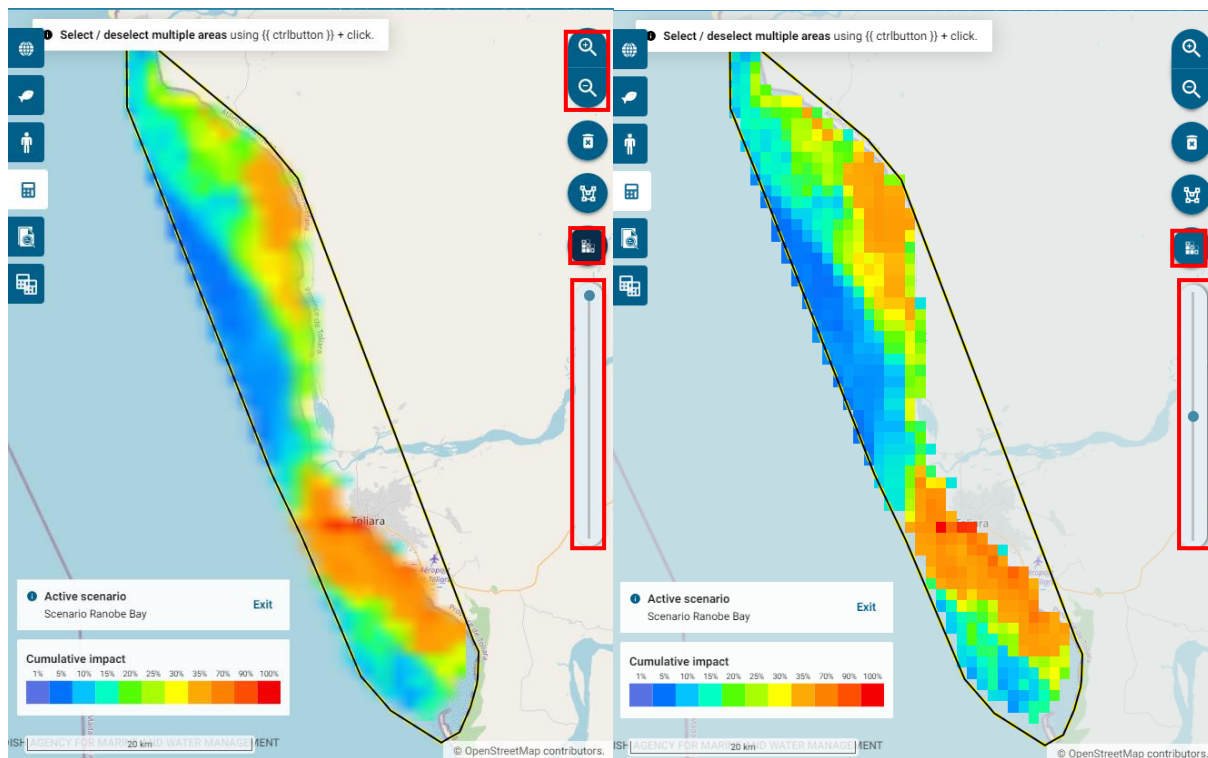
Clear the map

Clear off the colour map by **pressing the bin symbol** to the right, below the magnifier glasses.




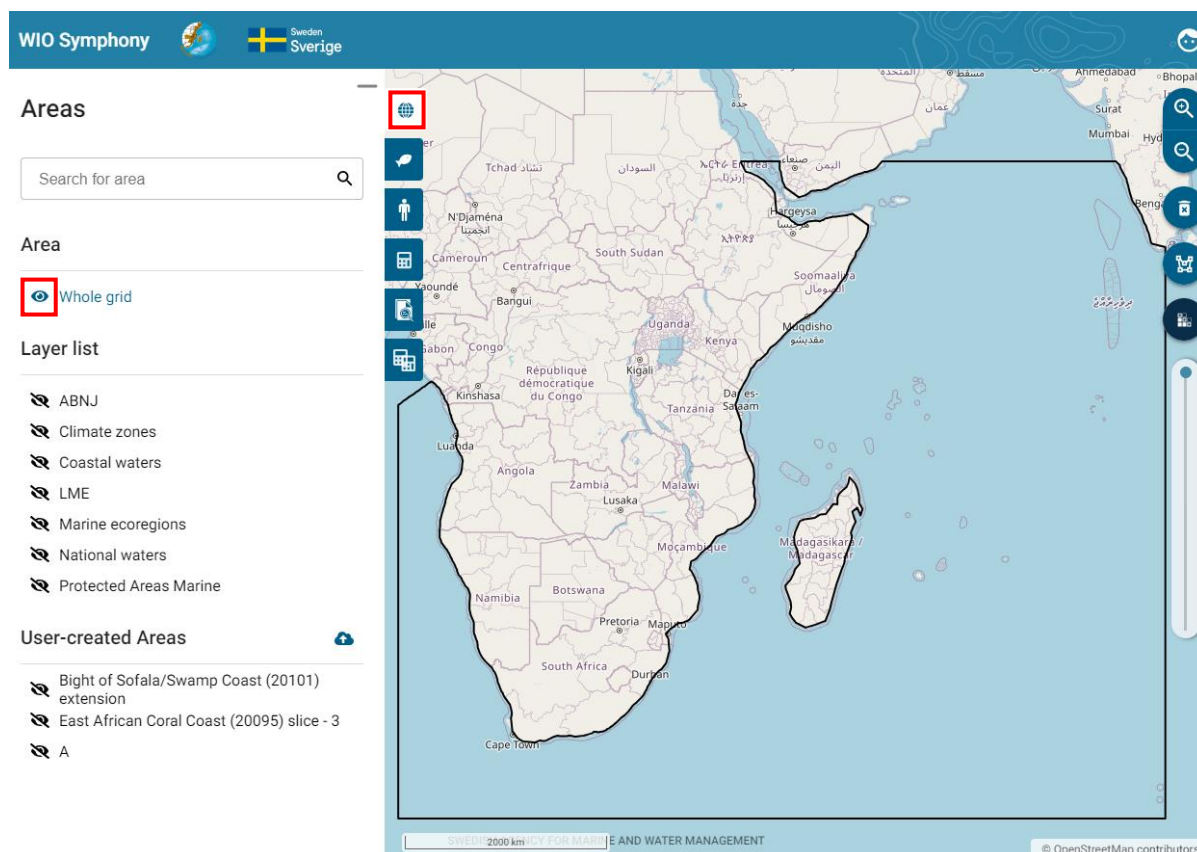
Zoom, Edge smoothing and transparency

Zooming in/out on the map is possible by scrolling the mouse wheel, or use the magnifier glasses. Pixel/edge smoothing (anti-aliasing) can be toggled on or off in the map overview by clicking the pixel symbol below. This makes the pixels smoothed or exact. A bar that sets the transparency of the background map is adjustable on the bar below.



5.2 Boundary polygons

The main page seen below comes up when you log in to the tool, or by moving back to the *Areas* tab (the globe symbol). Boundary polygons are key to all analyses. WIO Symphony comes with a number of pre-loaded shape files that can be used. You activate a boundary polygon by **unticking the eye**  symbol.



The *Whole grid* area is the full WIO Symphony grid. This grid, or *bounding box*, spans the Western Indian Ocean and part of the South-Eastern Atlantic. Calculations in this *Whole grid* area are computer intense and will take up a lot of space on your user's memory once calculated. Most analyses better target smaller areas. Pre-loaded polygons include:

Natural boundaries

- *Climate zones* (tropical, temperate)
- [LME](#) (large marine ecosystems)
- [Marine ecoregions](#) (from Spalding *et al.* 2007)

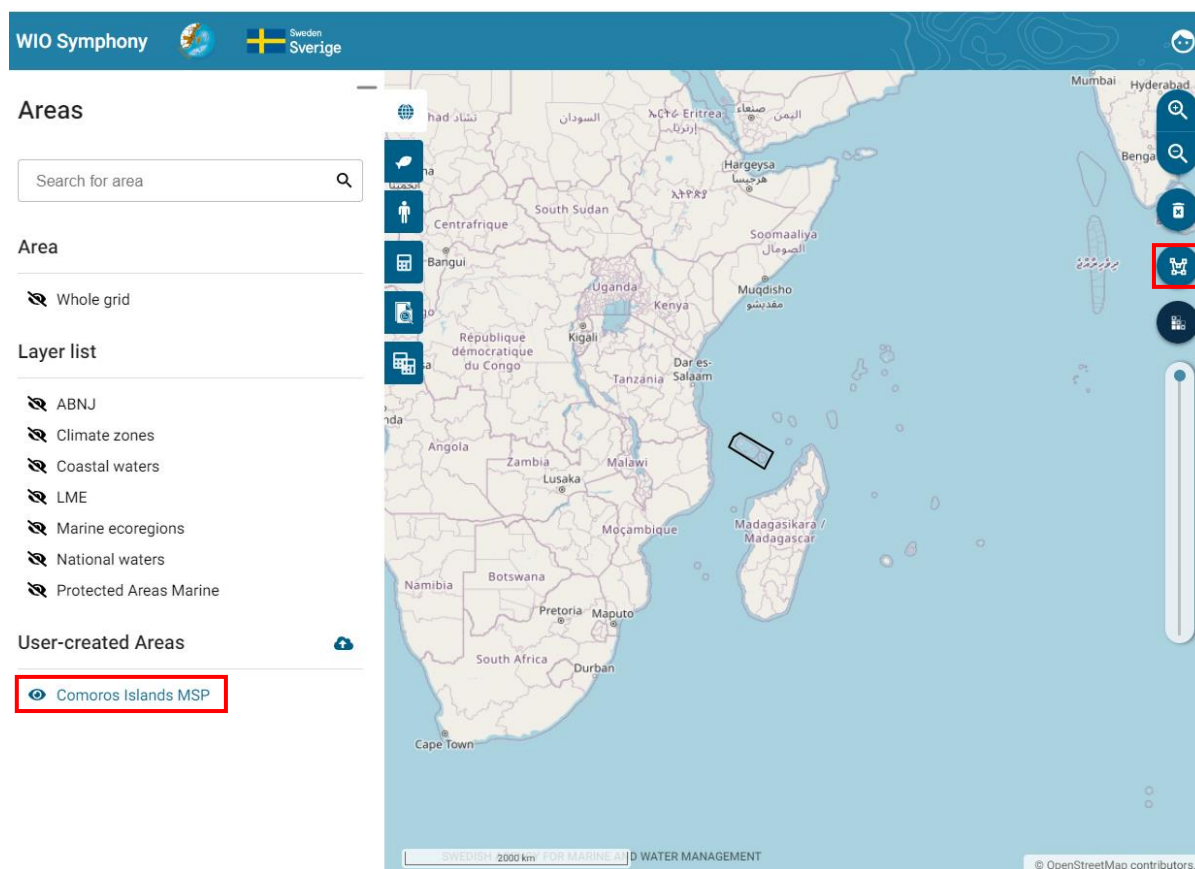
Other

- *ABNJ* (Areas Beyond National Jurisdiction)
- *National waters* (all water except ABNJ)
- *Coastal waters* (coastline +2 nautical miles).

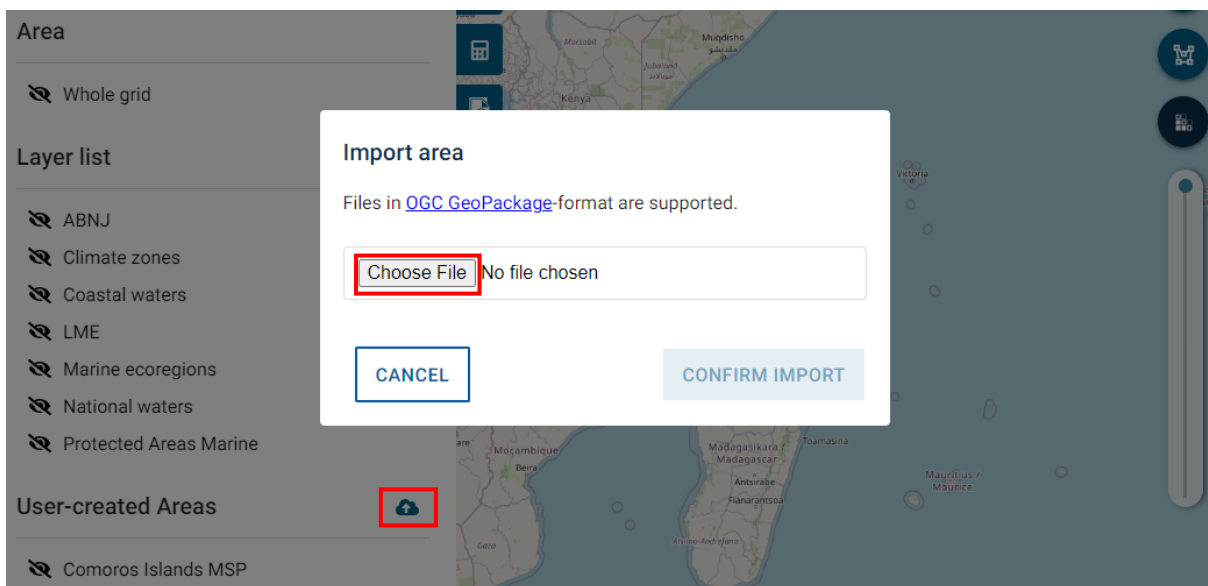
[Protected Areas Marine](#) (these areas partly but not fully correspond to existing MPAs)

You may draw your own boundary polygons by **using the draw-polygon button**. Note that you can click on *land* or outside of the *Whole grid* area when drawing polygons. However, since the tool only have data within the *Whole grid*, the areas of your polygon that are outside the grid will

be empty when calculating, so at least one part of your polygon has to be within the *Whole grid*. Your created polygon will be saved under *User-created Areas*.




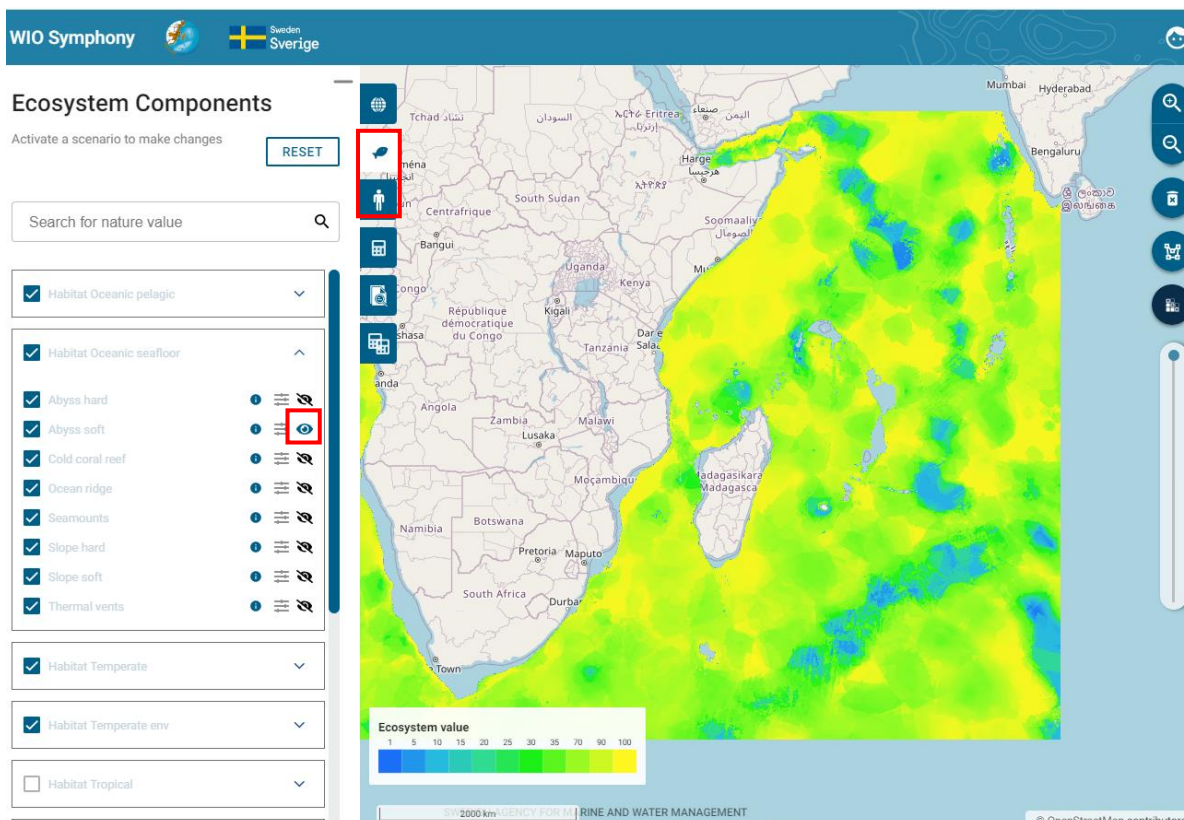
It is also possible to upload new boundary polygons using the **upload new area** symbol. Note that your shape file has to be in a geopackage (gpkg) format. However, a function that allow imports of shape files directly is being developed. Similar to drawing your own polygon directly in the tool, your imported polygons will not be cropped to the *Whole grid*, but the tool will only calculate pixels within the grid. However, it is encouraged to crop your polygons before importing them in to the tool. This is solved by **cropping your shape file with the WIO Symphony boundary box** (same extent as the *Whole grid*). The boundary box is available and can be requested from wiosym@nairobi-convention.org.



You click on a polygon to activate it for analysis. You start the analysis by **clicking inside the polygon** → **move to the Scenarios tab** → **press the plus + symbol**. See chapter 5.5.


