USER MANUAL

INTRODUCTORY MANUAL TO THE NON-INDIGENOUS SPECIES EFFECT ASSESSMENT TOOL (NEAT)

PREFACE

The Non-indigenous species Effect Assessment Tool (NEAT) is the result of a collaborative effort by marine scientists, supported by the EEA and Norway Grants Fund for Bilateral Relations and the Horizon Europe project BLUE4All. This initiative builds on the shared vision of delivering scientifically robust, spatially explicit, and policy-relevant tools for managing the growing threat of marine non-indigenous species (NIS).

NEAT was developed to address the need for standardized, data-driven assessment methods that can support marine management and conservation decisions. By combining systematic literature reviews, species distribution modelling, and quantitative ecological metrics, the tool represents an important step from expert-only assessments towards more transparent and reproducible evaluations of the potential ecological effects of marine NIS.

Initially developed for the Baltic Sea and Oslofjord, and later expanded to cover the Greater North Sea and Celtic Seas, NEAT now provides spatially explicit impact assessments through the BlueBioSites portal. The tool supports marine planners, policymakers, and other stakeholders in identifying potential NIS impact hotspots, evaluating potential ecological risks, and supporting evidence-based responses in both data-rich and data-poor contexts.

NEAT directly supports the implementation of key EU directives and strategies, including the Marine Strategy Framework Directive and the EU Biodiversity Strategy for 2030, and contributes to more consistent and science-based effect assessments in marine ecosystems.

INTRODUCTION

NEAT is an operationalization of the framework developed by Kotta et al. (2025) for the assessment of the potential impact of NIS in marine environments. The digital tool integrates species distribution maps based on probability of occurrence with effect sizes derived either from scientific literature or expert assessment to estimate the potential ecological and environmental effects, both negative and positive, of NIS.

The tool calculates the following outputs based on the user-defined analysis extent and selected species:

- Potential effects for each species (mean and standard error): $E_{ij} = P_{ij} \times E_j$

where Eij is the potential effect of species i in cell i, Pij is the probability of occurrence of species i in grid cell j, andEj is the effect size estimated for species i at maximum abundance/biomass.

- Combined potential negative effects: $NI_j = \sum_{i \epsilon S_j^-} E_{ij}$

where NIj is the overall negative impact of the species occurring in cell j, and Sj- is the set of species with identified negative effects in cell j.

The tool currently includes probability of occurrence maps for 40 species across Northern Europe, with expert-validated maps available for the Baltic Sea, Oslofjord, and the French Natura 2000 network. These maps are combined with evidence- or expert-based effect sizes for each species to calculate spatially explicit species-level effects. Details on the integration distribution maps and effect sizes are provided below.

NON-INDIGENOUS SPECIES PROBABILITY OF OCCURRENCE MAPS

Distribution maps were generated using MaxEnt presence-only modelling. Occurrence data for the NIS was obtained from open-access databases GBIF and OBIS. Environmental and anthropogenic input data were obtained from open-source European databases (Table 1). Species-specific environmental tolerance limits were also compiled and used to support model development. The same variables were considered for all species, with two exceptions: nitrate and phosphate were included only for primary producers, whereas net primary productivity was included for all other species. For each species, two models were developed: a full model including all available variables, and a reduced model including only variables that contributed more than 5% to the jackknife test of the full model. The best-performing model was selected based on the Area Under the Curve (AUC) value and expert judgement. Model development was carried out iteratively with local experts from Oslofjord, Baltic Sea and France. Additional data from national data sources and participatory mapping were incorporated to improve the predictions, preliminary maps were validated through several rounds of expert review, and both the models and environmental tolerance limits were refined based on the feedback received. Final maps considered suitable by local experts for specific areas were integrated into NEAT and indicated as “validated” in the tool.

Table 1. Environmental and anthropogenic data included in species distribution models.

Variable	Source	Resolution
Depth	EMODnet	1/16 * 1/16 arc min (~115 m)
Substrate type*	Horizon Blue4all project	1:250,000 scale (~0.25–2.5 km)
Vessel average density	EMODnet	1 km² grid
Windspeed	Copernicus	0.25° × 0.25° (~25 km)
Net Primary Production	Copernicus	0.25° × 0.25° (~25 km)
Nitrate Concentration	Copernicus	0.25° × 0.25° (~25 km)
Phosphate Concentration	Copernicus	0.25° × 0.25° (~25 km)
Salinity	Copernicus	0.083° × 0.083° (~9 km)
Sea surface temperature	Copernicus	0.083° × 0.083° (~9 km)
Tidal Amplitude	AVISO	0.063° × 0.063° (~7 km)

*The substrate type layer was developed within the Horizon Europe Blue4All project by refining the EMODnet EUNIS 2023 seabed habitat map using habitat information validated for the French Natura 2000 network. Based on the best available information, all habitat polygons were reclassified into three substrate categories: soft sediment, mixed sediment, and hard substrate. Further methodological details are provided in the Blue4all Deliverable 3.3 (Nurkse et al., 2025).

Species-specific environmental tolerance limits were applied where threshold values could be derived from published evidence or defined in consultation with local experts from the relevant areas (Table 2).

Table 2. Non-indigenous species known tolerance limits based on best available knowledge

Species	Salinity (min)	Salinity (max)	Depth (max)
Acartia tonsa	2	35	
Sinelobus vanhaareni	1		
*Gracilaria vermiculophylla**	5		6
Evadne anonyx	2		
Ficopomatus enigmaticus	1		3
Cordylophora caspia		35	
Dasya baillouviana	5		100
Mya arenaria	5	35	
Caprella mutica	6		
Dreissena polymorpha		6	
Ensis leei	15		
Mnemiopsis leidyi	7		
Ruditapes philippinarum	12		
Petricolaria pholadiformis	7.5		
Chara connivens		9	7
Dasysiphonia japonica	10		10
Laonome xeprovala	10		15
Hemigrapsus spp.	8		
Grateloupia turuturu	12		14
Crepidula fornicata	15		
Asparagopsis armata	20		40
Magallana gigas	4		20
Sargassum muticum			10
Palaemon elegans			30
Bonnemaisonia hamifera			10
Undaria pinnatifida	20		10
Codium fragile	12		10

Probability of occurrence maps for 40 species are included in NEAT, with 24 species maps validated for the Baltic Sea, 13 for the Oslofjord, and 21 for the French Natura 2000 network area by local experts (Table 3).

For ecologically similar alien species, a single probability of occurrence map was produced. For example, species within the genus Marenzelleria (M. viridis, M. neglecta, and M. arctica) and the genus Hemigrapsus (H. sanguineus and H. takanoi) are represented by shared maps. The probability maps for Rhithropanopeus harrisii, Rangia cuneata, Marenzelleria spp., Gammarus tigrinus, and Neogobius melanostomus should be interpreted with caution. For these species, modelled probabilities are provided only for the Baltic Sea. Outside the Baltic Sea, their occurrence is either unconfirmed or assumed to be absent; accordingly, their probability of occurrence is displayed as zero in those areas.

Table 3. Non-indigenous species probability of occurrence maps validated in NEAT for different areas.

