ASPACE

User Guide V.1

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ASPACE

User Guide V.1

DESIGN BY LANDS

Acknowledgments
The ASPACE team in grateful to the wider Marine Spatial Planning Addressing Climate Effects team, our advisors and stakeholders, for insightful collaborations that informed the concept of ASPACE. The ASPACE initiative is funded via a UK Natural Environment Research Council (NERC) and Economic and Social Research Council (ESRC) grant for the project Marine Spatial Planning Addressing Climate Effects (MSPACE, grant NE/V016725/1), part of the Sustainable Management of Marine Resources programme (UK). ASPACE has also benefitted from funding support from ActNOW (Horizon Europe grant #101060072 and UKRI grant # 10042858), and from the AXA Investment Managers Award 2022 to Ana M Queirós. Additional support is provided by NERC grant EQUIFy (NE/Z504099/1) and the NERC / INSITE Industry Consortium grant VALMAS.

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Published February 2026

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1

Introduction

Assisted Spatial Prioritisation Addressing Climate Effects (ASPACE) is an assisted spatial prioritisation software conceived to support the design and exploration of climate-resilient, socially acceptable and economically viable marine spatial policy intervention scenarios. It combines climate change modelling analyses, stakeholder value assessment, and economic modelling together in an integrated, transdisciplinary, fully interactive tool, designed to help meet the needs of policy makers and other practitioners, as well as of researchers.

ASPACE is a free, web-based tool, that can be used in any marine and coastal region where suitable datasets are available. ASPACE provides a number of datasets to enable users to carry out analysis in some regions of the world, but users can also upload their own datasets. Data uploaded by users can be private or shared with the ASPACE community. As the ASPACE community grows, our mission is to grow capability to manage our ocean around the world in more sustainable and climate-resilient ways, for future generations.

ASPACE emerged from co-created scientific research in the United Kingdom and other nations.

1.1 Aims of the Tool

ASPACE was developed to advance the capability of Marine Spatial Planners and others interested in marine space to make decisions which are evidence-based and address climate change (i.e. that are climate-smart). Climate-smart decisions seek to promote climate change adaptation for nature and people, including nature-based climate change mitigation interventions.

ASPACE supports this aim by helping users identify and explore opportunities for climate-smart marine spatial management via the development of alternative spatial management scenarios that make use of climate-resilient areas in our coasts and seas. Scenarios can then be compared based on the areal extent of explored spatial uses that is climate-resilient, as well as on how each scenario affects the blue economy of concerned regions, and how it aligns with the values of their stakeholders (see Optimisation Option 2). The user can also compare these scenarios with the current status-quo (see Optimisation Option 1), to determine whether and which potential changes in spatial uses (i.e. “interventions”) may be required to help build climate resilience in a way that supports the economy of regions and values people hold about the sea around them.

ASPACE was co-created with Marine Spatial Planners and others involved in marine sectoral activities, with the aim to improve their ability, and that of researchers, in creating evidence-based, climate-smart decisions for marine space management.

In this v1.0, ASPACE users can access and analyse state of the art ocean climate modelling datasets and GIS data made available, to create scenarios in some regions of the world, and score and compare them on climate resilience, economic effects and alignment with social values. Users can also upload their own datasets for use within the tool, and may choose to share them with the ASPACE user community or to keep them private. ASPACE’s development will continue at least until 2030, and updates will be communicated to registered users.

1.2 Who is ASPACE for?

ASPACE was co-created with Marine Spatial Planners and others involved in marine sectoral activities, with the aim to improve their ability, and that of researchers, in creating evidence-based, climate-smart decisions for marine space management. Our users are government agencies, marine sectors, NGOs, academia, and others interested in climate-resilient decision-making about marine space.

1.3 What does this manual cover?

This manual for ASPACE v1.0 covers all essential functions and features of ASPACE, as well as system requirements and troubleshoot, to help users get started. It includes a quick-start guide as well as technical background on main tool features and functions.

2 Setting up

2.1 System requirements

- Supported operating systems: Windows 10, 11 or later. Ubuntu 20.04 or later
- Minimum hardware requirements (CPU, RAM, storage): Intel Core i3, 8 GB, 60 GB or more.
- Network Requiremen:t The ASPACE Tool is a web-based application and requires a stable internet connection for normal operation. Users must be able to access the application over standard HTTPS (port 443). No special network configuration is required for typical use. However, institutional or corporate networks must allow outbound HTTPS traffic to the ASPACE domain and associated services used for secure authentication, data upload, and visualisation. For optimal performance, particularly when uploading large ZIP files or interacting with spatial visualisations, a broadband connection is recommended. If accessing the tool from a restricted network (e.g. behind a firewall or proxy), users should ensure that web traffic to the ASPACE Tool is not blocked or rate limited.
- Browser Requirements: Latest Google Chrome or Microsoft Edge or any other Chromium-based web browser.

2.2 Installation & setup

No additional software or tools are required to use the web-based ASPACE Tool. The application is accessible through any Chromium-based web browser, such as Google Chrome or Microsoft Edge. Users should install and maintain their browser using the standard installation and update procedures provided by the browser vendor.

3 Quick-start guide

3.1 Introduction

Welcome to the Quick-start guide. This contains everything you need to get you started with ASPACE quickly. It focusses on the most common tasks and essential actions to get you using ASPACE confidently. The contents page contains direct links to each section allowing you to jump straight to the information that you need. Screenshots are annotated to help guide you through the key controls, reducing your guesswork and saving you time.

3.2 ASPACE workflow

The workflow below shows the grouping of the salient tasks to be completed within ASPACE. It is split into four phases. The contents page is divided into these phases to help structure your experience.

Phase 1	Phase 2	Phase 3	Phase 4
Preparing data	Ocean climate modelling analysis	Generating and scoring alternative spatial management scenarios	Visualising, comparing and downloading alternative spatial management scenarios

3.3 Data upload: formatting requirements

You do not need to upload data to use ASPACE. But if you would like to, here's how to do it:

By using this platform, you acknowledge that uploaded data is stored on shared infrastructure and may be accessed by authorised developers for system administration and support. Do not upload commercially sensitive, confidential, or restricted information.

Modelling data upload requirements

All modelling data must be placed within **a single folder** (directory), which must then be compressed into a **ZIP file before being uploaded** to the ASPACE Tool. The folder should contain modelling outputs organised by year and structured to support 20-year comparative analyses. The modelling approach assumes a fixed 20-year reference period, which is compared against one or more 20-year future periods derived from the dataset. The reference period must be clearly defined and must never overlap with, or include, any years from the future periods. For example, a reference period of 2006-2025 may be compared against rolling future periods such as 2026-2045, 2027-2046, and subsequent windows; these years are provided for illustration only. For each year-representing the first year of a 20-year aggregation window, exactly three files are required to summarise the model outputs: the mean (mn), sample size or count (n), and standard deviation (sd).

All files must strictly follow the naming convention:

[PROJECT]_[CATEGORY]_[VARIABLE]_[YEAR]_[STATISTICS].txt.
with underscores (_) separating each element of the filename. For example: FuMa-Portugal_EcospaceMapBiomass_Tunas_2006_mn.txt, FuMa-Portugal_EcospaceMapBiomass_Tunas_2006_n.txt, and FuMa-Portugal_EcospaceMapBiomass_Tunas_2006_sd.txt.

Here, "**_mn.txt**" denotes the mean, "**_n.txt**" the sample size, and "**_sd.txt**" the standard deviation.

How this aligns with the description

Table 1: Naming conventions for modelling data

Period type	Filename year	20-year window represented
Reference	**2006**	2006–2025
Future slice 1	**2026**	2026–2045
Future slice 2	**2027**	2027–2046
…	…	…
Future slice n	**2079**	2079–2098

Each modelling data file **(.txt)** must contain **comma-separated** regular spatial grid data, where each row represents a horizontal slice of the spatial grid and each comma-separated value represents a single grid cell. **Numeric values** correspond to the modelled statistic for that grid cell, while **NA** indicates no data (e.g. land areas, masked cells, or locations outside the model domain). **Zero (0)** values are valid numeric entries and must be preserved as they represent meaningful model outputs rather than missing data. All files must contain data values only and **must not include any headers, column names,**

or metadata rows. The spatial grid layout (number of rows and columns) must be consistent across all years and statistics for a given dataset to ensure correct temporal comparison and aggregation within the ASPACE Tool.

Spatial structure and coordinate requirements for modelling data
All datasets must be provided as spatially explicit time series in .txt. Each data file must be structured as a numeric matrix representing the model domain, where the matrix dimensions correspond consistently to the spatial grid (for example, x = longitude and y = latitude). The spatial resolution and matrix dimensions must be identical across all years and statistics within the same dataset to ensure valid temporal comparisons.

The geographic coordinates of each grid cell must be supplied separately in an accompanying longitude-latitude reference file **(for example, lonlat.csv)**. This file must contain two columns: lon and lat; which together define the spatial coordinates of the model grid cells in the same order as they appear in the modelling data matrices.

The lonlat.csv file must fully describe the spatial domain of the modelling data and must remain consistent across all time steps and statistical outputs.

An example of the coordinate reference file structure is shown below:

lon,lat
-16.90747833,47.03308105
-16.90747833,47.13289642
-16.90747833,47.23271179
-16.90747833,47.33252716
-16.90747833,47.43234253
-16.90747833,47.5321579
-16.90747833,47.63197327
-16.90747833,47.73178864
-16.90747833,47.831604

Please note that ASPACE visualises data using the lat/lon coordinate as the centre of the grid cell. If model outputs use lat/lon as the (e.g.) SW corner of the cell, please amend the lat/lon file prior to upload to ensure that data aligns correctly with the basemap in the tool

GIS layer upload requirements:
You do not need to upload GIS data to use ASPACE. But if you would like to, here's how to do it. The ASPACE Tool allows users to add custom GIS layers in order to support spatial visualisation, analysis and scenario development. GIS layers can be added using one of two supported methods:

1. **Uploading a Shapefile (ZIP upload)**
2. **Providing an External WFS (Web Feature Service) link**

Both methods are supported, depending on where your data is hosted.

Option 1: Uploading a GIS Layer using Shapefiles (ZIP)
To upload a GIS layer to the ASPACE Tool, all required files must be placed together within a single folder (directory), which must then be compressed into a ZIP file prior to upload. The ZIP archive must contain the following mandatory shapefile components:

.shp - Geometry data
.dbf - Attribute table containing feature properties
.shx - Index file linking geometry to attributes
.prj - Projection file defining the coordinate reference system (CRS)

All mandatory shapefile components **must share the same base filename** to ensure the layer can be correctly read and processed by the ASPACE Tool. For example:

ne_10m_land.shp
ne_10m_land.dbf
ne_10m_land.shx
ne_10m_land.prj

If the component layers of the shapefile do not have identical names, the data may be interpreted incorrectly.

The use of a .prj file is recommended to ensure correct spatial alignment. The ASPACE Tool is optimised for the EPSG:4326 coordinate reference system. Layers provided in this projection will ensure maximum compatibility and accurate visualisation.

Option 2: Adding a GIS layer using an external WFS Link
GIS layers hosted on external platforms (for example, EMODnet or other public geospatial services) can be added using a Web Feature Service (WFS) link.

How to upload a WFS layer
- Select Source Type: “External URL”
- Paste the WFS GetFeature URL into the provided field

Example WFS URL (EMODnet):
https://ows.emodnet-seabedhabitats.eu/geoserver/emodnet_open_maplibrary/wfs?service=WFS&version=2.0.0&request=GetFeature&typeNames=emodnet_open_maplibrary:be000142&outputFormat=application/json&srsName=EPSG:4326

Notes for WFS layers
- Publicly accessible URLs are required
- No authentication should be needed
- The service should support GeoJSON output (application/json).
- EPSG:4326 is recommended for best compatibility

3.4 Quick Start Contents

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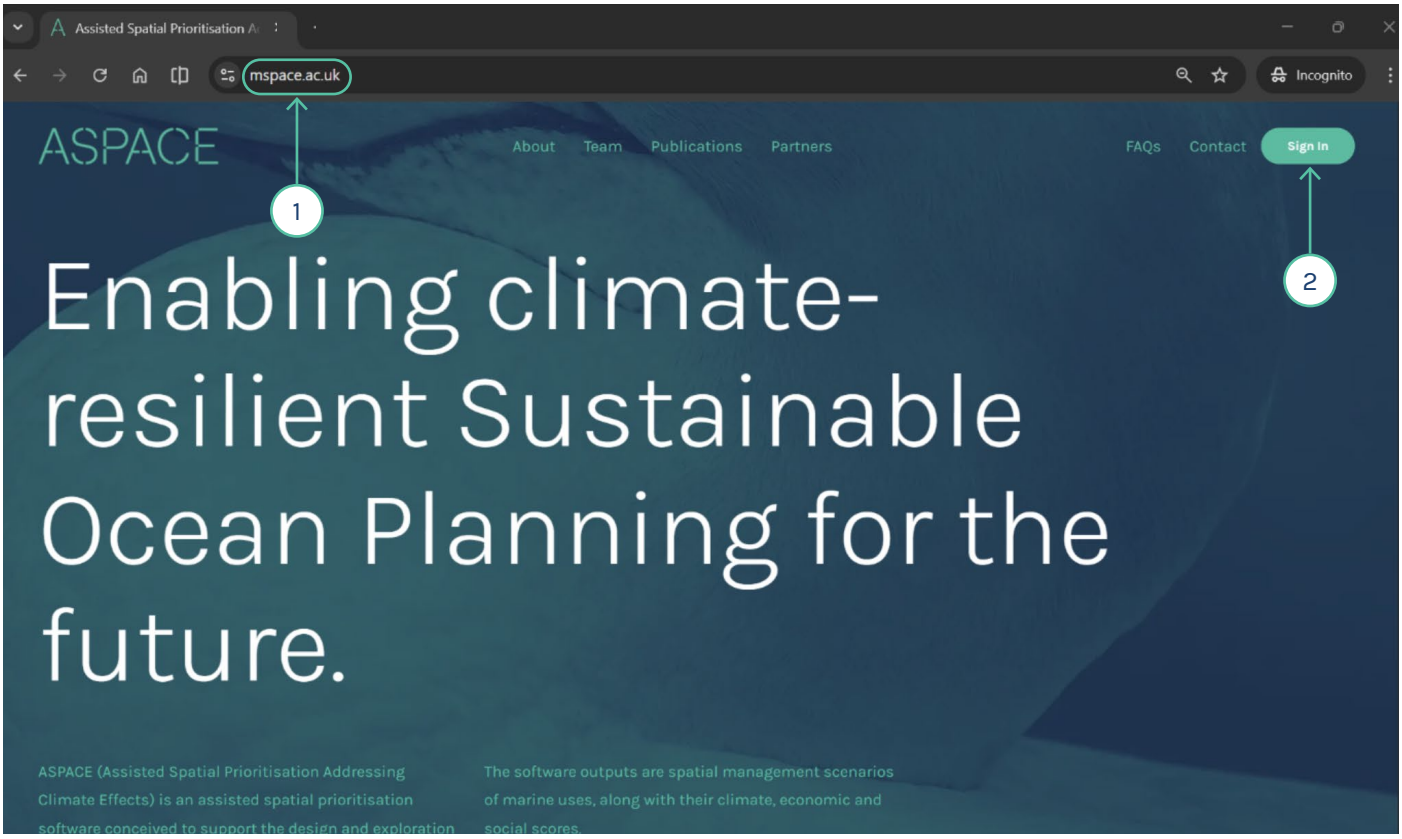
Set Up

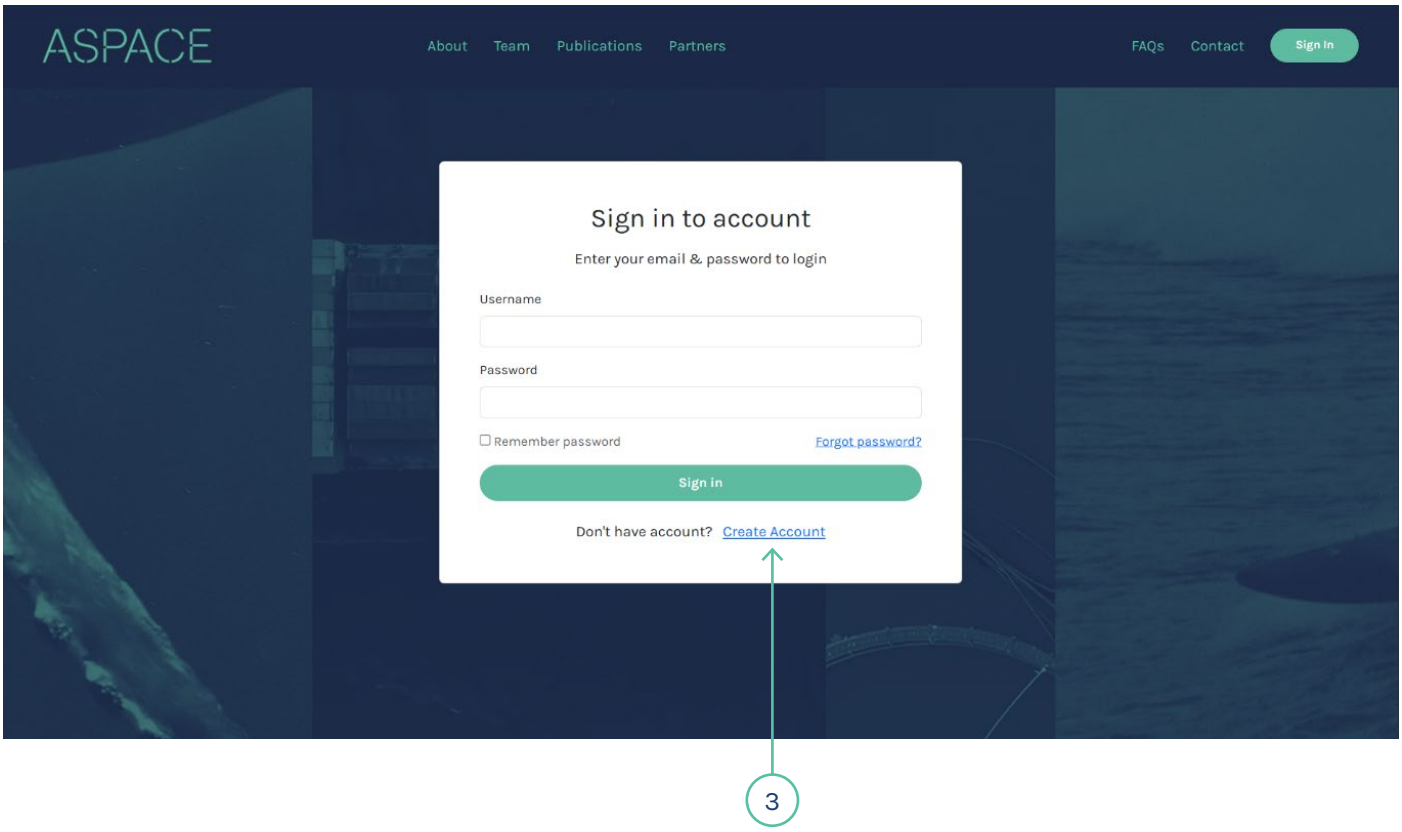
ASPACE

—User administration
—Where to find help

3.5 User registration

Set Up





1. Navigate to **mspace.ac.uk**
2. Press the “Sign In” button
3. Press the “Create Account” link

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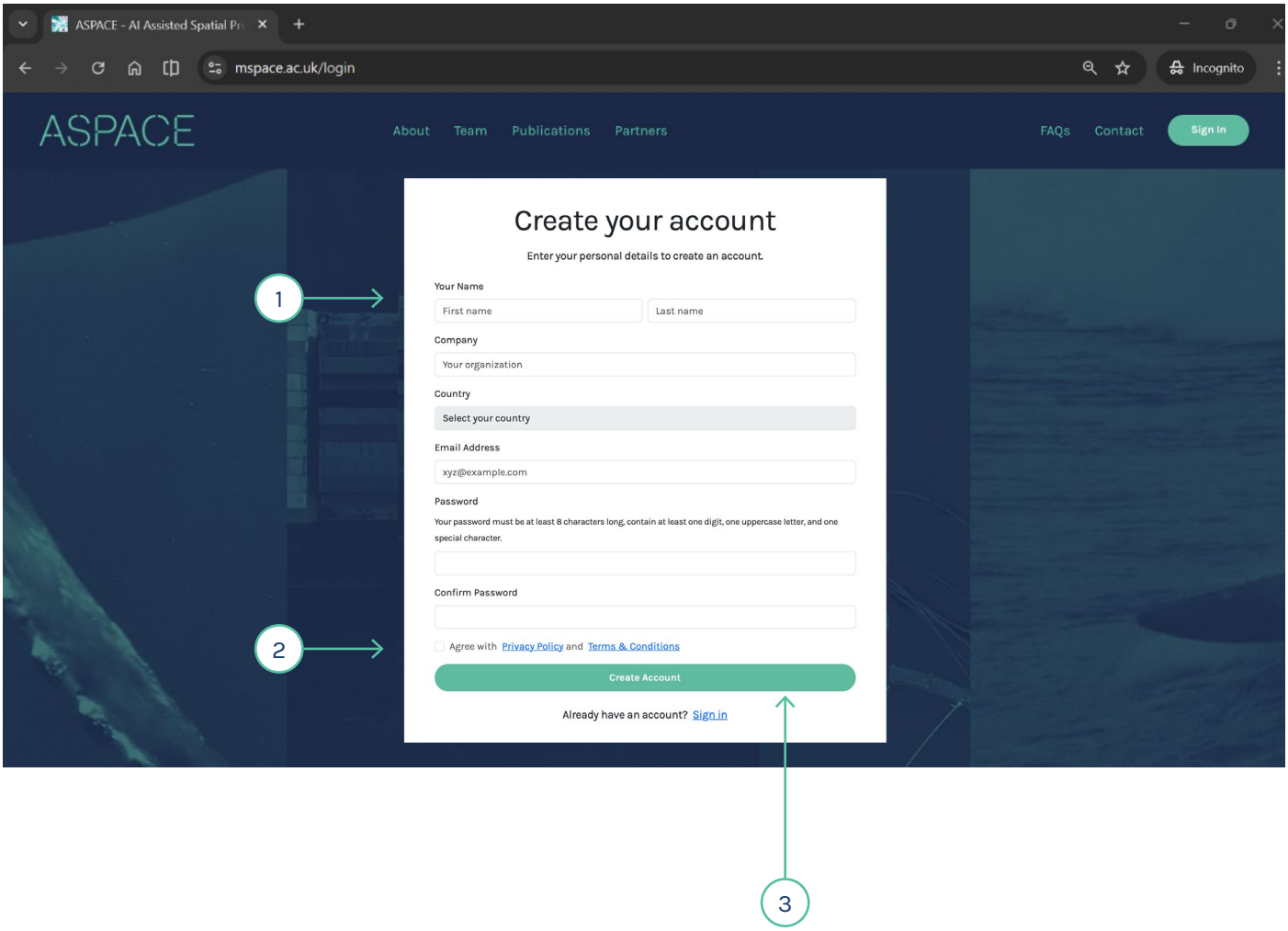
3.5 User registration (continued)

Set Up



1. Fill in details
2. Read and agree to:
    I. Terms and Conditions
    II. Privacy Policy
3. Press the “Create Account” button
4. Please check the junk folder for the registration email

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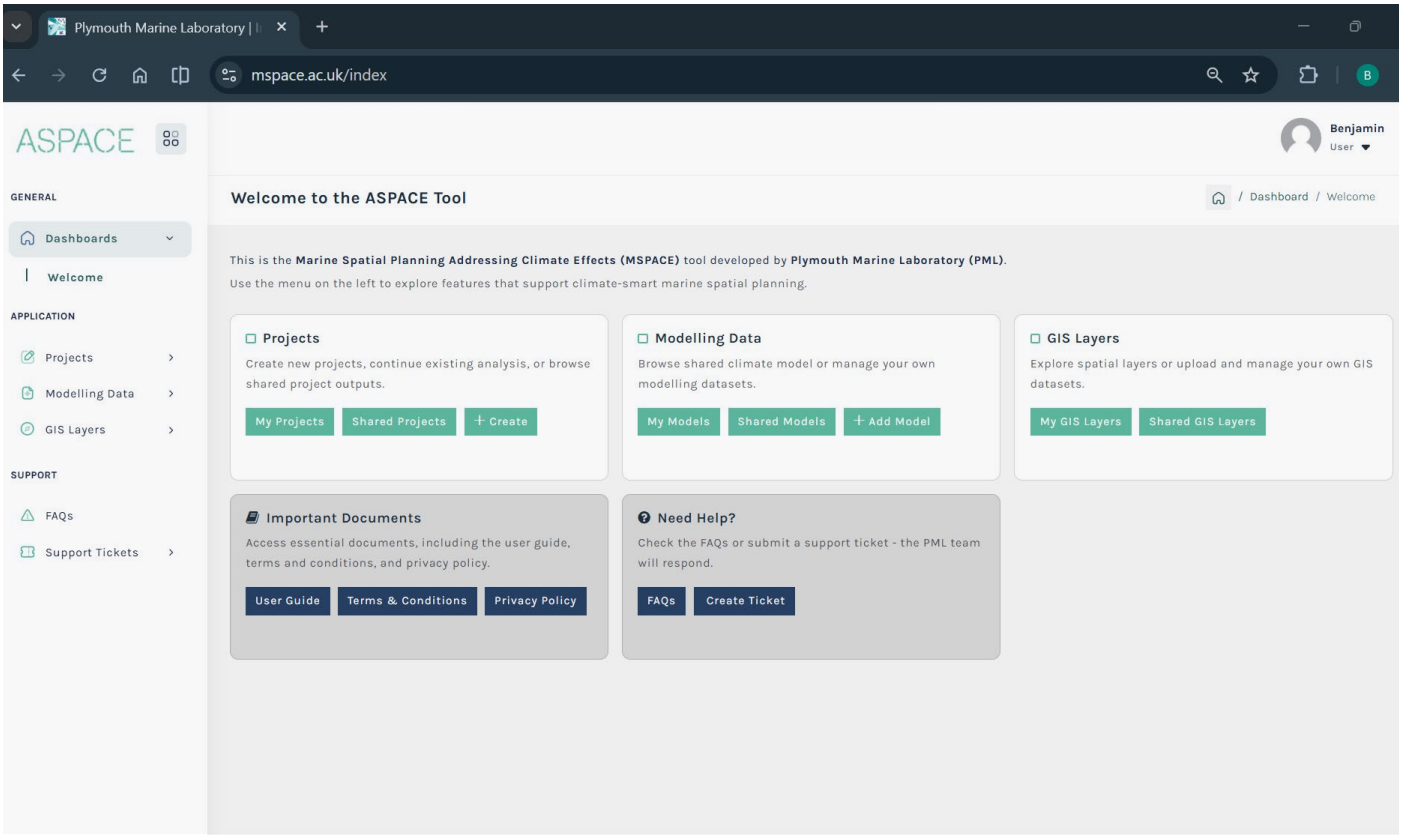
3.6 User dashboard

Set Up



- Overview of dashboard
- Simplifies navigation across tool

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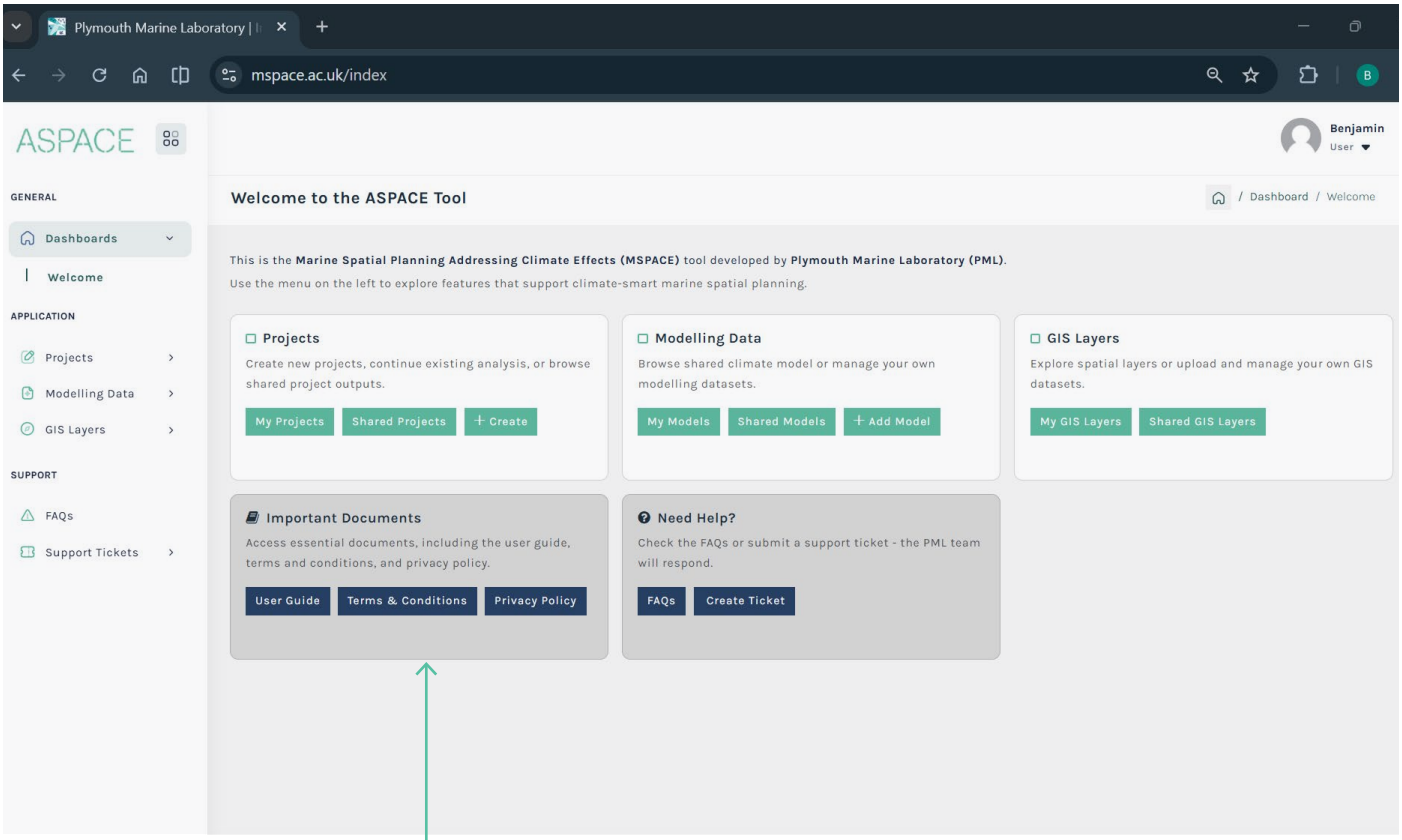
3.7 Read the documentation

Set Up



1. Links to the User Guide, Terms and Conditions and Privacy Policy can be found under the “Important Documents” card.

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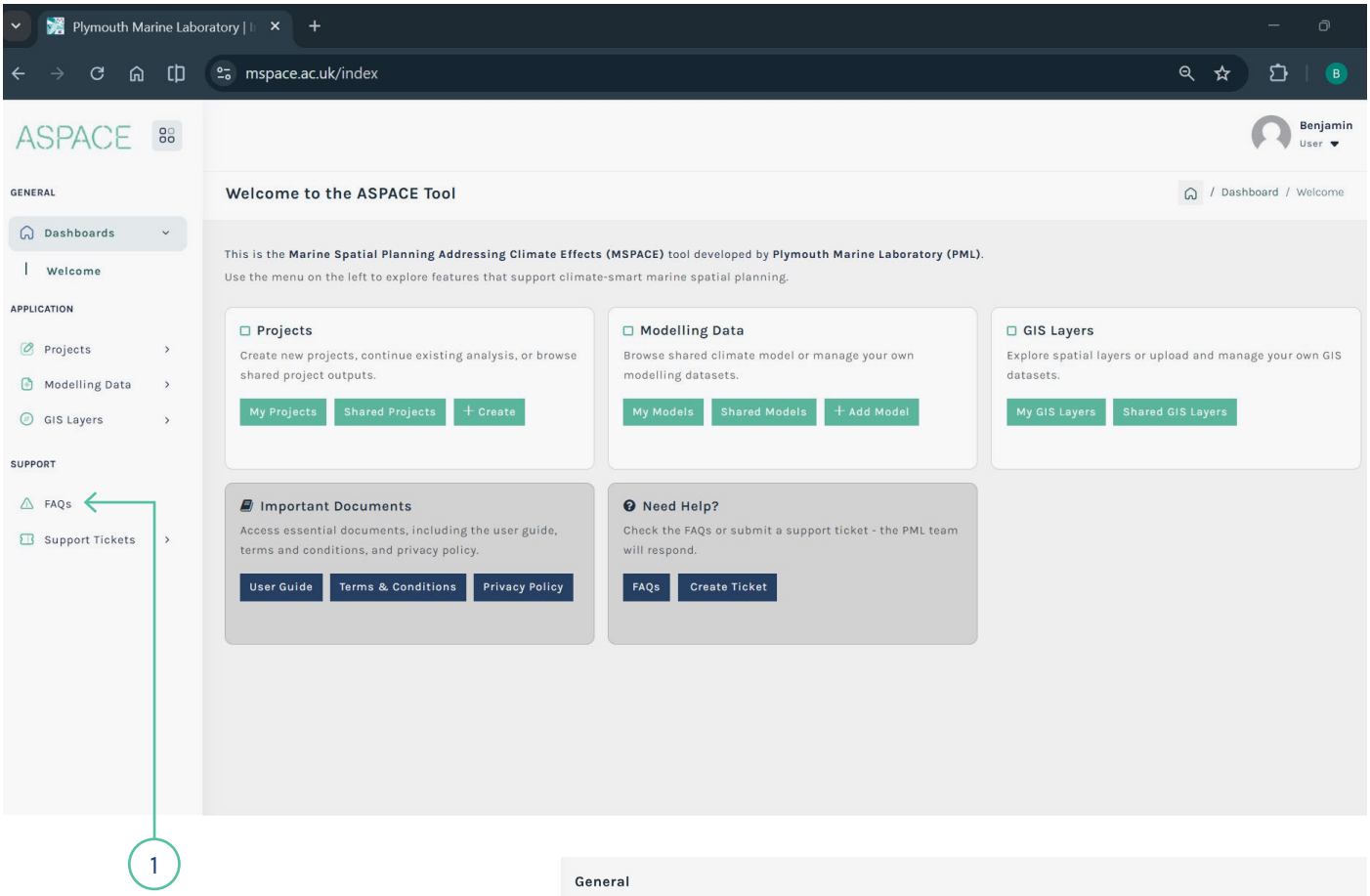
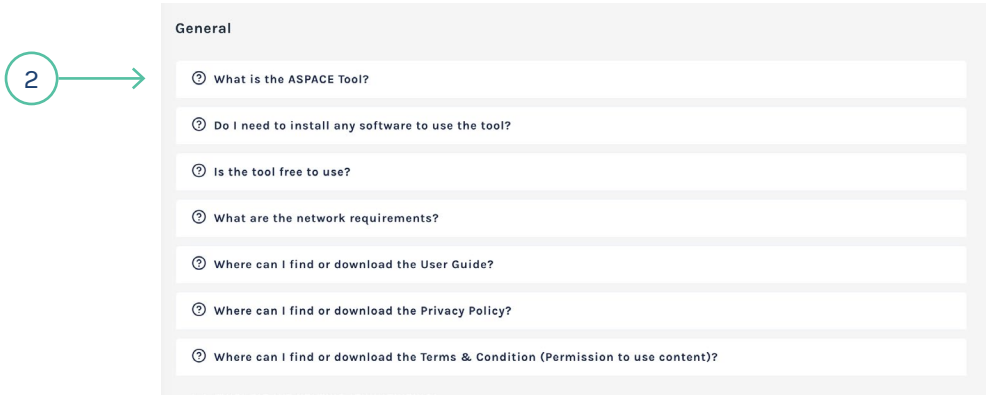
3.8 Read the FAQs

Set Up





1. Navigate to the FAQ tab
2. Review the FAQs by pressing on the title and expanding the dialogue box

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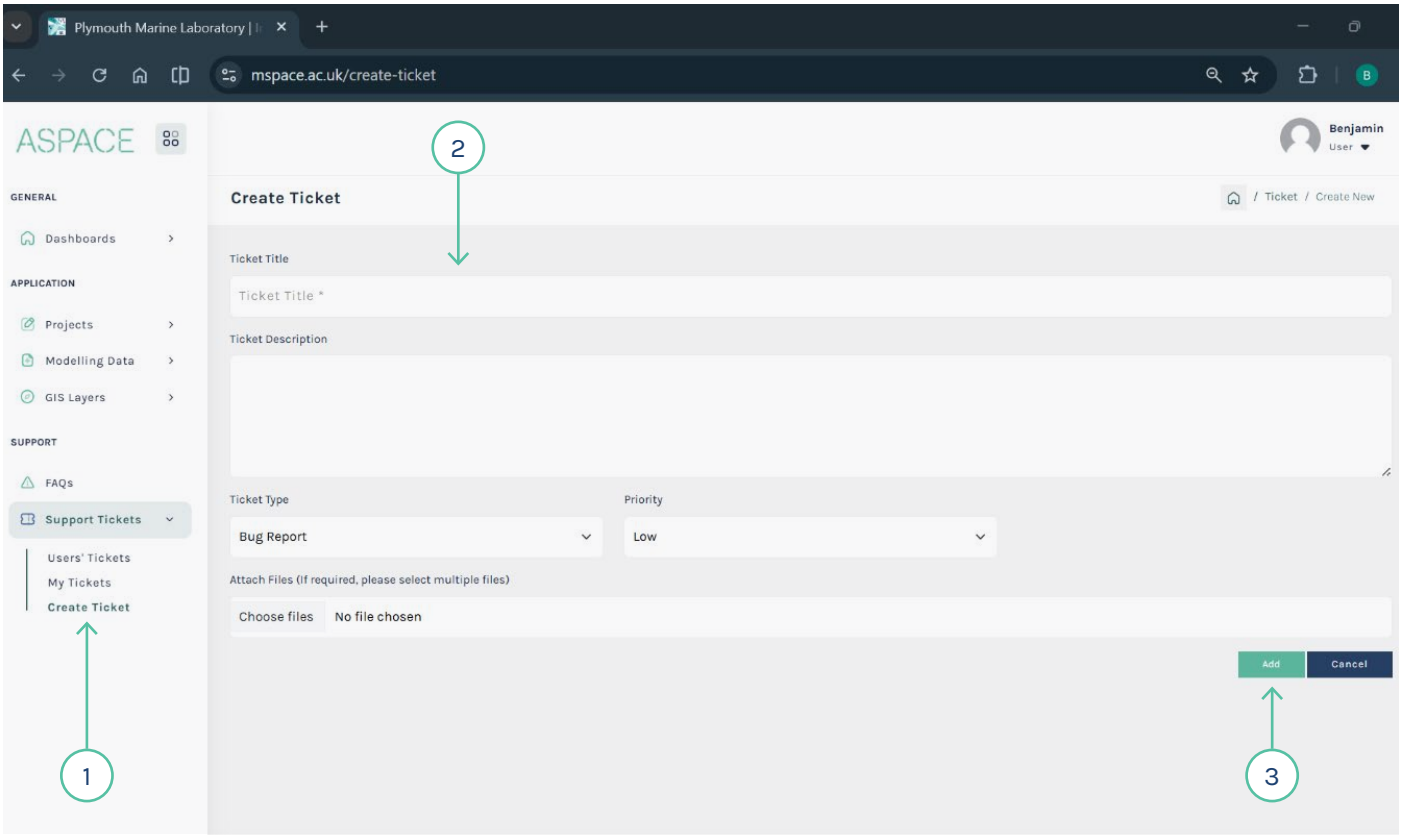
3.9 Raise a ticket

Set Up



1. Navigate to the “Create Ticket” tab under the “Support Tickets” tab
2. Fill in the details
3. Press the “Add” button
4. The ASPACE team will review your ticket and get back to you promptly

