Marxan Connect practical GUIDE

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Funding to develop this material provided by:
CHONe- Canadian Healthy Oceans Network, Department for Fisheries and Oceans, Canada

and:
PacMARA- Pacific Marine Analysis & Research Association, *PO BOX 49002Victoria, Canada V8P5V8 · 778-300-1801*

Last updated: Jan 2024
IntroMarxanConnect_CourseHandbook_25-MAR-2021_FINAL_editedOc21_2021_NS.docx

Key Marxan Connect paper:

Daigle, R., A. Metaxas, A. Balbar, J. A. McGowan, E. A. Treml, C. Kuempel, H. P. Possingham, J. Clarke, and M. Beger. 2020. Operationalizing ecological connectivity in spatial conservation planning with Marxan Connect. *Methods in Ecology and Evolution* 11:570– 579.

Disclaimer: *The tasks in this guide are based on a hypothetical case study and do not represent the real world or any actual spatial plans.*

Table of Contents

1 Background and HOWTO guide

This guide was originally written to accompany a technical course on Marxan Connect (Daigle et al., 2020). It is a graphical user interface that can be used to preprocess and prepare existing connectivity data for inclusion in a Marxan analysis (Ball et al., 2009). This guide provides basic information on Marxan Connect and contains a series of tasks to work through steps to do spatial planning with connectivity. The Marxan Connect website (http://marxanconnect.ca) includes supplementary information and tutorials on how to use the app. Further information about Marxan can be found in the Marxan Manual (Serra et al., 2020) and the Marxan Good Practices Handbook (Ardron et al., 2010). This document guides you through five scenarios, teaching you how Marxan Connect works:

- **Scenario 1. BASELINE.** It introduces you to Marxan Connect and outlines the minimum steps required to run the app and to interpret Marxan outputs. It does not include any connectivity data.
- **Scenario 2. LANDSCAPE.** It walks you through a series of steps to incorporate landscape-based connectivity data as a conservation feature into Marxan.
- **Scenario 3. FEATURES.** It outlines instructions to include demographic-based connectivity data as a conservation feature into Marxan.
- **Scenario 4. DEPENDENCIES.** It provides instructions for incorporating connectivity data as spatial dependencies into Marxan.

We are unlikely to get through all scenarios in the prac, but I have included them here so that you have the option to work through all.

Tips for using this guide:

- "This kind of text" refers to something you can type, such as a file name.
- Text that **"looks like this"** refers to a button, selection, or panel in Marxan Connect.
- Any text that looks like this refers to a file or folder, while text that looks\like\this indicates a file path. Mac users need to adapt these path's as needed.

Note: A link to your MarxanConnect OneDrive folder is here: MarxanConnect_Imperial (password: "Imperial2024"), it contains spatial data files, this guide, and supplemental materials. Save this folder in a convenient directory (C:\ if working on your own machine). Take note of the path to the directory, you must amend the path name accordingly whenever the instructions in this guide refer to C:\MarxanConnect.

2 Introduction to Marxan Connect

2.1 The Marxan Connect Workflow

Marxan Connect was developed to help conservation practitioners incorporate connectivity into a Marxan analysis. A standard Marxan workflow does not explicitly consider connectivity in the selection of protected areas. Marxan Connect can facilitate the use of connectivity data by producing connectivity metrics and connectivity strengths prior to running Marxan (Figure 1). These connectivity metrics and linkage strengths are then used as inputs in the standard Marxan workflow.

There are two main ways to incorporate connectivity data into the Marxan work flow:

1) as a conservation feature, and

2) as spatial dependencies between planning units (also see in Box 1).

Here, Scenario 2 and Scenario 3 incorporate connectivity data as a conservation feature into Marxan, while Scenario 4 incorporates connectivity data as spatial dependencies.

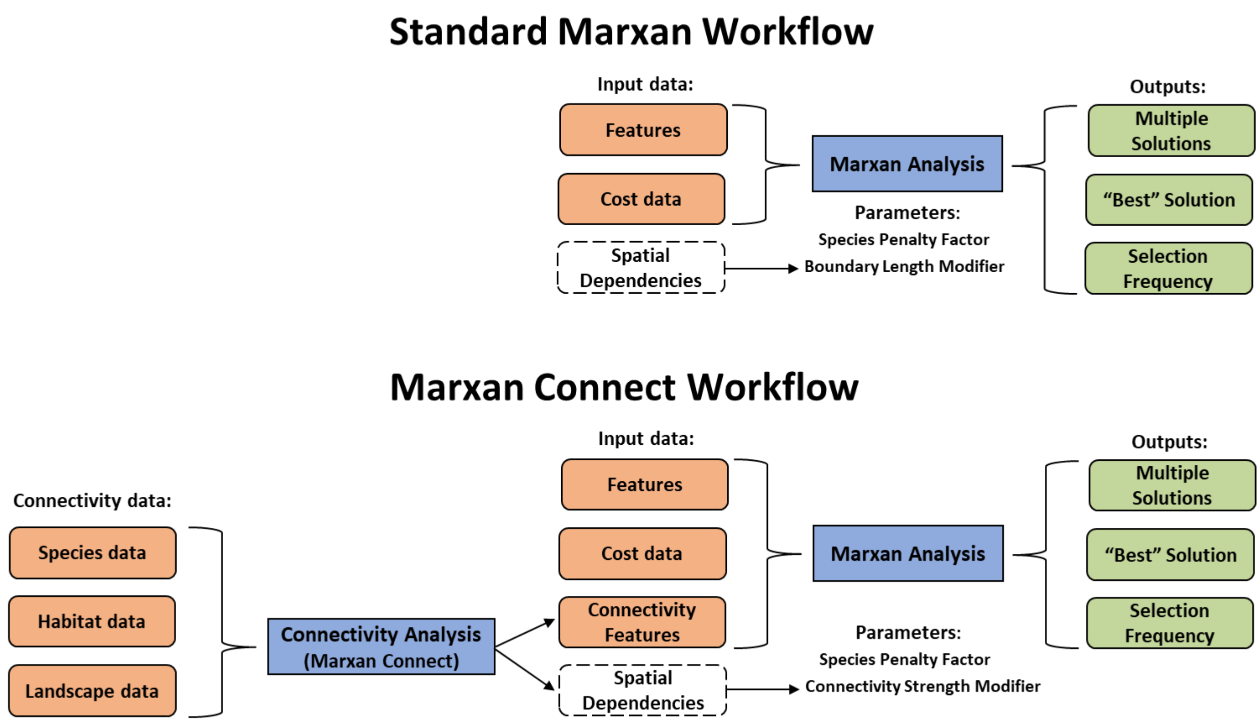
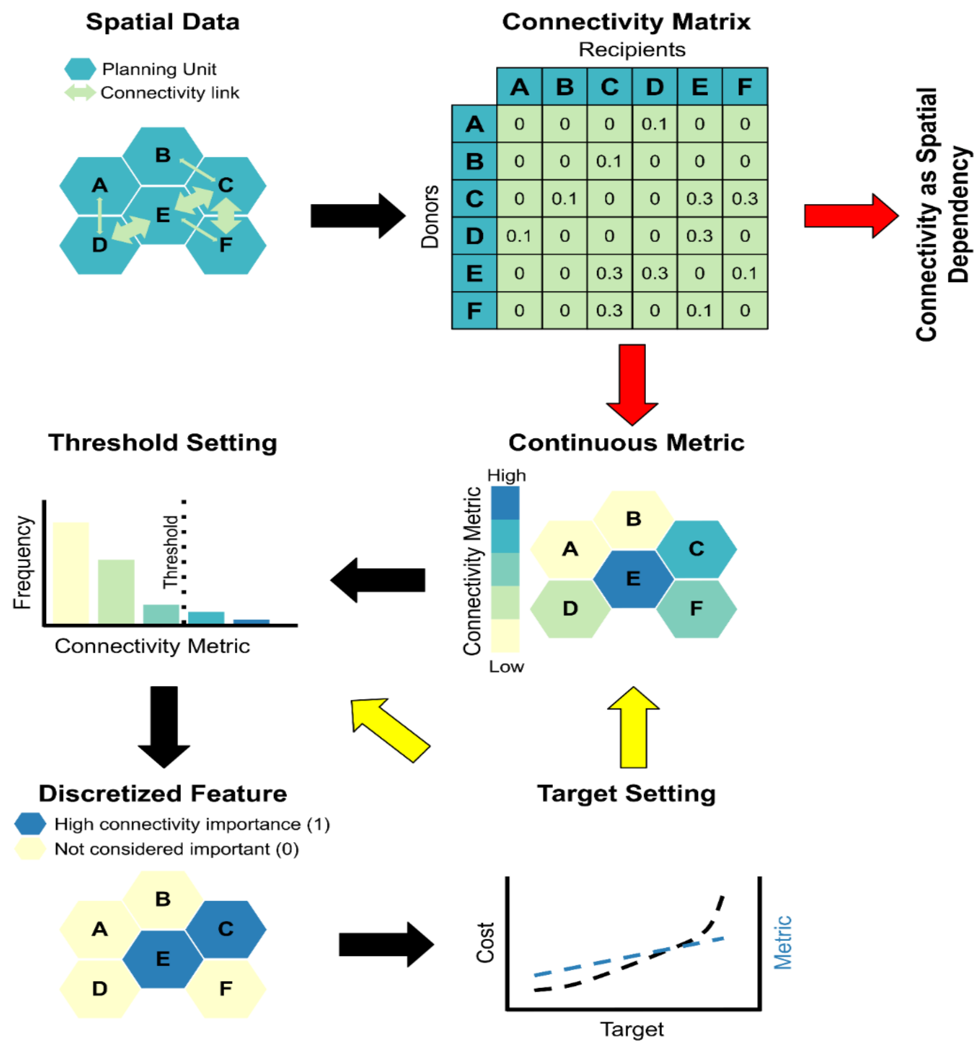


Figure 1. Comparison of workflows between the standard Marxan and Marxan with Connectivity.

Box 1. Incorporating connectivity data into Marxan *(Page 1 of 2)*

There are two primary ways to incorporate connectivity data into the Marxan input files: as a *conservation feature* and as *spatial dependencies* between planning units. The diagram below illustrates the data processing workflow for these two methods.



Data processing workflow for two possible methods for using raw connectivity data in spatial prioritization*: 1) Connectivity as Spatial Dependency in the objective function (Raw Data > Connectivity Matrix > Connectivity as Spatial Dependency), or 2) Discrete conservation features (Raw Data > Connectivity Matrix > Continuous Metrics > Threshold Setting > Discrete Feature > Target Setting).* ***Black*** *arrows indicate a logical workflow, while* ***red*** *and* ***yellow*** *indicate a decision point.* ***Red*** *arrows indicate the conservation feature versus spatial dependency method decision point.* ***Yellow*** *arrows indicate new metric or new threshold decision point after target setting and post-hoc evaluation of conservation success.*

Box 1. Incorporating connectivity data into Marxan *(Page 2 of 2)*

1) Incorporating connectivity as a 'feature'

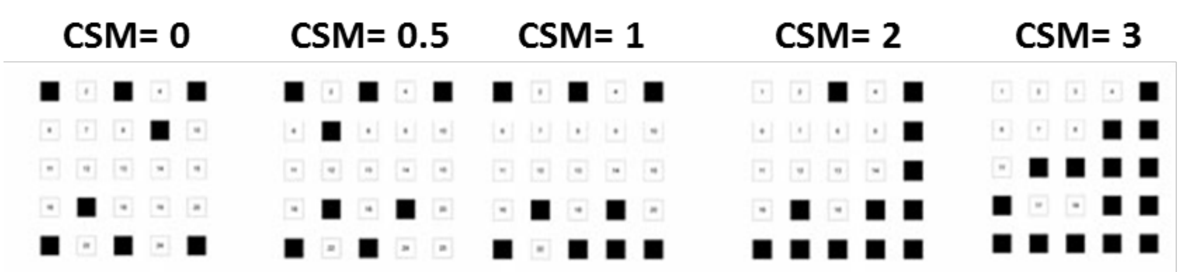
A simple way to integrate connectivity data into Marxan is to create connectivity-based conservation features that are represented in each planning unit. Incorporating connectivity-based conservation features in Marxan Connect requires calculating connectivity metric(s) which represent connectivity process(es). Discrete conservation features are generated based on threshold values set on the range of the continuous metric. Planning units that meet the threshold are then discretised into unique features for which a target is set. For example, you may wish to take only the planning units with a betweenness centrality (a commonly used connectivity metric) value of 0.8 or higher, which are then converted into a discrete (in this case binary) feature (*i.e.,* important areas for connectivity). These discrete connectivity features are then treated as any other feature in Marxan, where a minimum target is set.

Key References:
Álvarez-Romero JG, et al. (2018). *Global Change Biology* 24: e671-e691.
D'Aloia CC, et al. (2017). *Biological Conservation* 216: 93-100.
Magris RA, et al. (2018). *Conservation Letters* 96: e12439.

2) Incorporating connectivity data as 'spatial dependencies' in the objective function

Another approach to incorporate connectivity in Marxan is using the connectivity-based data to inform the boundary cost term in the objective function. This cost signifies the penalty associated with excluding connectivity linkages, which can be manipulated through the Connectivity Strength Modifier (CSM). The CSM is functionally similar to that of the Boundary Length Modifier (BLM) in standard Marxan. For example, increasing the BLM reduces the edge to area ratio by applying a penalty to unprotected boundaries, and increasing the CSM will apply a greater penalty if one planning unit in a well-connected pair of planning units is protected, but not the other. Marxan aims to minimise the penalty associated with unprotected connectivity linkages.

Comparison of varying the "Connectivity Strength Modifier" (CSM) in Marxan when using connectivity data as a spatial dependency. *Increasing the CSM increases the importance of connectivity. Note that CSM = 0 means there is no preference for connectivity (Modified from Beger et al. 2010).*



Key References:
Beger M, et al. (2010). *Conservation Letters* 3: 359-368.
Beger M, et al. (2015) *Nature Communications* 6: 8208

2.2 The Marxan Connect Interface and Tabs

You will begin by exploring the Marxan Connect interface and its workflow tabs, which can be used to preprocess and prepare existing connectivity data for inclusion in Marxan.

2.2.1 Installation

➔ **Step 1:** Ensure that the Marxan Connect app is installed on your computer. On cluster computers, find the app using AppsAnywhere, await validation and click launch. The app should open two separate windows. Ensure that you save the files to the C drive of the computer and extract all the files if they save as a zipped folder.

Note: The latest version of the Marxan Connect installer file is signposted in Minerva, and should be in the C:\MarxanConnect\Install\ MarxanConnect_Installation folder.

➔ **Step 2:** Close the ***"Marxan Connect: Getting Started"*** pop-up window.

➔ **Step 3:** You should now see the interface of the Marxan Connect app. Directly below the menu bar is the workflow tab bar. The tab bar consists of 8 separate workflow tabs, each dedicated to the task named by the tab. Take a few minutes to familiarise yourself with the tabs and the function(s) available in each tab. A brief description of each tab is provided below. Visit http://marxanconnect.ca for additional information.

2.2.2 Spatial Input

The Spatial Input tab (Figure 2) allows users to identify and load their planning units, and optionally focus areas or avoidance areas.

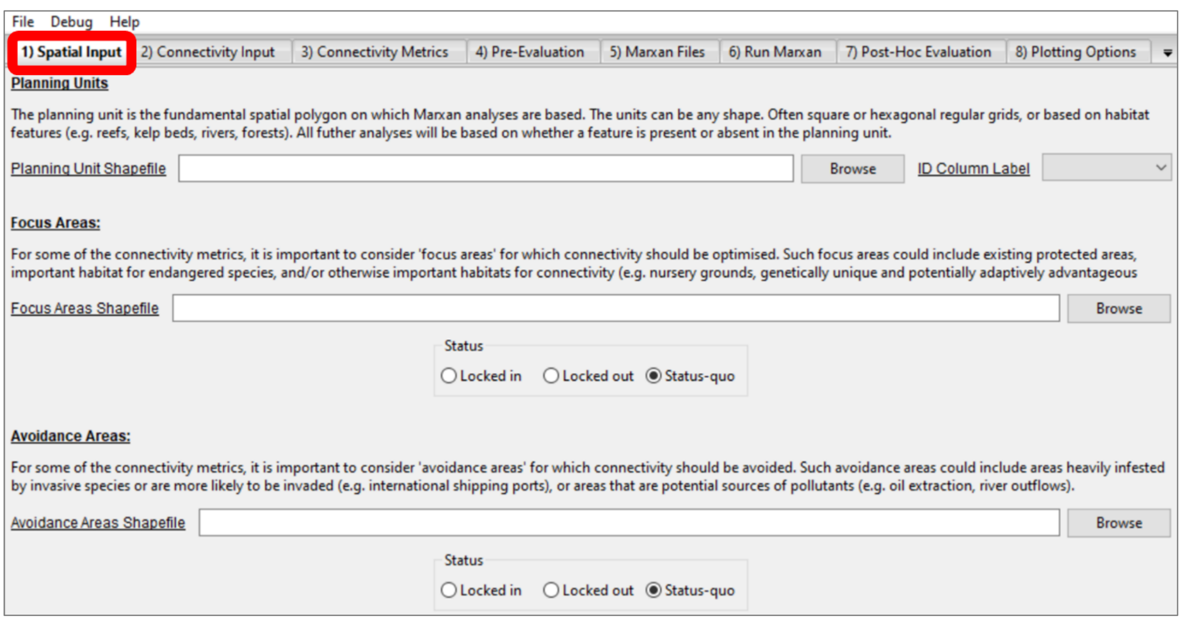


Figure 2. Spatial Input tab.

2.2.3 Connectivity Input

The Connectivity Input tab (Figure 3) allows users to input demographic or landscape-based connectivity data, generate landscape-based connectivity data ("isolation by distance" or "isolation by resistance"), or rescale demographic-based data. Note that rescaling connectivity data can be problematic, and it is recommended to collect or generate connectivity data to the scale of the planning units.

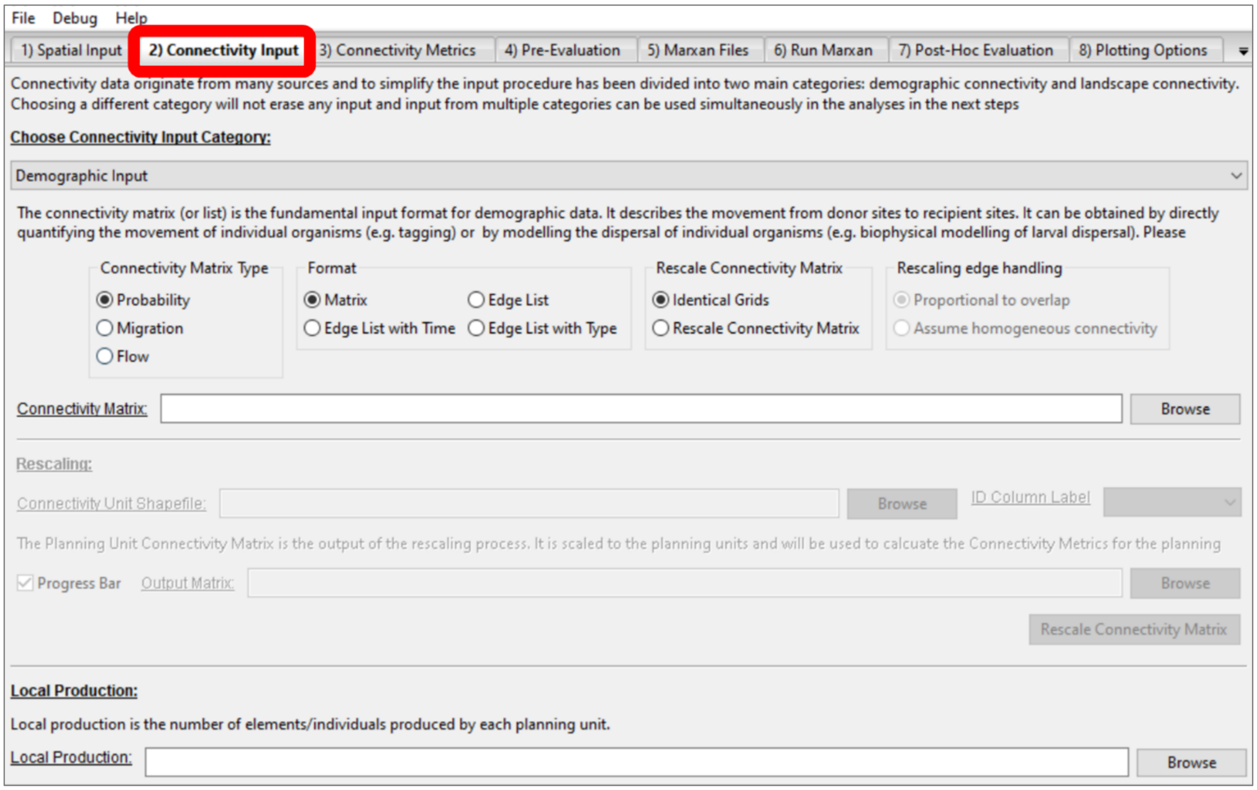


Figure 3. Connectivity Input tab

Note: While Marxan Connect provides some tools to generate connectivity data, no single tool, tutorial, or manuscript can cover this field comprehensively. Connectivity data can be derived from a wide variety of sources (particle tracking models, genetic analyses, landscape models, tagging data, etc.) and requires local connectivity expertise. Thus, projects involving connectivity objectives and datasets should work in collaboration with connectivity experts who already possess expertise in their specific domain.

2.2.4 Connectivity Metrics

The Connectivity Metrics tab (Figure 4) allows users to select which connectivity metrics to calculate. It is dependent on the type of connectivity data imported on the previous tab.

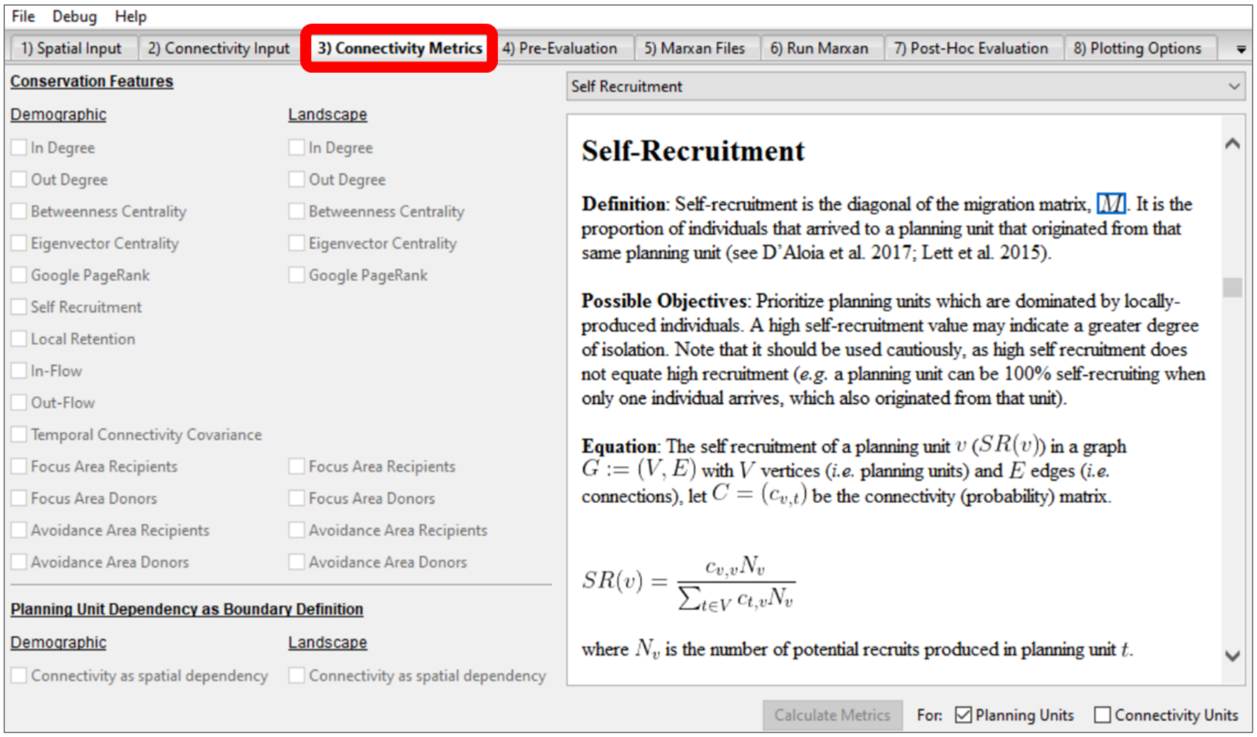


Figure 4. Connectivity Metrics tab.