Species	Species group	French MPA network area	Baltic Sea	Oslofjord
Sargassum muticum	algae/brown	x		x
Undaria pinnatifida	algae/brown	x		
Chara connivens	algae/charophyte		x	
Codium fragile	algae/green	x		x
Asparagopsis armata	algae/red	x		
Bonnemaisonia hamifera	algae/red	x		x
Dasya baillouviana	algae/red			x
Dasysiphonia japonica	algae/red	x		x
Gracilaria vermiculophylla	algae/red	x	x	x
Grateloupia turuturu	algae/red	x		x
Dreissena polymorpha	bivalve		x	
Ensis leei	bivalve	x		
Magallana gigas	bivalve	x		x
Mya arenaria	bivalve	x	x	
Mytilopsis leucophaeata	bivalve		x	
Petricolaria pholadiformis	bivalve			
Rangia cuneata	bivalve		x	
Ruditapes philippinarum	bivalve	x		
Eriocheir sinensis	benthic crustacean/crab		x	
Hemigrapsus spp.	benthic crustacean/crab	x	x	x

Rhithropanopeus harrisii	benthic crustacean/crab		x	
Amphibalanus improvisus	benthic crustacean	x	x	x
Caprella mutica	benthic crustacean	x		x
Gammarus tigrinus	benthic crustacean		x	
Hemimysis anomala	benthic crustacean		x	
Palaemon elegans	benthic crustacean		x	
Sinelobus vanhaareni	benthic crustacean		x	
Carassius gibelio	fish		x	
Neogobius melanostomus	fish		x	
Crepidula fornicata	gastropod	x		x
Potamopyrgus antipodarum	gastropod		x	
Cordylophora caspia	hydrozoa	x	x	
Ficopomatus enigmaticus	polychaete	x		
Laonome xeprovala	polychaete		x	
Marenzelleria spp.	polychaete		x	
Acartia tonsa	plankton crustacean	x	x	
Cercopagis pengoi	plankton crustacean		x	
Evadne anonyx	plankton crustacean		x	
Mnemiopsis leidyi	ctenophore	x	x	
Styela clava	tunicate	x		x

OSLOFJORD

High-resolution environmental data provided by NIVA enabled the development of fine-scale probability of occurrence maps (50 m x 50 m grid) for 13 taxa in the Oslofjord region (Table 4). Each of these species has the potential to affect native species and habitats in the area, as indicated in the Norwegian Alien Species List.

The reliability of the distribution maps representing the current range of each species was assessed and validated by NIVA experts.

Table 4. Non-indigenous species in Oslofjord.

Species	Species group	French MPA network area	Baltic Sea	Oslofjord
Sargassum muticum	algae/brown	x		x
Undaria pinnatifida	algae/brown	x		
Chara connivens	algae/charophyte		x	
Codium fragile	algae/green	x		x
Asparagopsis armata	algae/red	x		
Bonnemaisonia hamifera	algae/red	x		x
Dasya baillouviana	algae/red			x
Dasysiphonia japonica	algae/red	x		x
Gracilaria vermiculophylla	algae/red	x	x	x
Grateloupia turuturu	algae/red	x		x
Dreissena polymorpha	bivalve		x	
Ensis leei	bivalve	x		
Magallana gigas	bivalve	x		x
Mya arenaria	bivalve	x	x	
Mytilopsis leucophaeata	bivalve		x	
Petricolaria pholadiformis	bivalve			
Rangia cuneata	bivalve		x	
Ruditapes philippinarum	bivalve	x		
Eriocheir sinensis	benthic crustacean/crab		x	
Hemigrapsus spp.	benthic crustacean/crab	x	x	x

NON-INDIGENOUS SPECIES EFFECT SIZES

Science-based evidence

The literature search for effect sizes used in the NEAT was conducted using the Web of Science and Scopus databases in December 2024. It was complemented with the effect size database developed for the PlanWise4Blue tool. The extraction process for obtaining effect sizes from each study followed the methodology described in the PlanWise4Blue user guide (https://gis.sea.ee/bluebiosites/files/PW4B_manual.pdf).

Science-based effect sizes related to both biotic and abiotic environment effects are now included for 13 taxa in the NEAT – Cercopagis pengoi (9 evidence), Dreissena polymorpha (79), Gammarus tigrinus (24), Marenzelleria spp. (202), Neogobius melanostomus (67), Palaemon elegans (48), Rhithropanopeus harrisii (100), Gracilaria vermicophylla (46), Magallana gigas (15), Sargassum muticum (18), Mnemiopsis leidyi (8), Hemigrapsus spp. (15), Crepidula fornicata (1). The database is continuously expanding as new findings are incorporated through different projects and should therefore not be considered final.

Based on the available evidence, the per capita Hedges' g (Hedges and Olkin, 1985) was calculated for species having two or more evidence records, following the approach proposed by Kotta et al. (2025). As the tool currently uses only probability of occurrence maps, rather than the biomass or abundance maps originally proposed by Kotta et al. (2025), the final effect size calculation was adjusted to reflect the potential maximum effect of a species if it reaches maximum abundance or biomass, based on reported maximum values in the scientific literature or on expert judgement.

EXPERT ASSESSMENT

The NEAT tool also enables effect assessment in situations where data availability is low. For these cases, effect sizes were determined through expert assessment, considering the potential positive and negative impacts that a species may have at maximum densities.

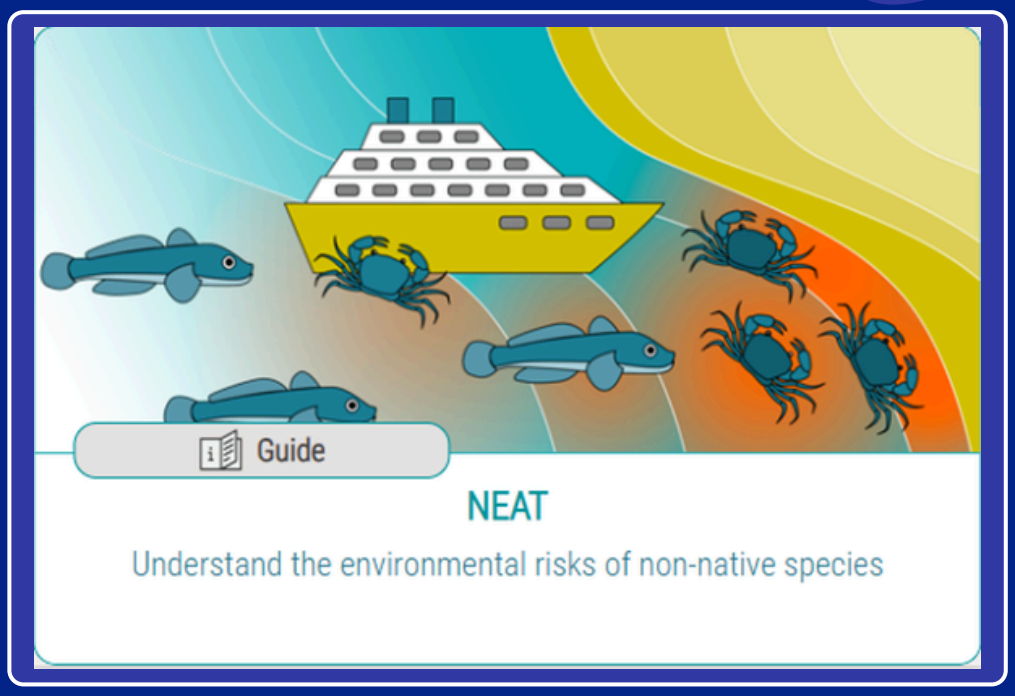
The assessment template shared with experts evaluates species effects across key ecological and environmental dimensions. It considers how each species may alter abiotic conditions in the water column and sediments, affect habitat formation, and influence biotic interactions, including predator–prey relationships and competition with other species. Experts assessed the potential effects of each invasive species across all mentioned ecological and environmental dimensions. Each dimension was scored on a scale from −3 to +3, using 0.5-point intervals.