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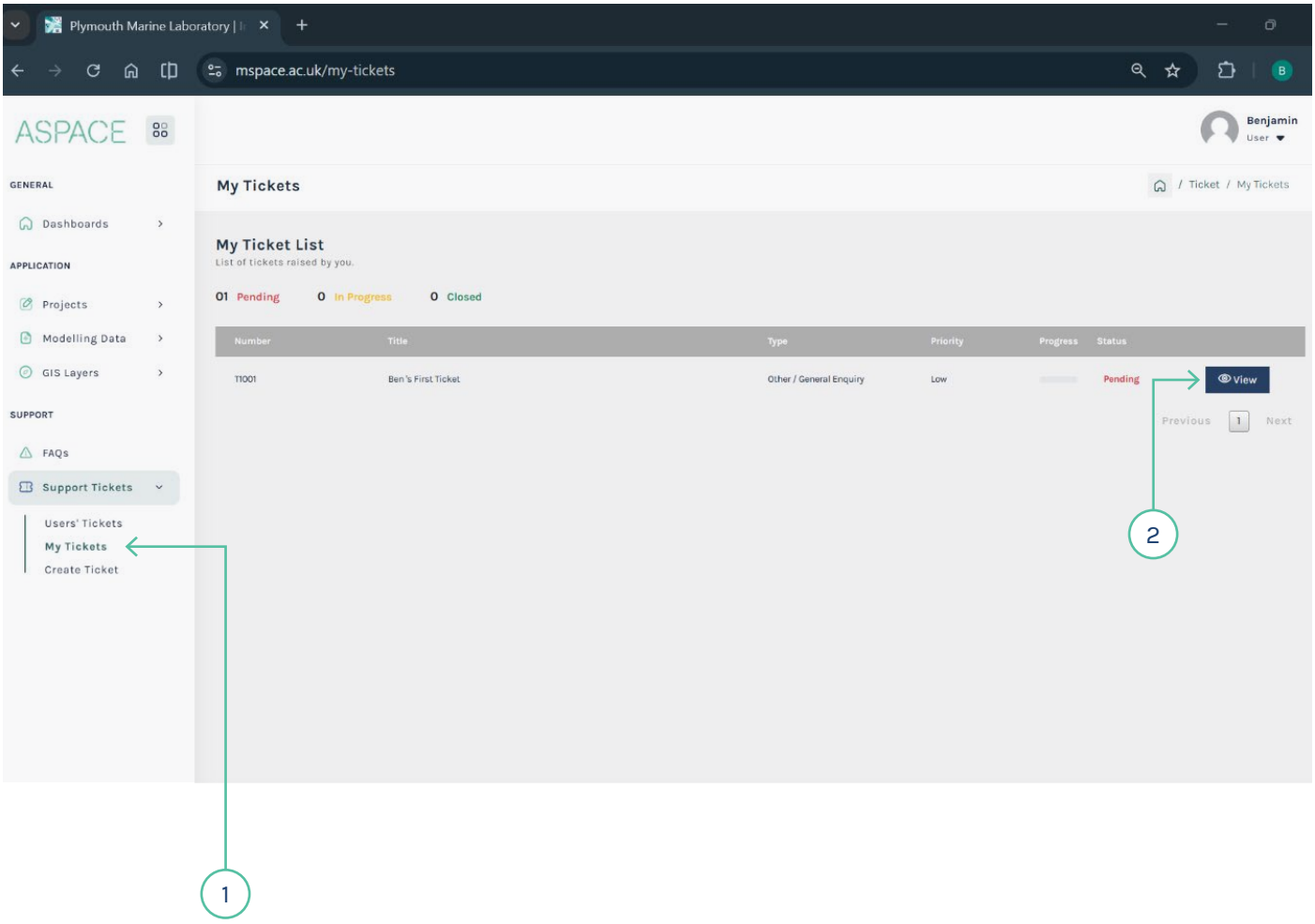
3.10 Review tickets raised

Set Up



1. Navigate to the “My Tickets” tab under the “Support Tickets” tab
2. Review any tickets that you have raised with their progress

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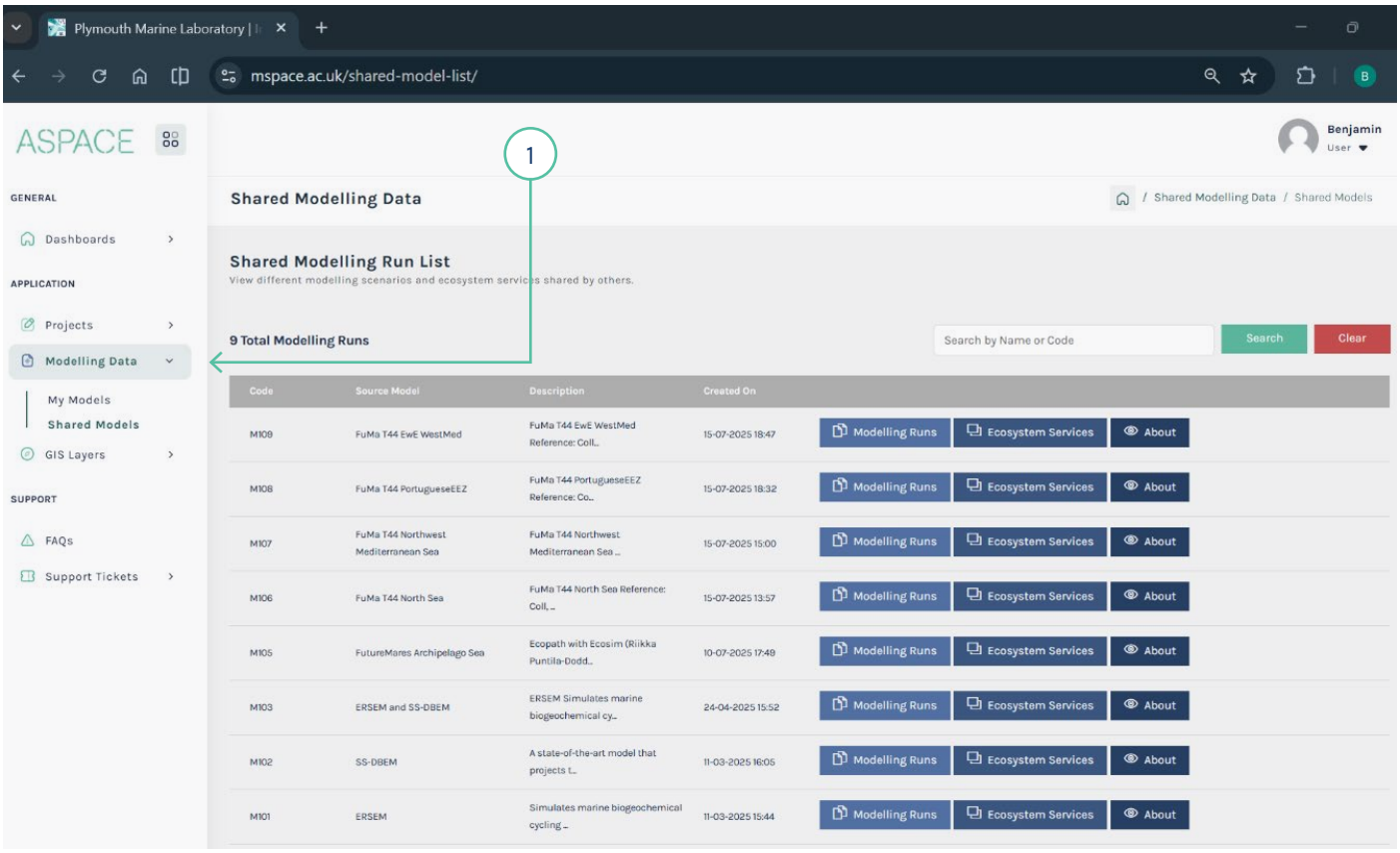
Phase 1

Preparing data

— **Modelling data, preparing data, economic data and social values**

3.11 Uploading ocean climate modelling data

Phase 1



You do not need to upload modelling data to use ASPACE. But if you would like to, here's how to do it.

1. Navigate to the "My Models" / "Shared Models" tab within the "Modelling Data" tab

My models: modelling data uploaded by the user.

Shared models: modelling data uploaded by ASPACE team or other users, for shared use in the platform.

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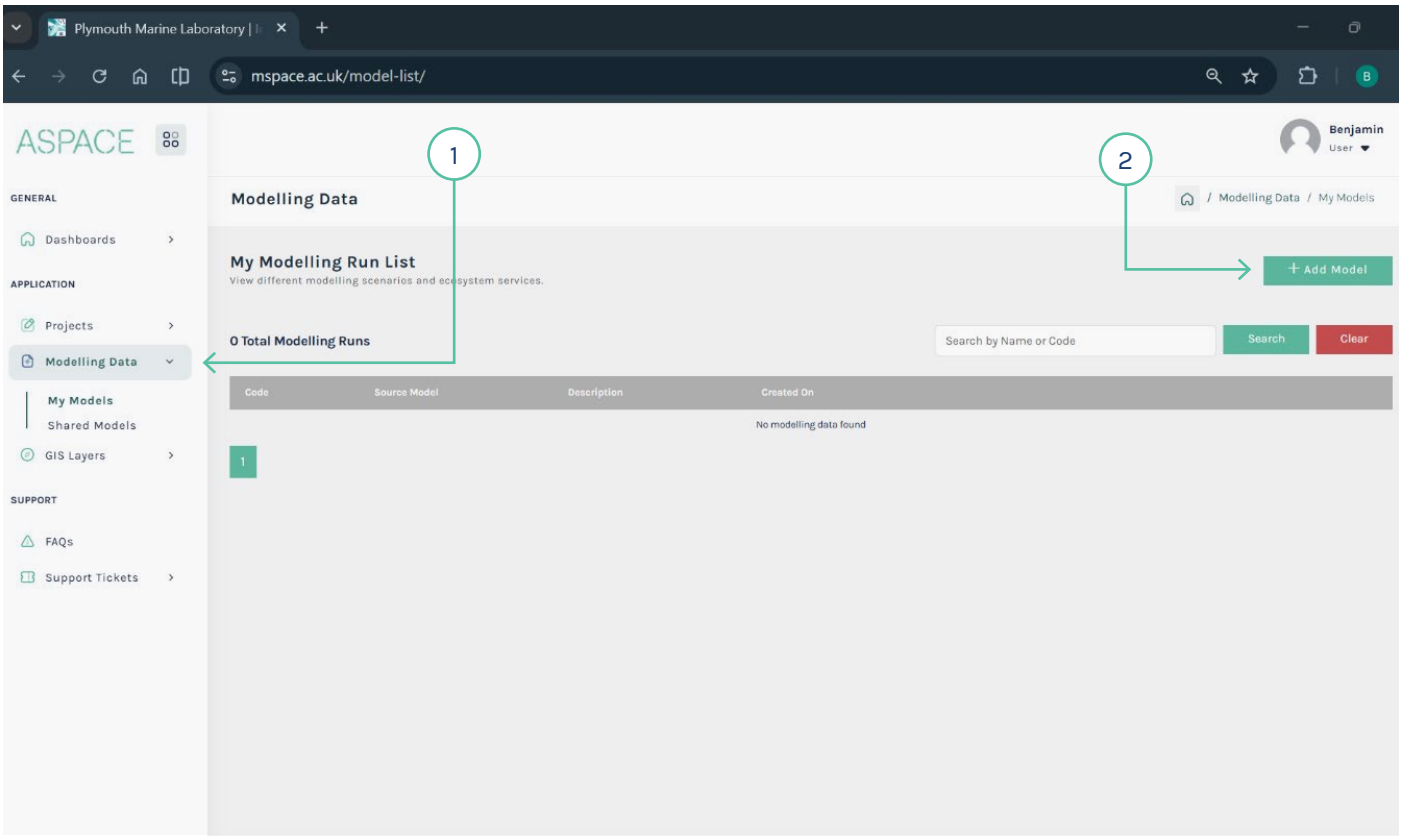
3.11 Uploading ocean climate modelling data (continued)

Phase 1



To upload your own modelling dataset(s):

1. Navigate to “My Models”
2. Press on “Add Model” button

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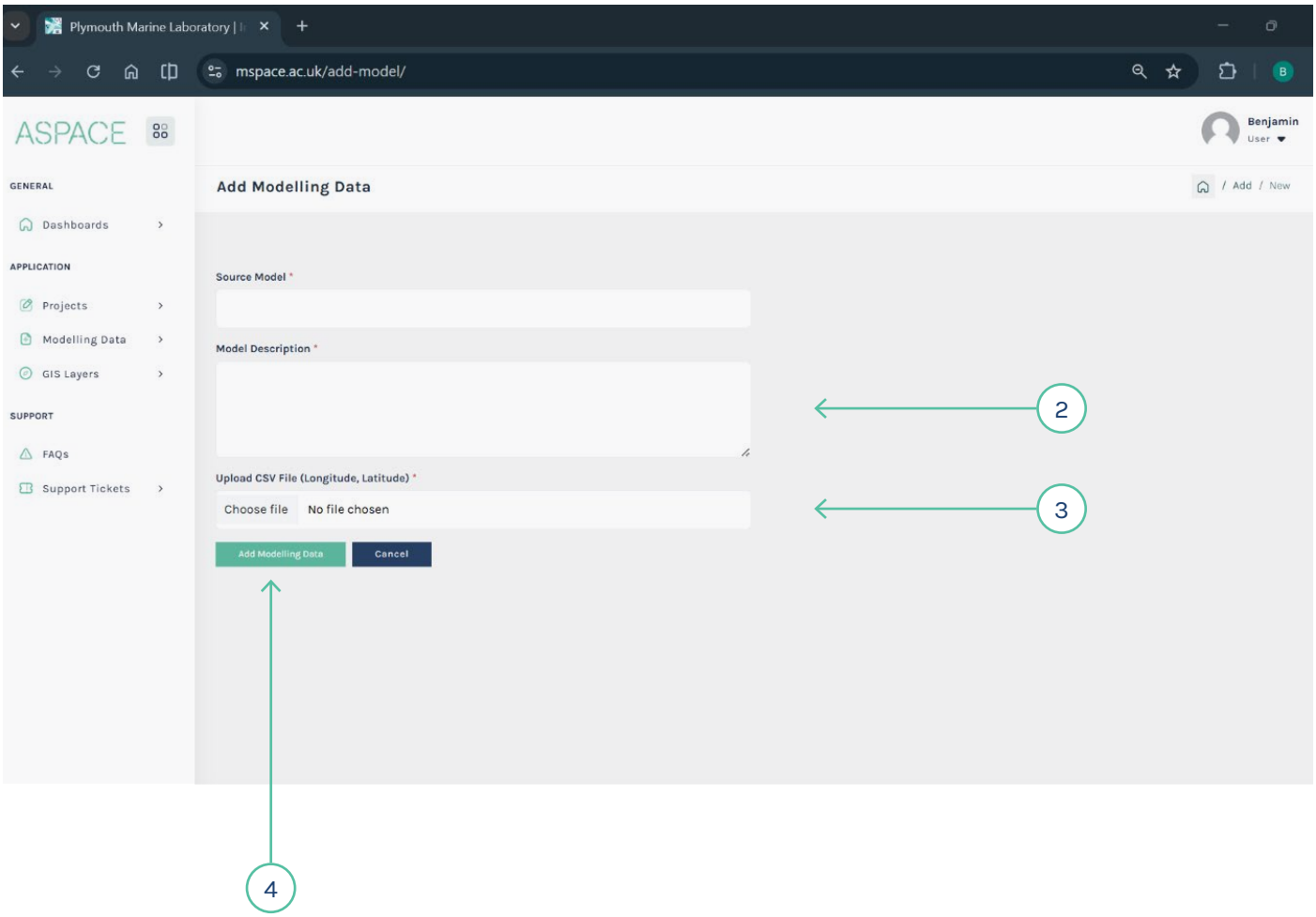
3.11 Uploading ocean climate modelling data (continued)

Phase 1



1. Read the formatting rules for new modelling data upload
2. Fill in the form
3. Attach CSV file
4. Press “Add Modelling Data” button

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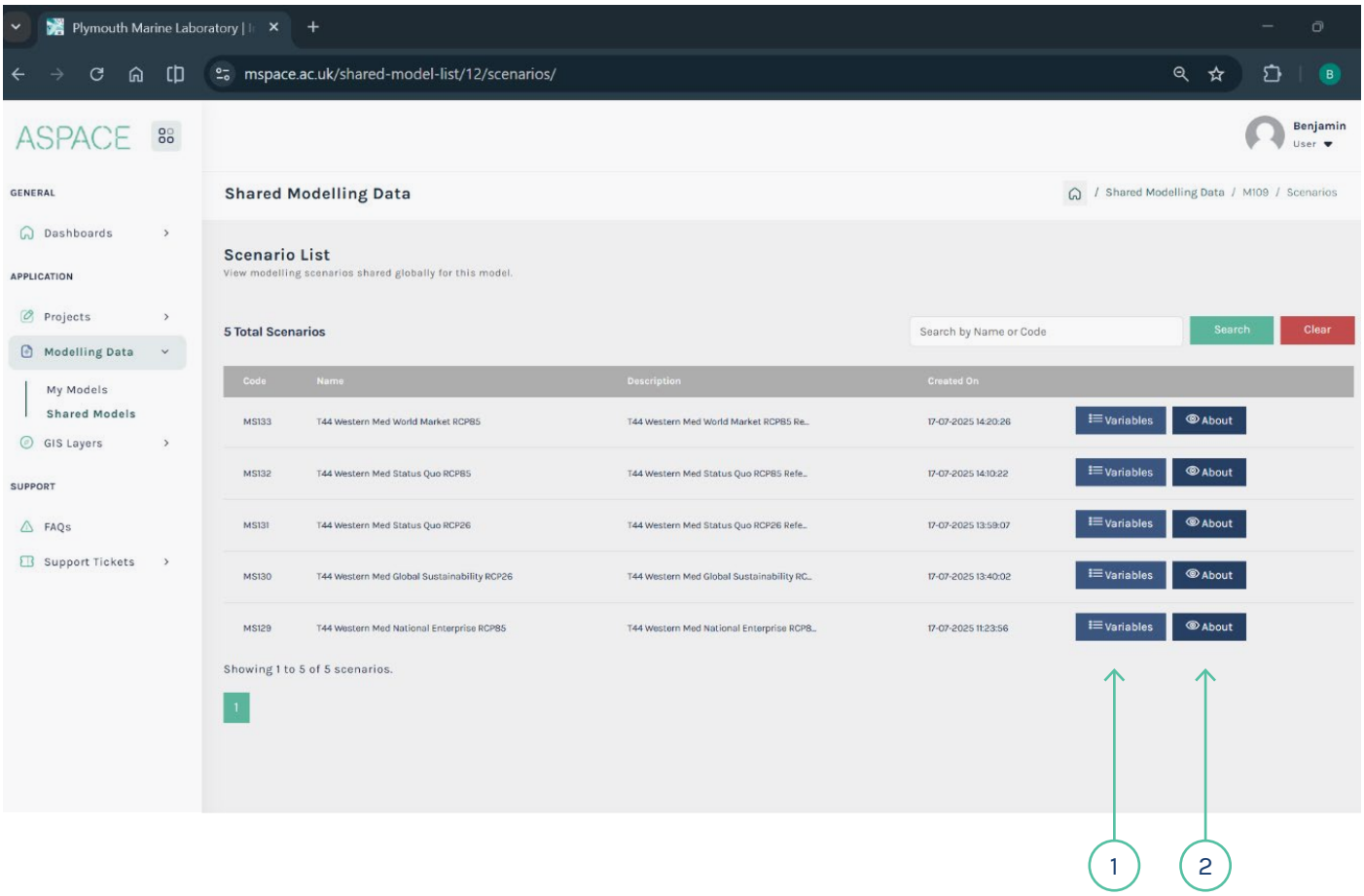
3.12 Viewing details of ocean climate modelling data

Phase 1



1. Under the model of choice press the “Variables” button to highlight which variables are used for the climate modelling and their direction
2. Under the model of choice press the “About” button to provide details about the modelling datasets

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Phase 1

3.13 Uploading economic modelling data

Coming soon!

3.14 Viewing details of economic modelling data

Coming soon!

3.15 Uploading social values data

Coming soon!

3.16 Viewing details of social values data

Coming soon!

3.17 Integration with the Offshore Renewable Impacts on Ecosystem Services (ORIES) project

Coming soon as part of the EQUIFy project

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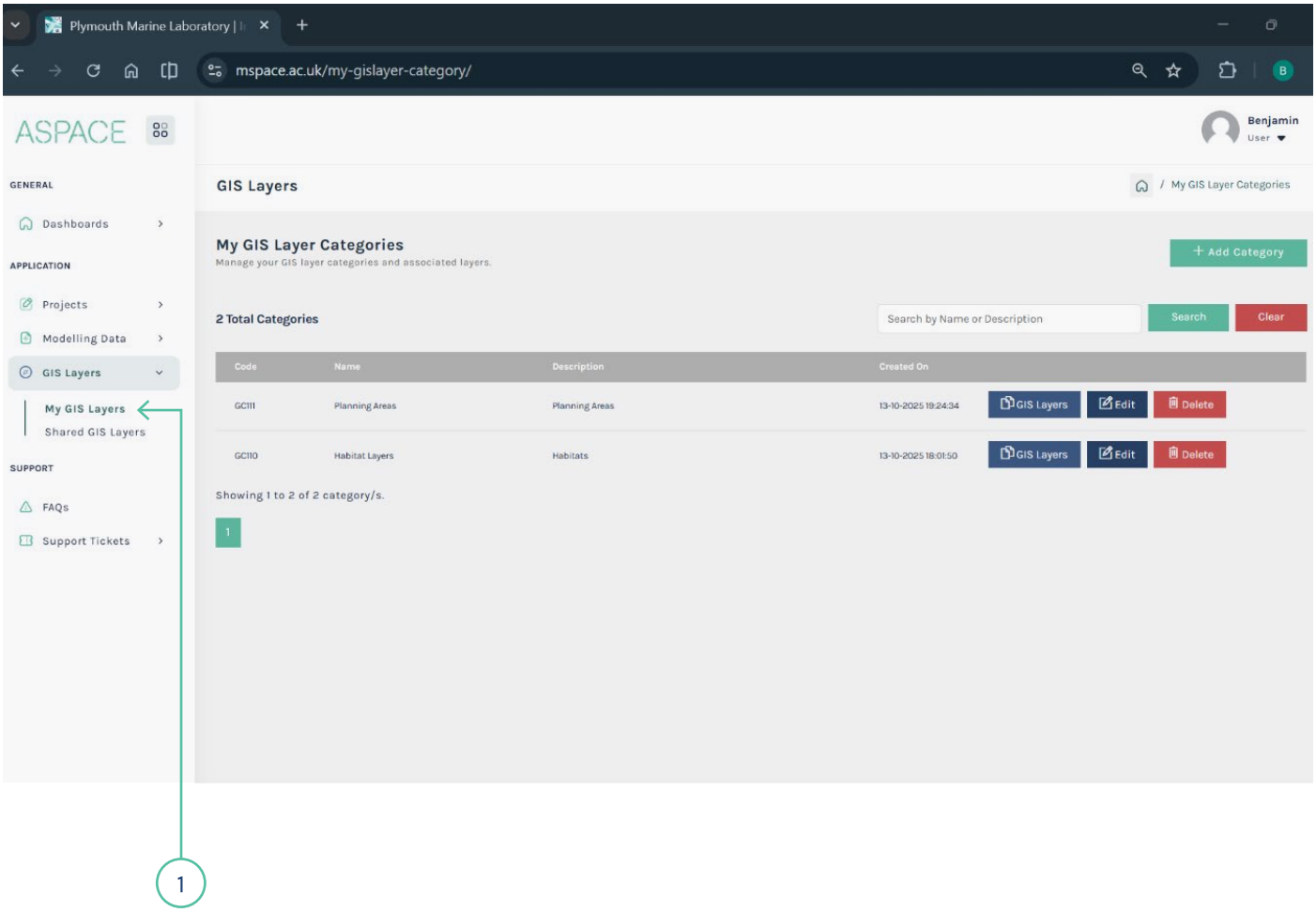
Phase 2

Ocean climate modelling analysis

—Analyses
—GIS layers

3.18 Adding GIS layers

Phase 2



You do not need to upload GIS data to use ASPACE. But if you would like to, here's how to do it.

1. Navigate to the "My GIS layers" / "Shared GIS layers" tab within the "GIS layers" tab

My GIS layers: GIS layers uploaded by the user.

Shared GIS layers: GIS layers uploaded by the ASPACE team or other users, for shared use on the platform.

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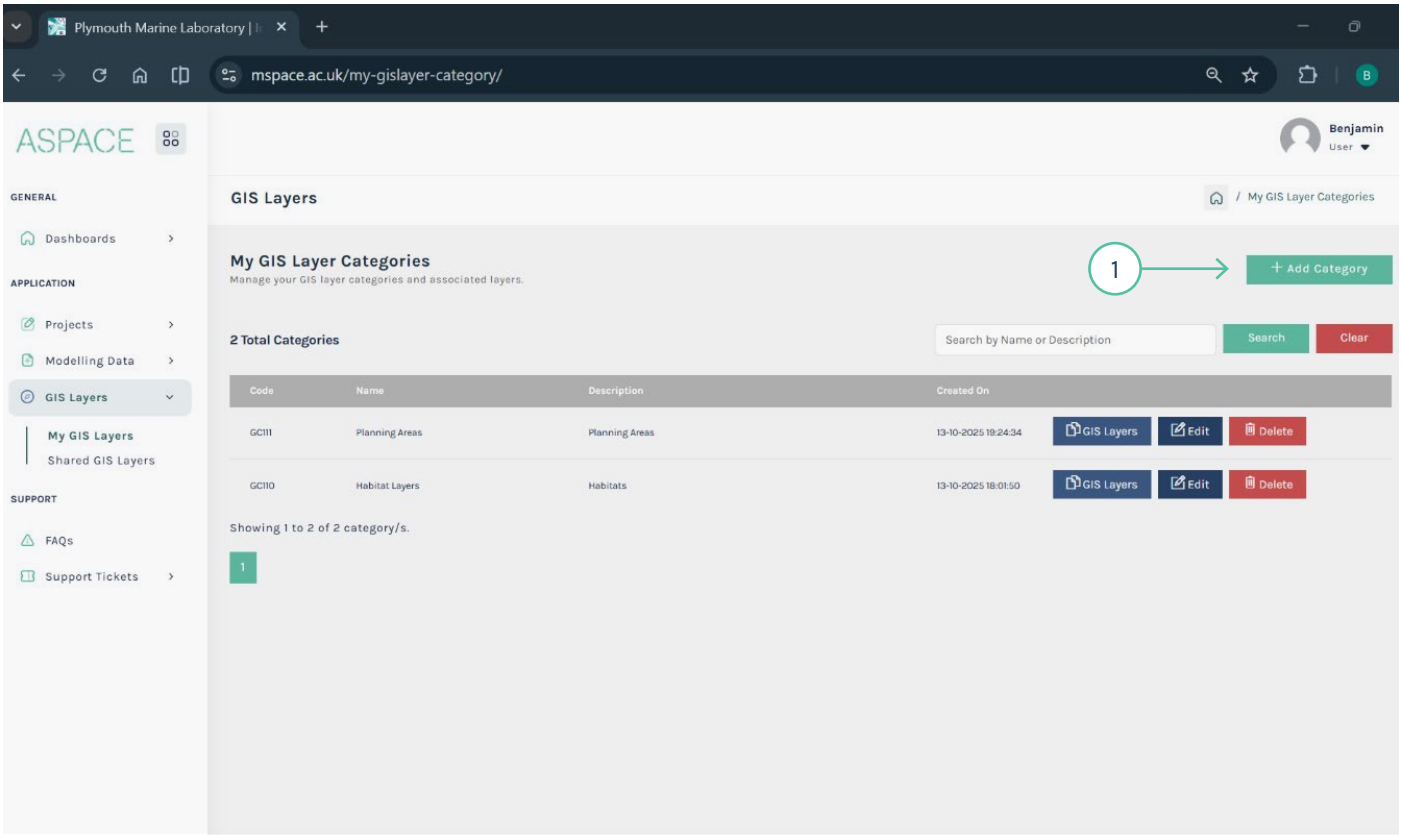
3.18 Adding GIS layers (continued)

Phase 2



1. Press the “+ Add Category” button—This will create a category where your GIS layer will reside
2. Fill in the form
3. Press Add Category button

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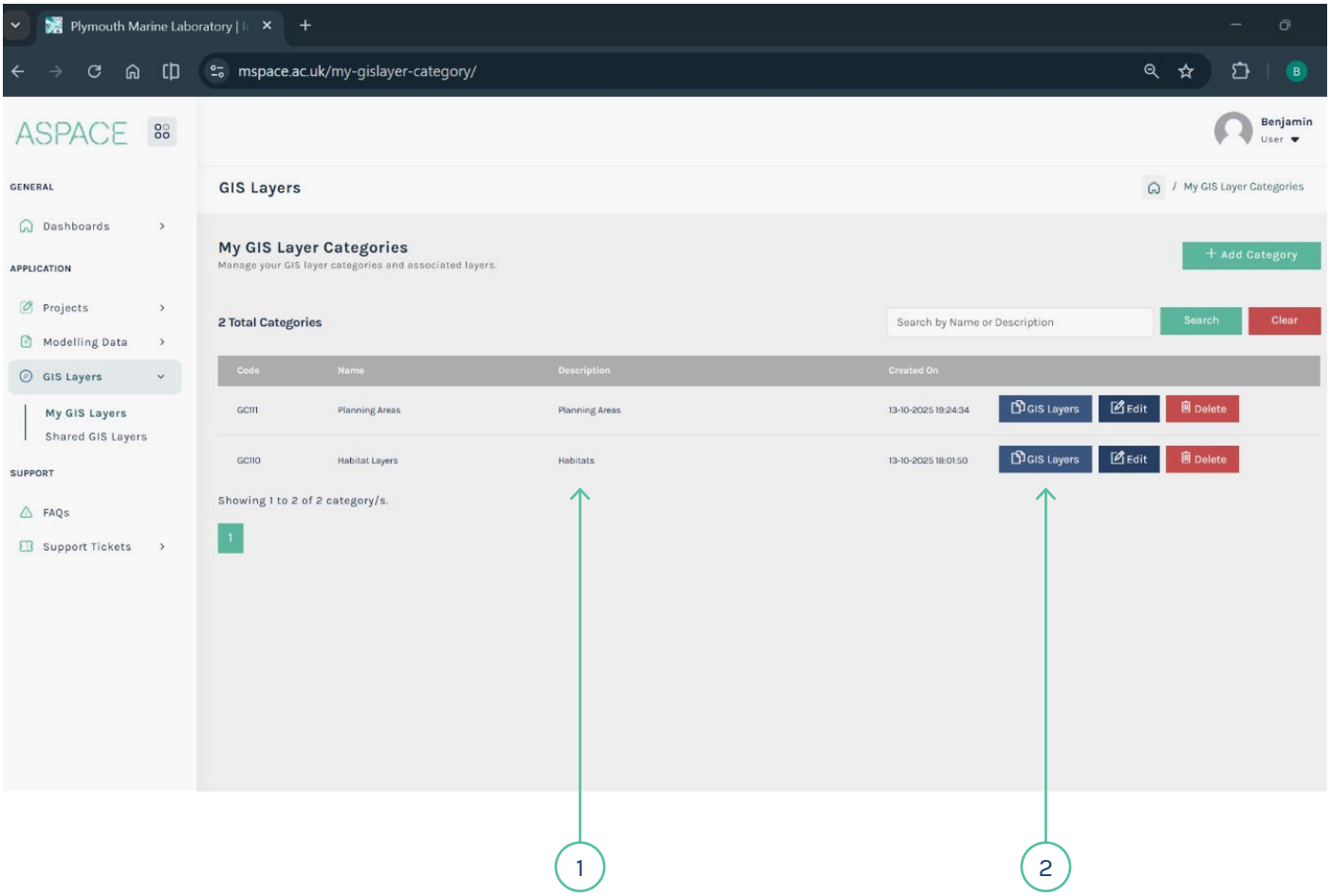
3.18 Adding GIS layers (continued)

Phase 2



1. Your newly created category will appear in the table
2. Press the button “GIS layers” for your newly created category

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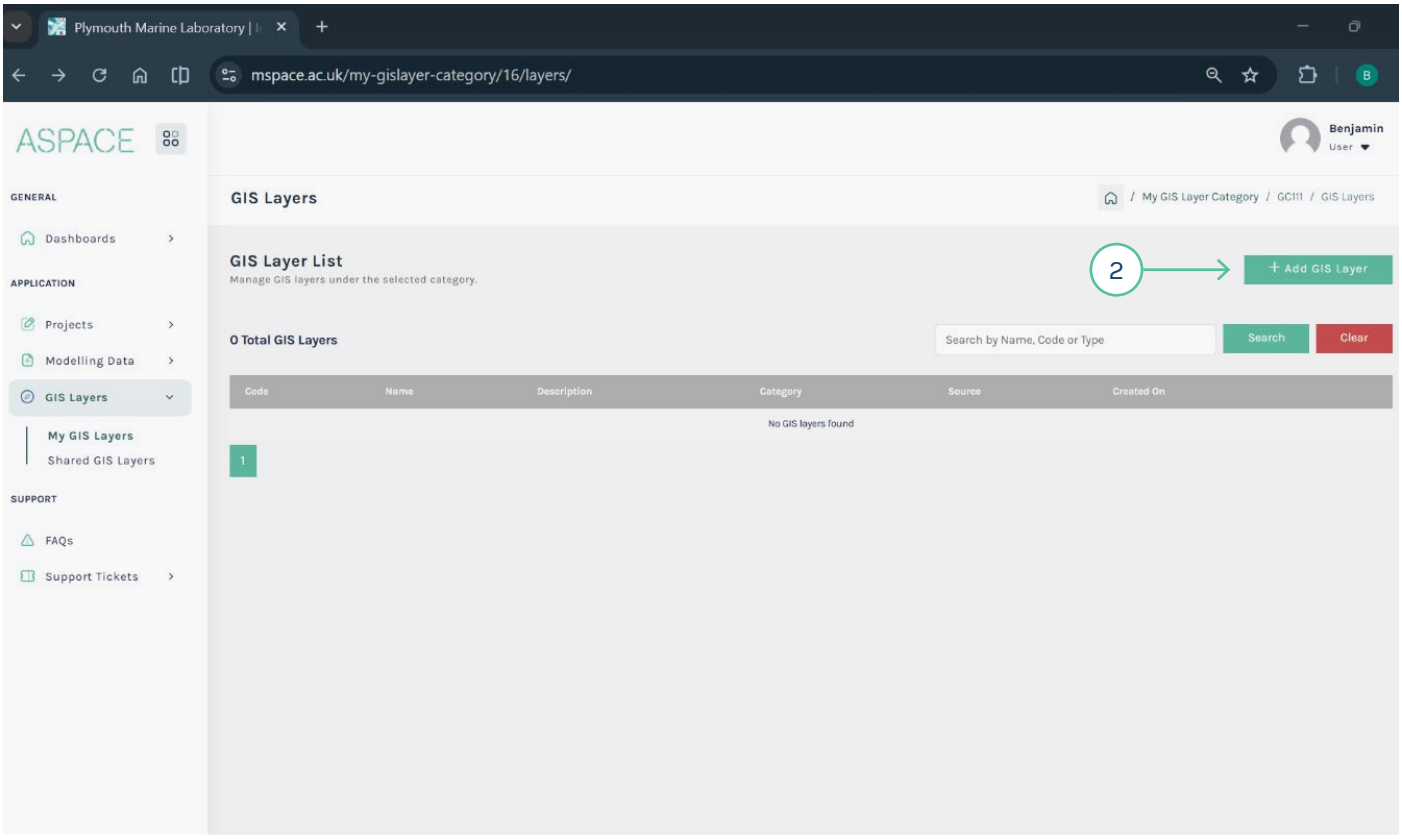
3.18 Adding GIS layers (continued)

Phase 2



1. Check the formatting guidelines for GIS layers
2. Press the Add GIS layer button

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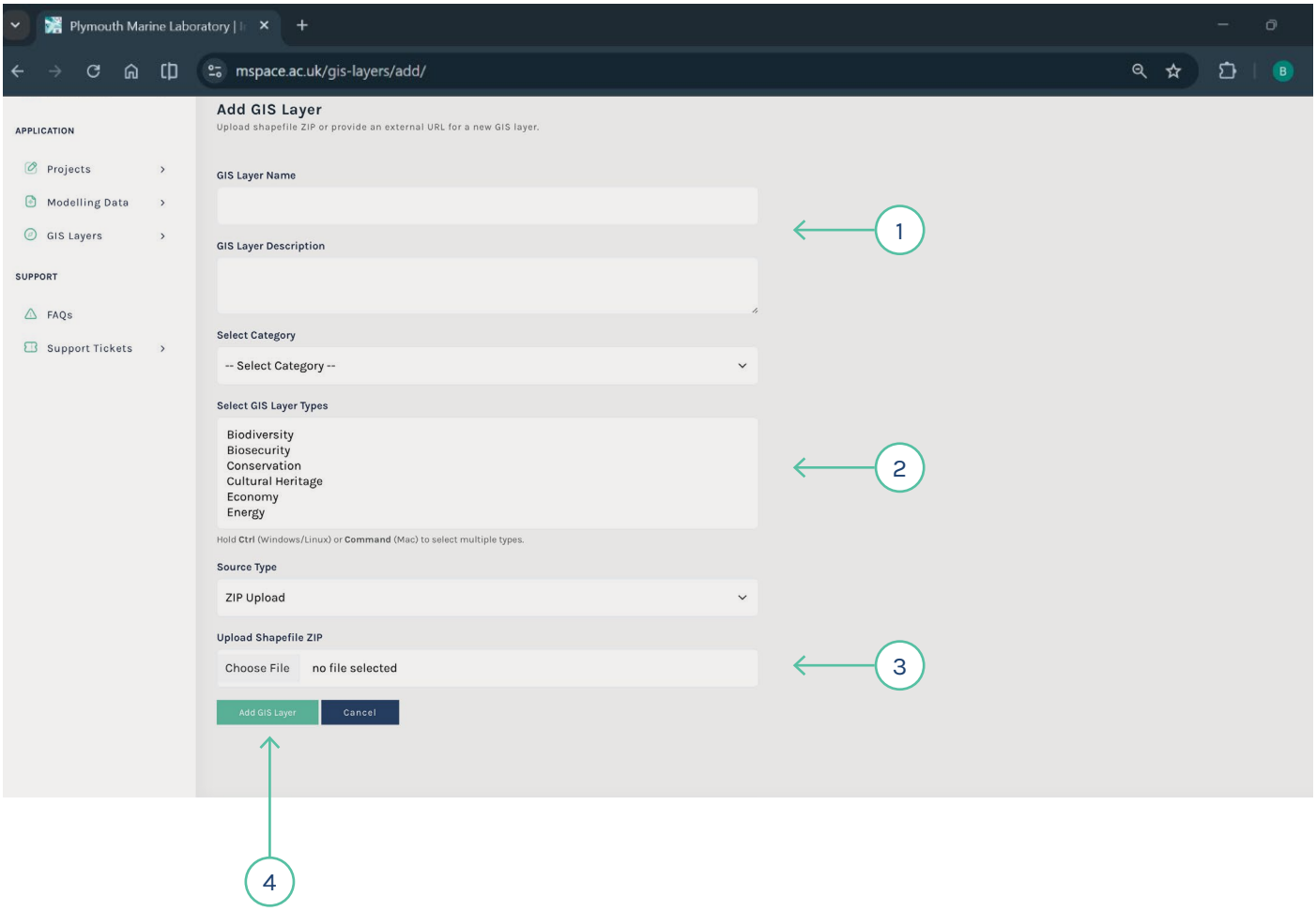
3.18 Adding GIS layers (continued)

Phase 2



1. Fill in the form
2. Multi-select the “Layer Types” that are appropriate for your GIS layer by holding down the “Ctrl” button on your keyboard
3. Attach the shape file
4. Press on the “Add GIS layer” button

