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# MYTIGATE — *Mytilus edulis* (Blue Mussel) Mitigation Farm Site Selection Tool for the Western Baltic Sea

User Manual

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URL:

<https://au-bios-model.shinyapps.io/MYTIGATE/>

## Short summary

The *Mytilus edulis* (Blue Mussel) Mitigation Farm Site Selection Tool for the Western Baltic Sea (MYTIGATE) is meant to provide stakeholders with a science-based decision support tool that offers flexible site selection solutions. Site selection is based on customized input criteria and, therefore fully dynamic with respect to the user's selections. MYTIGATE is based on 'a spatial model for nutrient mitigation potential of blue mussel farms in the western Baltic Sea' (Holbach et al., 2020) and a thorough selection of available spatial data about utilization of the respective marine areas. It works on a spatial resolution of 1x1 km<sup>2</sup> pixels. Within the tool, users can select specific areas of interest, investigate the model input parameters and results, adapt aquaculture farm setup, specify criteria for site-exclusion, set individual weights on potential conflict criteria, and define a specific criterion for the generated site-selection scenario. MYTIGATE uses an algorithm that integrates the spatial model result for the selection criterion (e.g. mussel weight, farm harvest) with locally applying exclusion and weighted conflict criteria. The algorithm then generates a ranking among all available sites, and selects the adequate number of most suitable sites until the selection target (e.g. no. of farms, nitrogen reduction) is reached. MYTIGATE will always only place one mitigation farm within each 1x1 km<sup>2</sup> pixel. A summary of the selection results is reported, a respective map is created, and detailed information on the selected sites can be downloaded as a table.

Users are encouraged to apply different sets of criteria and so to generate several selection scenarios. These can subsequently be used as a basis for discussion prior to a final site-selection decision. Users should be aware that the authors are not the originators of the spatial data on marine utilization and that they cannot be held responsible for their correctness and integrity. Data provided within MYTIGATE, is not necessarily comprehensive and we strongly recommend to acquire further information on relevant specific local conditions and knowledge, prior to decision-making and establishing mussel mitigation farms at the selected sites. Currently, MYTIGATE is spatially limited to the western Baltic Sea.

## Purpose of MYTIGATE

MYTIGATE is a publicly available platform that can be used as decision support tool in the process of marine spatial planning (MSP) with respect to establishing mussel mitigation aquaculture for nutrient reduction. It is addressed to all kinds of stakeholders involved in MSP and mitigation aquaculture and should be used as a scientific basis for discussion, when it is considered to implement mussel mitigation aquaculture. MYTIGATE enables stakeholders to interactively generate several site-selection scenarios by applying variable settings. The site selection output provides users with potential solutions, but these must not be seen as a form of advice for implementation. We strongly recommend to acquire further information on relevant specific local conditions and knowledge, prior to decision-making.

## Background and data used

The core of MYTIGATE is a ‘spatial model for nutrient mitigation potential of blue mussel farms in the western Baltic Sea’ (Holbach et al., 2020, [link](#)). This scientific paper is published open access and publicly available. All details and relevant information regarding the calculation of this spatial model are given in the paper, and readers may want to refer to this publication for a more extensive background.

In short, the spatial model is a modular setup (Figure 1), which links in situ monitoring data, blue mussel growth experiments in the field, an eco-physiological dynamic energy budget model (DEB-model) for blue mussels, and information on bathymetry and the intended farm setup by the following 4 modules:

**Module 1** provides spatial and temporal models of the long-term average pelagic habitat factors temperature, salinity, and chlorophyll-*a* concentration along with estimates of their natural variability. This module is based on data from the operationally performed monitoring programs of Denmark (NOVANA), Germany (LUNG, LLUR), and Sweden (SharkWEB).

**Module 2** contains a blue mussel growth model based on inputs of Module 1. This model was fit to results of DEB-model runs and validated with data from blue mussel growth experiments in the field. This module is used to estimate biomass of individual blue mussels at harvest in November throughout the whole model domain.

**Module 3** contains a statistical model function to up-scale biomass of individual blue mussels to the farm-scale and delivers respective biomass harvest and nutrient reduction potentials. This function is based on blue mussel growth experiments in the field and describes different types of mitigation farm setups in relation to local bathymetry.