The overall effect size was calculated as the average of all categories relevant to the species, while non-applicable categories were excluded from the calculation (e.g. primary producers were not assessed as predators). Variability in the effect assessment is represented by the standard error among experts. The expert assessments were conducted by local marine ecologist, including three experts from the Baltic Sea region and two experts from the French MPA network area.

STEP-BY-STEP USAGE OF NEAT

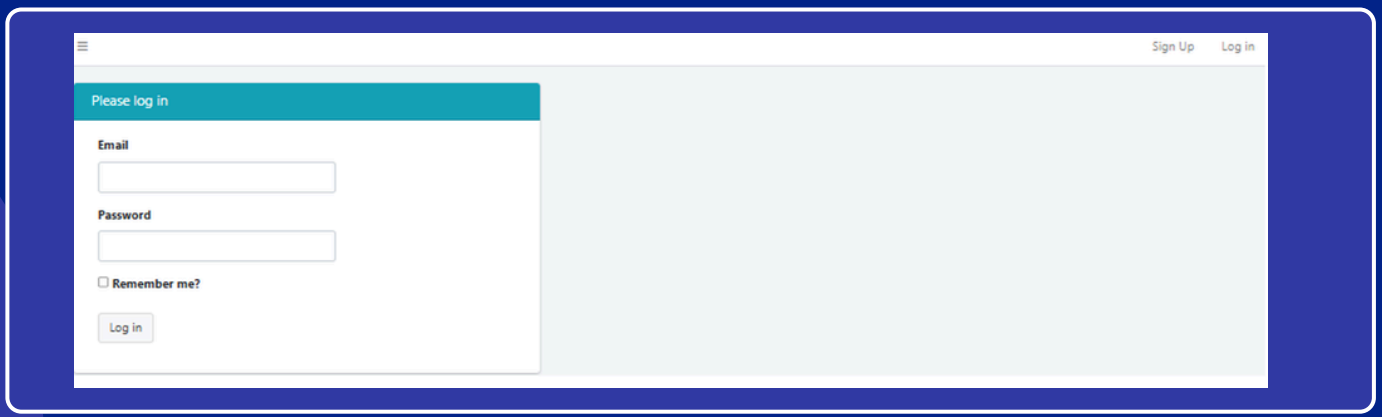
STEP 1: CREATE A USER ACCOUNT AND LOG IN

Go to https://gis.sea.ee/bluebiosites/ and select NEAT.



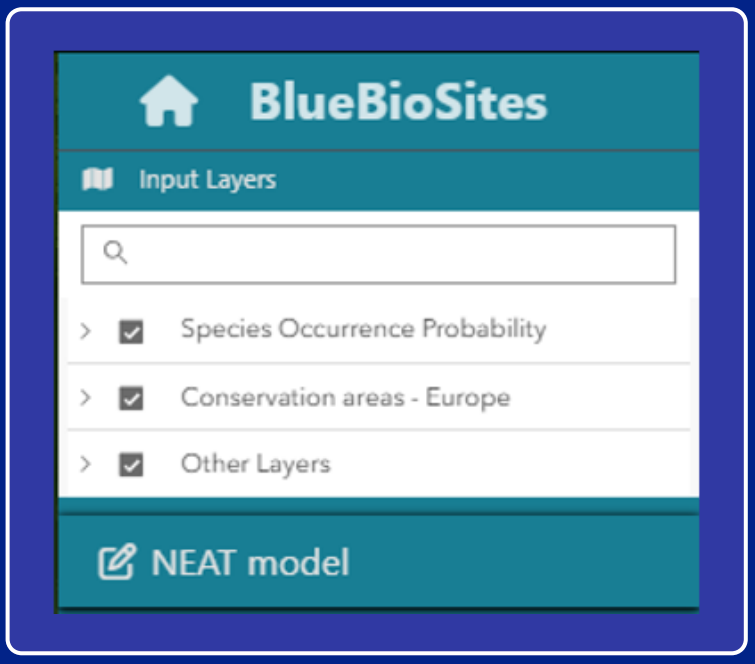
Click “Register” (new users) or “Log in” (existing users).

NOTE: For new users the confirmation email may take up to 2 days.



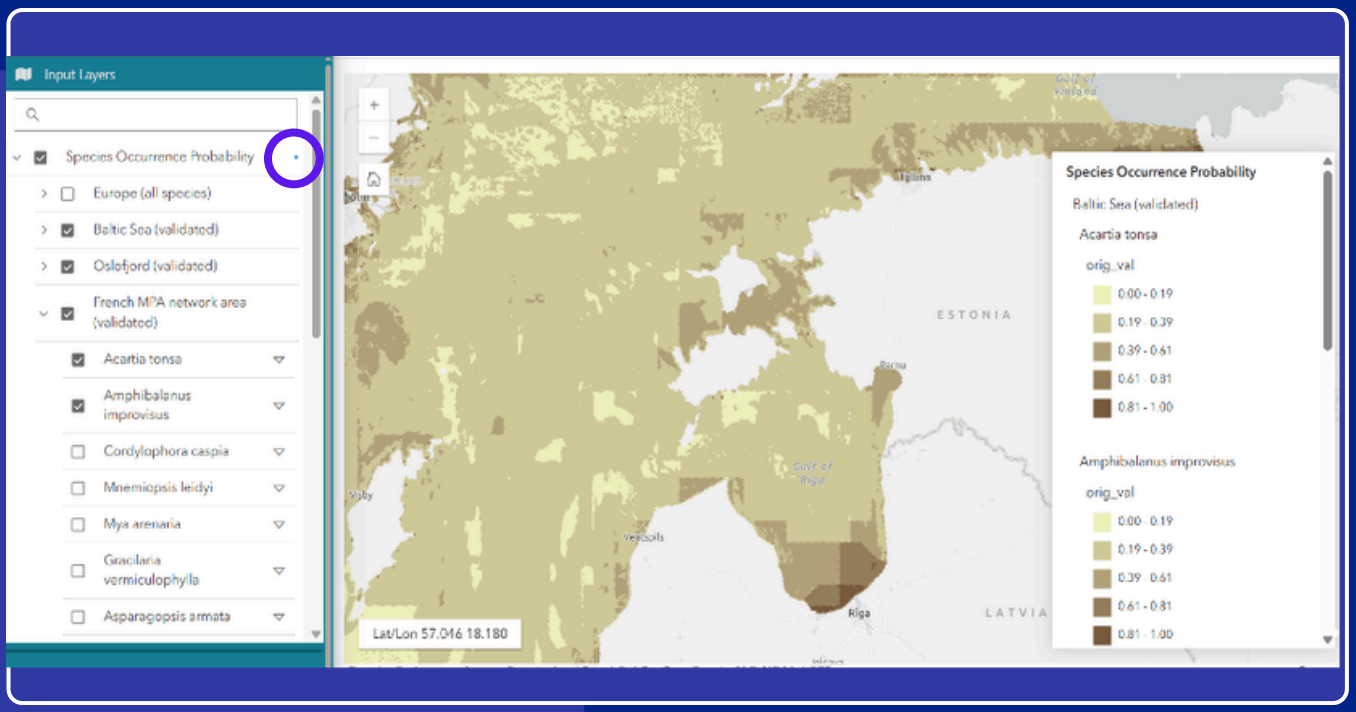
STEP 2: VERIFY THE SUITABILITY OF SPECIES PROBABILITY OF OCCURRENCE MAPS

Before running an analysis, users should review the species' probability-of-occurrence maps in the "Input Layers" section to ensure that the underlying distribution patterns are reasonable for the area of interest. Depending on the region, three pathways are available:



