Title	**A customised Marine Spatial Planning tool in Arc-GIS to facilitate development and evaluation of Marine Protected Area scenarios in the CCAMLR Area**

Author(s)	Sharp, B.R.[1] & Ollivier, K.[2]
Address(es)	[1]New Zealand Ministry for Primary Industries, PO Box 1020, Welllington, New Zealand 6011. Telephone: +64 4 819-4604/ + 64 27 452 4669
	[2] Ollivier & Co., PO Box 34 86, Birkenhead, Auckland, New Zealand 0746 Telephone +64 9 418 2220

Name and email address of person submitting paper: ben.sharp@mpi.govt.nz

Published or accepted for publication elsewhere?	Yes ☐	No ☒
If published or in press, give details:		
To be considered for publication in CCAMLR Science*?*	Yes ☐	No ☒

ABSTRACT

We describe the use of a GIS-based Marine Spatial Planning (MSP) tool designed to aid the development and transparent evaluation of MPA scenarios with reference to spatially explicit protection objectives and cost layers representing rational use in a systematic conservation planning framework. The MSP tool has been customised to enable rapid set-up and use in any of the nine CCAMLR MPA planning domains.

Summary of findings as related to nominated agenda items

Agenda Item	Findings
3	We present a marine spatial planning tool for use in ArcGIS, customised to facilitate transparent evaluation of MPA scenarios in each of nine CCAMLR MPA planning domains.

1. INTRODUCTION

In 2010 (SC-CAMLR XXIX, paragraph 5.20),

> *The Scientific Committee noted that it was important to create a transparent process by which multiple objectives for spatial protection could be considered in balance with rational use.... In the development of MPA proposals there is a need to clearly identify how achievement of the objectives will be assessed, while taking account of uncertainty.*

In 2011 the Commission (CCAMLR-XXX paragraph 7.3) endorsed advice that 'MPA proposals should include a clear description of the balance between the protection of ecological function and allowance for, and impact on, harvesting'. The Commission also noted advice from the Scientific Committee (SC-CAMLR XXX paragraph 5.18 ii and vi) that 'the interests of rational use need to be accounted for in the process of establishing MPAs', and that analyses, including optimisation analyses, of the degree to which objectives have been met and rational use have been affected, should be presented. The attractiveness but inherent difficulty of achieving a transparent and repeatable method by which to design and propose MPA scenarios that balance multiple or competing objectives, including the use of computerised decision support tools such as MARXAN, has been the subject of considerable discussion within CCAMLR (e.g. SC-CAMLR XXIX/Annex 6, paragraphs 3.111-3.114).

In 2011 New Zealand produced and utilised a custom GIS-based marine spatial planning (MSP) tool to inform the development of MPA scenarios in the Ross Sea region that achieved multiple protection objectives while minimising associated cost to rational use (SC-CAMLR-XXX/10) consistent with Systematic Conservation Planning principles as expressed in SC-CAMLR-XXX/6 Appendix D. The MSP tool facilitates rapid and transparent evaluation of alternate MPA scenarios by calculating the performance of any MPA boundary design with respect to spatially defined protection objectives and 'cost' to rational use (e.g. fishing effort displacement). The MSP tool and its application by New Zealand to the Ross Sea region MPA planning process is described in paper WS-MPA-11/25.

The main strength of the MSP tool relative to automated optimisation tools such as MARXAN is that the MSP tool allows evaluation of alternate MPA scenarios and negotiation of trade-offs between multiple competing objectives and rational use *even in the absence of agreement about objectives, protection targets, and acceptable levels of cost.* This is because the input data layers (i.e. bioregionalisations, target areas, and fishing effort data), are science products divorced from the associated value judgments about which areas are most important to protect and how much protection is enough (i.e. protection targets) or how much accommodation should be made for acceptable fishery outcomes (acceptable cost). Ultimately these value judgments are inherent in the final decision about which MPA scenario is preferred, but instead of being required as inputs (as in spatial optimisation tools like MARXAN) in the MSP tool these value judgments only affect the interpretation and use of tool outputs. The main weakness of the MPA planning tool is that without these value judgments (protection targets) coded explicitly as inputs, optimisation is not possible except by iterative adjustment of user-defined boundaries against pre-conceived targets. However in WS-MPA-11/25 New Zealand demonstrated that by iterative adjustment of MPA boundaries using the MSP tool in an open stakeholder setting attended by a range of interest groups pursuing different objectives, it was possible to identify a highly optimised MPA scenario that closely mirrored a MARXAN output achieving similar protection targets.