> **Note:** There are a number of metrics that can be used for both landscape and demographic data. You can find definitions and examples of available connectivity metrics under the Connectivity Metrics tab. The choice of metric will depend on the connectivity data and the conservation objectives and should be made in consultation with a connectivity expert.

2.2.5 Pre-Evaluation

The Pre-Evaluation tab (Figure 5) allows users to modify (*i.e.* discretise), plot, and remove connectivity metrics calculated on the previous tab (*i.e.*, the Connectivity Metrics tab).

> **Note:** No action is required in the Pre-Evaluation tab for the spatial dependencies calculated using the "connectivity as boundary" option in the previous tab. However, if users want to include connectivity as a conservation feature, they will need to evaluate each of these metrics before moving on.

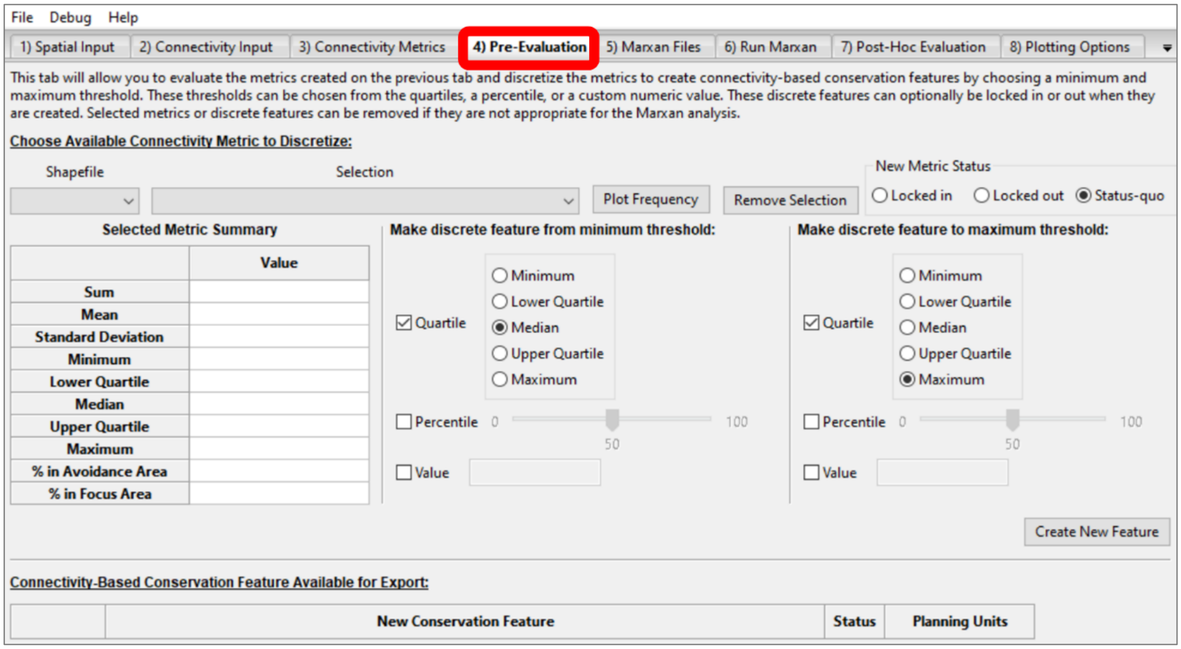


Figure 5. Pre-Evaluation tab

2.2.6 Marxan Files

The Marxan Files tab (Figure 6) allows users to append, export, or ignore discrete connectivity metrics, spatial dependencies and the planning unit status to Marxan formatted files.

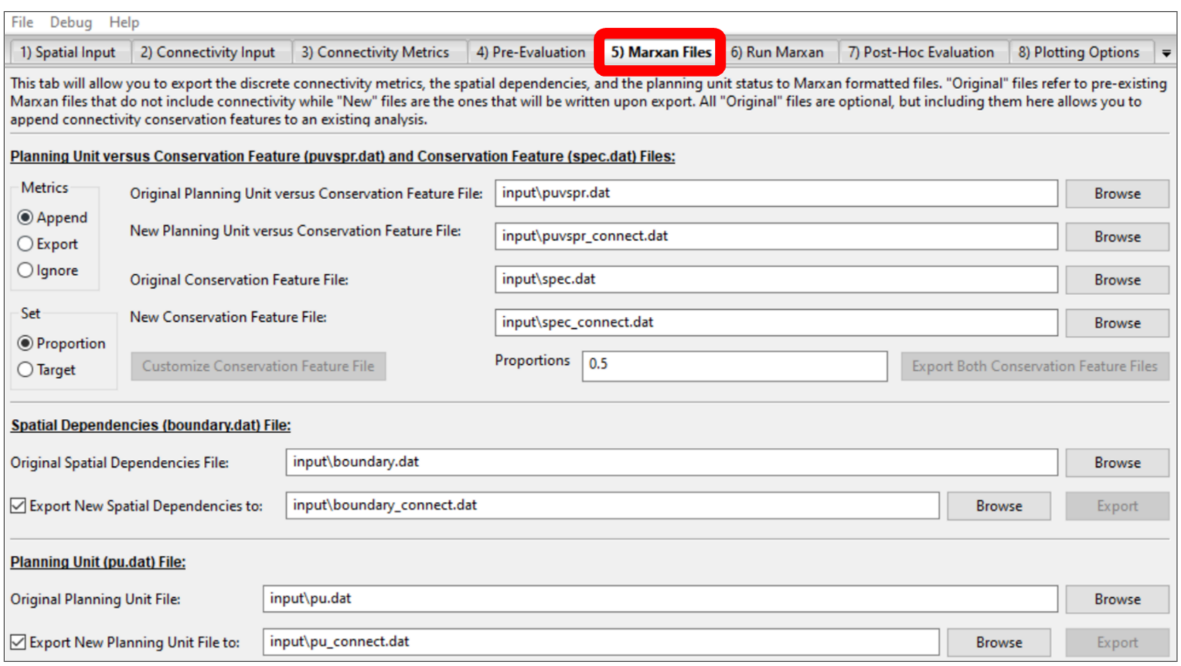


Figure 6. Marxan Files tab

2.2.7 Run Marxan

The Run Marxan tab (Figure 7) allows users to run the Marxan.exe (Figure 8) from within Marxan Connect.

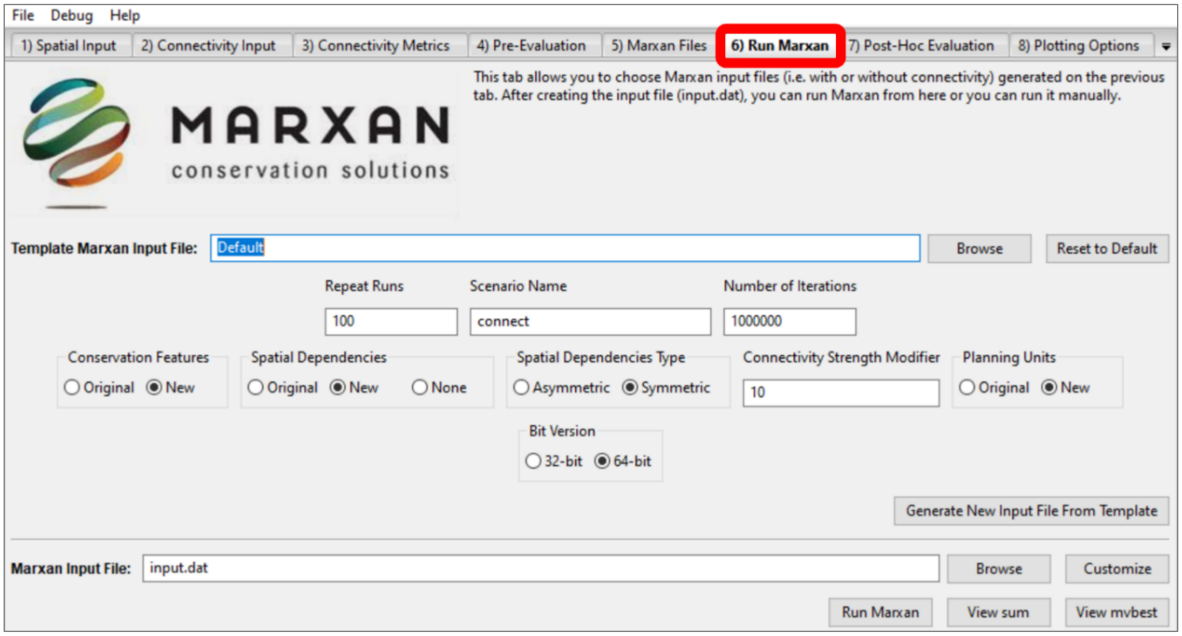
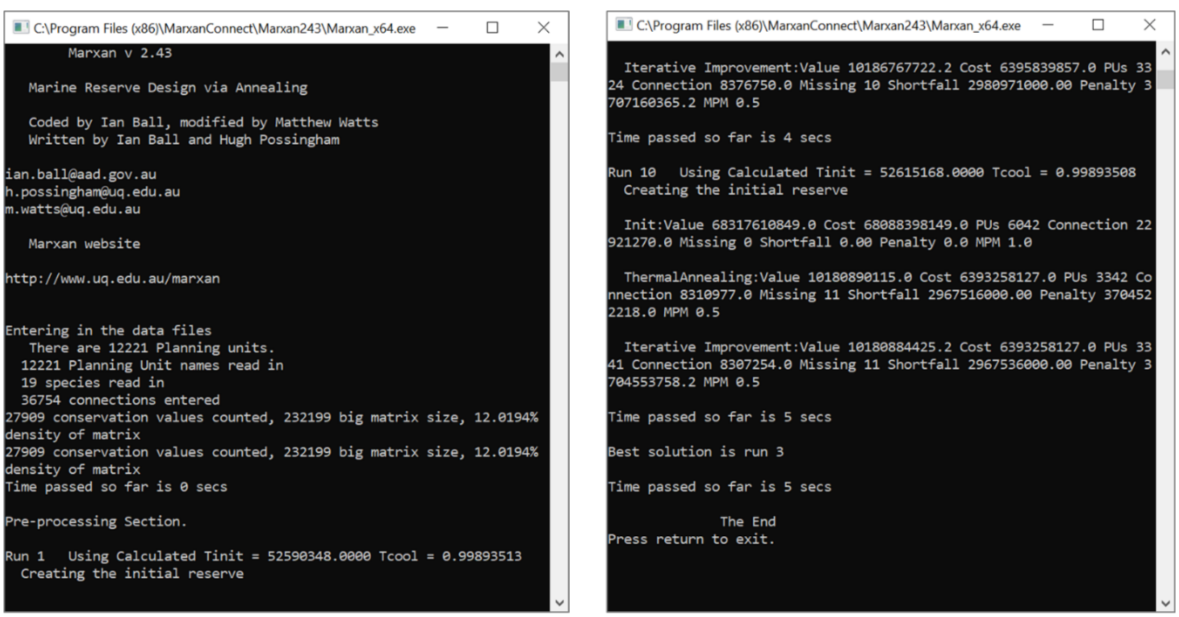


Figure 7. Run Marxan tab



Top portion of window | **Bottom portion of window**

Figure 8. Marxan.exe window

2.2.8 Post-Hoc Evaluation

The Post-Hoc Evaluation tab (Figure 9) includes several useful functions and can be used to interpret outputs of Marxan (individual solutions, the best solution, and the selection frequency). Table 1 defines the post-hoc parameters that can be used to interpret Marxan outputs. It also identifies which parameters require connectivity data.

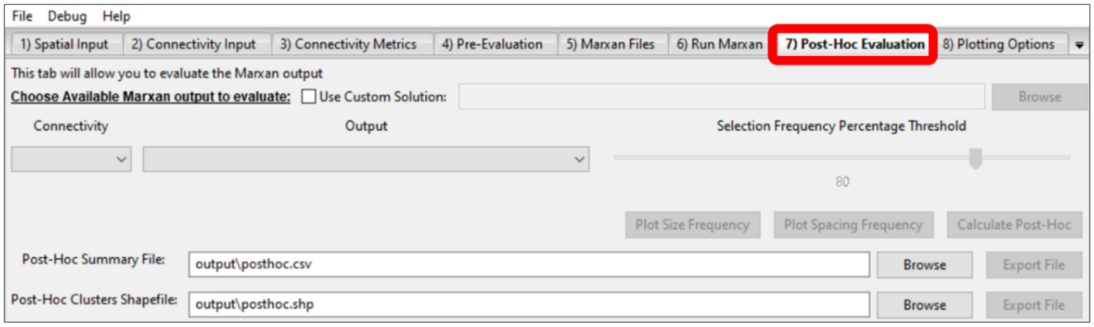


Figure 9. Post-Hoc Evaluation tab

Table 1. Definitions for post-hoc parameters

Parameter	Connectivity required?	Description
Planning Units	No	The number of planning units included in the solution.
Clusters	No	The number of contiguous selected areas (i.e. merged planning units).
Mean Size (km^2)	No	The mean size (km^2) of clusters.
Min Size (km^2)	No	The area (km^2) of the smallest cluster.
Mean Nearest (km)	No	The mean distance between each pair of nearest neighbour clusters. The distance is calculated from the outer boundaries of the clusters.
Max Nearest (km)	No	The distance between the furthest pair of nearest neighbour clusters. Distance is calculated from the outer boundaries of clusters.
ProtConn (10km)	No	The proportion of clusters that have another cluster within 10 km.
ProtConn (50km)	No	The proportion of clusters that have another cluster within 50 km.
ProtConn (150km)	No	The proportion of clusters that have another cluster within 150 km.
Fragmentation	No	The network-wide fragmentation as measured by the square root of the sum of the cluster perimeters squared divided by the sum of the cluster areas (sqrt(∑Perimeters^2/∑Areas).
Connections	Yes	Number of connections (i.e. edges) between selected planning units.
Graph Density	Yes	The ratio of the number of connections (i.e. edges) between selected planning units and the number of possible connections (i.e. edges) between selected planning units.
Eigenvalue	Yes	A matrix algebra metric that indicates the evolution of a system. In a flow matrix that includes survival and mortality, the eigenvalue is equal to the metapopulation growth rate. Eigenvalues should only be used to compare different scenarios using the same connectivity data.

Once a Post-Hoc Evaluation is run, a table will appear in the tab window with the post-hoc calculations. The first column of the table lists the post-hoc parameters (see Table 1). The column headings are described in Table 2.

Table 2. Description of post-hoc table headings

Table heading	Description
Parameter	Indicates the post-hoc parameter.
Type	Indicates the connectivity-based features (*e.g.*, ALL, FEAT_1, FEAT_2, etc.). This column is only present when there are *multiple* connectivity-based features.
Planning Area	Calculations based on entire study region.
Solution	Calculations based on selected planning units.
Percent	Percentage calculations (Solution ÷ Planning Area × 100).

Figure 10 includes 3 examples of post-hoc tables.

- Example (1) is from a Marxan run with no connectivity data. As such, post-hoc parameters that require connectivity (Connections, Graph Density and Eigenvalue) do not appear in the table.
- Example (2) has a single connectivity-based feature and calculations for Connections, Graph Density and Eigenvalue parameters (post-hoc parameters requiring connectivity) are present in the table.
- Example (3) has multiple connectivity-based features (FEAT_1, FEAT_11, and FEAT_16) and calculations for Connections, Graph Density and Eigenvalue parameters are generated for each of them.

1) Post-hoc evaluation without connectivity data

	Planning Area	Solution	Percent
Planning Units	12221	3422	28.0
Clusters		567	
Marxan Score		16432178084	
Mean Size (km^2)		24.14	
Min Size (km^2)		4.0	
Mean Nearest (km)		1.87	
Max Nearest (km)		11.84	
ProtConn (10 km)		1.0	
ProtConn (50 km)		1.0	
ProtConn (150 km)		1.0	
Fragmentation		109.15	

2) Post-hoc evaluation with one connectivity-based feature

	Planning Area	Solution	Percent
Planning Units	12221	3427	28.04
Clusters		551	
Marxan Score		16557683688	
Mean Size (km^2)		24.88	
Min Size (km^2)		4.0	
Mean Nearest (km)		1.81	
Max Nearest (km)		8.61	
ProtConn (10 km)		1.0	
ProtConn (50 km)		1.0	
ProtConn (150 km)		1.0	
Fragmentation		109.94	
Connections	6880545	508686	7.39
Graph Density	0.046073	0.043326	94.04
Eigenvalue	0.57	0.2	35.58

3) Post-hoc evaluation with multiple connectivity-based features

	Type	Planning Area	Solution	Percent
Planning Units	All	12221	6111	50.0
Clusters	All		482	
Marxan Score	All		31838636010	
Mean Size (km^2)	All		50.71	
Min Size (km^2)	All		4.0	
Mean Nearest (km)	All		1.58	
Max Nearest (km)	All		7.55	
ProtConn (10 km)	All		1.0	
ProtConn (50 km)	All		1.0	
ProtConn (150 km)	All		1.0	
Fragmentation	All		111.96	
Connections	FEAT_1	18031	6150	34.11
Graph Density	FEAT_1	0.000121	0.000165	136.42
Eigenvalue	FEAT_1	0.79	0.7	88.99
Connections	FEAT_11	188207	45650	24.26
Graph Density	FEAT_11	0.00126	0.001223	97.01
Eigenvalue	FEAT_11	-0.03	0.68	-2144.45
Connections	FEAT_16	23479	7442	31.7
Graph Density	FEAT_16	0.000157	0.000199	126.78
Eigenvalue	FEAT_16	0.75	0.46	61.2

Figure 10. Examples of post-hoc tables

2.2.9 Plotting Options

The Plotting Options tab (Figure 11) allows users to plot connectivity metrics and Marxan results. It can export maps and shapefiles that contain those connectivity metrics and Marxan results. Maps generated here are displayed on a separate tab, the Plot tab.

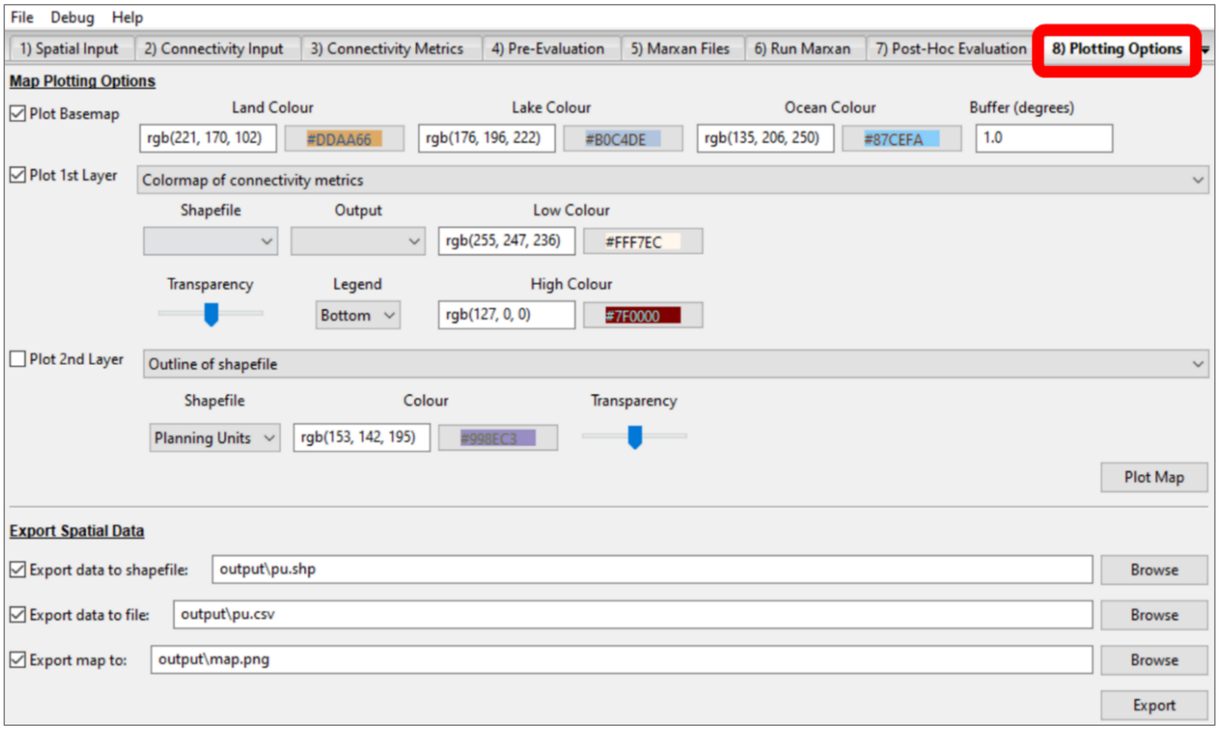


Figure 11. Plotting Options tab

2.2.10 Plot

The Plot tab (Figure 12) allows users to visualise graphs and maps generated in other tabs. Note that the tab will only appear after the first graph or map has been generated.

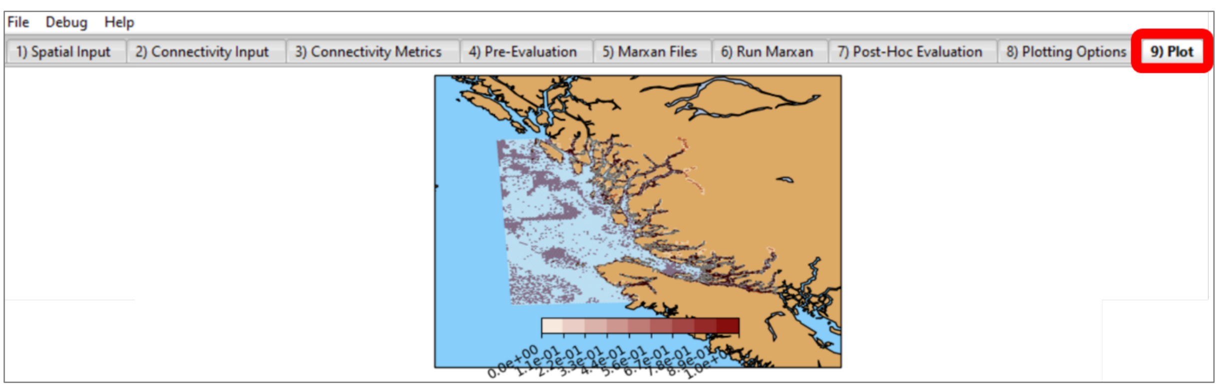


Figure 12. Example of a Marxan output displayed on the Plot tab

3 Introduction to the Conservation Problem

3.1 Goals and Objectives

All scenarios are based on a hypothetical case study for planning a marine protected area (MPA) network off the coast of British Columbia, Canada. You will be tasked with designing a well-connected, ecologically representative, and spatially efficient MPA network with minimal impacts to commercial fisheries. In working towards this goal, you have chosen to use the Marxan Connect app, along with the Marxan software, to identify potential MPA configurations that:

- achieve conservation targets to protect at least 30% of each conservation feature of interest in the study region;
- minimise the overall cost for commercial fisheries; and
- contain well-connected sites that are most important to connect the system.

All scenarios share the same objectives and rely on the same spatial datasets (conservation features and cost data). However, they use different approaches and types of connectivity data (if any) to address connectivity criteria.

3.2 Spatial Data Exploration

You will start by examining the spatial data files that underpin the scenarios. You have spatial data on the distribution of 19 conservation features, which are listed and described in Table 3. You also have spatial data on fisheries catches (Table 4), which you will use as the planning unit cost layer. Given that fishing will be restricted in the MPA network, this dataset will act as a surrogate for predicted impacts on fisheries from establishing new MPAs. Your assumption here is that including areas with high catch values in MPAs will be more costly for fisheries than protecting areas with low catch values.

Spatial datasets on conservation features and commercial fisheries were acquired from the British Columbia Marine Conservation Analysis (www.bcmca.ca).