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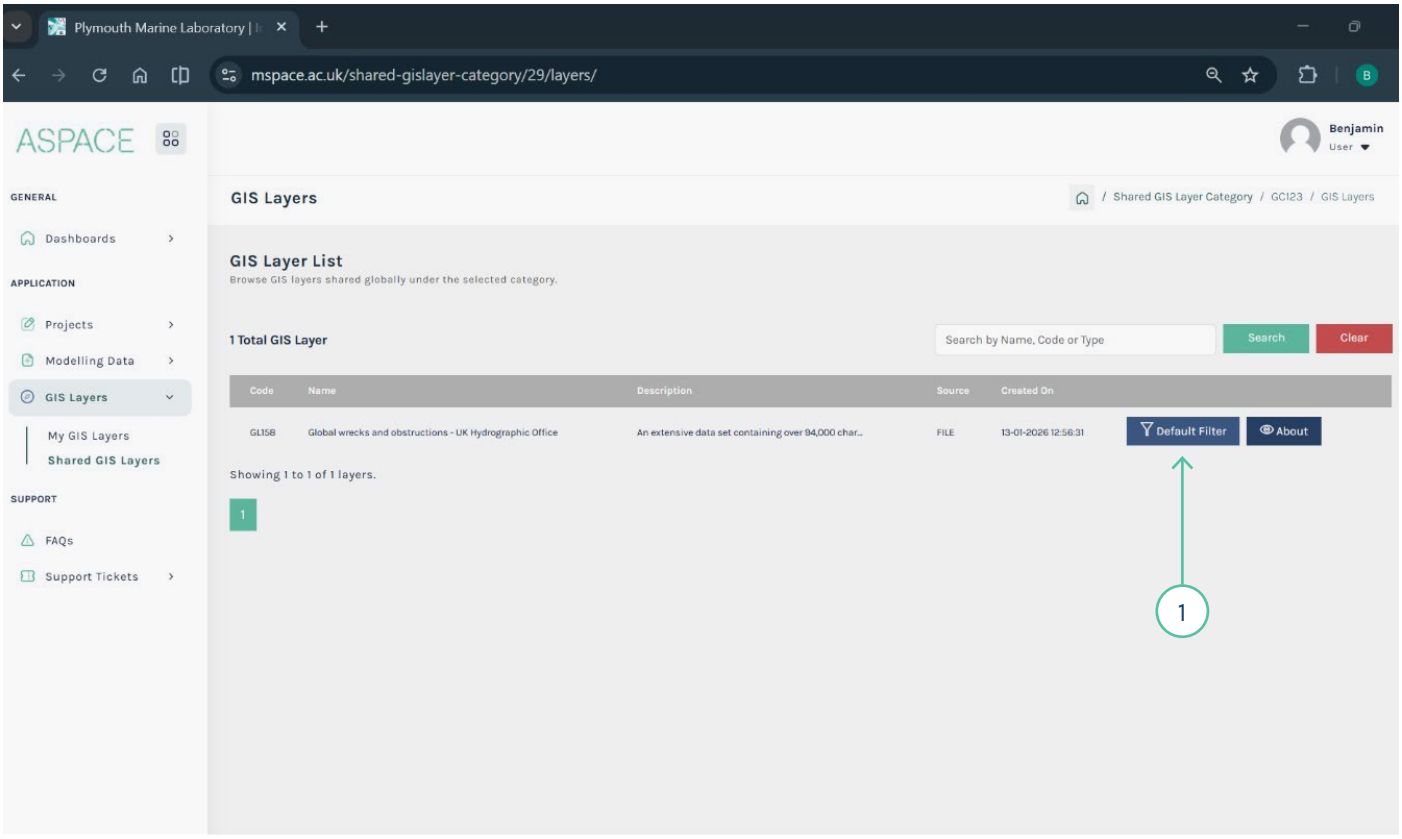
3.19 Using GIS layers

Phase 2



1. To find out more information about the default filters used for the GIS layer press the “Default Filters”

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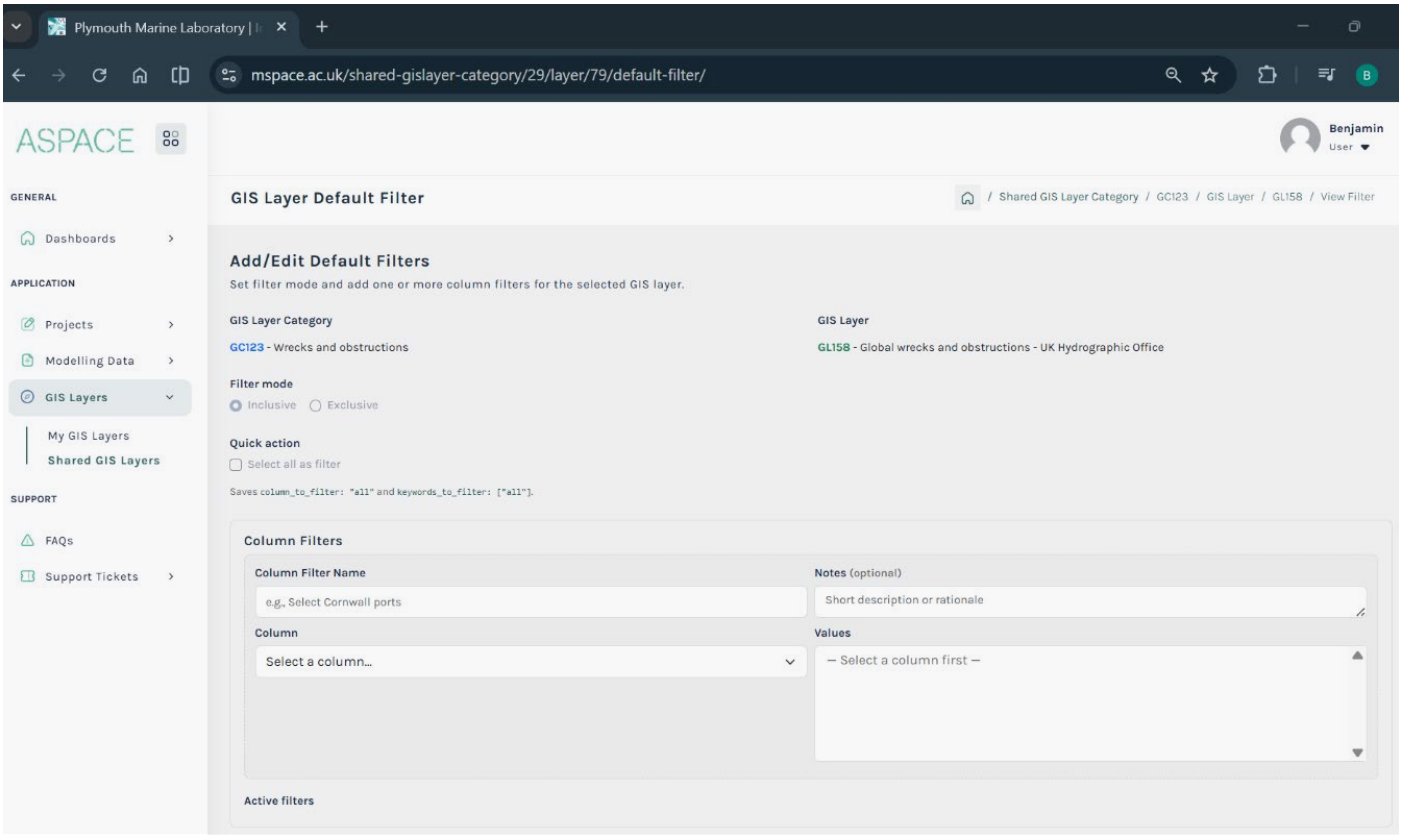
3.19 Using GIS layers (continued)

Phase 2



1. This page will detail the Filters that are applicable to the GIS layer. These filters will be the defaults for any ASMS generation that involves this layer if the user chooses to use it with when creating ASMS via the Basic Wizard.

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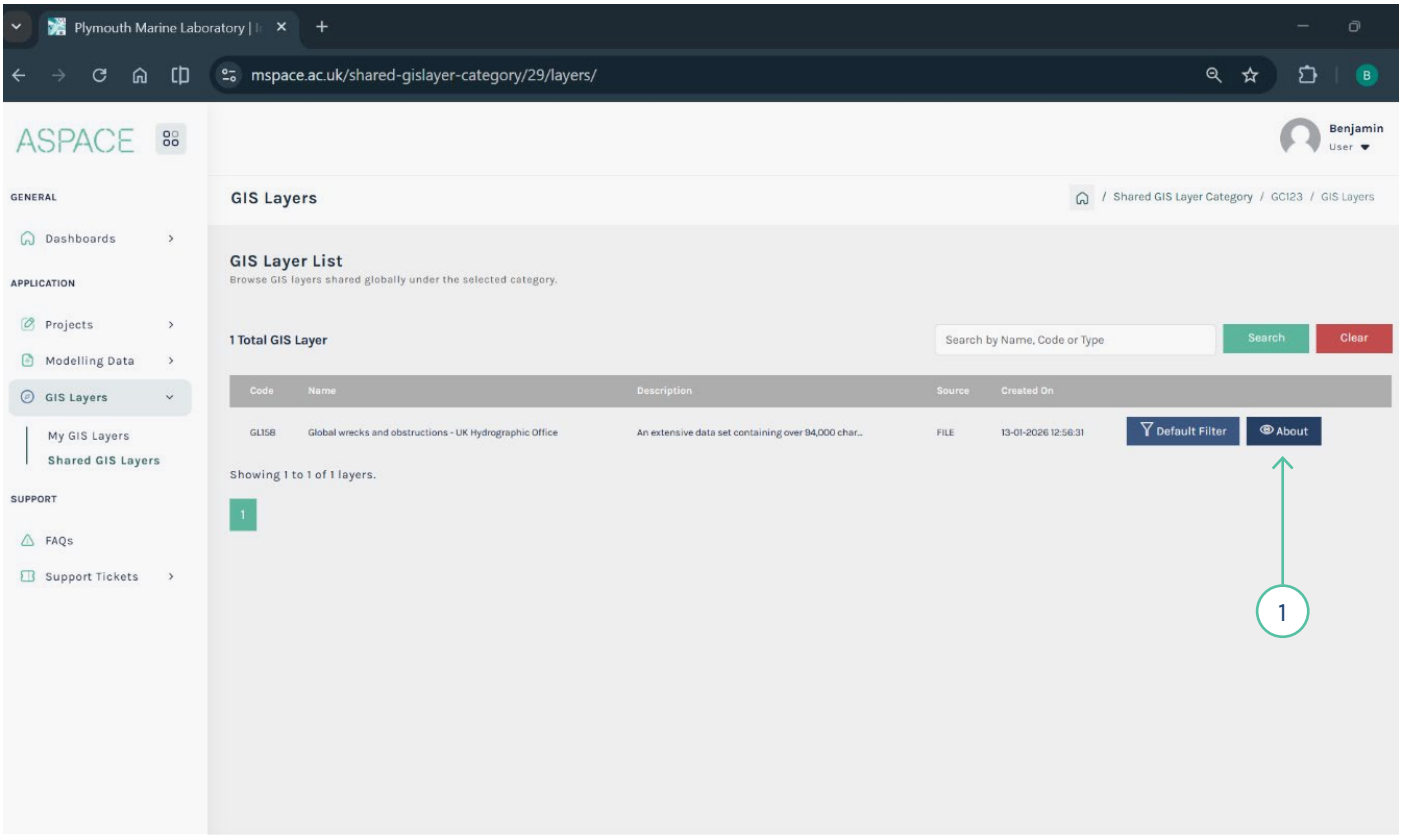
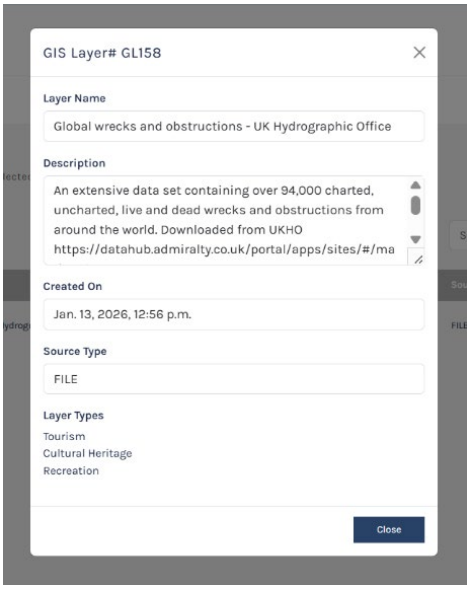
3.19 Using GIS layers (continued)

Phase 2



2



1. To find out more information about the GIS layer including referencing details press the “About” button
2. This dialogue box will provide an overview of the information for the GIS layer including: Name, Description, Creation date, Source Type and Layer Types

In order to visualise GIS layers please follow the instructions described in Analysis IV—Overlaying GIS layers of interest

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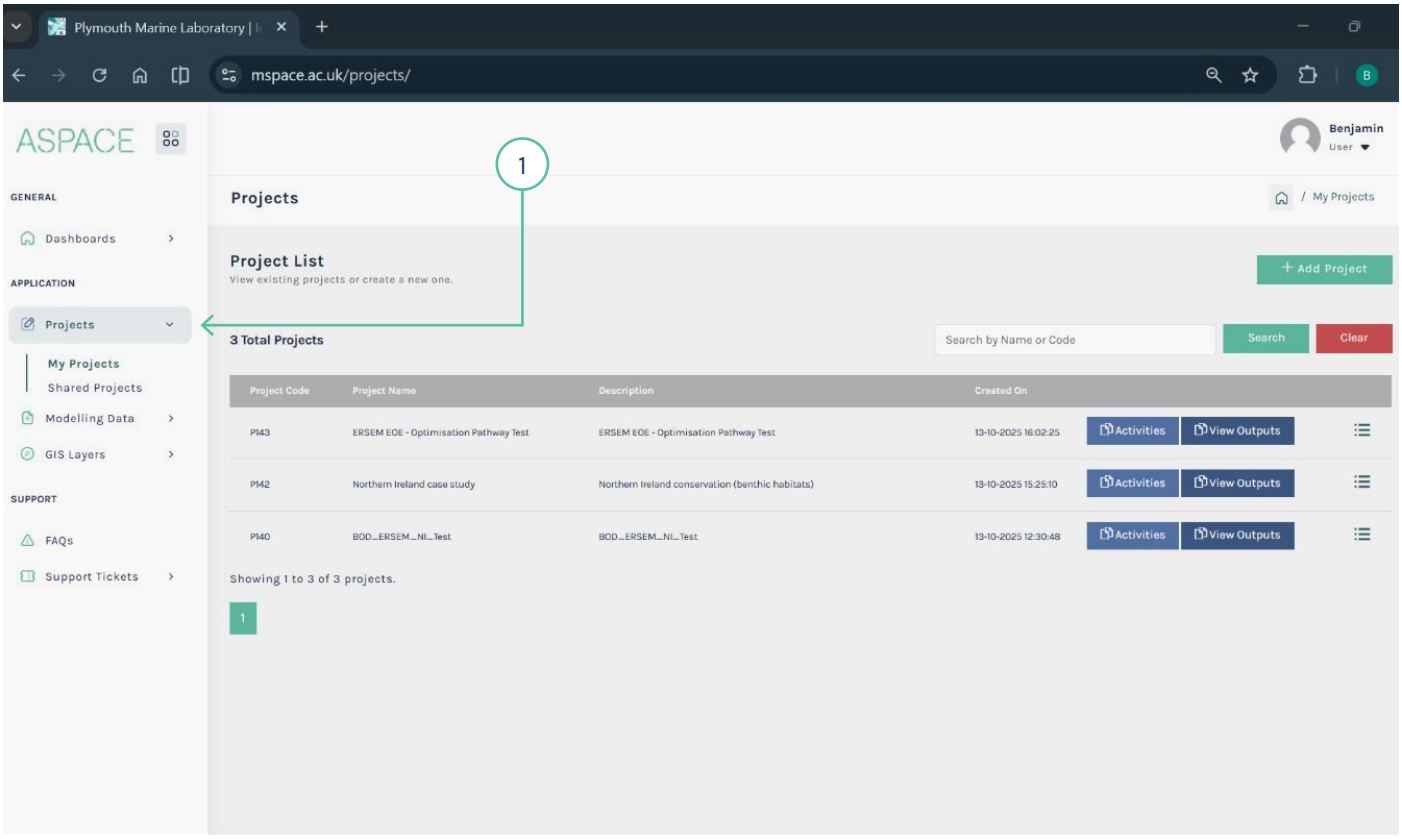
3.20 Analysis I—Creating a new project

Phase 2



1. Projects are how individual analysis workflows are identified in the ASPACE platform.

My Projects dashboard shows a list of analysis workflows created by the user

Shared Projects analysis workflows created by the ASPACE team or other users, for access by all on the platform

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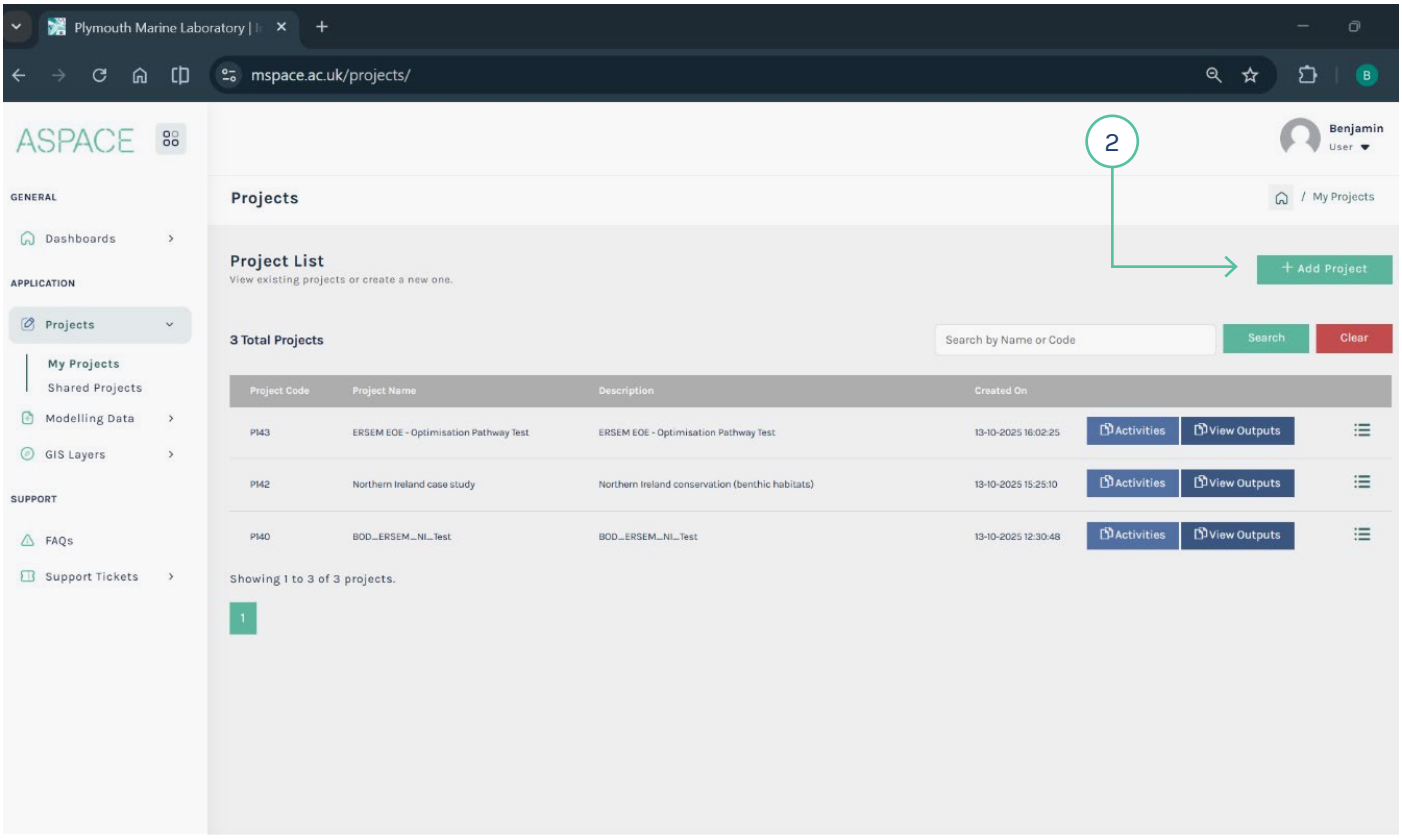
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Read the section on Meta—Analysis in the User Guide which explains the analysis framework used in the tool
2. Press the "+ Add Project" button

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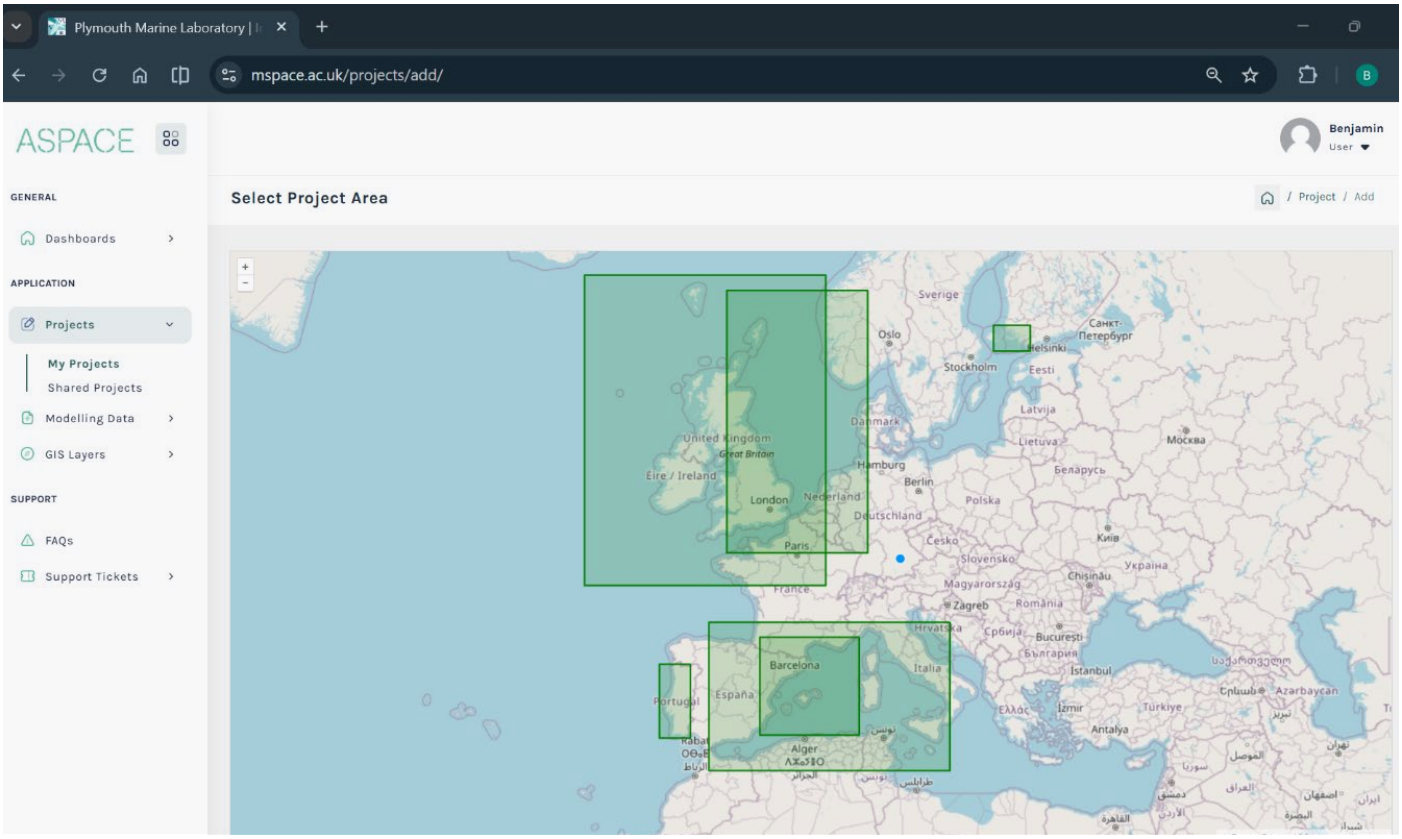
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Navigate to the region of interest
2. Use left click on your mouse to Drag and Drop your area of interest.

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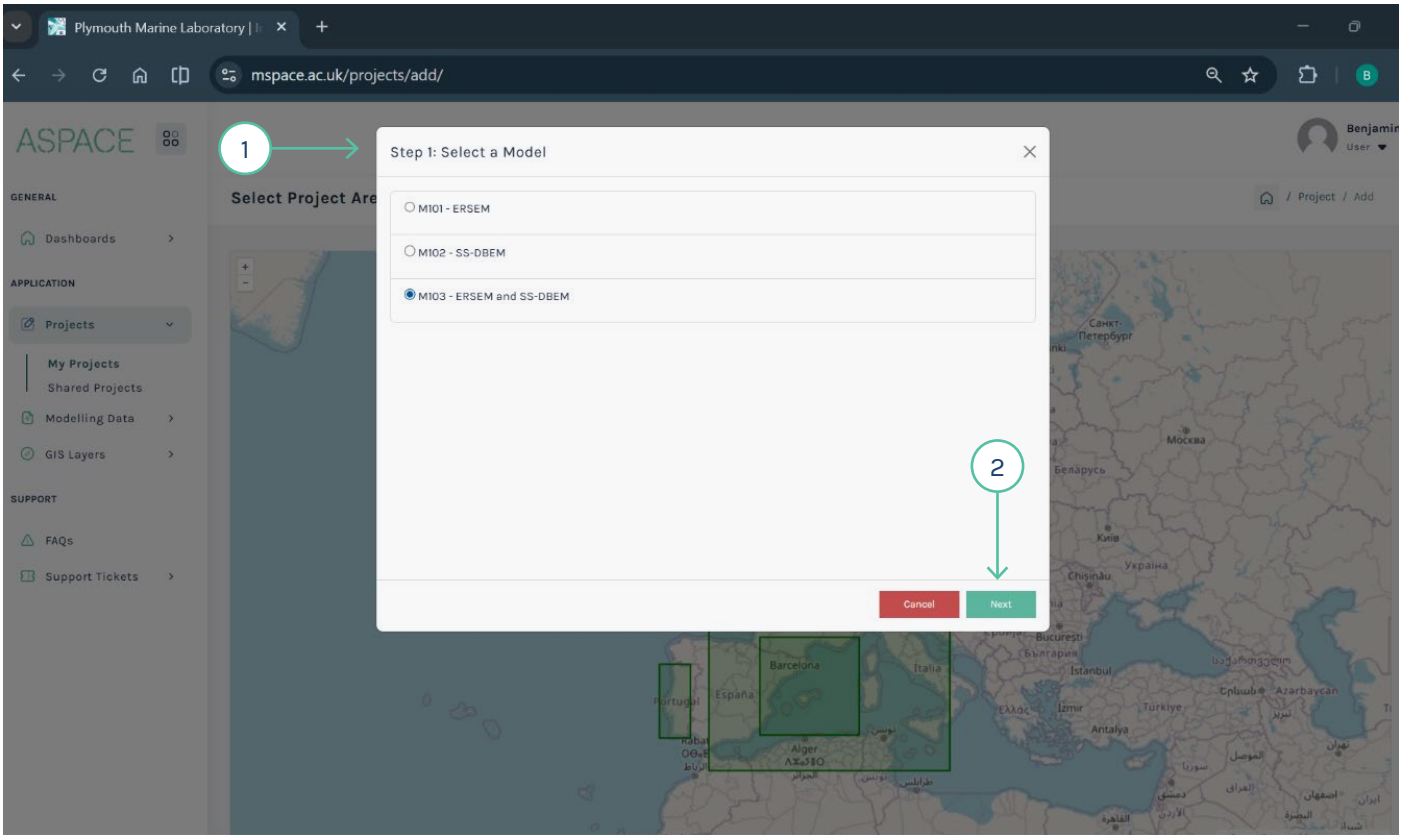
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Select the Model (modelling dataset) of interest. This can be one of your datasets or a shared dataset.
2. Press the “Next” button.

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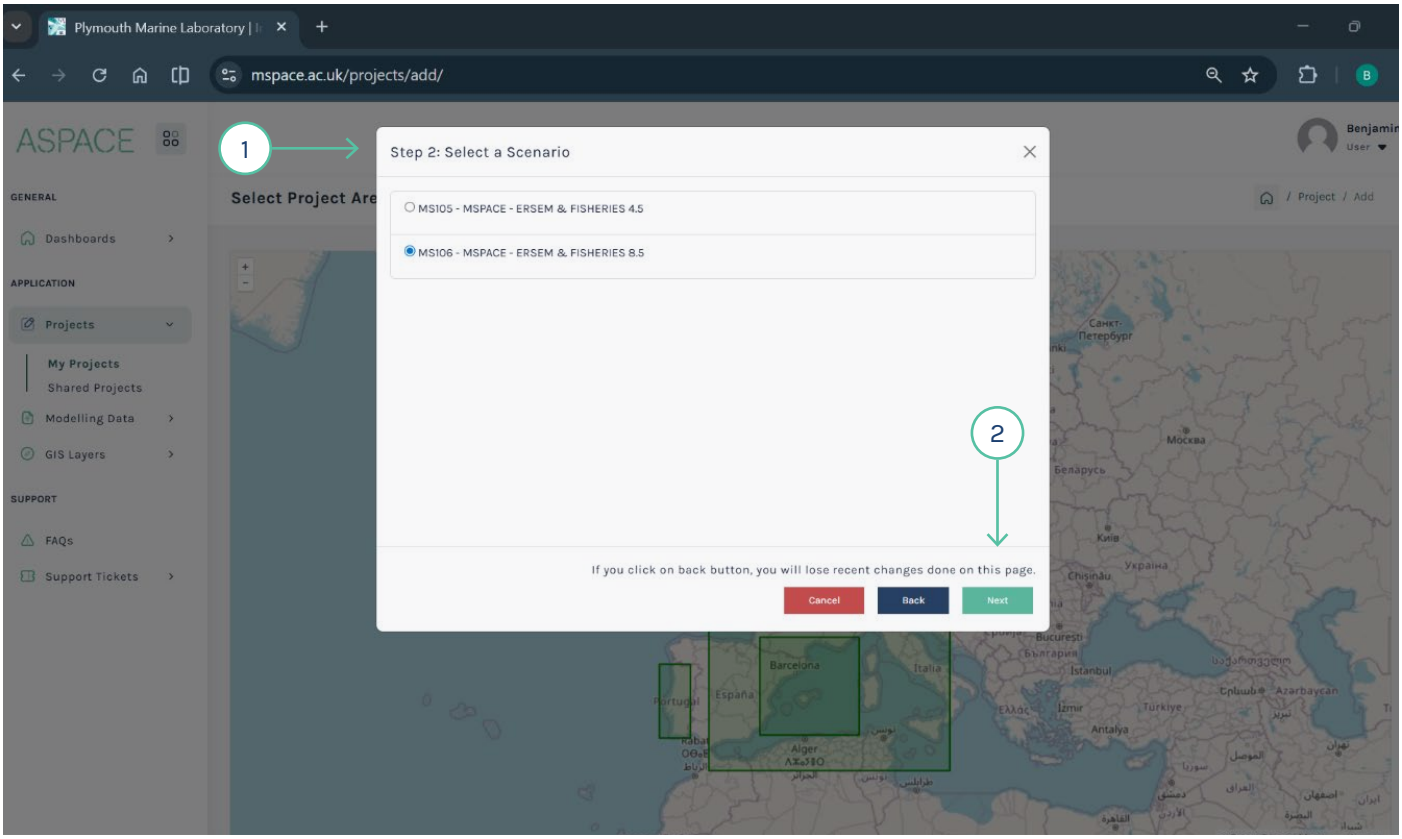
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Select the dataset for the Greenhouse Gas Emissions Scenario or other Scenario available, of interest.
2. Press the “Next” button

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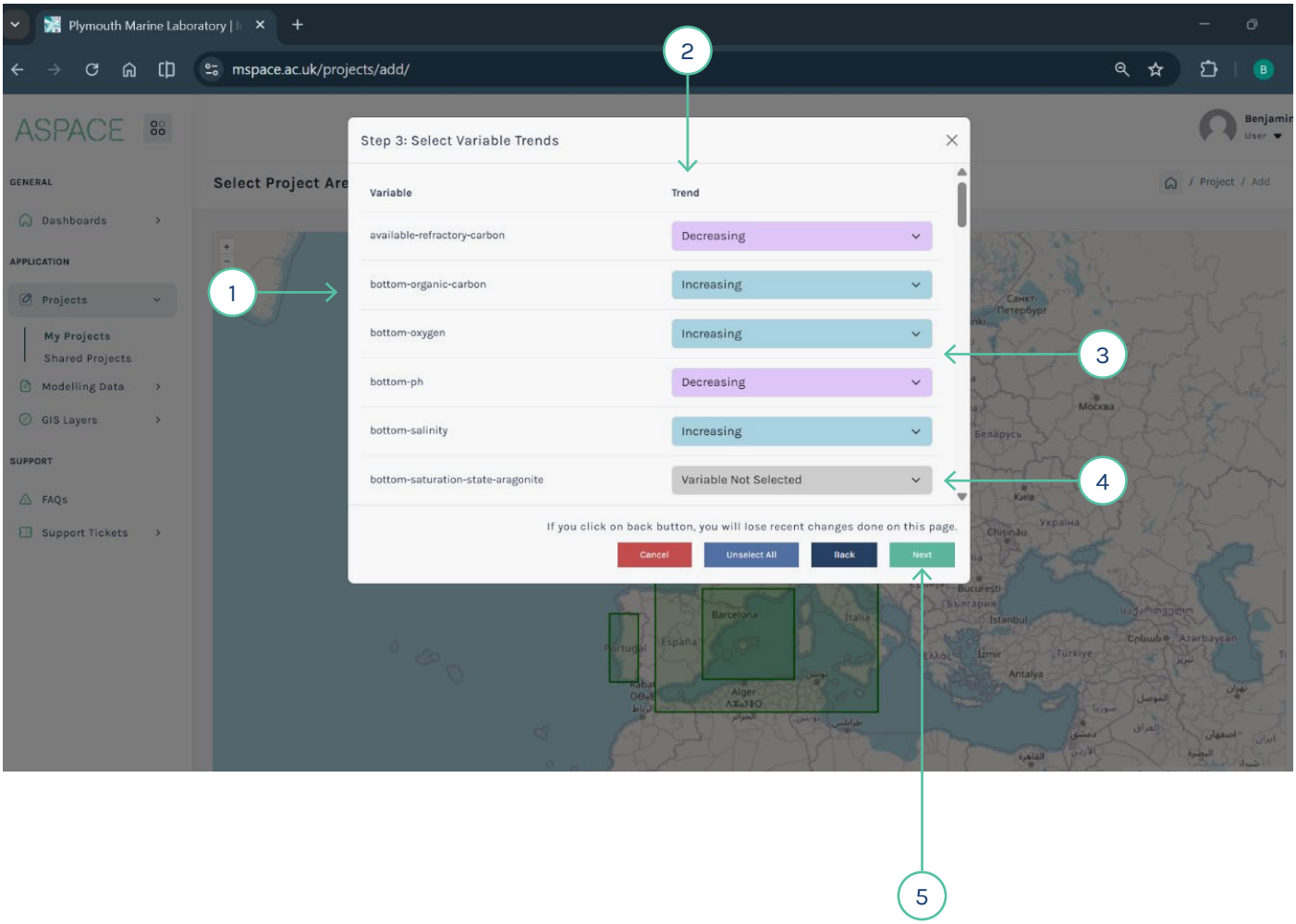
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Review the individual variables available in the selected dataset by scrolling down, and select them by using the expected climate change trend using the drop down menu.
2. To select a variable, a trend must be selected. This step of the analysis is very important and should be taken with care as it affects the overall outcomes: please refer to the Meta-Analysis is section of the user guide for detail.
3. If using datasets uploaded by the ASPACE team, several or all variables available will have already be presented with their expected climate change trends for the region, but these can also be modified by the user in their present workflow, if they have different information.
4. To unselect variables, use the dropdown menu.
5. Once you have selected all (and only) your variables of interest and entered their expected climate change trend in the region of analysis, press the “Next” button.

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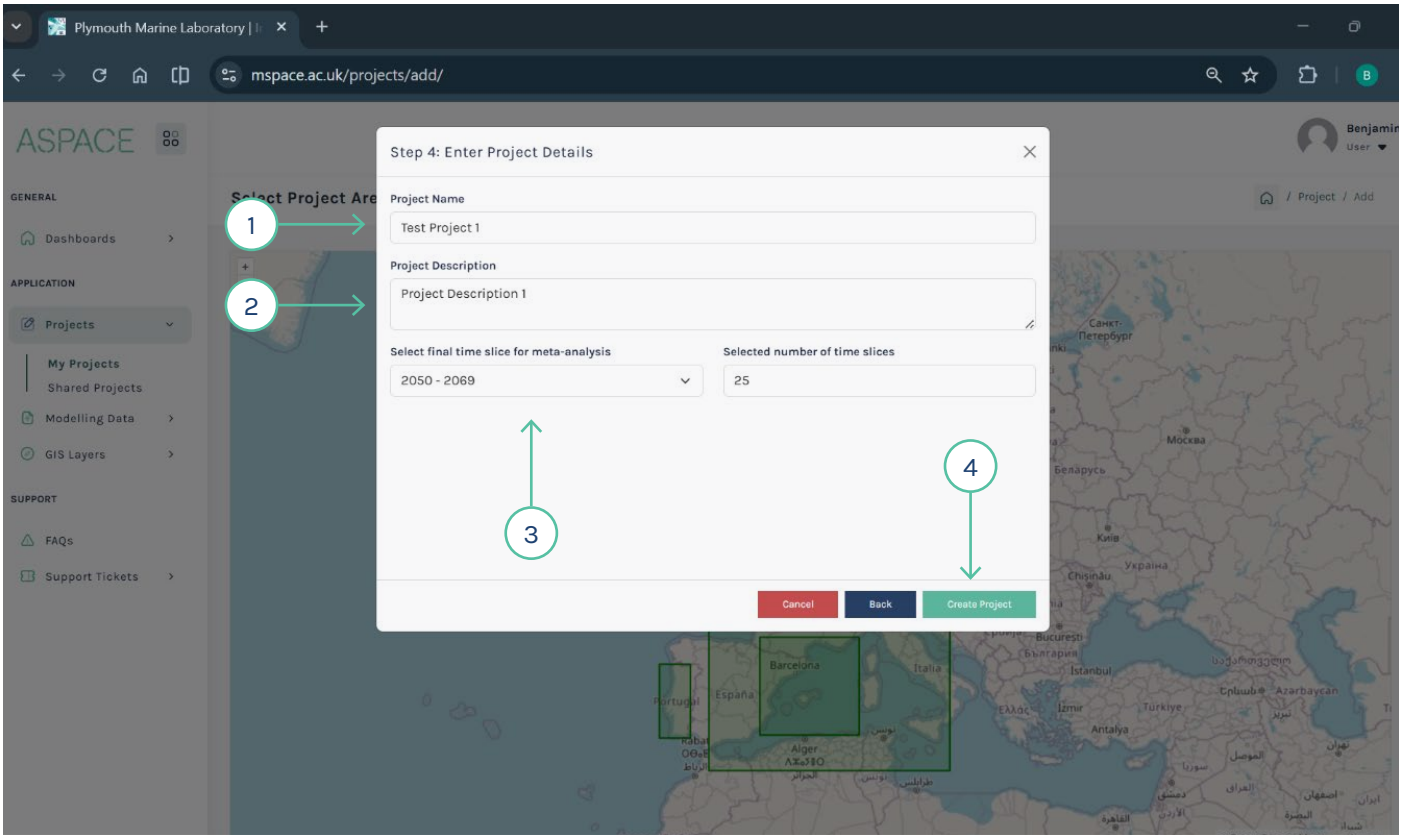
3.20 Analysis I—Creating a new project (continued)

Phase 2



1. Enter the desired Project Name (field cannot be blank).
2. Enter the desired short Project Description (field cannot be blank).
3. Select the final time slice for Meta-Analysis
4. Complete the project settings by pressing the Create Project button. This establishes the conditions for the meta-analysis part of the workflow.