2. METHODS

The CAMLR Commission in 2011 (paragraph 7.4) endorsed nine spatial planning domains within which MPA planning would proceed. New Zealand has offered to share its MSP tool with interested Members (SC-CAMLR XXX paragraph 5.43); however the tool had been custom designed for application in the Ross Sea region (planning domain 8) and could not be easily applied in the other planning domains.

In 2012 New Zealand has devoted resources to modify the MSP tool for use in any of the nine CCAMLR MPA planning domains. The new tool (called 'CORAX-MSP', developed by Ollivier & Co. of Auckland, New Zealand) runs in automates the assembly, format transformation, re-projection, and spatial clipping of input data layers within any user-selected planning domain. Input data layers may be in polygon or point format and can include habitat classifications, target areas for protection, and/or cost layers to rational use (e.g. fishing effort data).

The CORAX-MSP tool also includes improved functionality, e.g. allowing the user to: i) choose among multiple options by which to define MPA boundaries; ii) modify the subset of the data on which calculations are performed using data queries, and iii) modify the format and content of analytical outputs by making changes to the ArcGIS Table of Contents display.

The CORAX-MSP tool runs in ArcGIS or ArcView v. 10.0 or newer.

The use of the CORAX-MSP tool is described below. This tool will be made available to other Members at the WG-EMM working group meeting and deposited with the CCAMLR Secretariat for upload to the MPA Special Fund Subgroup website (below). This website has also been identified as an appropriate place to store spatial data layers (i.e. spatially defined protection objectives, bioregionalisation layers) to be shared and used by Members to aid MPA scenario development and evaluation until such time as the CCAMLR GIS database (CCAMLR-XXX paragraph 7.2) is operational.

http://www.ccamlr.org/prm/sc/mpa-sf-cg/mpa-sf-cg-info.htm

New Zealand makes the CORAX-MSP tool available to all CCAMLR Members to facilitate the development and evaluation of draft MPA scenarios in the CCAMLR Area. Use for any other purpose is restricted and requires the permission of the New Zealand government and the tool developer.

The current version of the CORAX-MSP tool is still in the early testing and error trapping stages; it is expected that users may encounter errors or compatibility problems as they test the application of the tool in new areas or using new data layers. Users are encouraged to report error messages to the author of this paper (ben.sharp@mpi.govt.nz) to be passed on to the software developer, but to be aware that without additional resources to devote to software development, replies or upgrades may not be immediate. Members wishing to devote additional resources to upgrade the tool or to customise it for use in particular applications can be put directly in touch with the software developer, with encouragement to share improved versions with all CCAMLR Members. It is New Zealand's intention that by making the tool available to all Members at WG-EMM 2012 we can stimulate productive discussions and collaboration between Members in the design and evaluation of MPA scenarios within CCAMLR in advance of SC-CAMLR XXXI.

3. **RESULTS**

The basic operation of the CORAX-MSP tool is described as follows. This paper does not constitute a full user manual but should enable a new user to explore the functionality of the tool sufficient to generate useful outputs. Limited proficiency in ArcGIS or ArcView is required. The tool includes an integrated help function and explanatory text in the dialog boxes of every step, to facilitate uptake by new users. The use of the CORAX-MSP tool can be demonstrated for interested users at the WG-EMM meeting at Tenerife.

Data layer preparation:

The CORAX-MSP tool can utilise three types of input data layers representing protection objectives or cost layers for rational use, with formatting requirements as below.