**Module 4** contains a simplified model to estimate locally required hydrodynamics to avoid food limitation for the mussel growth (Module 2) under the given farm setup (Module 3). Due to the lack of consistent and area-wide hydrodynamic reference data for the whole model domain, this module has not yet been implemented in MYTIGATE.

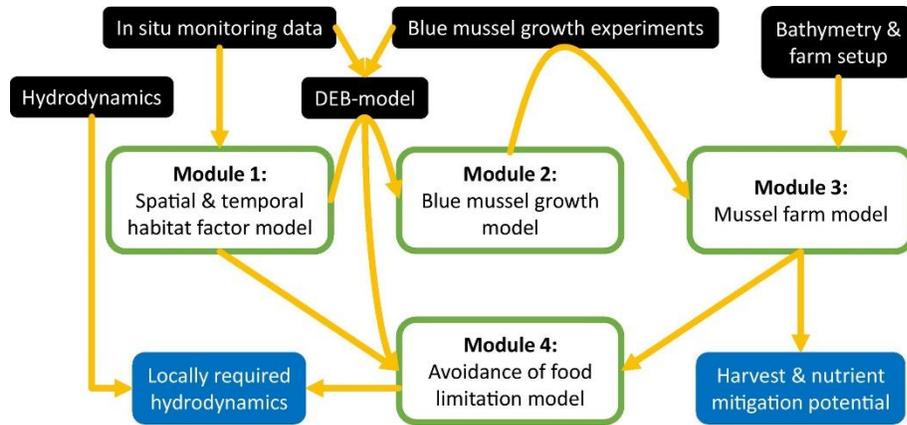


Figure 1: Flow diagram of the spatial modular modelling approach to estimate harvest and nutrient reduction potentials and locally required hydrodynamics for Mussel Mitigation Farms on trans-national scale in the western Baltic Sea. Black: inputs to the spatial model; green: modules of the spatial model; blue: outputs of the spatial model (from Holbach et al., 2020).

In MYTIGATE, users can visualize and investigate the parameters of Modules 1, 2, and 3. For the site selection, however, MYTIGATE only uses the outputs of Module 2 (Weight of individual blue mussels) and 3 (farm harvest and nutrient reduction) in the form of long-term averages of a standard longline mitigation farm at harvest in November. The standard mitigation farm is based on longline farms, already applied in the field and is schematically shown in Figure 2.

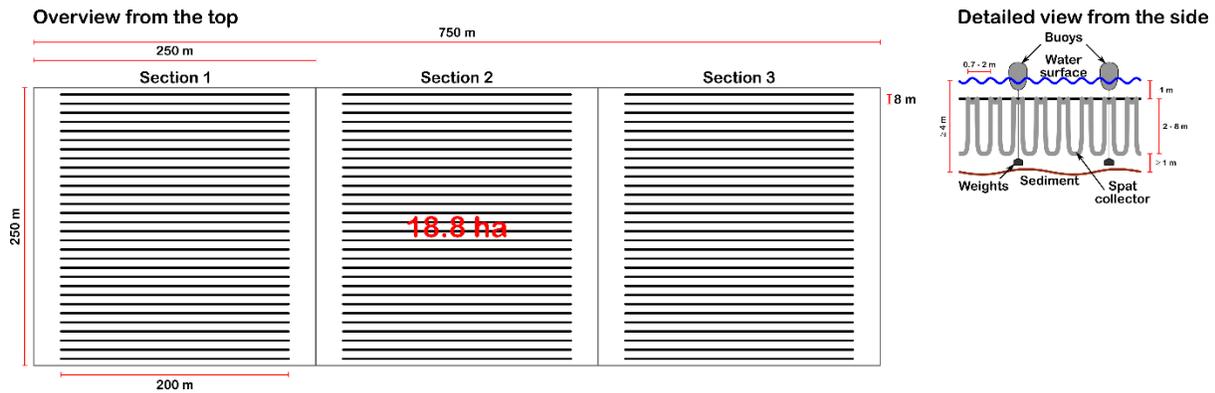


Figure 2: Layout of a standard model mitigation farm. The farm layout in the model is kept flexible with respect to the depth-range of spat collectors and the horizontal density of collector loops (from Holbach et al., 2020).

## Structure of MYTIGATE

### Layout

The MYTIGATE webtool is structured into several fields, which are illustrated in Figure 3 and Figure 4.

