Introduction to Marxan
Course Manual
Day 2

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Table of Contents

Day 2

1. What is Zonae Cogito?

Zonae Cogito (ZC) is software designed as a decision support system and database management system to supplement the Marxan software. It incorporates open-source GIS software components, and is a freely available software package. See the ZC user manual for more detailed information (located in C:\IntroMarxan\documents).

In ZC you can:

- Edit Marxan some parameters and input files
- Run Marxan analyses
- Interactively view the results of Marxan analyses
- Interactively make changes to Marxan solutions
- Calibrate Marxan parameters
- Run the full range of Marxan software (including Marxan, Marxan with Zones, Threat Probability, and cluster analysis of Marxan solutions)
- Use as the GIS for the C-Plan Conservation Planning System

2. Creating a backup database

Before creating a new ZC project it is good practice to create a backup copy of all of your work. This way if something happens or you make changes you will have a clean original copy ready to work with.
We did this step the day before by creating the folder Marxan_database_backup.

3. Scenarios in ZC

Most Marxan analyses will require you to explore a number of slightly different problem definitions that have varying conservation feature targets, cost layers, groups of conservation features and/or clumping. It is rare that only one problem definition will be run to inform a conservation plan. We refer to these different problem definitions (with one or more different "key" parameters) as **scenarios.**

Another important definition for Zonae Cogito is the **project**. A project links Zonae Cogito to Marxan, the current scenario database, and the current scenario's copy of the planning unit shapefile. Any edits you make to a project are written directly to that scenario's input files (writing over what was previously there!). This is why it is important to have a backup database, so that you can work backwards if you make a change to the input files, run Marxan, and realize that you didn't want to make that change.

An example: your aim is to create a comprehensive, adequate, representative, and efficient marine reserve network in your study region. You might explore adequacy by having different scenarios with varying conservation feature targets. When you change the target level (perhaps 20%, 30% and 50% of the current extent of your conservation

features) to compare the results, you will need to run Marxan with each of those targets. You cannot run all 3 target levels in the same Zonae Cogito project because when you change the target and re-run Marxan, the results will write over the previous results. So each scenario needs its own project to link what you are doing in Zonae Cogito to the correct version of the database and the planning unit shapefile.

It is good practice to **start every new scenario** (i.e. every time you are changing a key parameter like the target level) with the following steps:

- Create a new folder with the scenario name
- Copy the entire contents of the Marxan_database folder into the scenario folder
- Create a new project to link Zonae Cogito with your new database and shapefile – the old file is still connected

After you have created a new scenario, and linked a new project to it, you can safely edit your project. Sometimes you might want to "build" on a previous scenario (for example if you have calibrated the SPF or BLM). In this case you will need to put the calibrated input database into your new scenario, taking care to place a clean planning unit shapefile in your new scenario and to create a new project linking the new scenario to Zonae Cogito.

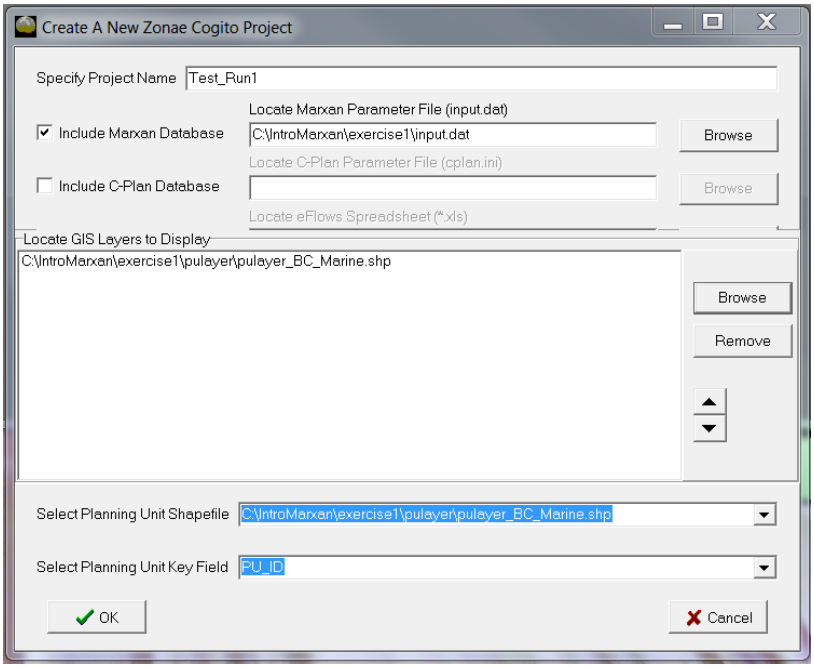
4. Creating a new ZC project

Start Zonae Cogito from the windows menu system like this:

- Create a new folder in the IntroMarxan folder. Name it "exercise1"
- Copy the entire contents of the Marxan_database folder into the exercise1 folder
- Go to "Start" > "All Programs" > "Zonae Cogito" > "Zonae Cogito"
- If Zonae Cogito is not in the start menu, browse to "C:\Program Files\Zonae Cogito" and double click on "ZonaeCogito.exe" to launch the software
- From the ZC main menu select "File" > "New" to create a new ZC project
- Give your project a name, e.g., "Test_Run1"

For now it is alright to use any name, but when you begin to develop more complex scenarios it is important to develop a naming convention that allows you to easily identify the scenario. If you have many different scenarios, it is also good to keep a master list indicating the costs, targets, and other parameters for each scenario.