1. Point-based objectives (e.g. fishing effort data or grid-based model outputs summarized as grid midpoints): point-based Arc feature classes beginning with an alphabetic filename; attribute tables may contain multiple columns summarizing fishing effort according to alternate metrics (e.g. km of longline, total historical catch, catch by year, etc.)
2. Target area objectives (i.e. spatially explicit areas of particular priority for protection, such as key habitats, ecosystem processes or species distributions): single-part or multipart polygons with no internal attributes
3. Classified objectives (bioregionalisations): Classified polygons with a numeric attribute table column named 'GRIDCODE' specifying the class or bioregion number.

For ease of upload, the user should organize all objectives files of a particular type into a common folder. The input spatial files need not be in a common map projection, and the spatial extent of the objective layer need not be wholly located within the planning domain.

Setup Domain:

- The MSP tool (current version MSP9_9a) comes in a zipped folder for download. Unzip to a destination on the computer directory (e.g. D:\MSP). (*Note: Avoid spaces in the choice of directory path names and file names).*
- Open the project file D:\MSP\ChooseDomain.mxd
- Open the Arc toolbox list, right-click ArcToolbox → 'add toolbox', and navigate to select the file D:\MSP\CoraxMSP.tbx.
    → A new toolbox called 'Marine Spatial Planner' will appear in the toolbox list
- Open step 'A – Setup domain' and run step '0 - Cleanup domain'. This deletes previous working folders to enable creation of a new domain project file in the workspace (*Note: be sure you have first saved previous work to another location*)
- Run step '1a – Choose CCAMLR Domain' and select a planning a domain from the list (*in this example we use Domain 8*)
    → A new folder 'D:\MSP\Domain8' is created
- Run steps 2, 3, and 4 in turn to select objectives layers with formats as above. In each dialog window first specify the planning domain folder (e.g. 'D:MSP\Domain8') then navigate to select one or more point-based objectives (step 2), target area objectives (step 3) or classified objectives (step 4).
    → the selected layers are transformed into .gdb format, clipped to the planning domain boundary, re-projected into a common equal-area projection, and added to a new Arc project file called 'D:\MSP\Domain8.mxd'
- Close the 'ChooseDomain.mxd' project file.

Initialize Domain

- Open the new project file generated in the previous step (e.g. D:\MSP\Domain8.mxd)

    o Note that the new project file includes three folders named 'POINTBASED', 'TARGETAREA', and 'CLASSIFIED' in the Table of Contents (TOC), each containing the corresponding objective data layers. Each objective layer has been clipped to the spatial extent of the planning domain, re-projected to the 'South Pole Stereographic' equal-area projection, and transformed to .gdb format.

- All layers appearing in these three folders will be analysed and will appear in the output table generated by the MSP tool. (*Note: do not manually add new layers to these folders that were not generated there by the domain setup process*).

- Manipulation of the layers appearing in these folders in the Table of Contents display (e.g. by changing layer names, turning off columns in the attribute table of point-based objectives, or running spatial queries to filter for subsets of the data) will change the contents of the output table.

- Open the Arc toolbox list, right-click ArcToolbox → 'add toolbox', and navigate to select the file D:\MSP\CoraxMSP.tbx.
  → The toolbox 'Marine Spatial Planner' re-appears in the toolbox list
- Run steps 'B1 – Cleanup MPA layers' and 'B2 – Initialize output table'

Generate and process MPAs

- Generate an MPA boundary using the available tools in steps C options 1-3 as follows:

  - ' C1 – MPA from sketch or feature' allows the user to draw MPA boundaries by hand by clicking on boundary vertices. The scroll bars and mouse wheel allow zooming and roaming while sketching, to improve spatial accuracy.

  - Alternately step 'C1 – MPA from sketch or feature' enables the user to import a previously prepared MPA boundary from an existing Arc feature class file

  - 'C2 - MPA from Table' enables the user to import boundary MPA vertices (latitude and longitude in decimal degrees) from a table. East-west boundaries will be automatically densified so that boundaries follow the curvature of the latitude line in protected space.