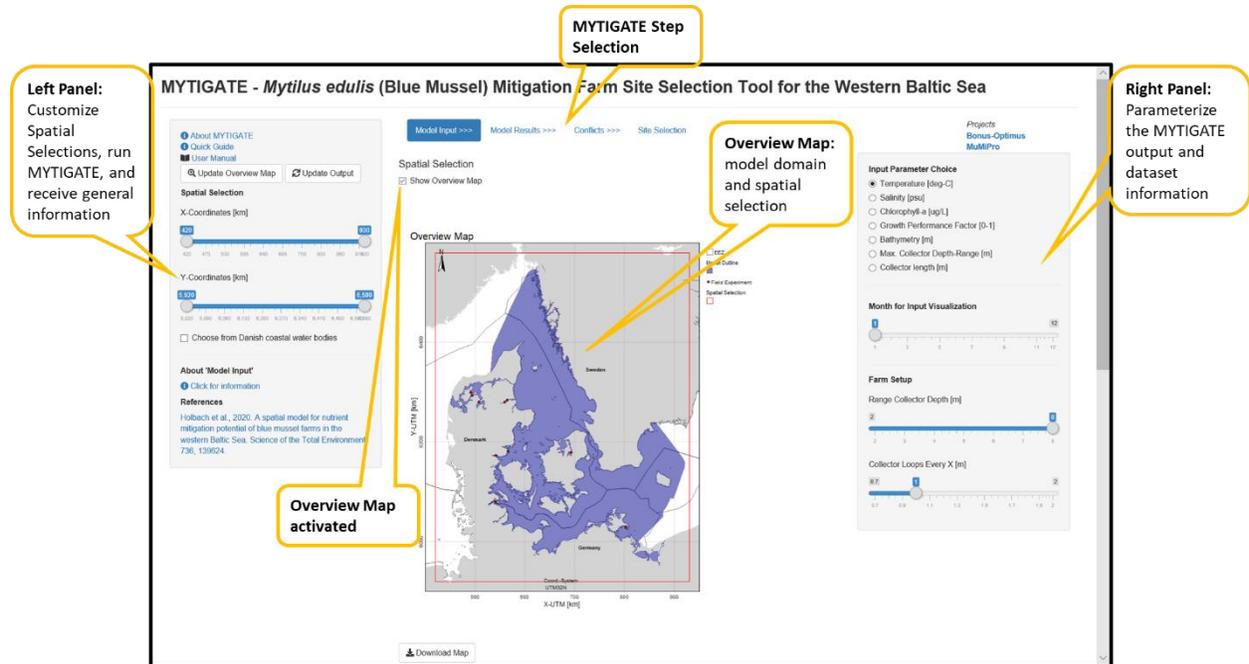


Figure 3: Screenshot of the MYTIGATE entrance page. Yellow boxes give information about the different parts.

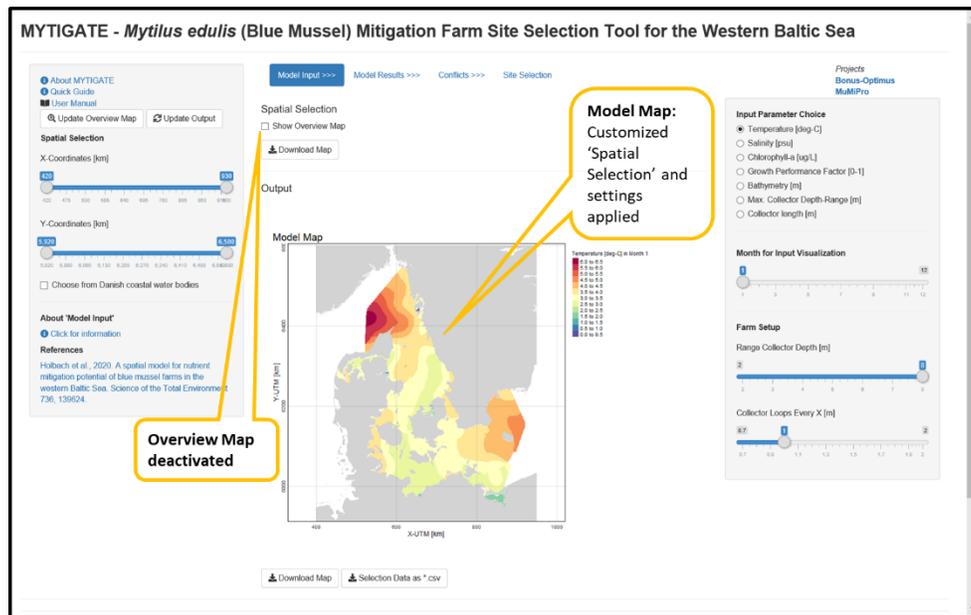


Figure 4: Screenshot of the MYTIGATE page after clicking on 'Update Output' and deactivating 'Show Overview Map'. Long-term average temperature distribution in January (default) is shown in the Output map.