- Tick the box next to "Include Marxan Database" and then use the browse button to navigate to and select the input.dat file in "C:\IntroMarxan\exercise1\"



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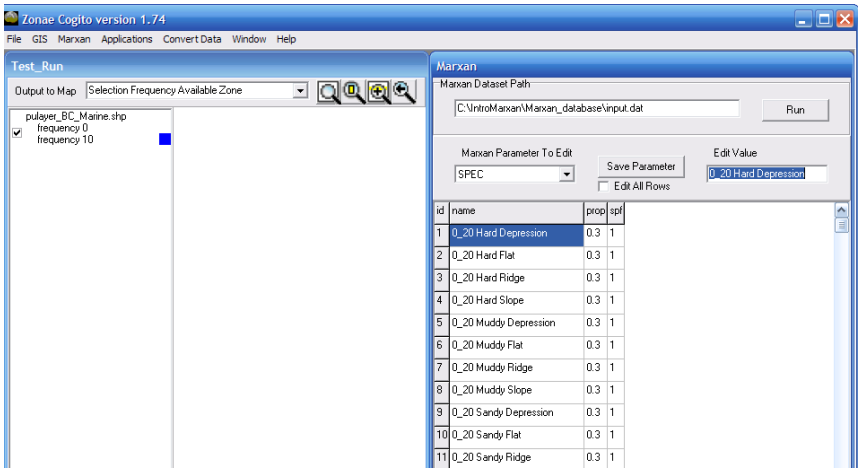
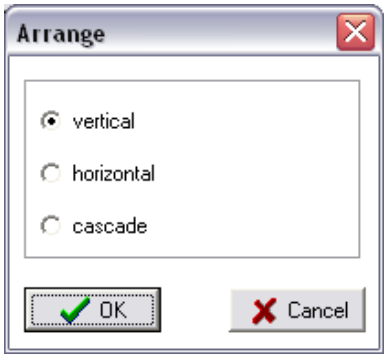
- Use the browse button next to the "Locate GIS Layers to Display" window to navigate to the pulayer folder in "C:\IntroMarxan\exercise1\MarxanDatabase\", and select "pulayer_BC_Marine.shp"
- Confirm that "pulayer_BC_Marine.shp" is the file listed in the "Select Planning Unit Shapefile" drop down menu
- Select "PUID" (or "PU_ID") from the drop down menu next to "Select planning unit key field"
- Click OK to generate the new ZC project



5. Resizing the ZC windows

When you first open ZC, you will see two windows, the GIS display window and the Marxan window. You might also notice that ZC does not fill your entire desktop.



- To resize ZC, double click on the maximize window
- After maximizing, from the ZC menu select "Window" > "Arrange"
- Select "vertical" to re-arrange in the same manner, or "horizontal" to change the arrangement of the models

You will probably also have noticed the GIS window in ZC is currently blank. Whenever you create a new project, the GIS window will appear blank until you have run Marxan for the first time (this is not always the case, however). At this point it is also a good idea to save the Marxan project you have just created.

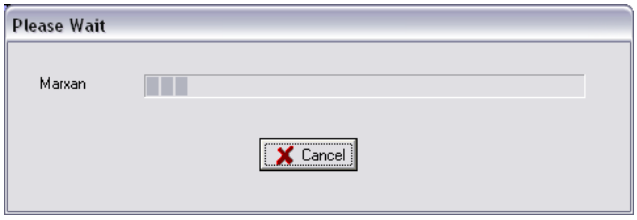
6. Saving a ZC project

- To save the project, select "File" > "Save" from the main ZC menu

You will notice that whenever you create a new ZC project, it will create a file "<filename>.zcp" inside the Exercise1 folder. This file can also be used to reopen a scenario, but it is best if you save the scenario with a name that reminds you what the scenario is. After saving the scenario we are ready to run Marxan from ZC.

7. Running Marxan

- To run Marxan, click "Run" in the Marxan Box
- After clicking run, you should see a process:



After the run is complete, your planning unit layer will appear in the GIS window.
Note: *the ZC default setting is for viewing the available, rather than reserved, planning units).*

8. Viewing Marxan results

- Results from an individual run can be displayed by selecting the run number from the drop down menu next to "Output to Map" in the GIS display
- From the main menu select "Marxan" > "View Output" > "Summary Report" to display the summary information for all runs
- Look at the Missing Values field as an indication of how many of your conservation features do not meet their targets in that solution – are your targets being met?
- From the main menu select "Marxan" > "View Output" > "Best Solution" > "Report" to open the target achievement report for the solution with the lowest objective function score
- Look through this file to see if your targets have been met in the "best" solution – if they are not, check the "MPM" field to indicate how close the target is to being met (1 = 100% met, 0.99 = 99% met, etc.) (you can also view this in bar graph format)
- To view all of the other Marxan output files, go directly to the "output" folder for that Marxan run (in this case in folder Exercise 1) and open the files with a text editor or in Excel to view