5.3 View data layers


A total of 52 ecosystem components and 48 pressures are listed in the WIO Symphony tool, whereof 88 have been modelled and are available as data layers (maps). Clicking on the **ecosystem component** tab lets you view the different habitats and taxa. Similar, the **pressures** tab lets you view the pressures categorised by sector. **Untick the eye**  **symbol to view the data.**

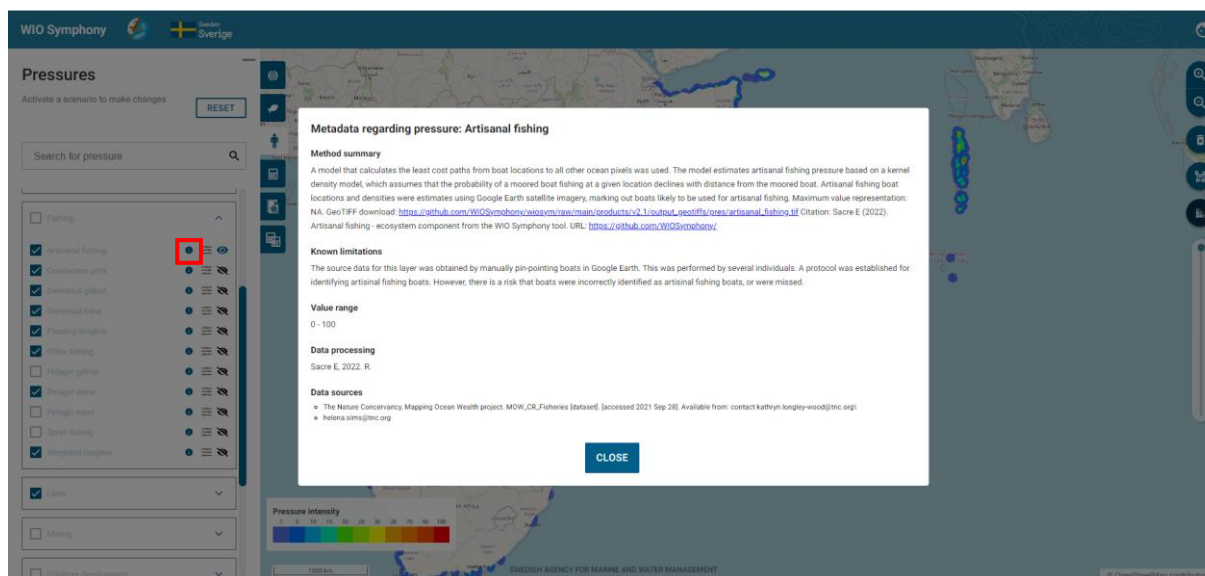


Some layers are still empty, but can be included in analyses, nonetheless. Empty layers are:

Ecosystem components	Pressures
Mesophotic coral	Invasive species
	Pelagic gillnet
	Pelagic trawl
	Sport fishing
	Seabed mining
	Impulsive noise
	Infrastructure
	Renewable energy
	Oilspill risk
	Shark control
	Research sampling

It is recommended to **close the data display again** (tick the eye  symbol) before moving on, otherwise you might be swamped by many open data layers displayed at the same time. If this happens it is often easiest to simply refresh the browser and start over.

A brief summary of metadata and data sources is available. **Press the info  symbol** by each ecosystem component or pressure. The dialog box provides a method summary of the layer, including a link to access that particular layer. Known limitations are stated, as well as range, processor, and sources.



The screenshot shows the WIO Symphony interface. On the left, the 'Pressures' panel lists various layers. The 'Artisanal fishing' layer is highlighted with a red box around its eye icon. A modal dialog box is open, displaying metadata for 'Artisanal fishing'. The dialog box contains the following information:

- Metadata regarding pressure: Artisanal fishing**
- Method summary**: A model that calculates the least cost paths from boat locations to all other ocean pixels was used. The model estimates artisanal fishing pressure based on a kernel density model, which assumes that the probability of a moored boat fishing at a given location declines with distance from the moored boat. Artisanal fishing boat locations and densities were estimated using Google Earth satellite imagery, marking out boats likely to be used for artisanal fishing. Maximum value representation: NA. GeoTIFF download: https://github.com/WIO2/mehony/wio2ym/raw/main/products/v2.1/output_geoTIFFs/press/artisanal_fishing.tif Citation: Sacre E (2022). Artisanal fishing - ecosystem component from the WIO Symphony tool. URL: <https://github.com/WIO2/mehony/>
- Known limitations**: The source data for this layer was obtained by manually pin-pointing boats in Google Earth. This was performed by several individuals. A protocol was established for identifying artisanal fishing boats. However, there is a risk that boats were incorrectly identified as artisanal fishing boats, or were missed.
- Value range**: 0 - 100
- Data processing**: Sacre E, 2022. R.
- Data sources**:
 - The Nature Conservancy, Mapping Ocean Wealth project. MDW_CS_Fisheries [dataset]. [accessed 2021 Sep 28]. Available from: contact.kathryn.borgley-wood@nrc.org
 - helena.sims@nrc.org

The dialog box has a 'CLOSE' button at the bottom.

Some pressures and ecosystem components are listed but still not available (they are unticked). This is either because they are expected to be modelled and uploaded soon, or because they may be important for scenario-building (for example, *Renewable energy* installations or *Oilspill risk*). See chapter 5.8.

The screenshot shows the WIO Symphony software interface. On the left, the 'Pressures' panel is visible, containing a search bar and several categories of pressures. The 'Oilspill risk' checkbox is highlighted with a red box. The main area is a map of the Indian Ocean region, showing various countries and islands. The interface also includes a 'RESET' button and a search bar for pressures.


5.4 Notes on individual data layers

Some data layers deserve **special attention**:

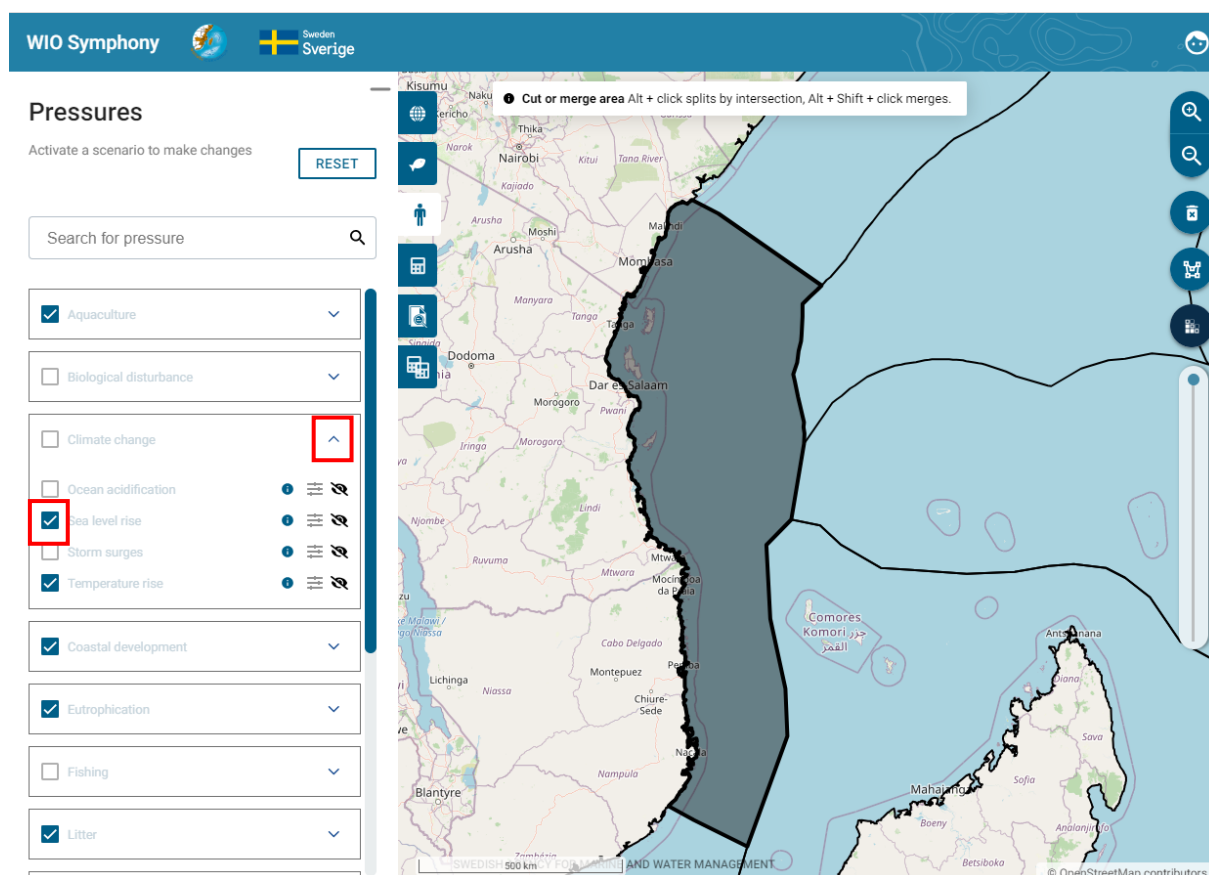
- *Seismic survey*. This pressure has strong influence when included. However, the impact is temporary and the existing data layer shows already conducted (past) surveys. Since surveys can provide lasting data, it is unlikely that a survey is repeated. The seismic surveys shown in the data layer hence refers to past, not ongoing, impact.
- *Impulsive noise*. Construction works such as pile driving can generate harmfully loud noise peaks. The pressure map is currently empty but can be populated by manually adding of constant (1-100). This pressure is temporary and should preferably be analysed alone (for example, MINISYM), typically not as part of the full model. A tip here would be to use a do an analysis of several areas, since you then can differentiate pressures within the same scenario. This could perhaps be combined with the “difference” function (“clip out” from a larger surrounding polygon) to get a realistic output.
- *Oilspill risk*. Larger oil spill is a very rare and unpredictable pressure. Like impulsive noise it is also rather temporary and should preferably not be mixed with other pressures. Oil spill analyses can however be suitable for MINISYM analyses.
- *Infauna*. This is a broad taxon that exists in all soft marine habitats. Because the habitat ecosystem components already include invertebrates per default, it may be considered double counting to run the analysis with infauna along with other. Studying impacts on infauna specifically can be done through MINISYM.
- *Mobile epifauna*. Same as *Infauna* above, but even more pronounced results if included with other ecosystem components.
- *Dugongs*. Some very rare species like dugongs have widely spread data layer. This is to mark important potential habitat rather than indicating extensive abundance of them.
- *Rays and skates*. These organisms are common and this data layer gives strong emphasis to them. Such as it can be recommended not to include this ecosystem component in general analyses with many other ecosystem components.

5.5 Calculate cumulative impact

Cumulative impact is the straight-forward estimate of all selected pressures impact on all selected ecosystem components combined.

In the ecosystem components tab and pressures tab, you choose which data layers to be included in an analysis. **Ticked data layers are selected and will be included.** This is true as long as there is a map available, which can be checked by unticking the eye  symbol.

You may wish to double-check that all your intended pressure and/or ecosystem components are selected. As you have noted, individual data layers may be selected even if the category is not ticked. This is due to some layers within the category might be available, while some are not.



You calculate cumulative impact by **selecting a boundary polygon** → **select/unselect data layers to be included** → **go to Scenario tab** → **press the plus + button** → **rename your scenario if relevant** → **press CALCULATE button.**

WIO Symphony Sweden Sverige

Scenarios

East African Coral Coast (20095)

User Scenarios

Filter scenarios by name

Scenario 2
2023-11-16 13:48

2

Scenario 1
2023-11-16 13:47

1

Select / deselect multiple areas using ((ctrlbutton)) + click.

Cut or merge area Alt + click splits by intersection, Alt + Shift + click merges.

WIO Symphony Sweden Sverige

Test East African Coral Coast

2023-11-16 15:08

Scenario areas

East African Coral Coast (20095)

Scenario Changes

No scenario changes

Make changes in the Ecosystem or Pressures tabs.

Algorithm

Cumulative impact

Rarity-adjusted cumulative impact

Result Colormap

Set maximum value based on:

95e percentile in MSP area

Maximum value in computed area

Mean +/- multiple of standard deviation: 0

DELETE CALCULATE

Select / deselect multiple areas using ((ctrlbutton)) + click.

Active scenario Test East African Coral Coast Exit

The resulting map indicates where in your area cumulative impact is relatively high (red) and relatively low (transparent). Mind that the number of included ecosystem components are often fewer offshore, making it hard to compare coastal and offshore areas directly based on colour. It can be reasonable to look for hotspots, both coastal and offshore, even if offshore hotspots are only mediocre colour heat.

Options for cumulative impact calculations

This above-described procedure runs a default analysis, but several options beyond default settings.

What to include? In default mode, habitats are selected, but not individual taxa. Analysing only habitats is the most balanced model and similar to the original method by Halpern *et al.* This can be changed by ticking the empty boxes for taxa of your choice, such as *Tuna and billfish*. Or *Mammals, Birds, Turtles* etc.

Algorithm. Cumulative impact is the default algorithm. See chapter 6.3 for the alternative rarity-adjusted cumulative impact, which may be suitable from a conservation viewpoint.

Sensitivity Matrix. The default sensitivity matrix is the final revised product of the WIO expert panel (*WIO nov-2022 Revised*). The panel includes a number of regional experts following a protocol including large group discussion (50 experts), anonymous scoring (19 experts), and review (workshop and open review).

By selecting *User-defined matrix* and *Edit Matrix* it is possible to manually change the sensitivity to any specific combination of pressure and ecosystem component, motivated by new knowledge or simulation of management measures. See chapter 6.5.

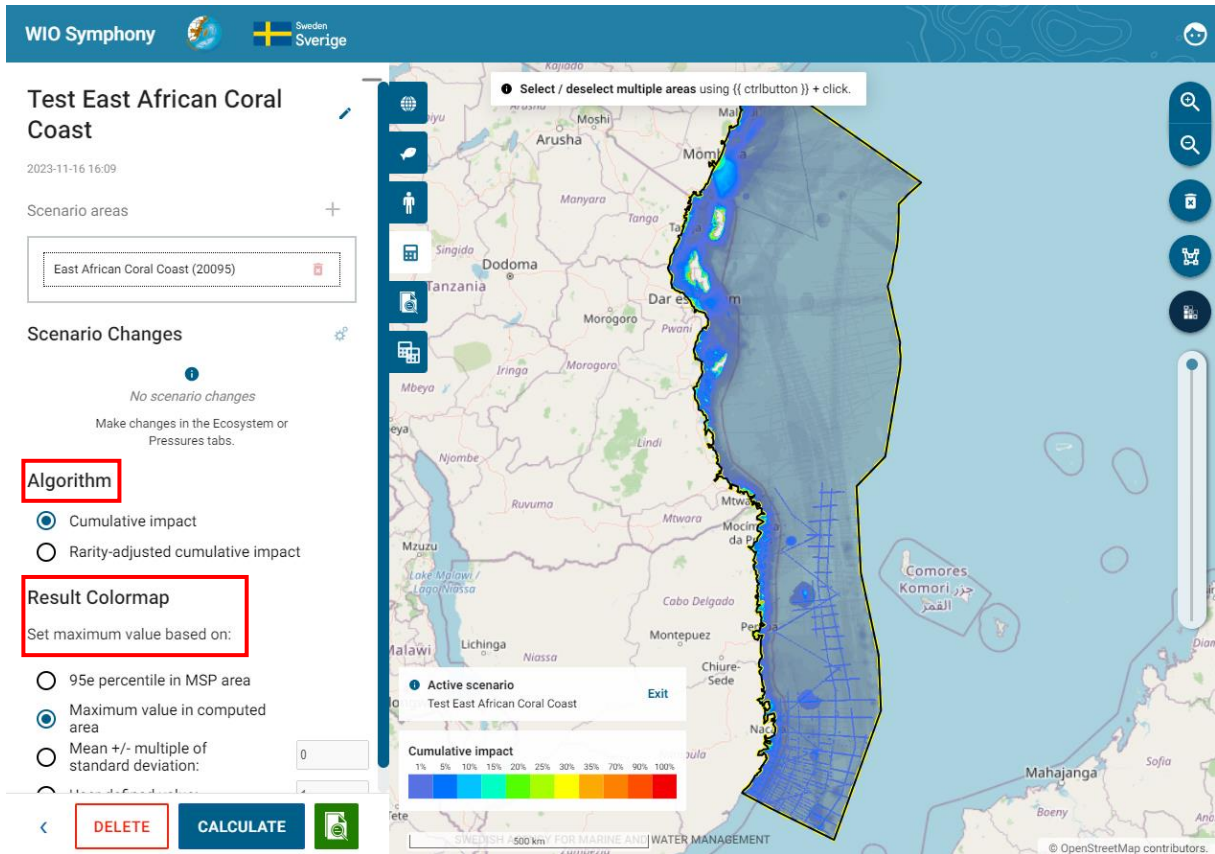
Result Colourmap. Result of a cumulative impact calculation is a unit less, relative, index which can be called an impact score. The resulting heat map simply display this index from transparent and blue to orange and red. The tool's default colour scale setting is per automatic the *95e percentile in MSP area*. However, it is recommended to use *Maximum value in computed area* (your selected boundary polygon) as default for your calculation.

If selecting the *95 percentile in MSP area*, the colour scale will scale towards the 95 percentile of the fully loaded *Whole grid* scenario instead of your maximum. Since the *Whole grid* contain a lot of offshore water, the 95 percentile is a rather low value. This typically generates more colourful, but less detailed result maps.

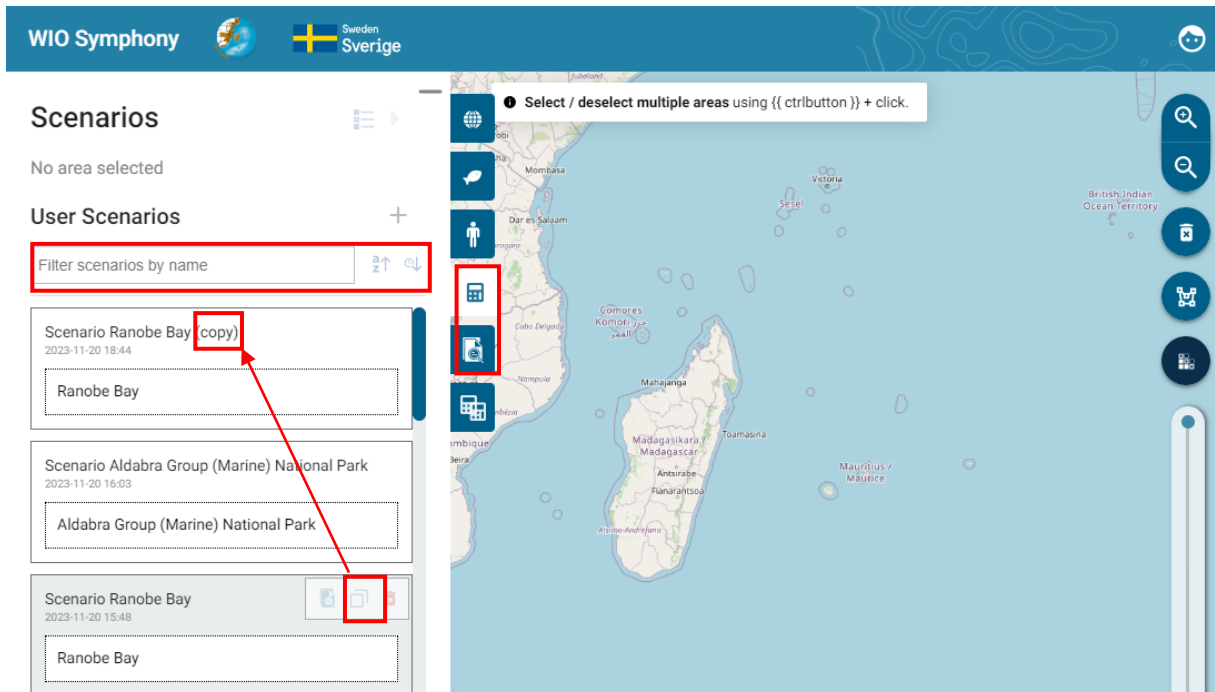
If selecting *Mean +/- multiple of standard deviation*, the result colour map sets its max value to the dataset means +/- some user-defined multiple of the standard deviation.