Table 3. Conservation features

ID	FEAT_ID*	Target	Name	Measure	Description
1	1	0.3	0-20 Hard	Area/PU (in m^2)	Benthic habitat class defined based on depth (m) and substrate type
2	2	0.3	0-20 Muddy	""	""
3	3	0.3	0-20 Sandy	""	""
4	4	0.3	20-50 Hard	""	""
5	5	0.3	20-50 Muddy	""	""
6	6	0.3	20-50 Sandy	""	""
7	7	0.3	200+ Hard	""	""
8	8	0.3	200+ Muddy	""	""
9	9	0.3	200+ Sandy	""	""
10	10	0.3	200+ UnID**	""	""
11	11	0.3	50-200 Hard	""	""
12	12	0.3	50-200 Muddy	""	""
13	13	0.3	50-200 Sandy	""	""
14	14	0.3	50-200 UnID**	""	""
15	15	0.3	IBA		Important bird areas (IBAs)
16	16	0.3	Kelp		Distribution of 3 kelp species
17	17	0.3	Killer Whales		Important areas for Killer whale
18	18	0.3	Sea Lions		Steller Sealions rockeries and haulouts
19	19	0.3	Sea Otters		Important sea otter habitat

*Headings used in pulayer_BC_marine_hx_conservationfeats.shp

**UnID= Unidentified substrate

Table 4. ***Planning unit cost***

Name	Measure	Description
cost	Mean annual fisheries catch	Combined mean annual catch for three fisheries occurring in the area (sablefish longline, groundfish trawlers, and rockfish hook and line) and planning unit area. Fisheries data were log-transformed to normalize the data distribution. The log-transformed fisheries data were then added together to obtain a total catch measure for all fisheries. The cost based on fisheries catch and area was then estimated using the formula in Stewart and Possingham (2005).

To explore the dataset, follow these steps:

➔ **Step 1:** In your file directory, navigate to C:\MarxanConnect\Data\GIS_data. Open the ArcMap project ArcMap_data.mxd or the QGIS project QGIS_data.qgs.

➔ **Step 2:** Briefly explore the following shapefiles below. Note, you may need to repair the data source of the shapefiles, which are located in the C:\MarxanConnect\Data\GIS_data folder.

- Study_Region_BC_Ocean.shp: The marine extent of the study region.
- Study_Region_BC_Land.shp: The land extent of the study region.
- pulayer_BC_marine_hx.shp: The planning unit layer, comprised of 12,221 hexagonal planning units (each 4 km^2 in size), and covers the marine extent of the study region.
- pulayer_BC_marine_hx_conservationfeats.shp: The planning unit layer with attribute information on 19 conservation features.
- pulayer_BC_marine_hx_cost.shp: The planning unit layer with attribute information on cost values for commercial fisheries.

➔ **Step 3:** Right click on pulayer_BC_marine_hx.shp and open the "Attribute Table". Note that the "PUID" field indicates the unique ID of each planning unit. There are 12,221 entries in this field, corresponding to the total number of planning units across the study region.

➔ **Step 4:** Open the "Attribute Table" for pulayer_BC_marine_hx_conservationfeats.shp. Again, the "PUID" field lists the unique ID of each planning unit. The additional 19 fields (headings from "FEAT_1" to "FEAT_19") correspond to the 19 conservation features listed in Table 3. The values indicate the amount (area coverage in m^2) of each conservation feature contained in each planning unit.

➔ **Step 5:** Open the "Attribute Table" on pulayer_BC_marine_hx_cost.shp. Note that this table has the same content as a planning unit file (pu.dat) in a Marxan database. It contains information on the cost (combined catch values from 3 commercial fisheries) and the status of each planning unit.

3.3 Marxan Database Exploration

You will now manually inspect the Marxan database that underpin the Scenarios in this guide, including the standard set of input files required to run Marxan. The C:\MarxanConnect\Scenarios folder contains the Marxan databases for all Scenarios, as well as a default database. The Marxan_database folder is the default database. The spatial data files you examined in Section 3.2, along with a Marxan plugin (for ArcGIS or QGIS), were used to create the input files in this database. Take a few minutes to explore the Marxan_database folder.

➔ **Step 1:** In your file directory, browse to the C:\MarxanConnect\Scenarios folder. This folder contains the Marxan_database folder, along with separate database folders for Scenario 1 (Sc1), Scenario 2 (Sc2), Scenario 3 (Sc3), and Scenario 4 (Sc4).

➔ **Step 2:** Open the Marxan_database folder. Take note of the organization of the Marxan database: the input folder, the output folder, the pu folder (i.e., the Planning Unit folder), the input.dat file, and the Marxan.exe application.

➔ **Step 3:** Open the pu folder. Note that it contains the planning unit shapefile (pulayer_BC_marine_hx.shp) you examined in Section 3.2.

➔ **Step 4:** Go back to the Marxan_database folder. Open the input folder to view the standard set of input files (spec.dat, puvsp.dat, bound.dat, and pu.dat) required to run Marxan.

➔ **Step 5:** Open the planning unit file (pu.dat) in Notepad or Excel. This file lists all the planning unit IDs. For each planning unit, it indicates the cost (values reflect the cost for commercial fisheries) and status (“0” = planning unit available for selection in a Marxan run).

Note: The species penalty factor (SPF) is critical to getting good results. If the SPF values are very small (relative to the boundary length modifier and planning unit costs), then the “lowest cost” solution could miss achieving several targets (the costs of selecting additional planning units is greater than the small penalties for missing conservation targets). If the SPF values are too high, then the simulated annealing algorithm may not be able to explore as many options in the solution process, resulting in fewer different solutions with higher average costs. Hence, SPF values must be chosen so that penalties for missing conservation targets are scaled appropriately and relative to each other. See Section 8.3 of the Marxan Good Practice Handbook for more information about calibrating SPF values.

➔ **Step 6:** Next, open the feature file (spec.dat). This file lists 19 conservation features. For each feature, it indicates the corresponding unique id, name, targets, and species penalty factor (SPF) to be applied if the target is not met. Given that your target is to represent a least 30% of each conservation feature in MPAs, all targets are set to “0.3”. Note that targets are set as proportions in the “prop” field, rather than absolute amounts in the “target” field. It is also important to note that the SPF is set to “50”, rather than the default setting of “1”. This higher SPF value was set here to drive Marxan to find solutions that meet all of the set conservation targets.

➔ **Step 7:** Open the planning unit versus feature file (puvsp.dat), which lists the conservation feature IDs (in the "species" field), planning unit IDs (in the "pu" field), and the amount of each feature in each planning unit (in the "amount" field).

➔ **Step 8:** Open the boundary length file (bound.dat), which indicates the spatial relationship between planning units. The file lists every pair of planning units (fields "id1" and "id2"), and a measurement (the length of the shared boundary between two adjacent planning unit) that represent the spatial relationship between each pair under the "boundary" field.

> ***Note:*** A key component of any Marxan application is the calibration process, which involves calibrating the main parameters for running Maran: 1) the number of iterations (NUMITNS), 2) the number of restarts (NUMREP), 3) the species penalty factor (SPF), and 4) the boundary length modifier (BLM). As stated in the Marxan Good Practice Handbook (Ardron et al., 2010), good practice dictates that these parameters need to be calibrated for every change in the problem being solved. For example, users should perform a calibration check following changes to conservation targets or the BLM.
>
> For the purpose of this practical, the main parameters have been pre-set to save time. Moreover, the NUMITNS and NUMREP are set to low values to minimize processing time. If this were a real-world application of Marxan (it is not!), the values for the main parameters would need to be revised following proper calibration procedures. See Section 8.3 of the Marxan Good Practice Handbook for more information regarding calibration procedures.

➔ **Step 9:** Go back to the Marxan_database folder and open the input parameter file (input.dat). This file defines many of the parameters that control the way that Marxan works. It tells Marxan where to find the input files and where to save the output files. Note that the Boundary Length Modifier (BLM) is set to "10", NUMREPS to "10", NUMITNS to "1000000", and MISSLEVEL to "1". Recall that the BLM controls the clustering and compactness of individual solutions. The BLM value here has been increased from a default setting of "0" to "10" to produce more "clumped" solutions (*i.e.*, to avoid "scattered" solutions).

➔ **Step 10:** When you are done exploring the database, make sure to exit/close all the files you opened in this section.

4 Scenario 1: Running Marxan Connect and Interpreting Results

4.1 About Scenario 1

For this first scenario, you will be using the Marxan Connect app to set up and run a standard Marxan analysis without any connectivity data. Your task is to identify potential MPA network configurations for the BC study region that:

- protect at least 30% of each conservation feature;
- minimise the overall cost for commercial fisheries; and
- promotes connectivity between MPAs, which is the case if the network addresses set “rules of thumb” for MPA size and spacing.

You do not have access to any connectivity data for this scenario. The absence of connectivity data is a common problem in conservation planning. In response, conservation practitioners often use “rules of thumb” for MPA sizing and spacing to address connectivity concerns in conservation planning (see Box 3 on page 33). Here, you will use “rules of thumb” for MPA sizing and spacing to evaluate the Marxan outputs within the optional Post-Hoc Evaluation tab in Marxan Connect. Note that this is a “post-hoc” approach for addressing connectivity considerations in spatial planning.

4.2 Marxan Database for Scenario 1

The Marxan database for Scenario 1 is the Sc1 folder, located in C:\MarxanConnect\Scenarios folder. The database for Scenario 1 is the same as the default database you examined in Section 3.3 (*i.e.*, Sc1 and Marxan_database folders are identical).

➔ **Step 1:** In your file directory, navigate to the C:\MarxanConnect\Scenarios folder. Make a copy of the Sc1 folder and name it “Sc1_1”. Remember, it is good practice to have a backup for each Scenario you run!

➔ **Step 2:** Open the new Sc1_1 folder. Briefly explore the standard input files, along with the input.dat file. Recall that the SPF is set to “50” for all features and the BLM is set to “10”.

➔ **Step 3:** While exploring the Marxan database for Scenario 1, take note that there are no files relating to connectivity, as you do not have access to connectivity data for this scenario.

4.3 Set Up and Run Marxan Connect without Connectivity Data

You are now ready to set up and run your first Marxan scenario using the Marxan Connect app and the Marxan database for Scenario 1. As previously stated, you will be running Marxan Connect without any connectivity data. Accordingly, you will not use any of the following tabs associated with connectivity data: Connectivity Input, Connectivity Metrics, and Pre-Evaluation.

4.3.1 Create a New Project

- ➔ **Step 1:** If you have not done so already, open the Marxan Connect app.
- ➔ **Step 2:** In the ***"File"*** menu, click on ***"Save Project"***. Navigate to the Sc1_1 folder and save a new project under the file name, "Sc1_1".

4.3.2 Spatial Input

You will now import the planning unit shapefile in the Spatial Input tab.

- ➔ **Step 1:** Open the ***"1) Spatial Input"*** tab.
- ➔ **Step 2:** Next to the ***"Planning Unit Shapefile"*** field, click the ***"Browse"*** button. Browse and open the planning unit shapefile (pulayer_BC_marine_hx.shp) in the pu folder corresponding to the Marxan database for Scenario 1.
- ➔ **Step 3:** Set the ***"ID Column Label"*** to ***"PUID"***.
- ➔ **Step 4:** Ensure that the tab looks like Figure 13 before proceeding to the next tab.

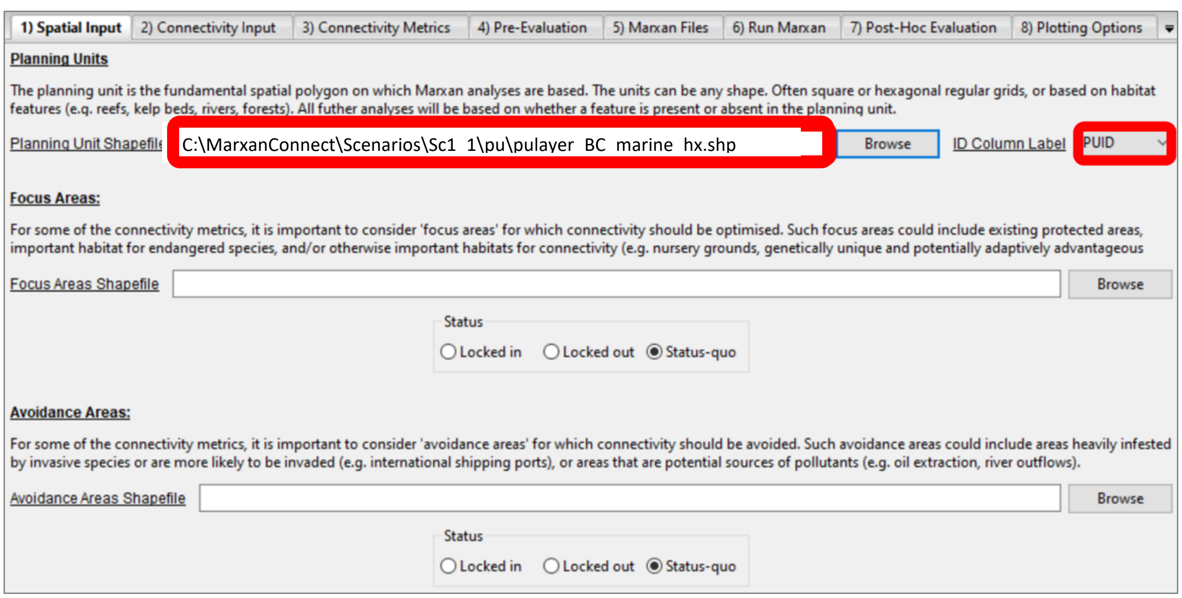


Figure 13. Spatial Input tab for Scenario 1

4.3.3 Marxan Files

You will now skip ahead to the Marxan Files tab. Typically, this tab allows users to export new connectivity metric features to Marxan input files. However, this scenario has no connectivity data, so you do not need to deal with any "new" input files. All you need to do is load the "original" files (pre-existing Marxan files) that do not include connectivity.

> ***Note:*** There are fields in the Marxan Files tab that are completed by defaults. Please ignore them and make sure to browse for the files needed for this scenario

➔ **Step 1:** Open the ***"5) Marxan Files"*** tab.

The first panel is the ***"Planning Unit versus Conservation Features (puvspr.dat) and Conservation Features (spec.dat) Files"*** panel. You will use this panel to import the puvsp.dat and spec.dat files for Scenario 1. For this scenario, you will not use the ***"Customize Conservation Feature File"*** button and the ***"Proportions"*** text box, as these functions relate to setting "connectivity" targets.

➔ **Step 2:** In the ***"Metrics"*** panel (left side of window), select ***"Ignore"*** to avoid exporting connectivity-based conservation features.

➔ **Step 3:** By the ***"Original Planning Unit versus Conservation Feature File"*** option, click the ***"Browse"*** button and open the puvsp.dat file for this Scenario.

➔ **Step 4:** Leave the ***"New Planning Unit versus Conservation Feature File"*** blank. In other words, you may need to delete the content in this field if it appears completed by default.

➔ **Step 5:** For the "***Original Conservation Feature File"*** option, browse and open the spec.dat file.

➔ **Step 6:** Leave the ***"New Conservation Feature File"*** blank. You may need to delete the content in this field if it appears completed by default.

➔ **Step 7:** In this scenario, you will leave the ***"Proportions"*** text box blank.

➔ **Step 8:** Check that your ***"Planning Unit versus Conservation Features (puvspr.dat) and Conservation Features (spec.dat) Files"*** panel look like Figure 14.

You can now move on to the second panel, ***"Spatial Dependencies (boundary.dat) File"***, where you will input the bound.dat file for Scenario 1.

➔ **Step 9:** For the ***"Original Spatial Dependencies File"*** option, browse and open the bound.dat file.

➔ **Step 10:** Unselect the **"*Export New Spatial Dependencies to*"** option box and keep it blank.

Finally, use the ***"Planning Unit (pu.dat) File"*** to input the pu.dat file for this scenario.

➔ **Step 11:** Browse and open the pu.dat file for the ***"Original Planning Unit File"*** option.

➔ **Step 12:** Unselect the ***"Export New Planning Unit File to"*** option box and keep it blank.

➔ **Step 13:** Ensure that your tab looks like Figure 14, before moving onto the next tab.

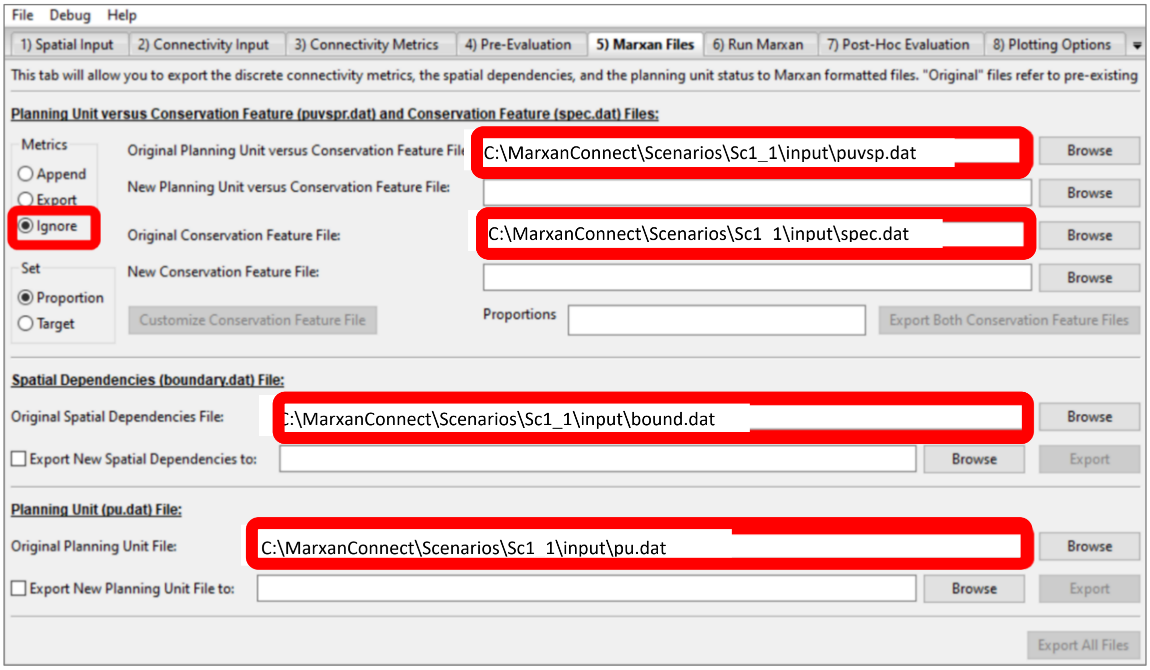


Figure 14. Marxan Files tab for Scenario 1

4.3.4 Run Marxan

You will now proceed to the **Run Marxan** tab. You will use this tab to load the input file (input.dat) and to run Marxan.

Note: You already have an input.dat file prepared here, so you do not need to generate a new input file using the template in the top portion of the tab window.

➔ **Step 1:** Open the ***"6) Run Marxan"*** tab.

➔ **Step 2:** Near the bottom of the tab window, click the ***"Browse"*** button next to the ***"Marxan Input File"*** option. Browse and open the input.dat file in the Marxan database folder in Sc1_1.

➔ **Step 3:** You are finally ready to run Marxan! Click the ***"Run Marxan"*** button to run the software. If a warning pop-up window appears (Figure 15), click ***"OK"***.

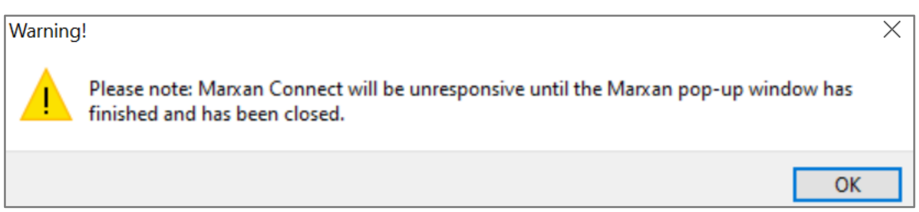


Figure 15. Warning pop-up window

➔ **Step 4:** You should now see the Marxan application window displaying information as Marxan completes its run (see an example of Marxan.exe window in Figure 8). When Marxan has completed its run (displays the text "The End"), exit the window.

Note: If you encounter an error while running Marxan, there is probably an issue with the input files or with the set up of the app.

4.4 Interpretation of Results for Scenario 1

You will now investigate the results of the Marxan run using the following tabs:

- *Run Marxan tab:* You will use this tab to view the "mvbest" and "sum" tables (see note box below for more information) to identify whether all conservation targets were met in the best solution and across all 10 solutions.
- *Plotting Options and Plot tabs:* You'll use these two tabs to plot and visualise the Best Solution and the Selection Frequency, which are key Marxan outputs that are often used to facilitate conservation planning.
- *Post-Hoc Evaluation tab*: You'll use this tab, along with "rules of thumb" for MPA spacing and sizing (see Box 3 on page 33), to determine whether the best solution contains well-connected sites that are important to the network.

Note: The **Summary Information** file (output_sum.csv or output_sum.txt) contains summary information for each repeat run. The first column indicates the run number. The "Missing_values" column (second to last column) shows the number of conservation features that did not achieve their target in the final solution for that run.

The **Missing Values for the Best Solution** file (output_mvbest.csv or output_mvbest.txt) contains information about the representation of conservation features for the Best Solution (i.e., the run that produced the solution with the best objective value). The file consists of nine columns which report on how the Best Solution performed relative to the targets. The "Target Met" column identifies whether targets set for that feature are met ("yes") or not ("no").

4.4.1 Interpret Results Using the Run Marxan Tab

You'll begin by investigating two Marxan outputs: the Summary Information ("sum") and the Missing Values for the Best Solution ("mvbest"). These outputs are files (TXT or CSV format) that appear in the output folder of the Marxan database after running Marxan. As you will soon discover, these files can be viewed as tables in the Run Marxan tab.

You'll look at the Summary Information report first.

➔ **Step 1:** To open the summary report, click on the ***"View sum"*** button at the bottom right corner of the ***"6) Run Marxan"*** tab window. The summary information table (Figure 16) will appear in a pop-up window.

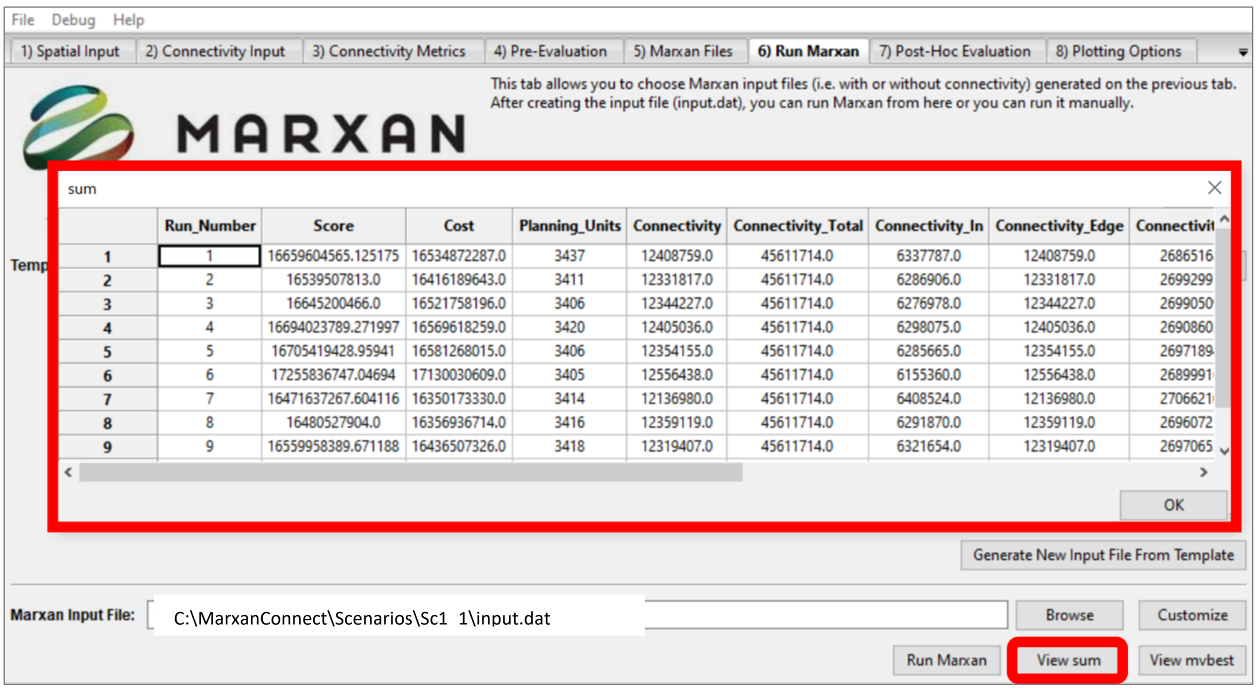


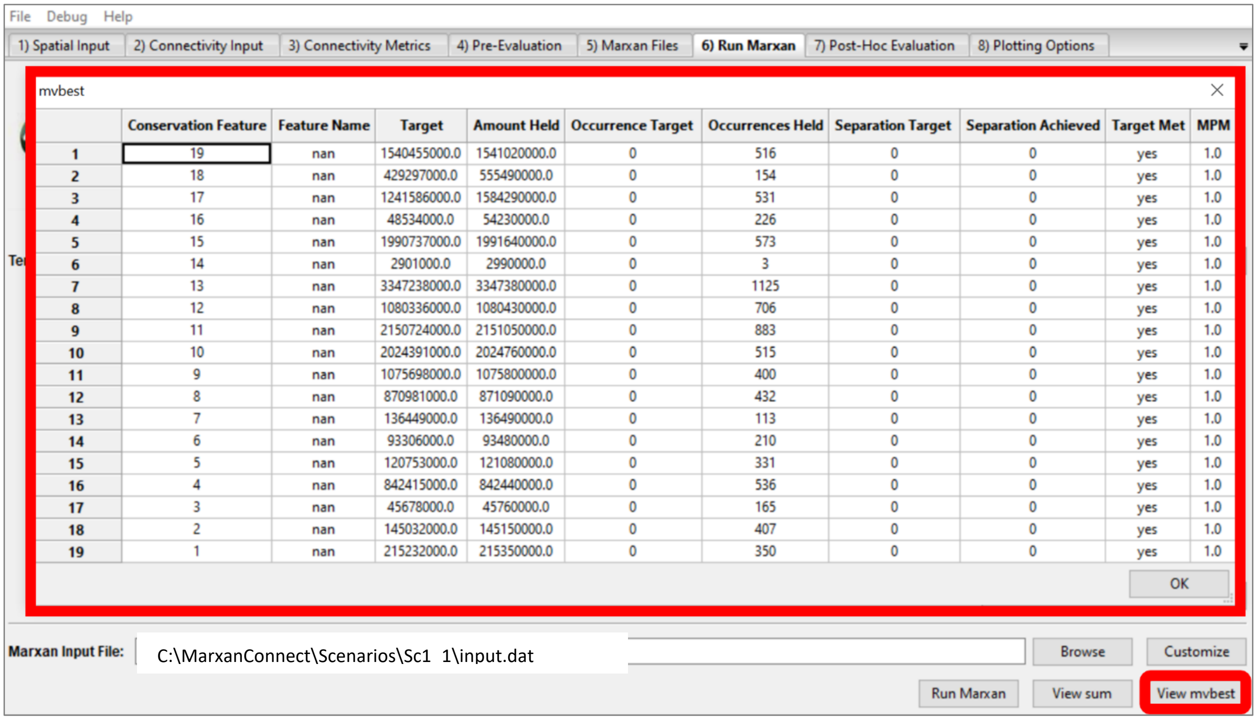
Figure 16. Sum table in the Run Marxan tab

➔ **Step 2:** Look at the "Missing Values" field and answer the question below. When you are done, exit the table to return to the tab window.