9. Independent work – Scenarios

Make sure to start every new scenario with the following steps:

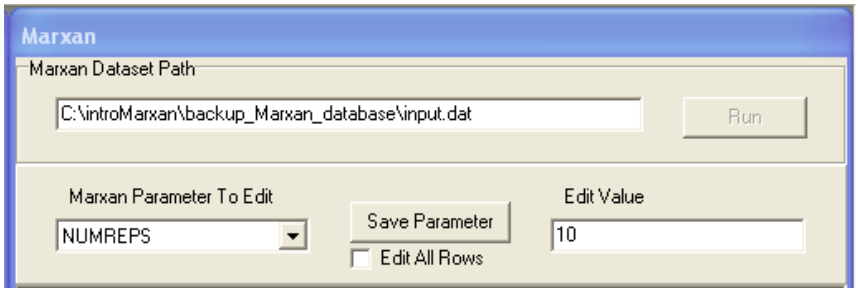
1. Create a new folder with the scenario name
2. Copy the entire contents of the Marxan_database folder into the scenario folder

After you've created a new scenario you can safely edit your scenario – most Marxan parameters can be accessed through the Marxan window in ZC.

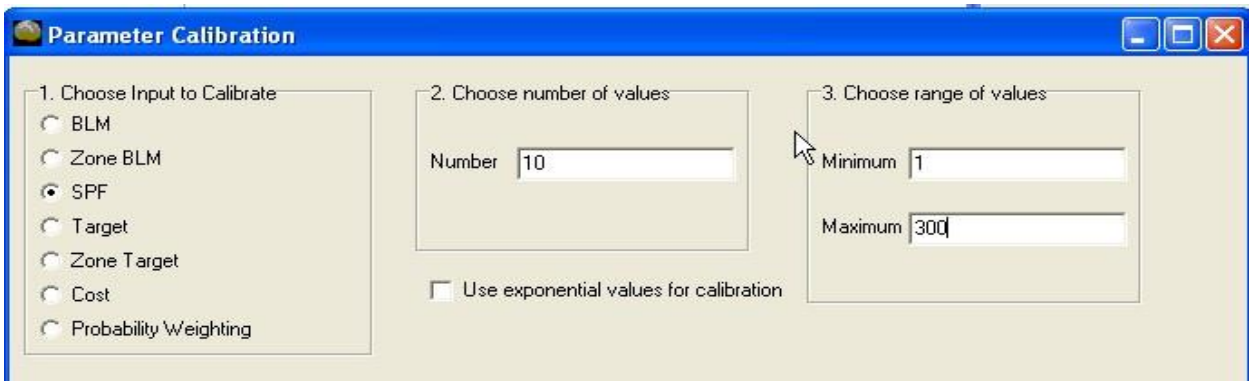
9.1 Scenario 1 – Calibrating the species penalty factor (SPF)

Above you checked the conservation feature targets in the summary report (indicated by the missing values). There were probably many features that did not have their targets met. **To meet all of the conservation feature targets, you may need to increase the species penalty factor (SPF).** In this scenario you will learn how to calibrate the SPF using the calibration tool. The calibration tool allows you to easily explore a range of values for some of the key Marxan parameters.

- After you copy the database to create a new scenario, create a new ZC project
- Calibration requires more than 10 runs to give a clear picture of how to set a parameter – if you are calibrating for a project, it is a good idea to calibrate with 100 runs (for the purpose of this course, we will use 50 runs to save time, but the resulting values will not be as accurate as they would need to be for an actual analysis)
- In the Marxan window, under the "Marxan parameters to edit" heading, select "NUMREPS" and type "50" into the "Edit value" field to set the number of runs to 50



- From the main menu select "Marxan" > "Calibration" (the window below will appear):



- Select "SPF" from the "Choose Input to Calibrate" menu
- Specify "10" values in the "Choose number of values" box
- In the "Range of values" field, use "1" as a minimum and "300" as a maximum value

The "number of values" specifies the number of SPF values that will be tested, with different values selected in equal intervals from the range specified. Since you do not know how high the SPF will need to be to meet all of your targets, you need to test a wide range.