If selecting *User-defined value*, you will assign a customized value for the colour scale maximum. This can be recommended when demonstrating results for others or for increasing the optical resolution in either too-red areas (impact hotspots) or transparent areas (low-impacted offshore areas). You may want to run a primary analysis and then read the report to find reasonable numbers for the customized colour scale, such as using the average value or a certain percentage of the maximum value. You may also set the colour scale in relation to environmental impact benchmarks.

Changes to the result colour map do not affect the impact index or numbers. It only changes the scale of colours. Changing colour scales can be done sequentially in your GIS program after downloading the resulting map from WIO Symphony. See chapter 5.6.



A side note regarding scenarios is that there is an option to copy a previous scenario under the *Scenario* tab. By pressing the *Copy scenario* button, a copied scenario will be generated on top of the list.



Above the list of scenarios under the *Scenario* and *Previous calculations* tabs, you can filter your scenarios by name and sort by name or date, making it easier to find the scenarios you are looking for.

5.6 Cumulative impact Calculation Report

All analyses create a *Calculation report*. The report provides both an overview and a detailed result.

Impact map and basic statistics

The scenario name and impact colour map are shown in the upper left corner. The same resulting map can be exported (downloaded) as a raster file by pressing *EXPORT AS GEOTIFF*.

In the upper right corner, you find applied versions, settings, and summary statistics for the report. *Calculated area* is crossed because the WIO Symphony projection in the data raster does not allow to calculate the surface measurement programmatically.

Calculation Report

Test East African Coral Coast (5)

Baseline version: BASELINE2023-v2
 Algorithm: Cumulative impact
 Result colorscale: Maximum value in area

Cumulative effect

Total:	619,038,687
Average:	1,311,344.8
Min:	0
Max:	142,675
Std. Dev.:	3,918,218.2
Calculated-area:	N/A

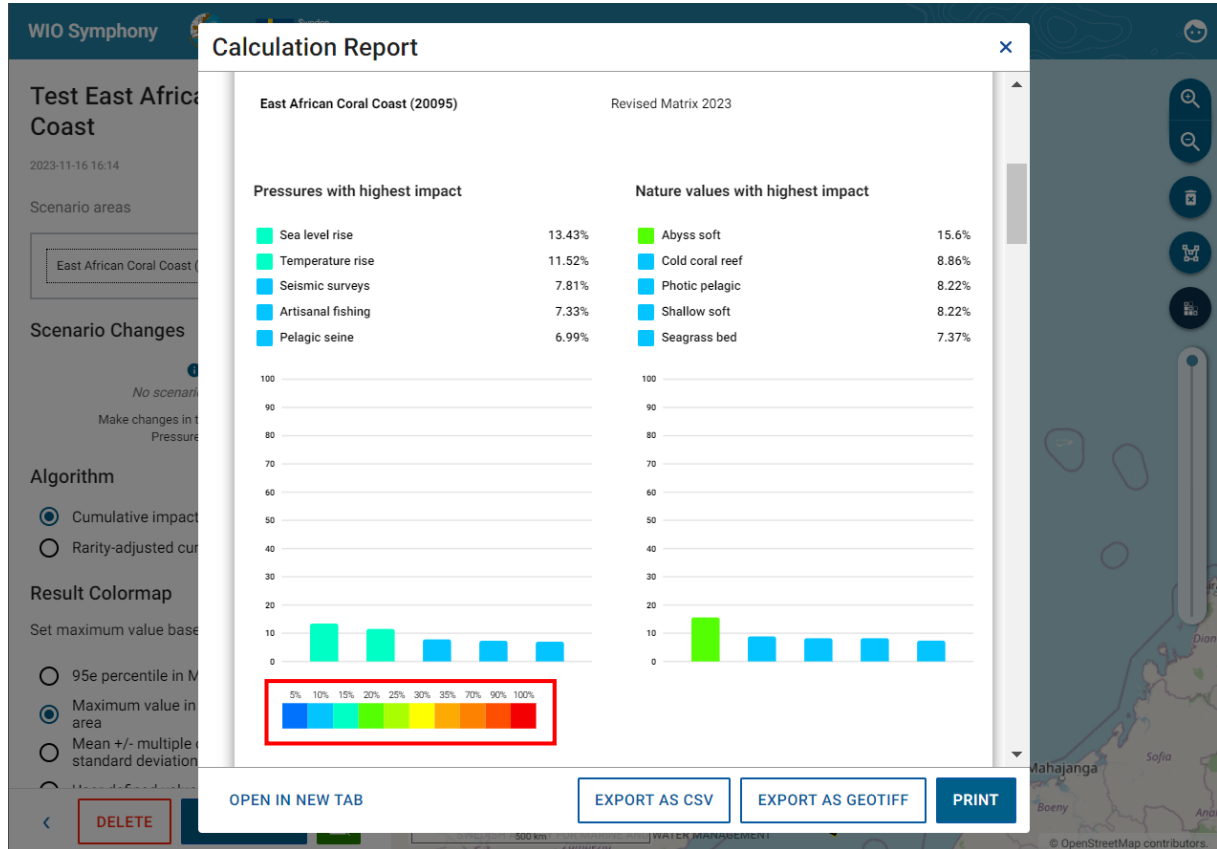
Sensitivity matrix

East African Coral Coast (20095) Revised Matrix 2023

OPEN IN NEW TAB EXPORT AS CSV EXPORT AS GEOTIFF PRINT

Top-5 summary table

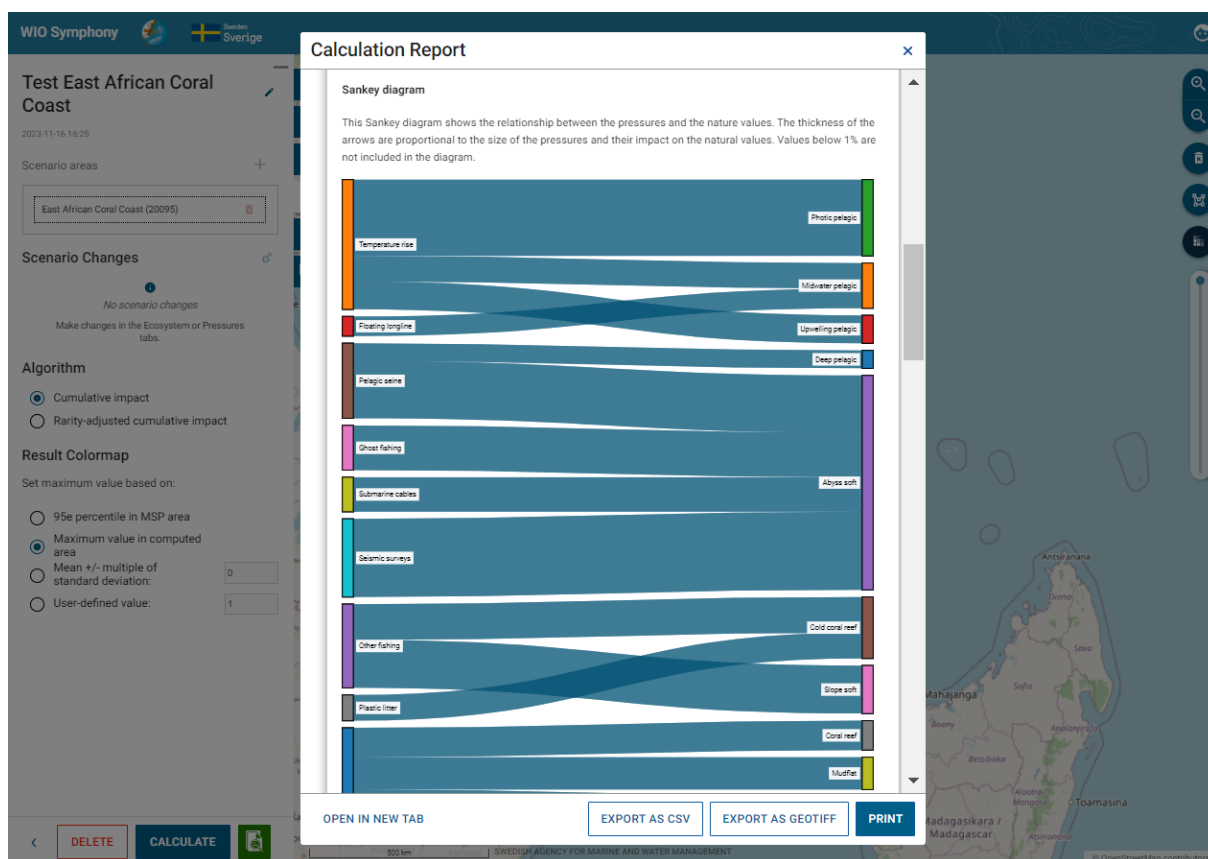
A summary of the top-5 contributing pressures and the top-5 ecosystem components affected are provided as numbers and bars. Note that the colour legend is also related to the *Colourmap* (the colours match).



Sankey diagrams show contribution flows

The report also provides a Sankey diagram, which gives an informative illustration of the main (largest) impact flows. This means that you can see how relatively much each major pressure (left axis) contributes with environmental impact to each of the main impact-receiving ecosystem components (right axis). Wide flows indicate that the impact is proportionally large.

The Sankey diagram allows you to get a good understanding of the details. You can see which of the pressures that dominate the impact on each ecosystem component. Precise numbers are given when you hover with your mouse across the impact flows. Keep in mind that uncertainties are large and numbers should be interpreted as orders of magnitude, rather than to decimals.



Scenario parameters and statistics

The report provides *Scenario Parameters* (only relevant after scenario simulations) and a table showing the details of contributions and receiving numbers behind the above diagrams. In a later scenario where you have made pressure changes, they will be shown under *Scenario Parameters*. Note in the red box that if you have made general or area specific changes, they will be shown under here, as well. These numbers, in even more detail, can be downloaded and analysed separately by pressing the **EXPORT AS CSV** button.

Scenario Parameters

COMMON CHANGES

Piers and docks Percent change with **+43%**

AREA-SPECIFIC CHANGES

East African Coral Coast (20095)

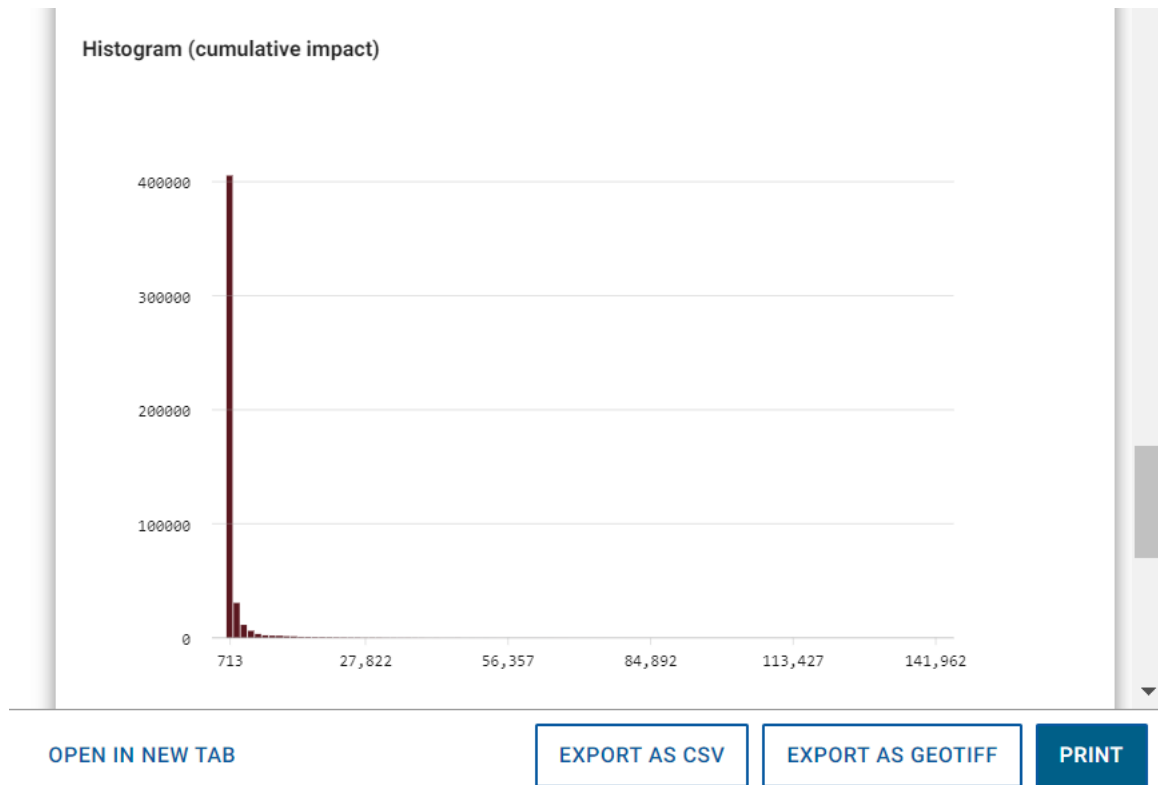
Algae farming Percent change with **+49%**

Impact per pressure			Impact per natural		
	CUMULATIVE	% OF TOTAL		CUMULATIVE	% OF TOTAL
AQUACULTURE			HABITAT OCEANIC PELAGIC		
Algae farming	12,784,878	2.07%	Deep pelagic	16,337,990	2.64%
Mariculture	22,106,207	3.57%	Midwater pelagic	22,601,866	3.65%
BIOLOGICAL DISTURBANCE			Photic pelagic	50,893,565	8.22%
<i>Invasive species</i>			Upwelling pelagic	19,150,586	3.09%
CLIMATE CHANGE			HABITAT OCEANIC SEAFLOOR		
<i>Ocean acidification</i>			Abyss hard	11,201,182	1.81%
Sea level rise	83,133,021	13.43%	Abyss soft	96,553,778	15.6%
<i>Storm surges</i>			Cold coral reef	54,823,653	8.86%
Temperature rise	71,323,441	11.52%	Ocean ridge	1,313,280	0.21%
COASTAL DEVELOPMENT			Seamounts	5,378,245	0.87%
Dredging	19,653,682	3.17%	Slope hard	6,199,025	1%
Dumping	7,735,596	1.25%	Slope soft	41,244,379	6.66%
Hydrology change	9,375,768	1.51%	Thermal vents	0	0%
Industrial pollution	145,381	0.02%	HABITAT TEMPERATE		
Land reclamation	4,334,774	0.7%	Algae bed (temp)	0	0%
Light pollution	1,995,997	0.32%	Kelp forest (temp)	0	0%
Piers and docks	685,236	0.11%	Mudflat (temp)	0	0%
Ports	6,206,180	1%	Penguin feedground	0	0%
			Salt marsh (temp)	0	0%
			Seagrass bed (temp)	0	0%

EXPORT AS CSV EXPORT AS GEOTIFF PRINT

Histogram of impact scores

The report histogram shows a number of pixels (y-axis) across different levels of impact score (x-axis). Move your mouse along the bars to inventory check numbers. This can be useful information when customizing the colour scale or correlating impact scores to environmental impact benchmarks. In areas with both coastal areas and vast offshore areas, the histogram will show a strong L-shape.



End of report

Lastly, at the end of the report, it will provide further information of when the report was created, how WIO Symphony was created, how to cite, the license, as well as the people behind the tool and its contributors.


WIO Symphony



Calculation Report

Date and time: 2023-11-16 16:07

Calculations of the cumulative environmental impact is made using the Swedish Agency for Marine and Water Management's application
For more information about Symphony please visit <https://www.havochvatten.se/en/swam/eu-international/marine-spatial-planning/sy>

Cite as:
WIO Symphony
version 1.14.2
Nairobi Convention

License:

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Share and adapt, but always give appropriate credit and share under this same license, etc – see full license for terms and conditions.

Developed in collaboration between the Nairobi Convention, its ten member states, and a Swedish team of government agencies and universities led by the Swedish Agency for Marine and Water Management.

Financed by the Swedish Government Offices and Sida, the Swedish International Development Cooperation Agency.
www.nairobiconvention.org/wio-symphony

Contributors
Thank you! See list at
www.nairobiconvention.org/wio-symphony

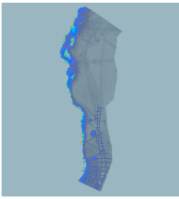
DELETED **OPEN IN NEW TAB** **EXPORT AS CSV** **EXPORT AS GEOTIFF** **PRINT**

A final function in the reports is the **PRINT** button. This gives you the option to print or save the report as a PDF, for example.

11/16/23, 4:43 PM

WFO Symphony

Test East African Coral Coast (5) In collaboration with:



Baseline version: BASELINE2023-02
Algorithm: Cumulative impact
Result color scale: Maximum value in area

Cumulative effect

Total:	619,238,887
Average:	1,211,3448
Min:	0
Max:	142,679
Std Dev:	3,918,2182
Collected areas:	10/18

Sensitivity matrix

East African Coral Coast (20095) Revised Matrix 2023

<https://symphony.naibioconvention.org/map> 1/6

Print

6 pages

Destination: Save as PDF

Pages: All

Pages per sheet: 1

Margins: Default

Options: Headers and footers
 Background graphics

Save Cancel

© OpenStreetMap contributors.