## Help and Information

At several locations throughout MYTIGATE, you will find links to relevant additional information. E.g. on the left panel you always find a link to a summary 'About MYTIGATE', a 'Quick Guide' and to this 'User Manual'. Further, you will detect blue hyperlinks to information indicated by a circled 'i', which you can click to access them.

## Spatial Selection – Overview & Model Maps

The current 'Spatial Selection' is always displayed as a red polygon in the Overview Map. The Output Map will always zoom in to the extent of the selected area. There are two ways of customizing your 'Spatial Selection' in MYTIGATE:

1. You can shift the sliders for X- and Y-Coordinates in the left panel in 5 km steps. The coordinate system used is UTM32N. You can conveniently use the 'Overview Map' to read the coordinates you need. The maps themselves are not directly interactive.
2. You can choose specific marine water bodies and/or catchments from the Danish River Basin Management Plans for the years 2015–2021 (EPA, 2016) by clicking the checkbox for 'Choose from Danish coastal water bodies' and select the desired water bodies from the appearing dropdown list. Selection of several water bodies/catchments is possible. Selections from Danish coastal water bodies will always overrule the selection by coordinate sliders.

Recommendation: Click on 'Update Overview Map' first, to apply the new 'Spatial Selection' only to the Overview Map for validation. After the selection fits, click on 'Update Output'. This can save some computation time.

## Farm setup

The dynamic parameters in the farm setup are 'Max. Loop Depth [m]' and the 'Loop Interval [m]' (Figure 2). The 'Max. Loop Depth' ranges between 2-8 m, and is reactive to local bathymetry. The model will always restrict the loop depth to 2 m less than local bathymetry to ensure no bottom contact of the loops, which are placed 1 m below the water surface. The 'Loop Interval' ranges between 0.7-2.0 m and is independent of other local parameters. A farm with 2 m loop depth and 1 m loop interval will yield a total collector length of 90.000 m, while a farm with 8 m loop depth and 1 m loop interval will yield 306.000 m.

## Model Input

As model input, users can choose from the relevant pelagic habitat factors temperature, salinity, and chlorophyll-*a* concentration. These are integrated to a growth performance factor between 0 and 1 (Holbach et al., 2020). Those parameters are available as long-term averages (2007-2017) at monthly resolution, and the specific month is selected by the slider 'Month for Input Visualization'.

Further, local bathymetry, collector depth, and total collector length can be chosen. Collector depth and collector length are dependent on local bathymetry and the chosen farm setup (see 'Farm setup'). These parameters are time independent, and the slider 'Month for Input Visualization' does not affect respective outputs.

## Model Results

In the 'Model Results' section, users can visualize and investigate the different model outputs under varying farm setups.

The mussel weight, as biomass dry-weight of individual mussels, is a product of the Blue Mussel Growth Model (Module 2 in Figure 1), while all the other choices are derived from the Mussel Farm Model (Module 3 in Figure 1). Therefore, different farm setups will only affect outputs of the latter.

The cost function is still under development and not yet fully validated. This feature should, therefore, only be used for information purposes and outputs be treated with caution in the evaluation. The cost

function takes the different steps of mussel farming into account: (1) establishment, (2) start-up, (3) maintenance, and (4) harvest, while all these steps contain fixed and flexible costs. The material costs are estimated on the background of the intended farm setup, an expected lifetime of the different parts, as well as the expected amount of harvest, because larger biomass in the farm requires more buoys. Further, costs are estimated on the background of distance to the next harbor, while assuming the use of three types of boats for the different tasks.