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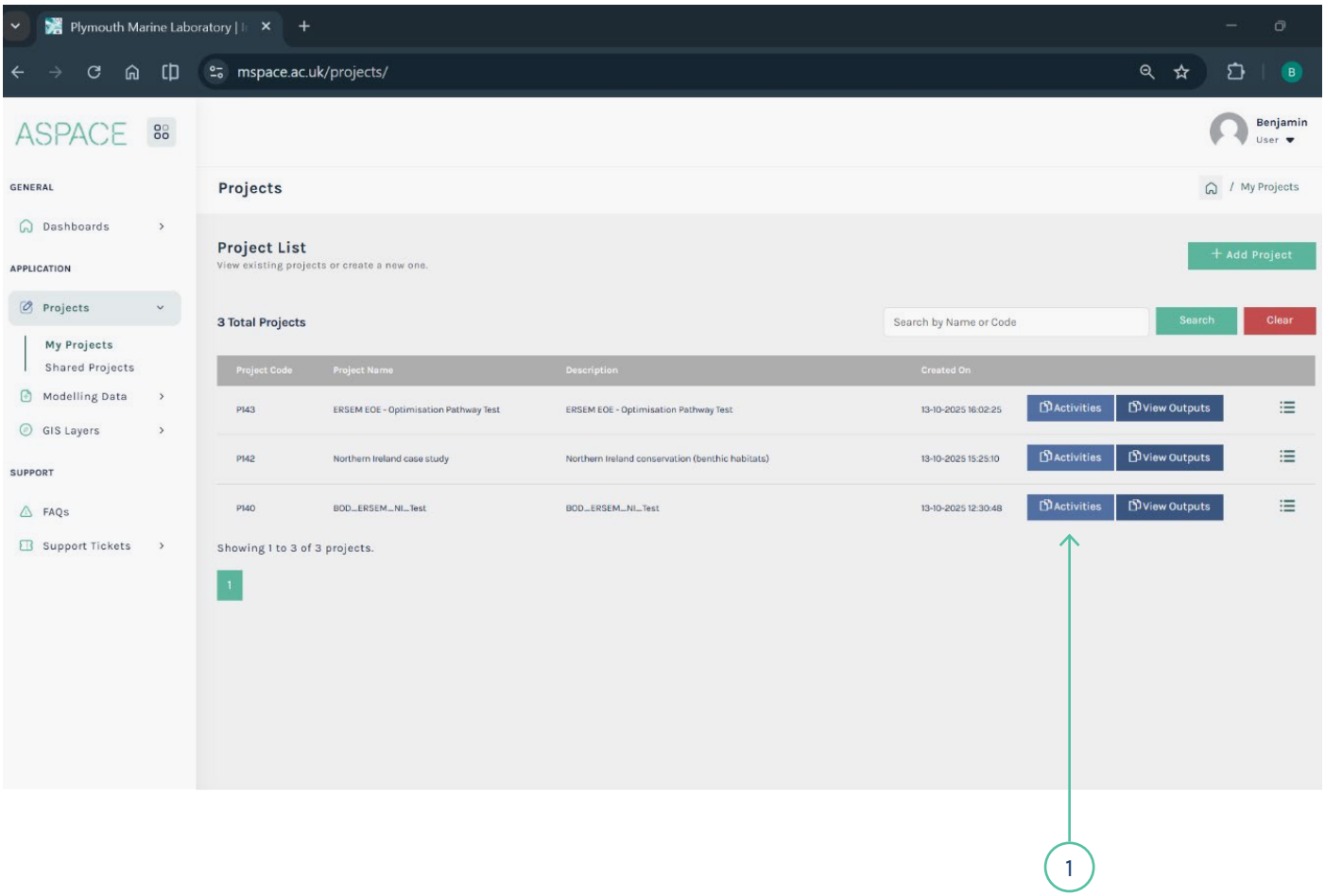
3.21 Analysis II—Running meta-analyses on ocean climate modelling data

Phase 2



1. Using the projects dashboard, press the “Activities” button to initiate individual meta-analyses setup within a project.

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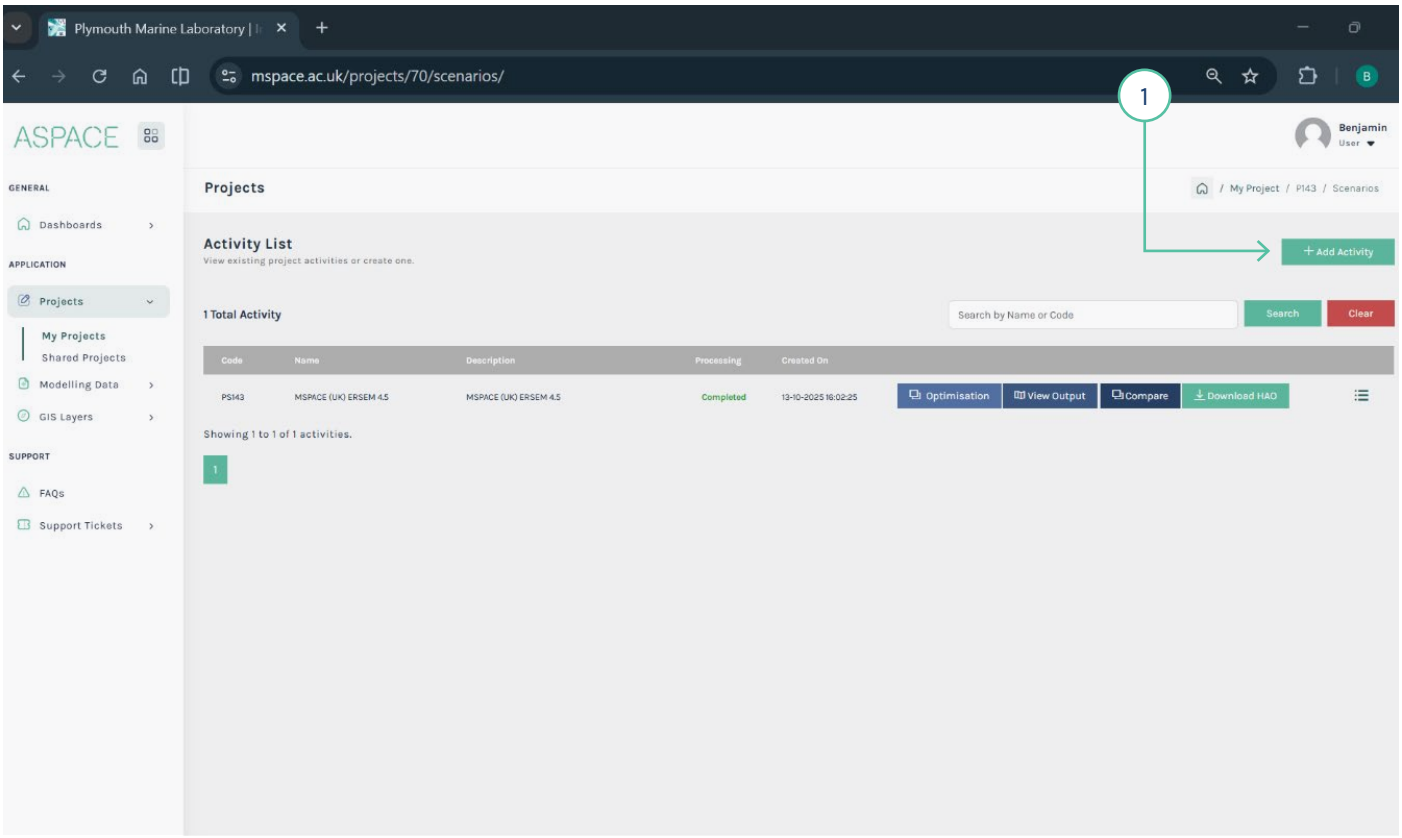
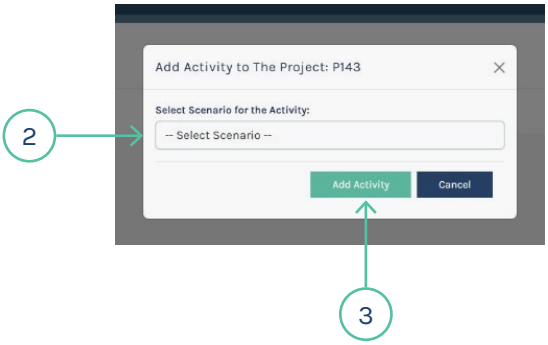
3.21 Analysis II—Running meta-analyses on ocean climate modelling data (continued)

Phase 2





1. Press the “+ Add Activity” button
2. Use the dropdown menu to select the modelling data of interest, which refers to a specific scenario of interest (e.g. RCP 8.5)
3. Press the “Add Activity” button

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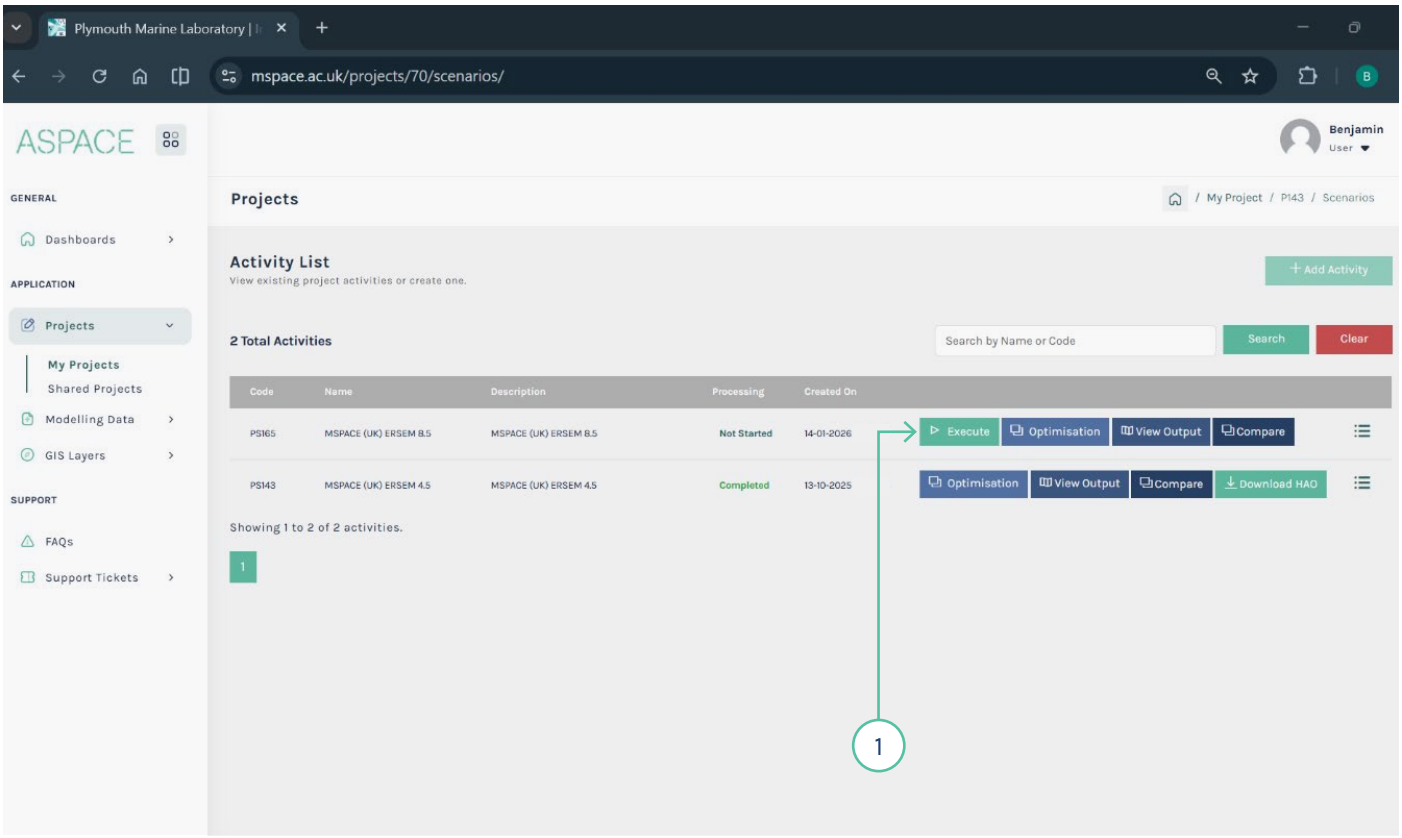
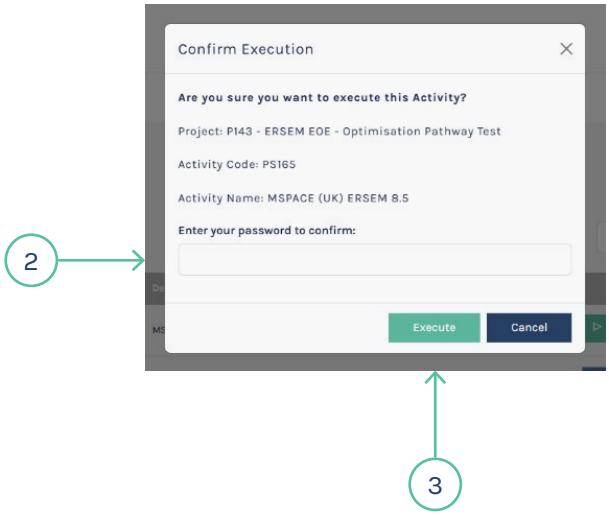
3.21 Analysis II—Running meta-analyses on ocean climate modelling data (continued)

Phase 2





The target dataset for analysis will appear in the Analysis dashboard

1. Press the “Execute” button to initiate the meta-analysis.
2. Enter your password
3. Press the “Execute” button

Completing the meta-analysis takes at least 30 minutes. You will receive an email when this is complete. You can close the browser and shut down your computer.

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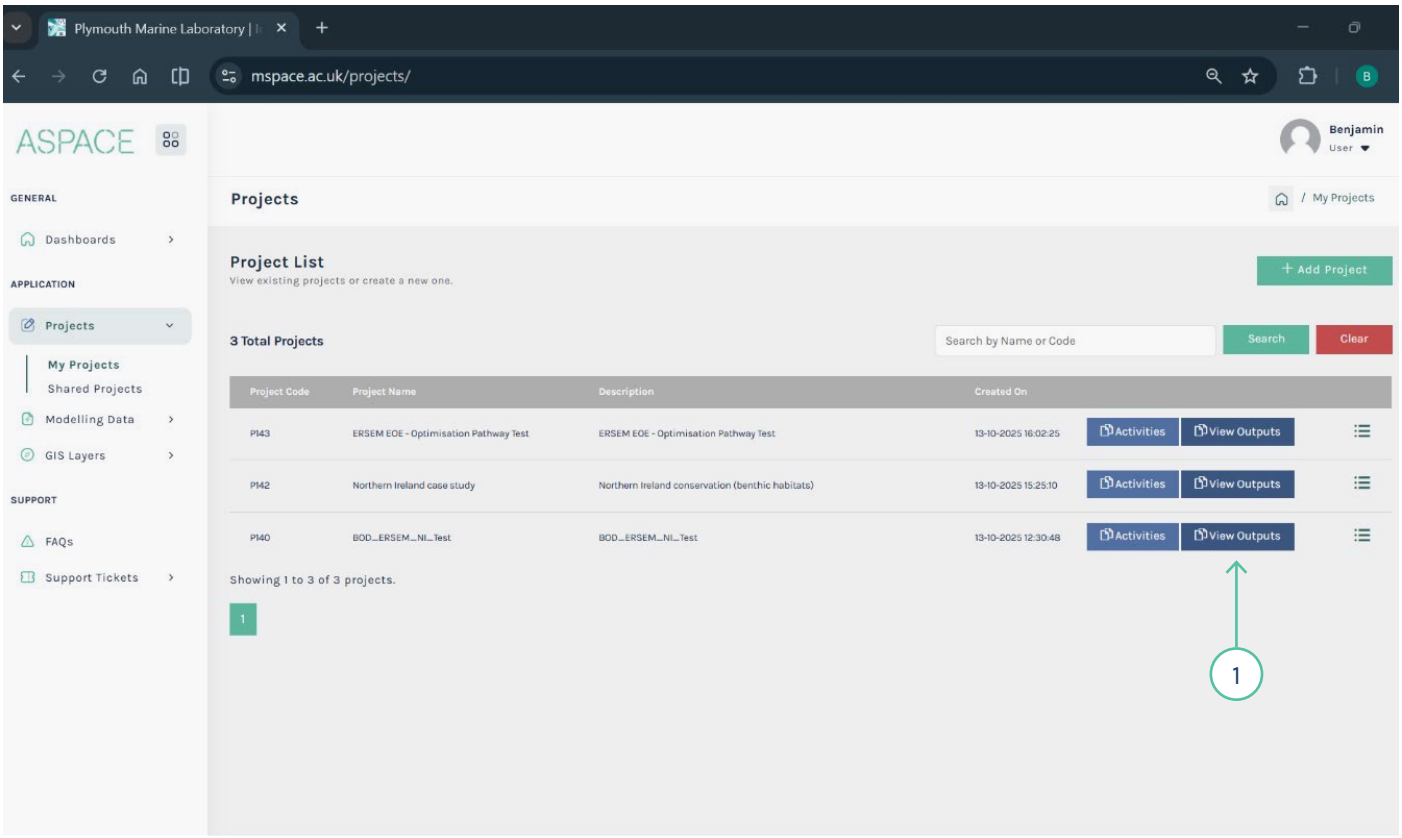
3.22 Analysis III—Visualising meta-analysis results

Phase 2



1. Using the Projects Dashboard, press the View Outputs button.

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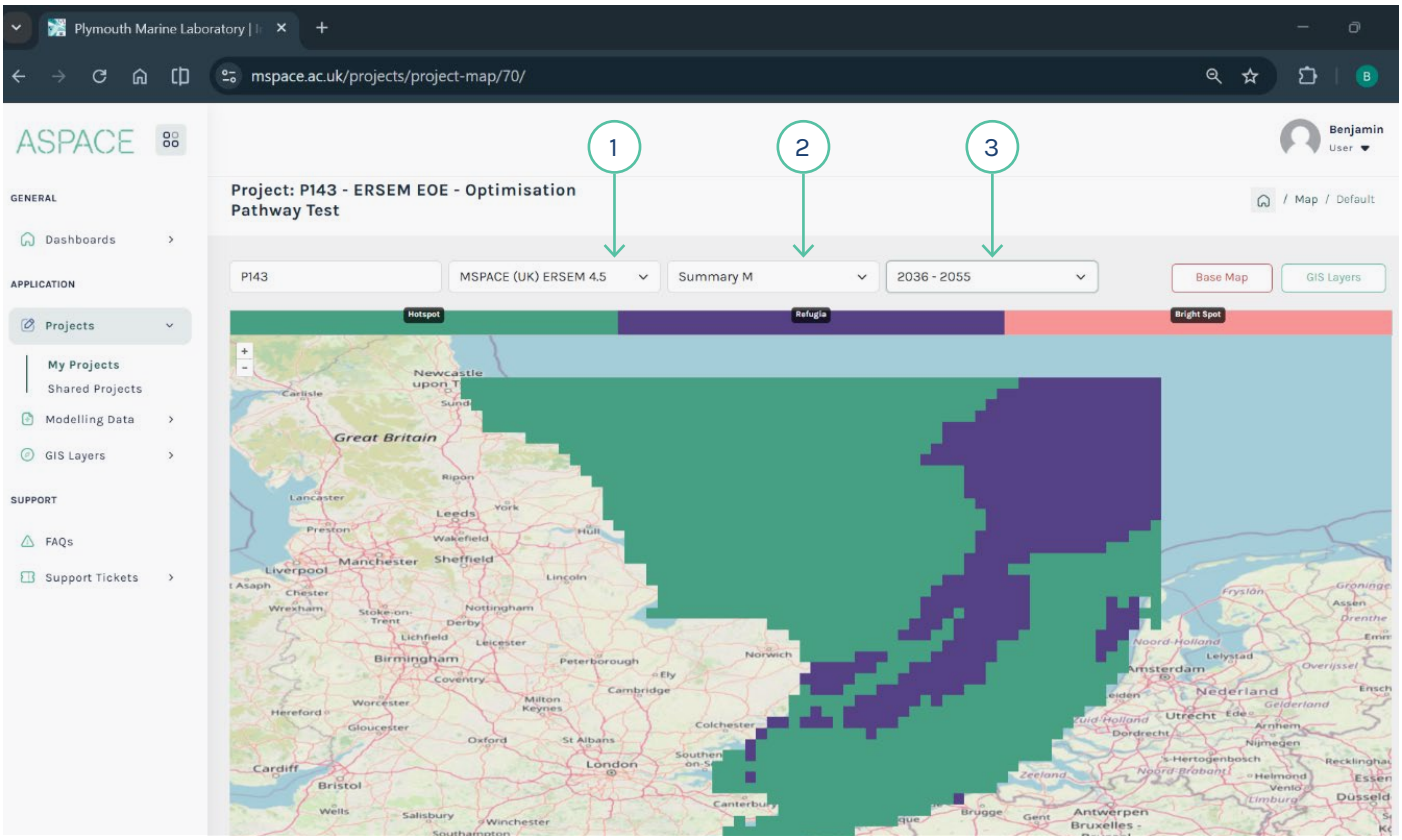
3.22 Analysis III—Visualising meta-analysis results (continued)

Phase 2



Using the Dropdown menus above the map:

1. Select the dataset of interest
2. Select the output Statistics of interest (please refer to the Meta-Analysis section of the user manual for interpretation).
3. Select the future period of interest (compared against the reference period in the meta-analysis)
4. Select the variable of interest (Choice dependent)

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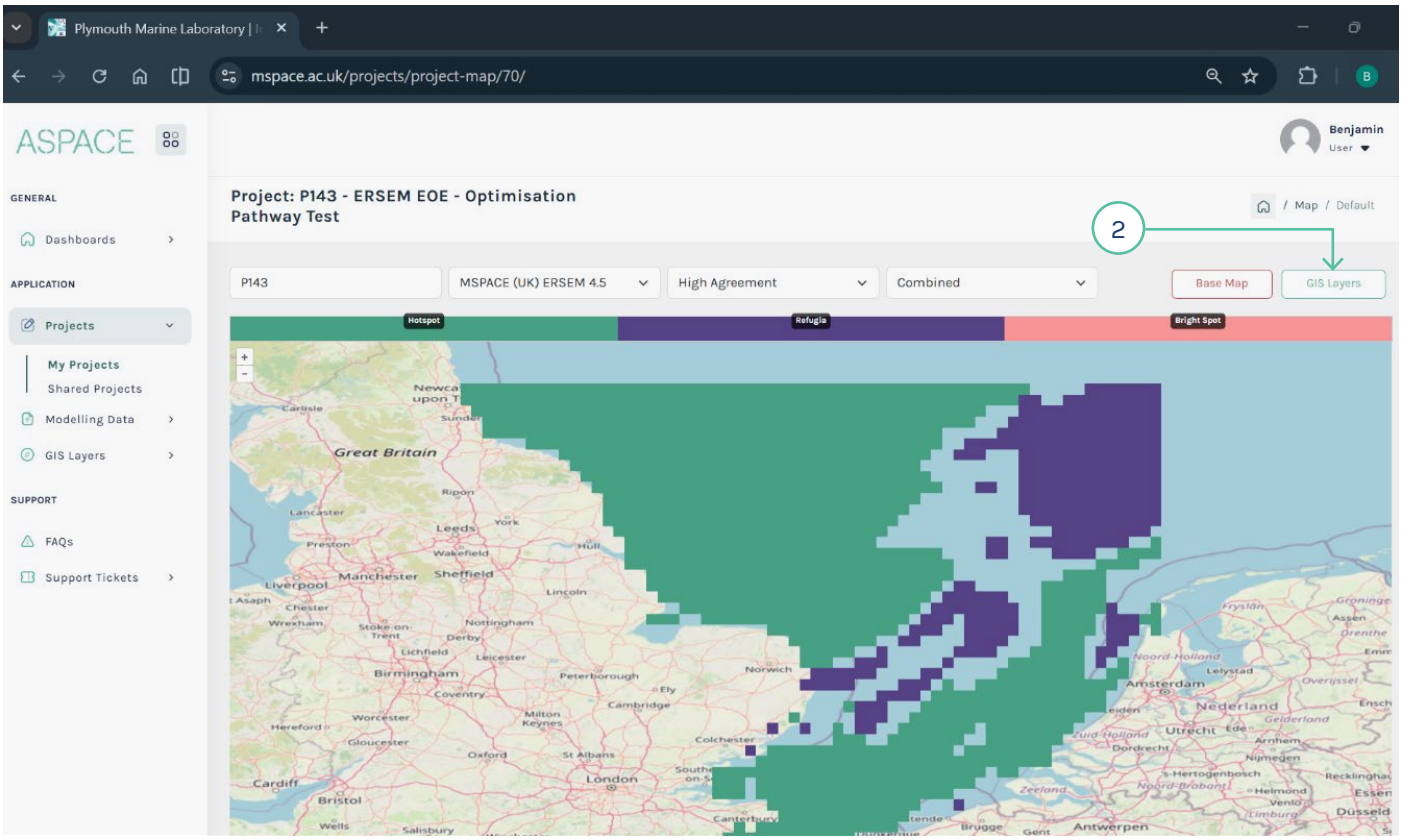
3.23 Analysis IV – Overlaying GIS layers of interest onto meta-analysis results

Phase 2



The relationship between climate change sensitivity and the distribution of species, habitats, marine activity sectors and administrative borders

1. Follow the instructions given in Analysis III— Visualising met-analysis results to bring up the plots of interest
2. Press the “GIS layers” button

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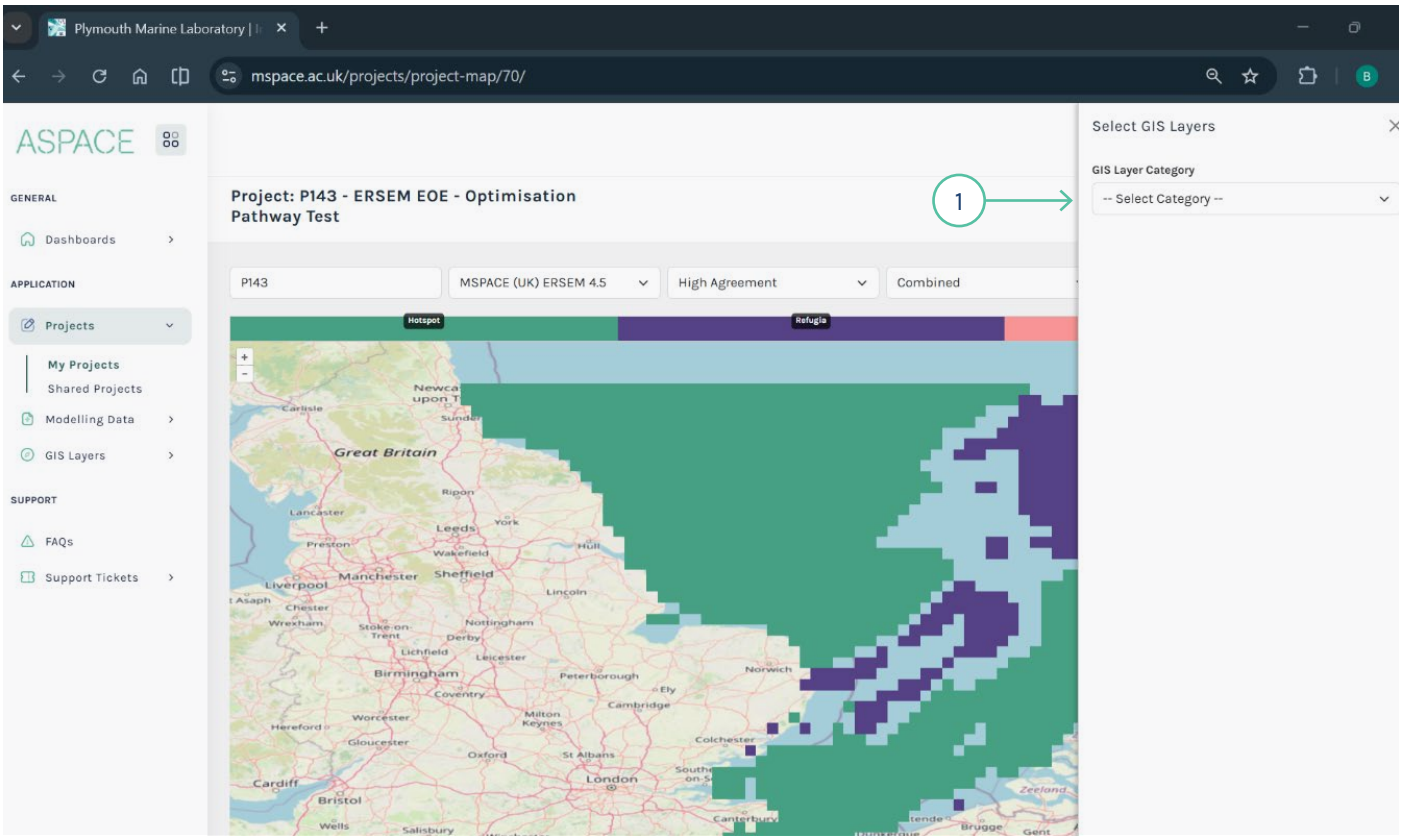
3.23 Analysis IV – Overlaying GIS layers of interest onto meta-analysis results (continued)

Phase 2



1. Select the GIS layer Category for the GIS layer of interest

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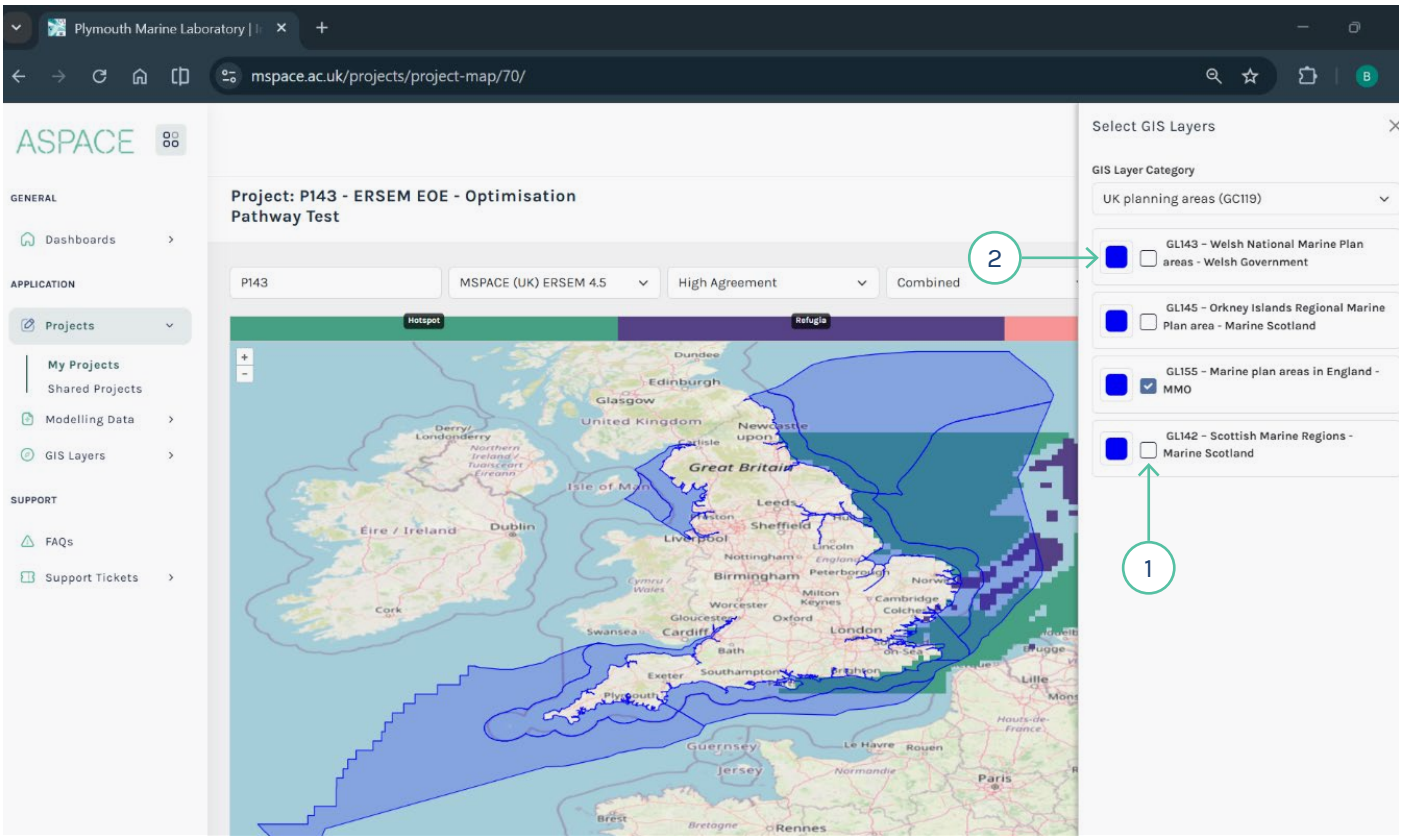
3.23 Analysis IV – Overlaying GIS layers of interest onto meta-analysis results (continued)

Phase 2



1. Check the box for the GIS layer of interest
2. Note that you can change the colour of the GIS layer by pressing on the Blue Square next to the checkbox

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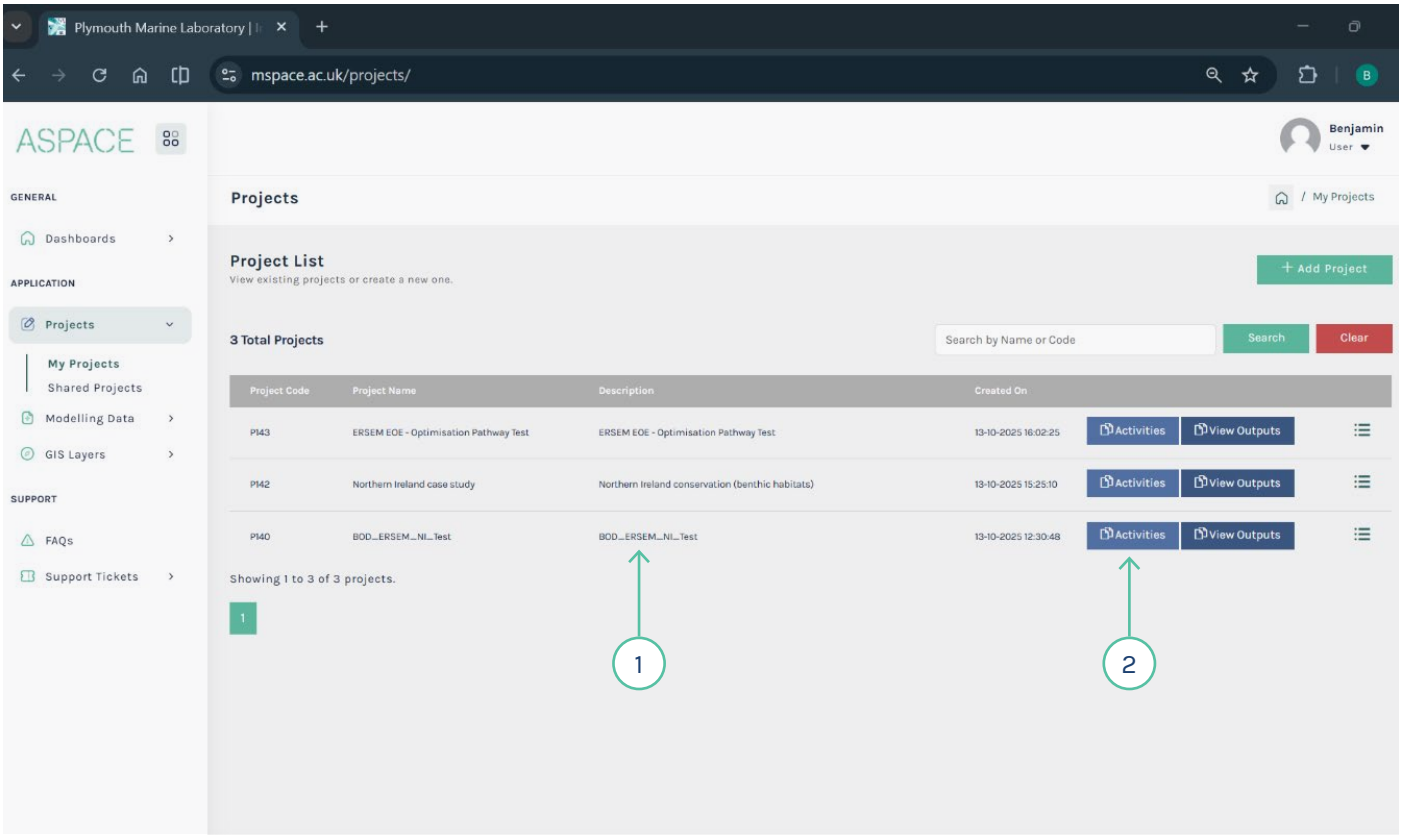
Phase 3

Generating and scoring alternative spatial management scenarios

3.24 Creating ASMS

Phase 3



1. Navigate to the Project where you would like to create an ASMS
2. Press the “Activities” button

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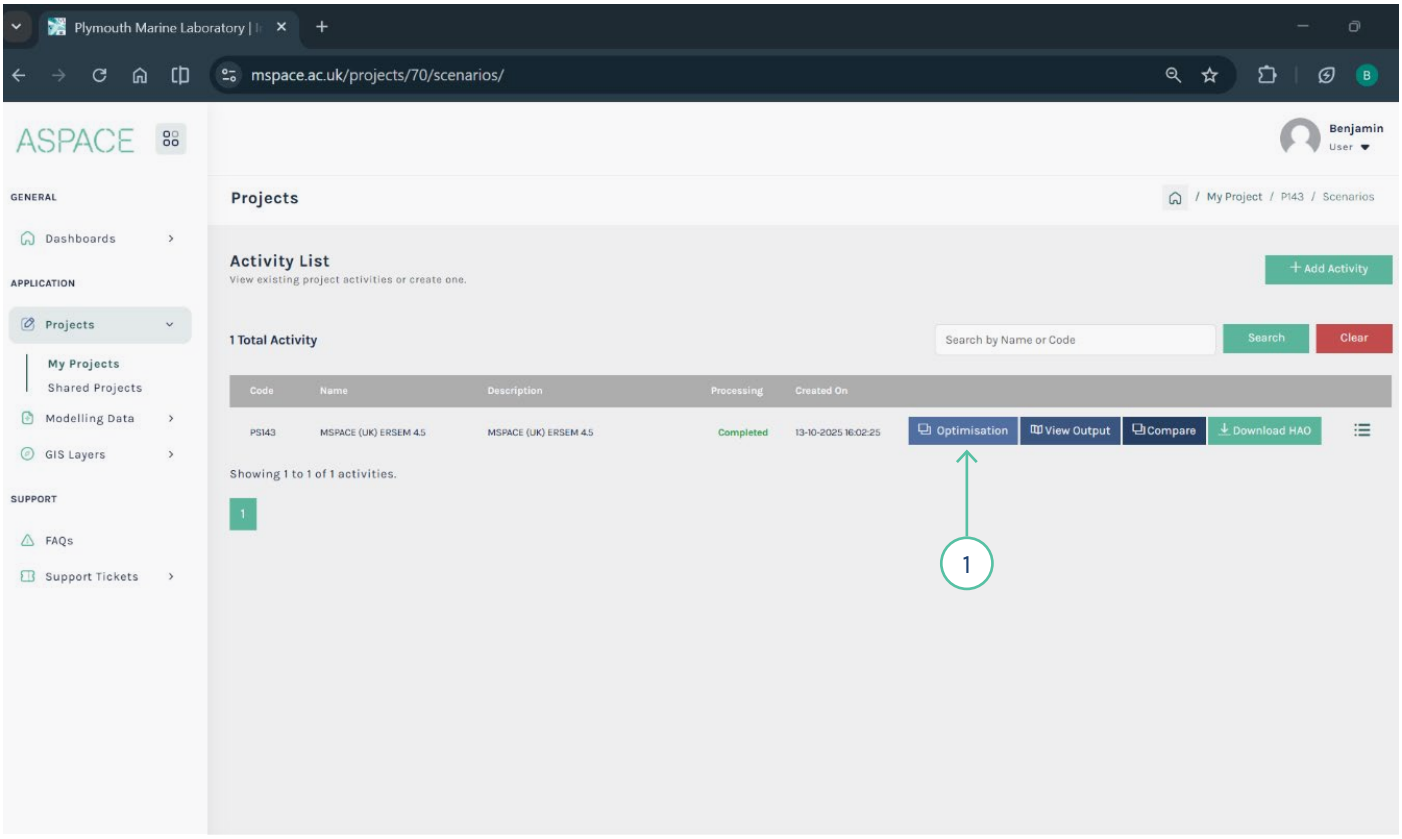
3.24 Creating ASMS (continued)

Phase 3



1. Press the “Optimisation” button on the Project Activity of choice

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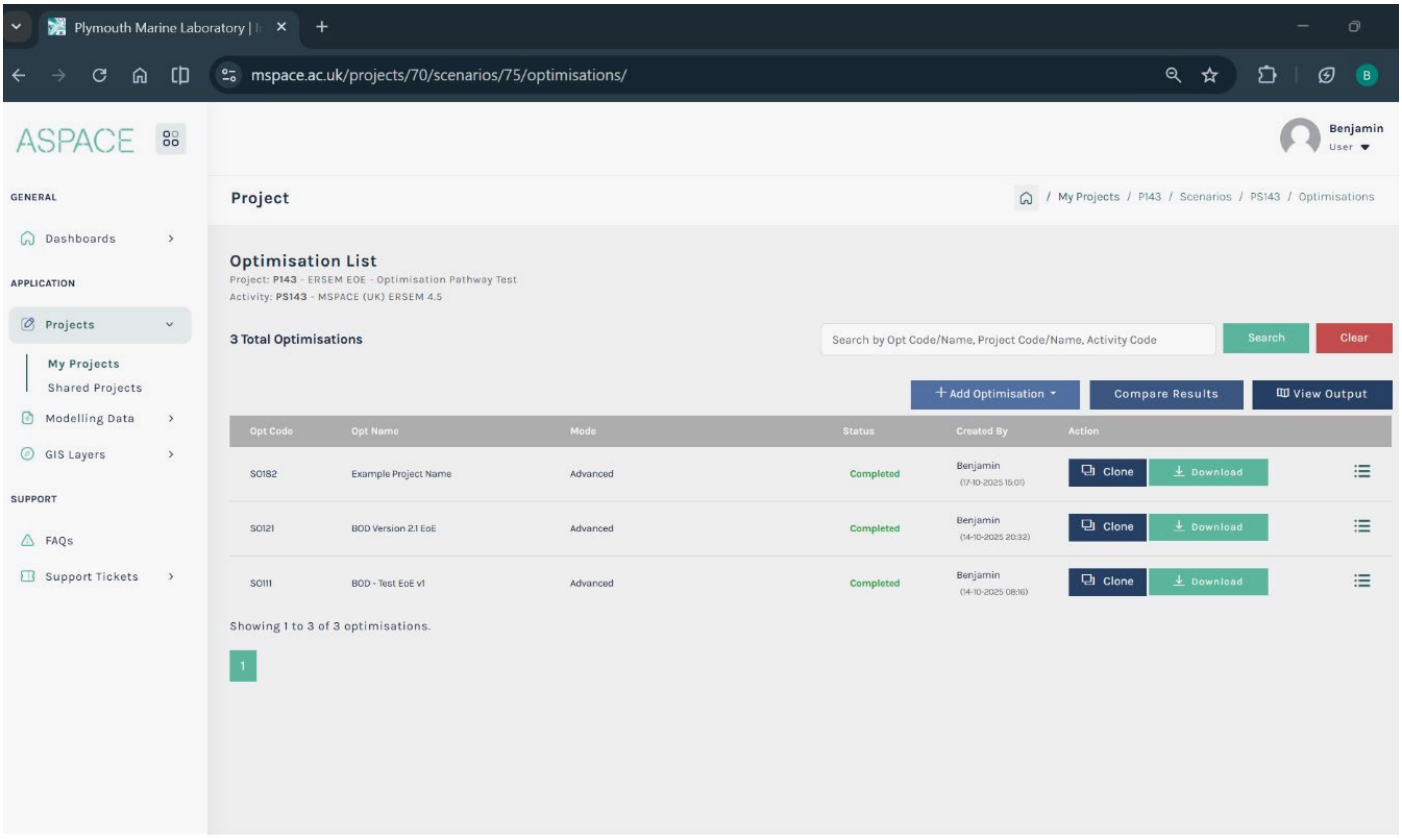
3.24 Creating ASMS (continued)

Phase 3



There are three methods to create ASMS from within the Optimisation List tab.