5.7 Erase and reset

Colour maps are removed by pressing the **bin** symbol. You can retrieve the colour map again by clicking on your scenario under the *Previous Calculations* tab. If you wish to delete a scenario, press the small **red bin** symbol. To view the report again, press the **report** icon next to the red bin symbol.

The screenshot displays the WIO Symphony web application. The top navigation bar includes the logo and the text 'Sverigen Sverige'. The main interface is divided into two primary sections: 'Baseline Calculations' and 'Previous Calculations'. The 'Previous Calculations' section features a search filter and a list of scenarios. The top scenario, 'Test East African Coral Coast (5)', is highlighted with a red border, and its associated 'bin' (delete) icon is also highlighted with a red box. The map on the right shows the East African coast and Madagascar, with a 'Cumulative impact' overlay. A legend at the bottom of the map indicates the impact levels from 1% (blue) to 100% (red). The map is credited to 'OpenStreetMap contributors'.


Your selection of included data layers can be reset by returning to the pressure tab and ecosystem component tab and press the **RESET** button. Now, the default selection is restored. This **reset will also remove changes** you have done to scenario simulations (changed/added values for individual pressures).

The screenshot displays the WIO Symphony software interface. At the top left, the logo 'WIO Symphony' and the Swedish flag with 'Sverige' are visible. The main interface is divided into a left sidebar and a central map area. The sidebar, titled 'Pressures', contains a search bar and a list of pressure categories with checkboxes: Aquaculture (checked), Biological disturbance (unchecked), Climate change (unchecked), Coastal development (checked), Eutrophication (checked), Fishing (unchecked), Litter (checked), Mining (unchecked), and Offshore development (unchecked). A 'RESET' button is highlighted with a red rectangular box. The central map area shows a geographical view of East Africa, with a white dialog box overlaid in the center. The dialog box is titled 'Confirm reset' and contains the text 'Reset selected components/pressures?' with two buttons: 'CANCEL' and 'RESET'. The bottom of the map area includes a scale bar for 500 km and the text 'FOR MARINE AND WATER MANAGEMENT' and '© OpenStreetMap contributors'.


5.8 Create and analyse scenarios


A main functionality in WIO Symphony is to make changes to an area and compare the results with a baseline (no-change) scenario of the same area. Otherwise, it is possible to make two different changes to an area and compare the two.

This way, you can simulate what happens to environmental impact if a marine spatial plan (MSP) is implemented or if a management plan of a marine protected area (MPA) is followed.

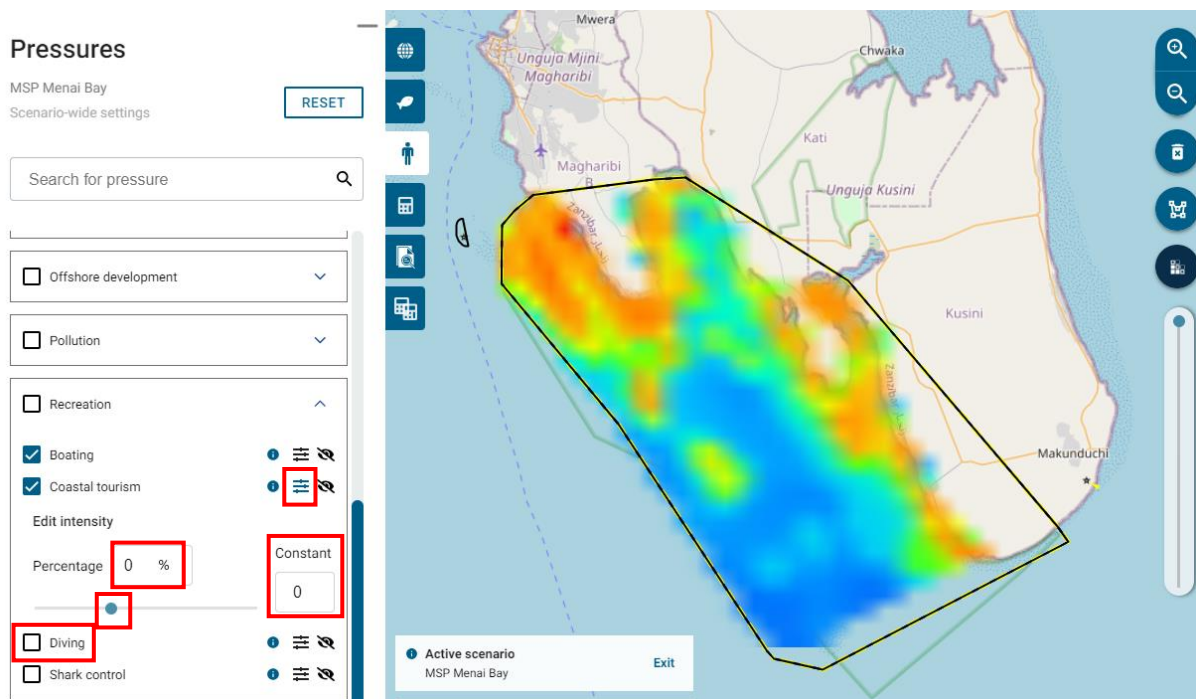
First, select an area and create a baseline scenario by **selecting** or **drawing a boundary polygon** → select which data **layers to include** (ticking) → go to *Scenario* tab → press the plus + button → rename your scenario with (for example) prefix “Baseline” on the pen  symbol → press **CALCULATE**.

Then study the *Calculation Report* or other information (such as your draft MSP plan) and develop an understanding of appropriate changes that you wish to simulate. When testing the tool, you have no restrictions. In real life, you will probably consult marine spatial planners and stakeholders, or MPA documents and stakeholders if you are working with conservation.

Press the *Return*  symbol to go back and out of the current baseline scenario you just created and analysed. You may also want to erase the baseline colour map by pressing the **bin** symbol.

Next step is to simulate the changes of pressures inside your boundary polygon, based on new ways of using the area. Such simulations can be done in four ways, first pressing the adjustment  symbol:

1. **Reducing a pressure by percentage**, meaning that the current levels of that pressure from a human activity is reduced with a specified percentage across the whole area of analysis: drag intensity percentage to the left, click the downward arrow within the percentage square or type in the percentage change you want.
2. **Adding a pressure by percentage**, meaning that the current levels of that pressure is intensified in the same places as it is currently existing, within the area of analysis: drag intensity percentage to the right, upward arrow within the percentage square or type in the percentage change you want.
3. **Completely removing a pressure**, meaning the pressure is no longer happening at all in the area: set the percentage to -100%. Note that if you untick a pressure in your scenario, but it is still in the baseline, the comparison later on will not generate a report, since it cannot compare the changes anymore.
4. **Add new pressure scores across the area**, regardless of whether the pressure already exists in the area. This increases or decreases a constant: type in a number in the *Constant* field, where the number equals the pressure intensity that will be added to every pixel in the area (value 100 means full coverage of the pressure everywhere).



Changes made in this example (see figures below):

- Increased existing *Algae farming* with +50%
- Completely banned (removed) *Dredging* and *Dumping* with -100%
- Increased *Coastal tourism* and *Boating* with +30%
- Moved out *Shipping* from the area, thus removing shipping related pressures with -100%

WIO Symphony Sweden Sverige

Pressures
MSP Menal Bay
Scenario-wide settings

RESET

Search for pressure

- Aquaculture
- Algae farming
- Edit Intensity
 - Percentage: 50 %
 - Constant: 0
- Mariculture
- Biological disturbance
- Climate change
- Coastal development
 - Dredging
 - Edit Intensity
 - Percentage: -100 %
 - Constant: 0
 - Dumping
 - Edit Intensity
 - Percentage: -100 %
 - Constant: 0
- Hydrology change
- Industrial pollution
- Land reclamation
- Light pollution

Active scenario: MSP Menal Bay

SWEDISH AGENCY FOR MARINE AND WATER MANAGEMENT

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WIO Symphony Sweden Sverige

Pressures
MSP Menal Bay
Scenario-wide settings

RESET

Search for pressure

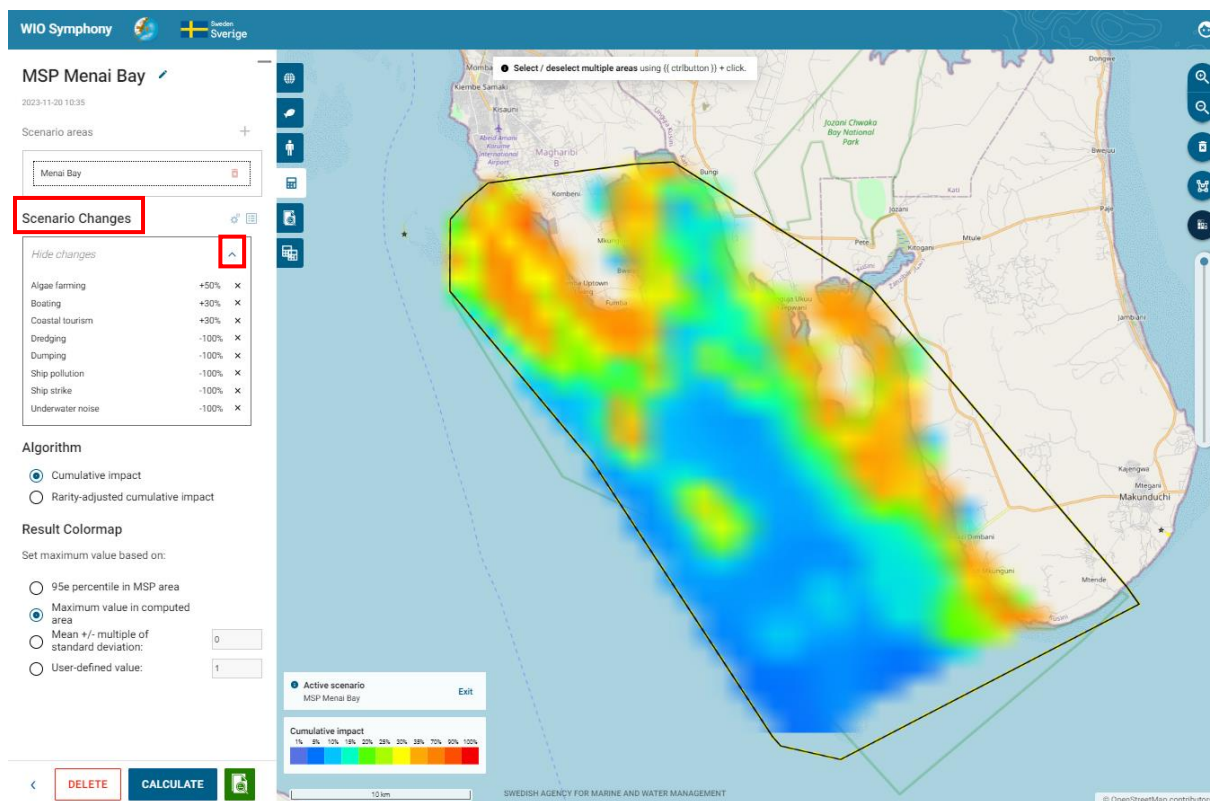
- Boating
 - Edit Intensity
 - Percentage: 30 %
 - Constant: 0
- Coastal tourism
 - Edit Intensity
 - Percentage: 30 %
 - Constant: 0
- Diving
- Shark control
- Shipping
 - Ship pollution
 - Edit Intensity
 - Percentage: -100 %
 - Constant: 0
 - Ship strike
 - Edit Intensity
 - Percentage: -100 %
 - Constant: 0
 - Underwater noise
 - Edit Intensity
 - Percentage: -100 %
 - Constant: 0


Active scenario: MSP Menal Bay

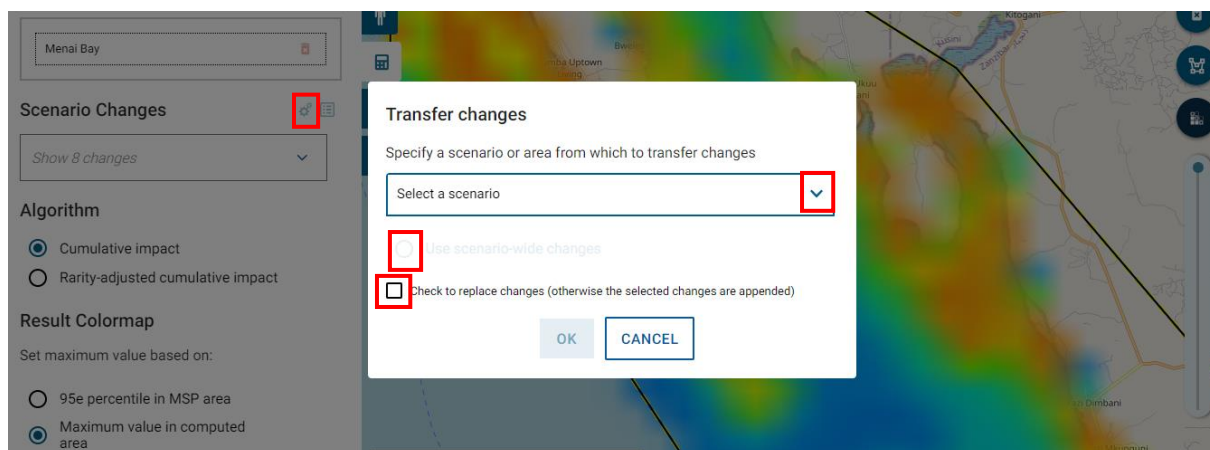
SWEDISH AGENCY FOR MARINE AND WATER MANAGEMENT


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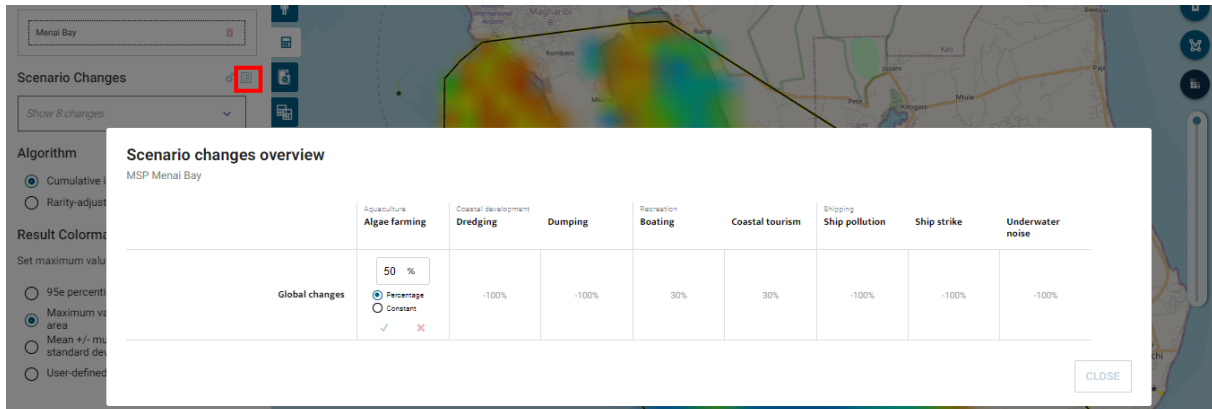
Go to *Scenarios* tab → press the plus + button → **rename** your scenario with, for example, prefix “MSP” → move to the pressures tab → make **changes to relevant pressures**, corresponding to your simulated plan → return to the *Scenarios* tab → press **CALCULATE** → have a look at the report → press the **Return** symbol to get back.




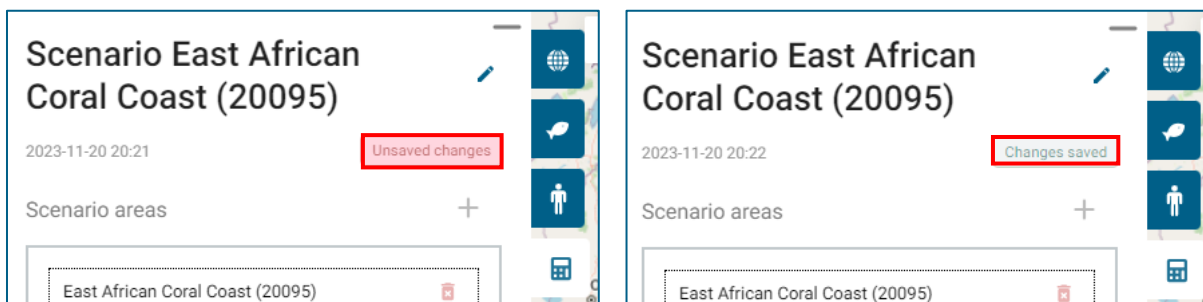
Under the *Scenario Changes*, you can show the changes you have made by pressing the arrow  button, making sure you have not missed any before calculating. This box only shows the pressures you have actually changed, and does not show the ones that are removed, since that might be many with all the pressures removed by default.



At the **cog wheel** icon, you have the option to transfer changes from an existing scenario or scenario area if you wish to apply the same ones. This is useful if you wish to do the pressure changes to different areas. Press the arrow  button to view previous scenarios with changes. The round button refers to the scenario's general changes. If a scenario is chosen with several areas, the user is provided with an opportunity to choose changes from one of those areas. If the square tick box is ticked, then it will replace all changes. So, if there are changes in the output scenario, these will be removed first. If this box is unticked, the user can add changes. Changes in the output scenario will remain, although overwritten if a change to the same pressure or ecosystem component occurs in the scenario where it is from.



On the **table icon** next to the **cog wheel**, there is a tabulated overview of all the changes made in the scenario. This intuitive table let you adjust all the changes you have made, similarly like previously back at the *pressures* tab, however, without going back there. By clicking the pen  button, you may adjust both the percentage increase/decrease and constant of the changes you made before, which is especially helpful in complex scenarios.