Option A: Expert-validated areas:

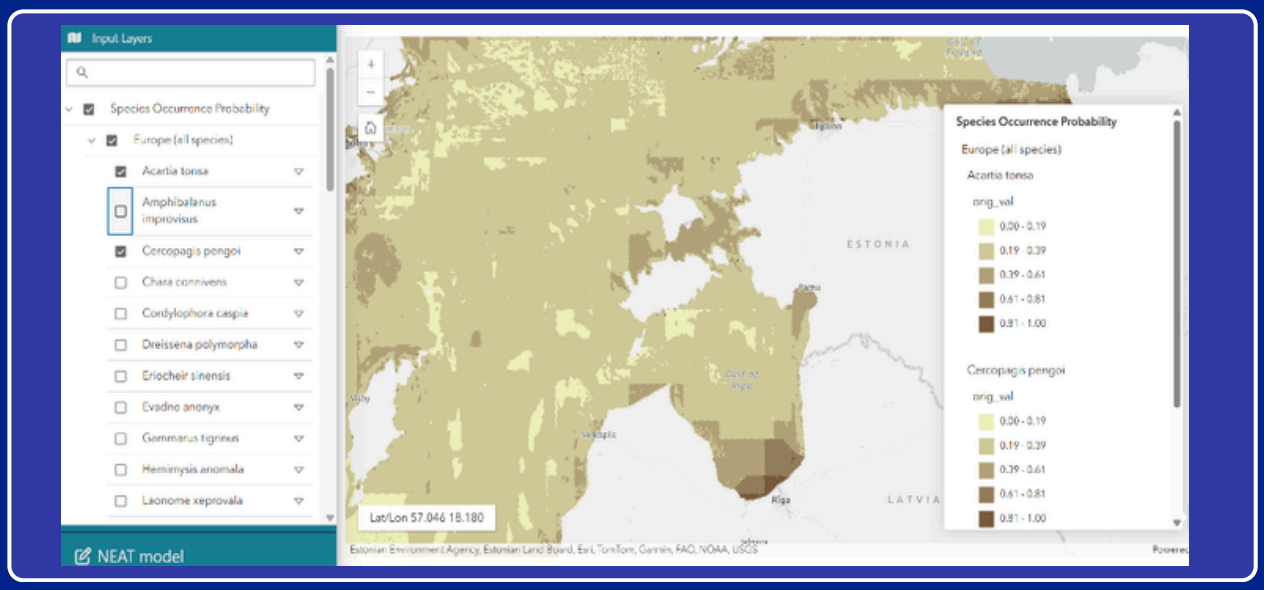
If the area of interest falls within regions where input layers have been validated using local expert knowledge (currently the French Natura 2000 MPA network area, the Oslofjord, and the Baltic Sea), users can proceed with the existing layers. The probability of occurrence maps for each species can be viewed in the "Species occurrence probability" layer within the Input Layers section. "(Validated)" indicates that the species occurrence probability maps have been validated for the specific area by local expert knowledge. The maps can also be checked when selecting species for the NEAT model (STEP 5).



NOTE: A small blue dot (purple circle) indicates that the selected layer is still loading.

Option B: Areas covered by existing maps but not yet locally validated

If the area is included in existing distribution layers (dropdown list “Europe (all species)) but lacks local validation, users should verify the maps for the selected species in consultation with relevant experts (e.g., scientists with local expertise, national monitoring specialists, taxonomic experts).



Option C: Areas not covered by existing maps

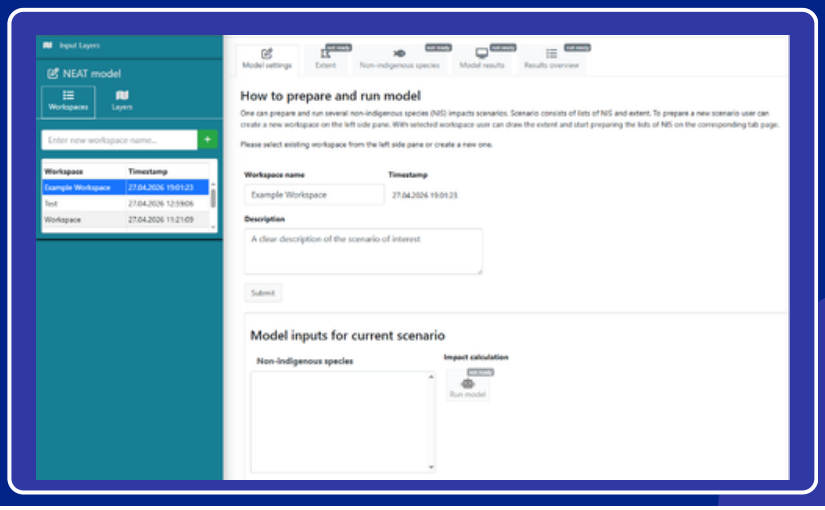
If the area is not covered by current distribution layers, users should contact NEAT user support (bluebiosites@ut.ee) and provide new spatially gridded input data for integration. Where suitable maps are unavailable, new modelling will be required.

STEP 3: CREATE A NEW WORKSPACE IN THE “NEAT MODEL” SECTION

To prepare a new scenario, users can create a workspace using the left-side panel by clicking the “+” icon. Users can either:

- Name the workspace in advance by entering a name before clicking “+”, or
- Click the green “+”, then provide a name and description, and select “Submit” to save

NOTE: After running the model and getting the results, an overview of the non-indigenous species used in that workspace will be available in the “Model inputs for current scenario” tab.