In order to conduct Economic modelling and Social scoring please follow the additional steps described in Scoring ASMS using climate evidence, economic modelling and alignment with social values

1. Create ASMS via the basic wizard:
   Using the basic mode allows users to apply pre-loaded defaults, for the constraints in their analysis. These defaults have been set by the ASPACE team and are applicable for a set of very specific scenarios. Therefore, the basic mode provides very limited benefit to the user and is suitable for only a few case study sites. This method is not recommended for most use cases.

2. Create ASMS via the advanced wizard:
   Using advanced mode allows users to customise the constraints in their analysis. Users can filter the GIS layers based on the parameters within the data file. This method is recommended for most users

3. Create ASMS via cloning
   Users can clone existing ASMS. Users can then modify the parameters of the ASMS with values that suit their analysis. This facilitates rapid ASMS creation as it allows the user to fine tune parameters quickly.

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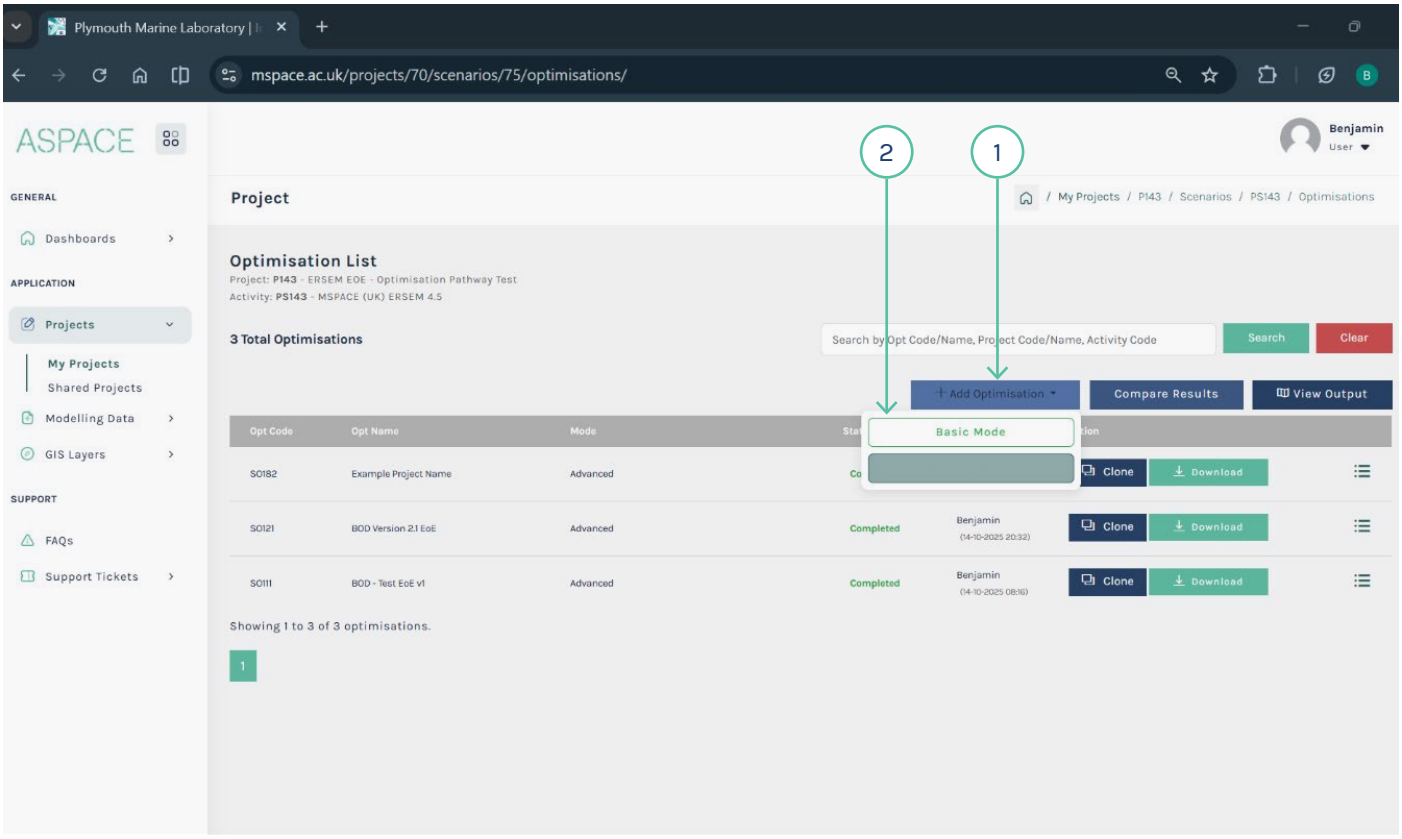
3.25 Create ASMS via the basic wizard

Phase 3



1. Press the “+ Add Optimisation” button
2. Press the “Basic Mode” button

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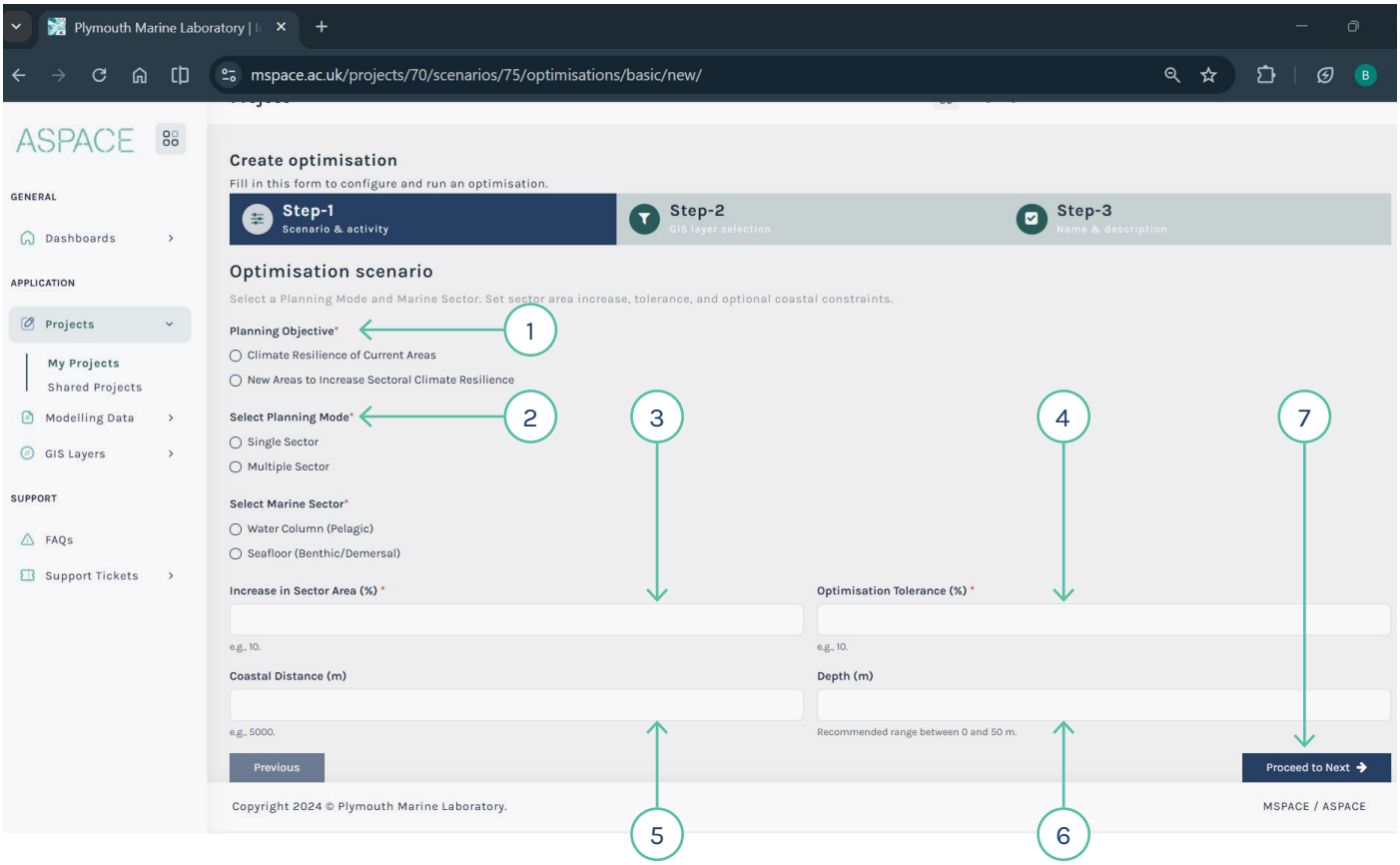
3.25 Create ASMS via the basic wizard

Phase 3

(continued)



Your options on the page will change depending on your selections. The descriptions below cover all possible options:

1. Select the planning objective

A. Climate Resilience of Current Areas

B. New Area to Increase Sectoral Climate Resilience

2. Select planning m,ode:

C. Single Sector:

D. Multi Sector: (Coming soon)

3. Enter Value for “Increase in Sector Area (%)”:
This gives the target percentage increase in provision for your primary sector based available climate resilient areas. This value is calculated after filtering on the GIS layer has been conducted. A 10% increase on a primary sector with 100 km² will attempt to increase the region by 10 km².

4. Enter Value for “Optimisation Tolerance (%)”:
This sets the flexibility in the final ASMS region calculation. A lower optimisation tolerance will require the optimisation pathway to work harder to find region within the upper and lower bounds, this can cause delays in the calculation and can even leave the ASMS generation failing. Relaxing this value gives broader region of values that are acceptable for the region to be. A 10% increase on a primary sector with 100 km², with a 10% optimisation tolerance will attempt to increase the region by 10 km² but will settle on anything between 9 km²< x < 11 km². It is recommended to start with a value of 10%.

5. Enter Value for “Coastal Distance (m)”:
Some sectors require a maximum distance from the coast to be considered for their analysis. Entering a value in this input will constrain the ASMS output to areas that are within this distance from the coastline. Leaving this blank will include all regions regardless of the distance from the coast.

6. Enter Value for “Depth (m)”:
Some sectors require a maximum depth to be considered for their analysis. Entering a value in this input will constrain the ASMS output to areas that are within this depth. Leaving this blank will include all regions regardless of the depth.

7. Press the “Proceed to next” button

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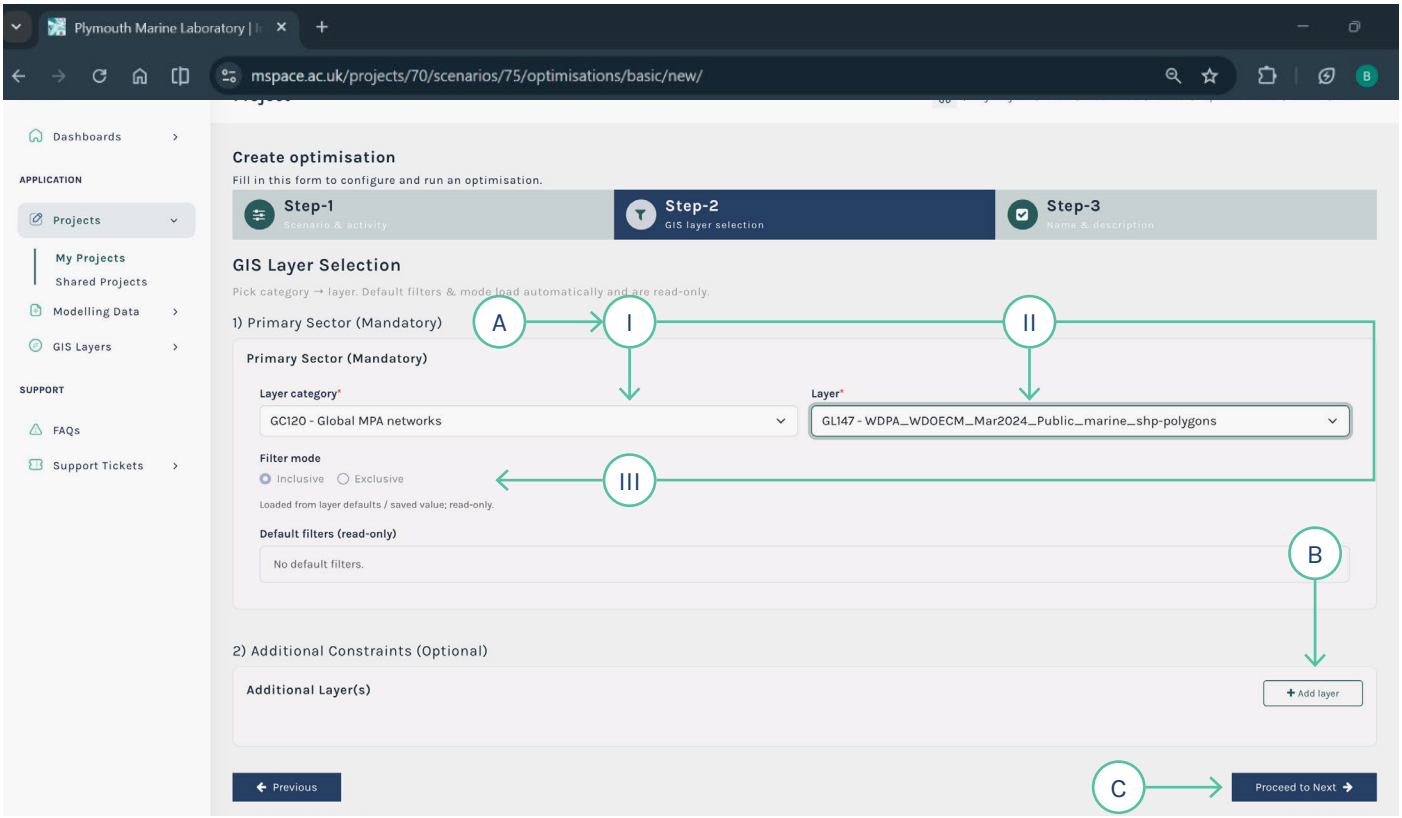
3.25 Create ASMS via the basic wizard

(continued)

Phase 3



The completion of Step 2 depends on which Planning Objective has been selected.

1. **Climate Resilience of Current Areas** - The order in which layers are selected **is not considered** for this ASMS type.

A. **In the "Primary Sector" card:**
   I. Select the "Layer Category" for your GIS layer of choice
   II. Select the GIS layer from the "Layer" dropdown
   III. You will notice that the "Filter Mode" and "Default Filters" are set by defaults, these can not be changed in this mode. If you wish to change these please follow the instructions described in the Create ASMS via the advanced wizard

B. **In the "Additional Constraints" card:**
   I. If you require additional constraints for your analysis, press the "Add layer"
   II. Repeat steps mentioned above for all of the additional constraints required for your analysis.
   III. When you have added all of the appropriate constraints press the "Proceed to Next" button

2. **New Area to Increase Sectoral Climate Resilience** - The order in which layers are selected **is considered** for this ASMS type.

A. **The "Primary Sector" card represents the sector in which you would like to expand provision. In the "Primary Sector" card:**
   I. Select the "Layer Category" for your GIS layer of choice
   II. Select the GIS layer from the "Layer" dropdown
   III. You will notice that the "Filter Mode" and "Default Filters" are set by defaults. These can not be changed in this mode. If you wish to change these please follow the instructions described in the Create ASMS via the advanced wizard

B. **In the "Additional Constraints" card:**
   I. If you require additional constraints for your analysis, press the "Add layer"
   II. Repeat steps mentioned above for all of the additional constraints required for your analysis.

C. **When you have added all of the appropriate constraints press the "Proceed to Next" button**

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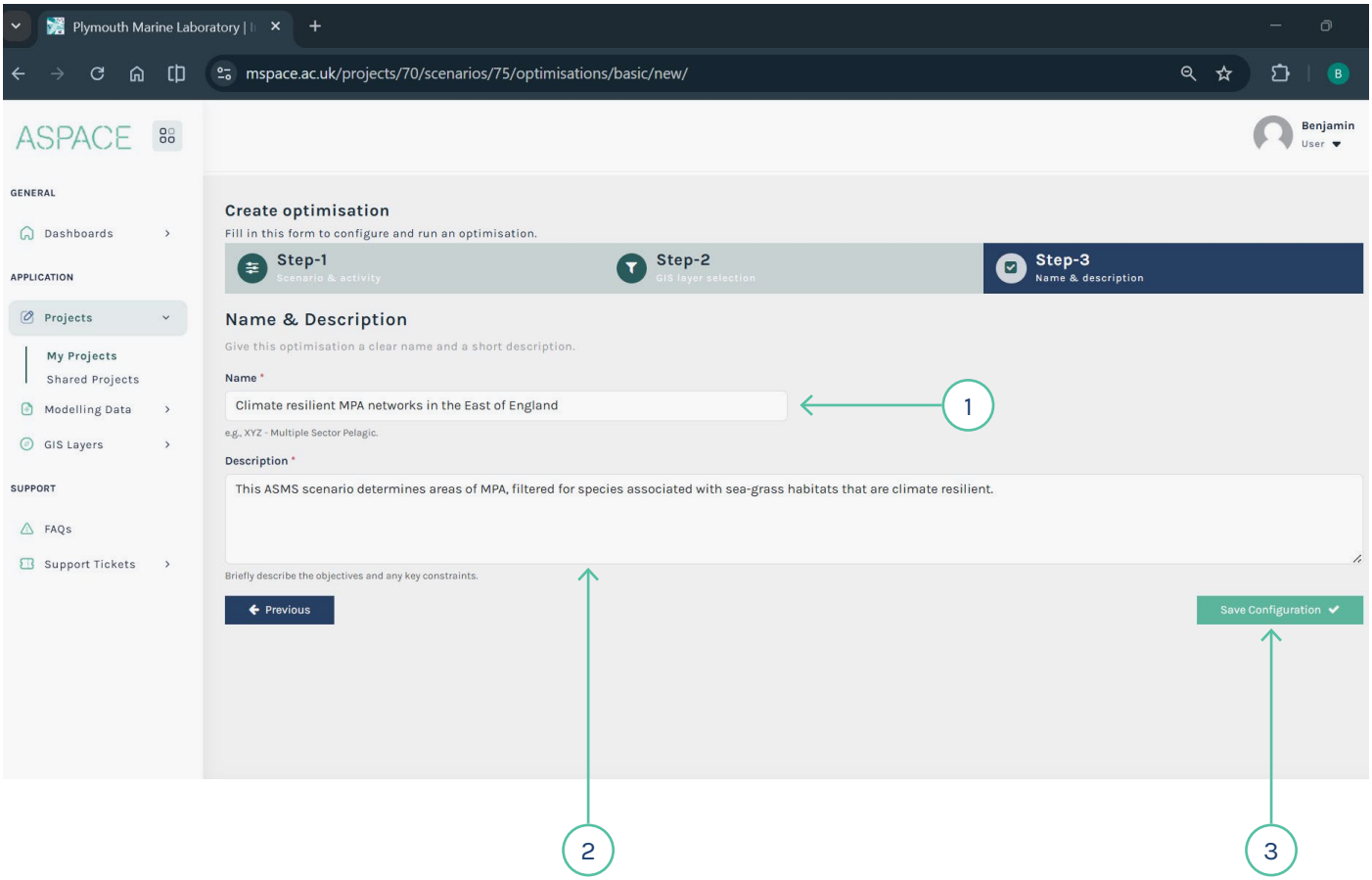
3.25 Create ASMS via the basic wizard

(continued)

Phase 3



1. Complete the “Name” input
2. Complete the “Description” input
3. Press the “Save Configuration” button

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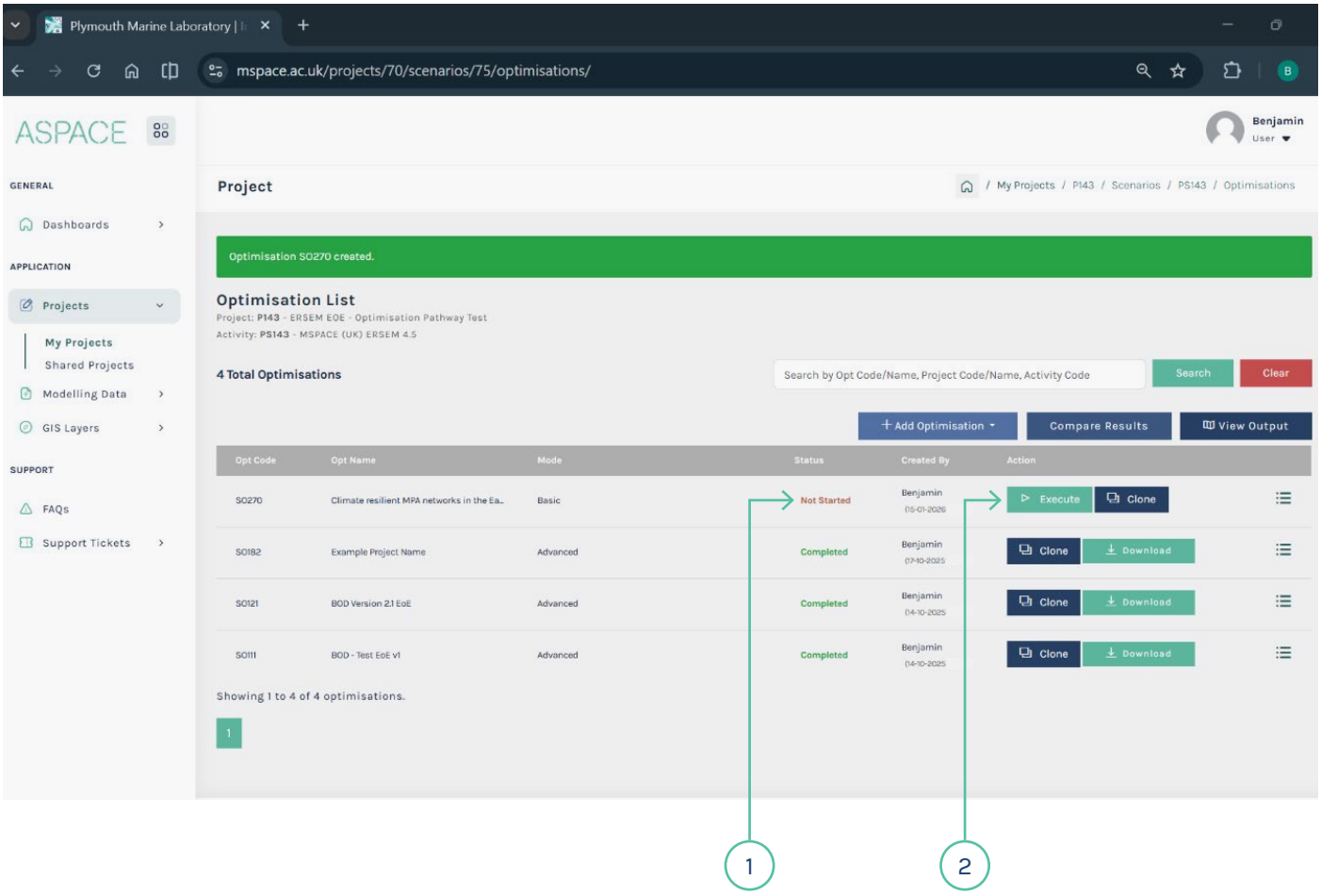
3.25 Create ASMS via the basic wizard

(continued)

Phase 3



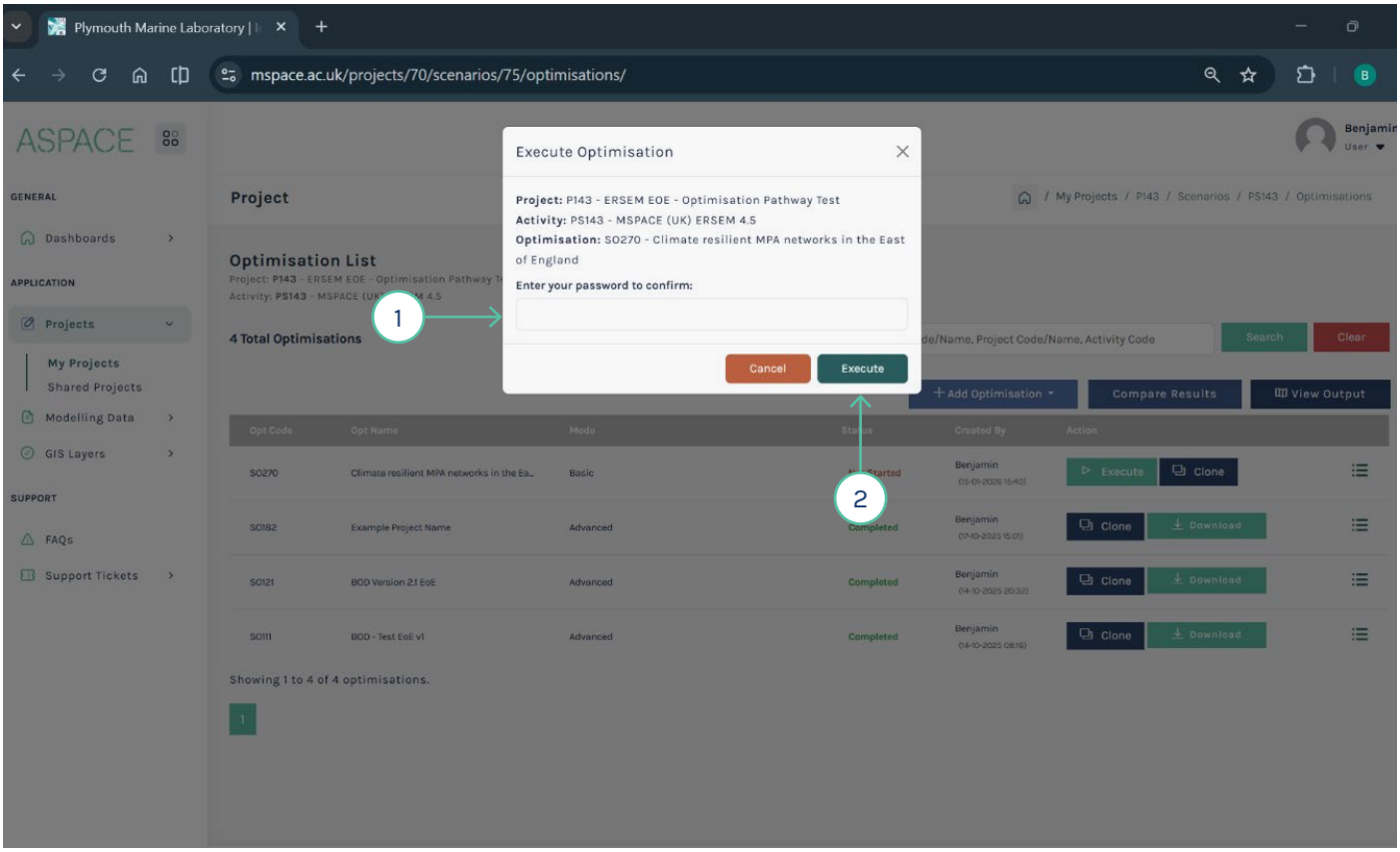
1. Your ASMS will appear at the top of the table with a status of “Not Started”
2. Press the “Execute” button

← Back to quick start contents

3.25 Create ASMS via the basic wizard

(continued)

Phase 3



1. Enter your password
2. Press the “Execute” button

Completing the ASMS generation takes at least 10 minutes. You will receive an email when this is complete. You can close the browser and shut down your computer.

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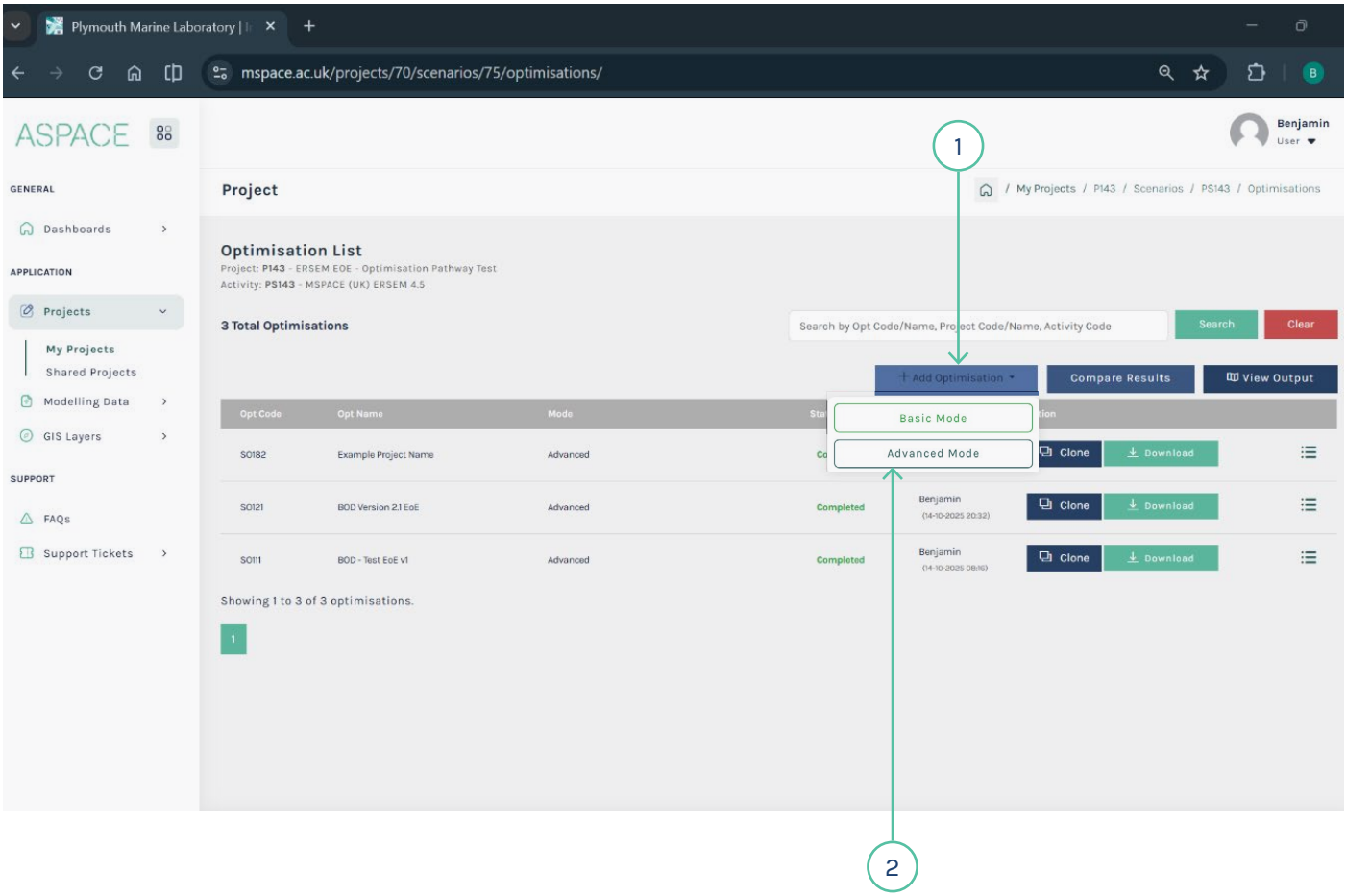
3.26 Create ASMS via the advanced wizard

Phase 3



1. Press the “+ Add Optimisation” button
2. Press the “Advanced Mode” button

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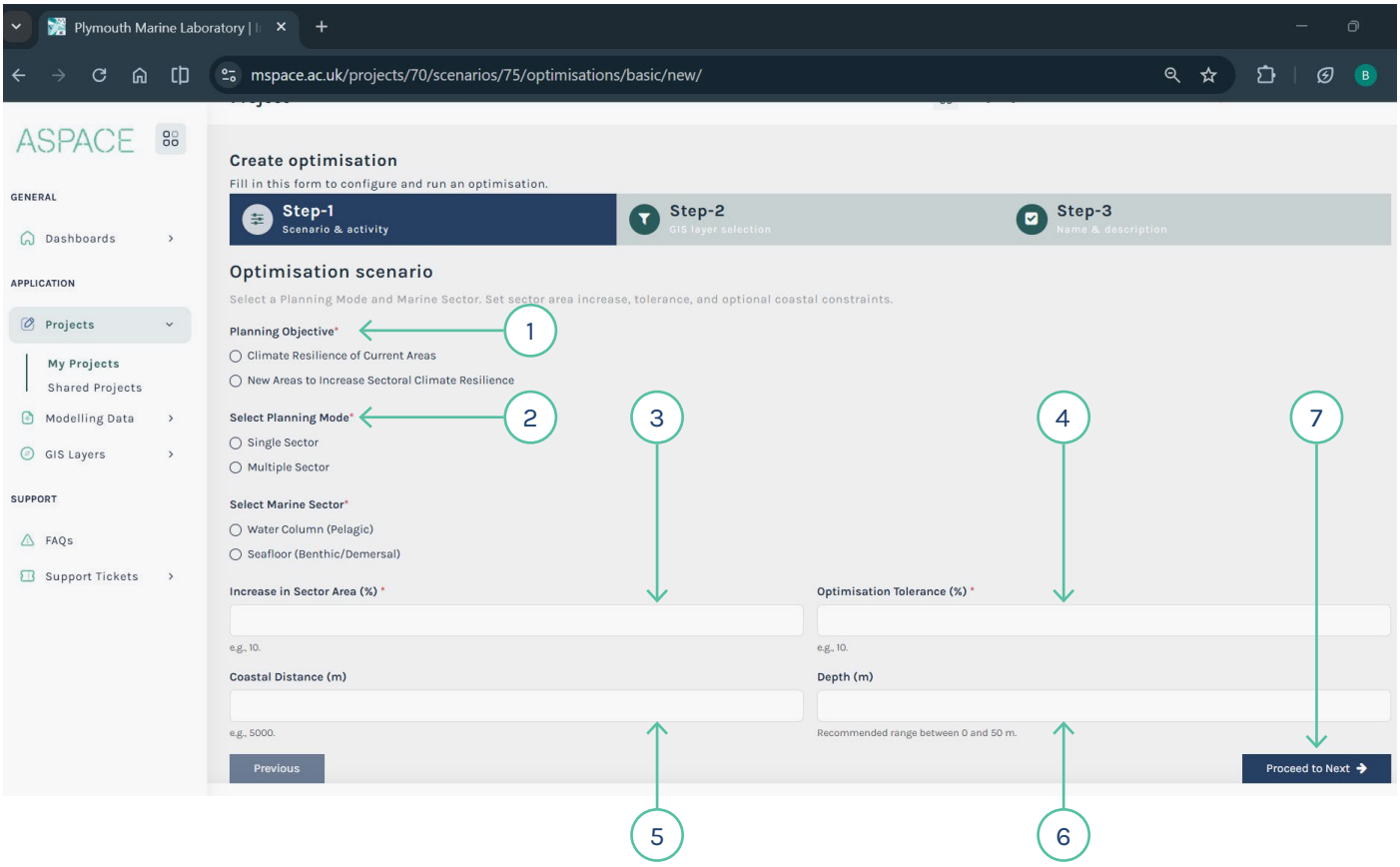
3.26 Create ASMS via the advanced wizard

Phase 3

(continued)



Your options on the page will change depending on your selections. The descriptions below cover all possible options:

1. Select the planning objective

A. Climate Resilience of Current Areas

B. New Area to Increase Sectoral Climate Resilience

2. Select Planning Mode:

C. Single Sector:

D. Multi Sector: (Coming soon)

3. Enter Value for “Increase in Sector Area (%)”:
This gives the target percentage increase in provision for your primary sector based available climate resilient areas. This value is calculated after filtering on the GIS layer has been conducted. A 10% increase on a primary sector with 100 km² will attempt to increase the region by 10 km².

4. Enter Value for “Optimisation Tolerance (%)”:
This sets the flexibility in the final ASMS region calculation. A lower optimisation tolerance will require the optimisation pathway to work harder to find region within the upper and lower bounds, this can cause delays in the calculation and can even leave the ASMS generation failing. Relaxing this value gives broader region of values that are acceptable for the region to be. A 10% increase on a primary sector with 100 km², with a 10% optimisation tolerance will attempt to increase the region by 10 km² but will settle on anything between 9 km²< x < 11 km². It is recommended to start with a value of 10%.

5. Enter Value for “Coastal Distance (m)”:
Some sectors require a maximum distance from the coast to be considered for their analysis. Entering a value in this input will constrain the ASMS output to areas that are within this distance from the coastline. Leaving this blank will include all regions regardless of the distance from the coast.

6. Enter Value for “Depth (m)”:
Some sectors require a maximum depth to be considered for their analysis. Entering a value in this input will constrain the ASMS output to areas that are within this depth. Leaving this blank will include all regions regardless of the depth.