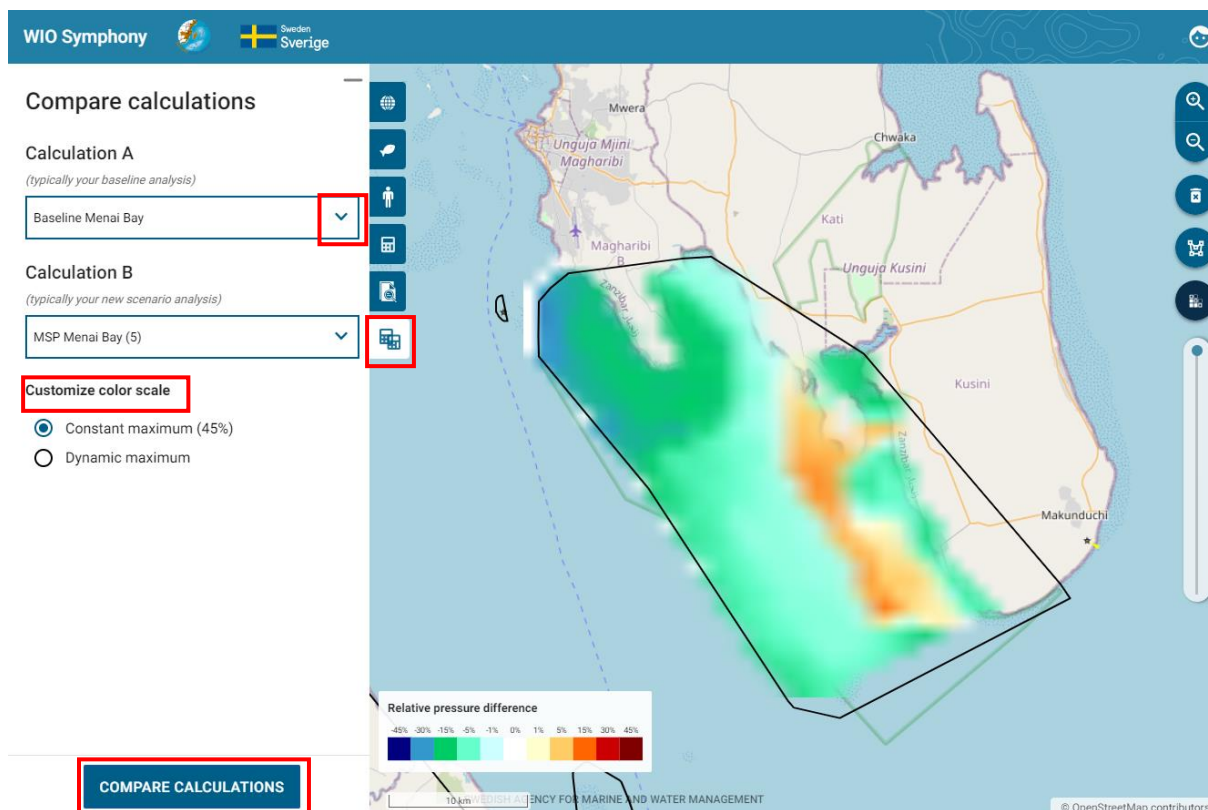
In previous versions of WIO Symphony, when a scenario was being edited, the tool itself saves all changes made (to the scenario) by the user at a regular interval, and following certain actions such as starting a calculation or leaving the edit mode. The new, and current, feature makes the saved state of the active scenario explicit to the user. A notification/button alerts the user if the user interface displays unsaved changes (left figure above). Clicking the notification Unsaved changes persists the scenario setting to the database (right figure above). This interactive save scenario function is to give the users the certainty that made changes have been saved.

Now when the “MSP” scenario has been simulated, you might have noticed some differences in the reports between the “Baseline” and the “MSP” scenarios. However, the full comparison will be computed to have quantitative results, which are easier to interpret. See next chapter **5.9**.

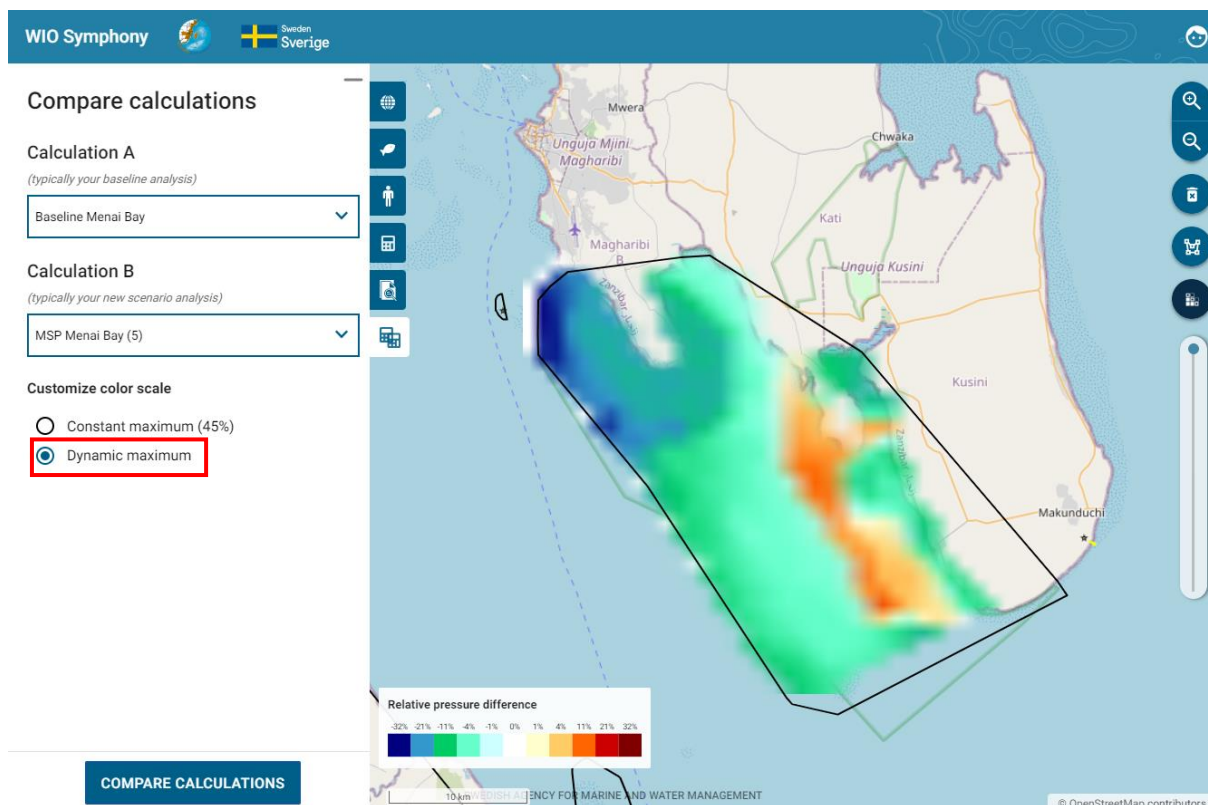
5.9 Compare two scenarios

Two scenarios from the same boundary polygon(s), such as the “Baseline” and “MSP” scenarios, can be compared using the *Compare Calculations* tab.

Move to the *Compare Calculations* tab → select your “Baseline” scenario as Calculation A and your “MSP” scenario as Calculation B → press **COMPARE CALCULATIONS**. There are two ways under *Customize colour scale* to showcase the differences.



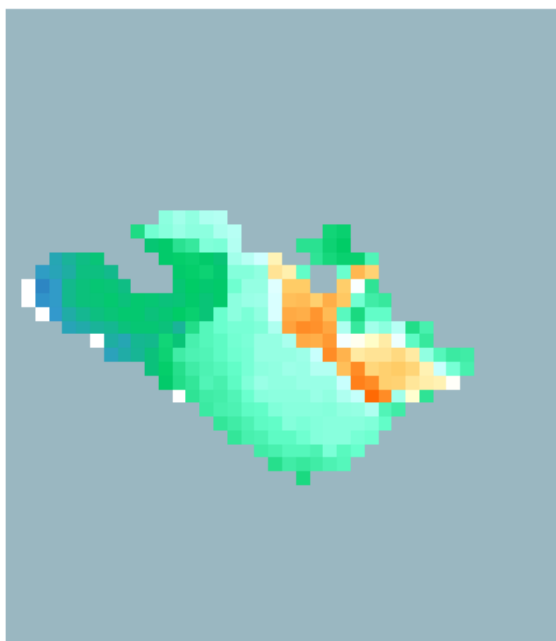
The first adaptive colouring range for the comparison report is the default *Constant maximum (45%)*.



The second is the *Dynamic maximum*, adapting the colour scale maximum to the actual max value of the specific comparison, instead of a set min and max of 45.

The *Calculation Comparison Report* that pops up once you click *Compare Calculations* generates a graphic illustration of differences in cumulative environmental impact. More orange-red colours equal an increase in cumulative impact, while more green-blue colours equal decreased environmental impact.

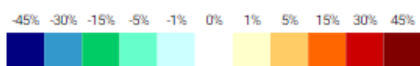
Baseline Menai Bay and MSP Menai Bay (5)



Baseline version: BASELINE2023-v2
 Algorithm: Cumulative impact

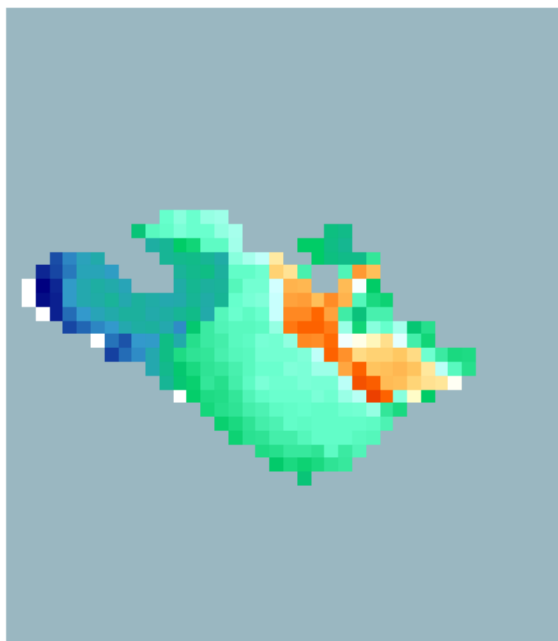
Cumulative effect

	Baseline Menai Bay	MSP Menai Bay (5)	Relative change
Total:	7,169,125	6,481,527	-9.59%
Average:	11,012.4808	9,956.2627	-9.59%
Min:	0	0	0%
Max:	60,342	56,988	-5.56%
Std. Dev:	10,878.3601	9,451.9345	-13.11%
Calculated area:	N/A		



In the associated summarizing table of Cumulative impact, the *Relative change* gives an indication of total outcome, across the whole area. For this example, where you have increased algae farming and tourism, while reduced dredging, dumping and nearby shipping, the net result of the cumulative is -9.59%, which is positive for the environment.

Baseline Menai Bay and MSP Menai Bay (5)

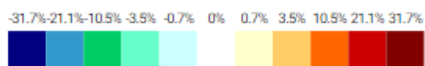


Baseline version: BASELINE2023-v2
 Algorithm: Cumulative impact

Cumulative effect

	Baseline Menai Bay	MSP Menai Bay (5)	Relative change
Total:	7,169,125	6,481,527	-9.59%
Average:	11,012.4808	9,956.2627	-9.59%
Min:	0	0	0%
Max:	60,342	56,988	-5.56%
Std. Dev:	10,878.3601	9,451.9345	-13.11%

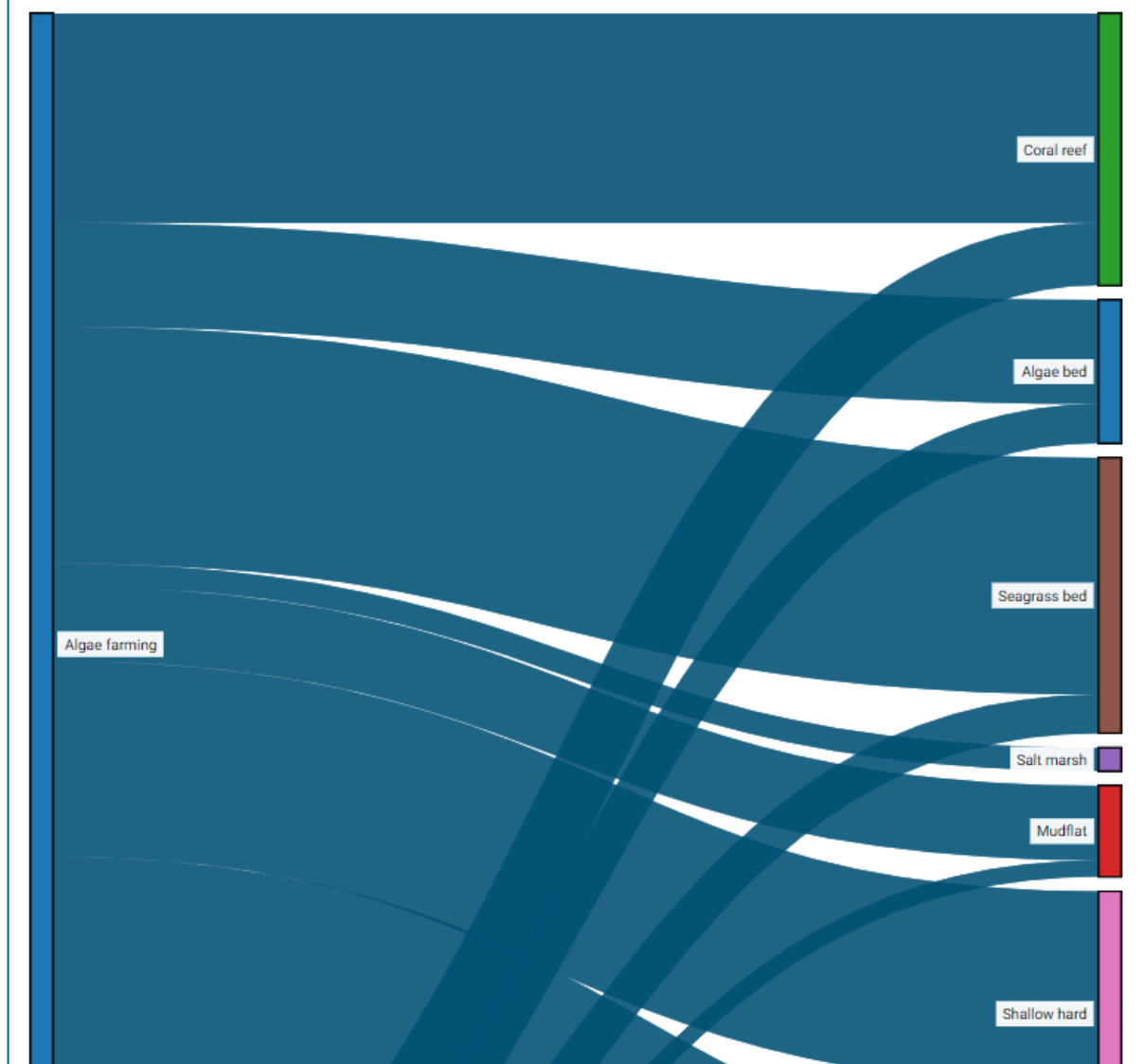
Calculated area: N/A



Being basically the same, the *Dynamic maximum* report provides identical information as the default Constant maximum (45%). However, as previously said, the difference lies in the map illustration. Although, the differences on the map are more visible in a larger area, compared to this quite small one.

Sankey diagram (increasing)

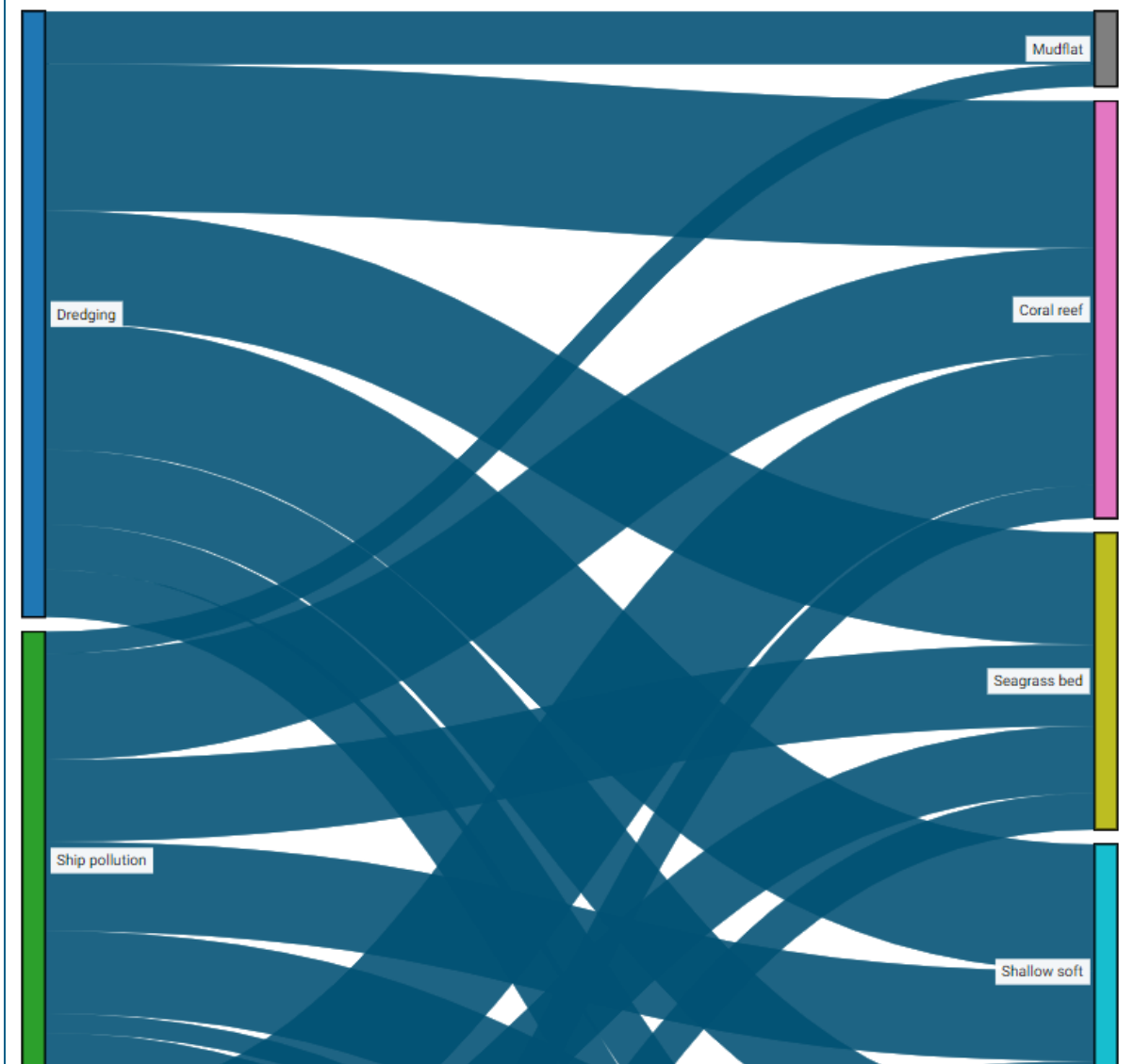
This Sankey diagram shows the relationship between the pressures whose impact increases on different natural values in scenario B, relative to scenario A. The thickness of the arrows are proportional to the increase of each pressure between the two specified scenarios, with respect to the affected nature values. Values below 1% are not included in the diagram.