CheckPoint 1: *For each run, identify how many conservation features are missing their targets? Are solutions similar in terms of the number of missing values?*

You'll now look at the missing values for the Best Solution. As noted in the note box on the following page, the Best Solution is the Marxan solution or run with the best objective value.

➔ **Step 3:** To open the "mvbest" table within the app, click on the ***"View mvbest"*** button at the bottom of the tab window. This will open the table with information about the missing values for the Best Solution (Figure 17).



	Conservation Feature	Feature Name	Target	Amount Held	Occurrence Target	Occurrences Held	Separation Target	Separation Achieved	Target Met	MPM
1	19	nan	1540455000.0	1541020000.0	0	516	0	0	yes	1.0
2	18	nan	429297000.0	555490000.0	0	154	0	0	yes	1.0
3	17	nan	1241586000.0	1584290000.0	0	531	0	0	yes	1.0
4	16	nan	48534000.0	54230000.0	0	226	0	0	yes	1.0
5	15	nan	1990737000.0	1991640000.0	0	573	0	0	yes	1.0
6	14	nan	2901000.0	2990000.0	0	3	0	0	yes	1.0
7	13	nan	3347238000.0	3347380000.0	0	1125	0	0	yes	1.0
8	12	nan	1080336000.0	1080430000.0	0	706	0	0	yes	1.0
9	11	nan	2150724000.0	2151050000.0	0	883	0	0	yes	1.0
10	10	nan	2024391000.0	2024760000.0	0	515	0	0	yes	1.0
11	9	nan	1075698000.0	1075800000.0	0	400	0	0	yes	1.0
12	8	nan	870981000.0	871090000.0	0	432	0	0	yes	1.0
13	7	nan	136449000.0	136490000.0	0	113	0	0	yes	1.0
14	6	nan	93306000.0	93480000.0	0	210	0	0	yes	1.0
15	5	nan	120753000.0	121080000.0	0	331	0	0	yes	1.0
16	4	nan	842415000.0	842440000.0	0	536	0	0	yes	1.0
17	3	nan	45678000.0	45760000.0	0	165	0	0	yes	1.0
18	2	nan	145032000.0	145150000.0	0	407	0	0	yes	1.0
19	1	nan	215232000.0	215350000.0	0	350	0	0	yes	1.0

Figure 17. Missing values for the Best Solution table in the Run Marxan tab

➔ **Step 4:** Look at the “Target Met” field to answer the question below, then exit the table.

<u>CheckPoint 2:</u> *Are the targets for the Best Solution being met? If not, note which conservation features are not meeting your targets.*

4.4.2 Map and Visualise Results Using the Plotting Options and Plot Tabs

Using the app, you will now plot and visualise two key outputs of Marxan: the Best Solution and the Selection Frequency (see note box below for more information). You will use the **Plotting Options** tab to plot these outputs. The mapped outputs will then be displayed in the **Plot** tab.

> ***Note:*** Marxan produces two types of outputs that typically facilitate conservation planning:
>
> _Best Solution:_ The Best Solution is the run that produced the solution with the best objective values. Remember, the Best Solution is only superior with regard to the objective function value. In reality, this does not make it the "best" protected area network plan for implementation.
>
> _Selection Frequency:_ This output identifies the number of times each planning unit was selected across all solutions. It provides an indication of how useful each planning unit is for creating an efficient protected area network.

You'll begin by potting and visualising the Best Solution.

➔ **Step 1:** Open the ***"8) Plotting Options"*** tab.

➔ **Step 2:** In the ***"Map Plotting Options"*** panel, ensure that the ***"Plot Basemap"*** checkbox is selected (Figure 18). Leave the default color settings for the base map.

➔ **Step 3:** Next, select the ***"Plot 1st Layer"*** checkbox. Right next to this checkbox, select the ***"Colormap of connectivity metrics"*** option from the dropdown list. Select ***"Planning Units (Marxan Data)"*** under ***"Shapefile"***, and ***"Best Solution"*** under ***"Output"***. (See Figure 18).

➔ **Step 4:** Verify that the ***"Map Plotting Options"*** panel in the tab window look like Figure 18. If so, click on the ***"Plot Map"*** button. It may take a few seconds or minutes to plot the results.

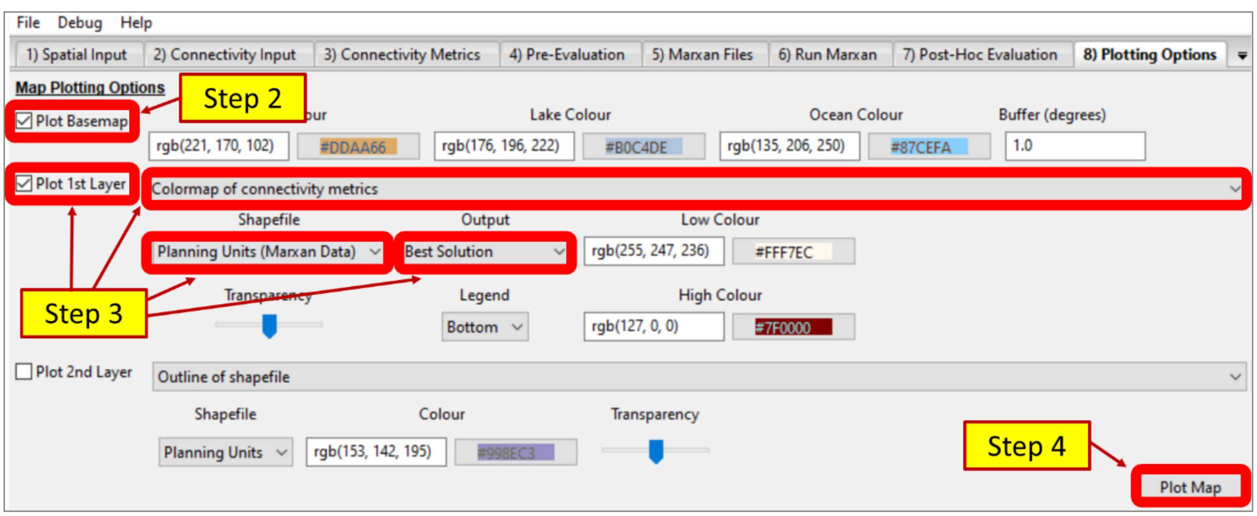


Figure 18. Map Plotting Options panel in the Plotting Options tab

➔ **Step 5:** A map will appear in the ***"9) Plot"*** tab window. This map (see left portion of Figure 19) displays the planning units selected for the Best Solution.

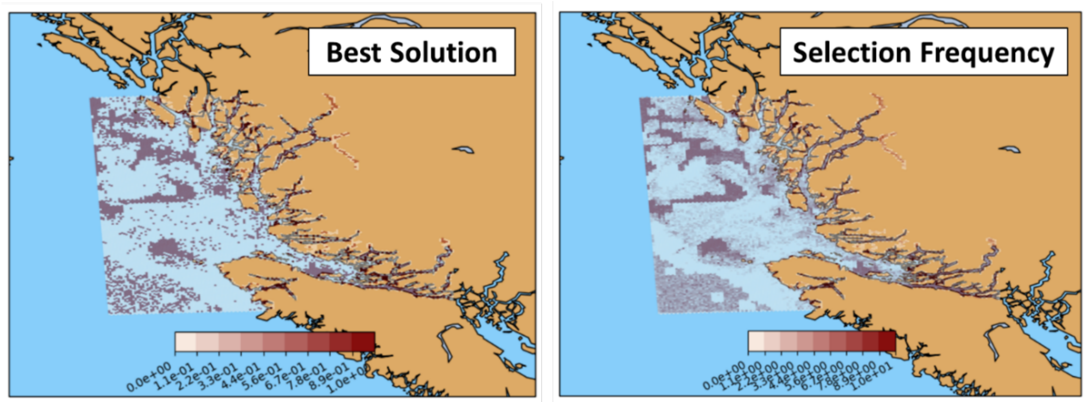


Figure 19. Maps of the Best Solution and Selection Frequency (results may vary)

The Plotting Options tab allows users to export maps and shapefiles displayed in the Plot tab. Here you will use the ***"Export Spatial Data"*** panel in the Plotting Options tab to export the map and shapefile for the Best Solution.

➔ **Step 6:** Return to the ***"8) Plotting Options"*** tab.

➔ **Step 7:** To set up the export for the shapefile, select the checkbox for the ***"Export data to shapefile:"*** option under ***"Export Spatial Data"***, browse to the Sc1_1 folder and name the file "Sc1_1best" (Figure 20).

➔ **Step 8:** Unselect the checkboxes for ***"Export data to file"*** and leave the text box for it blank (Figure 20).

➔ **Step 9**: To set up the export for an image file, select the checkbox for the ***"Export map to:"*** option, then browse to the Sc1_1 folder and name the file "Sc1_1bestmap" (Figure 20).

➔ **Step 10:** If your "Export Spatial Data" panel looks like Figure 20, click ***"Export"***. It may take a few seconds to export the files. Check to see if you can see the new shapefile and map image in the Sc1_1 folder.

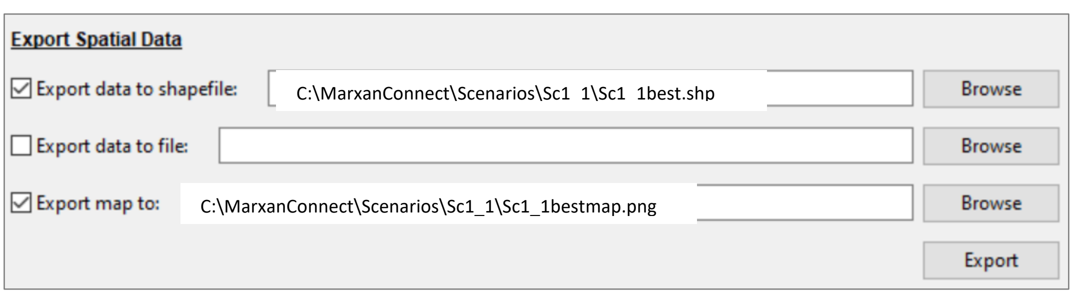


Figure 20. Export Spatial Data panel in the Plotting Options tab

Take the next few minutes to visually examine the Best Solution. You can do this in a few different ways. You can visualize the map in the Plot tab. You can open the image file in the Sc1_1 folder to view the map as an image. Another option is to import the shapefile in the

Sc1_1 into ArcGIS or QGIS. You can then use some tools available in the GIS software to investigate the outputs in more detail. See Box 2 (page 33) for instructions for visualising Marxan results in ArcGIS and QGIS.

➔ **Step 11:** Examine the map and answer the question below.

CheckPoint 3: *What do you note about the configuration of protected areas selected under the Best Solution (e.g., number, sizing, and spacing of MPAs)?*

Next, you will plot and visual the Selection Frequency (*i.e.*, the number of times each planning unit was selected across all solutions).

➔ **Step 12:** Repeat steps 1 to 4, but this time, select the ***"Selection Frequency"*** option under ***"Output"*** (rather than ***"Best Solution"***). A map will appear in the ***"9) Plot"*** tab window (Figure 19) that displays the selection frequency.

➔ **Step 13:** Use the ***"Export Spatial Data"*** panel at the bottom portion of the Plotting Options tab to export a shapefile and map image into the Sc1_1 folder. Name the shapefile "Sc1_1ssoln" and the image file "Sc1_1ssolnmap".

➔ **Step 14:** Visually examine the map for the Selection Frequency to answer the question below.

CheckPoint 4: *What does the Selection Frequency map show? How does it compare with the Best Solution? Why do you see defined clusters apart from the south-west portion of the study region?*

Box 2. Instructions for visualizing Marxan results in ArcMap and QGIS

Option A: Visualizing Marxan results in ArcMap

1. Open a new ArcGIS project and add the shapefiles (Sc1_1best.shp and Sc1_1ssoln). In the main menu, select **File > Add Data > Add Data**. Browse and open the shapefiles, then click **Add**. You should now see the added layers in the Layers panel.
2. To visualize the Best Solution, right click on the related layer and open its **Properties**. In the **Symbology** tab, select **Categories > Unique values** as the visualization method. Selection **SOLUTION** for the **Value Field**. Click **Add All Values** to view the values in this field. Note that '**0**'= unselected planning unit and '**1**'= selected planning unit. Choose appropriate colors for unselected and selected planning units, then click **OK**.
3. To visualize the Selection Frequency, go to layer's **Properties**, select **Quantities > Graduate colors**, and select **select_fre** for the **Value**. *[If you get a message from ArcMap about 'Maximum sample size reached', you will need to increase the data sampling. To do so go to Classify, then Sampling, and increase the Maximum Sample Size to 1,000,000].* Classify the values into '**5**' classes, with '**0**' values having their own class, and click **OK**.
4. Save the ArcMap project in the Sc1_1 folder.

Option B: Visualizing Marxan results in QGIS

1. Open a new QGIS project and add the shapefiles (Sc1_1best.shp and Sc1_1ssoln). Go to the top of your screen menu and select **Layer > Add Layer > Add Vector Layer**. The Vector tab will now appear in the Data Source Manager window. For **Vector Dataset(s)**, browse and open the shapefiles, then click **Add** in the Vector tab. Click **Close** to exit the window. The added layers should be in the Layers panel.
2. To display the Best Solution, go to **Layer Properties** for this layer, and open the **Style** (or **Symbology**) tab. Select **Categorized**, then select **best_solut** in the **Column** menu. Click **Classify**. Note that '**0**'= unselected planning unit and **1**= selected planning unit. Choose your colors (e.g., blue to symbolize unselected planning units, and green for selected planning units), and click **OK**.
3. To display the Selection Frequency, go to the **Layer Properties** for Sc1_1ssoln. In the **Style** (or **Symbology**) tab, select the **Graduated** option in the first dropdown menu. Select **select_fre** in **Column** field and click **Classify**. Change the values in the **Legend format** so the first class is '**0**'. Leave the number of classes to '**5**'. Click **OK**.
4. Save the QGIS project in the Sc1_1 folder.

4.4.3 Post-Hoc Evaluation

In this Scenario, you did not incorporate connectivity into Marxan, as connectivity data was unavailable. Given the low availability of connectivity data, "rules of thumb" or general guidelines for MPA size and spacing are often used to address connectivity criteria in conservation planning (Box 3). Here, you will use "rules of thumb" for MPA size and spacing to evaluate the Marxan outputs for Scenario 1. To help you do this, you will use some helpful functions in the **Post-Hoc Evaluation** tab that relate to MPA size and spacing. As stated previously, this is a post-hoc approach for addressing connectivity considerations in conservation planning.

Box 3. “Rules of thumb” for MPA size and spacing

Marine protected areas (MPAs) established to conserve biodiversity need to protect multiple species with a wide array of dispersal properties and home range sizes. To meet that goal, “rules of thumb” for MPA size and spacing have been used as proxies for addressing connectivity and species movements in the design of MPA networks.

MPA size: Rules of thumbs for MPA size set a minimum size for each MPA.

- *Example 1:* The Scientific Advisory team for California’s Marine Life Protection Act (MLPA) specified that MPAs should have an alongshore minimum length of 5 km or preferably 10-20 km (CDFG 2009).
- *Example 2:* The Great Barrier Reef (GBR) rezoning project in Australia set a minimum size dimension of 20 km across the narrowest part of a MPA (Fernandes et al., 2005).
- *Example 3:* The Marine Conservation Zone (MCZ) project in England stated that MPAs should have a minimum diameter of 5 km with an average minimum diameter of 10-20km (Natural England and the Joint Nature Conservation Committee, 2010).

MPA spacing: Rules of thumbs for MPA spacing set a maximum distance between MPAs.

- *Example 1:* The MLPA team stated that MPAs should be placed within 50-100 km of each other to enhance connectivity between protected sites and maximize larval supply in adjacent unprotected sites (CDFG 2009).
- *Example 2:* The GBR rezoning set a maximum spacing of 200 km between individual MPA sites (Fernandes et al., 2005).
- *Example 3:* The MCZ project set a maximum spacing of 40-80 km between MPA sites (Natural England and the Joint Nature Conservation Committee, 2010).

You’ll begin by running a Post-Hoc Evaluation for the Best Solution.

➔ **Step 1:** Open the ***“Post-Hoc Evaluation”*** tab.

➔ **Step 2:** Select the ***“Best Solution”*** option from the ***“Output: output”*** drop-down list (Figure 21).

➔ **Step 3:** Click on the ***“Calculate Post-Hoc”*** button (Figure 21).

➔ **Step 4:** It may take a few seconds for Marxan Connect to complete the calculations. When the calculations are complete, a table with values for different Post-Hoc parameters will appear in the tab window (Figure 21). Note, values may vary from those in Figure 21.

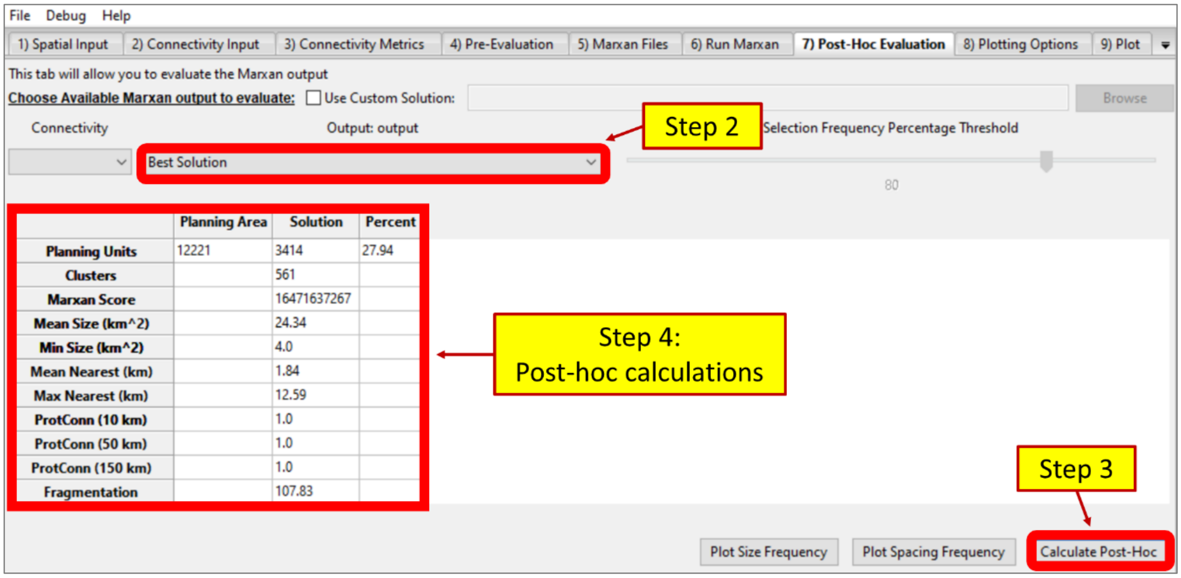


Figure 21. Post-Hoc Evaluation tab for Scenario 1

Given the absence of connectivity data, the table only includes post-hoc parameters that do not require connectivity in the calculation, described in Table 5 (see Table 1 on page 14 for the full list of parameters).

➔ **Step 5:** Take the next few minutes to familiarize yourself with the Post-Hoc Evaluation parameters. At the same time, examine the values of each parameters, which were calculated through the Post-Hoc Evaluation of the Best Solution.

Table 5. Definitions for post-hoc parameters that do not require connectivity

Parameter	Description
Planning Units	The number of planning units included in the solution.
Clusters	The number of contiguous selected areas (i.e. merged planning units).
Mean Size (km^2)	The mean size (km^2) of clusters.
Min Size (km^2)	The area (km^2) of the smallest cluster.
Mean Nearest (km)	The mean of the distance between each pair of nearest neighbour clusters. The distance is calculated from the outer boundaries of the clusters.
Max Nearest (km)	The maximum distance between the furthest pair of nearest neighbour clusters. The distance is calculated from the outer boundaries of the clusters.
ProtConn (10 km)	The proportion of clusters that have another cluster within 10 km.
ProtConn (50 km)	The proportion of clusters that have another cluster within 50 km.
ProtConn (150 km)	The proportion of clusters that have another cluster within 150 km.

For the “Planning Units” parameter, the “Planning Area” value is the total number of planning units in the study region, the “Solution” value is the number of planning units included in the Best Solution, and the “Percent” value is the percentage of planning units included in the solution. The remaining parameters were all calculated based on <u>selected</u> planning units in the Best Solution.

Based on the results displayed in Figure 21 (your results may vary slightly), the Best Solution contains 561 clusters of selected planning units (contiguous selected areas). The average cluster is 24.34 km^2 in size and the smallest cluster is 4.0 km^2 (i.e., the size of a single planning unit). The average distance between each pair of nearest neighbour clusters is 1.84 km and the maximum distance between nearest neighbour clusters is 12.59 km. A value of "1.0" for the "ProtConn (10km)" parameter indicates that all clusters (or at least most, within rounding error) of selected planning units are within a 10 km distance of one another.

- ➔ **Step 6:** To save the post-hoc evaluation of the Best Solution as CSV file, click on the ***"Browse"*** button corresponding to the ***"Post-Hoc Summary File"*** option and browse to C:\MarxanConnect\Scenarios\Sc1_1. Name the file "Sc1_1posthoc_best" and then click ***"Open"***. Finally, click on the ***"Export File"*** button at the bottom portion of the tab window to save the calculated values as CSV files.
- ➔ **Step 7:** You will now use some of the Post-Hoc parameters, together with the "rules of thumb" for MPA size and spacing in Box 3 (page 33), to answer the questions below.