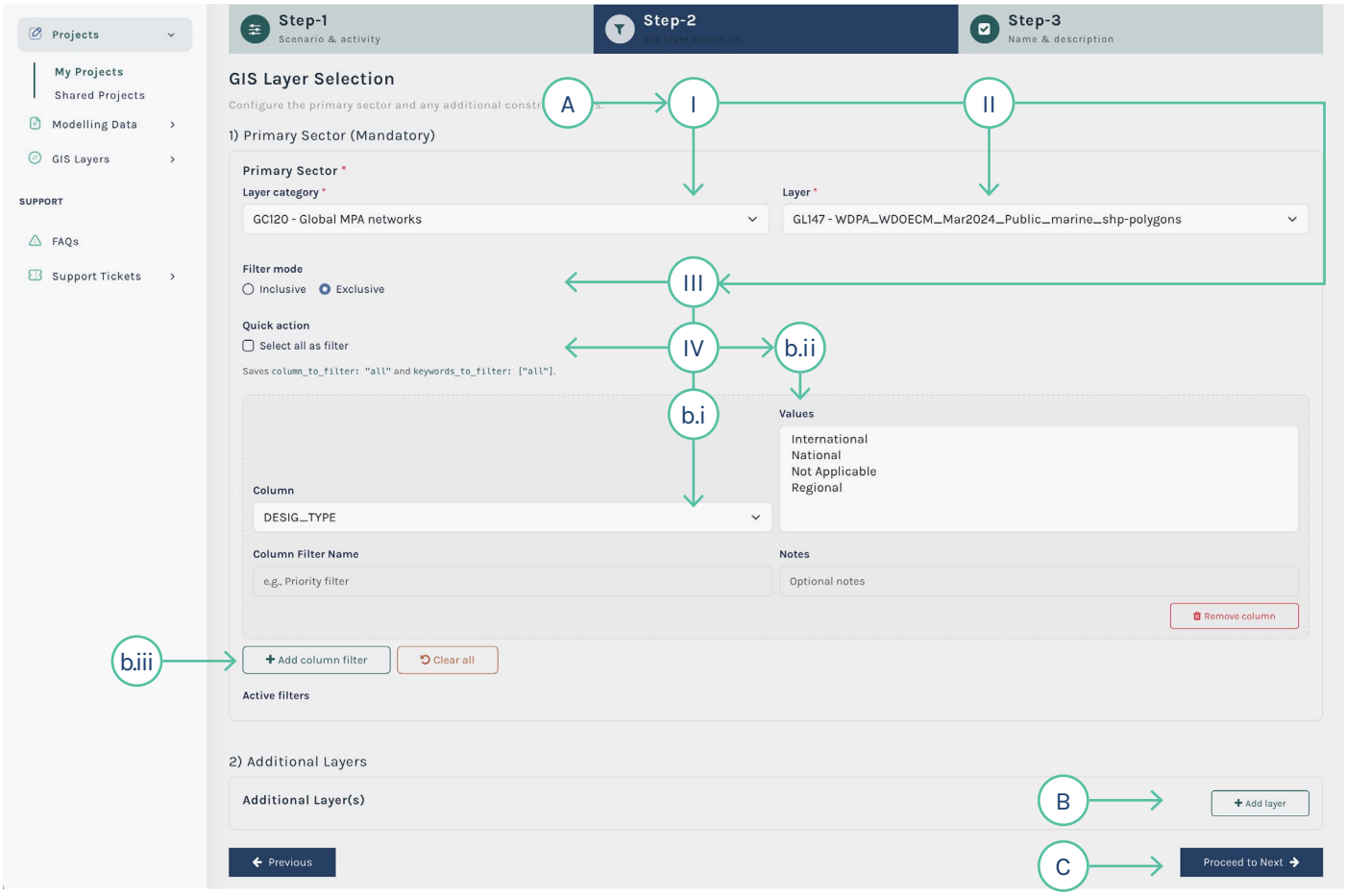
7. Press the “Proceed to next” button

⟵ Back to quick start contents

3.26 Create ASMS via the advanced wizard

(continued)

Phase 3



The completion of Step 2 depends on which Planning Objective has been selected.

1. **Climate Resilience of Current Areas - The order in which layers are selected is not considered for this ASMS type.**

A. **In the "Primary Sector" card:**
   I. Select the "Layer Category" for your GIS layer of choice
   II. Select the GIS layer from the "Layer" dropdown
   III. Select the Filter Mode for your GIS layer:
      a. If a GIS layer is set to "Inclusive" then the ASMS calculation will analyse areas where the layer overlaps with climate resilient areas.
      b. If a GIS layer is set to "Exclusive" then the ASMS calculation will subtract this layer away from any climate resilient areas. This is used when the user is aware of the influence of existing areas which must be catered for in their analysis.
   IV. Filter the GIS layer. The user has the option to subset the GIS layer for their specific analysis:
      a. If the user would like to include all of the regions in their analysis press the "Select all as filter" button
      b. If the user would like to subset the region:
         i. Firstly, select the column to filter on by using the "Column" dropdown.
         ii. Secondly, multi-select the values to filter against from the "Values" input. Note that for larger GIS layers it can take up to one minute for all of the values to appear on the screen.
         iii. If the user requires multiple filters then repeat the above two steps after pressing the "+ Add Column Filter" button

B. **In the "Additional Constraints" card:**
   I. If you require additional constraints for your analysis, press the "Add layer"
   II. Repeat steps mentioned above for all of the additional constraints required for your analysis.

C. **When you have added all of the appropriate constraints press the "Proceed to Next" button**

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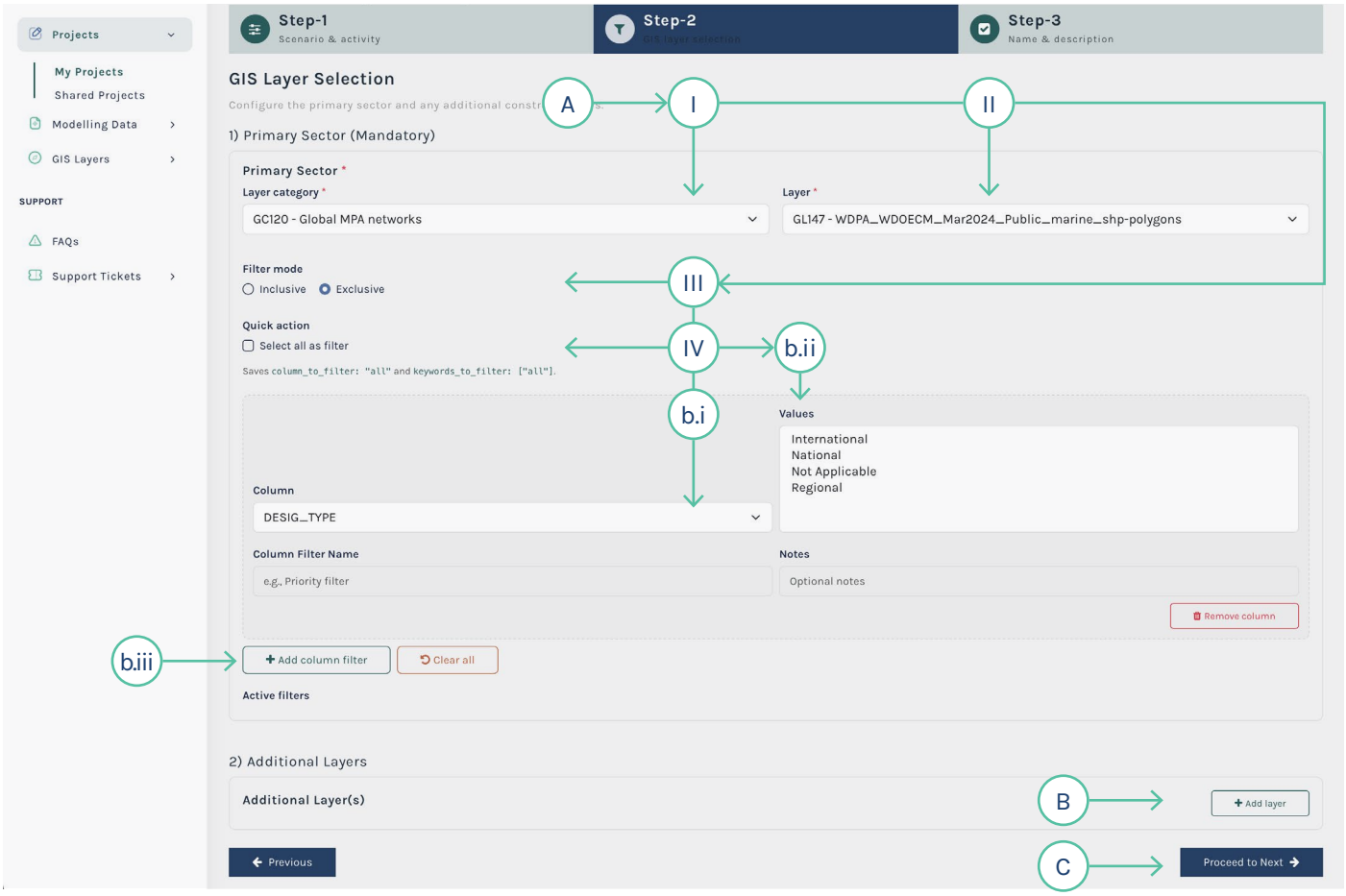
Continued overleaf →

3.26 Create ASMS via the advanced wizard

(continued)

Phase 3



2. **New Area to Increase Sectoral Climate Resilience - The order in which layers are selected is considered for this ASMS type.**

A. **The "Primary Sector" card represents the sector in which you would like to expand provision. In the "Primary Sector" card:**
   I. Select the "Layer Category" for your GIS layer of choice
   II. Select the GIS layer from the "Layer" dropdown
   III. Select the Filter Mode for your GIS layer.
      a. If a GIS layer is set to "Inclusive" then the ASMS calculation will analyse areas where the layer overlaps with climate resilient areas.
      b. If a GIS layer is set to "Exclusive" then the ASMS calculation will subtract this layer away from any climate resilient areas. This is used when the user is aware of the influence of existing areas which must be catered for in their analysis.
   IV. Filter the GIS layer. The user has the option to subset the GIS layer for their specific analysis.
      a. If the user would like to include all of the regions in their analysis press the "Select all as filter" button
      b. If the user would like to subset the region:
         i. Firstly, select the column to filter on by using the "Column" dropdown.
         ii. Secondly, multi-select the values to filter against from the "Values" input. Note that for larger GIS layers it can take up to one minute for all of the values to appear on the screen.
         iii. If the user requires multiple filters then repeat the above two steps after pressing the "+ Add Column Filter" button

B. **In the "Additional Constraints" card:**
   I. If you require additional constraints for your analysis, press the "Add layer"
   II. Repeat steps mentioned in above for all of the additional constraints required for your analysis.

C. **When you have added all of the appropriate constraints press the "Proceed to Next" button**

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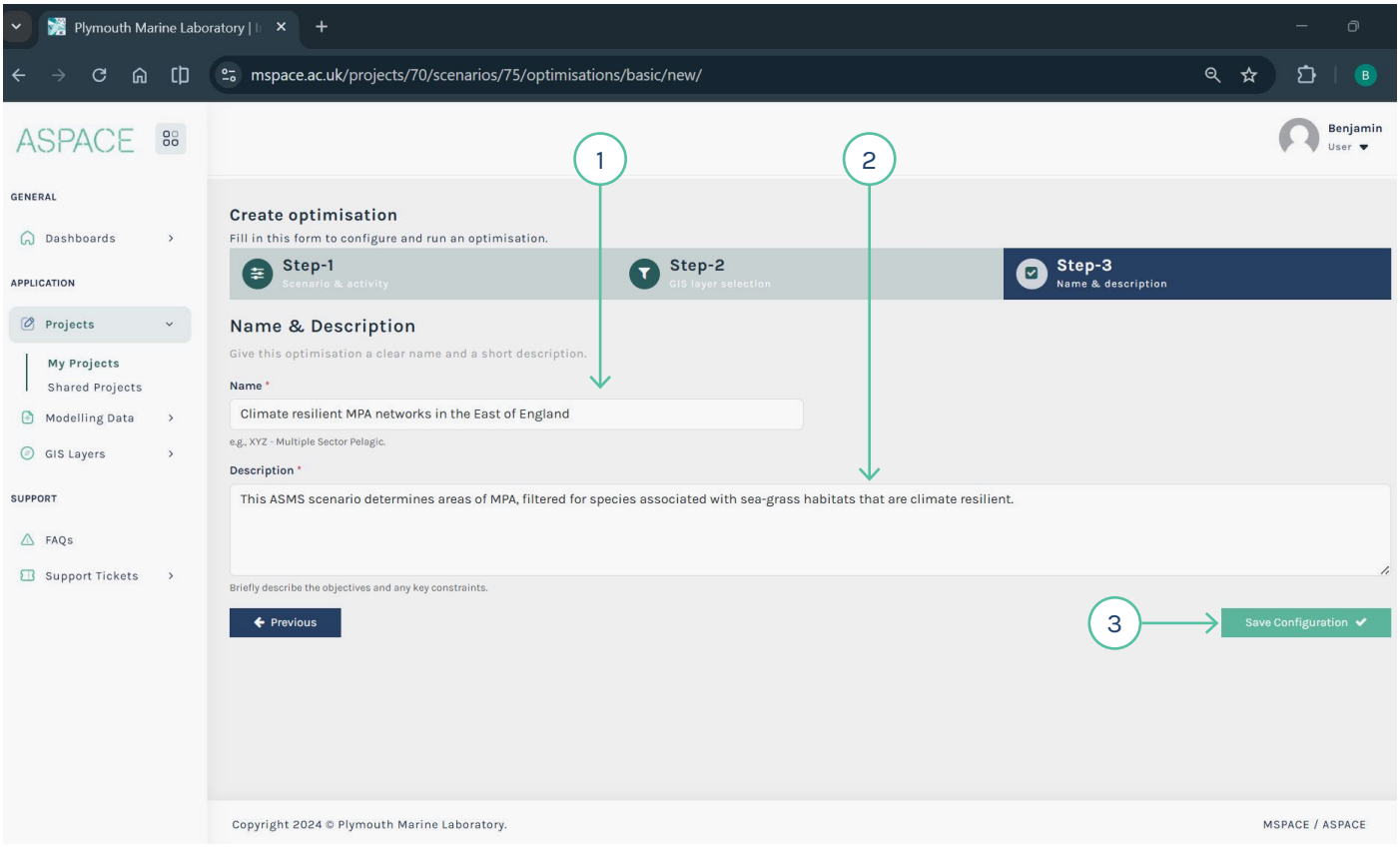
3.26 Create ASMS via the advanced wizard

Phase 3

(continued)



1. Complete the “Name” input
2. Complete the “Description” input
3. Press the “Save Configuration” button

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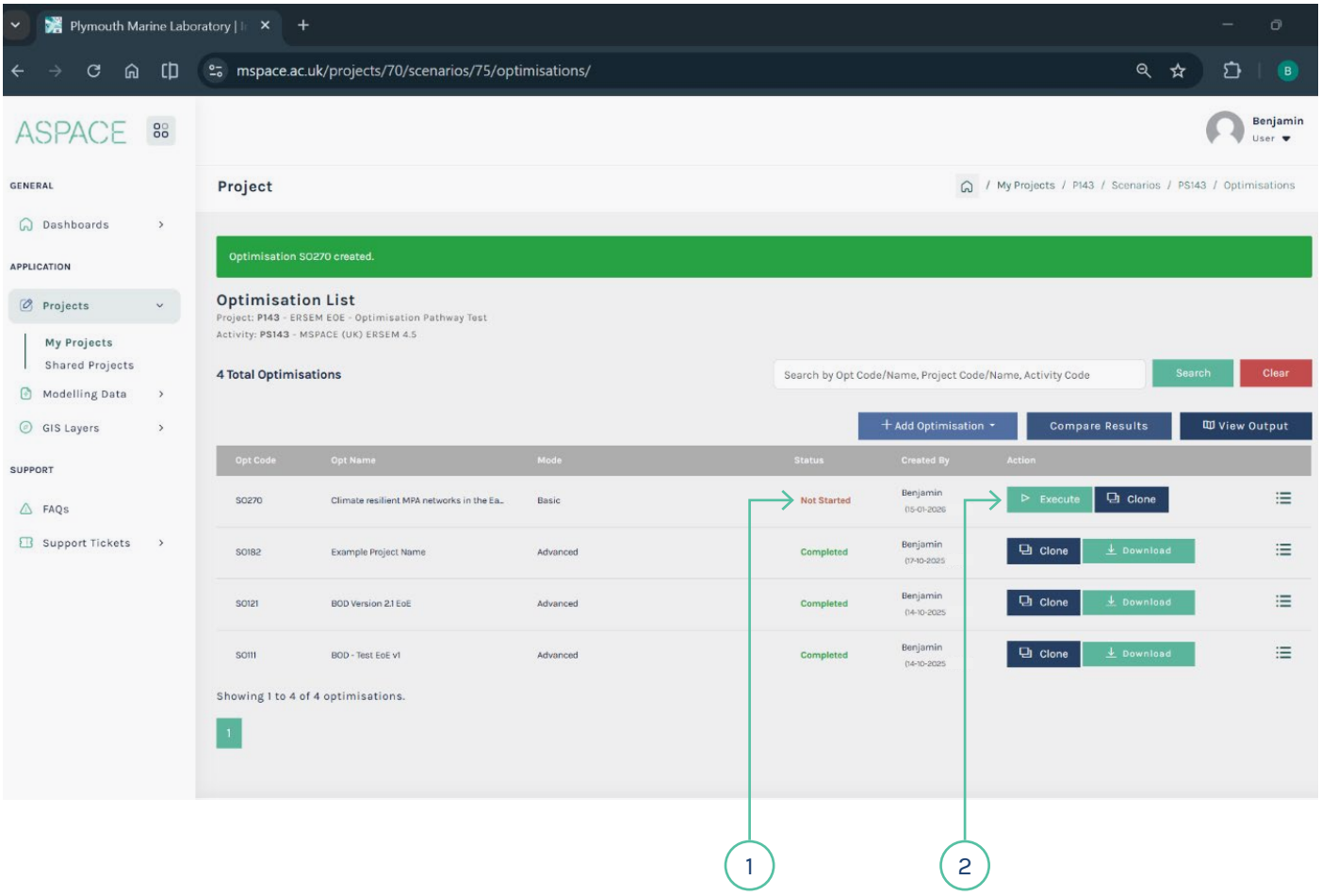
3.26 Create ASMS via the advanced wizard

Phase 3

(continued)



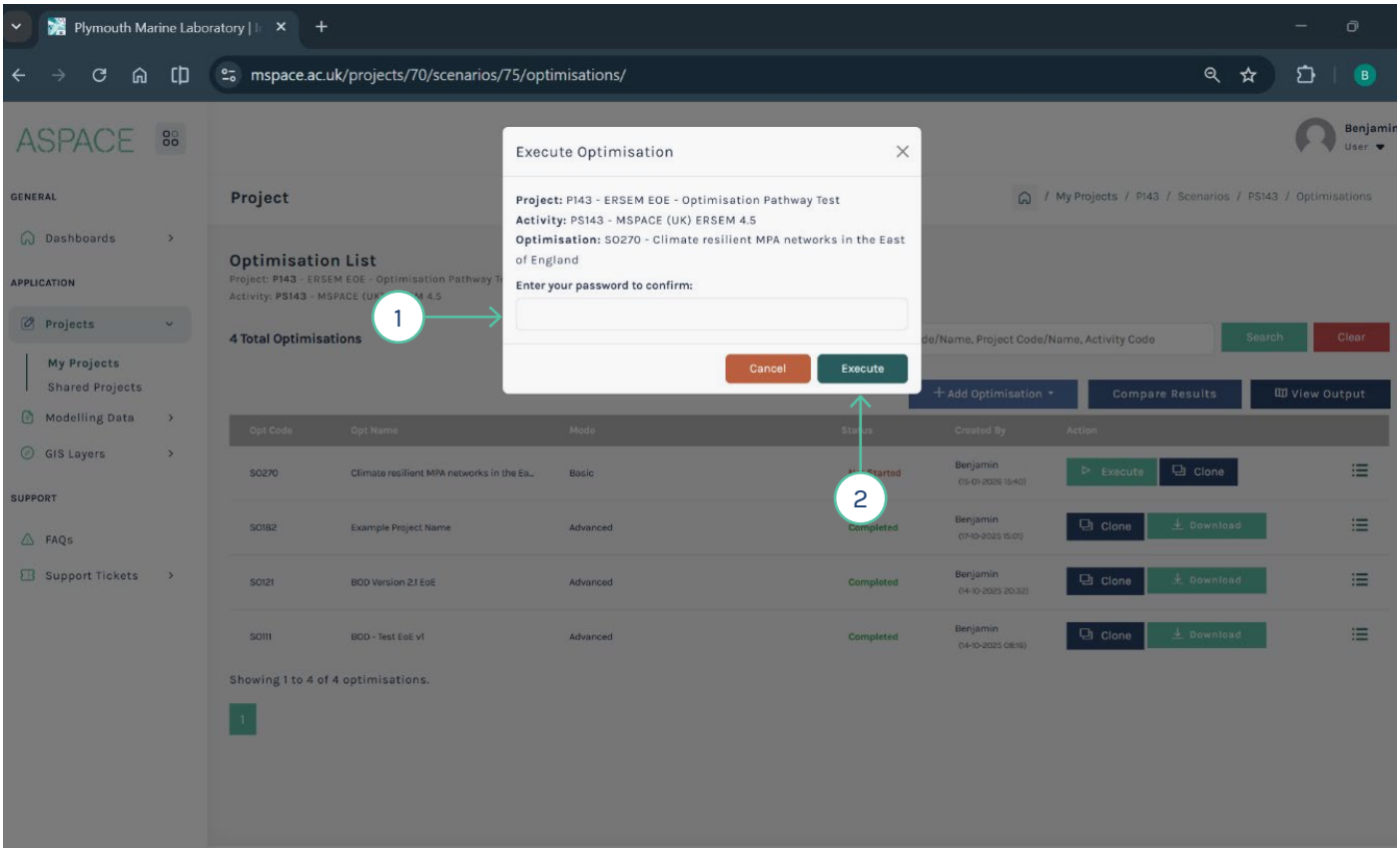
1. Your ASMS will appear at the top of the table with a status of “Not Started”
2. Press the “Execute” button

⟵ Back to quick start contents

3.26 Create ASMS via the advanced wizard

(continued)

Phase 3



1. Enter your password
2. Press the “Execute” button

Completing the ASMS generation takes at least 10 minutes. You will receive an email when this is complete. You can close the browser and shut down your computer.

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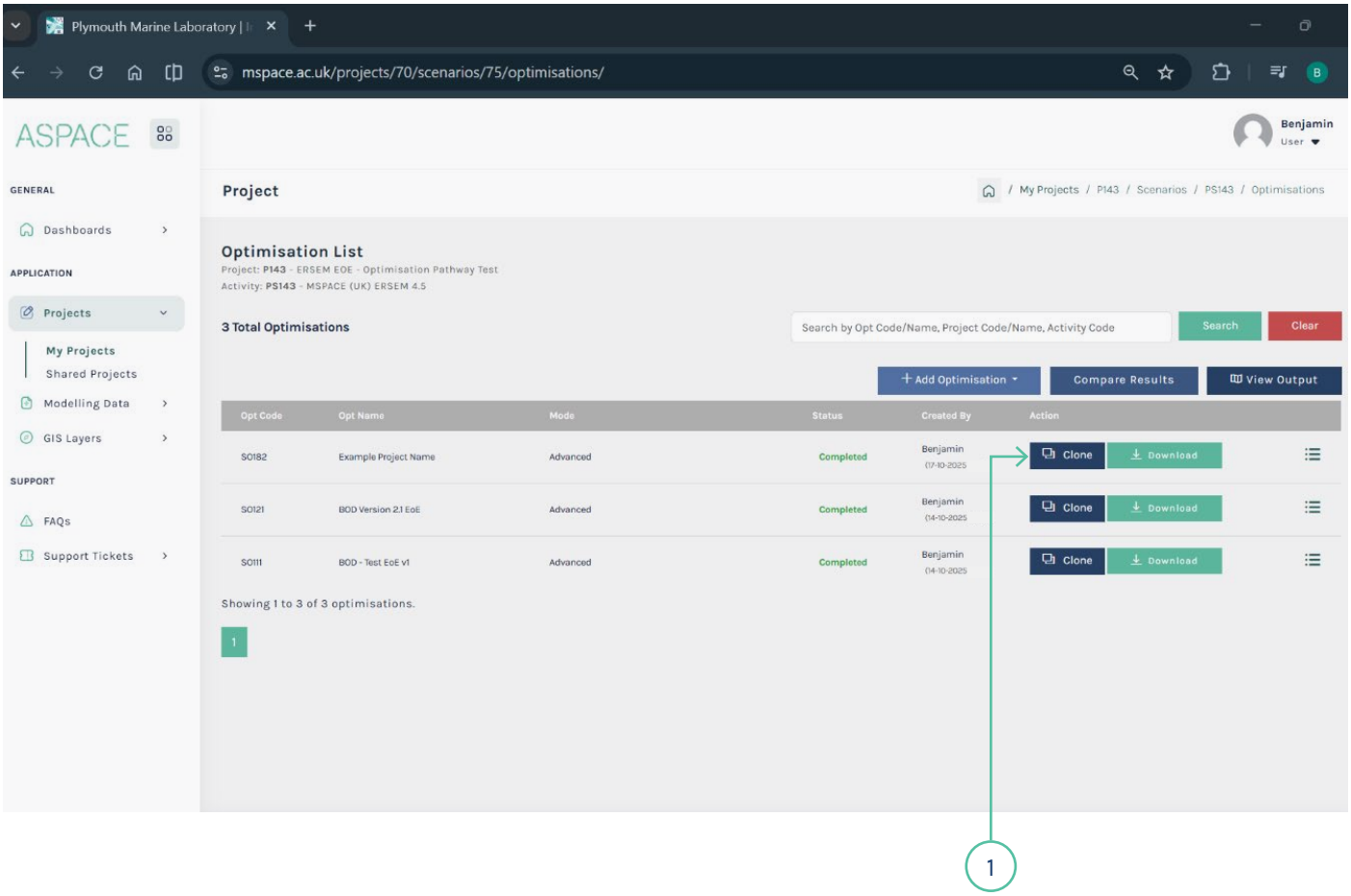
3.27 Create ASMS via cloning

Phase 3



1. Press the “Clone” button on the ASMS of choice

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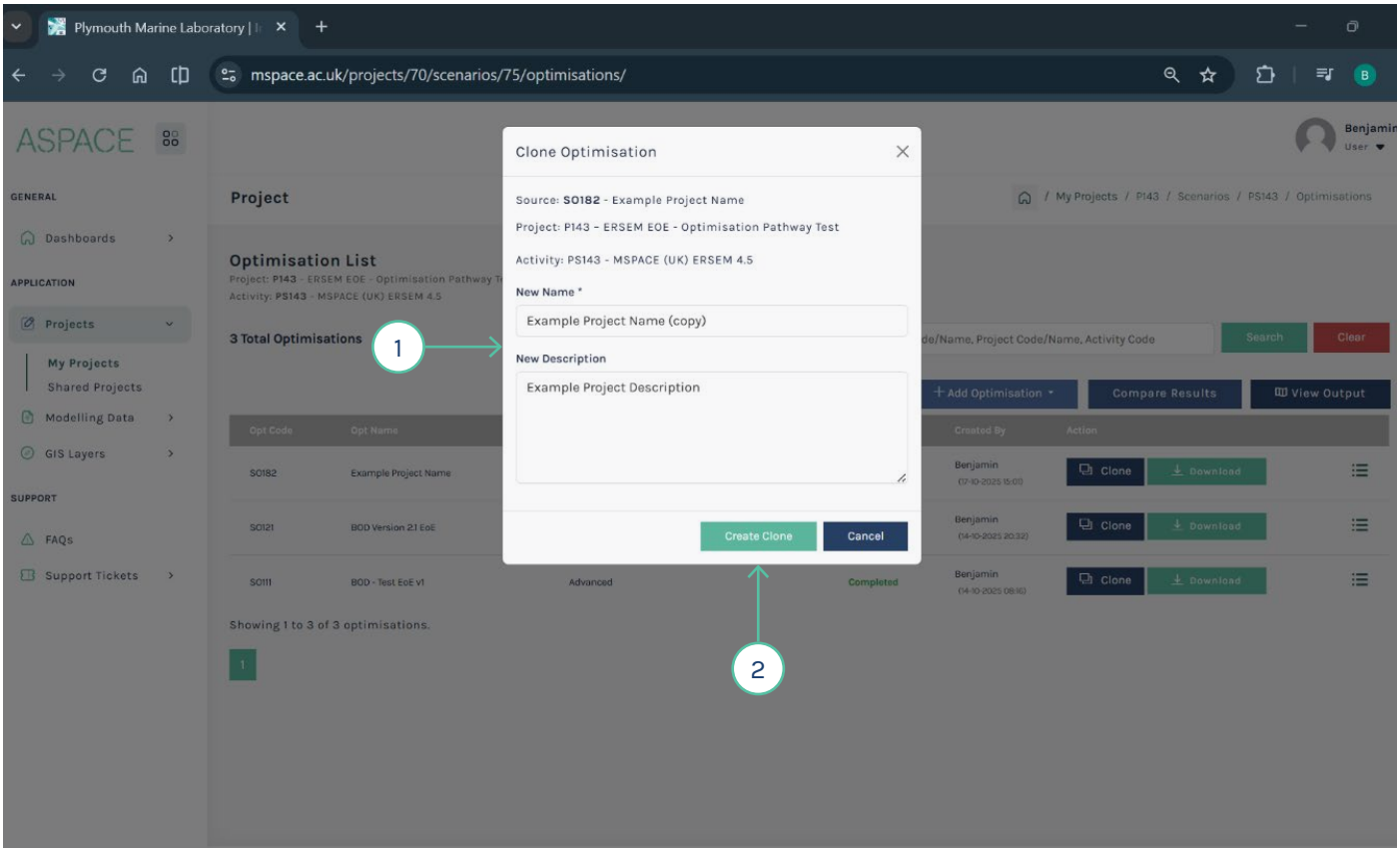
3.27 Create ASMS via cloning (continued)

Phase 3



1. Cloning a project will launch a dialogue box with a default “Name” and “Description” added. Change the contents of these entries.
2. Press the “Create Clone” button.

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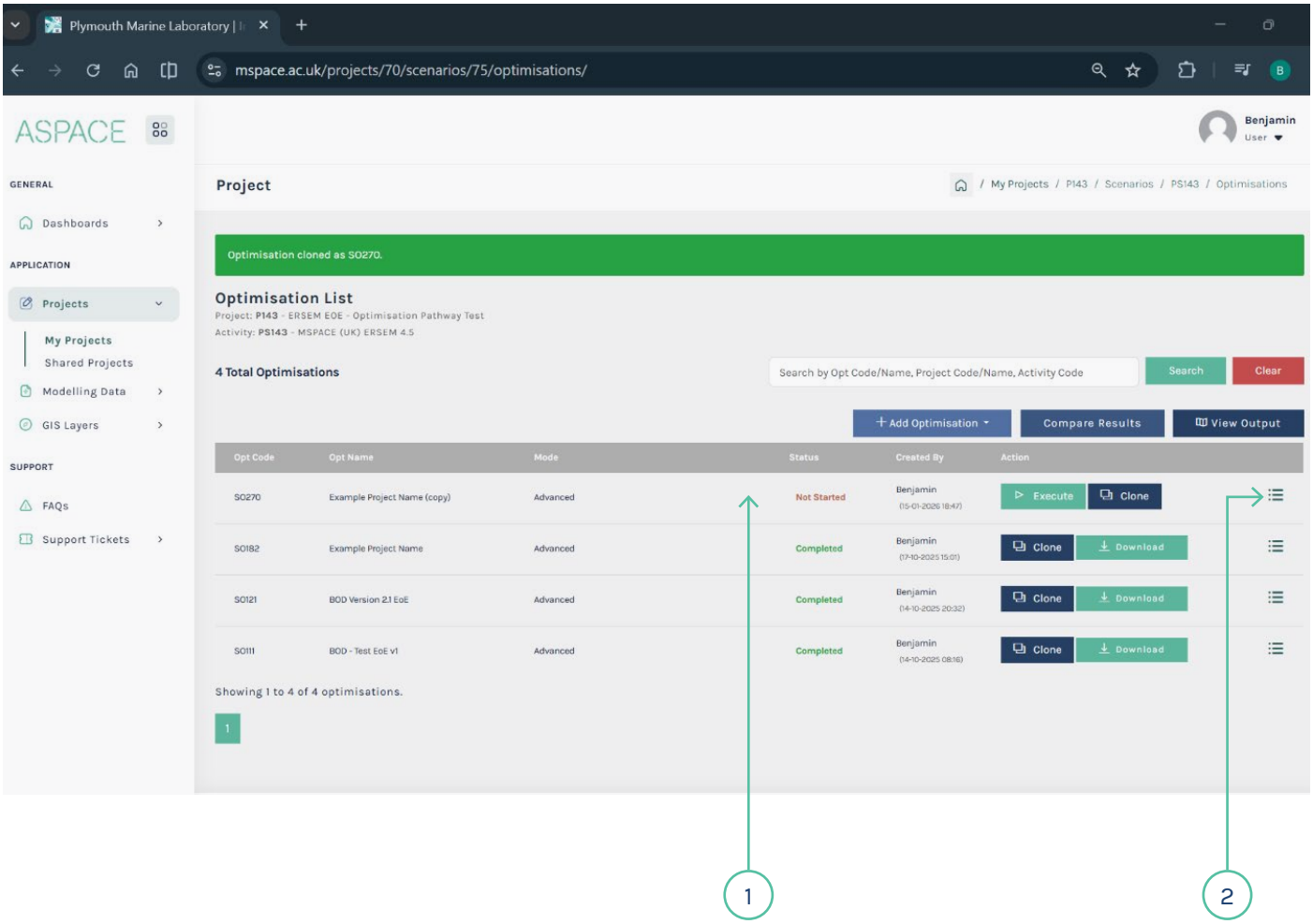
3.27 Create ASMS via cloning (continued)

Phase 3



1. The cloned ASMS will appear in the top row of the table
2. To change the ASMS configuration, press the Burger Menu icon
3. Then press the “Edit” icon
4. Edit the contents of ASMS configuration by following the instructions for Basic and Advanced modes respectively

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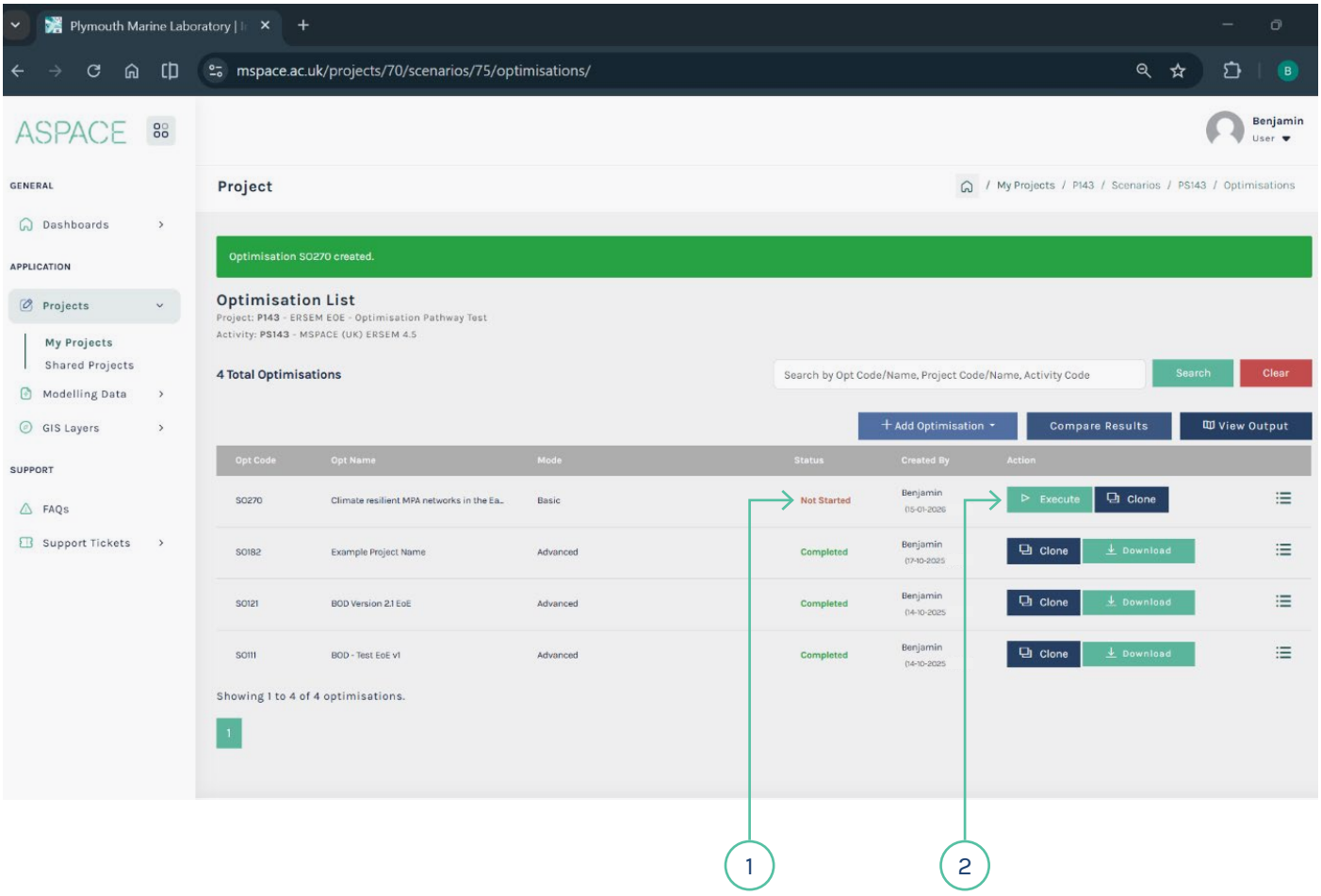
3.27 Create ASMS via cloning (continued)

Phase 3



1. Your ASMS will appear at the top of the table with a status of “Not Started”
2. Press the “Execute” button

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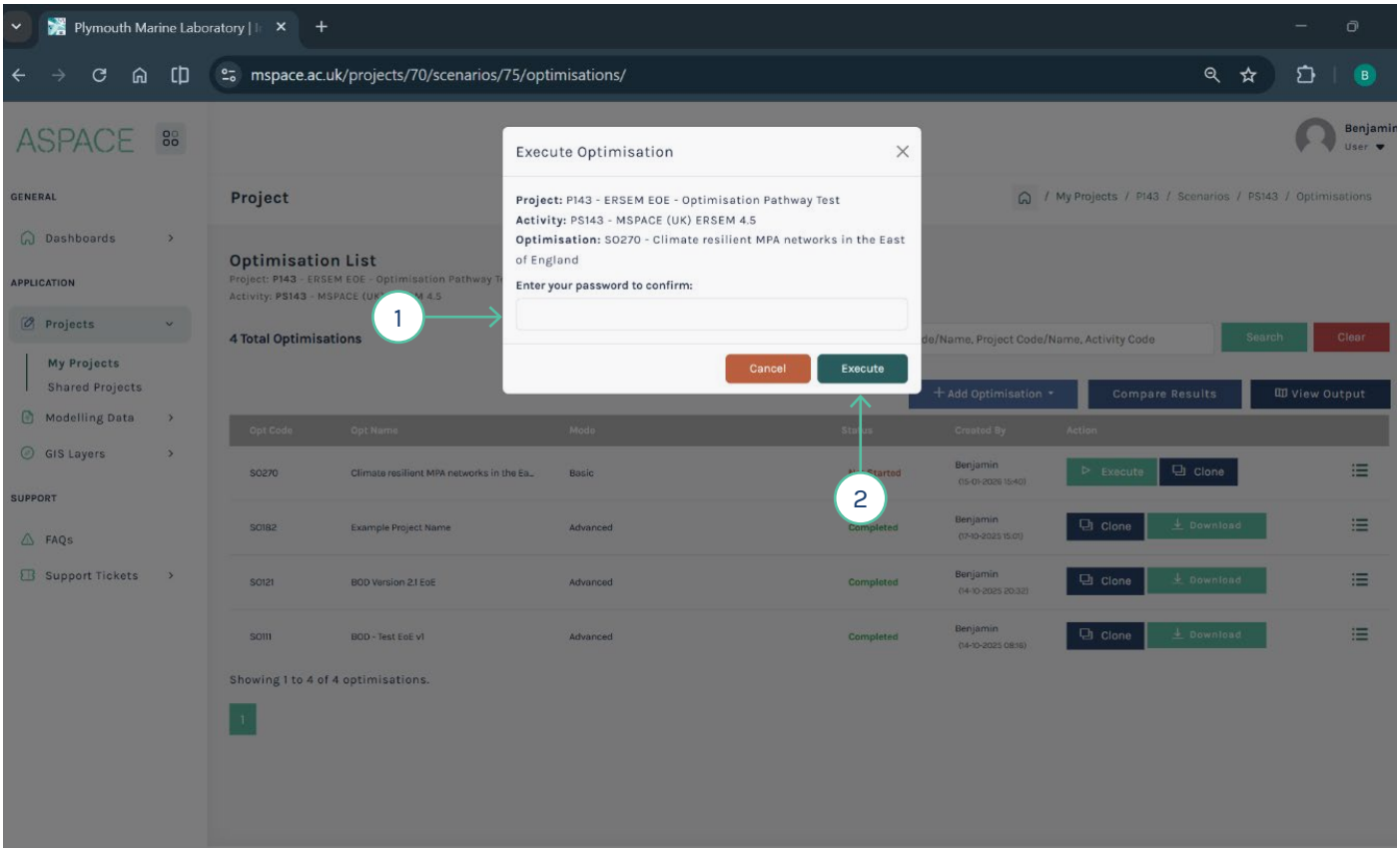
3.27 Create ASMS via cloning (continued)

Phase 3



1. Enter your password
2. Press the “Execute” button

Completing the ASMS generation takes at least 10 minutes. You will receive an email when this is complete. You can close the browser and shut down your computer.