- Click "Run Calibration"

***Note**: Depending on the speed of your computer, you might want to go have a cup of tea because it will take a few minutes for the calibration to run*

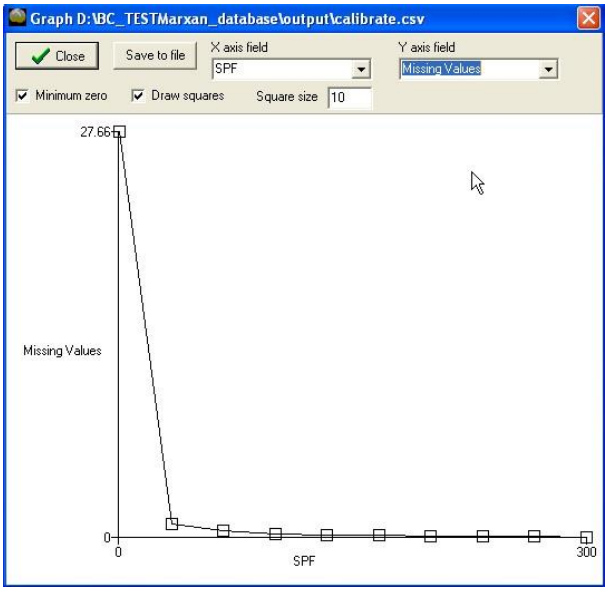
- After the calibration runs are complete you will see a summary table similar to the table below. Note that the average number of missing values in a test drops towards zero very quickly.

D:\BC_TESTMarxan_database\output\calibrate.csv

rows 11 fields 9 data elements 99

test	SPF	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	1	17725821.4715595	10624806.88	2414.54	5947200	7101014.59155952	3520647960	27.66
2	34.2222222222222	28063417.0658312	28062965.92	3338.2	12456880	451.14583124	8220	0.92
3	67.4444444444444	28792818.2831925	28792372.8	3343.3	12648880	445.4831925	1980	0.46
4	100.666666666667	29430192.0341953	29430043.92	3345.44	12727760	148.11419534	1060	0.26
5	133.888888888889	29419520.8256924	29419223.84	3346.4	12797200	296.98569244	640	0.16
6	167.111111111111	29826652.1868189	29826638.56	3345.2	12838160	13.62681888	480	0.16
7	200.333333333333	29818246.1089814	29818235.12	3345.44	12846880	10.98898136	360	0.1
8	233.555555555556	29980360.5734717	29980349.84	3345.28	12852960	10.73347168	320	0.08
9	266.777777777778	29837600.9802595	29837588.72	3349.54	12902160	12.26025952	320	0.08
10	300	30020304.748998	30020302.08	3348.3	12881040	2.66899796	40	0.02

- To use the graphing functions built into ZC, select "Text Table" > "Graph Table"
- Graph SPF on the X-axis and missing value on the Y-axis



When choosing an appropriate SPF value, look for the areas of the graph where the average number of missing values approaches zero. This will give you an idea of where the efficient SPF value should be set. This calibration narrowed down the potential appropriate values, but now you will need to look at your graph, choose a range of values where the missing values are approaching zero (e.g., 30-200), and run another calibration.

- Choose the value range that looks appropriate from your graph (it may or may not look similar to the one on the right), and run a new calibration with the new value range
- Graph your results and choose the lowest SPF value that allows you to meet nearly all of your targets (e.g. average missing value is less than 1).

  You could continue to refine this value with additional calibrations, but for the sake of time in the course, **we will choose a value after two calibrations.**

  Note that you can choose a value where you are nearly meeting all of your targets if you are using the Boundary Length Modifier (BLM) to increase the clumping in your solution. This clumping usually will help meet the rest of the conservation feature targets without needing to set an inefficiently high SPF. However, if your objective is to use a BLM of zero, you would need to continue calibrating the SPF until all of your targets are met.

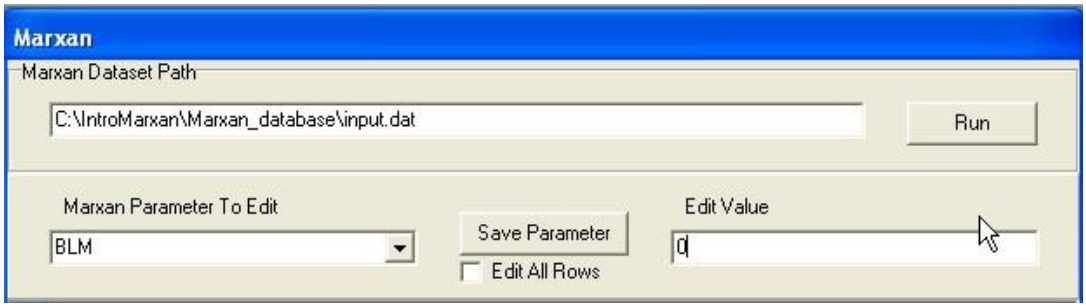
  Record your chosen SPF here: _____

  ***Note** that the instructors will ask you to share your chosen SPF value as part of a calibration discussion*

9.2 Scenario 2 – Variable Boundary Length Modifier (BLM)

Here we will explore how increasing the emphasis on compactness (that is increasing the value of the BLM) affects Marxan results.