CheckPoint 5: *Which Post-Hoc parameter(s) can be used to identify the smallest MPA in the network plan for the Best Solution? Based on this parameter, what is the size of the smallest MPA? Does this minimum size fit within the "rules of thumb" for MPA size used for the MLPA in California (see Box 3 on page 33)? Does it fit within the "rules of thumb" on MPA size used for the GBR rezoning project and the MCZ project?*

CheckPoint 6: *Which Post-Hoc parameter(s) can be used to identify the maximum distance between nearest neighbour MPAs in the network plan for the Best Solution? Based on this parameter, what is the maximum distance between MPAs? Does this maximum distance fit within the "rules of thumb" for MPA spacing used for the MLPA in California (see Box 3 on page 33)? Does it fit within the "rules of thumb" for MPA spacing used in the GBR rezoning project and the MCZ project?*

CheckPoint 7: *How can maintaining a minimum MPA size and a maximum distance between nearest neighbour MPAs support larval dispersal and promote connectivity?*

CheckPoint 8: *What are some benefits and limitations of using "rules of thumb" for MPA size and spacing for designing and evaluating MPA network plans?*

4.4.4 Further Exploration (OPTIONAL ACTIVITY)

If you have time, you can choose to run additional Marxan analysis with changes to the SPF, BLM, and/or conservation targets. For each change you choose to explore, create a new Marxan database (copy and past the Sc1 file folder and give the new folder an appropriate name) and make the necessary edits to the input.dat (if you plan to change the BLM) and/or the spec.dat (if you plan to change the SPF and/or the conservation targets). You can then follow the steps for Scenario 1 to run Marxan with the desired changes. Follow the directions in Sections 4.4.1 to 4.4.3 to interpret the results and compare your results to those of Sc1_1 (i.e., the Scenario with a BLM=10, SPF=50, and targets=0.3). You can use the questions below to explore the implications of changing the targets, SPF, or BLM.

CheckPoint 9: *If some of your conservation feature targets were not met, what parameter(s) might you change in order to achieve those targets? Give it a try!*

CheckPoint 10: *What effect does the BLM have on the spatial configuration of your MPA network? See what happened when you set the BLM to a lower value (e.g., BLM=0) versus and higher value (e.g., BLM=100). Take note of whether the targets are met across solutions and for the Best Solution, visualize your results, and look for difference in the Post-Hoc Evaluation metrics.*

CheckPoint 11: *Try increasing the conservation targets for some or all the conservation features (e.g., change the conservation target "0.5" or higher). Compare the Marxan results to those in Sc1_1? Are you able to meet all the conservation targets in the Best Solution, in addition to the "rules of thumb" for MPA size and spacing? Can you observe any major changes in maps displaying the Best Solution and the Selection Frequency? Have the values of Post-Hoc parameters changed in any minor or major ways?*

5 Scenario 2: Incorporating Landscape-Based Connectivity Data as a Feature into Marxan

5.1 About Scenario 2

As previously described in Box 1 (pages 7-8), there are two main ways to incorporate connectivity data into the Marxan input files: 1) as a conservation feature, and 2) as spatial dependencies between planning units. This Scenario focuses on the former.

Scenario 2 is designed to guide you through an example of a possible workflow to incorporate landscape-based connectivity data as a conservation feature in Marxan, using the Marxan Connect app. The Scenario is based on the same case study as the previous Scenario. The main difference is you now have connectivity data!

Your task is to identify potential MPA network configurations for the BC study region that:

- protect at least 30% of each conservation feature of interest in the study region;
- minimize the overall cost for commercial fisheries; and
- promotes connectivity between habitat patches within the network of protected areas.

Just like in Scenario 1, you have 19 conservation features and your aim is to protect at least 30% of the total area of each feature. For Scenario 2, you will create additional connectivity-based features for 5 conservation features, listed in Table 6. These conservation features are associated with hard substrates and kelp beds and have been selected as important habitat types for bottom-dwelling invertebrates. Hence, your connectivity objective for the MPA network is to promote connectivity between these types of habitat patches.

Table 6. Conservation features

FEAT_ID	Name	Description
1	0-20 Hard	Hard substrate at 0-20 m depth
4	20-50 Hard	Hard substrate at 20-50 m depth
7	200+ Hard	Hard substrate at depths >200 m
11	50-200 Hard	Hard substrate at 50-200 m depth
16	Kelp	Distribution of 3 kelp species

5.2 Marxan Database for Scenario 2

The Marxan database for Scenario 2 can be found in the Sc2 folder. It is based on the same database you explored in Section 3.2 and includes landscape-based connectivity data. This means you now have access to connectivity data. Specifically, you have a matrix of pairwise distances between planning units for each of the 5 conservation features listed in Table 6, where a greater distance between habitat patches represents lower connectivity (i.e., isolation by distance). The connectivity matrix is the IsolationByDistance_edgelist.csv file in the C:\MarxanConnect\ Scenarios\Sc2\connectivity_data folder.

➔ **Step 1:** In your file directory, navigate to C:\MarxanConnect\Scenarios folder. Make a copy of the Sc2 folder and name it "Sc2_1". You will use this new folder for this Scenario.

➔ **Step 2:** Open the new Sc2_1 folder to view the Marxan database. Note that it is the same as the database used in the previous Scenario, apart from having an additional folder called connectivity_data.

➔ **Step 3:** Take a few minutes to explore the Marxan input files in the input folder in Sc2_1. Note that the spec.dat file lists 19 conservation features and the targets are all set to "0.3". The species penalty factor (SPF) is set to "50", like the previous Scenario.

➔ **Step 4:** Go back to the Sc2_1 folder, then open the input.dat file. Note that the boundary length modifier (BML) is set to "10" as the previous Scenario.

➔ **Step 5:** Finally, open the connectivity_data folder in Sc2_1. The folder contains the IsolationByDistance_edgelist.csv file, which is the connectivity matrix you will use here.

Note: To save time, the connectivity matrix has been prepared for you. Hence, you will load the prepared connectivity matrix directly into Marxan Connect instead of creating one in the app. The connectivity matrix was generated using R (the R script is available here). It describes the landscape connectivity based on the inverse of the distance between pairs of planning units which contain the same type of conservation feature (*i.e.* habitat type). For example, 2 adjacent planning units which both contain kelp beds are more connected than 2 distant kelp-containing planning units. Since this data is an edgelist by type, it has a *'habitat'* column which contains a set of connectivity data for each habitat type.

5.3 Set Up & Run Marxan Using Landscape-Based Connectivity Data

You will now work through the workflow tabs using the landscape-based connectivity data and Marxan input files in the Sc2_1 folder.

➔ **Step 1:** Open the Marxan Connect app.

➔ **Step 2:** Create a new project (click on ***"New Project"*** in the ***"File"*** menu). Name the project "Sc2_1" and save it in the Sc2_1 folder.

5.3.1 Spatial Input

➔ **Step 1:** Navigate to the ***"1) Spatial Input"*** tab.

➔ **Step 2:** In the ***"Planning Unit Shapefile"*** option, browse and open the planning unit shapefile (pulayer_BC_marine_hx.shp) for Scenario 2 (contained in pu folder in Sc2_1 folder).

5.3.2 Connectivity Input

You will use the **Connectivity Input** tab for the first time, seeing as you now have access to connectivity data. As a reminder, this tab allows users to input demographic or landscape-based connectivity data, generate landscape-based connectivity data, or rescale demographic-based data.

There are multiple input types that can be used to calculate connectivity matrixes. In the Connectivity Input tab, users can choose to:

- load a habitat type shapefile and an optional resistance matrix, which can be used to calculate the connectivity matrix via least-cost path or Euclidean distance analysis;
- load a resistance surface that can be used to calculate the connectivity matrix via least-cost path analysis; or
- load a connectivity matrix directly.

Given that the connectivity matrix (IsolationByDistance_edgelist.csv) has been prepared for you, you will load it directly into the Connectivity Input tab.

Note: As mentioned previously, the connectivity matrix used in this Scenario was generated using R and requires no further work from you. However, the same connectivity matrix could have also been generated using Marxan Connect. It could have been created in the Connectivity Input tab of the app with a habitat type shapefile and a resistance matrix, using a ***Euclidean Distance*** method. This would involve the following steps:
1) select ***"Landscape Input"*** in the second dropdown list;
2) select the ***"Habitat type + Isolation"*** in the second dropdown;
3) select ***"Euclidean Distance"*** for the ***"Distance Calculation Type"***;
4) browse and import the habitat type shapefile for the "***Habitat Type Shapefile"***; and
5) then click ***"Generate Connectivity Matrix"***.

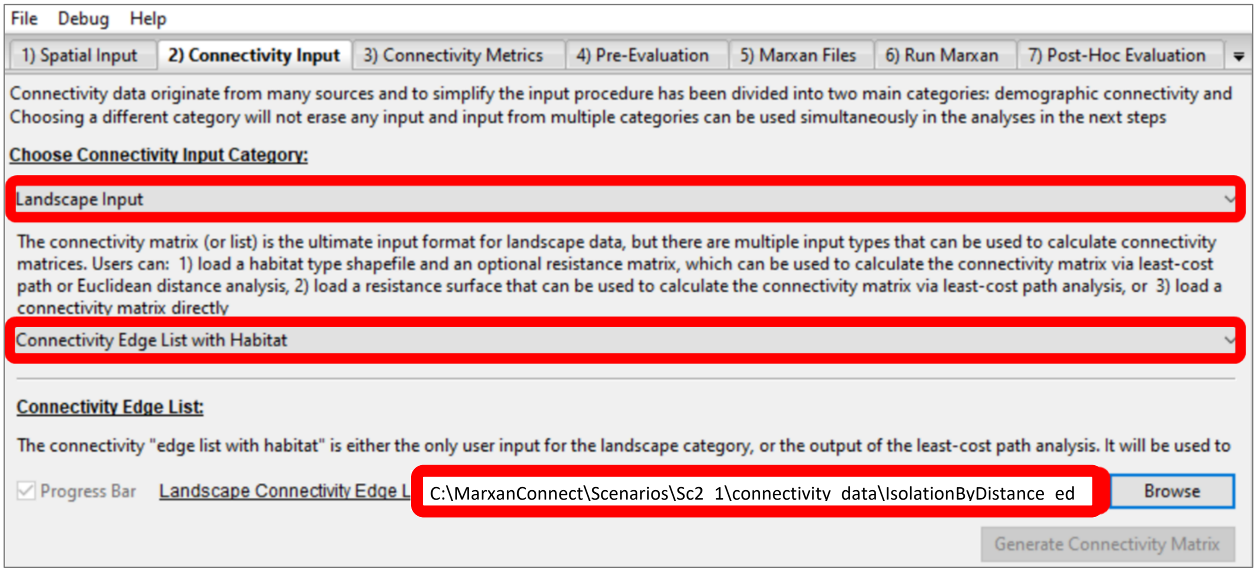


Figure 22. Connectivity Input tab window for Scenario 2

➔ **Step 1:** Open the ***"2) Connectivity input"*** tab window.

➔ **Step 2:** Since you are working with landscape-based connectivity data, select the ***"Landscape Input"*** option from the ***"Choose Connectivity Input Category"*** dropdown menu.

➔ **Step 3:** In the second dropdown menu, select ***"Connectivity Edge List with Habitat"***.

➔ **Step 4:** Under ***"Connectivity Edge List"***, click on the ***"Browse"*** button by the ***"Landscape Connectivity Edge List"*** option. Navigate to the connectivity_data folder in the Sc2_1 folder, select the IsolationByDistance_edgelist.csv file, and click ***"Save"***.

➔ **Step 5:** Ensure that the tab window look like Figure 22 before proceeding to the next tab.

5.3.3 Connectivity Metrics

Next, you will use the **Connectivity Metrics** tab. This tab allows users to select which connectivity metric to calculate. In this Scenario, you will use the "Google PageRank" as your chosen metric.

➔ **Step 1:** Open the ***"3) Connectivity Metrics"*** tab window.

➔ **Step 2:** To learn about Google PageRank metric (or any other featured metric), select the ***"Google PageRank"*** option from the drop-down menu on the right-hand side of the tab window (Figure 23). Doing so will allow you to view the definition, possible objectives, equation, and an illustration on how the metric works.

Note: You can choose to calculate metrics for planning units, connectivity units, or both. The connectivity units are there for scenarios where you have a connectivity matrix that is not scaled the same as your planning units. You can then calculate the metrics for the connectivity units to see if the re-scaling works well in that case. You can't run a Marxan analysis on the connectivity units. It is only for comparison with the planning units. Although it is preferable to collect or generate connectivity data to the scale of the planning units, if it is not possible to do so, then you can calculate metrics for both the planning units and connectivity units to see if the re-scaling works well in that case. In our example, the connectivity data was generated at the scale of the planning units, so we only need to calculate metrics for planning units.

➔ **Step 3:** On the left-hand side of the tab window, select the ***"Google PageRank"*** option under ***"Landscape"*** (Figure 23).

➔ **Step 4:** At the bottom of the window, select the ***"Planning Units"*** option (Figure 23). Do <u>not</u> select the ***"Connectivity Units"*** option.

➔ **Step 5:** Finally, click on the ***"Calculate Metrics"*** button (Figure 23). It may take a few seconds to minutes to calculate metrics.

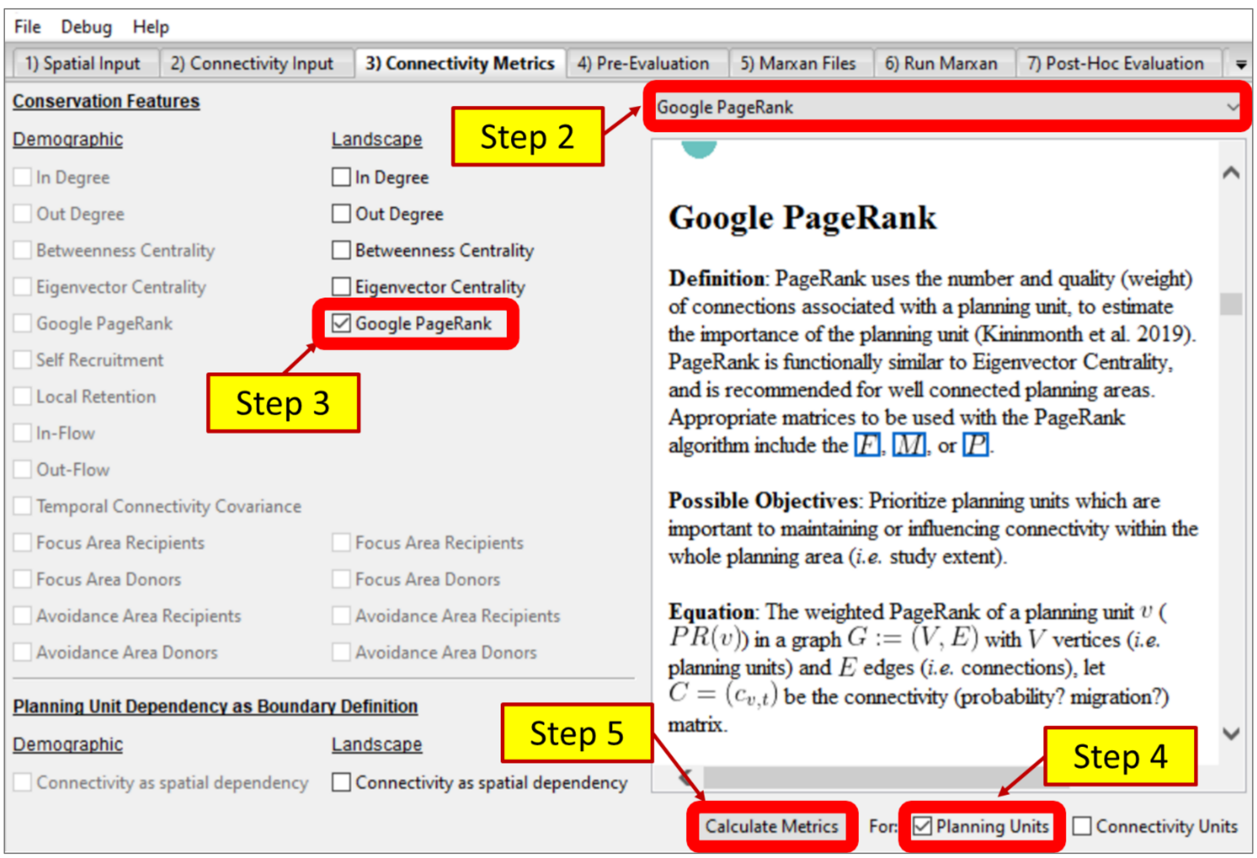


Figure 23. Connectivity Metric tab window for Scenario 2

➔ **Step 6:** If all goes well, a pop-up window should appear stating that all calculations have been completed successfully (Figure 24). Click ***"OK"*** and proceed to the next tab.

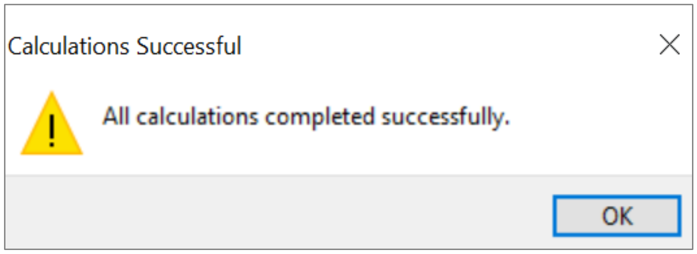


Figure 24. Calculation successful pop-up window

5.3.4 Pre-Evaluation

The next connectivity tab you will use is the **Pre-Evaluation** tab. This tab allows users to modify (*i.e*. discretize), plot, and remove connectivity metrics calculated on the Connectivity Metrics tab.

Most of the metrics that you can calculate on the Connectivity Metrics tab are non-additive, including the Google PageRank metric. For example, protecting a single planning unit with a Google PageRank of 0.5 is not ecologically equivalent to protecting two planning units with a Google PageRank of 0.25 each (*i.e*., 0.5 ≠ 0.25 + 0.25). To account for this, you will use the Pre-Evaluation tab to modify (*i.e*., discretize) the metrics into connectivity-based conservation features by choosing a minimum and maximum threshold. These thresholds can be chosen from quartiles, percentiles, or custom values using the ***"Make discrete feature from minimum threshold"*** and the ***"Make discrete feature to maximum threshold"*** panels.

Note: Discretizing creates a binary spatial feature which is "present" when the value of the continuous connectivity metrics is between the minimum and maximum thresholds. Some conservation features, such as those based on area, are additive. For example, 2 m^2 + 2 m^2 is more or less equivalent to 4 m^2, however, selecting 2 planning units each with an out degree of 2 will not have the same conservation outcomes as selecting one planning unit with an out degree of 4.

Discretizing the connectivity-based conservation features allows us to make binary presence/absence features for the "best" connected areas. Alternatively, we can make multi-tiered discrete layers with different targets from a single metric. For example, we may choose to set very high targets (e.g. 75%) for the "best" connected areas (e.g. 90^{th} percentile of Google PageRank) and then a moderate target (e.g. 20%) for sites that are "important" (e.g. 50-90^{th} percentile of Google PageRank).

In this Scenario, you will make binary presence/absence features for the "best" connected areas ("0" for absence and "1" for presence of planning units for which the metric is above the selected threshold).

In this Scenario, you will create connectivity-based discrete features using the Google PageRank to calculate connectivity for each of the 4 depth stratified hard-bottom conservation features and the kelp feature which requires hard substratum (see Table 3 on conservation features). Collectively, these features will be referred to as "the hard-bottom conservation features".

For the purposes of this scenario, you want to find a minimum threshold that will return 50% of the planning units containing a given feature (*i.e.*, are connected) or the "better half" of the Google PageRank values that are not effectively '0' (see note below about real-world conservation planning scenarios). This is complicated by the fact that many planning units are not connected (*i.e.*, a planning unit that does not contain the feature) and the Google PageRank metric does not return '0' values when planning units are not connected. To account for this, you must manually find Google PageRank "percentile" minimum thresholds.

Based on the minimum thresholds that you will set, the discrete connectivity features will contain the upper 50% of the connectivity values, as obtained by Google PageRank, for each of the 5 conservation features. This means that each of the discrete features will include 50% of the planning units which contain one of the hard-bottom conservation features. For example, if Feature X is present in 30% of all planning units, then a discrete feature which contains 50% of those will include 15% of all planning units (0.3 x 0.5 = 0.15).

One way to identify the minimum threshold setting in Google PageRank is to create a temporary discrete feature that contains all of the connected planning units. Doing so will produce a table that includes the percentage of planning units containing that discrete feature, because any planning unit that contains that feature will be connected to other similar planning units. In Scenario 2, the minimum threshold can be determined by multiplying the percentage of planning units not containing the hard-bottom conservation features by 50% to convert to the desired percentile threshold. Once the minimum threshold setting is found, the temporary discrete feature can be deleted, and a new discrete feature can be generated with the identified minimum threshold.

Note: In real-world conservation planning scenarios, setting the minimum threshold values will require more elaborate fine-tuning and thought based on the sensitivity of the connectivity process and the effectiveness of spatial protection for the feature in question.

In this Scenario, you will need to identify the minimum thresholds that will return 50% of the planning units containing a given feature and discretize the connectivity metric associated with each of the 5 conservation features separately. Start with the connectivity metric for Feature 1 (i.e., hard substrate at 0-20 m depth), then repeat the same steps for the remaining 4 connectivity metrices associated with Feature 4, 7, 11, and 16 (see Table 6 on page 39 for a list of the 5 conservation features).

➔ **Step 1:** In the ***"4) Pre-Evaluation"*** tab window, you can use the drop-down list for the ***"Selection"*** option to view a summary report in the ***"Selected Metric Summary"*** panel. The report contains summary information about the selected metric, such as the sum, mean, median, standard deviation, minimum and maximum, and lower and upper quartile for the calculated metric. To view the summary report for the metric associated with Feature 1, select ***"Google PageRank (Feat_1)"*** from the drop-down list (Figure 25).

➔ **Step 2:** You can plot the frequency of values using the ***"Plot Frequency"*** button (Figure 25). To generate a frequency plot for the first metric, select ***"Google PageRank (Feat_1)"*** from the ***"Selection"*** drop-down menu, then click ***"Plot Frequency"***. It may take a few seconds to plot.

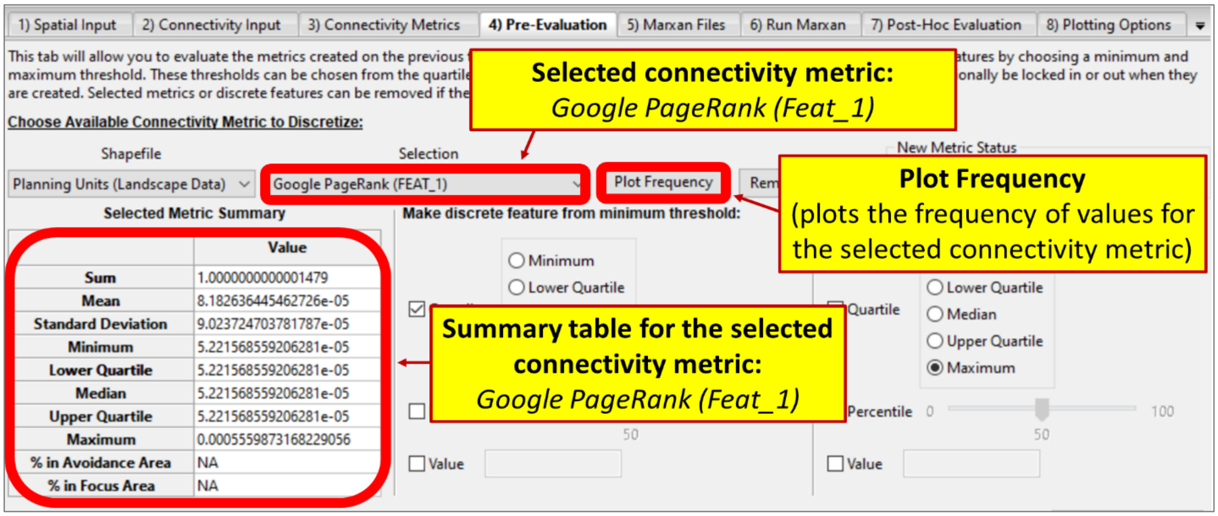


Figure 25. Key steps to set up the Pre-Evaluation tab

➔ **Step 3:** A graph will appear on the **Plot** tab, a separate tab to the Pre-Evaluation tab. If you have enough room on your computer screen, you can split your screen to make toggling between the Plot and the Pre-Evaluation tabs unnecessary. Grab (click and hold) the "***9) Plot"*** tab and drag it to the far right (or left) of your screen and let it go. The app should now look similar to Figure 26, with both tab windows visible at the same time.