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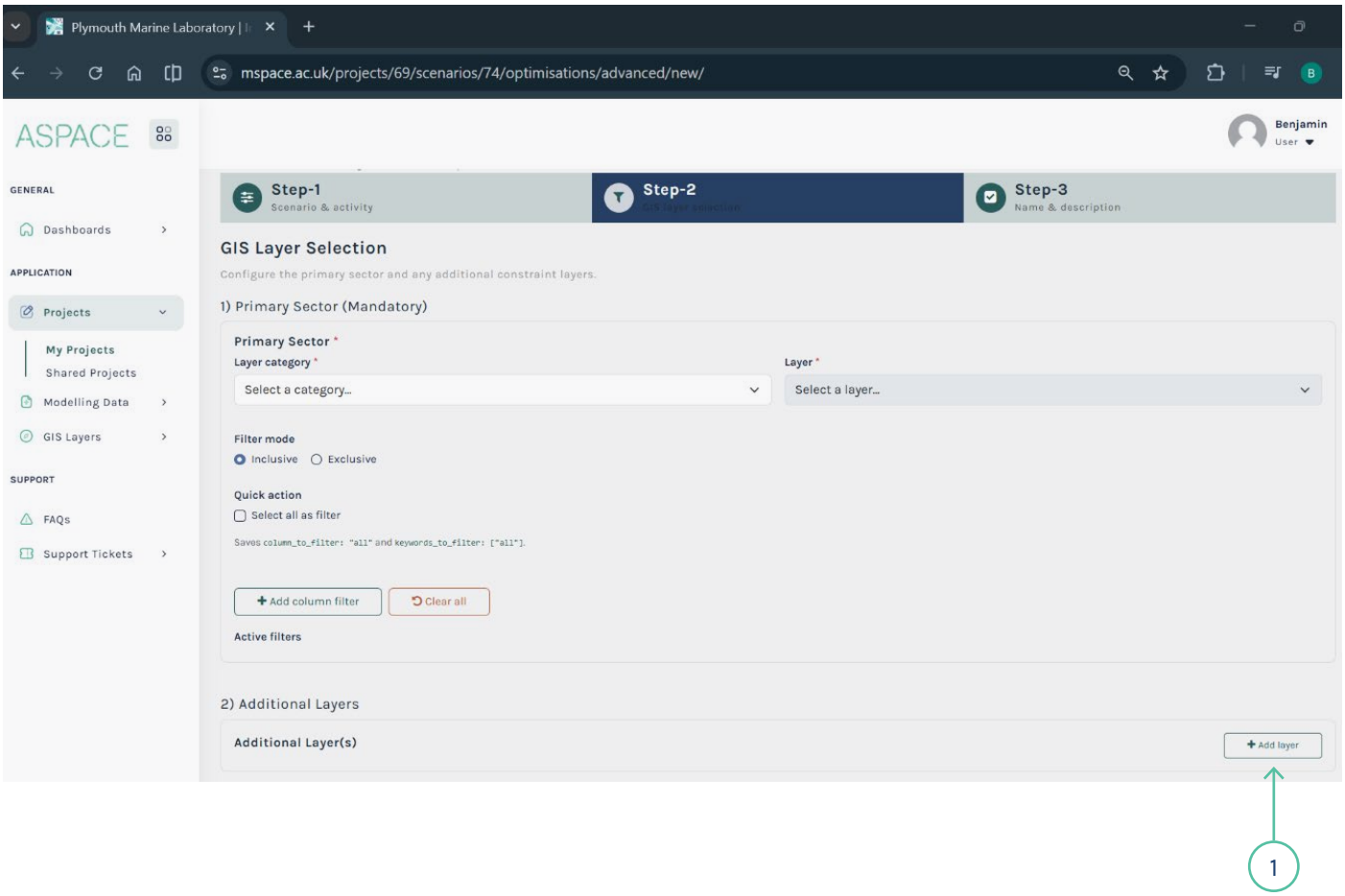
3.28 Scoring ASMS using climate evidence, economic modelling and alignment with social values

Phase 3



The ASPACE platform can estimate economic modelling and social values scoring of ASMS to enhance the decision support capabilities to the user(please see section 4). These features are only currently available for UK regions , with other areas currently in development for future releases. At present, these features are specifically available at the UK level, and also at nation and regional level as follows:

- United Kingdom Exclusive Economic Zone (EEZ)
- Orkney Islands Marine Plan (Scotland)
- East of Marine Plan (England)
- Welsh National Marine Plan
- Marine Plan for Northern Ireland

In order for the ASPACE to provide these estimates for individual ASMS (created using Optimisation option 2), the user must select one of the appropriate GIS layer when conducting ASMS generation, which enables the ASPACE tool to select the correct economic model and social values matrix for the region of interest, according to those listed above.

1. In the ASMS creation wizard, add an additional layer by pressing the “+ Add layer” button within the “Additional Layers” card.

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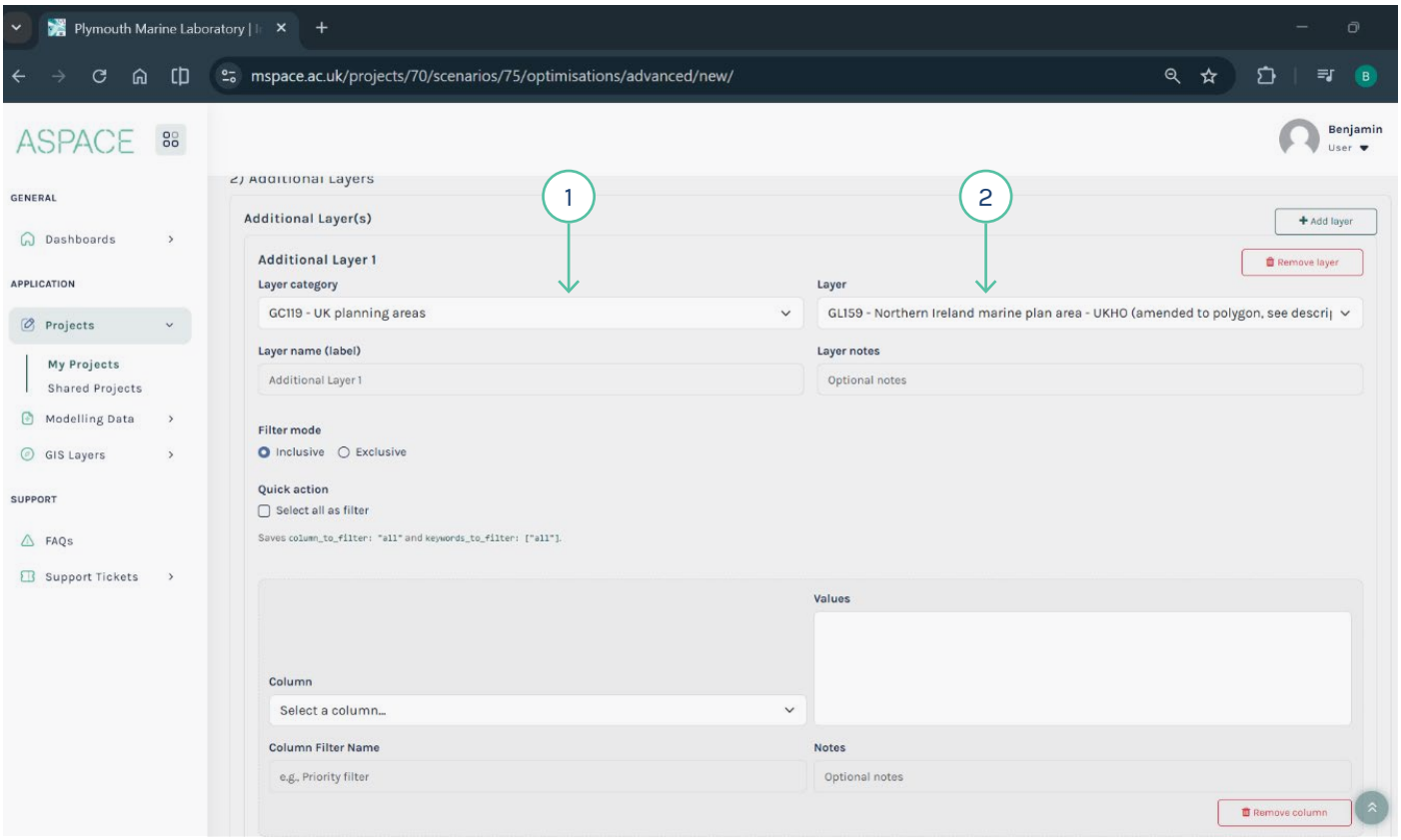
3.28 Scoring ASMS using climate evidence, economic modelling and alignment with social values (continued)

Phase 3



Case Study Site	Layer Category Code	Layer Category Description	Layer Code	Layer Description
Orkney Islands	GC119	UK planning areas	GL145	Orkney Islands Regional Marine plan
Wales	GC119	UK planning areas	GL143	Welsh National Marine plan areas
East of England	GC119	UK planning areas	GL155	Marine plan areas in England
Northern Ireland	GC119	UK planning areas	GL159	Northern Ireland marine plan area
United Kingdom EEZ	GC122	Maritime limits and boundaries	GL156	United Kingdom EEZ

1. Select the “Layer category” and “Layer” shown in the table above. This selects the economic model and social values matrix for the region of interest for the user defined when they created their current Project.
2. In the screenshot above the user has selected the “Layer Category” and “Layer” associated with the Northern Ireland marine plan area.
3. The user is still able to subset this GIS layer in the same way as mentioned in the ASMS advanced wizard.

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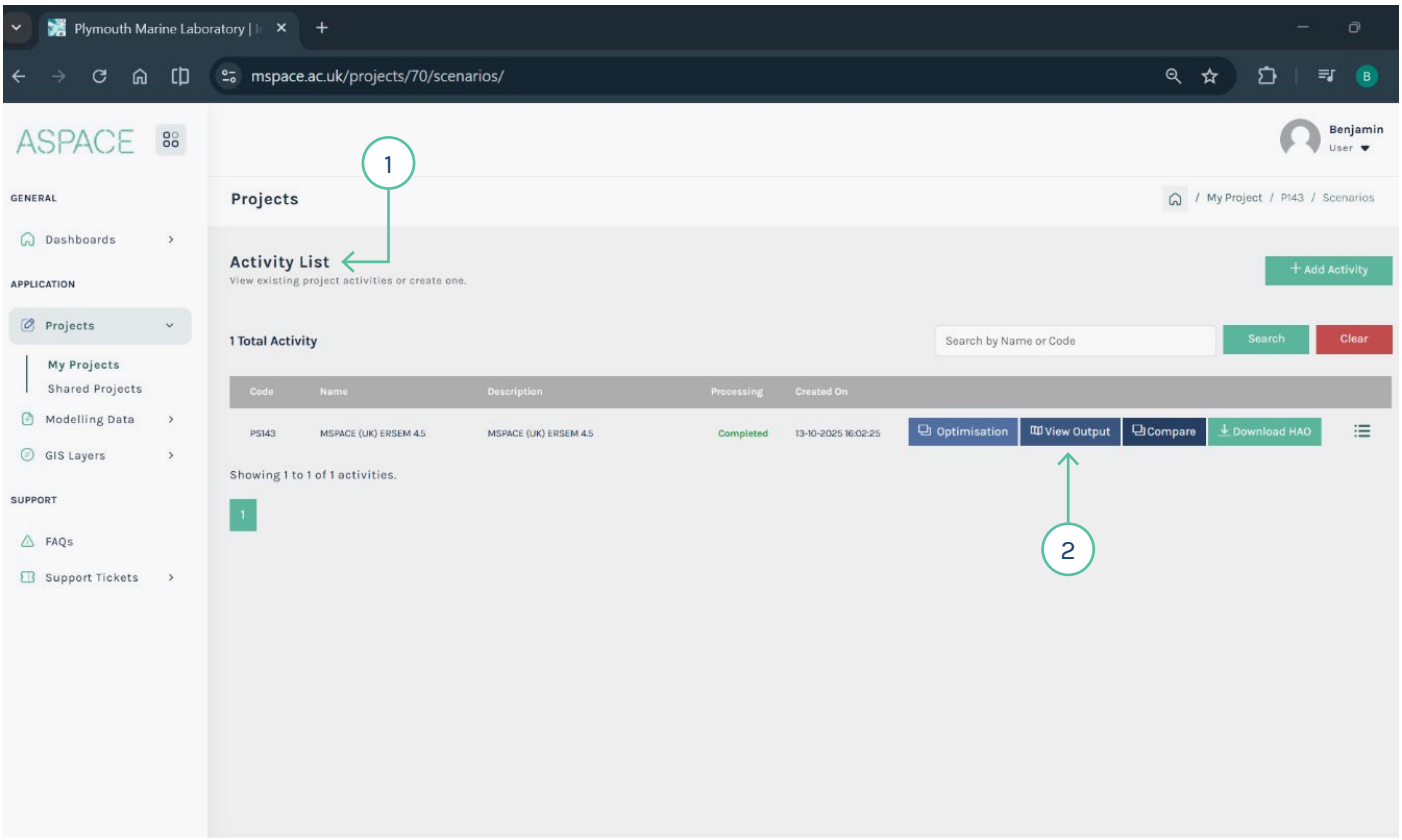
Phase 4

Visualising, comparing and downloading alternative spatial management scenarios

—Visualising ASMS
—Comparing ASMS

3.29 Visualising from the ASMS activity overview page

Phase 4



1. Navigate to the “Activity List” page of the Project of interest
2. Press the “View Outputs” button on the Activity containing the ASMS of interest

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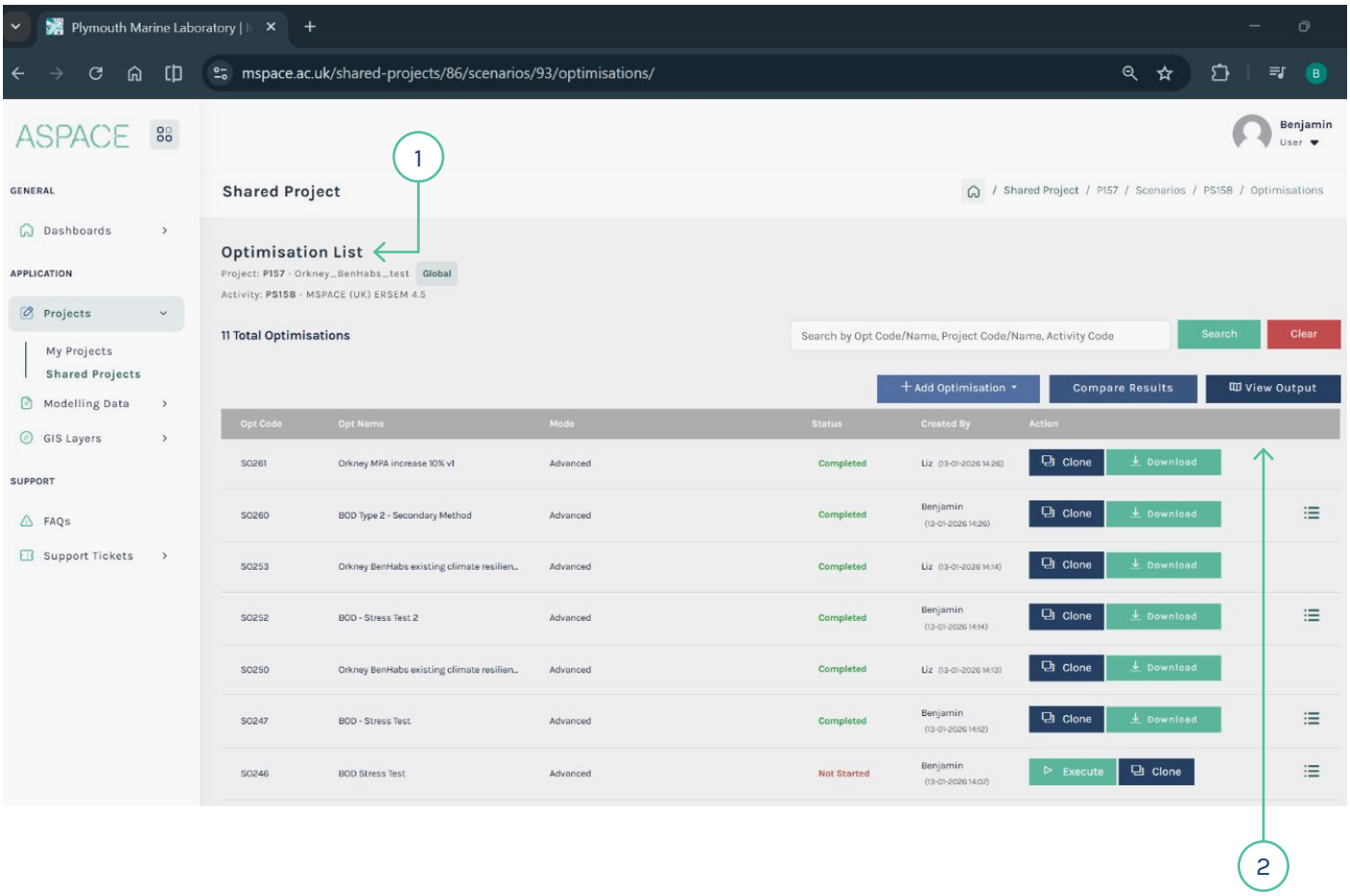
3.29 Visualising from the ASMS activity overview page (continued)

Phase 4



1. Navigate to the “Optimisation List” page on the Project Activity of interest
2. Press the “View Outputs” button on the top of the ASMS table list

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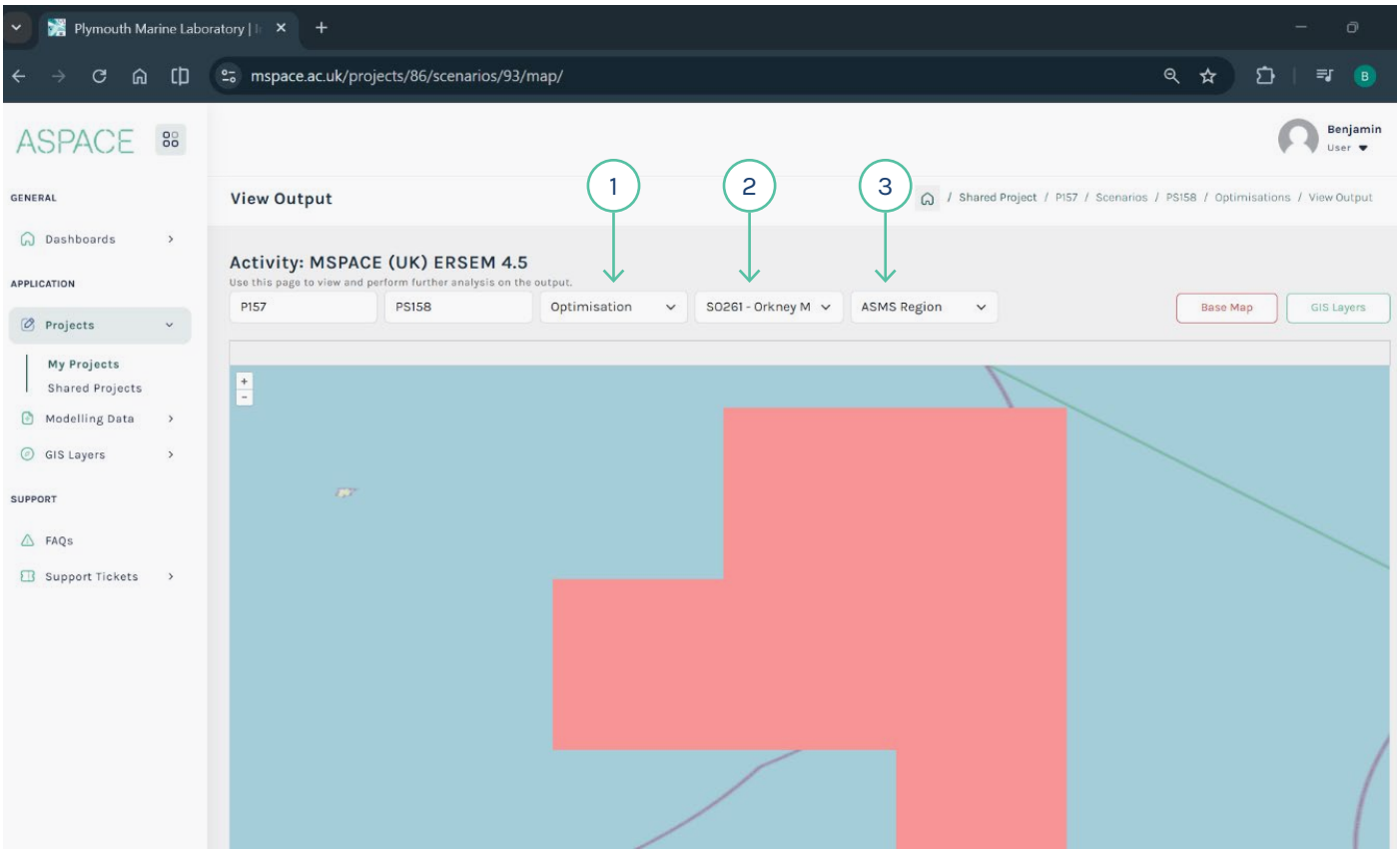
3.29 Visualising from the ASMS activity overview page (continued)

Phase 4



Using the Dropdown menus above the map:

1. Select the “Optimisation” option from the “Select Statistics” dropdown
2. Select the “ASMS Name” from the “Select Optimisation” dropdown
3. Select the output of interest:

A. ASMS Region:
   I. For Climate resilience of current areas scenarios this shows the region(s) which intersect all of the user provided GIS layers with areas that are predicted to be climate resilient.
   II. For New areas to increase sectorial climate resilience scenarios this shows the new areas that could be used to increase the climate resilience of the primary sector, based on user provided GIS layers.
   III. The user can overlay any GIS layers in the system to this map using the GIS layers button on the top right corner, as done when visualising the outputs of meta-analysis.

B. Refugia / Hotspots / Brightspots
   I. Regions of Refugia / Hotspots / Brightspots, useful in providing the user with wider context on how the ASMS region(s) was calculated.

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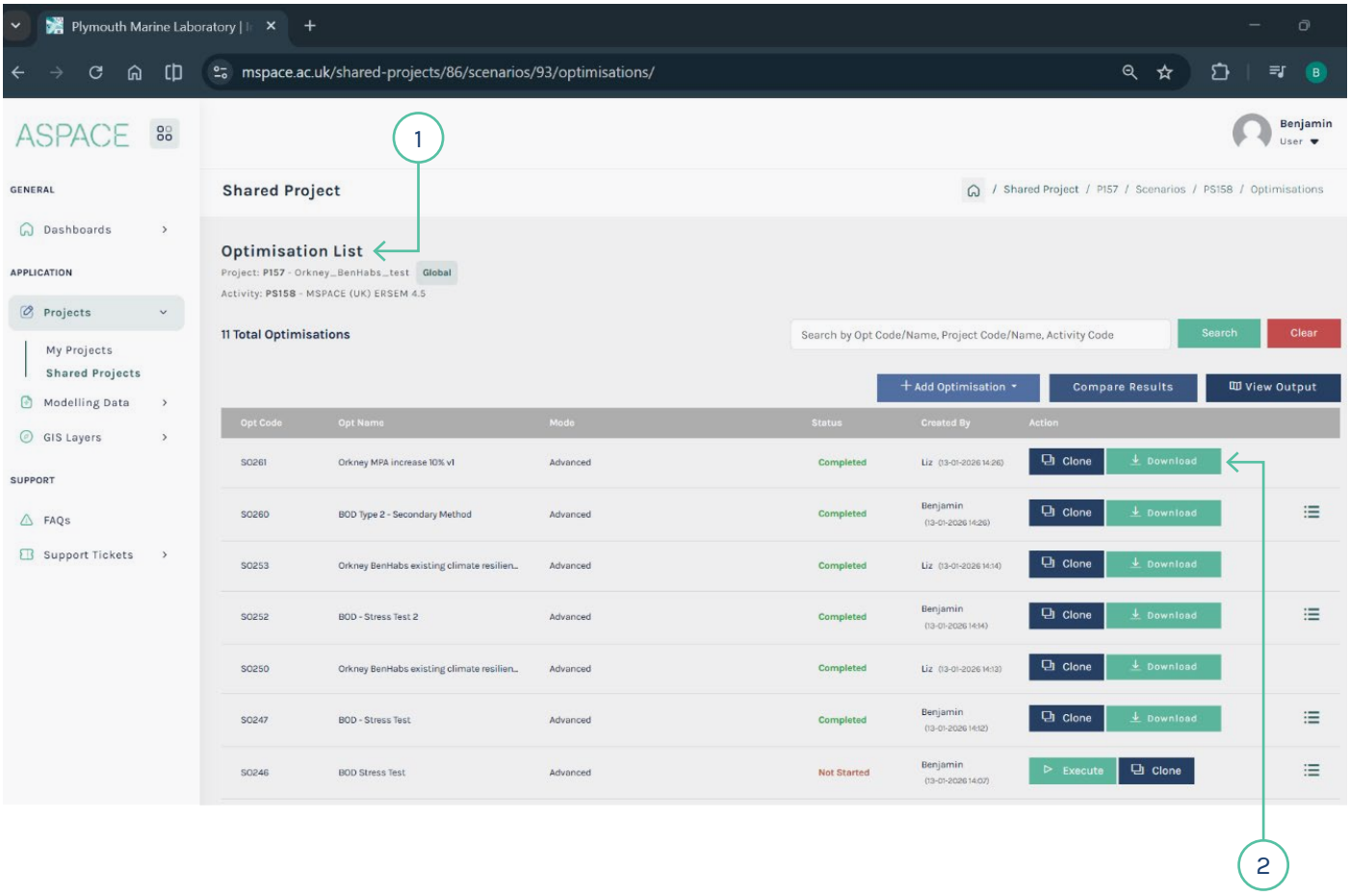
3.30 Downloading the data

Phase 4



1. Navigate to the “Optimisation List” page on the Project Activity of interest
2. Press the “Download” button on the ASMS of interest

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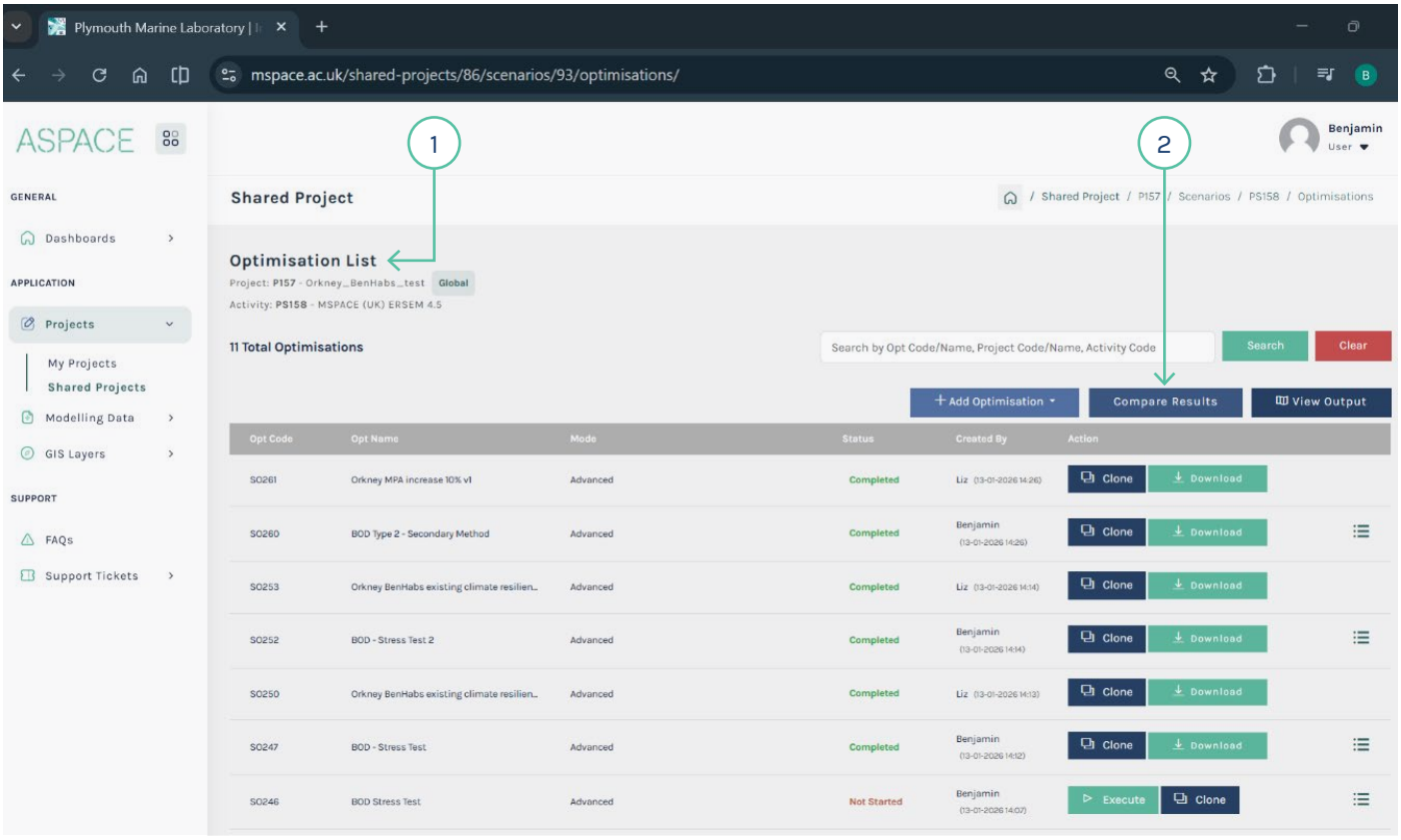
3.31 Comparing ASMS

Phase 4



1. Navigate to the “Optimisation List” page on the Project Activity of interest
2. Press the “Compare Results” button on the top of the ASMS table list

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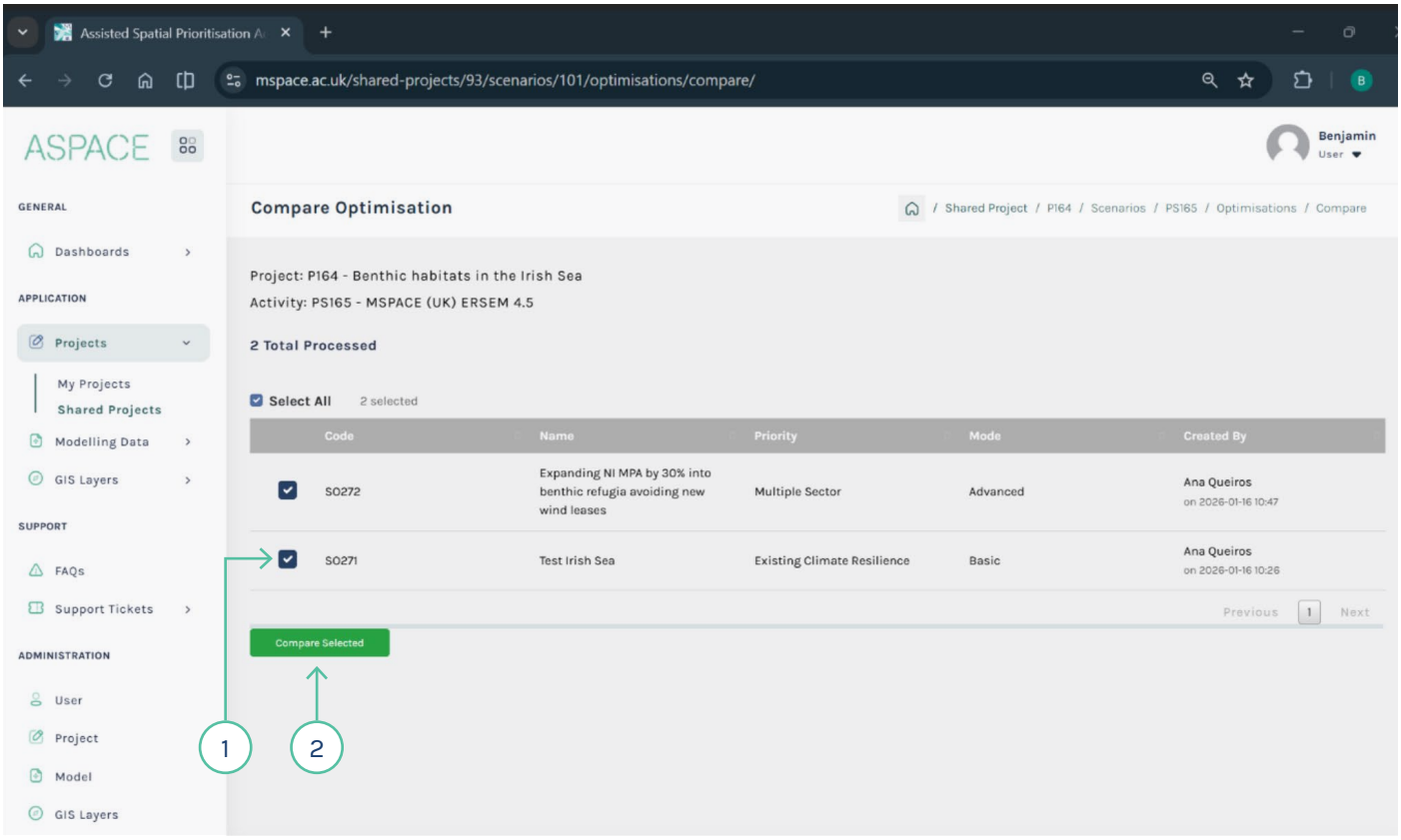
3.31 Comparing ASMS (continued)

Phase 4



1. Use the check boxes on the left hand side to select the ASMS of interest
2. Press the “Compare Selected” button
3. Scroll to the bottom of the page to see the comparisons

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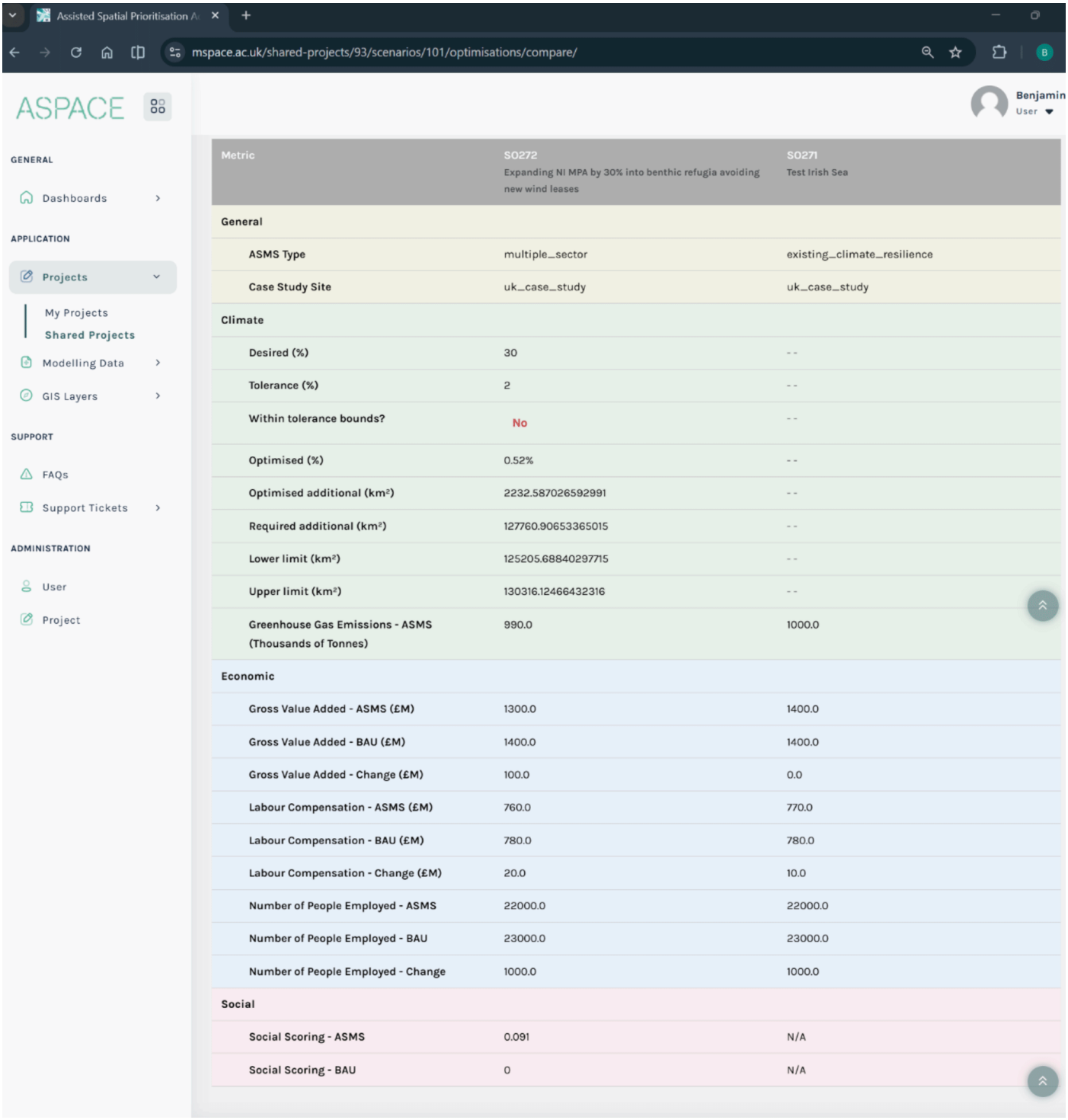
3.31 Comparing ASMS (continued)

Phase 4



Metric	SO272 Expanding NI MPA by 30% into benthic refugia avoiding new wind leases	SO271 Test Irish Sea
General		
ASMS Type	multiple_sector	existing_climate_resilience
Case Study Site	uk_case_study	uk_case_study
Climate		
Desired (%)	30	--
Tolerance (%)	2	--
Within tolerance bounds?	No	--
Optimised (%)	0.52%	--
Optimised additional (km²)	2232.587026592991	--
Required additional (km²)	127760.90653365015	--
Lower limit (km²)	125205.68840297715	--
Upper limit (km²)	130316.12466432316	--
Greenhouse Gas Emissions - ASMS (Thousands of Tonnes)	990.0	1000.0
Economic		
Gross Value Added - ASMS (£M)	1300.0	1400.0
Gross Value Added - BAU (£M)	1400.0	1400.0
Gross Value Added - Change (£M)	100.0	0.0
Labour Compensation - ASMS (£M)	760.0	770.0
Labour Compensation - BAU (£M)	780.0	780.0
Labour Compensation - Change (£M)	20.0	10.0
Number of People Employed - ASMS	22000.0	22000.0
Number of People Employed - BAU	23000.0	23000.0
Number of People Employed - Change	1000.0	1000.0
Social		
Social Scoring - ASMS	0.091	N/A
Social Scoring - BAU	0	N/A

The table overleaf describes every parameter within the comparison table.

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3.31 Comparing ASMS (continued)

Phase 4

Name	Description
ASMS Type	Type of Alternative Spatial Management Scenario being evaluated
Case Study	Site Geographic area or site used as the case study for this analysis
Desired (%)	Target percentage of area to be optimised under the scenario
Tolerance (%)	Allowed percentage deviation from the optimisation target
Within tolerance bounds?	Indicates whether the optimisation result falls within allowed tolerance
Optimised (%)	Percentage of area optimised relative to the target
Optimised additional (km^2)	Additional area successfully optimised by the scenario
Required additional (km^2)	Total additional area required to achieve the optimisation goal
Lower limit (km^2)	Minimum additional area required to meet the optimisation target.
Upper limit (km^2)	Maximum additional area allowed within tolerance limits
Greenhouse Gas Emissions - ASMS (Thousands of Tonnes)	Estimated greenhouse gas emissions under the ASMS scenario
Greenhouse Gas Emissions - BAU (Thousands of Tonnes)	Estimated greenhouse gas emissions under the Business-as-Usual scenario
Greenhouse Gas Emissions - Change (Thousands of Tonnes)	Difference in greenhouse gas emissions between ASMS and BAU
Gross Value Added - ASMS (£M)	Economic value generated under the ASMS scenario.
Gross Value Added - BAU (£M)	Economic value generated under the Business-as-Usual scenario
Gross Value Added - Change (£M)	Change in economic value between ASMS and BAU
Labour Compensation - ASMS (£M)	Total labour compensation under the ASMS scenario
Labour Compensation - BAU (£M)	Total labour compensation under the Business-as-Usual scenario
Labour Compensation - Change (£M)	Change in labour compensation between ASMS and BAU
Number of People Employed - ASMS	Number of people employed under the ASMS scenario
Number of People Employed - BAU	Number of people employed under the Business-as-Usual scenario
Number of People Employed – Change	Change in employment between ASMS and BAU
Social Scoring - ASMS	Overall social impact score under the ASMS scenario
Social Scoring - BAU	Overall social impact score under the Business-as-Usual scenario

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4 Core features and functions

ASPACE is a transdisciplinary decision-support tool, for those exploring and making decisions about marine space that address the effects of climate change. The user can assess the current climate effects within a region of interest and compare this with alternative spatial management scenarios of their region of interest, based on climate change resilience, economic and social value metrics.