  - 'C3 – MPA Vertices' enables the user to specify boundary vertex coordinates interactively one at a time. East-west boundaries will be automatically densified so that boundaries follow the curvature of the latitude line in protected space.

  → At processing of Step C the MSP tool clips the boundaries of the MPA using the outer boundary of the planning domain and generates a new featureclass for each MPA boundary

  - Step C can be repeated for as many separate MPAs are desired

- For *each* MPA from step C, run step 'D1 - Clip Objectives'; this clips each protection objective to the boundaries of the MPA and calculates the proportion of that objective that is located inside the MPA.

- Alternately steps D2 and D3 allow the user to merge multiple MPAs and batch process multi-part or merged MPAs in a single step, to speed processing time.

Display outputs

- Run step 'E – Show spreadsheet' to generate the output table. The table is automatically opened up using a spreadsheet browser (e.g. MS Excel).

- The output table displays protection (or rational use) objectives as rows and MPAs as columns

  - Point-based objectives will have one row for every active column of the objective file attribute table, e.g. to display alternate metrics of fishing effort displacement (% total effort displaced, % total catch displaced, % catch displaced in particular years, etc)

- o Target area objectives have a single how (e.g. % protection inside the MPA)

- o Classified objectives have a row for every habitat class (e.g. % protection of each bioregion)

- Each cell reports the contribution of each MPA to total protection (or cost) for each objective as the percentage of the total within the planning domain. As new MPAs are generated and processed, new columns are added to the table.

Manipulate and interpret outputs

Because the output is exported as a spreadsheet for manipulation in other programs, it is easy to save as a separate file and customize the display for ease of interpretation, and to manipulate outputs to represent different combinations of MPAs or different zoning approaches within MPAs. For example:

- Cell formatting or conditional formatting can be used to group objectives into interpretable categories and to highlight particular results of interest, e.g. where protection falls short of desired targets.

- Different combinations of MPAs can be explored by adding new columns that sum the contributions of different subsets of MPA columnss (*note that care must be taken not to sum totals for spatially overlapping MPAs, to avoid double-counting features in the area of overlap*)

- Zoning for different types of protection in different portions of the MPA can be explored by including or excluding the contribution of particular MPAs (columns) to different objectives (rows) depending on the nature of the objective and the type of MPA. (E.g. column values for MPAs that are designated for benthic protection only would make no contribution to pelagic representativeness or protection of krill).