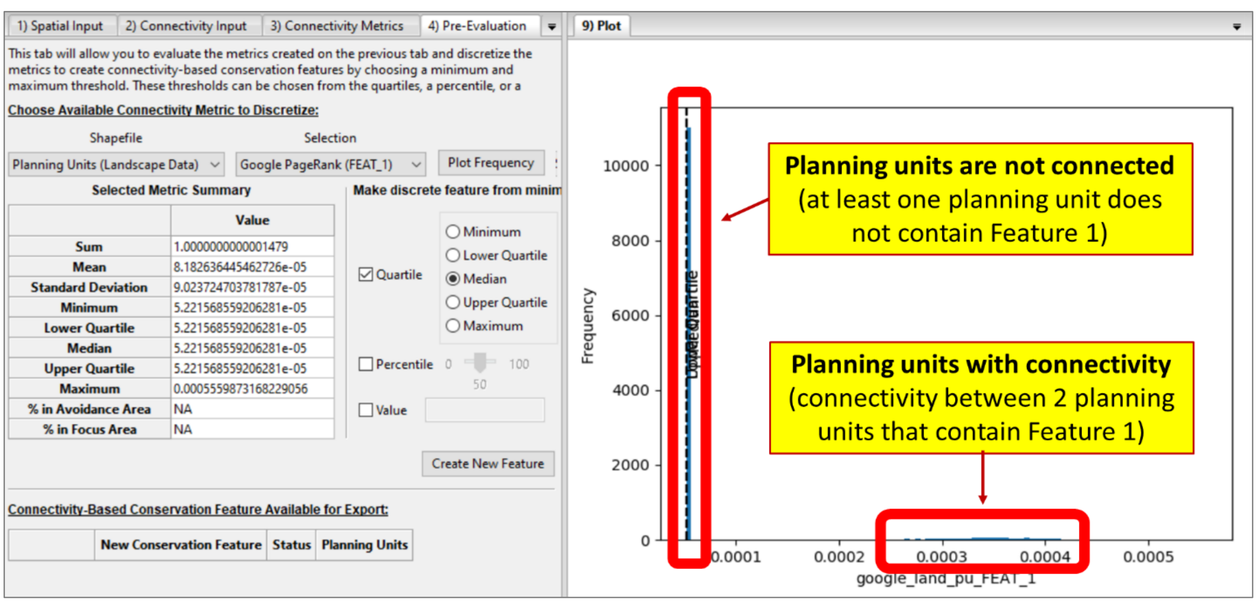


Figure 26. App displaying the "Pre-Evaluation" and "Plot" tabs

➔ **Step 4:** Examine the results in the graph (Figure 26). Note that there are many values below "0.0001", because there are very few planning units that have FEAT_1. This means that most of the planning units have little or no connectivity. Google PageRank does not go to “0”, so all the “5.221e-05” values are effectively not connected and can be regarded as “fake” zeros. Notice that there are some values between “0.0002” and “0.0005”. These values correspond to planning units with connectivity (i.e., connectivity between two planning units that contain Feature 1). About half of the values that are connected are above “0.00035”. Values above “0.00035” represent the highest 50% or the “better half” of the Google PageRank. Finally, take note of the values between the fake zeros and the actual connectivity data. While it is difficult to identify the boundaries of these sets of values, you can clearly observe that it includes values between “0.0001” and “0.0002”.

It’s now time for you to determine the minimum threshold setting, which will subsequently be used to generate a connectivity-based discrete feature from the Google Page Rank for Feature 1. You’ll start by creating a temporary discrete feature from the “Google PageRank (Feat_1)” metric, using a minimum threshold value between the fake zeros and the actual connectivity data (i.e., any value between “0.0001” and “0.0002”). You’ll then examine an output table at the bottom of the tab window, which will show the percentage of planning units that contain Feature 1. Next, you will calculate 50% of that percentage and convert the value (a percentage) to a percentile. This percentile value will act as the minimum threshold setting when it comes time to generate the connectivity-based discrete feature from the “Google PageRank (Feat_1)” metric.

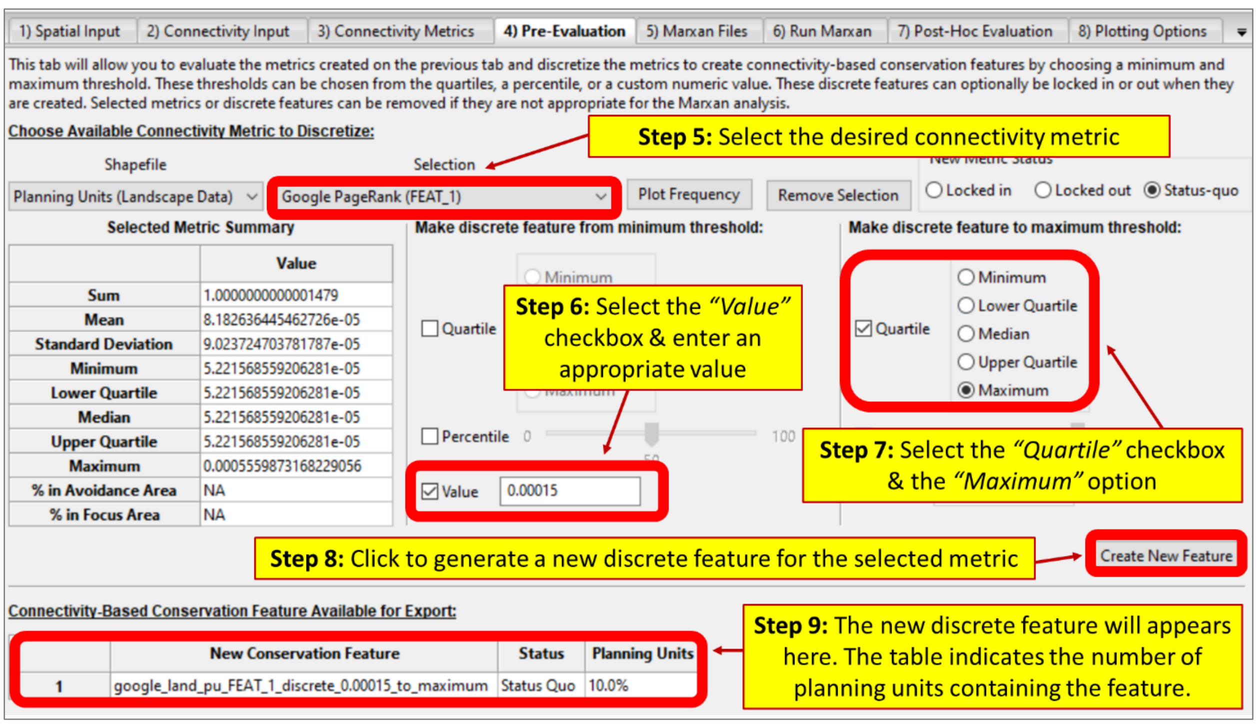


Figure 27. Process to generate a new discrete feature for the selected connectivity metric

➔ **Step 5:** Ensure that the ***“Google PageRank (FEAT_1)”*** is selected (see step 5 in Figure 27).

➔ **Step 6:** In the ***“Make discrete feature from minimum threshold”*** panel, check ***“Value”*** and enter a value between the fake zeros and the actual connectivity data, such as “0.0001”, “0.00015” or “0.0002” (see step 6 in Figure 27).

➔ **Step 7:** In the ***“Make discrete feature from maximum threshold”*** panel, check ***“Quartile”*** and then ***“Maximum”*** (see step 7 in Figure 27). This is the upper value that will be included in the discrete feature. For simplicity, this is set to the maximum in this example.

➔ **Step 8:** Next, click on the ***“Create New Feature”*** button. This will create a discrete feature, which will be visible under the ***“Connectivity-Based Conservation Feature Available for Export”*** panel in a table format (see step 8 in Figure 27).

➔ **Step 9:** Examine the table with information on the new feature. The table column heading ***“Planning Unit”*** indicates the percentage of planning units containing the original feature. Note that Feature 1 is present in 10% of all planning units. You want to target the top 50% of these relevant planning units. In other words, you want to target the top 5%, so the 95th percentile. To produce a discrete feature that includes 5% of all planning units, you will need to create a new feature with the minimum threshold set to the 95th percentile. In sum, you are using information provided from the temporary discrete feature (*i.e.*, the feature created following steps 5-8) to identify the minimum threshold that will need to be set to create the desired connectivity-based discrete feature that includes 5% of all planning units (this will be done in step 11).

➔ **Step 10:** Before proceeding, you must delete the temporary feature that served to identify the minimum threshold setting. You will delete this feature by 1) selecting it from the ***“Selection”*** list, and 2) then removing it with the ***“Remove Selection”*** button. To select the feature, click on the ***“Selection”*** drop down list and select the name corresponding to the temporary feature. The name of the temporary feature will include the FEAT_# and the minimum threshold value used to create it. For example, if you used a minimum threshold value of “0.00015”, then the feature will be named “Google PageRank (Feat_1) google_land_pu_FEAT_1 _discrete_ 0.00015_to_maximum”. With the feature selected, click on the ***“Remove Selection”*** button to delete it. Note that the feature has been removed as an option in the ***“Selection”*** menu and is no longer visible in the table at the bottom of the tab window.

After identifying the minimum threshold setting and deleting the temporary feature, you can proceed to generating the (final) discrete feature from the Google PageRank metric.

➔ **Step 11:** In this step, you will generate the (final) discrete feature for Google PageRank (Feat_1). With the ***“Google PageRank (FEAT_1)”*** selected in the ***“Selection”*** menu, check the ***“Percentile”*** box in the ***“Make discrete feature from minimum threshold”*** panel and slide the slider to ***“95”*** (i.e., the minimum threshold calculated in step 9). In the ***“Make discrete feature from maximum threshold”*** panel, check ***“Quartile”*** and then ***“Maximum”***. Next, click on the ***“Create New Feature”*** button to generate the discrete feature. Examine the output table. Note that the discrete feature is present in 5% of all planning units.

Well done! You have successfully created a discrete connectivity-based feature for Feature 1. Marxan Connect will incorporate this connectivity-based feature in the Marxan analysis, along with the conservation features. You will now need to create the additional connectivity-based features for Feature 4, 7, 11, and 16.

➔ **Step 12:** Repeat the above steps for the remaining 4 conservation features. Alternatively, you can opt to skip steps 1 to 10 by using the "cheat sheet" in Table 7, which provides the minimum threshold settings of each conservation feature. If you choose to go this route, move straight to step 11. Remember to select the desired metric from the ***"Selection"*** menu, and to slide the slider to the corresponding minimum threshold value, which is provided in Table 7 under the ***"Set Minimum Threshold"*** column heading.

Table 7. Google PageRank minimum threshold by conservation features

FEAT_ID	% of total PUs containing original feature	% of total PUs containing discretized feature	Set Minimum Threshold
1	10%	5%	95%
4	16%	8%	92%
7	3%	1.5%	~99%
11	25%	12.5%	~88%
16	7%	3.5%	~97%

➔ **Step 13:** When you are done, the table under the ***"Connectivity-Based Conservation Feature Available for Export"*** should look like Figure 28. Make sure you have not made any mistakes. You can do this by reviewing the "names" of the connectivity-based conservation features in the ***"New Conservation Feature"*** column; which includes the FEAT_# and the minimum threshold value. If you made a mistake, select the connectivity-based conservation feature (with the mistake) from the ***"Selection"*** drop-down menu and click the ***"Remove Selection"***. You can then re-create the conservation feature with the corrected values.

Connectivity-Based Conservation Feature Available for Export:

	New Conservation Feature	Status	Planning Units
1	google_land_pu_FEAT_1_discrete_95th_percentile_to_maximum	Status Quo	5.0%
2	google_land_pu_FEAT_4_discrete_92th_percentile_to_maximum	Status Quo	8.0%
3	google_land_pu_FEAT_7_discrete_99th_percentile_to_maximum	Status Quo	1.0%
4	google_land_pu_FEAT_11_discrete_88th_percentile_to_maximum	Status Quo	12.0%
5	google_land_pu_FEAT_16_discrete_97th_percentile_to_maximum	Status Quo	3.0%

Figure 28. The 5 connectivity-based conservation features available for export

5.3.5 Marxan Files

Using the **Marxan files** tab, you will now export the discrete connectivity metrics (generated in the previous tab) to Marxan formatted files.

➔ **Step 1:** Go to the ***"5) Marxan Files"*** tab.

➔ **Step 2:** Like in Scenario 1, browse to open the "original" files in the Sc2_1 database (*i.e.*, Marxan input files that do not include connectivity). In other words, open the puvsp.dat file for ***"Original Planning Unit versus Conservation Feature File"***, the spec.dat file for ***"Original Conservation Feature File"***, the bound.dat for ***"Original Spatial Dependencies File"***, and pu.dat file for ***"Original Planning Unit File"***.

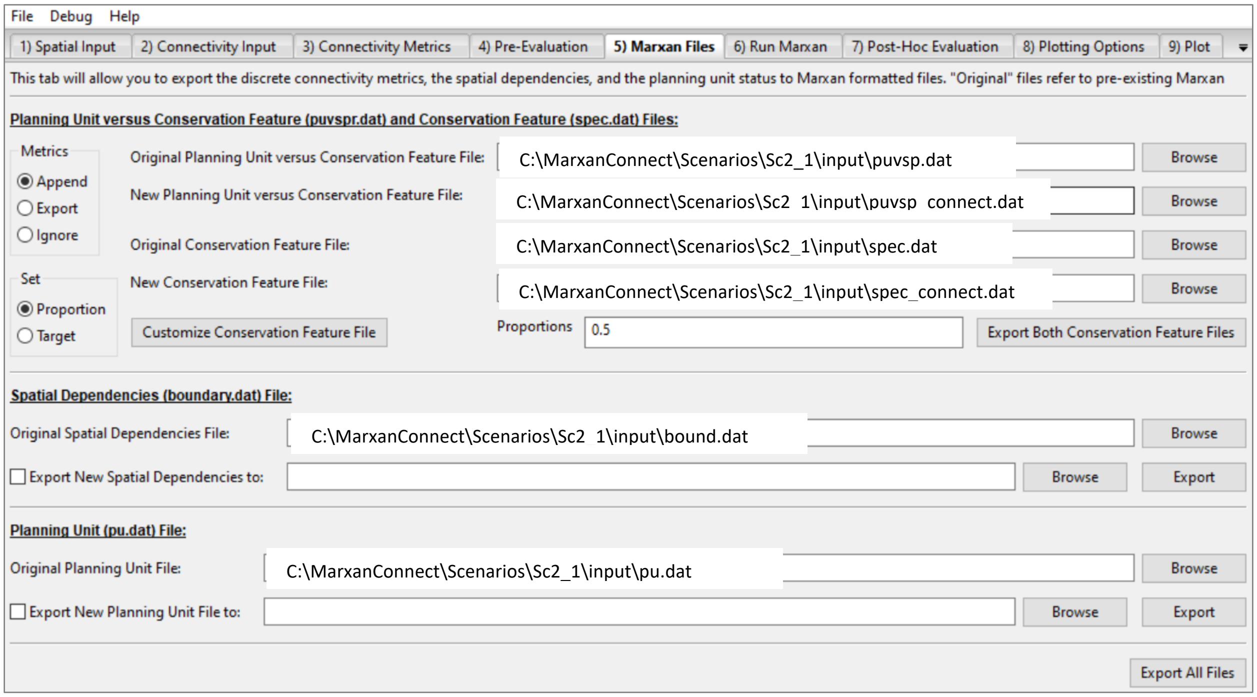


Figure 29. Marxan Files tab for Scenario 2

You will now export the discrete connectivity metrics to "new" Marxan input files. You only need to create new files for the puvsp.dat and spec.dat. The bound.dat and pu.dat will not change, so you do not need to export new files for these files. In other words, you will use the "original" files for the bound.dat and pu.dat files.

➔ **Step 3:** In the ***"Planning Unit versus Conservation Feature (puvspr.dat) and Conservation Feature (spec.dat) Files"*** panel, select ***"Append"*** under ***"Metrics"*** and ***"Proportion"*** under ***"Set"***.

➔ **Step 4:** The "new" files for the puvsp.dat and the spec.dat need to point to a yet to be created file. For each "new" file, copy the file paths for the corresponding "original" file and add "_connect" (e.g., change the file path ending for "spec.dat" to "spec_connect.dat"). See file names for new files in Figure 29.

> ***Note:*** You can set proportions or targets for connectivity-based features in multiple ways. Users can click on the ***"Customize Conservation Feature File"*** button to set individual targets for each feature. They can also use the ***"Proportions"*** or ***"Targets"*** text box (depends on what is selected under the ***"Set"*** panel) to set the same proportion or target for all features. This text box can also be used to enter comma separated string of values (one value per new feature).

➔ **Step 5:** In this Scenario, targets for connectivity-based features will be set as proportions (*i.e.*, ***"Proportion"*** is selected for ***"Set"*** panel in Step 3). You have chosen to set the same target of "0.5" for all your connectivity-based features. To set this target in the tab, enter the value of "0.5" in the ***"Proportions"*** text box. Note, the value of "0.5" entered here only applies to the connectivity-based features that will be generated. The conservation targets for the conservation features will remain at "0.3", as specified in the spec.dat file.

➔ **Step 6:** Uncheck ***"Export New Spatial Dependencies to:"*** and ***"Export New Planning Unit File to:".***

Note: *In the Pre-Evaluation tab, you chose the Minimum Thresholds based on a Google PageRank value that would select ~50% of the planning units for the discrete feature. These planning units are those where the values of the Google PageRank are highest. Which means that if the original feature covered 10% of the planning units, this strategy would create a discrete feature which covers ~5% of the planning area. When a target is set to "0.5" for such a discrete feature, it only applies to those retained planning units. Hence, a 50% target represents 2.5% of the whole planning area assuming you started with 10% (0.1*0.5*0.5=0.025).*

➔ **Step 7:** Ensure that your tab window looks similar to Figure 29. If so, click the ***"Export All Files"*** button to export the discrete connectivity metrics to Marxan formatted files. A pop-up window will let you know if the export has been successful.

➔ **Step 8:** In your file directory, open the input folder for Sc2_1. In addition to the original input files, you should see two connectivity-based input files: puvsp_connect.dat and spec_connect.dat.

➔ **Step 9:** Open both spec.dat file and spec_connect.dat files to compare them. There are a few things to note here. First, the spec_connect.dat contains 5 additional rows that correspond to the generated connectivity-based features. Second, the targets ("prop") in the spec_connect.dat file are set to "0.3" for the 19 conservation features, while the targets for the connectivity-based features are set to "0.5", as set in the "Proportions" text box in the Marxan Files tab. Note that the SPF for the connectivity-based features is set to "1000", a really high value to try to meet these targets.

➔ **Step 10:** Next, open both puvsp.dat and puvsp_connect.dat files. Look through both to see if you can spot any differences between the values in the third column (i.e., the "amount" header). You may notice that the puvsp_connect.dat file has some values of "1", which indicate the presence of connectivity-based features. You may also note that there are more rows in the puvsp_connect.dat file due to the added connectivity-based features.

5.3.6 Run Marxan

You are almost ready to run Marxan for this Scenario. In Scenario 1, you imported a prepared input.dat file to use in the Run Marxan tab. This time, you'll generate one with the new connectivity-based input files using the Run Maran tab.

- ➔ **Step 1:** Go to the ***"6) Run Marxan"*** tab.
- ➔ **Step 2:** Using the default template, enter "10" for ***"Repeat Runs"***, "Sc2_1" for ***"Scenario Name"***, and "1000000" for ***"Number of Iterations"***.
- ➔ **Step 3:** Under ***"Conservation Features"***, select ***"New"*** to use the new files generated from the previous tab (spec_connect.dat and puvspr_connect.dat).
- ➔ **Step 4:** You will use original files for the bound.dat, because no new files were generated for spatial dependencies. Select ***"Original"*** for ***"Spatial Dependencies Type"***. In the ***"Boundary Length Modifier"*** text box, set the value to "10".

> ***Note:*** The "Connectivity Strength Modifier" is the same as the "Boundary Length Modifier" in standard Marxan. They both act to modify the importance of the spatial dependencies part of the Marxan equation which has values of connectivity strength or shared boundary length respectively.

- ➔ **Step 5:** You will use original files for the pu.dat, because a new file was not generated for planning units. For the ***"Planning Unit"*** option, select ***"Original"***.

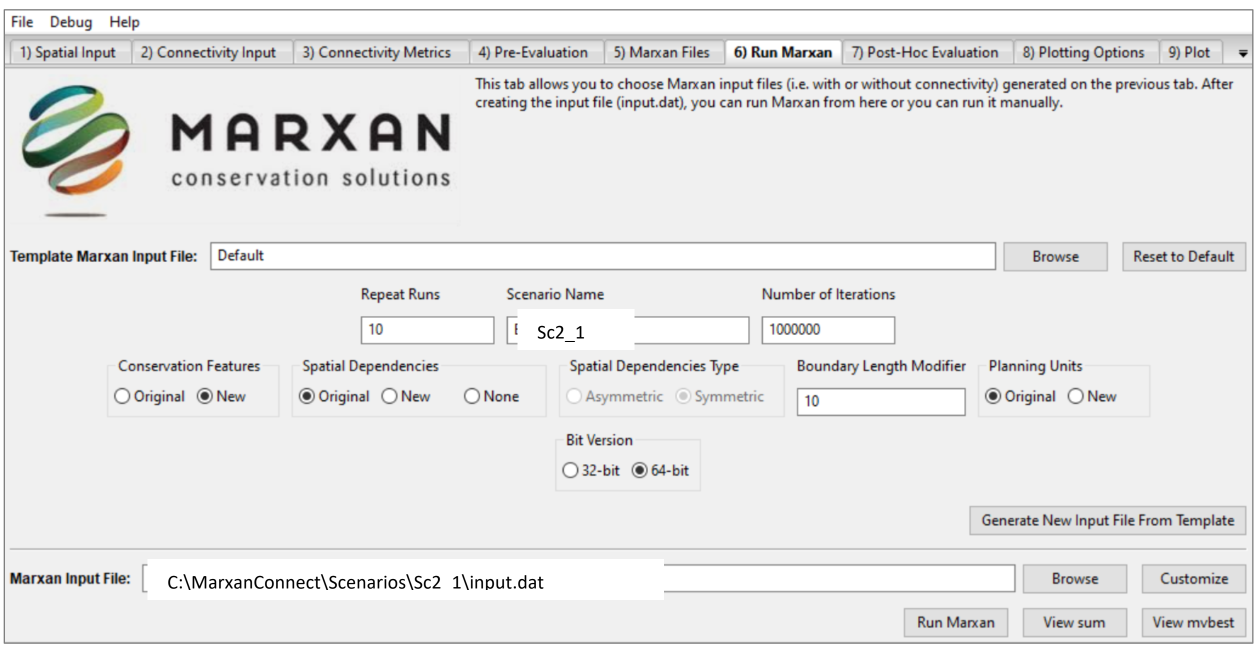


Figure 30. Run Marxan tab for Scenario 2

- ➔ **Step 6:** Depending on your computer, select ***"32-bit"*** or ***"64-bit"*** for the ***"Bit Version"***.
- ➔ **Step 7:** For the ***"Marxan Input File"*** option, browse to the Marxan database for Scenario 2 and open the input.dat file. The tab window should look like Figure 30.

- **Step 8:** Click the ***"Generate New Input File From Template"*** to create the new input file. An already existing input.dat will be overwritten in the next step. An ***"Operations Successful"*** pop-up window should appear if the file was successfully created. Click ***"OK"***.
- **Step 9:** Next, click on ***"Customize"***. This will show you the details of the Marxan input file. Check that the new input files generated in Section 5.3.5 called "puvsp_connect" and "spec_connect" appear in the input.dat.
- **Step 10:** As a final step, click on the ***"Run Marxan"*** button at the bottom of the window to run Marxan within the app.

5.4 Interpretation of Results for Scenario 2

You will use similar steps as in Scenario 1 to interpret the Marxan results with landscape-based connectivity data.

5.4.1 Interpret Results Using the Run Marxan tab

Using the same process outlined in Scenario 1, use the Run Marxan tab to inspect the summary report and the missing values for the Best Solution for Scenario 2.

- **Step 1:** Open and inspect the missing values for the Best Solution report (mvbest table) and answer the question below.

CheckPoint 12: *Are the targets for the 5 connectivity-based features being met for the Best Solution? What about for the 19 conservation features? If not, what can be done to address the missing targets?*

- **Step 2:** Open and inspect the summary report (*i.e.*, the sum table).

CheckPoint 13: *For each run, identify how many features are missing their targets? Are solutions similar in terms of the number of missing values?*

5.4.2 Map and Visualise Results Using the Plotting Options and Plot Tabs

Like in Scenario 1, you will use the Plotting Options and Plot tabs to plot and visualise the Best Solution and Selection Frequency.

➔ **Step 1:** Plot and visually inspect the Best Solution map to answer the following question.