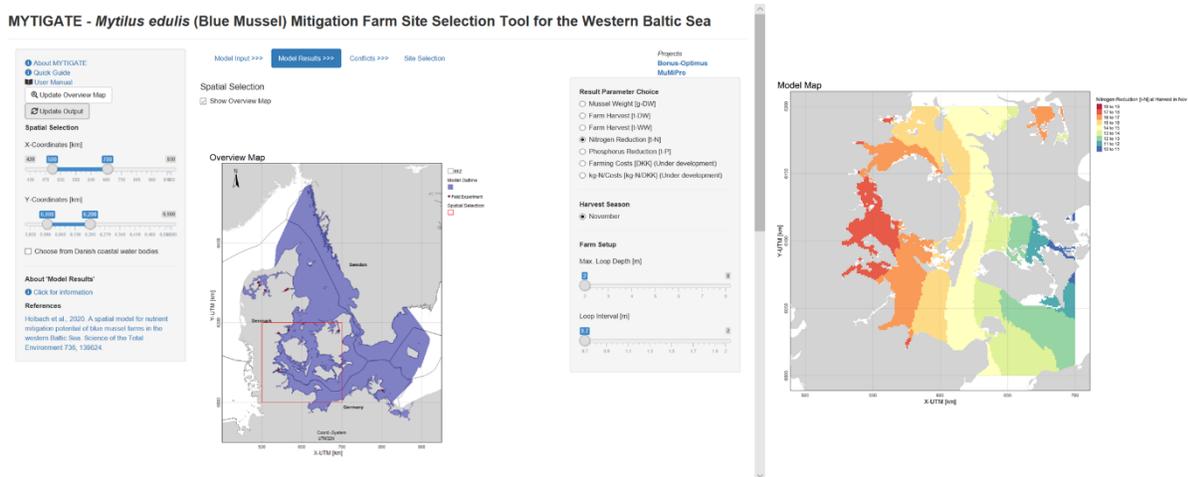


Figure 5: Example of an application of the 'Model Results' section in MYTIGATE. The spatial selection is applied for the result parameter Nitrogen Harvest.

## Conflicts

In the 'Conflicts' section, users can specify a row of exclusion and conflict criteria for the site selection process. The default is that none of these criteria is selected. 'Exclusion Criteria', act in a way that only those pixels remain, where none of the exclusion conditions is met. For the 'Conflict Criteria' users can specify a weight between 0 and 5, where 0 means that the conflict criterion is not considered, while 5 means a strong weight. Pixels are not categorically excluded, but the suitability of each pixel is reduced according to the weights and intensities of applying conflict criteria. Note that different levels of intensity are currently only available for 'Shipping Intensity' and 'Fishing Intensity'. All other 'Conflict Criteria' have constant intensity of 1.

'Suitability' for mussel farms is reduced based on conflict intensity and the selected conflict weight according to the following function:

$$Suitability = \frac{5}{5 + \sum(Intensity * Weight)}$$

Consequently, for areas in use for one conflict with Intensity = 1 and weight = 5, 'Suitability' is reduced by 50%.

## Site Selection

In the 'Site Selection' section, users can perform, visualize and investigate different site-selection scenarios, based on the optimization of different criteria and targets, as well as on the intended farm setup.

The selection is based on the optimization of the desired 'Selection Criterion'.

- Optimization for 'Mussel Weight' will yield the most suitable farms to gain largest individual mussels.
- Optimization for 'Farm Harvest' will yield the most suitable farms to gain largest harvest from the farm. As nitrogen content of mussels is assumed to be constant, this criterion equals to gain the largest nitrogen reduction.
- Optimization for 'kg-N/Costs' will yield the most suitable farm sites with respect to economic mitigation efficiency. Please note that the respective cost function is still under development and not yet fully validated. This feature should, therefore, only be used for information purposes and outputs be treated with caution in the evaluation.

The 'Selection Target' can be set to either a specified number of farms to be placed ('No of Farms'), or to a specified target reduction of nitrogen ('N-Reduction') within the current spatial selection. The slider will adapt according to the users' selection.

'Farming Suitability' is based on the site 'Suitability' (see 'Conflicts' section) and is then normalized to the maximum value of the 'Selection Criterion' within the given spatial selection area. 'Farming Suitability' is calculated as follows:

$$\text{Farming Suitability} = \text{Suitability} * \frac{\text{Selection Criterion}}{\max(\text{Selection Criterion})}$$

Based on 'Farming Suitability', a ranking of all sites is performed until the 'Selection Target' is reached. In case that there are several sites with equal 'Farming Suitability', as the last value in the ranking, all these sites are part of the selection. Pay attention to the 'Selection Report'. The selection report gives a summary of the selection procedure, as well as its results.