Similar to a regular scenario report, the comparison report provides a Sankey diagram. However, this is split up in two different diagrams, one with increasing pressure (above) and one with decreasing pressure (below).

Sankey diagram (decreasing)

This Sankey diagram shows the relationship between the pressures whose impact decreases on different natural values in scenario B, relative to scenario A. The thickness of the arrows are proportional to the amount each pressure is alleviated between the two specified scenarios, with respect to the affected nature values. Values below 1% are not included in the diagram.



Like in a scenario report where you have done changes, the comparison report lists the changes under Scenario Parameters. Below, we can to the right see all the changes we have made for the MSP scenario, while to the left, the baseline was left as a default analysis. Additionally, we can, in detail, see the specific relative change for all the included ecosystem components and pressures, which was summarized in the beginning of the comparison report.

Scenario Parameters Baseline Menai Bay				Scenario Parameters MSP Menai Bay (5)			
No changes				COMMON CHANGES			
				Algae farming	Percent change with +50%		
				Boating	Percent change with +30%		
				Coastal tourism	Percent change with +30%		
				Dredging	Percent change with -100%		
				Dumping	Percent change with -100%		
				Ship pollution	Percent change with -100%		
				Ship strike	Percent change with -100%		
				Underwater noise	Percent change with -100%		
Impact per pressure				Impact per nature value			
AQUACULTURE	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE	HABITAT OCEANIC PELAGIC	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE
Algae farming	605,990	797,069	+31.53%	Deep pelagic	0	0	0%
Mariculture	0	0	0%	Midwater pelagic	2,527	2,417	-4.35%
				Photic pelagic	203,347	186,561	-8.25%
				Upwelling pelagic	77,639	69,740	-10.17%
BIOLOGICAL DISTURBANCE	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE	HABITAT OCEANIC SEAFLOOR	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE
<i>Invasive species</i>				Abyss hard	0	0	0%
				Abyss soft	0	0	0%
CLIMATE CHANGE	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE	Cold coral reef	9,851	7,599	-22.86%
<i>Ocean acidification</i>				Ocean ridge	0	0	0%
Sea level rise	1,719,885	1,719,885	0%	Seamounts	0	0	0%
<i>Storm surges</i>				Slope hard	0	0	0%
Temperature rise	403,905	403,905	0%	Slope soft	0	0	0%
				Thermal vents	0	0	0%
COASTAL DEVELOPMENT	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE	HABITAT TEMPERATE	BASELINE MENAI BAY	MSP MENAI BAY (5)	RELATIVE CHANGE
Dredging	359,180	3,521	-99.02%	Algae bed (temp)	0	0	0%
Dumping	94,922	312	-99.67%	Kelp forest (temp)	0	0	0%
Hydrology change	824,399	824,399	0%	Mudflat (temp)	0	0	0%
Industrial pollution	0	0	0%	Penguin feedground	0	0	0%
Land reclamation	0	0	0%				
Light pollution	45,272	45,272	0%				

Comparison can be exported as **CSV** and **GEOTIFF** files, as well as printed and saved, just like the regular scenario reports.

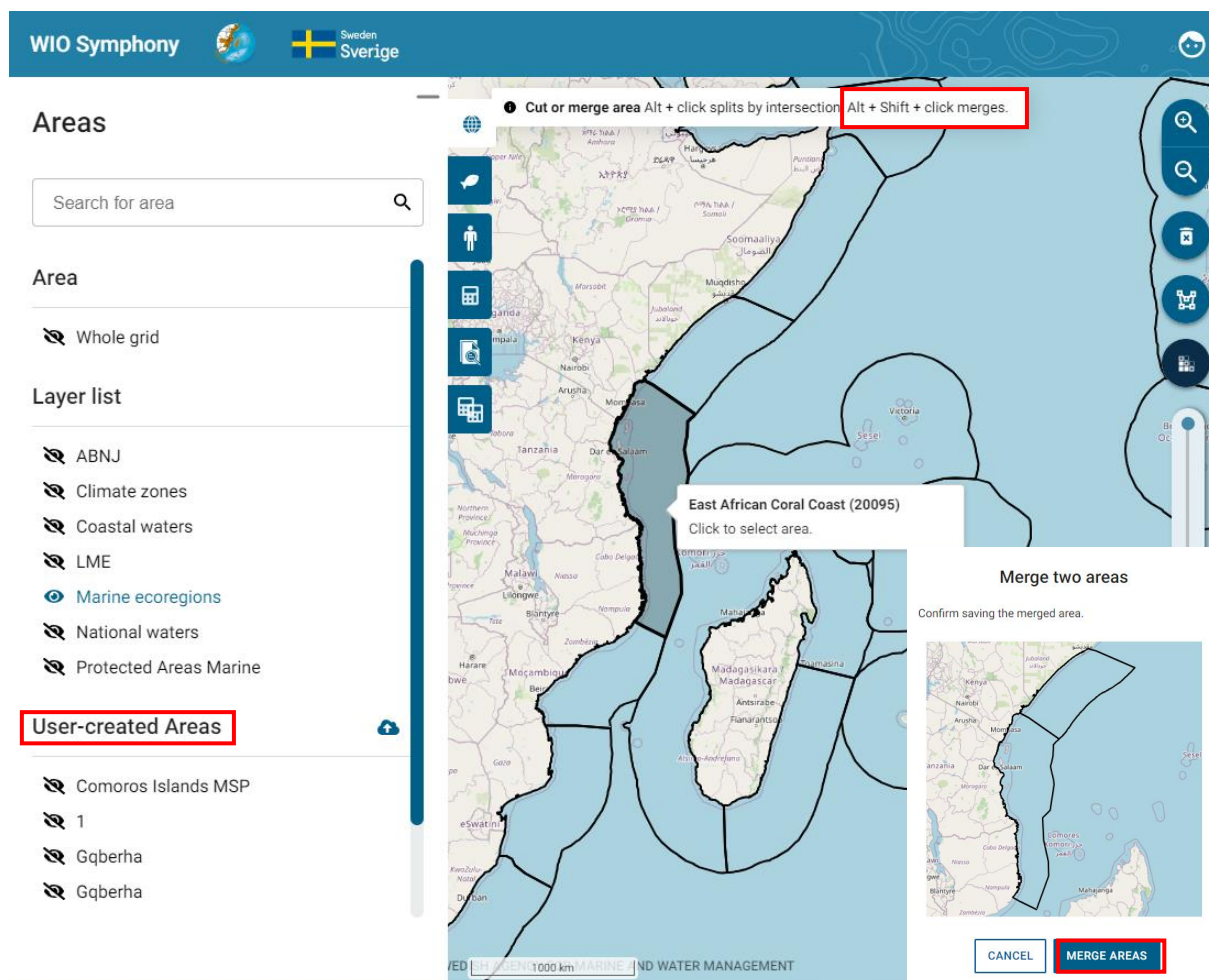
By comparing different MSP options with baseline, or with each other, the planner can analyse one or several MSP zones and evaluate solutions in an iterative process, easy to communicate to sector representatives and other stakeholders.

5.10 Select, Merge or Split several polygons

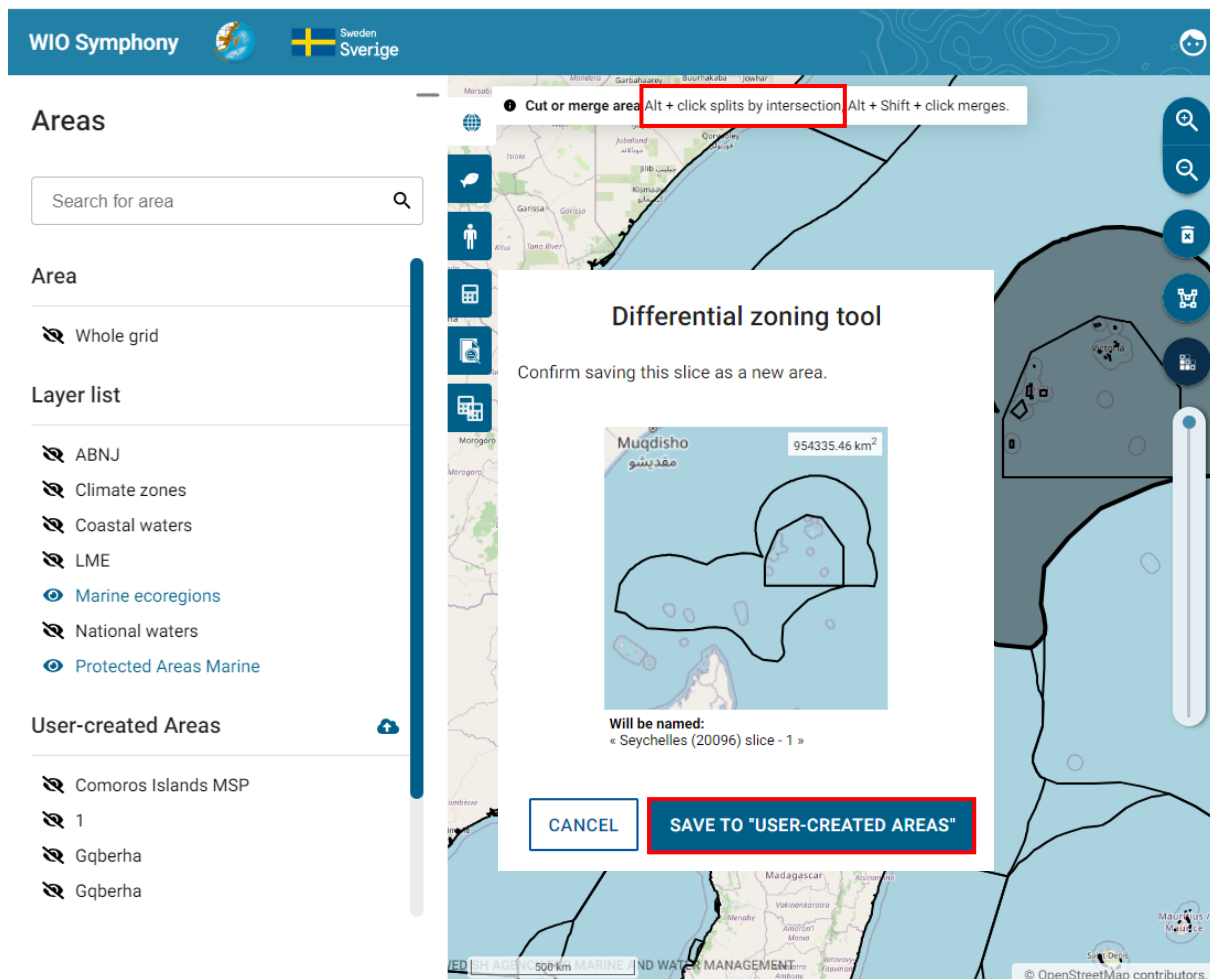
Another functionality of WIO Symphony that previously did not exist is to select, merge or split polygons.

Select several areas by holding **ctrl** and **left click** on two or more polygons. They will be calculated as one polygon.

You can also select two or more polygons and **merge** them into one by first selecting one or more, and on the final one hold **Alt + Shift + left click**. This triggers a dialog box (see figure below) that enables saving the result of merging both areas together as a new user-defined area, or overwriting either of the merged areas (option available if the one to overwrite is already a user-defined area). This will be saved under *User-created Areas* where you can rename it.



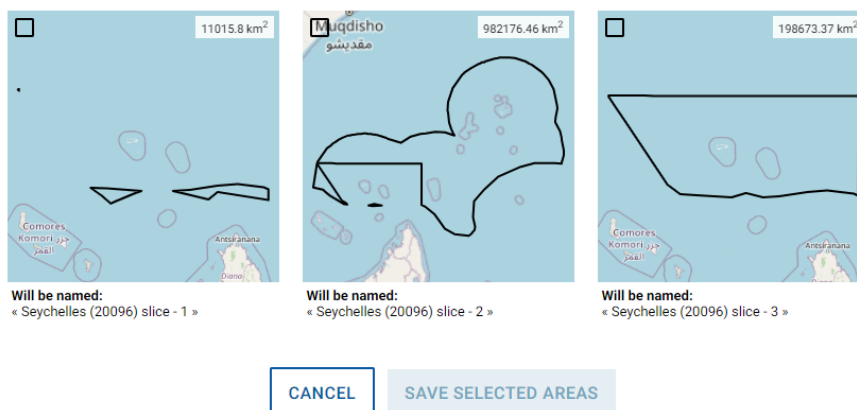
A final function is to **cut** or **split** an area by intersection. This is done by first selecting a polygon and then hold **Alt + left click**. This is a function for the so-called *Differential zoning*, using two distinct, overlapping areas. This triggers a dialog box allowing the user to create new areas based on the intersection and relative complements of the active selection. By clicking *Save to "User-created areas"*, the intersected polygon will be saved there.



Besides the dialog box above with the *Differential zoning tool*, an intersecting area might provide more than one slice to save as a new area, depending on how it overlaps other areas. See figure below for the different options.

Differential zoning tool

Select which slices to save as new areas.



5.11 Analyse several polygon areas

With the functionalities in chapter 5.10 to merge or split polygons, the tool allows scenario analyses of spatial extents spanning multiple calculation areas, and for different areas within the same scenario to freely specify their separate sensitivity matrices. This enables the option to create a proper MSP, by including all areas that the plan encompasses, and use this function to apply area specific changes according to the MSP. Hence, the user can compare this MSP with another if the same areas are used, but with different changes.

After selecting two or more polygons, go to the *Scenario* tab → press + button. This leads you to the user interface seen below. Here we can go back to the *Pressures* tab and do changes to our scenario, such as adding *Diving* with a 10 constant, increasing the diving tourism in all three areas.

The screenshot displays the WIO Symphony software interface. The top header includes the logo 'WIO Symphony' and the Swedish flag with 'Sweden Sverige'. The main title is 'Common and individual' with a timestamp '2023-11-20 20:37'. Below this, the 'Scenario areas' section lists three areas: Mayotte, Aldabra Group (Marine) National Park, and Farquhar Archipelago (Marine) Area of Outstanding Natural Beauty. The 'Scenario Changes' section, highlighted with a red box, shows 'Diving' with a '+10' constant. The 'Algorithm' section has 'Cumulative impact' selected. The 'Result Colormap' section has 'Maximum value in computed area' selected. At the bottom, there are 'DELETE' and 'CALCULATE' buttons. The central map shows the Comores islands with several polygons overlaid. A tooltip at the bottom of the map reads 'Active scenario: Common and individual' with an 'Exit' button. The bottom status bar includes 'AGENCY FOR MARINE WATER MANAGEMENT' and '© OpenStreetMap contributors'.

Going back to the *Scenarios* tab, you can click either of the three areas in the “*Scenario areas*” list, and you will enter that specific area, where you can afterwards go to the *Pressures* tab and make other changes, but just to that area and not for all three. Each scenario may apply the same general changes that were set for the original scenario, as well as specific changes, if any. Let us say that in Mayotte, we want to increase *Algae farming* by 10%. Remember to tick the *Override group setting* to make sure this change is only for Mayotte. There is also an option here to RESET and remove the changes made in this specific area of the whole scenario.

WIO Symphony Sweden Sverige

Common and individual

2023-11-20 20:35 Changes saved

Scenario areas

- Mayotte
- Aldabra Group (Marine) National Park
- Farquhar Archipelago (Marine) Area of Outstanding Natural Beauty

Select / deselect multiple areas using {{ ctrlbutto

Pressures

Common and individual Mayotte RESET

Search for pressure

- Aquaculture
 - Algae farming
 - Edit intensity
 - Percentage 10 % Constant 0
 - Override group setting
 - Mariculture

As stated in the beginning of this chapter, you may set separate sensitivity matrices to different areas within the same scenario, seen in the figure to the right.

Back at the *Scenario* tab, a table overview of your changes can be seen by clicking the *Show an overview of all changes* button. This table view the general, so-called *Global changes* for all areas, and the individual ones. See figure below.