CheckPoint 14: *What do you note about the configuration of protected areas selected under the Best Solution (e.g., number, sizing, and spacing of MPAs)?*

➔ **Step 2:** Plot and visually inspect the Selection Frequency map to answer the question below.

CheckPoint 15: *How does the Selection Frequency compare to the Best Solution?*

5.4.3 Post-Hoc Evaluation

In this Scenario, you incorporated connectivity into Marxan. As a result, you do not need to rely on the "rules of thumb" for MPA size and spacing to address your connectivity criteria for designing your MPA network. You will still run a Post-Hoc Evaluation for the Best Solution for Scenario 2 to compare it to the Post-Hoc parameters in Scenario 1.

➔ **Step 1:** Run a Post-Hoc Evaluation and investigate the results. Note that there are additional values for Post-Hoc evaluations, which are only available with connectivity. This includes values for "Connections", "Graph Density", and "Eigenvalue" for each of the 5 connectivity-based features.

See Table 1 in page 14 for the definitions for these Post-Hoc parameters.

- The connections represent the number of connections (*i.e.*, edges) between selected planning units.
- The graph density is the ratio of the number of connections (*i.e.*, edges) between selected planning units and the number of possible connections (*i.e.*, edges) between selected planning units.
- In a flow matrix that includes survival and mortality, the eigenvalue is equal to the metapopulation growth rate. Eigenvalues should only be used to compare different scenarios using the same connectivity data.

CheckPoint 16: *How do the values of the Post-Hoc Evaluation parameters for the Best Solution compare to those in Scenario 1? Are the limitations you identified in Scenario 1 regarding "rules of thumb" for MPA size and spacing addressed here?*

6 Scenario 3: Incorporating Demographic-Based Connectivity Data as Features into Marxan

6.1 About Scenario 3

In this Scenario, you will follow a series of steps to incorporate demographic-based connectivity data as a feature in Marxan. The Scenario is based on the same case study as Scenarios 1 and 2, and like Scenario 2, you have access to connectivity data (i.e., a connectivity matrix). This time however, you have demographic-based connectivity data rather than landscape-based connectivity data.

Your task is to identify potential MPA network configurations for the BC study region that:

- protect at least 30% of each conservation feature;
- minimize the overall cost for commercial fisheries; and
- promotes connectivity within the network of protected areas for a group of organisms with similar dispersal traits.

The connectivity data (*i.e.*, the connectivity matrix) for this third Scenario was generated using a passive particle tracking simulation. This is a biophysical model, which simulates passive larval dispersal with ocean circulation and is a typical approach for estimating connectivity based on larval dispersal trajectories in marine and aquatic ecosystems. The values in the connectivity matrix represent the proportion of larvae released in the simulation from site ***i*** that settle in site ***j*** after 14 days of passive dispersal. This could represent any passively dispersing organism with a similar planktonic larval duration. Since we did not directly observe the movement of larvae, this approach measures *potential* connectivity.

6.2 Marxan Database for Scenario 3

The Sc3 folder in the C:\MarxanConnect\ Scenarios folder is the Marxan database for Scenario 3. It is the same as the previous Scenarios, apart from containing demographic-based data. Again, we have created the connectivity matrix for you. The connectivity matrix for Scenario 3 is the BioPhysical_Flow_EdgeList.csv file in the Sc3\connectivity_data folder.

Note: The connectivity matrix is from a biophysical model output of passive particle tracking released at the bottom in the month of June from 1998 to 2003 with a planktonic larval duration (PLD) of 14 days. Note, the data were simulated solely for the purpose of this practical and should not be used for other purposes.

➔ **Step 1:** In your file directory, navigate to the Sc3 folder and make a copy it. Name the copied folder "Sc3_1". Use the Sc3_1 folder for the rest of the Scenario.

➔ **Step 2:** Reacquaint yourself with the input files, which are the same as those in the previous Scenarios. Take note of the SPF, the BLM, and the conservation targets.

➔ **Step 3:** Next, open the connectivity_data folder in the Sc3_1 folder, which contains the BioPhysical_Flow_EdgeList.csv file. Remember, this is the demographic-based connectivity data you will use to incorporate connectivity into Marxan.

6.3 Set Up and Run Marxan Using Demographic-Based Connectivity Data

➔ **Step 1:** Open the Marxan Connect app. Save the new project under the name "Sc3_1" in the Sc3_1 folder.

6.3.1 Spatial Input

➔ **Step 1:** In the ***"1) Spatial Input"*** tab, browse and open the planning unit shapefile (pulayer_BC_marine_hx.shp) for Scenario 3.

6.3.2 Connectivity Input

Next, you will load the connectivity matrix for Scenario 3 directly into the Connectivity Input tab.

➔ **Step 1:** Open the ***"2) Connectivity Input"*** tab.

➔ **Step 2:** Since this Scenario uses demographic connectivity data, select ***"Demographic Input"*** under the ***"Choose Connectivity Input Category"*** dropdown menu.

➔ **Step 3:** Select ***"Flow"*** under ***"Connectivity Matrix Type"*** to correctly identify the data type.

➔ **Step 4:** Select ***"Edge List"*** under ***"Format"*** to tell the software how the data was formatted (see the glossary on marxanconnect.ca for more details on data formatting and type).

➔ **Step 5:** Select ***"Identical Grids"*** under ***"Rescale Connectivity Matrix"*** because the connectivity data was built at the scale of the planning units making rescaling unnecessary.

➔ **Step 6:** For the ***"Connectivity Matrix"*** option, click on ***"Browse"*** to load the connectivity matrix (BioPhysical_Flow_EdgeList.csv) for Scenario 3. Ensure that the tab looks like Figure 31 before proceeding to the next tab.

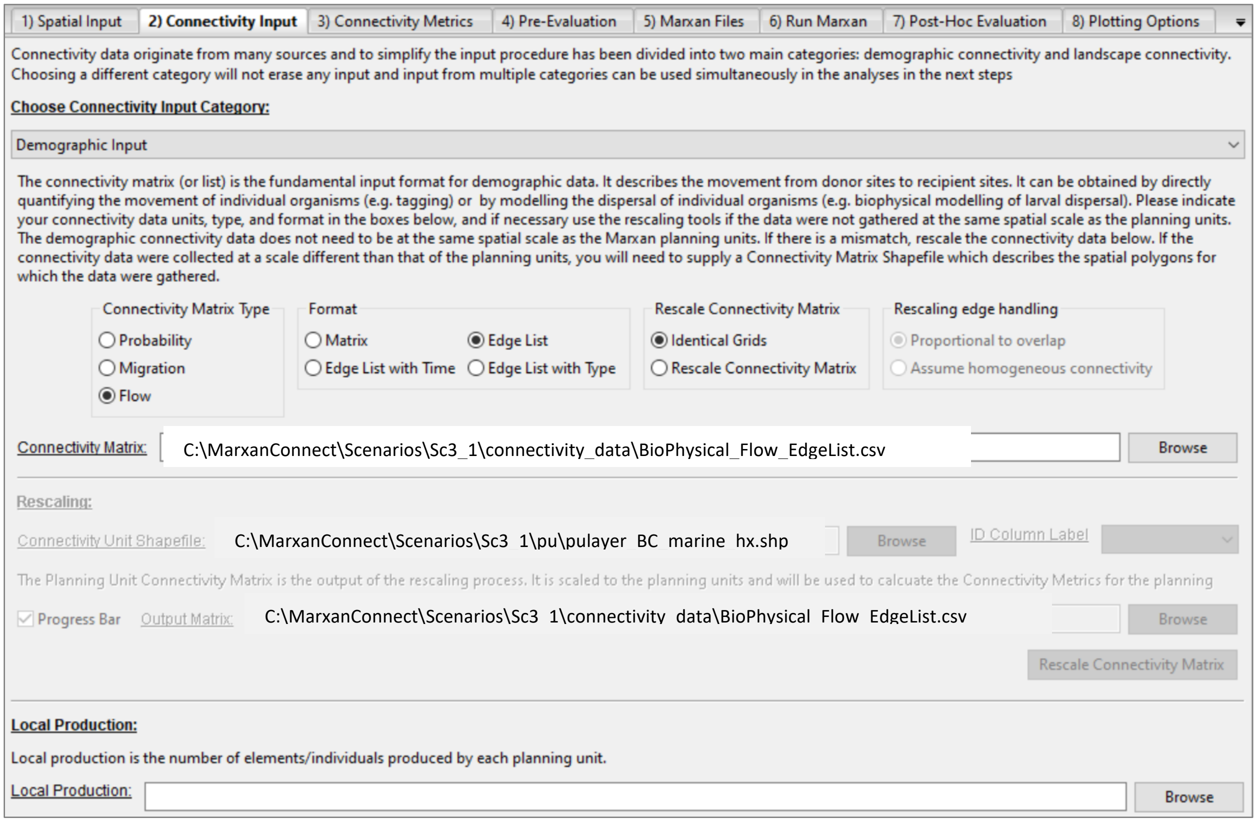


Figure 31. Connectivity Input tab for Scenario 3

6.3.3 Connectivity Metrics

Like in Scenario 2, you have chosen to use the Google PageRank here.

➔ **Step 1:** Open the ***"3) Connectivity Metrics"*** tab.

➔ **Step 2:** Under ***"Demographic"***, select ***"Google PageRank"*** as your metric.

➔ **Step 3:** At the bottom of the window, select the ***"Planning Units"*** option. Do not select the ***"Connectivity Units"*** option.

➔ **Step 4:** Click the ***"Calculate Metrics"*** button to calculate the metrics for planning units. This might take a few minutes. Once the calculations are complete, proceed to the next tab.

6.3.4 Pre-Evaluation

As done in Scenario 2, you will use the Pre-Evaluation tab to create a discrete connectivity-based feature according to a set threshold for the Google PageRank connectivity metric to be used within Marxan. Specifically, you will make binary presence/absence features for the "best" connected areas ("0" for absence and "1" for presence of planning units for which the metric is above the selected threshold). Refer to Scenario 2 (Section 5.3.4 Pre-Evaluation) for a reminder of how the discretization of connectivity-based features works.

In this Scenario, you will discretize the connectivity metric associated with the single connectivity-based feature. This differs from Scenario 2, which involved multiple connectivity matrices (one per conservation feature). There is only one connectivity-based feature in Scenario 3 because connectivity was measured based on generalized larval dispersal estimates, rather than on distance between patches for each critical habitat type. Larval dispersal was modelled to potentially include connectivity from any planning unit to any planning unit, rather than restricting possible connectivity to planning units that contain the original conservation to feature.

Unlike Scenario 2, the connectivity data covers nearly the entire planning area as opposed to being habitat specific. The percentile or quartile tools can thereby be used effectively to select the proportion of planning units directly. To generate the discrete connectivity-based feature, you have chosen to set the minimum threshold (as a percentile) to “80”, which you have deemed as low enough to avoid forcing Marxan to select specific planning units, yet high enough to maintain the ecological benefits of selecting planning units that contain ‘high connectivity’ (*i.e.*, high Google PageRank).

> ***Note:*** In real-world conservation planning scenarios, setting threshold values will require more elaborate fine-tuning and thought based on the sensitivity of the connectivity process and the effectiveness of spatial protection for the feature in question.

➔ **Step 1:** Open the ***“4) Pre-Evaluation”*** tab.

➔ **Step 2:** Because we are only working with one connectivity feature, we can only select *“Google PageRank”* under *“Choose Available Connectivity Metric to Discretize”*.

➔ **Step 3:** Next, generate a frequency plot by clicking the *“Plot Frequency”* button. A graph (Figure 32) will appear on a separate tab named “9) Plot”. Note that in this case there is more of a continuous range of values for the Google PageRank when compared to Scenario 2 because of the nature of the connectivity data (*i.e.*, fewer zeros in the connectivity matrix). We can also see that the quartile/median indicators are more valuable in this case. The lower quartile values have little or effectively no connectivity, and values above the upper quartile will have increasingly higher Google Page Rank.

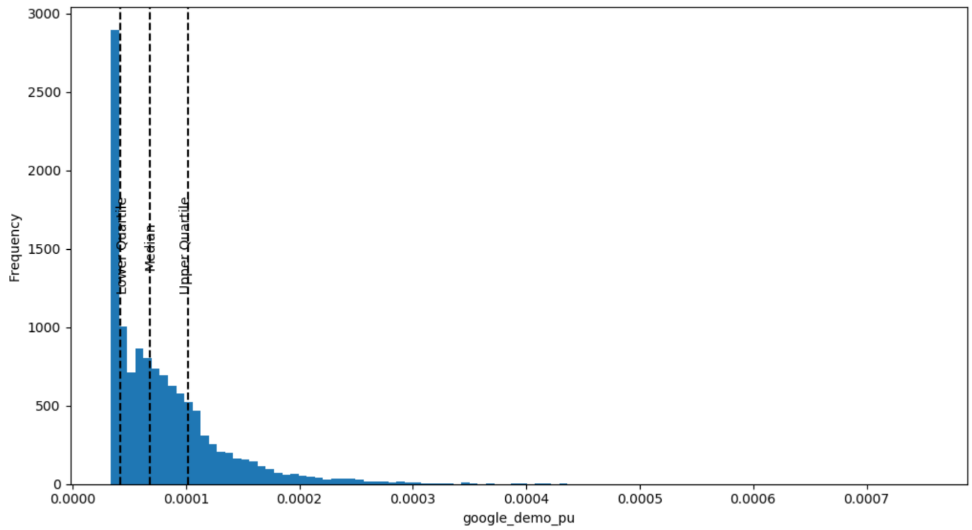


Figure 32. Plot Frequency of the Google PageRank metric for Scenario 3

- ➔ **Step 4:** Return to the Pre-Evaluation tab. In the ***"Make discrete feature from minimum threshold"*** panel, select ***"Percentile"*** and slide until you get "80".
- ➔ **Step 5:** Click on the ***"Create New Feature"*** button to create a discrete feature. Examine the table under the ***"Connectivity-Based Conservation Feature Available for Export"*** panel and note that the new discrete feature is present in the 20% of all planning units (Figure 33).

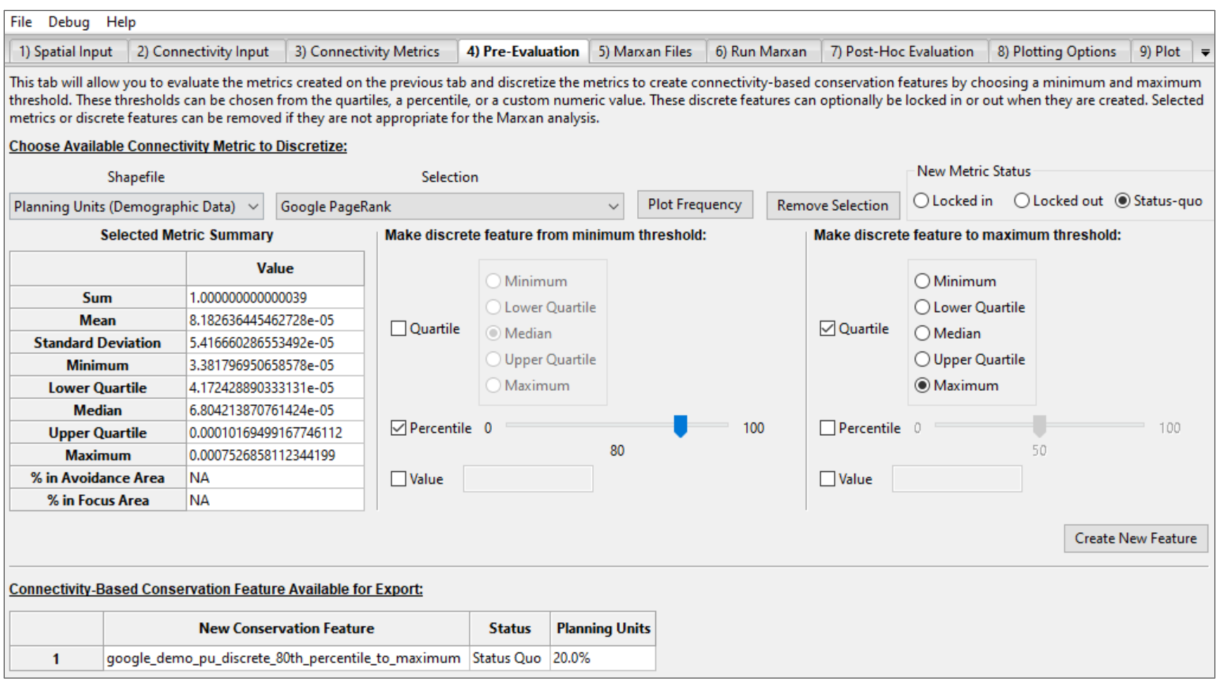


Figure 33. Pre-Evaluation tab for Scenario 3

6.3.5 Marxan Files

Using the **Marxan files** tab, you will now export the discrete connectivity metrics (generated in the previous tab) to Marxan formatted files. The steps below are similar to those of Scenario 2.

➔ **Step 1:** Go to the ***"5) Marxan Files"*** tab.

➔ **Step 2:** In the ***"Planning Unit versus Conservation Feature (puvspr.dat) and Conservation Feature (spec.dat) Files"*** panel, select ***"Append"*** under ***"Metrics"*** and ***"Proportion"*** under ***"Set"***.

➔ **Step 3:** For the ***"Original Planning Unit versus Conservation Feature File"*** and ***"Original Conservation Feature File"*** browse and open the puvsp.dat and spec.dat respectively.

➔ **Step 4:** For the ***"New Planning Unit versus Conservation Feature File"*** and ***"New Conservation Feature File"*** copy the file paths for the corresponding "original" file and add "_connect" (e.g., change the file path ending for "spec.dat" to "spec_connect.dat").

➔ **Step 5:** Like Scenario 2, set a target (prop) of "0.5" for your connectivity-based feature by entering the value of "0.5" in the ***"Proportions"*** text box. Remember, the targets for the conservation features will remain at "0.3", as specified in the spec.dat file.

➔ **Step 6:** For the ***"Original Spatial Dependencies File"*** and ***"Original Planning Unit File" Original Conservation Feature File"***, browse and open the bound.dat and pu.dat respectively.

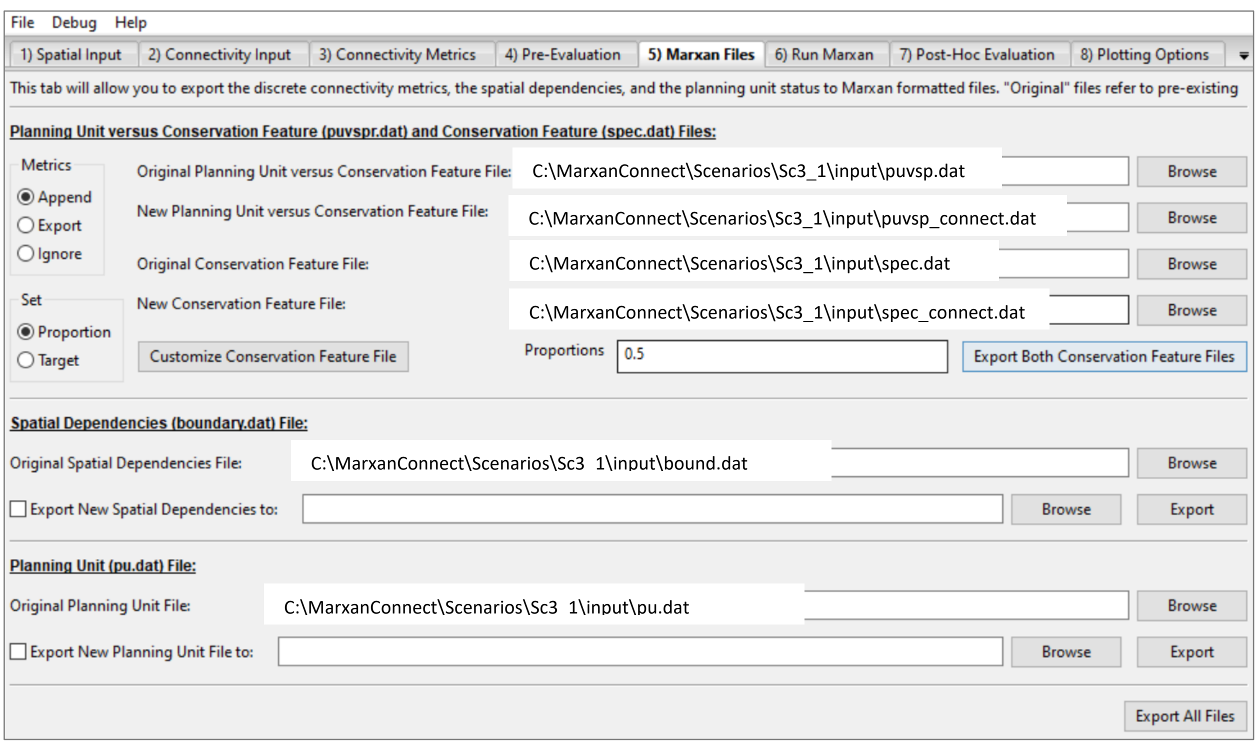


Figure 34. Marxan Files tab for Scenario 3

➔ **Step 7:** Uncheck ***"Export New Spatial Dependencies to:"*** and ***"Export New Planning Unit File to:"***, since you will be using the original files for these inputs.

➔ **Step 8:** Ensure that your tab window looks similar to Figure 34. If so, click the ***"Export All Files"*** button to export the discrete connectivity metrics to Marxan formatted files. A pop-up window will let you know if the export has been successful.

➔ **Step 9:** In your file directory, open the input folder for Sc3_1. In addition to the original input files, you should see two connectivity-based input files: puvsp_connect.dat and spec_connect.dat.

➔ **Step 10:** Open both spec.dat file and spec_connect.dat files to compare them. Note that the spec_connect.dat contains one additional row that corresponds to the generated connectivity-based feature. Notice that the targets ("prop") in the spec_connect.dat file are set to "0.3" for the 19 conservation features. In contrast, the prop is set to "0.5" for the connectivity-based feature, as specified in the ***"Proportions"*** text box in the Marxan Files tab.

➔ **Step 11:** Next, open both puvsp.dat and puvsp_connect.dat files. Note that in the puvsp_connect.dat file, the connectivity-based feature ("species" column = 20) has a value of "1" for each planning unit it overlaps with, which indicates the presence of the connectivity-based feature in that particular planning unit.

➔ **Step 12:** Close all the opened files before proceeding to the next tab.

6.3.6 Run Marxan

You are almost ready to run Marxan for Scenario 3. Like in Scenario 2, you will use the Run Marxan tab to generate a new input.dat file with the new connectivity-based inputs. The steps below are similar to those of Scenario 2.

➔ **Step 1:** Open the ***"6) Run Marxan"*** tab.

➔ **Step 2:** Using the default template, name the scenario "Sc3_1", set the number of repeat runs to "10", and the number of iterations to "1000000".

➔ **Step 3:** Under ***"Conservation Features"***, select ***"New"*** to use the new files generated (i.e., the spec_connect.dat and puvspr_connect.dat files). Select the original files for the ***"Spatial Dependencies Type"*** and the ***"Planning Unit"*** option. Set the ***"Boundary Length Modifier"*** to "10". Finally, select ***"32-bit"*** or ***"64-bit"*** for the ***"Bit Version"*** based on your computer.

➔ **Step 4:** Browse to the Marxan database for Scenario 3 and open the input.dat file. The tab window should look like Figure 35.