## Export of Tool Outputs

The outputs of MYTIGATE can be saved in two ways:

1. Each map can be downloaded as a '\*.png' image by clicking the 'Download Map' button to be found underneath each map.
2. Detailed information on all the selected sites within a specific scenario can be downloaded as a '\*.csv' table by clicking the 'Selection Data as \*.csv' button. This button appears underneath the output map in the 'Site Selection' section.

## Share Your Site Selection Scenario with Us

We are continuously investigating environmental impacts of mussel mitigation farms. Therefore, it is very valuable for us to receive your personally preferred MYTIGATE site selection scenario. Please support our further research by sending us your downloaded 'Selection Data as \*.csv'. Your input will be treated 100% anonymous. Next to the 'Selection Data as \*.csv' button you will find a 'Share your scenario with us'

button. By clicking this button and the following link, MYTIGATE will try to access your email client to open a pre-edited mail. Please use this form to send us your downloaded 'Selection Data as \*.csv'. You are also very welcome to let us know, if a relation to one of the following stakeholder groups has influenced the setting of your site selection criteria.

- local inhabitant
- local summerhouse owner
- professional mussel farmer
- member of an NGO
- working in environmental management
- something else

In the pre-edited mail, please just delete the fields that do not fit to yourself. You are also asked to provide us with criteria that you feel are missing in MYTIGATE.

For the Danish speaking people, a respective questionnaire in Danish language is attached to this manual, which you are also welcome to fill out and send to us (anho@bios.au.dk).

## Limitations and Liability

The spatial model for nutrient mitigation potential of blue mussel farms in the western Baltic Sea is subject to several limitations and underlying assumptions. These are thoroughly discussed in Holbach et al., 2020.

Users should further be aware that the authors are not the originators of the spatial data on marine utilization and that they cannot be held responsible for their correctness and integrity. Data provided within MYTIGATE, is not necessarily comprehensive and we strongly recommend to acquire further information on relevant specific local conditions and knowledge, prior to decision-making and establishing mussel mitigation farms at the selected sites. Currently, MYTIGATE is spatially limited to the western Baltic Sea.

## References

Holbach A, Maar M, Taylor D, Timmermann K, 2020. A spatial model for nutrient mitigation potential of blue mussel farms in the western Baltic Sea. *Science of the Total Environment* 736, 139624, <https://doi.org/10.1016/j.scitotenv.2020.139624>.

EPA (Environmental Protection Agency of Denmark), 2016. Vandområdeplaner 2015-2021. Ministry of Environment and Food of Denmark (2016), <https://www.mst.dk/natur-vand/vandmiljoe/vandomraadeplaner/vandomraadeplaner-2015-2021>.

## Appendix

### Spørgeskema — kriterier for placering af muslingeopdrætsanlæg

Aarhus Universitet, Institut for Bioscience

Danmarks Tekniske Universitet, Dansk Skaldyr Center

#### ***Kære Interessent,***

Tusind tak fordi du er villig til at bruge nogle få minutter til at hjælpe os med at gennemføre vores undersøgelse, som handler om forskellige mulige placeringer af muslinge anlæg i Horsens Fjord området. Muslingeopdræt er for tiden omtalt som et potentielt effektivt virkemiddel imod overskydende næringsstoffer i de danske kystfarvande, herunder Horsens fjord.

Du er medlem af én af de interessentgrupper, som vi ser som vigtige ift. mulige placeringer af sådanne virkemiddelanlæg. Vi vil derfor meget gerne høre din mening om samspillet mellem virkemiddelanlæg og andre interesser og aktiviteter på havet.

De følgende spørgsmål handler om de kriterier, vi bruger i et nyt værktøj til placering af muslinge anlæg. Ud fra disse kriterier, vil værktøjet identificere de optimale placeringer for virkemiddelanlæg i området. Vi vil gerne bruge dit værdifulde — og anonyme — bidrag til at udvikle forskellige scenarier for placering af muslinge anlæg. Scenarierne skal efterfølgende bruges i en økologisk modeløvelse, hvor vi undersøger, hvordan forskellige placeringer påvirker det marine økosystem, både positivt (f.eks. kvælstoffjernelse, reduktion af fytoplankton, vandklarhed) og negativt (f.eks. forandringer i sedimentet).