WIO Symphony Sweden Sverige

Mayotte

Algorithm

Cumulative impact

Result Colormap

95e percentile in MSP area

Scenario Changes

Algae farming +10% x

Sensitivity Matrix

Default matrix (Western Indian Ocean)

Alternate matrix

Choose matrix

User-defined matrix

Choose matrix

EDIT MATRIX

REMOVE AREA

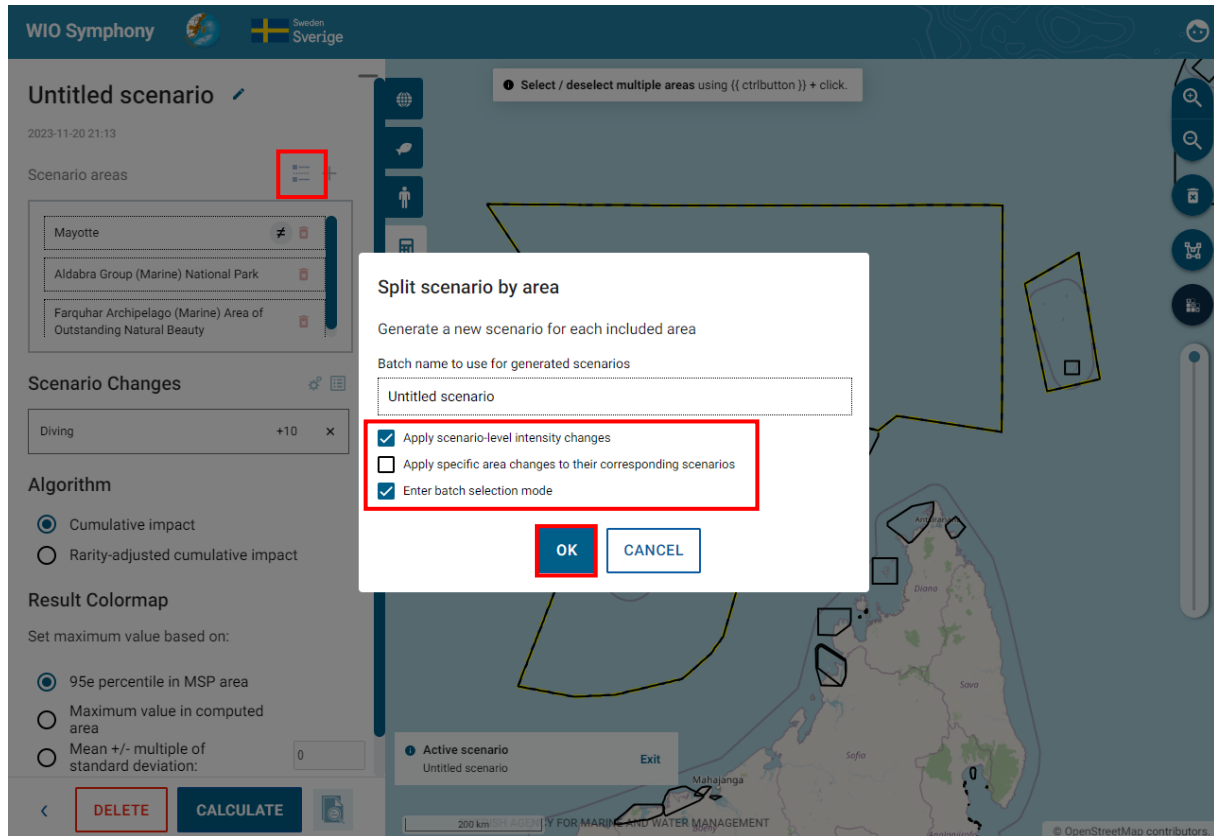
Scenario changes overview

Common and individual

	Aquaculture Algae farming	Recreation Diving
Global changes	-	10 <input type="radio"/> Percentage <input checked="" type="radio"/> Constant
Mayotte	10%	-

CLOSE


When all settings you wish to apply are done, you can run the analysis for the whole scenario, which includes all areas and you will get a report of the scenario.



5.12 Batch analysis

If you do not want to run your analysis for the whole scenario, you can click the *Split scenario by area* button. A dialog box will pop up. Name your batch to use for generated scenarios. Tick the boxes you wish to apply. The first one applies changes made for all areas within the scenario. The second applies the specific area changes made to their corresponding scenarios. The third lets you enter the batch mode, which will be described in chapter 5.12. Click OK. If the third box is left unchecked, you will come back to the *Scenario* tab and may *Calculate* your scenario. However, if checked, you will enter the batch mode, as said.

The scenario list view offers a batch mode, allowing multiple scenarios to be queued for sequential calculation. The idea behind it is that you can generate multiple scenarios with common and/or individual settings in one batch. By entering the batch mode by clicking enter batch mode, you will get one report for each area within the same scenario, seen in the figure below down to the right. Press the play ► button to run the batch analysis. The batch mode is also available directly when moving into the *Scenarios* tab. From here, you can make a batch analysis of previous scenarios that are in your scenario list. Press the enter batch mode button again to exit it.

WIO Symphony 

Scenarios

Mayotte

User Scenarios

Filter scenarios by name

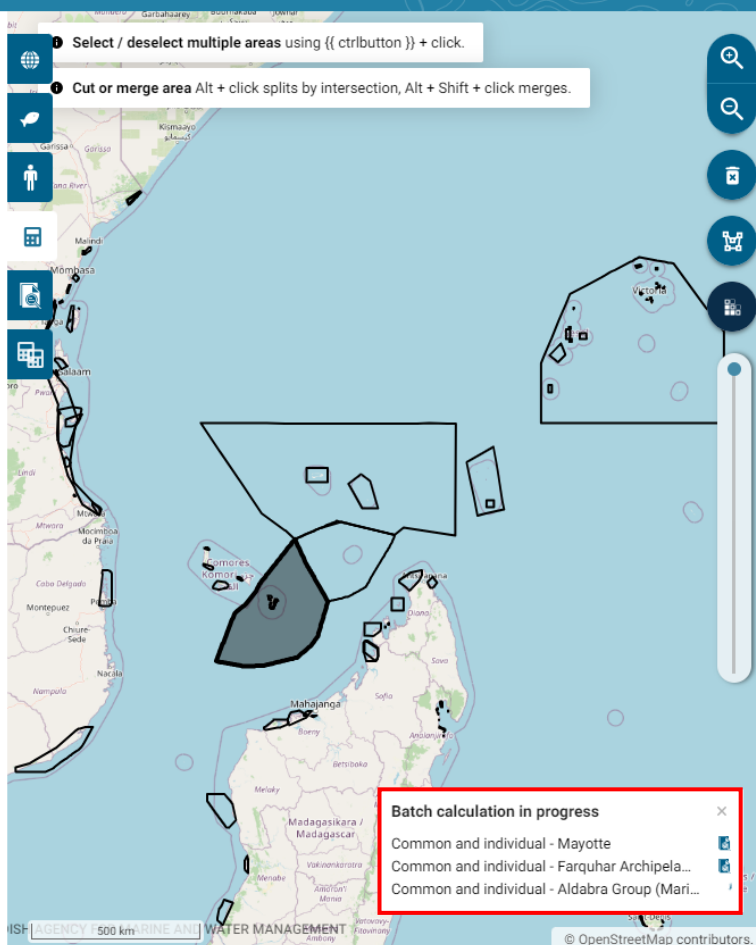
- Common and individual - Mayotte
2023-11-20 20:38
Mayotte
- Common and individual - Farquhar Archipelago (...)
2023-11-20 20:38
Farquhar Archipelago (Marine) Area of Outstanding Natural Beauty
- Common and individual - Aldabra Group (Marine...)
2023-11-20 20:38
Aldabra Group (Marine) National Park
- Common and individual - Farquhar Archipelago (...)
2023-11-20 20:36
Farquhar Archipelago (Marine) Area of Outstanding Natural Beauty
- Common and individual - Aldabra Group (Marine...)
2023-11-20 20:36
Aldabra Group (Marine) National Park

Select / deselect multiple areas using {{ ctrlbutton }} + click.

Cut or merge area Alt + click splits by intersection, Alt + Shift + click merges.

Batch calculation in progress

- Common and individual - Mayotte
- Common and individual - Farquhar Archipela...
- Common and individual - Aldabra Group (Mari...



© OpenStreetMap contributors.

6. Further analyses

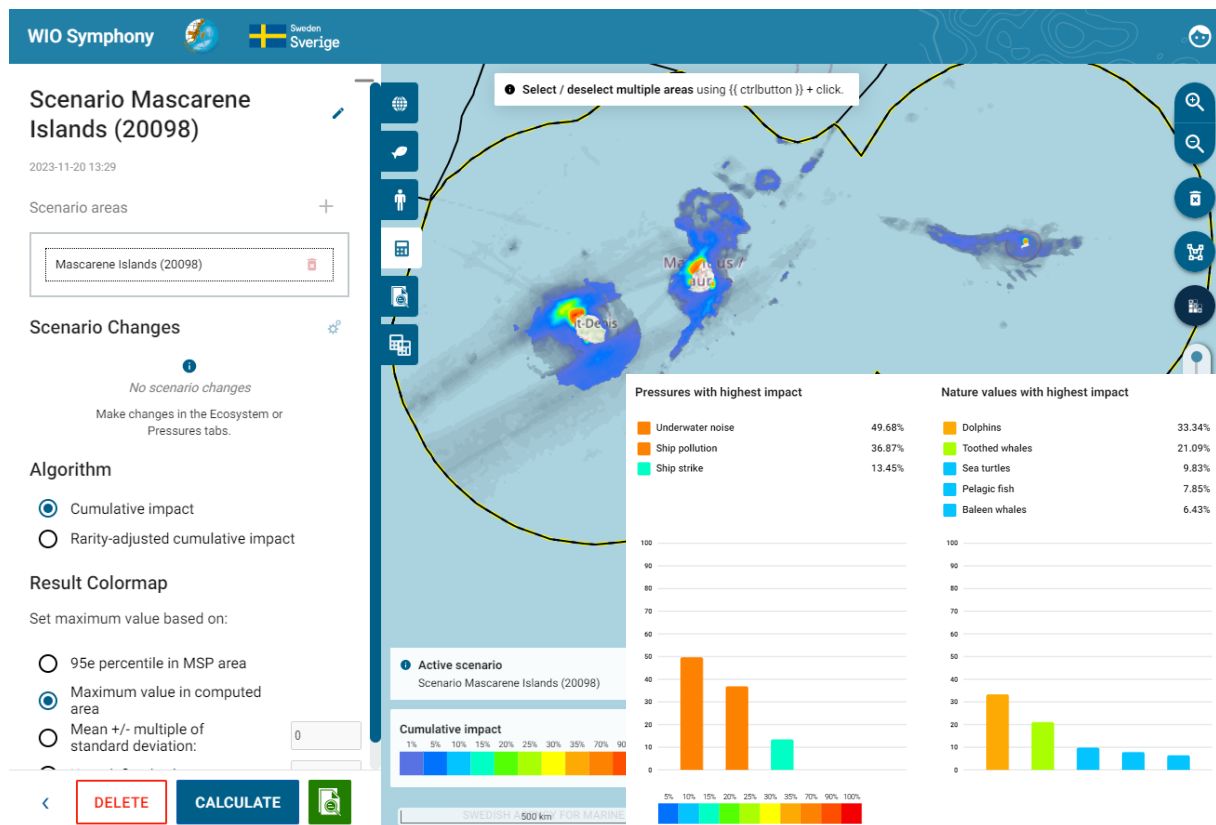
6.1 MINISYM – analysing individual pressures

Using the same principles as when analysing cumulative impact (chapter 5.5), it can sometimes be useful to focus on a single sector or pressure. This “one-over-many” analyses gives an understanding of the combined impact of that specific human activity alone.

Such focused analysis on only one sector or pressure is labelled as MINISYM.

Select **one or several boundary polygons** → go to the **scenario** tab → press **+** → go back to the **pressures** tab → select **only one or a few associated pressures** and **all relevant ecosystem components** → run the analysis as in chapter 5.5 and 5.6.

Mind that you may have to open the pressure categories (sectors) to untick the underlying pressures, even if the category appears already unticked.

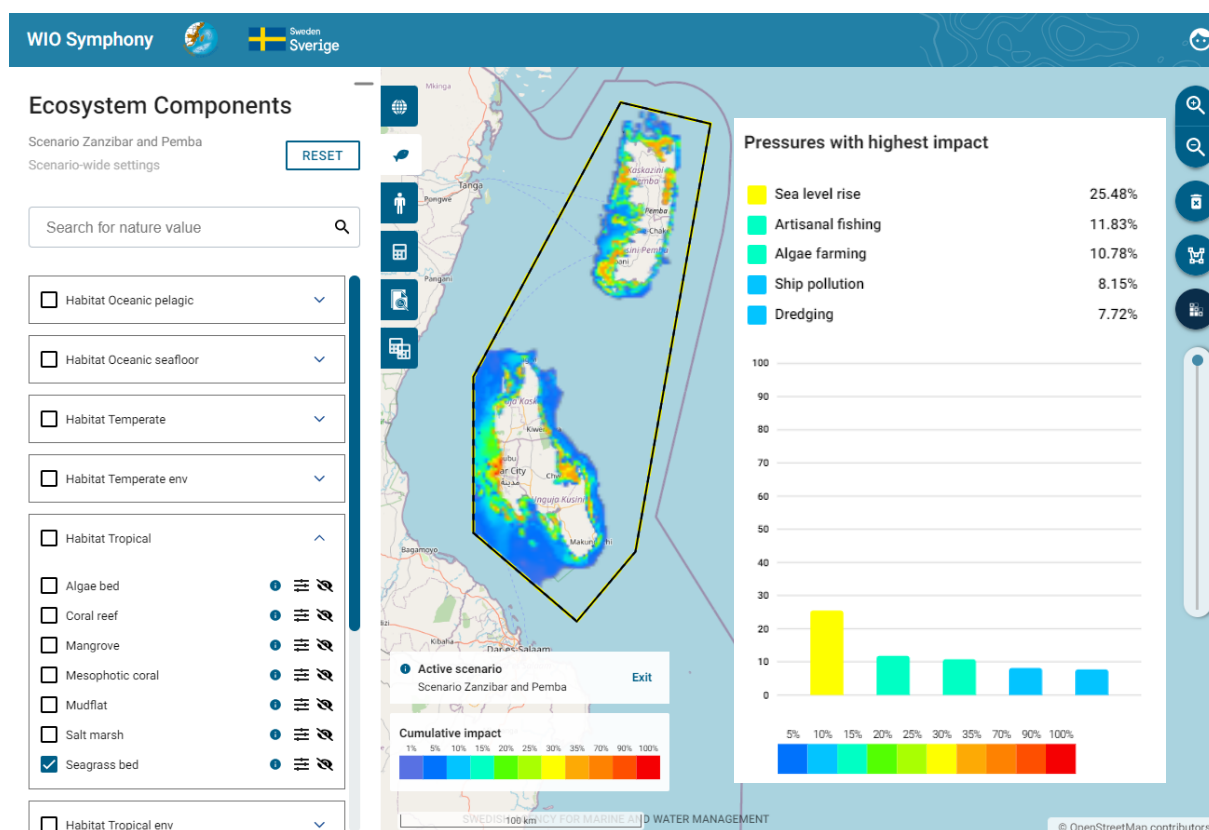


This example of a MINISYM analysis for shipping pressures around the Mascarene Islands, including Mauritius, Réunion and Rodrigues, included only taxa and no habitats. The result indicates that the shipping industry predominantly affects *Dolphins* and *Toothed whales*, but also *Sea turtles*, *Pelagic fish* and *Baleen whales* to some extent. Whether the impact is strong enough for action to be taken, it cannot be concluded by this analysis alone, since the impact score is a relative index. Deeper analysis into pressure levels and sensitivity scores can help.

6.2 MINISYM – analysing individual ecosystem components

In a similar way as above (chapter 6.1) it can be relevant to analyse how all pressures combined affect a single ecosystem component. With this “one-over-many” analysis, you get a screening of the major threats to a specific habitat or taxa of interest in your area.

Select your **boundary polygon** → go to the **scenario** tab → press + → go back to the **ecosystem components** tab → select only **one or a few associated ecosystem components** and **all relevant pressures** → run the analysis as in chapter 5.5 and 5.6.



This example of MINISYM result for *Seagrass beds* outside Tanzania’s mainland and indicate that this important habitat is most affected by *Sea level rise*, *Artisanal fishing*, and *Algae farming*.

6.3 Rarity-adjusted cumulative impact

Rarity-adjusted cumulative impact accounts for how rare or common the ecosystem components are. Ordinary cumulative impact often gives results that are dominated by common ecosystem components, which is justified because there are more organisms of these that are affected. Nevertheless, it can be more ecologically relevant to consider **how much is lost in relation to how much is left**, broadly speaking. In other words, impact per remaining habitat or population.

In WIO Symphony, the *Rarity-adjusted cumulative impact* algorithm calculate impact per ecosystem component and divides the impact sum by the total cover of the same ecosystem component. The resulting impact scores are numbers much lower, contrary to the ordinary cumulative impact scores, which are often in the thousands. So ordinary- and rarity-adjusted impact scores cannot be compared by numbers. However, the relative differences are comparable and both algorithms are informative for management and planning.

For comparison, start with first calculating an ordinary cumulative impact. Select your **boundary polygon** → go to **Scenarios** tab → press the **plus +** button → **rename** your scenario with prefix “**Ordinary**” → press **CALCULATE**.

WIO Symphony Sweden Sverige

Ordinary Comoros 2023-11-20 13:54

Scenario areas: Comoros

Scenario Changes: No scenario changes

Algorithm:

- Cumulative impact
- Rarity-adjusted cumulative impact

Result Colormap:

- 95e percentile in MSP area
- Maximum value in computed area
- Mean +/- multiple of standard deviation: 0
- User-defined value: 1

Active scenario: Ordinary Comoros

Cumulative impact: 1% 5% 10% 15% 20% 25% 30% 35% 70% 90% 100%

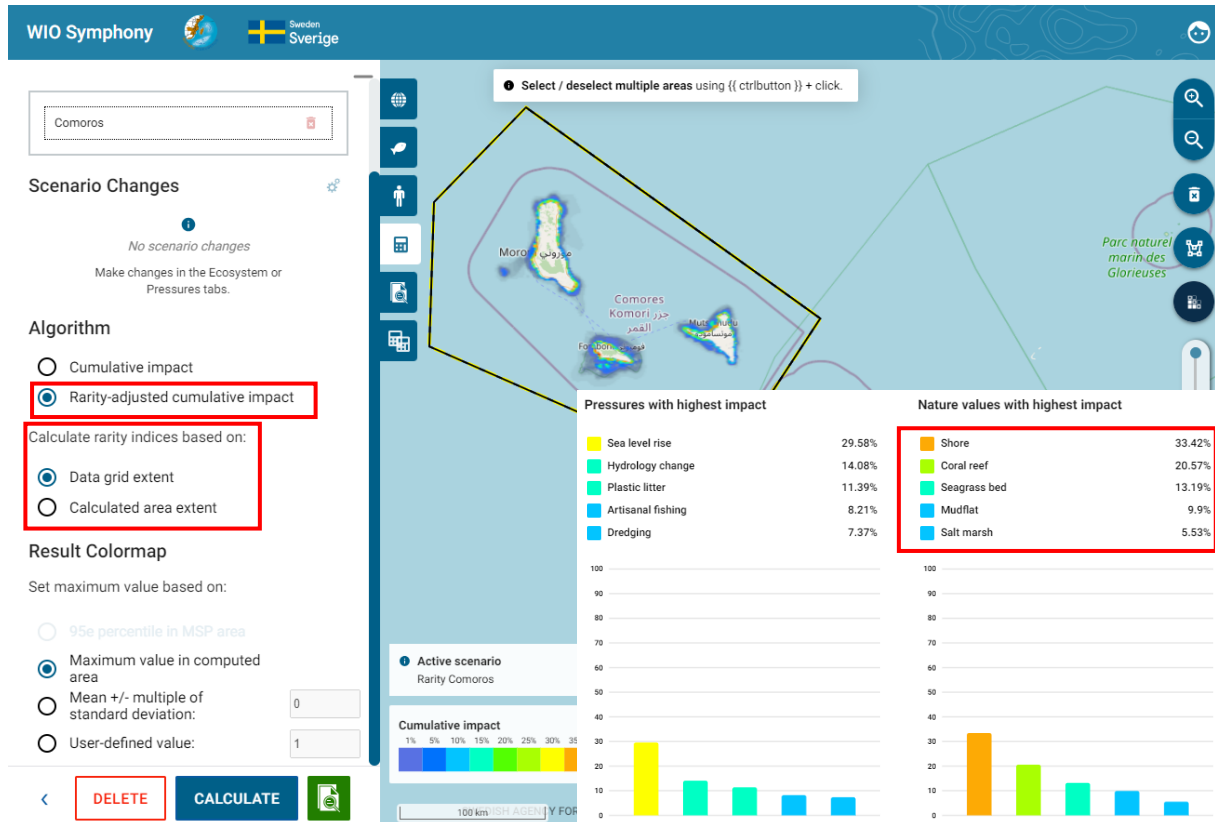
Pressures with highest impact:

Artisanal fishing	16.32%
Temperature rise	11.93%
Plastic litter	10.07%
Pelagic seine	9.26%
Sea level rise	8.59%

Nature values with highest impact:

Abyss soft	15.13%
Cold coral reef	12.79%
Photic pelagic	8.31%
Coral reef	7.65%
Abyss hard	6.84%

Select the same **boundary polygon** → go to **Scenario** tab → press the **plus +** button → **rename** your scenario with prefix “**Rarity**” → **choose the algorithm** *Rarity-adjusted cumulative impact* → press **CALCULATE**. When enabling the *Rarity-adjusted cumulative impact*, you get an option to choose between two alternatives under *Calculate rarity indices based on*. *Data grid extent* calculates rarity based on the *Whole grid*, and *Calculated area extent* is based on the scenario area.