- After you copy the database to create a new scenario, create a new ZC project
- Set the SPF value you chose from Scenario 1 (located in the SPEC portion of the Marxan parameter to edit drop down menu)
- In the Marxan window, select "BLM" from the "Parameter to edit" drop down menu
- Choose a new value of BLM – the higher the BLM, the more "clumped" your solution will be (the parameter can be edited by changing the value in the "Edit Value" field, and then saving the change by click "Save Parameter")



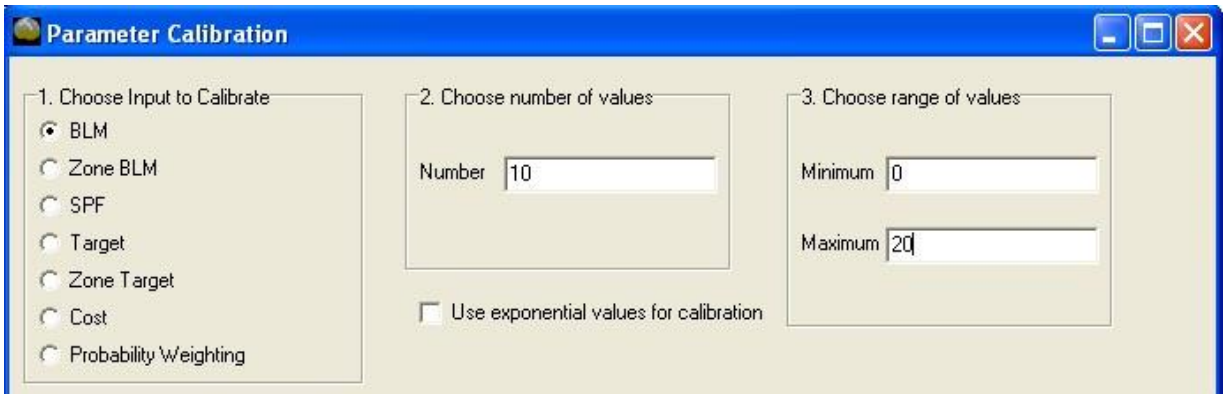
- For speed during the course, set your NUMREPS for this scenario to "10" – in an actual Marxan analysis you would likely use 100
- Make sure your GIS map is set to a Solution (not Selection Frequency)

- Experiment with several different BLM values (suggestion: 0.1, 1, 10, 100) – to try to get to a level of clumping that you think might work for implementation and management of reserves. Watch the GIS window map update to see the increase in clumping.

9.3 Scenario 3 – Calibrating BLM

In this scenario we will be looking at the calibration of the BLM within Marxan. The calibration tool allows you to easily explore a range of values for many key Marxan parameters.

- After you copy the database to create a new scenario, create a new ZC project
- Calibration requires more than 10 runs to give a clear picture of how to set a parameter. If you are calibrating for a project, it is a good idea to calibrate with 100 runs. For the purpose of this course, we will use **50 runs to save time**, but the resulting values will not be as accurate as they would need to be for an actual analysis.
- Set the NUMREPS to "50"
- Set the SPF to your previously calibrated value
- From the main menu select "Marxan" > "Calibration" (the window below will appear):



- Select "BLM" from the "Choose Input to Calibrate" menu
- Specify "10" values in the "Choose number of values" box
- In the range of values, try "0" as a minimum value and "20" as a maximum value

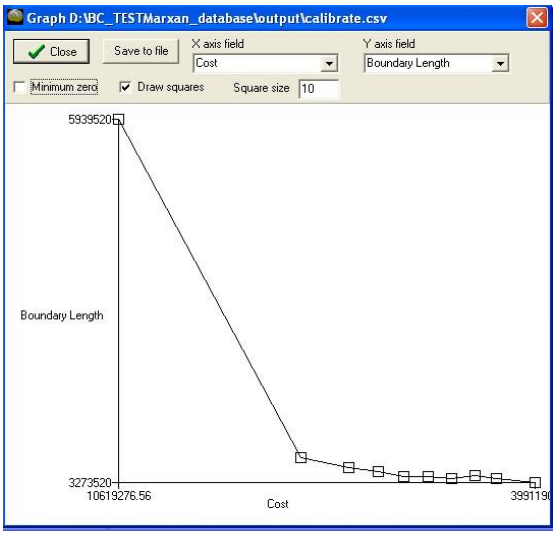
The "number of values" specifies the number of BLM values that will be tested, with

D:\BC_TESTMarxan_database\output\calibrate.csv

rows 11 fields 9 data elements 99

test	BLM	Score	Cost	Planning Units	Boundary Length	Penalty	Shortfall	Missing Values
1	0	17729808.9764193	10638051.6	2415.86	5949920	7091757.37641926	3517365300	27.62
2	2.22222222222222	29493562.9440086	18389886.64	3414.58	3839120	2572298.52623086	42777100	12.62
3	4.44444444444444	38440886.0503903	19571808.4	3428.06	3656160	2619477.65039048	37144880	10.08
4	6.66666666666667	46941251.1819216	20402858.24	3434.52	3570080	2737859.6085884	35181640	8.38
5	8.88888888888889	55267452.9979398	21793109.92	3441.7	3525920	2132831.96682906	24562180	8.36
6	11.1111111111111	63184609.8358665	23481433.52	3446.48	3464240	1211620.76031026	12464720	7.26
7	13.3333333333333	71328117.0109751	24525869.68	3447.18	3453520	755313.99764188	7084900	7.26
8	15.5555555555556	78949603.7667954	25224784.64	3447.06	3417120	569619.12679434	4823980	7.34
9	17.7777777777778	86963461.2399154	25780829.28	3444.72	3408640	584587.5154716	4436860	7.14
10	20	94224678.2300667	26144690.96	3448.16	3380160	476787.27006672	3120620	7.36

different values selected in equal intervals from the range specified. After the calibration runs are complete you will see a summary table similar to the table to the right.