Kriterierne er delt op i to overordnede kategorier:

- 1) **Udelukkelseskriterier** forårsager en kategorisk udelukkelse af virkemiddelanlæg på disse steder. I vores undersøgelse vil de første fem udelukkelseskriterier altid være aktive, fordi vi vurderer at disse former for brug af havet er vigtige og for svære at flytte. Du skal derfor ikke svare på de 5 første kriterier (grå baggrund) i tabellen. De resterende kriterier skal vægtes ift. afstand til anlægget (km) eller vanddybde (m).
- 2) **Konfliktkriterier** kan vægtes, så der enten overhovedet ikke tages højde for dem [0], eller der tages højde for dem med forskellig styrke [1-5]. Jo højere vægt du angiver for et kriterie, des mindre sandsynlighed er der for at virkemiddelanlæg bliver placeret i dette område.

Det er vigtigt for os at du tager stilling til alle kriterier, for ellers kan vi ikke beregne en endelig placering med værktøjet. Sæt venligst kryds ved de felter, som passer bedst til din personlige vurdering, i det følgende skema:

Udelukkelseskriterier		Valgmuligheder					
Vigtigste sejlruiter	aktiv	<i>Skal ikke udfyldes</i>					
Militære marine skydeområder	aktiv						
Områder med restriktioner for sejlads ankring og fiskeri	aktiv						
Marine vindmølleparker	aktiv						
Kabler & rørledninger	aktiv						
Hvor langt væk bør havneindgange som minimum holdes fri for virkemiddel anlæg? [i km]	Ved ikke	1	2	3	4	5	
Hvad bør den maksimale afstand fra et virkemiddel anlæg til den nærmeste egnede havn være? [i km]	Ved ikke	>75	75	50	25	15	
Hvad er den maksimale egnede vanddybde til placering af en virkemiddel anlæg? [i m]	Ved ikke	50	40	30	20	10	
Hvor langt væk bør en virkemiddel anlæg som minimum være placeret i forhold til det tætteste officielle badested? [i km]	Ved ikke	<1	1	2	3	4	5
Hvor langt væk bør en virkemiddel anlæg som minimum være placeret i forhold til det tætteste byområde? [i km]	Ved ikke	<1	1	2	3	4	5
Hvor langt væk bør en virkemiddel anlæg som minimum være placeret i forhold til det tætteste sommerhusområde? [i km]	Ved ikke	<1	1	2	3	4	5

Konfliktkriterier		Vægt					
Hvor stærkt ønsker du at undgå placering af virkemiddelfarme ...		[0: overhovedet ikke, 5: meget stærkt]					
... indenfor <b>beskyttede områder</b> ?		0	1	2	3	4	5
... ved steder hvor der for nuværende er betydelig <b>intensitet af skibstrafik</b> (ud over de officielle sejlruiter)?		0	1	2	3	4	5
... ved steder hvor der for nuværende er betydelig <b>intensitet af fiskeri</b> ?		0	1	2	3	4	5
... ved steder hvor der for nuværende <b>udgraves sediment</b> ?		0	1	2	3	4	5
... ved steder hvor der for nuværende <b>dumpes sediment</b> ?		0	1	2	3	4	5
... i <b>kapsejladser</b> ?		0	1	2	3	4	5

Savner du nogle vigtige kriterier til placeringen af virkemiddel anlæg i dette skema?

Til sidst vil vi gerne spørge dig om din personlige tilknytning til muslinge anlæg som marint virkemiddel:

Jeg er (sæt venligst kryds ved den valgmulighed, som mest påvirker din holdning over for virkemiddel anlæg)

- lokal beboer
- lokal sommerhusejer
- professionel muslingeopdrætter
- medlem af NGO
- medarbejder i miljøforvaltning
- andet

Skulle du være i tvivl om noget i dette spørgeskema, eller har du brug for yderlig information for at kunne besvare spørgsmålene, så er du meget velkommen til at kontakte os:

Andreas Holbach: [anho@bios.au.dk](mailto:anho@bios.au.dk), 24671986

Marie Maar: [mam@bios.au.dk](mailto:mam@bios.au.dk), 871158572

Daniel Taylor: [dtay@aqua.dtu.dk](mailto:dtay@aqua.dtu.dk), 93518975

## Relaterede projekter



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