Comparing the two analyses, you can see several differences. For instance, the colour map is more confined with high impact in coastal stretches and all of the top-5 impacted ecosystem components are coastal (including the new *Shore*, *Seagrass bed*, *Mudflat* and *Salt Marsh*) when *Rarity-adjusted cumulative impact* is applied. Interestingly, coral reef remains in the top-5 impacted ecosystems, regardless of which algorithm that was used.

6.4 Screen for Suitable Locations for new activities

WIO Symphony can be used for overview assessment (screening) of suitable locations for new activities. Such analyses can be quite informative for early stages of MSP or other development plans.

The principle is to add pressure scores to each pixel in the area of investigation, by using the *Constant* field (see chapter 5.8, bullet point 4). When analysing this added pressure in isolation (removing all other pressures), the resulting colour map will give indications of areas with high and low cumulative impact, where areas of low impact would be more suitable locations for the activity. For example, search for the most suitable locations for coastal seabed mining in an area of your choice.

Select or draw a **boundary polygon** representing the area in which the new activity could be located → go to *Scenario* tab → press the **plus +** button → move to the *Pressures* tab → **untick all pressures** except **Seabed mining** → click on the **adjustment symbol** for this pressure layer and type value 50 in the *Constant* field → go back to *Scenario* tab → **rename** your scenario with prefix "**Seabed mining**" → press **CALCULATE**.

WIO Symphony Sweden Sverige

Pressures

Scenario Seabed mining Nampula coast
Scenario-wide settings

RESET

Search for pressure

- Eutrophication
- Fishing
- Litter
- Mining
 - Seabed mining
 - Edit intensity
 - Percentage 0 %
 - Constant 50
- Offshore development
- Pollution

Active scenario: Scenario Seabed mining Nampula coast

It does not matter how much pressure you add in the *Constant* field as long as you have no other pressures involved and you use the colour scale with default setting. However, for reference, a value of 50 means that mining with an intensity half of maximum takes place in every pixel (that is, 50% of the area in every 1km² pixel is subjected to direct harvest of sand or other minerals).

WIO Symphony Sweden Sverige

Scenario Seabed mining Nampula coast

2023-11-20 14:22

Scenario areas

Seabed mining Nampula coast

Scenario Changes

Seabed mining +50 x

Algorithm

- Cumulative impact
- Rarity-adjusted cumulative impact

Result Colormap

Set maximum value based on:

- 95e percentile in MSP area
- Maximum value in computed area
- Mean +/- multiple of standard deviation: 0
- User-defined value: 1

Nature values with highest impact

Cold coral reef	29.06%
Abyss soft	25.04%
Slope soft	6.95%
Shallow soft	6.86%
Upwelling pelagic	5.68%

Cumulative impact

1% 5% 10% 15% 20% 25% 30% 35% 70% 90% 100%

Active scenario: Scenario Seabed mining Nampula coast

The resulting colour map indicate that the coastal stretches of the south are more suitable for seabed mining, from an environmental viewpoint. Yellow and green areas would mean substantially lower combined impact compared to dark orange or red areas. According to the colour legend, yellow is 30% of maximum, while dark orange is three times worse with around 90% of maximum.

These results obviously need to be confirmed with other studies before decision making, and it must be stressed that physical, economic, and social aspects are not involved here. Still, this screening can be highly efficient and save lots of resources in directing the search for locations into certain, more promising areas, with regards to the environment.

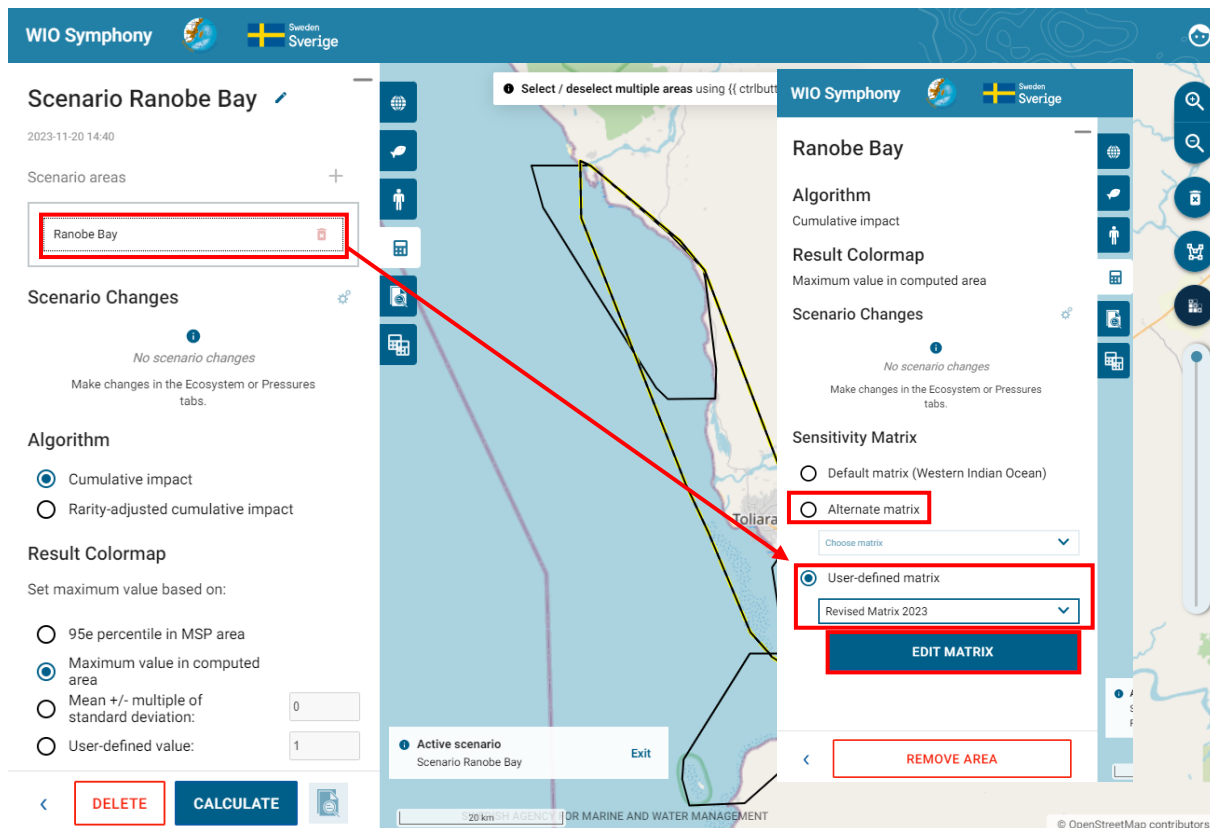
The *Calculation Report* with Sankey diagram and table may provide a first idea of expected impacts. But keep in mind that this result is for the whole area, whilst not only in the most suitable parts of the area. Additional analyses can be computed for the suitable locations, to learn more.

6.5 Choose and Edit Matrix

The default matrix is the standard. However, there is an option to choose between different preloaded matrices; *Revised*, *Original*, or *Exponential*. When pressing the **Scenario area**, you can click the **Alternative matrix** button and choose between the three different ones. Hence, in a scenario with several areas, you can apply different matrices to each area within the same scenario.

Some scenario simulations in MSP can be quite detailed. Perhaps the marine plan proposes to permit continued fishing, but with mandatory by-catch reducing measures. Then, the specific fishing pressure would not be altered or removed, as it is still endorsed and perhaps even increased in intensity. Regulatory changes, or general technical development, can instead be simulated by changing the sensitivity scores. In this case, the sensitivity between, say, artisanal fishing and by-catch ecosystem components such as turtles, rays, sharks, dolphins, and sea birds would be reduced. Perhaps, you may reduce sensitivity with 50% if mitigation expects to be 50% effective.

Select your **area** of interest → go to *Scenario* tab → press the **plus +** button → press on the **Scenario area** (*Ranobe bay*) → select *User-defined matrix* → select which matrix you wish to edit by clicking the arrow **▼** button → press **EDIT MATRIX**.



In the matrix, first rename the *Revised Matrix 2023* to, for example, *MSP Revised Matrix 2023* → **adjust the sensitivities according to the measures you are simulating** (reduce the pressure of artisanal fishing by half for *Sea birds* (0.4 to 0.2), *Rays/skates* (0.55 to 0.27), *Sharks* (0.56 to 0.28), *Dolphins* (0.3 to 0.15), and *Sea turtles* (0.48 to 0.24) by editing the numbers) → **SAVE AS NEW MATRIX** or **SAVE MATRIX** → back in the *Scenario* tab, you may **rename** your scenario with prefix **“By-catch reduction”** → choose your **new matrix “MSP Revised Matrix 2023”** → press **CALCULATE**.

MSP Revised Matrix 2023 Edit

Western Indian Ocean

isophotic coral	Mudflat	Salt marsh	Seagrass bed	Shallow hard	Shallow soft	Shelf hard	Shelf soft	Shore	Sea birds	Coral reef fish	Deep fish squid	Demersal fish	Pelagic fish	Rays skates	Sharks	Tuna billfish	Whale shark	Infauna	Mobile epifauna	Baleen whales	Dolphins	Dugong	Fur seals	Toothed whales	Sea turtles
Land reclamation	5	0.63	0.4	0.5	0.47	0.66	0.5	0.2	0.05	0.63	0.17	0.26	0.3	0.11	0.17	0.17	0.8	0.68	0.25	0.3	0.35	0.2	0.25	0.4	
Light pollution	7	0.1	0.1	0	0	0.27	0.45	0.38	0	0	0	0	0	0	0	0	0	0	0.25	0.3	0.3	0.3	0.25	0.64	
Piers and docks	5	0.57	0.27	0.43	0.4	0.51	0.45	0.3	0.1	0.26	0.22	0.2	0.2	0.2	0.2	0.13	0.37	0.33	0.3	0.35	0.3	0.2	0.25	0.3	
Ports	8	0.3	0.33	0.4	0.37	0.43	0.5	0.42	0.23	0.29	0.34	0.23	0.28	0.29	0.13	0.4	0.4	0.28	0.48	0.3	0.2	0.36	0.7		
Nutrient input	5	0.3	0.3	0.3	0.3	0.44	0	0.37	0.2	0.4	0.29	0.32	0.32	0.2	0.28	0.6	0.5	0.55	0.4	0.4	0.4	0.5	0.56		
Artisanal fishing	8	0.25	0.3	0.3	0.3	0.2	0.2	0.56	0.53	0.55	0.66	0.27	0.28	0.5	0.45	0.5	0.77	0.25	0.15	0.2	0	0.15	0.24		
Crustacean pots	5	0.35	0.35	0.3	0.3	0.16	0.4	0.24	0.33	0.45	0.16	0.15	0.24	0.07	0.2	0.2	0.77	0.27	0.33	0.2	0	0.13	0.35		
Demersal gillnet	7	0.4	0.5	0.3	0.45	0.2	0	0.54	0.55	0.71	0.43	0.53	0.46	0.34	0.4	0.12	0.28	0.53	0.53	0.33	0.4	0.33	0.65		
Demersal trawl	3	0.65	0.65	0.65	0.65	0.2	0.4	0.6	0.73	0.75	0.33	0.53	0.37	0.25	0.4	0.6	0.6	0.33	0.27	0.33	0.4	0.27	0.55		
Floating longline	8	0.3	0.4	0.35	0.4	0.2	0.53	0.43	0.35	0.4	0.4	0.43	0.63	0.78	0.34	0.06	0.11	0.35	0.5	0.4	0.6	0.45	0.52		
Other fishing	2	0.36	0.41	0.33	0.41	0.17	0.29	0.45	0.42	0.46	0.43	0.5	0.52	0.49	0.4	0.15	0.22	0.38	0.8	0.4	0.51	0.35	0.62		
Pelagic gillnet	4	0.3	0.4	0.35	0.4	0.2	0	0.4	0.2	0.35	0.57	0.55	0.6	0.64	0.55	0.1	0.1	0.53	0.6	0.5	0.6	0.53	0.65		
Pelagic seine	5	0.2	0.25	0.15	0.25	0.08	0.53	0.28	0.33	0.2	0.6	0.44	0.53	0.55	0.44	0.08	0.08	0.25	0.55	0.4	0.6	0.25	0.68		
Pelagic trawl	5	0.2	0.25	0.15	0.25	0.08	0.53	0.31	0.3	0.2	0.64	0.48	0.6	0.58	0.54	0.08	0.08	0.25	0.35	0.4	0.6	0.2	0.68		
Sport fishing	8	0.2	0.3	0.2	0.3	0.28	0.4	0.4	0.35	0.31	0.28	0.31	0.4	0.56	0.26	0.24	0.24	0.27	0.27	0.2	0.2	0.2	0.2	0.35	

CLOSE DELETE MATRIX SAVE MATRIX SAVE AS NEW MATRIX

Note that you can only save or delete your matrix once you have saved an original matrix as a new one. Changing sensitivity matrix manually can also be relevant when new science of environmental impact appears and you wish to update the sensitivity score accordingly.

7. Updating and new data

WIO Symphony updates to data layers will always be needed. The Nairobi Convention Secretariat are responsible to lead this work, although the scientific work will be undertaken by partners and end-users on their request.

Users or scientists willing to provide new data or models, or willing to review and comment, are encouraged to contact the Secretariat for further directions.

The software tool will be updated by the Secretariat when new versions are available on the GitHub repository. These upgrades may be provided by the parallel Swedish development of Symphony, and by other users of the software who shares new functionalities by uploading a new fork to the repository.

Only through continuous efforts of management and upgrades, the WIO Symphony tool will stay relevant for its users.

Contact information for updating data is from November 2022 wiosym@nairobiConvention.org.

Contact us

www.nairobiConvention.org/wio-symphony

8. References

- Andersen, J., Al-Hamdani, Z., Harvey, E., Kallenbach, E., Murray, C., Stock, A., 2020. Relative impacts of multiple human stressors in estuaries and coastal waters in the North Sea - Baltic Sea transition zone. *Sci. Total Environ.* 704, 135316. <https://doi.org/10.1016/J.SCITOTENV.2019.135316>.
- Bange, H. W., Bathmann, U., Behrens, J., Dahlke, F., Ebinghaus, R., Ekau, W., ... & Ziemek, H. P. (2017). *World Ocean Review 2015: living with the oceans 5. Coasts-a vital habitat under pressure*. maribus.
- Depellegrin, D., Menegon, S., Farella, G., Ghezzi, M., Gissi, E., Sarretta, A., Venier, C., Barbanti, A., 2017. Multi-objective spatial tools to inform maritime spatial planning in the Adriatic Sea. *Sci. Total Environ.* 609, 1627–1639. <https://doi.org/10.1016/J.SCITOTENV.2017.07.264>.
- European Commission. 1999. Integrating environment concerns into development and economic cooperation. Draft version 1.0. Brussels.
- Fernandes, M. da L., Esteves, T.C., Oliveira, E.R., Alves, F.L., 2017. How does the cumulative impacts approach support maritime spatial planning? *Ecol. Indic.* 73, 189–202. <https://doi.org/10.1016/j.ecolind.2016.09.014>
- Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C. V., Micheli, F., d'Agrosa, C., ... & Watson, R. (2008). A global map of human impact on marine ecosystems. *science*, 319(5865), 948-952.
- Hammar, L., Molander, S., Pålsson, J., Schmidbauer Crona, J., Carneiro, G., Johansson, T., Hume, D., Kågesten, G., Mattsson, D., Törnqvist, O., Zillén, L., Mattsson, M., Bergström, U., Perry, D., Caldow, C., & Andersen, J., 2020. Cumulative impact assessment for ecosystem-based marine spatial planning. *Science of The Total Environment*, 734, 139024.
- HELCOM, 2018. State of the Baltic Sea – second HELCOM holistic assessment 2011-2016. *Balt. Sea Environ. Proc.* 155, 155.
- Korpinen, S., & Andersen, J. H. (2016). A global review of cumulative pressure and impact assessments in marine environments. *Frontiers in Marine Science*, 3, 153.
- Spalding *et al.* 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. *BioScience* 57(7): 573-583. Available: <https://doi.org/10.1641/B570707>
- UNEP-WCMC (2023). Protected Area Profile for Africa from the World Database on Protected Areas, November 2023. Available at: www.protectedplanet.net

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Together with our partners, we strengthen the capacity to plan the future of the ocean, to take care of the ocean and to use the ocean – for the joy and benefit of all.

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