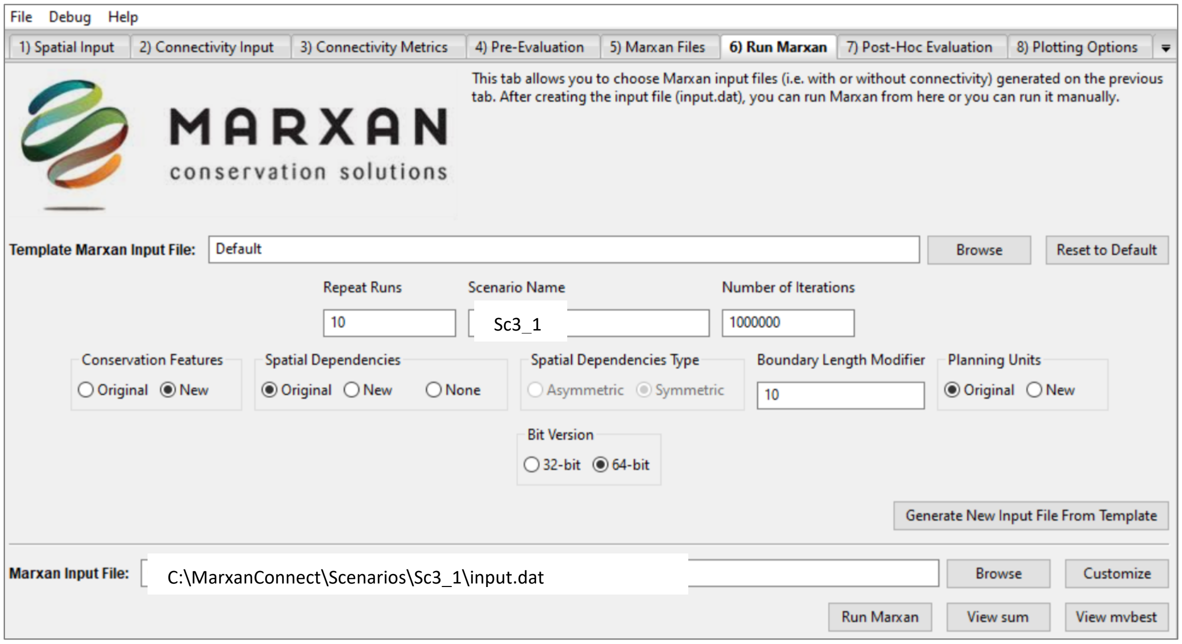


Figure 35. Run Marxan tab for Scenario 3

- ➔ **Step 5:** Click the ***"Generate New Input File From Template"*** to create the new input file. An already existing input.dat will be overwritten in the next step. An ***"Operations Successful"*** pop-up window should appear if the file was successfully created. Click ***"OK"***.
- ➔ **Step 6:** Click on ***"Customize"*** to examine the Marxan input file. The newly generated input files have "_connect" added to them. Check that all the parameters are set correctly.
- ➔ **Step 7:** Finally, click on the ***"Run Marxan"*** button to run Marxan.

6.4 Interpretation of Results for Scenario 3

You will use the same steps as in Scenario 1 and 2 to interpret the Marxan results with demographic connectivity data.

6.4.1 Interpret Results Using the Run Marxan tab

➔ **Step 1:** Open and inspect the missing values for the Best Solution report (mvbest table).

CheckPoint 17: *Are the targets for the connectivity-based feature being met for the Best Solution? What about for the 19 conservation features?*

➔ **Step 2:** Open and inspect the summary report (i.e. the sum table).

CheckPoint 18: *For each run, identify how many features are missing their targets? Are solutions similar in terms of the number of missing values?*

6.4.2 Map and Visualise Results Using the Plotting Options and Plot Tabs

Like you did in Scenario 1 and 2, use the Plotting Options and Plot tabs to create and visualise the Best Solution and Selection Frequency maps.

➔ **Step 1:** Plot and visually inspect the Best Solution map to answer the following question.

CheckPoint 19: *What do you note about the configuration of protected areas selected under the Best Solution (e.g., number, sizing, and spacing of MPAs)?*

➔ **Step 2:** Plot and visually inspect the Selection Frequency map to answer the question below.

CheckPoint 20: *How does it compare with the Best Solution?*

6.4.3 Post-Hoc Evaluation

You will now run a Post-Hoc Evaluation for the Best Solution for Scenario 3 to compare it to the post-hoc parameters in Scenario 1. See Table 1 in page 14 for the definitions for these Post-Hoc parameters.

➔ **Step 1:** Run a Post-Hoc Evaluation and investigate the results. Unlike Scenario 1 but similarly to Scenario 2, there are values for the following connectivity-based parameters: "Connections", "Graph Density", and "Eigenvalue". Note that there is only one set of values for each connectivity-based parameter, as opposed to Scenario 2, which included a value for each connectivity-based parameter for each of the 5 connectivity-based features.

CheckPoint 21: *How do the values of the Post-Hoc Evaluation parameters for the Best Solution compare to those in Scenario 1? Are the limitations you identified in Scenario 1 regarding "rules of thumb" for MPA size and spacing addressed here?*

7 Scenario 4: Incorporating Demographic-Based Connectivity Data as Spatial Dependencies into Marxan

7.1 About Scenario 4

Scenario 4 provides an example of a possible workflow using demographic-based connectivity data as **spatial dependencies**. The scenario is based on the same case study as the previous scenarios. It is similar to Scenario 2 and 3 in terms of having access to connectivity data but differs in how connectivity data is incorporated into Marxan.

Recall from Section 2.1 that connectivity data can either be incorporated into Marxan as a feature or as spatial dependencies between planning units. You already worked through some examples for incorporating connectivity data as a feature in Scenario 2 and 3. Now, you'll get the chance to practice incorporating connectivity as spatial dependencies.

Your task is to identify potential MPA network configurations for the BC study region that:

- protect at least 30% of each conservation feature;
- minimize the overall cost for commercial fisheries; and
- promotes connectivity and population growth within a network of protected areas, which is the case if the network has an eigenvalue higher than 1.

7.2 Marxan Database for Scenario 4

The Sc4 folder in the C:\MarxanConnect\Scenarios folder is the Marxan database for Scenario 4. In this Scenario, you will use the same demographic-based connectivity data used in Scenario 3, but the data has been randomly subsampled (i.e., 200,000 rows of the 6,880,545 in the original edgelist) to create a Scenario that can be computed in a workshop-friendly timeline. The connectivity matrix (BioPhysical_Flow_EdgeList_random200k_sample.csv) for Scenario 4 is in the connectivity_data folder in the Sc4 folder. In this Scenario, you will treat this matrix as an ideal flow matrix which represents the amount of movement, mortality, and reproduction between planning units for an imaginary benthic invertebrate. Under these conditions, the eigenvalue of the flow matrix is equal to the metapopulation growth rate. A metapopulation is defined as a group of spatially separate populations.

For the purposes of this Scenario, you can imagine that each planning unit contains a population, and the metapopulation corresponds to all the populations in the entire planning area or network (i.e. solution) depending on the column of the post-hoc results. If the metapopulation growth rate is <1, extinction will occur (in this Scenario, this is the species which is the conservation features). Note, if mortality and reproduction are not incorporated into the flow matrix, the eigenvalue is not equal to the metapopulation growth rate.

➔ **Step 1:** In your file directory, navigate to the Sc4 folder and make a copy it. Name the copied folder "Sc4_1". Use the Sc4_1 folder for the rest of the Scenario.

➔ **Step 2:** Reacquaint yourself with the input files, which are the same as those in previous Scenarios. Take note of the SPF, the BLM, and the conservation targets.

➔ **Step 3:** Next, open the connectivity_data folder in the Sc4_1 folder, which contains the BioPhysical_Flow_EdgeList_random200k_sample.csv file. Note that this is a subsample of the connectivity matrix used in Scenario 3.

➔ **Step 4:** Open the Marxan Connect app. Save the new project under the name "Sc4_1" in the Sc4_1 folder.

7.3 Set Up and Run Marxan

7.3.1 Spatial Input

➔ **Step 1:** In the ***"1) Spatial Input"*** tab, browse and open the planning unit shapefile (pulayer_BC_marine_hx.shp) for Scenario 4.

7.3.2 Connectivity Input

Next, you will load the connectivity matrix for Scenario 4 directly into the Connectivity Input tab.

➔ **Step 1:** Open the ***"2) Connectivity Input"*** tab.

➔ **Step 2:** Since this Scenario uses demographic connectivity data, select ***"Demographic Input"*** under the ***"Choose Connectivity Input Category"*** dropdown menu.

➔ **Step 3:** Select ***"Flow"*** under ***"Connectivity Matrix Type"*** to correctly identify the data type.

➔ **Step 4:** Select ***"Edge List"*** under ***"Format"*** to tell the software how the data was formatted (see the glossary on marxanconnect.ca for more details on data formatting and type).

➔ **Step 5:** Select ***"Identical Grids"*** under ***"Rescale Connectivity Matrix"*** because the connectivity data was built at the scale of the planning units making rescaling unnecessary.

➔ **Step 6:** For the ***"Connectivity Matrix"*** option, click on ***"Browse"*** to load the connectivity matrix (BioPhysical_Flow_EdgeList_random200k_sample.csv) for Scenario 4. Ensure that the tab looks like Figure 36 before proceeding to the next tab.

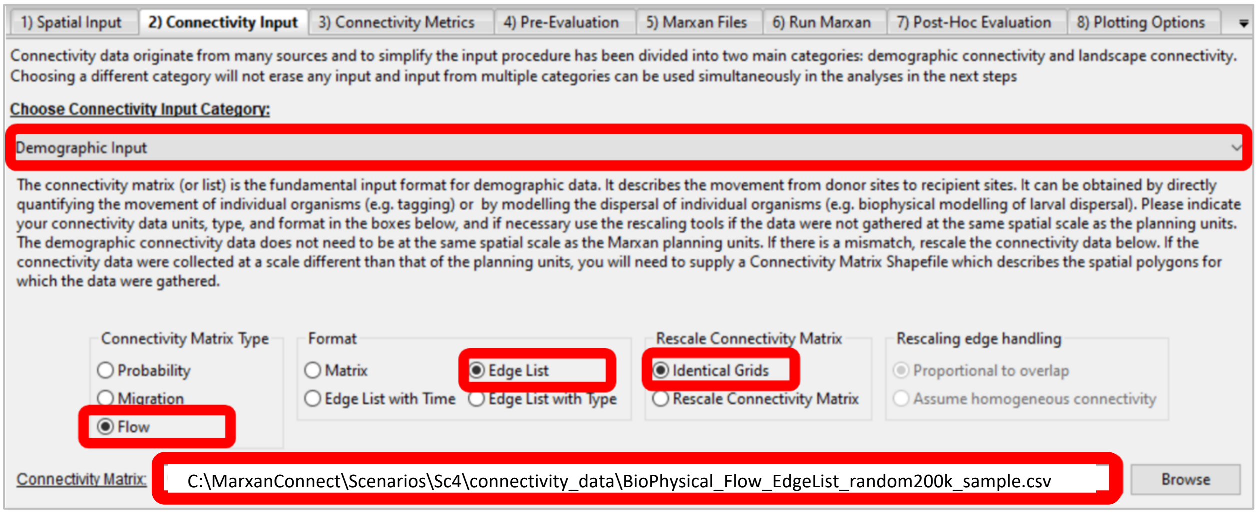


Figure 36. Connectivity Input tab for Scenario 3

7.3.3 Connectivity Metrics

➔ **Step 1:** Open the ***"3) Connectivity Metrics"*** tab.

➔ **Step 2**: Select ***"Connectivity as spatial dependency"*** under ***"Planning Unit Dependency as Boundary Definition"*** in the "***Demographic"*** column (Figure 37).

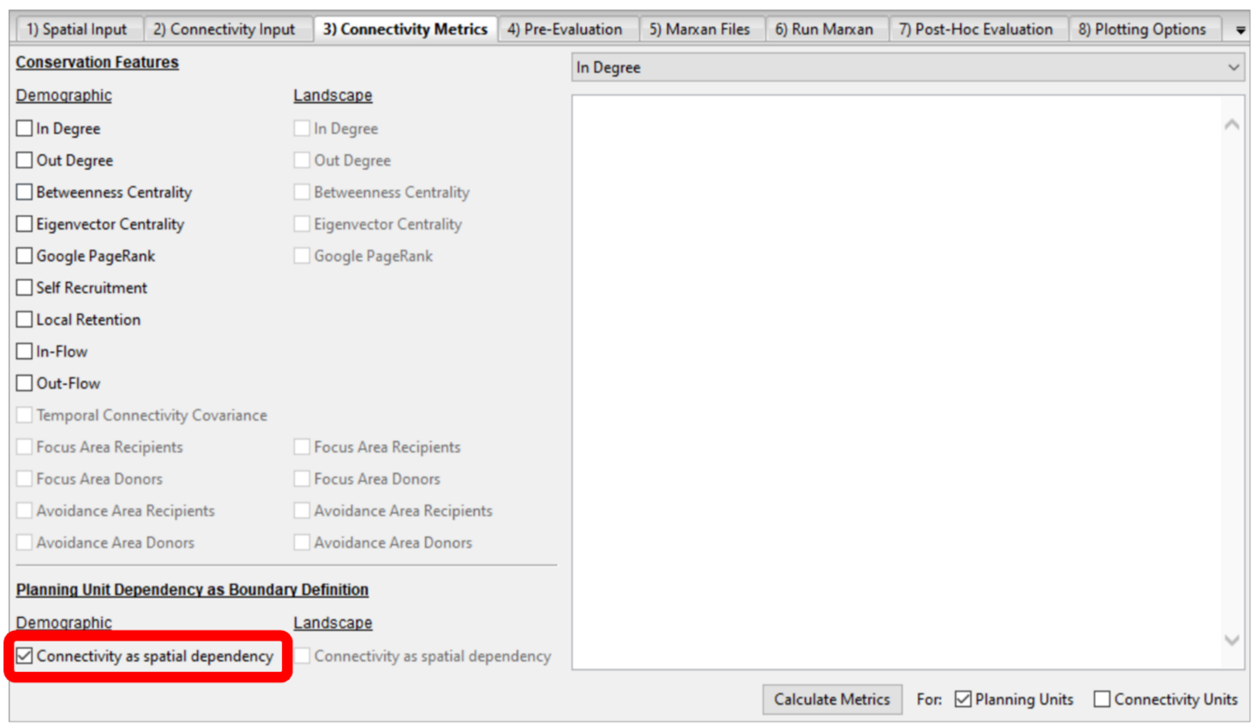


Figure 37. Connectivity Metrics tab for Scenario 4

➔ **Step 3**: Click on the ***"Calculate Metrics"***. The software will reform the connectivity matrix to the appropriate Marxan-compatible edgelist. You will export that edglist on the ***"Marxan Files"*** tab.

Note: No action is required in the ***"Pre-Evaluation"*** tab for spatial dependencies calculated using the ***"connectivity as boundary"*** option in the ***"Connectivity Metrics"*** tab. The ***"Pre-Evaluation"*** tab is required if users want to include connectivity as a conservation feature.

7.3.4 Marxan Files

Using the **Marxan files** tab, you will now export the new spatial dependencies data (reformatted in the Connectivity Metrics tab) to Marxan formatted files.

- ➔ **Step 1:** Go to the ***"5) Marxan Files"*** tab.
- ➔ **Step 2**: Select ***"Ignore"*** for the ***"Metrics"*** option since we are not exporting any connectivity-based features (Figure 38).
- ➔ **Step 3**: Under ***"Planning Unit versus Conservation Feature (puvspr.dat) and Conservation Feature (spec.dat) Files"*** and ***"Planning Unit (pu.dat) File"*** sections of this tab, you only need to identify the 'original' files since we are not exporting new versions. Click on the three corresponding ***"Browse"*** buttons to find the appropriate puvsp.dat, spec.dat, and pu.dat files in the input folder for Scenario 4 (Figure 38).
- ➔ **Step 4**: We will focus on the ***"Spatial Dependencies (boundary.dat) File:"*** section. Leave the ***"Original Spatial Dependencies File"*** blank, as you will generate a new spatial dependencies file. Verify that the ***"Export New Spatial Dependencies to"*** is selected. For the ***"Export New Spatial Dependencies to"*** option, browse to and open the bound.dat file for Scenario 4, then edit the file path by adding "_connect" to the end of the file name (i.e., change the file path ending from "bound.dat" to "bound_connect.dat").
- ➔ **Step 4**: Ensure that your tab looks like Figure 38. If so, click on ***"Export"*** for the ***"Spatial Dependencies (boundary.dat) File"*** section (not ***"Export All Files"***).

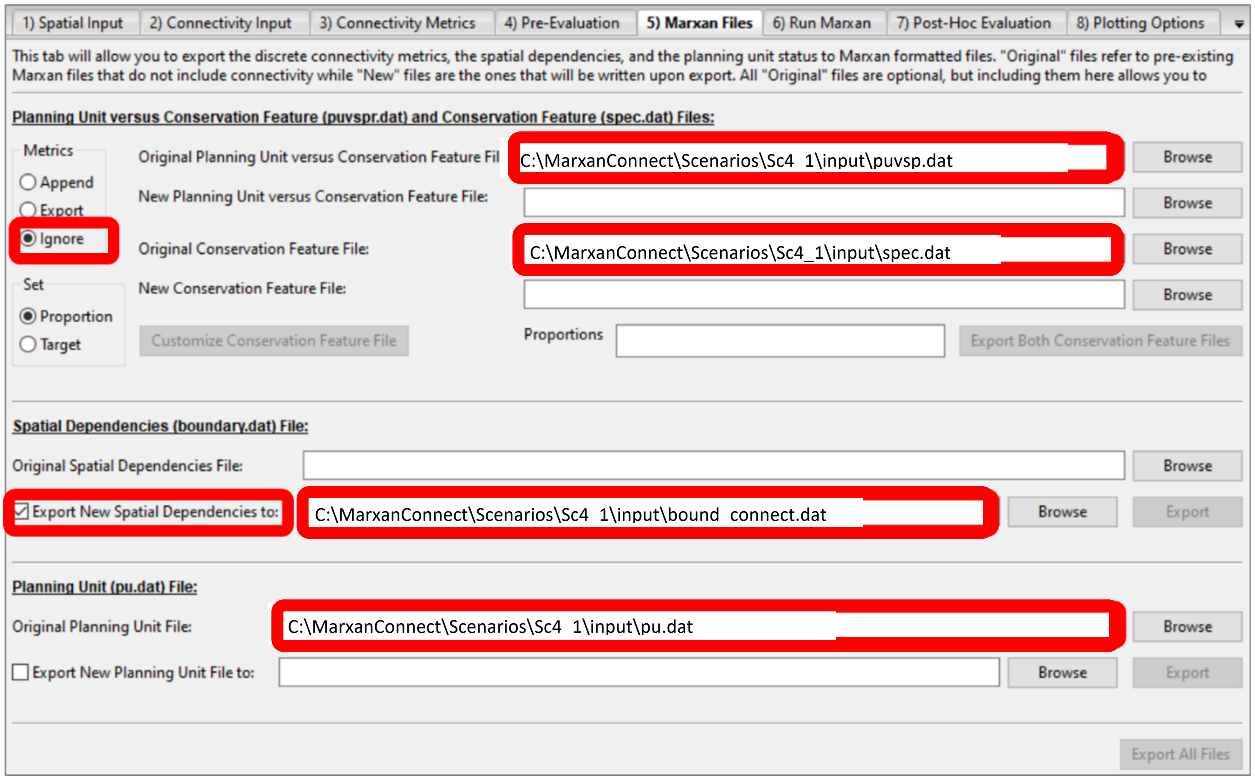


Figure 38. Marxan Files for Scenario 4

7.3.5 Run Marxan

➔ **Step 1:** Open the ***"6) Run Marxan"*** tab.

➔ **Step 2:** Using the default template, name the scenario "Sc4_1", set the number of repeat runs to "10", and the number of iterations to "1000000".

➔ **Step 3:** Select the original files for ***"Conservation Features"*** and the ***"Planning Units"*** option. Under ***"Spatial Dependencies"***, select ***"New"*** to use the new generated file (*i.e.*, bound_connect.dat). Select ***"Asymmetric"*** for ***"Spatial Dependencies Type"***. Under ***"Connectivity Strength Modifier"***, type "1000000000" (*i.e.*, 1 billion).

➔ **Step 4:** Select ***"32-bit"*** or ***"64-bit"*** for the ***"Bit Version"*** based on your computer.

➔ **Step 5:** For the ***"Marxan Input File"***, browse to the Marxan database for Scenario 4 and name your new file "input_connect.dat". The tab window should look like Figure 39.

➔ **Step 6:** Click the ***"Generate New Input File From Template"*** to create the new input file. An ***"Operations Successful"*** pop-up window should appear if the file was successfully created. Click ***"OK"***.

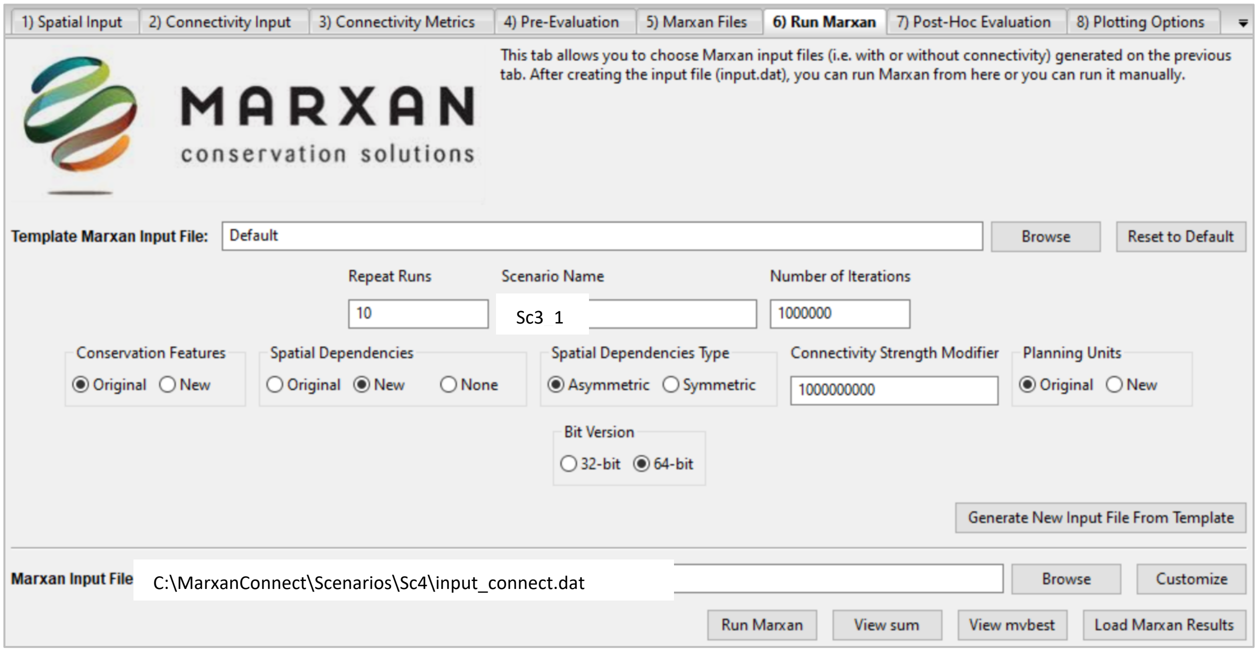


Figure 39. Run Marxan tab for Scenario 4

➔ **Step 7:** Click on ***"Customize"*** to examine the Marxan input file. The newly generated spatial dependencies file will have "_connect" added to it. Check that all the parameters are set correctly.

➔ **Step 8:** Finally, click on the ***"Run Marxan"*** button to run Marxan.

7.4 Interpretation of Results for Scenario 4

Follow the same steps as in the previous Scenarios to interpret the Marxan results of Scenario 4.

7.4.1 Interpret Results Using the Run Marxan tab

➔ **Step 1:** In the ***"6) Run Marxan"*** tab, open and inspect the missing values for the Best Solution report (mvbest table).

CheckPoint 22: *Are the targets for the 19 conservation feature being met for the Best Solution?*

➔ **Step 2:** Open and inspect the summary report (*i.e.*, the sum table).

CheckPoint 23: *For each run, identify how many features are missing their targets? Are solutions similar in terms of the number of missing values?*

7.4.2 Map and Visualise Results Using the Plotting Options and Plot Tabs

Use the Plotting Options and Plot tabs to create and visualise the Best Solution and Selection Frequency maps.

➔ **Step 1:** Plot and visually inspect the Best Solution map to answer the following question.

CheckPoint 24: *What do you note about the configuration of protected areas selected under the Best Solution (e.g., number, sizing, and spacing of MPAs)?*

➔ **Step 2:** Plot and visually inspect the Selection Frequency map to answer the question below.

CheckPoint 25: *How does it compare with the Best Solution?*

7.4.3 Post-Hoc Evaluation

You will now run a Post-Hoc Evaluation for the Best Solution of Scenario 4. See Table 1 in page 14 for the definitions for these Post-Hoc parameters.

➔ **Step 1:** Run a Post-Hoc Evaluation on the Best Solution and investigate the results. Take note of the values of connectivity-based post-hoc parameters, particularly the Eigenvalue.

CheckPoint 26: Does the eigenvalue for the best solution MPA network suggest the imaginary benthic invertebrate will go extinct?

CheckPoint 27: *Compare the post-hoc results of Scenario 4 with those of Scenario 2 and Scenario 3. Do you notice any differences between the connectivity-based parameters?*

CheckPoint 28: *Can you think of any advantages or disadvantages of incorporating connectivity into Marxan as spatial dependencies (Scenario 4) versus as conservation-based features (Scenario 2 and Scenario 3)?*

8 References

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