- To use the graphing functions built into ZC select "Text Table" > "Graph Table"
- Graph "Cost" on the X-axis and "Boundary Length" on the Y-axis. Remove the check mark from the "Minimum zero" box.

When choosing an appropriate BLM value, look for the steep areas on the graph where the boundary length is quickly reduced for a small increase in cost. If that value does not produce the desired level of clumping, shift to a higher BLM (knowing that this includes a trade-off in terms of cost).

- Choose the value that looks appropriate from your graph, and run Marxan with the new value (note that your graph may or may not look similar to the one shown here). Observe the change in the level of clumping with the new selected BLM value.

Record your chosen BLM here: _____

***Note** that the instructors will ask you to share your chosen BLM value as part of a calibration discussion*

- In the main menu, click "Marxan" > "View output" > "Summary" > "Report"
- Review the report – are you meeting all targets now? If not, you will need to increase your SPF

You can also calibrate the number of iterations necessary to get efficient solutions. You would need to do this by hand by choosing a range of iterations values (e.g., 1 million to 100 million) and a number of tests to do within that range. **The appropriate value for iterations will occur when the score in Marxan is no longer greatly improving (lowering) with additional iterations.** Try this if you have some extra time today, as it is necessary as part of the calibration process for a real Marxan analysis.

9.4 Scenario 4 – Updating planning unit status

In Marxan, planning units can be **never included** (or "locked out") in the Marxan analysis, or can be fixed and **always included** ("locked in") in Marxan solutions. See Table 1 for the different planning unit status options. For example, planning units located in existing protected areas could be locked in as it is unlikely that areas already protected will be traded for other areas. On the other hand, planning units intersecting with ferry routes, for example, could be locked out from a reserve system since it is improbable that these routes would be modified.

Table 1.

Status	Number
Available for inclusion in reserve system	0
Included in starting seed and available	1
Locked in	2
Locked out	3

There are a number of ways to change the status of your planning units. You can do this in ZC or in ArcMap (or QGIS) by editing the planning unit layer (in this case the pulayer_BC_Marine). Below we will show you a way to do it in ZC. For more examples see the Appendix at the end of this handbook.

- After you copy the database to create a new scenario, create a new ZC project
- Set your SPF and BLM to your calibrated values
- In the Marxan parameter to edit drop down menu, choose "PU" – note that all of the planning units have a status of 0 (available)
- Select a block of planning units (you can use the shift button to select many at once) and change their status to 2 (locked in). Make sure that the "edit all rows" box is not ticked. Why would some planning units be locked into a solution? What impact might that have on the solutions?
- Run Marxan and view the results with the locked in planning units
- Now try locking out (setting the status to 3) a number of planning units and re-running the analysis
- Explore the output files to see if files are still achieving targets after you have locked out a group of planning units
- If they are not, try increasing the species penalty factor (SPF) in the spec.dat file. As you increase the SPF, more emphasis will be placed on meeting the conservation feature targets.
  In some cases it is possible that you won't be able to achieve all your conservation targets because with planning units locked out of the solution; for example if more than 70% of one of the conservation features was locked out.

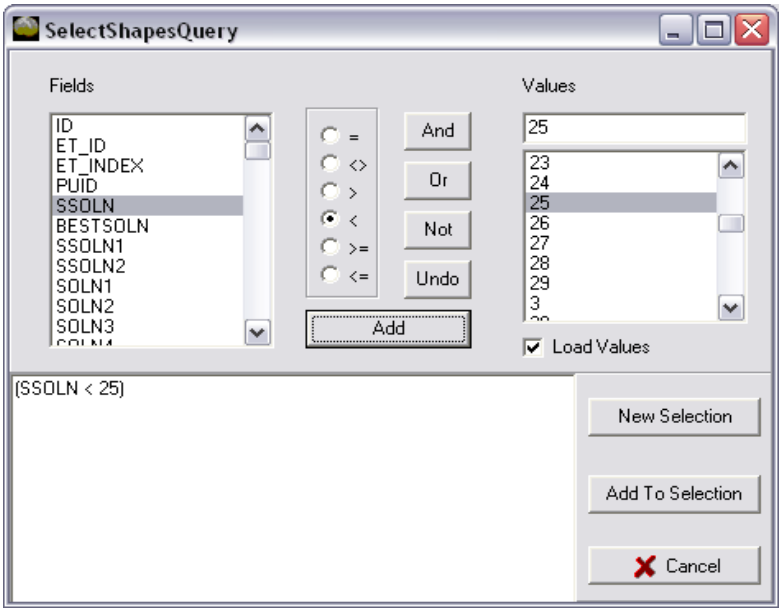
9.5 Scenario 5 – Changing Targets

- After you copy the database to create a new scenario, create a new ZC project
- Set your SPF and BLM to your calibrated values
- Edit your targets in the spec file – increase targets to all features to 50%
- Check to see if your targets are still being met, and compare with the 30% target results
- Experiment with different targets to see how that changes the solutions

9.6 Scenario 6 – Interacting with output

There are instances where it is useful to alter a Marxan solution, for example to avoid a particularly contentious place, as an exercise when meeting with stakeholders, or to make boundaries implementable. The configuration editor in ZC allows users to make changes to Marxan solutions, and then generate target/cost summary reports based on the new configuration. In this way, you can see how the changes you have made impact how well the solution meets your targets, and how it impacts the cost of the solution. New configurations can also be sent back to Marxan for additional analysis.