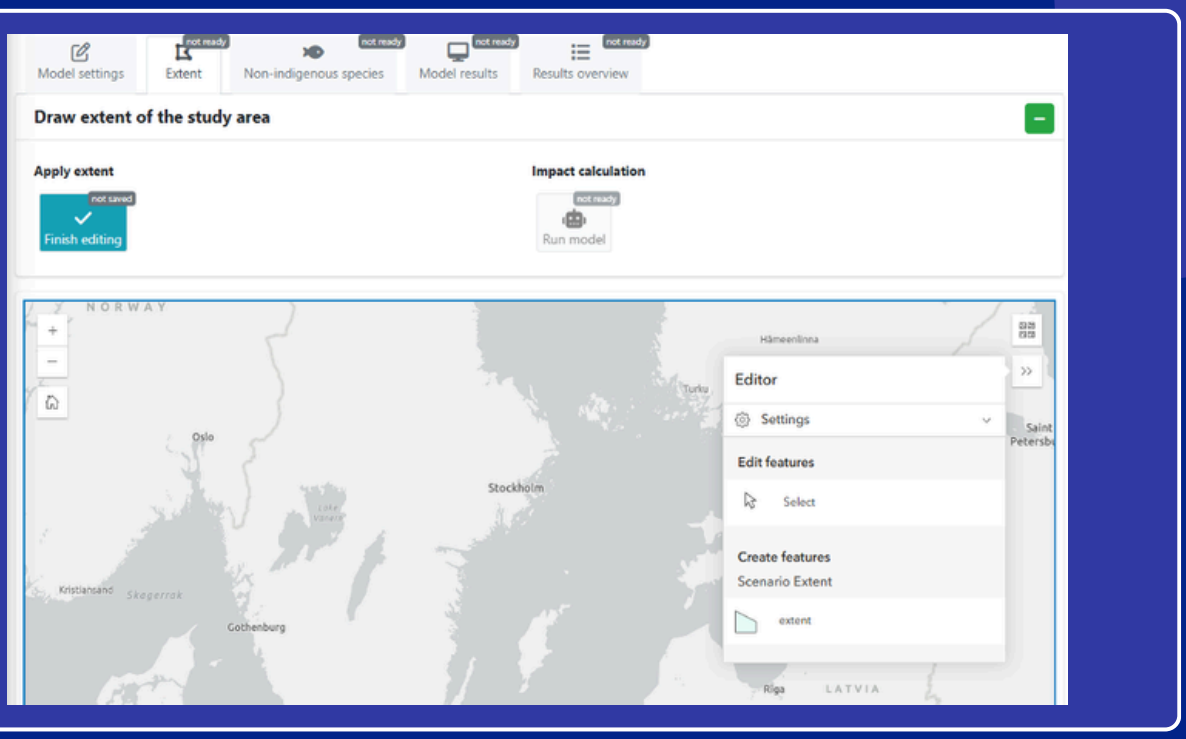


STEP 4: DEFINE THE EXTENT OF ANALYSIS

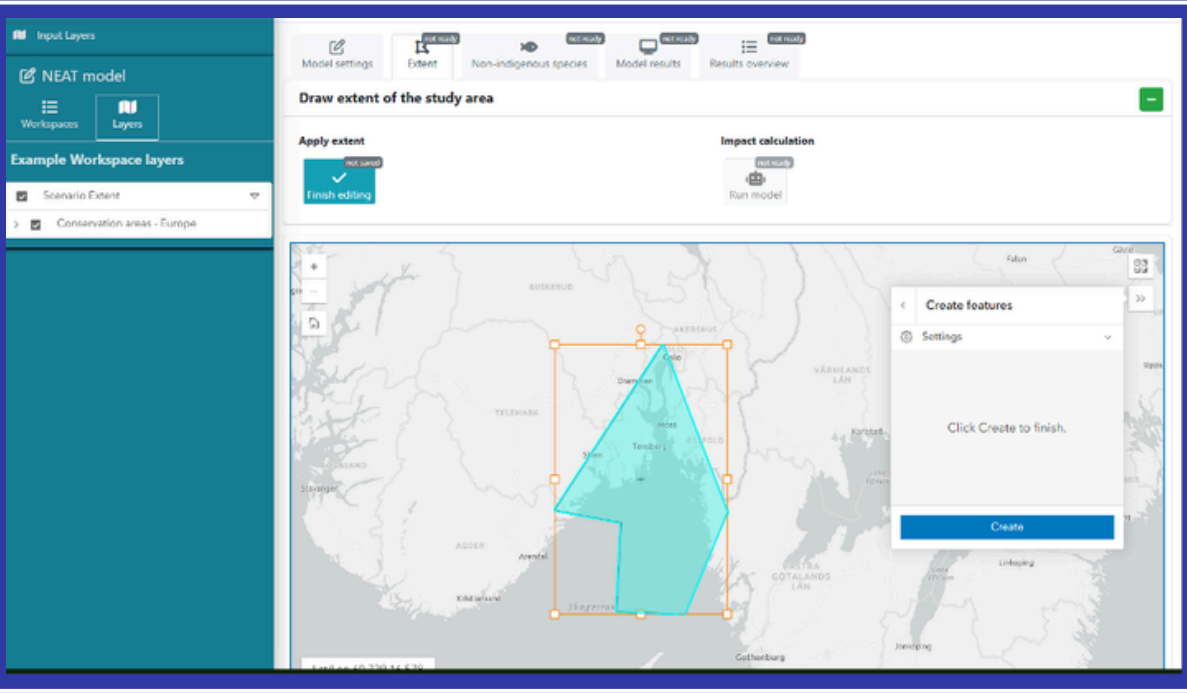
To run the model for a specific study area, define the extent in the “Extent” tab.

NOTE: The map style can be changed using the button in the top-right corner.

1) Select “extent” under the “Create features” in the editor box.

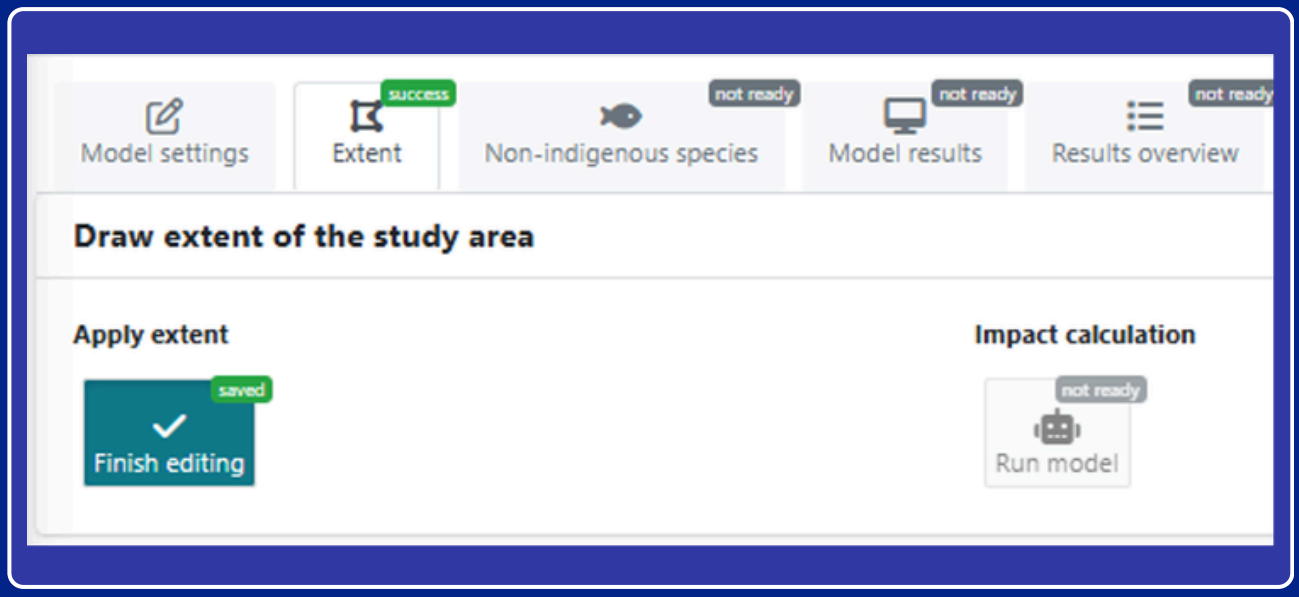


2) Click on the map to begin drawing; double-click to complete the extent. The defined area can then be resized or repositioned as needed. Once done, click “Create”.