The sections below outline, for each ASPACE feature, what it does, what is its scientific rationale, guidance for best use and interpretation, and current limitations.

4.1 Analysing ocean climate modelling data

In ASPACE, ocean climate modelling dataset analysis the first step of the workflow. The aim is to classify waters in the region of interest based on their estimated sensitivity to climate change. This analysis defines a **Project**: it is the first part of the ASPACE workflow available for any new Project (executed by user command in the project **Activities** dashboard). The outputs of one analysis within one project can then be used to create and compare alternative spatial management scenarios (see Section 4.2).

Analyses of ocean climate modelling data in ASPACE are configured by the user to target specific ecosystem components or marine sectors (e.g. benthic habitats; pelagic fisheries; etc). That choice determines which modelling datasets are selected for analysis by the user. One analysis may therefore yield different outputs from another, for the same region, depending on their specific design.

Ocean climate modelling dataset analyses in ASPACE use a well established technique to detect the emergence of a climate change signal (Hawkins and Sutton 2012)[1]. This technique (spatial random-effects meta-analysis, Queiros et al. 2021)[2] has been extensively used in marine climate change studies around the world in the last decade[2,3,4,5,6,7,8]: it builds on decades of development of statistical analyses methods in the medical literature, which have been more recently used in environmental sciences, and then adapted to the analyses of ocean climate change time-series[2].

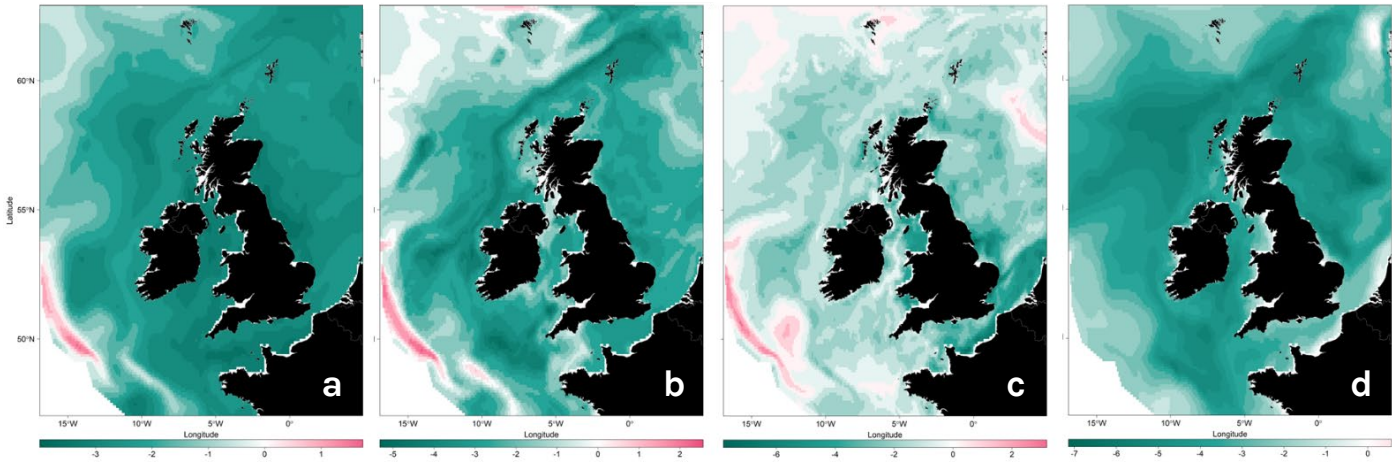


Figure 1: The patterns of change in different Essential Ocean Variables over time and space, contrasting the period 2006-2025 with 2055-2074, using the standardised mean difference estimator Hedges' g. Base data is (Kay et al. 2020), providing estimates under global emissions trajectory RCP8.5. a) sea surface temperature; b) sea surface dissolved oxygen; c) sea surface salinity; d) phytoplankton (carbon) biomass. Green is where a variable trend is consistent with the expected climate change trend, pink expresses the opposite trend, and white shows no change from the present period.

Ocean variables i.e. the physical, biogeochemical and biological components of marine ecosystems - vary in space and time due to natural cycles and man-made change[9]. Attributing the cause of those changes to climate change requires first an estimation of what is the expected natural variability for each variable: for instance, how much should temperature change due to seasonal and interannual variation, and climate oscillations. It is then necessary to estimate if estimated variability in a variable over the period of analysis exceeds natural variability, and then whether the trend of change in each variable (if any) is consistent with the expected long-term climate change trend for that variable, in that region. Additionally, different ocean conditions express climate change with different speed and magnitude (Figure 1; IPCC 2021)[10] and different species also respond to all of those changes with different speeds and magnitudes (Poloczanska et al 2013)[11]. Therefore, determining which areas of the ocean are more sensitive or more resilient to climate change is challenging, if we consider each ocean variable separately. This attribute makes it difficult to make decisions about how to use marine space sustainably in order to promote resilience for nature and people into the future. Ecosystem and community level metrics of ocean change are therefore required, that provide a broader picture of climate change for a particular region of the ocean for which management is required.

Resolving this challenge, ASPACE uses spatial random effects meta-analysis (SRMA) to analyse ocean climate modelling datasets. SRMA has been designed specifically, and widely deployed, to support marine spatial policy design to provide outputs that summarise the emergence of a climate signal across considered variables. Specifically, this method is used to estimate an objective ecosystem- or biological community-level quantification of the impacts of climate change over a region of interest, instead of the need to consider potentially different spatial and temporal patterns of change in different ocean variable separately, whilst accounting for the natural variability of individual variables.

Ocean climate modelling data selection

The starting point for the SRMA is for the user to select which ocean modelling datasets they want to analyse. These usually take the form of 4D modelling time-series, providing estimates for a particular ocean variable (e.g. temperature, the biomass of a given species…) over space and time. The user can select as many variables as they deem necessary to estimate the impact of climate change in a given ecosystem component (e.g. benthic habitats,

pelagic megafauna)[5] or marine activity sector (e.g. pelagic fisheries, seabed aquaculture)[2,12]. The selection of datasets should be done by or with end-users.

Inclusion of variables in each analysis requires that the user knows what is the expected climate change trend for that variable. For instance, temperature will warm as a result of climate change; species A is expected to decline due to ocean warming; pH is expected to decline due to climate change. This information on the direction of the trend is required by the SRMA algorithm in ASPACE, and should be gathered via literature review. In this absence of this information we advise that the user does not include a particular variable in the analysis, as this will lead to spurious results.

Ocean climate modelling data analysis

SRMA then has two steps, and these are implemented in ASPACE using the method previously described here.[2]

In the first step, the SMRA algorithm calculates the change in each individual modelling datasets considered, in the time-period of analysis. Specifically, change will be calculated for each variable, comparing two time periods: the present and as many future periods and the user requests. To account for natural variability (seasonal, interannual and climate oscillations) when determining human-induced climate change from the observational record, the Intergovernmental Panel on Climate Change, in its Sixth Assessment Report (AR6), assessed changes over 20-year periods (IPCC 2021). In line with this, in ASPACE, we consider the "present" as the 20 year period from 2006-2025, and the future as any 20 year time period, from 2026 onwards to the end of the 21st century: 2026-2045; 2027-2046; etc. In this way, the mean value of ocean variables is estimated over 20 year periods, and comparisons are only possible for time periods which are at least 20 years apart.

The variable produced in this first step of the analysis is called **Hedges' g (individual effect)** and expresses the mean local change in each individual variable (e.g. bottom seawater temperature), relative to their variability in both the present and the future period, as necessary to determine whether its change within the period of analysis is in agreement or beyond its expected natural variability. The calculation for each variable is set up so that a negative Hedges' g expresses a change consistent with the expected long-term climate-driven trend, while a positive value indicates the opposite trend. In Figure 1, mean climate-driven trends were defined based on literature review and can be found elsewhere (Queirós et al. 2023). Hedges' g estimated for each variable in each time-period comparison can be visualised in the **Project Outputs** dashboard, providing a heatmap that has the same scale across all variables, given that Hedges' g is a standardised measure that accounts for each variable's mean and variability in the present and each future period.

In the second step, change across all variables in each analysis (and for each modelling scenario and time-period) is estimated. This is called the **summary effect** (or **M**). M is estimated with a mean value and variance. Based on both, we can then classify areas of marine space based on whether the mean value of M is large and positive with low variance, large and negative with low variance, or whether it has a value close to zero and/or high variance (full details in Queirós et al. 2021). The final classification of areas is then:

I. **Climate change hotspot** areas where M is large and negative, with narrow variance. In these areas, variable trends are consistent with expected climate change effects, and trends often exceed the natural variability of each variable. These sites are seen as being sensitive to climate change and indicate areas where MPAs or other conservation mechanisms are likely to become less effective, or ineffective, within the period of analysis. Target species may experience a shift in distributions away from these areas.

II. **Climate change refuge** areas where M is close to zero and/or has large variance. In these areas, ecosystem change is overall small and/or change across various ecosystem or community characteristics is not overall in line with expected climate change impact trends. In these sites, climate change is therefore seen as milder, and species are expected to experience many conditions that will be similar to present time. We expect therefore that present uses of space in these areas would be by and large similar within period of analysis.

III. **Bright spots** areas where M is large and positive, with narrow variance. In these areas, variable trends are often or all contrary to the trend expected from climate change effects, and they exceed the natural variability of each variable. These areas may also be particularly important sites where focal sectors may be sustainable in support of overall climate change adaptation.

Tau-squared (τ^2) is also calculated during the calculation of M, giving the between model variance, and is calculated using the DerSimonian and Laird method (Borenstein et al. 2009)[13]. Regions of higher τ^2 indicate areas where the trends between variables disagree (i.e. where Hedges' g are most different) whilst τ^2 will be closer to zero where they are more consistent. Observing the variation of τ^2 is important especially where areas are classified as climate change refugia, as its value provides insight into whether M is classified as not significantly different from 0 because: 1) many variables are within their natural variability (**true climate refuge**); or whether 2) that classification emerges because several variables express divergent trends (**transitional refuge**).

Ocean climate modelling data analysis output

Hedges' g, M and τ^2 estimated in each time-period and scenario comparison can be visualised in the **Analysis Outputs** dashboard. The outputs take the form of heatmaps for Hedges'g and τ^2 (Figure 2). Hedges' g can be compared across variables within a given analysis, whereby the more the g departs from 0, the stronger the change in the variable relative to the present period. This is because Hedges' g is a standardised effect size measure that accounts for each variable's mean and variability in the present and each future period, as well as for τ^2.

If the analysis output selected for visualisation is M, this can be visualised using two possible options: per future 20 year period; or in "**High Agreement**". In these two outputs, the three classes (refuge, hotspot and bright spot) are identified with different colours (Figure 2), and they can be visualised together or separately. The **High Agreement** option is estimated by counting in how many future time slices (from the ones selected by the user) each model domain cell is classified in a particular class (refuge, hotspot or bright spot) over the whole period of

analysis. “High agreement” provides the class that each cell falls into in at least 80% of future time slices chosen by the user for analysis. This provides a view of long-term change in the region of analysis and of the stability of the climate change sensitivity classification. The longer a particular area falls within one of the 3 classes of sensitivity to climate change, the more confident a user can be of the outcome of spatial interventions in that area. Areas where a cell does not fall into any particular category in at least 80% of future time slices are not classified as any of the three categories when the option selected to visualising M is “High Agreement”. In those areas, only the background map is seen.

Any GIS layers available through ASPACE or uploaded by the user can be overlain onto the ocean climate modelling data analysis output (Figure 2, middle panel).

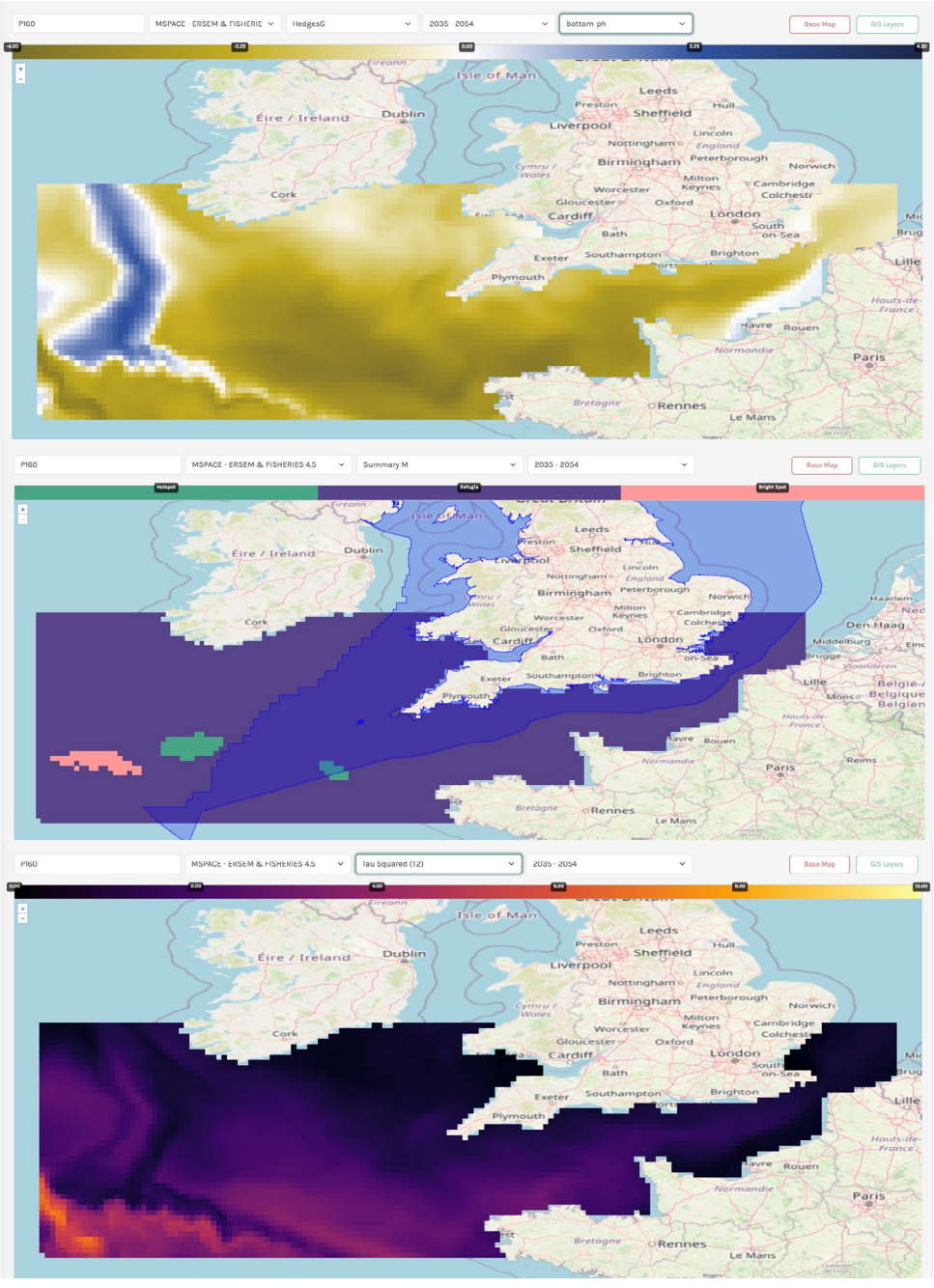


Figure 2: Example of ocean climate modelling data analysis outputs: Hedges’ g (top), M (middle) and $\dagger^2$ (bottom). The UK EEZ has been added as a GIS layer overlain on M in the middle plot (blue).In all plots, the region of analysis is shown by the edge of the variable values. Analysed modelling data is Kay et al. 2020, providing estimates under global emissions trajectory RCP4.5

4.2 Alternative spatial management scenarios

The aim of ASPACE is to allow users to explore and identify opportunities for climate-smart marine spatial management via the development of alternative spatial management scenarios (ASMS). These scenarios are mathematical solutions for the use of marine and coastal space that make use of climate-resilient areas (identified in 4.1) towards a specific spatial management goal set out by the user. The way the user creates a scenario is by using the "Optimisation" feature.

The Optimisation feature currently selects regions of Refugia and Brightspots when considering climate resilient areas. In future, users will be able to define which areas are involved in calculations.

The Optimisation feature has two options:

1. **Climate resilience of current areas:** in this mode, the user is comparing the outputs of the Ocean Climate Modelling Analysis (4.1) with one (primary) or more (secondary) GIS layers that describe one or more marine sectors (e.g. an MPA network; the national distribution of aquaculture facilities), or species and habitats (e.g. the distribution of Priority Marine Features), as they are currently distributed in the present. The output of this Optimisation is the identified area of the selected marine sector (s) that is climate-resilient. This type of ASMS therefore represents the status quo, if no changes are made to marine sector distributions, and is sometimes referred to as the Business as Usual scenario.

2. **New areas to increase sectorial climate resilience:** in this mode, the user is building on the outputs of the Ocean Climate Modelling Analysis (4.1) to find new areas that could be used to increase the climate resilience of one (primary) or more (secondary) marine sectors (s) or habitat(s), based on used GIS layers selected during Optimisation. The output of this optimisation is the new area(s) that could be used to meet that management goal. During this type of optimisation, ASPACE seeks areas based on a given threshold for the size of the sector we want to it to increase by (e.g. 10%). Those areas may include areas where compatible marine uses occur, and ASPACE will avoid areas where incompatible activities take place – both of which are set by the user as secondary "inclusive" or "exclusive" sectors. This type of ASMS therefore represents a climate-smart scenario, as its output identifies changes to spatial management (i.e. new areas) that address climate change.

ASMS using the same Ocean Climate Modelling Analysis and more than one Optimisation Pathway can then be compared using the "**Compare Results**" tab of the **Optimisation** dashboard. ASMS are compared based on the provided information about the area of explored sector that is climate-resilient, as well as estimates of how each scenario affects the economy of concerned regions and how it aligns with the values of their stakeholders (see Sections 4.3 and 4.4).

4.3 Scoring alternative spatial management scenarios using economic modelling

Overview

The economic results generated within the ASPACE tool illustrate how changes in activity in one sector affect not only that sector, but also the wider economy through supply chain linkages. This perspective enables users to assess and compare Alternative Spatial Management Scenarios (ASMS) using a common set of economic indicators (which also translate to social and climate change indicators in some cases), without relying on detailed or highly uncertain economic forecasts.

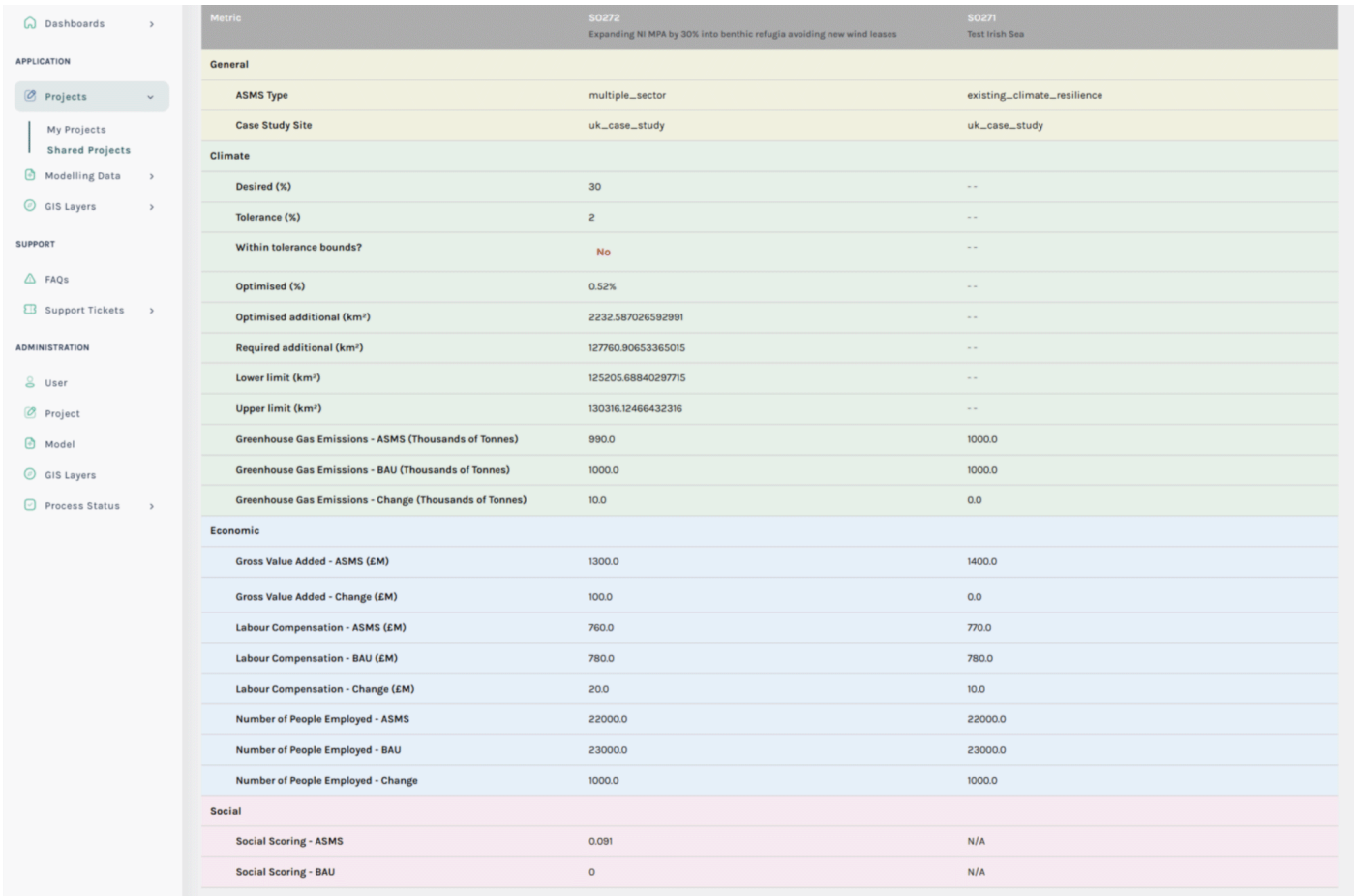
In practical terms, the economic modelling component of ASPACE represents the economy in the region of interest as a system of interconnected marine activity sectors. The model employs a macro-economic technique approach called Input-Output (IO) Economic Modelling, and uses real world data (i.e. Input-Output tables) published by individual nations, which the ASPACE team has further refined for the marine environment. In ASPACE v1.0 this feature is only available for the UK and individual UK nations, based on published evidence (Roca-Florido and Mair, 2024; Roca-Florido et al, 2025)[14,15]. In future versions, this feature will be available for other regions of the world, and users will also be able to upload their own IO economic model.

Methodology and workflow in ASPACE

When an ASMS is created in using the option **New Areas to Increase Sectoral Climate Resilience**, ASPACE searches for new areas that could be used to increase the climate resilience of a particular sector (s), or ecosystem component(s). The optimisation pathway is configured considering how that particular variable chosen by the user can or cannot share space with other marine space(s), as selected by the user. This will lead to changes in how user-selected marine activity sectors use space. Specifically, the sector for which ASPACE is seeking new areas, and those (any) for which activity may now be restricted as a result. This pathway is taken into the economic model through an adjustment in the size of economic activity of selected sectors, with repercussions to other marine economy sectors directly and indirectly linked to these target sectors, though the Input-Output model ("IO model").

Table 2: List of economic and social metrics estimated by the ASPACE economic model

Economic Modelling Output	Units	Description
Greenhouse Gas Emissions	Thousand tonnes	GHG emitted per £ million changed in gross output in the relevant sectors
Gross Value Added	£ million	GVA generated for each £ million changed in gross output in the relevant sectors
Labour Compensation	£ million	Income generated for each £ million changed in gross output in the relevant sectors
Number of People Employed	Workers	Jobs created for each £ million changed in gross output in the key sectors



Metric	SO272 Expanding NI MPA by 30% into benthic refugia avoiding new wind leases	SO271 Test Irish Sea
General		
ASMS Type	multiple_sector	existing_climate_resilience
Case Study Site	uk_case_study	uk_case_study
Climate		
Desired (%)	30	--
Tolerance (%)	2	--
Within tolerance bounds?	No	--
Optimised (%)	0.52%	--
Optimised additional (km^2)	2232.587026592991	--
Required additional (km^2)	127760.90653365015	--
Lower limit (km^2)	125205.68840297715	--
Upper limit (km^2)	130316.12466432316	--
Greenhouse Gas Emissions - ASMS (Thousands of Tonnes)	990.0	1000.0
Greenhouse Gas Emissions - BAU (Thousands of Tonnes)	1000.0	1000.0
Greenhouse Gas Emissions - Change (Thousands of Tonnes)	10.0	0.0
Economic		
Gross Value Added - ASMS (£M)	1300.0	1400.0
Gross Value Added - Change (£M)	100.0	0.0
Labour Compensation - ASMS (£M)	760.0	770.0
Labour Compensation - BAU (£M)	780.0	780.0
Labour Compensation - Change (£M)	20.0	10.0
Number of People Employed - ASMS	22000.0	22000.0
Number of People Employed - BAU	23000.0	23000.0
Number of People Employed - Change	1000.0	1000.0
Social		
Social Scoring - ASMS	0.091	N/A
Social Scoring - BAU	0	N/A

Figure 3: Example of comparison of 3 ASMSs using all metrics estimated by ASPACE. 1 line scenario descriptions are given as header names. This feature can be used to compare ASMS within the same Project: it is accessed using the Compare Results button within the Optimizations dashboard

This approach then leads to the calculation of economic and social metrics for the ASMS (Table 2) that reflect a an economy wide view of the consequences of spatial management decisions, rather than focusing solely on individual marine space uses or industries.

Metrics estimated for generated ASMS using this feature can then be used to compare multiple ASMS for the same Ocean Climate Modelling Project, using the button **Compare Results** from a particular **Project's Optimisations List**. The metrics estimated by this feature (Table 2 and Figure 3) are then provided side-by-side for the different ASMS compared, alongside climate change metrics and the score for alignment with stakeholder values metric. At this stage of the ASPACE workflow, the aim is not to predict short term economic performance of individual ASMS, but to compare multiple ASMS in terms of their broader climate-resilience, and their economic and social implications. **This enables the user to make an explicit assessment of a balance of trade offs, such as balancing improvements in climate resilience with the maintenance of economic activity or employment.**

The baseline scenario is estimated first to provide a reference point for comparison and to define the initial indicator values. It represents total output based on all species harvested and landed at port in the region, regardless of where fishing takes place.

The Business as Usual scenario assumes that fishing activities can occur across the entire marine plan area in the region of interest. It accounts for capture losses associated with climate change hotspots (and thus economic loss), irrespective of the fishing gear used or the species targeted.

For simplification, in ASPACE v1.0, when an ASMS seeks to increase the area of a Marine Protected Area network by adding ecologically and biologically meaningful climate-resilient areas, these areas are assumed to not allow for any fishing activity. The ASPACE team acknowledges this assumption is not always valid, as different types of restrictions apply to different conservation site types. In future release versions, the user will be able to select whether this assumption should or should not be applied during **Optimisation**.

The effects associated with each ASMS are expressed as deviations from Business as Usual, enabling the user to compare ASMS on a common and internally consistent basis (e.g. Figure 3).

Important

- Metrics can only be estimated using this feature if a Marine Spatial Planning area (or Marine Planning Area in the UK) is selected by the user as one of the Additional Constrains during Optimisation. The user must therefore ensure they have selected this GIS layer (which may require uploading their own GIS dataset for their region) to be able to use this feature. Please refer to the Quick Start Guide (Section 3) to find out how to use a Marine Plan area during Optimisation.
- In ASPACE v1.0, this feature generates metric estimates **after** the spatial constraints solution has been found by the tool. In future versions, the tool will allow the user to select the maximisation of this feature's outcome as one of the criteria driving the solution finding algorithm **during Optimisation**.
- All ASMS metrics (climate-resilience, economic and social) are comparable only for ASMS generated from the same Ocean Climate Modelling analysis output: i.e. different **Optimisations** within the same **Project**.
- The resulting social and economic metric estimates (e.g. Table. 2) are intended to support comparison of ASMS rather than to deliver precise predictions for individual ASMS.
- For simplification, in ASPACE v1.0, when an ASMS seeks to increase the area of a Marine Protected Area network by adding ecologically and biologically meaningful climate-resilient areas, these areas are assumed to not allow for any fishing activity. The ASPACE team acknowledges this assumption is not always valid, as different types of restrictions apply to different conservation site types. In future release versions, the user will be able to select whether this assumption should or should not be applied during **Optimisation**.
- In ASPACE v1.0, changes to the size of the area accessible to fishing are the primary driver of the economic model used, with repercussions estimated based on how the fishing sector relates to other sectors directly or indirectly. ASPACE v2.0, with planned launch for Autumn 2026, will include the wind sector also as a primary driver of the economic model.

Differences between ASMS highlight how strongly economic activity, employment, income, and emissions are linked to particular spatial distribution of marine sectors. For example, an ASMS in which climate change hotspots reduce the area available to certain fishing fleet segments may lead to lower fishing activity in the area of analysis, which is then estimated by the IO model. These reductions can then affect related sectors within the model, such as processing, storage, and transport. By contrast, scenarios that redirect activity of that fishing fleet towards more climate resilient areas, such as bright spots or refugia, may generate stronger economy wide effects per unit of activity, which will be captured in the ASMS metrics.

Clear documentation of data sources used, assumptions made by the tool, and user decisions are therefore essential when results are used for reporting or decision making.

Interpreting the results of this feature

Care is needed when interpreting these results. Tool assumptions are applied consistently across all ASMS compared. For instance, changes in activity of a sector are assumed to be proportional to changes in available area to the sector in the region of analysis, such that a reduction or expansion in spatial access is assumed to lead to a corresponding reduction or increase in sectoral activity. These results should also be interpreted at an appropriate level of aggregation, as economy wide indicators may mask variation across individual sectors or smaller locations within the region of analysis.

The results from this feature should always be considered alongside the other metrics estimated by ASPACE when comparing ASMS (Fig. 3). ASPACE is designed as an integrated decision support tool, and economic performance alone does not capture all relevant dimensions of spatial management choices. Clear documentation of data sources used, assumptions made by the tool, and user decisions are therefore essential when results are used for reporting or decision making.

Finally, the economic modelling approach used in ASPACE v1.0 relies on fixed relationships between sectors based on the stated refences and does not account for changes in prices, input substitution, or behaviour. Production structures are assumed to remain unchanged over the time of analysis. Outputs should therefore be interpreted as indicative estimates of structural impacts rather than exact forecasts. Within these limits, this feature provides a robust and internally consistent basis for comparing ASMS and for understanding their broader economic, social, and environmental implications within the ASPACE framework, that should be of use to Sustainable Ocean Planning and other marine spatial management mechanisms.

4.4 Scoring alternative spatial management scenarios using stakeholder values

Alignment of ASMS with social values is currently estimated for individual scenarios, when the Planning objective used in a Project's **Optimisation** dashboard is set to **New areas to increase sectorial climate resilience**.

IMPORTANT

- In ASPACE v1.0, we provide estimates of how marine planning stakeholders perceive different attributes of marine space in the UK only, as collected during the MSPACE project (https://www.smmr.org.uk/funded-projects/marine-spatial-planning-addressing-climate-effects). A detailed methodology for the stakehodler values assessment can be found in Reinhardt and Danahey Janin 2025[16], with results presented in Talbot et al. 2025a-d[17,18,19,20]. Depending on where the region of interest the user selects is located when they set up a new **Project**, ASPACE will use different stakeholder values matrices. In future ASPACE version releases, we will allow the user to customise a stakeholder values matrix, based on new inputs (e.g. resulting from new research, or stakeholder consultations).

- The estimated scores for a set of ASMS are comparable within the same **Project**, but not between different Projects
- In order to estimate how a particular ASMS aligns with stakeholder values, ASPACE must be setup such that GIS layers involved in ASMS generation and particular attributes of marine space that stakeholders have scored are mapped to each other. Specifically, the primary sector layer selected in **Optimisation** must be mapped to the correct GIS layer types, which are internally linked to the stakeholder value matrices. When users upload new GIS datasets (or layers) to ASPACE, they are invited to assign tags to these, which are used in the internal mapping between data and values matrices. In this way, this new GIS data can be used in subsequent ASMS generation in **Optimisation**. These layer types are therefore linked to marine activity sectors or habitat components that should feature in a dedicated stakeholder value assessment engagement activity. An example of some of the tags available are: “Tourism”, “Cultural Heritage” and “Recreation”. The first part of the assessment involves weighting the stakeholder values in the case study area across all sectors. These weights are then multiplied by any percentage change in the tagged primary sector layer due to the ASMS scenario generation to give a social score value.

The first part of the ASMS social scoring involves weighting the stakeholder values in the case study area across all sectors, based on the correct stakeholder values matrix, i.e. that which best represents the region of interest. These weights are then multiplied by any percentage change in the tagged primary sector layer due to the ASMS scenario generated, to give a social score value.

The estimated scores for a set of ASMS are comparable within the same **Project**, but not between different Projects, such that, for the same region of interest selected within a **Project**:

- The Business as Usual scenario (“BAU”, see section 4.3) is scored 0, as the central point for ASMS comparison.
- Larger, positive scores indicate an ASMS aligns better with how stakeholders value marine space than the BAU.
- More negative scores indicate an ASMS aligns less well with how stakeholders value marine space than the BAU.
- The final social score of individual ASMS can be visualised in the **Compare Results** table, accessible from the **Optimisations** dashboard, and exported for further uses.

4.5 Features in development

We are always improving the ASPACE platform. Here are some exciting things that we are working on that will be in the tool soon:

- Users to choose which regions from Refugia / Brightspots / Hotspots they want included in the ASMS creation
- Wind in economic model (see section 4.3)
- Relaxing no take zone assumption in Optimisation (see section 4.3)
- Users to have the ability to upload Economic Modelling Data
- Users to have the ability to upload Social Values
- Multi-sector ASMS optimisations
- “Integration with the Offshore Renewable Impacts on Ecosystem Services (ORIES) project. This will be added as part of the funded EQUIFy project.

5 Frequently asked questions

5.1 General

What is the ASPACE Tool?
ASPACE is an assisted spatial prioritisation software conceived to support the design and exploration of climate-resilient, socially acceptable and economically viable marine spatial policy intervention scenarios. It combines climate change modelling analyses, stakeholder value assessment, and economic modelling together in an integrated, transdisciplinary, fully interactive tool, designed to help meet the needs of policy makers and other practitioners, as well as of researchers.

Do I need to install any software to use the tool?
No. The ASPACE Tool is fully web-based and does not require any additional software or plugins. It can be accessed using any modern Chromium-based web browser, such as Google Chrome or Microsoft Edge.

Is the tool free to use?
Yes! All you need to get started is a new account. Since we don't have a roadmap for adding subscription/paid services yet, we can always change in this with future releases.

What are the network requirements?
A stable internet connection is required. The tool operates over standard HTTPS (port 443). Institutional firewalls or proxies must allow outbound HTTPS access to the ASPACE domain.

Where can I find or download the User Guide?
You can download the full ASPACE User Guide as a PDF from the following link: https://mspace.ac.uk/media/ASPACE_User_Guide.pdf

5.2 Account registration and sign-up

How do I create an account?
Click Sign Up (https://mspace.ac.uk/signup/) on the ASPACE login page and complete the registration form with your name, email address, company and country. Once submitted, you will receive an email to verify your email address and activate your account.

Do I need institutional approval to sign up?
No. The ASPACE Tool is open for users to create an account directly. However, access to certain datasets or features may depend on project or administrator permissions.

I didn't receive the sign-up verification email. What should I do?
Please check your spam or junk folder first. If the email does not arrive within a few minutes, contact aspace@pml.ac.uk.

5.3 Privacy and accounts

What personal data does ASPACE collect?
Basic account and usage information (e.g. name, email address, organisation, country, login details, and platform activity). Please read the Privacy Policy for further details.

Are cookies used?
Only essential cookies required for secure operation. No marketing cookies are used. Please read the Privacy Policy for further details.

How long is my data kept?
Personal account data is retained only as long as necessary and is deleted or anonymised after inactivity, in line with policy requirements. Please read the Privacy Policy for further details.

5.4 Signing in

How do I sign in to ASPACE?
Go to the ASPACE login page (https://mspace.ac.uk/login), enter your registered email address and password, and click Sign In.

What should I do if I forget my password?
Click "Forgot Password?" (https://mspace.ac.uk/forget_password) on the login page and follow the email-based password reset process. If you do not receive the reset email, contact the system administrator aspace@pml.ac.uk.

Why can't I sign in even though my password is correct?
This may happen if:

- Your email address has not been verified
- There is a temporary system issue
- Please check your email for activation messages or contact aspace@pml.ac.uk if the issue continues.

What is 2FA and why is it used?
Two-Factor Authentication (2FA) adds an extra layer of security by requiring a one-time verification code sent to your email after you enter your password. This helps protect your account from unauthorised access.

When is the 2FA email sent?
A 2FA verification email is sent each time you sign in after entering your correct email address and password.

I didn't receive the 2FA email. What should I do?

- Check your spam or junk folder
- Wait a few minutes and try again
- Try Resend Code
- Ensure your email inbox is not full

If the issue persists, contact the system administrator.

Can I disable 2FA?

No. Email-based 2FA is enabled to maintain a consistent security standard across all ASPACE accounts.

Please contact your IT Department to allow emails from notifications@mspace.ac.uk and aspace@pml.ac.uk.

Does ASPACE store my password?

Yes, to allow the password function, each password is stored in an encrypted and hashed form which cannot be accessed by the system administrator.

5.5 Copyright and data ownership

Who owns the data I upload?

You retain ownership of your data. By uploading, you grant PML a non-exclusive, royalty-free licence to host and process the data solely to operate the ASPACE platform.

Can ASPACE or other users reuse my uploaded data?

Other users can use your data within the ASPACE framework only if you have made it available as a shared dataset. The use of data on the platform is regulated by our Privacy Policy and Terms and Conditions

What licence applies to ASPACE-provided content?

ASPACE content is provided under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 licence, allowing reuse for non-commercial purposes with attribution.

What happens if copyrighted material is uploaded without permission?

If notified, PML will temporarily remove the content, investigate, and take appropriate action. Users are responsible for ensuring they have permission to upload data.

5.6 Performance and processing

How long does it take the tool to run meta-analysis and Alternative Spatial Management Scenario (ASMS)?

Processing times depend on the size of the study area and the number of datasets selected:

- Initial meta-analysis of ocean climate modelling data can take up to one hour.
- Optimisation of an ASMS typically takes up to 10 minutes.

All processing runs on secure servers at Plymouth Marine Laboratory. You will receive an email notification once processing is complete, and you may safely close your browser after starting a run.

What does the Optimisation do?

The optimisation engine helps users design spatial solutions, such as identifying priority areas for conservation or balancing protection with human activities. It uses user-defined constraints, spatial layers, and numerical thresholds to explore ASMS.

5.7 Outputs and export

Can I export results for external use?

Yes. Processed outputs as maps (such as GeoTIFFs and shapefiles) or results tables will be available for download.

5.8 Troubleshooting

My upload failed. What should I check first?

Check the following as mentioned in the User Guide:

- Files are inside a ZIP archive
- Filenames follow the required convention
- All required files are present
- Headings in model data matrices removed
- Spatial dimensions are consistent

Why does my map look shifted or misaligned?

- Common causes include:
- Incorrect Coordinate Reference System (not EPSG:4326)
  - Wrong longitude/latitude values
  - Mismatch between grid dimensions and coordinate ordering

5.9 Support

Who do I contact for help or legal issues?

- Admin support: aspace@pml.ac.uk
- Copyright or legal concerns: legal@pml.ac.uk
- Raise Ticket: https://mspace.ac.uk/create-ticket

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ASPACE is an assisted spatial prioritisation software conceived to support the design and exploration of climate-resilient, socially acceptable and economically viable marine spatial policy intervention scenarios. It combines climate change modelling analyses, stakeholder value assessment, and economic modelling together in an integrated, transdisciplinary, fully interactive tool, designed to help meet the needs of policy makers and other practitioners, as well as of researchers.

ASPACE is a free, web-based tool, that can be used in any marine and coastal region where suitable datasets are available. ASPACE provides a number of datasets to enable users to carry out analysis in some regions of the world, but users can also upload their own datasets. Data uploaded by users can be private or shared with the ASPACE community. As the ASPACE community grows, our mission is to grow capability to manage our ocean around the world in more sustainable and climate-resilient ways, for future generations.

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