- After you copy the database to create a new scenario, create a new ZC project
- Ensure that the NUMREPS parameter is set to "100"
- Set your SPF and BLM to your calibrated values
- Run Marxan
- From the Main menu select "GIS" > "Edit Configurations"
- Enter a name for the new configuration
- From the Seed configuration drop down select "Marxan Solution 1". The seed configuration allows you to load a Marxan result into the configuration editor.
- From the main menus select "GIS" > "Select with" > "Mouse"
- Use the mouse to highlight a group of planning units on the map
- Change the "assign to" status to "Reserved" and Click "Save" – you have just changed the status of these planning units to reserved
- Click "Report" to open the reporting tool
- Tick the box next to all the reports that you would like to generate, and click "OK"



You can also select planning units based on attributes of the planning unit shapefile.

- From the main menus select "GIS" > "Select with" > "Query"

- After creating your selection, click “new selection” to select those planning units. (the query above will select those planning units with a selection frequency of less than 25)
- Assign the selection to a new status (not selected, reserved, excluded) and click “Save”
- Generate new reports to see the impact of changing these planning units

9.7 Scenario 7 – Installing R and exploring cluster analysis

Zonae Cogito is compatible with the free statistical computing and graphics software, R. You can download this software for free from the R website: http://www.r-project.org/. You will need to install packages to make R work with your Marxan outputs (see Day 1 Handbook for information about these packages). Zonae Cogito is configured to run R automatically when it is installed on your computer (unless you could not log in as an administrator, in which case R and ZC will likely not communicate). The outputs include a 3-dimensional plot of the solution space, a 2-dimensional plot of the solution space, and a dendogram showing the dissimilarity of Marxan solutions.

Note: R and packages should be already installed on your computer.

- After you copy the database to create a new scenario, create a new ZC project
- From the main menu in ZC select “Marxan” > “Do Cluster analysis” (or make sure that it is checked on)
- Run Marxan, and the 3-D graphic output should automatically appear
- To view the other R outputs, go directly to your scenario 7 **output** folder and view the “output_2d_plot” and “output_dendogram” images

If you don’t see any of the graphic outputs you may need to install the packages again:

- Launch R
- From the main menu in R choose “Packages” > “Set CRAN mirror” and select a location near you
- Then choose “Packages” > “Install Packages” and select the 4 files: "labdsv", "rgl", "tkrgl" and "vegan" (hold ctrl to select multiple items at once)
- Then from the main menu in R choose “File” > “Open script”, navigate to your Scenario 7 folder and choose “Script.R”

  Note: *The source might change depending on the where the script.R file is stored, and the scenario that you are working on.*
- Copy and paste the script into the R Console and the script will run automatically.

This is the end of Day 2 activities. For more, please go to "Extra_Activities" folder.

Thank you for your participation in the course!

Appendix

A. "Locking in" planning units in ArcMap

In this case study, we included a Rockfish Conservation Area (RCA) found the Scott Islands that need to be included into the reserve system (note that there are more RCAs in this area, but we included only one for simplification).

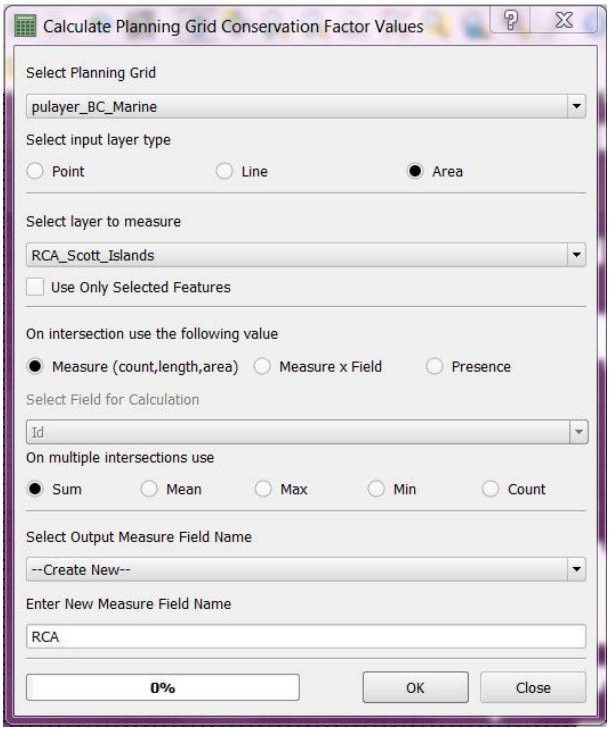
- First we select those planning units in pulayer_BC_Marine layer that intersect with the RCA polygon, using Select by Location tool in ArcMap
- Then open the attribute table of the pulayer_BC_Marine and note that a number of planning units have been selected.
- Add a new Field and named "RCA" and select "Short Integer" as type value.
- Right click on the new field and select "Field Calculator", and add the value of 2 (locking in planning units) to the new field.