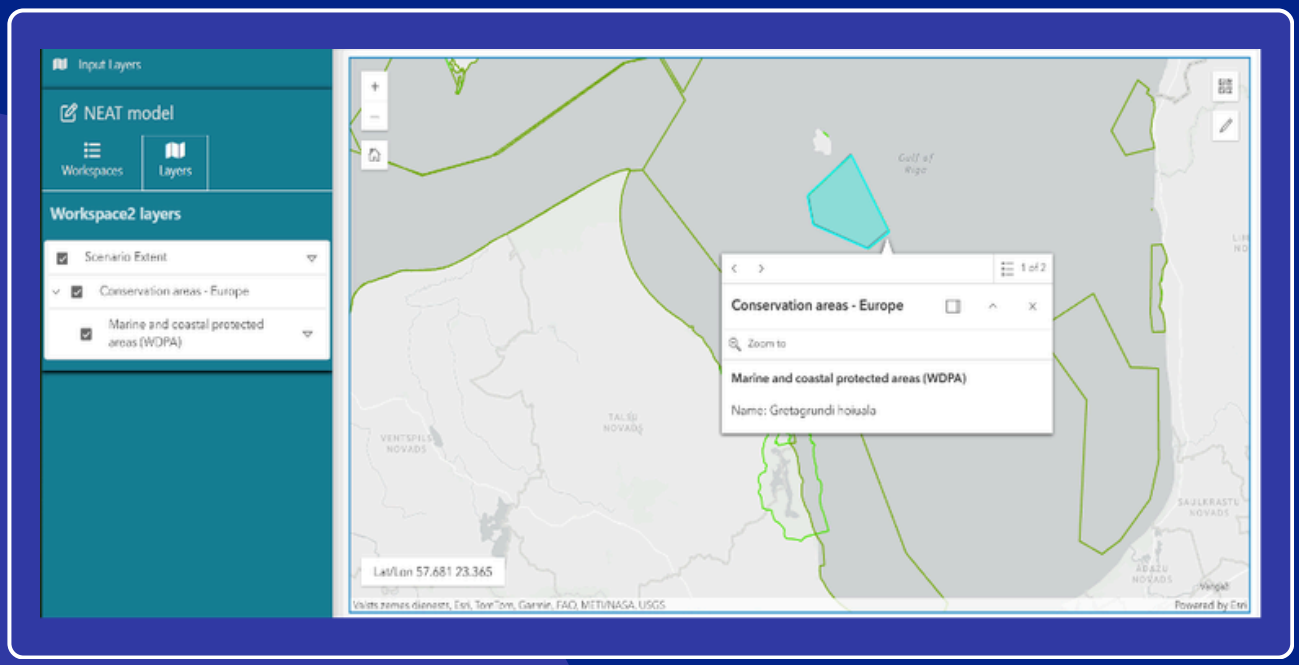
STEP 4: DEFINE THE EXTENT OF ANALYSIS

3) Click “Finish editing”. A green “success” indicator will confirm completion in “Extent” tab.



Optional: To align the extent with conservation areas (e.g., MPAs), enable “Marine and coastal protected areas (WDPA)” (areas will be displayed in green) and follow their boundaries when drawing. This allows analysis within a specific conservation area and supports viewing corresponding values in the results table.

NB! You can also draw multiple extents, to assess potential effects within a MPA network.



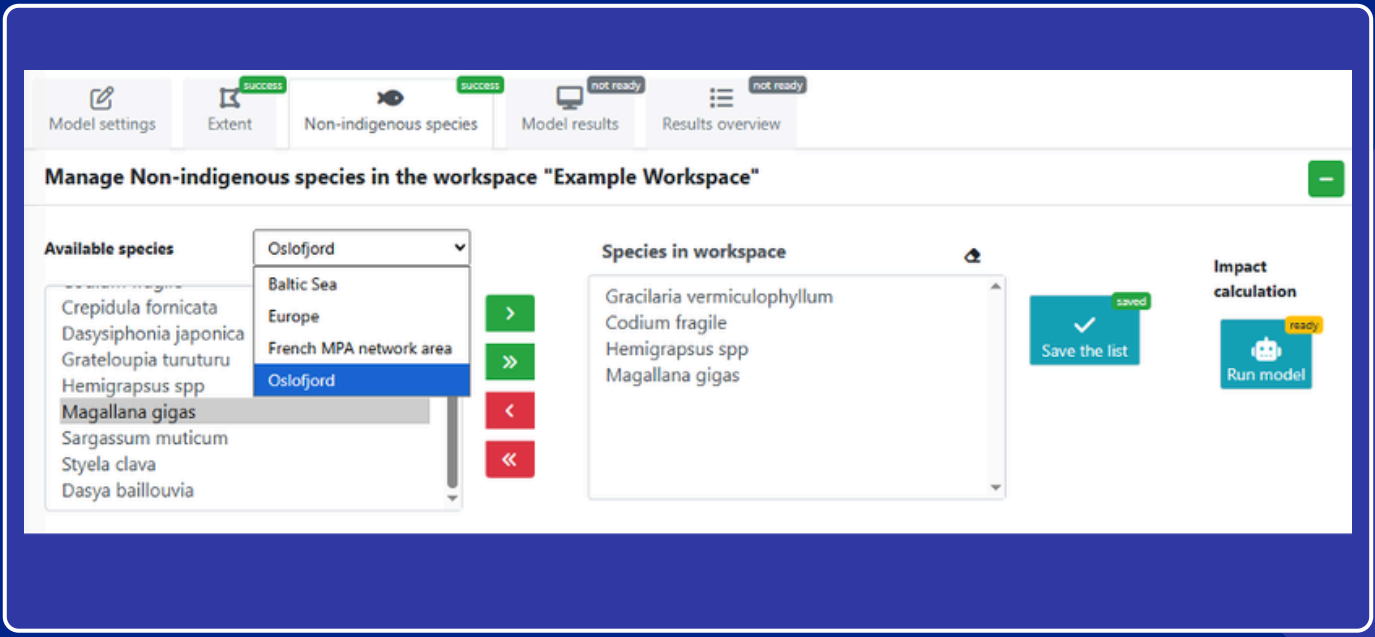
STEP 5: SPECIES SELECTION

In the “Non-indigenous species” tab, users define the scenario by selecting species relevant to the area of interest. Selection should be guided by local knowledge or monitoring data where available to ensure the scenario reflects current conditions and likely risks. If such information is unavailable, users may:

- Select all species for a precautionary screening overview
- Consult local experts (e.g., scientists with local expertise, national monitoring specialists, taxonomic experts) to define an appropriate subset

Managing the list of species:

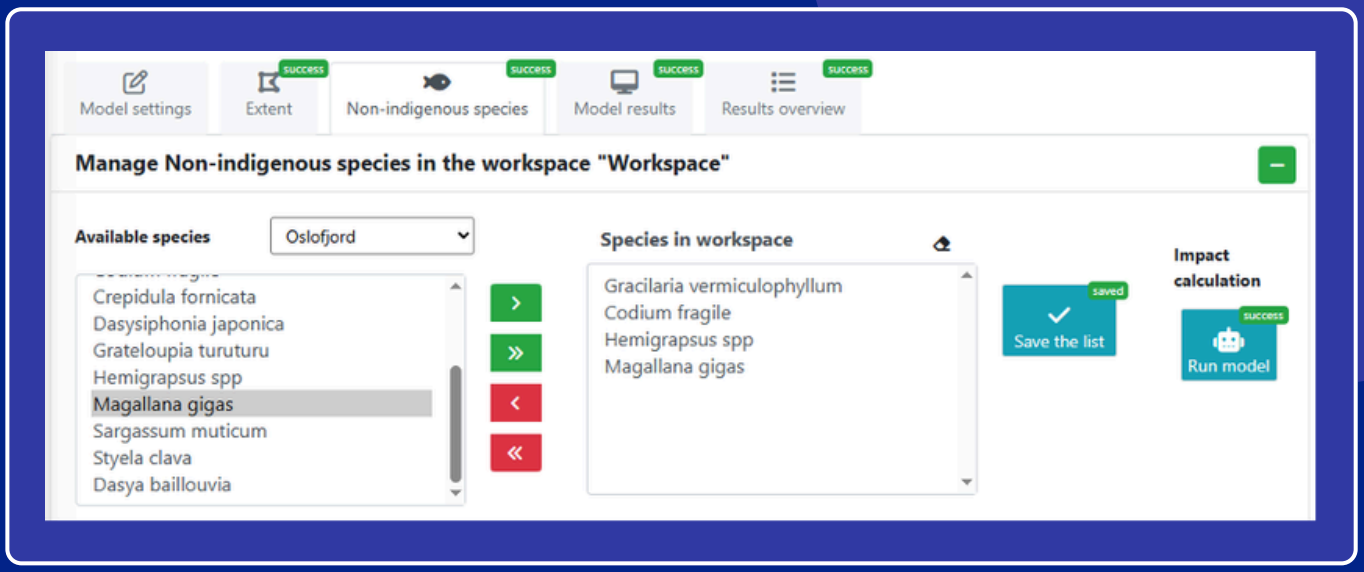
- “Europe” species list contains all species, while Baltic Sea, French MPA network area, and Oslofjord lists contain only the species whose maps have been validated using local expert knowledge.
- Use single arrows to add (green) or remove (red) individual species. Use double arrows to add or remove all species.
- After selection, click “Save the List”. A green “success” indicator confirms completion.



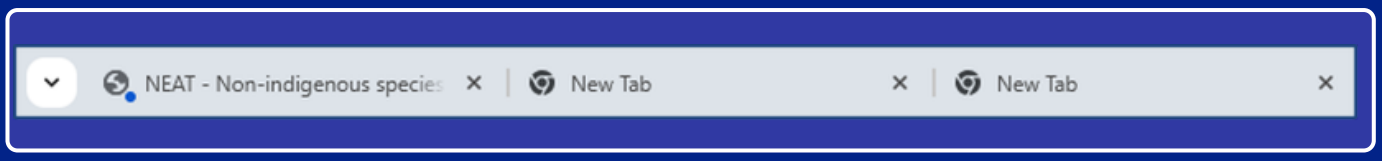
NOTE: High-resolution maps (50m x 50m) are only available for Oslofjord area, other areas maps are at 1 km2 resolution.

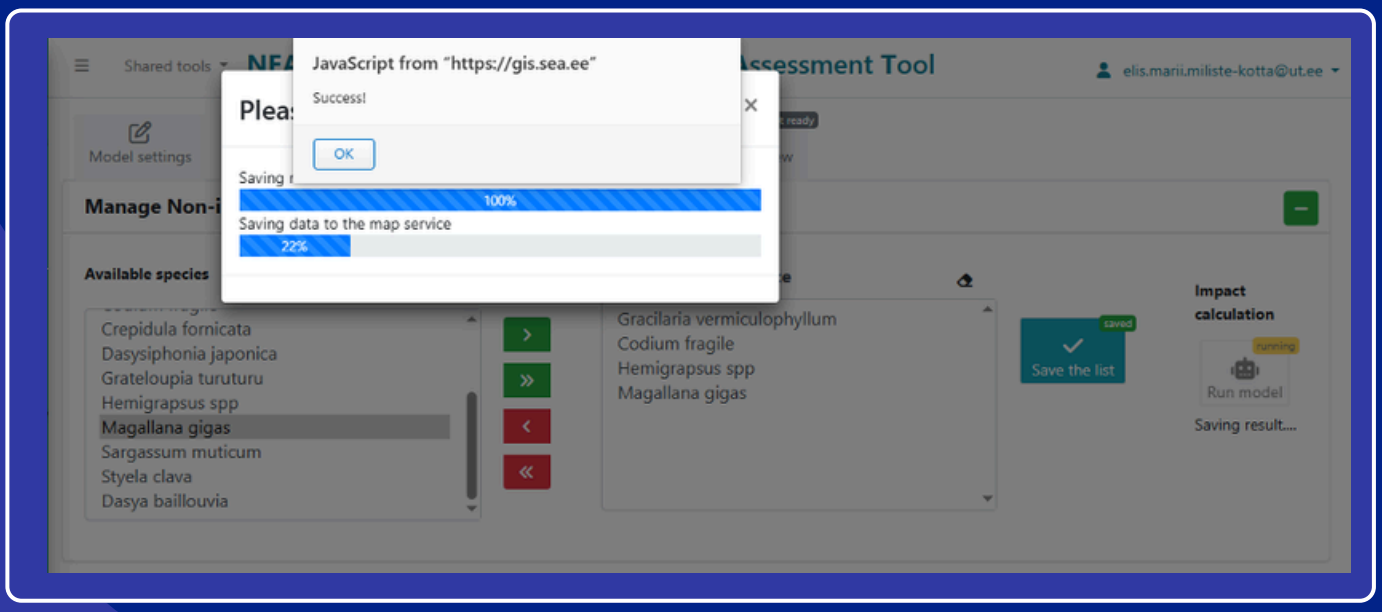
STEP 6: RUN THE MODEL

Once both the “Extent” and “Non-indigenous species” tabs display a green “success” indicator, click “Run model” to start the effects calculation.



NOTE: Processing time depends on the number of selected species and the size of the analysis extent, ranging from a few minutes to an hour or more. Once the model has finished running, a blue dot will appear in the browser tab along with “Success!” on the website