B. "Locking in" planning units in QGIS

In this case study, we included a Rockfish Conservation Area (RCA) found the Scott Islands that need to be included into the reserve system (note that there are more RCAs in this area, but we included only one for simplification).

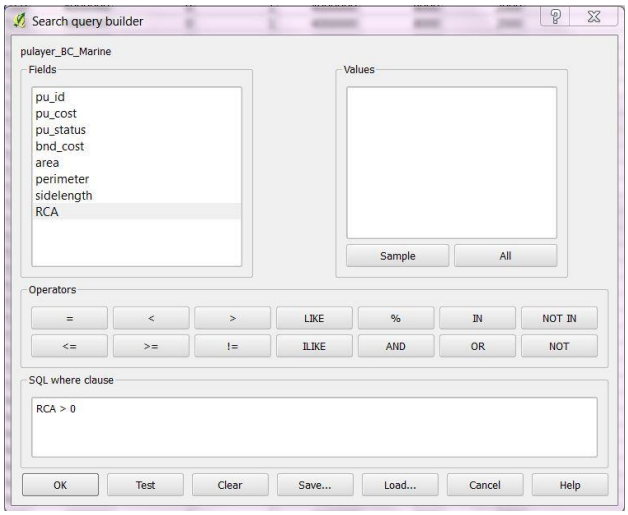
First, we calculate the amount of RCA found in each planning unit:

- In the "Plugins" menu, select "Qmarxan", then click "Calculate Conservation Values".
- On the form that displays, set "Select Planning Grid" to "pulayer_BC_marine",
- Set "Select input layer type" to "Area",
- Set "Select layer to measure" to "RCA_Scott_Islands",
- Set "On intersection use the following value" to "Measure (count, length, area), and
- Set "Enter New Measure Field Name" to "RCA",



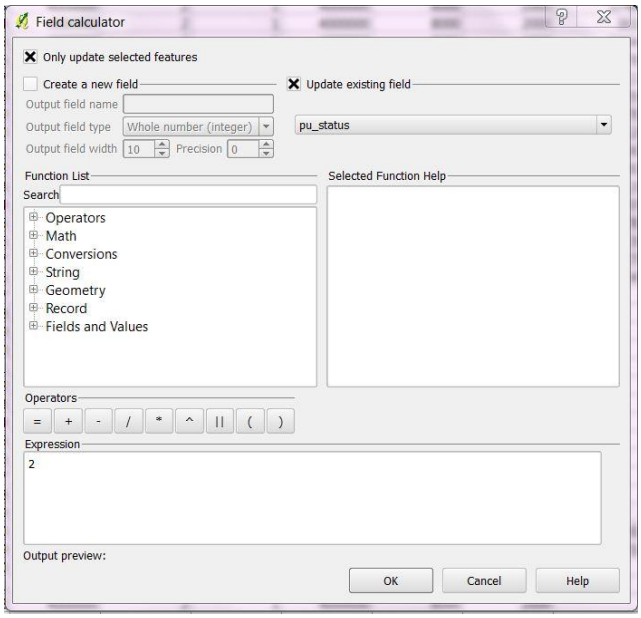
- Your form should then look like the figure to the right:
- Now click "Ok" to calculate the amount of reserve in each planning unit.
- When it is finished running, click "Close".

Second, we populate the status field (“pu_status”) with a value of “2” only for those planning units with a RCA value greater than 0 (that is, that intersect with RCAs).



- In the "Layers" list on the left, right-click “pulayer_BC_marine”, then click "Open Attribute Table",
- Click the "Advanced search" button in the bottom-right corner of the attribute table
- On the form that displays, double click the "RCA" field,
- Click on " > " operator,
- Click in the "SQL where clause" window, and enter “0”. This will select all those planning units where the RCA is present
- Your form should then look like the figure below:
- Click "Ok"

To view selected values check “Show selected only” box in the bottom-left of the attribute table. Now we will give a value of “2” to the “pu_status” only to the selected, as follows:



- On the form that displays, click the "Toggle editing mode" button 
- Now click the "Open field calculator" button: 
- Select "Update existing field", set it to " pu_status",
- Click the "Expression" box, type "2".
- Your form should then look like the figure to the right.
- Now click "Ok" to set a status of "2" to selected planning units, which are occupies completely or partially by a RCA.
- Now click the "Toggle editing mode" button  to switch off edit mode,
- Click "Save" when prompted to save the changes to the planning unit attribute table,
- Click the "Unselect all" button  to de-select the planning units whose status you have just set to "2", and click "Close" to close the attribute table window.