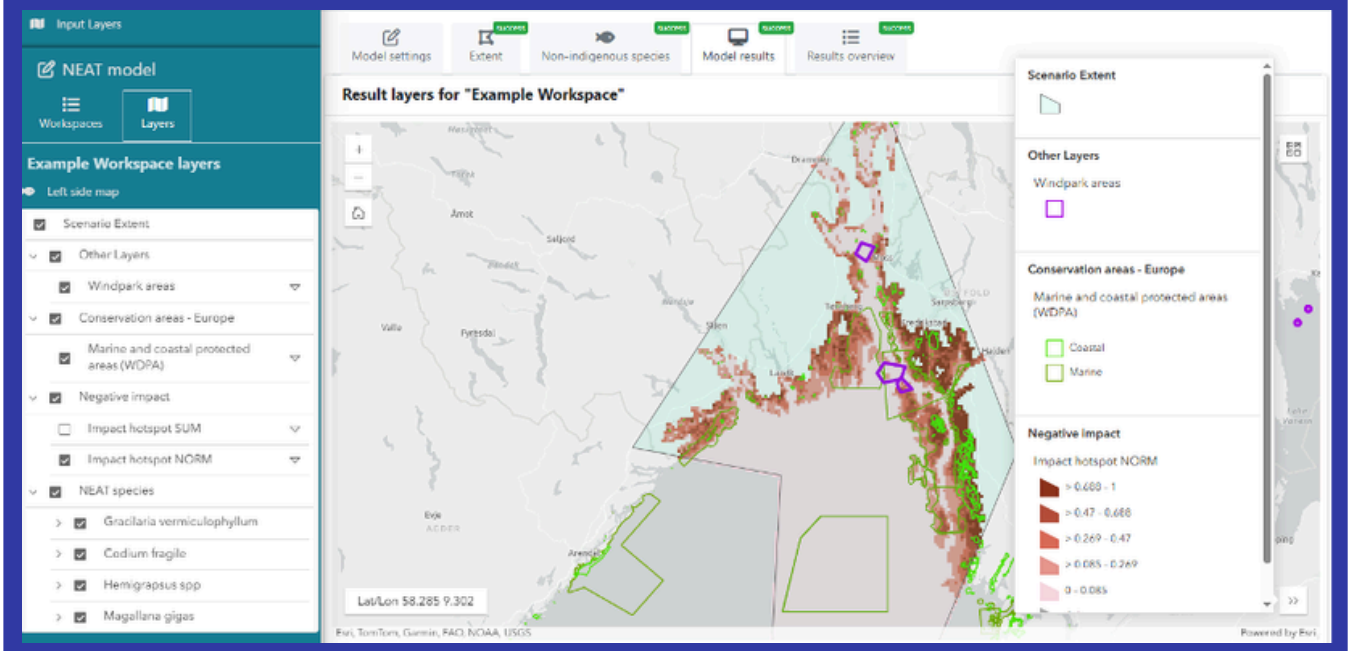




RESULTS

The tool generates potential effect maps and a summary table for the selected extent. The results can also be overlaid with conservation areas and wind park development areas to support interpretation.

Under the “Model results” tab, results are presented as interactive spatial maps for interpreting both species-specific effects and cumulative impacts. All layers and controls are accessible via the left-side panel, where users can explore the results maps and additional layers, by adjusting visibility and each layer’s opacity (i.e., visual transparency).



NOTE: Open the legend by expanding the bottom right corner button.

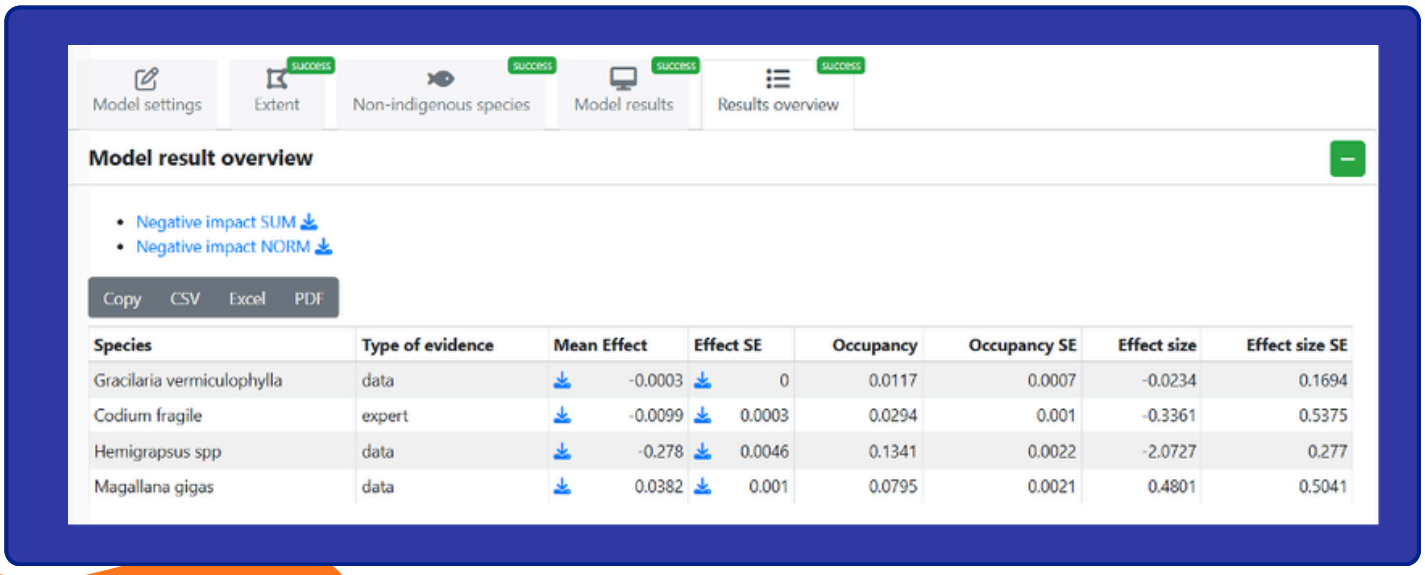
RESULTS

- **Scenario Extent:** Displays the extent chosen for the scenario and where the calculations are made.
- **Conservation areas – Europe:** Displays marine and coastal protected areas in Europe from the World Database on Protected Areas (WDPA). The WDPA is updated monthly, and updates are automatically reflected in the NEAT tool: https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA
- **NEAT species:** Potential effect maps for each NIS, including both mean potential effect and associated uncertainty, indicating where individual NIS are most likely to exert stronger ecological effects within the study area.
- **Negative impact:** Additive negative impact for all species included in the scenario, indicating potential negative impact hotspots of NIS. Both total sum and normalized (0–1) values are available. While each species effect size is evaluated from -3 (strong negative) to +3 (strong positive effect), the total sum value should be considered with caution, as the potential negative effects of different NIS could be related to not spatially overlapping nature values.
- **Other Layers:** Areas of interest (e.g., wind park areas), that could be overlapped with model results to evaluate potential effects withing a specific area.

Summary table

NEAT provides a results overview table for the selected NIS and analysis extent, available in the "Results overview" tab. For each species in the chosen extent, the table reports:

- Average potential effect and associated effect uncertainty
- Average probability of occurrence and associated occurrence uncertainty
- Effect-size values used in model calculations
- Source of effect estimates ("data" for scientific literature-based, "expert" for expert-based assessment)



Species	Type of evidence	Mean Effect	Effect SE	Occupancy	Occupancy SE	Effect size	Effect size SE
Gracilaria vermiculophylla	data	-0.0003	0	0.0117	0.0007	-0.0234	0.1694
Codium fragile	expert	-0.0099	0.0003	0.0294	0.001	-0.3361	0.5375
Hemigrapsus spp	data	-0.278	0.0046	0.1341	0.0022	-2.0727	0.277
Magallana gigas	data	0.0382	0.001	0.0795	0.0021	0.4801	0.5041

Download: Results can be downloaded as tables (.csv, .xlsx, .pdf) and maps, by clicking on the blue icons (GeoTIFFs compatible with GIS software such as ArcGIS or QGIS)

Recommendations on how the outputs can be used

NEAT outputs are intended to support decision-making, not replace, local ecological assessment, expert interpretation, or field validation. The main value of NEAT is therefore not that it gives a single answer, but that it helps structure choices. It can support decisions on where to monitor first, where to investigate further, where to focus mitigation, where restoration may face higher risk, and where cross-sector dialogue is needed to agree on practical responses.

Key applications:

- Monitoring prioritization: Identify areas where non-indigenous species (NIS) effects are likely to be concentrated and where field surveys may be most effective.
- Prevention and mitigation: Identify areas where early intervention could reduce the risk of more severe impacts.
- Restoration planning: Indicate where NIS pressures may hinder recovery or where additional safeguards may be required.
- Spatial planning and environmental assessment: Support decisions on research needs, monitoring efforts, and mitigation measures, particularly in relation to existing or planned developments (e.g., offshore wind farms).

More broadly, NEAT outputs can serve as a shared evidence base for dialogue among public authorities, experts, and stakeholders. They support structured discussion and can help reduce conflicts between sectors (e.g., conservation, fisheries, offshore energy) by providing a common spatial understanding.

REFERENCES

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