4. DISCUSSION

Transparent evaluation of MPA scenarios with reference to clearly stated and spatially explicit protection objectives, with consideration of the consequences for rational use in a systematic conservation planning framework, has been recognized as a useful way of undertaking MPA planning within CCAMLR. Where protection objectives and spatial data layers to represent them can be agreed by scientists (for example the 'Phase 1' outputs of the Domain 1 and Domain 5 MPA workshops being considered by WG-EMM-2012), use of the MSP tool will enable individual Members to complete their own policy-driven 'Phase 2' MPA boundary design processes with reference to common scientific inputs, so that alternate scenarios can subsequently be compared and evaluated between Members in an objective way. Sharing of relevant GIS layers between Members, and/or depositing this data on the MPA Special Fund Subgroup website (or on the CCAMLR GIS database when it becomes operational), will facilitate this process. Fishing effort data to represent cost to rational use can be requested from the Secretariat. By providing the CORAX-MSP tool for use by others New Zealand hopes to promote open discussion among CCAMLR Members to help identify optimal and mutually agreed MPA scenarios in all CCAMLR MPA planning domains.
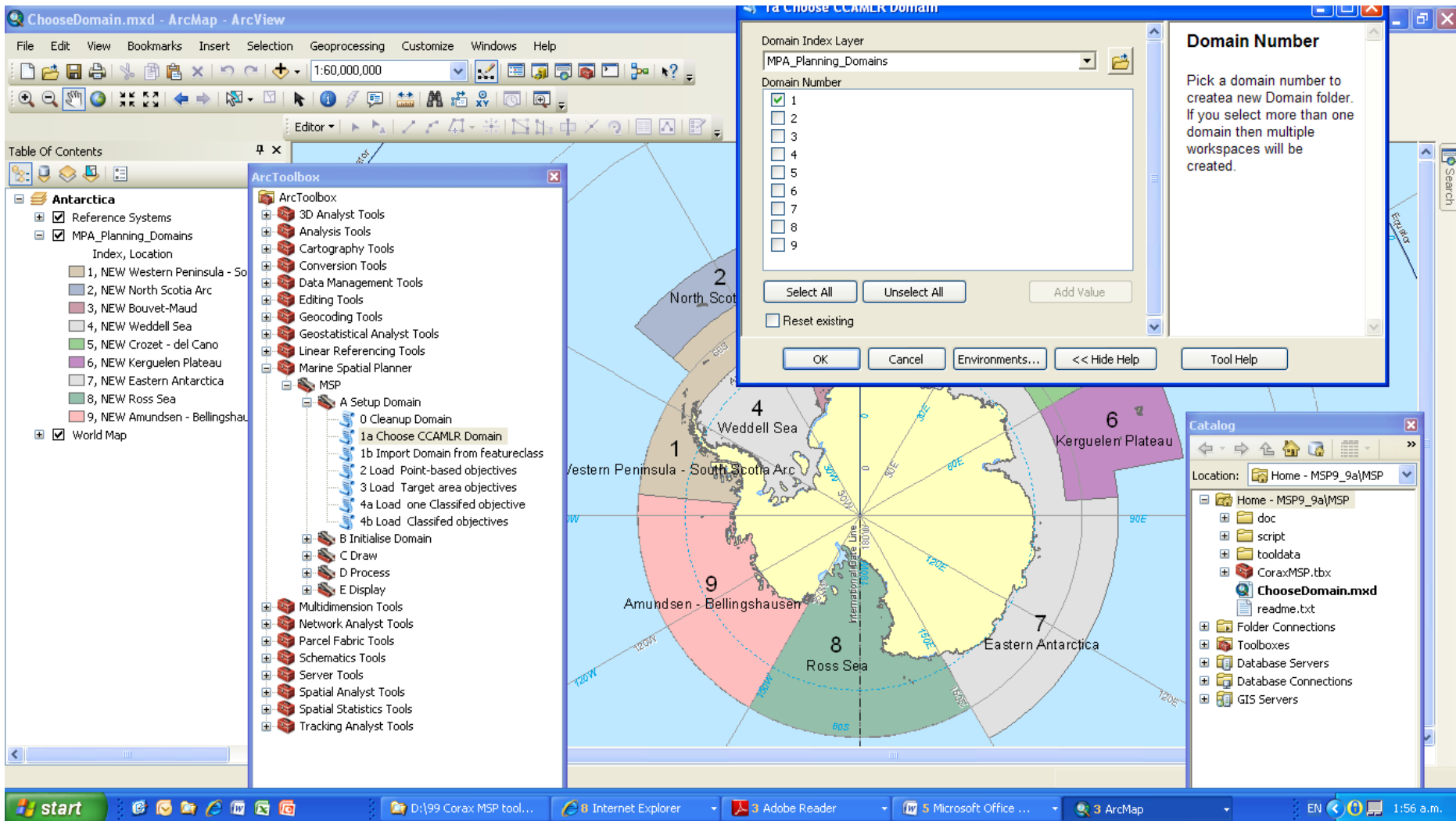
Figure 1. Screen capture of step 'A – 1a Choose CCAMLR Domain' run within the 'MSP\ChooseDomain.mxd' ArcGIS project file.
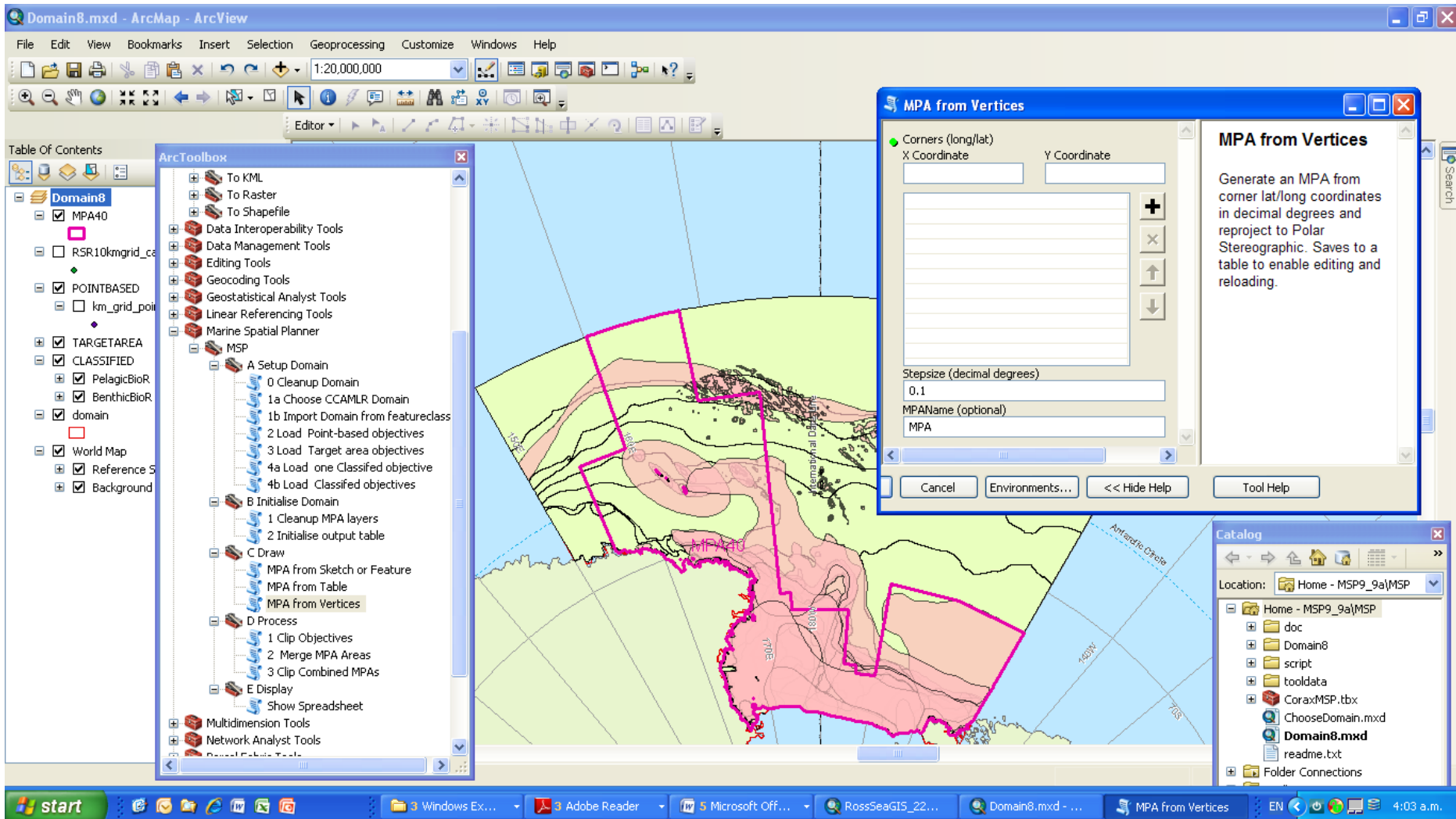
Figure 2. Screen capture of step 'C – 3 MPA From Vertices' run from within the 'MSP\Domain[x].mxd' ArcGIS project file.
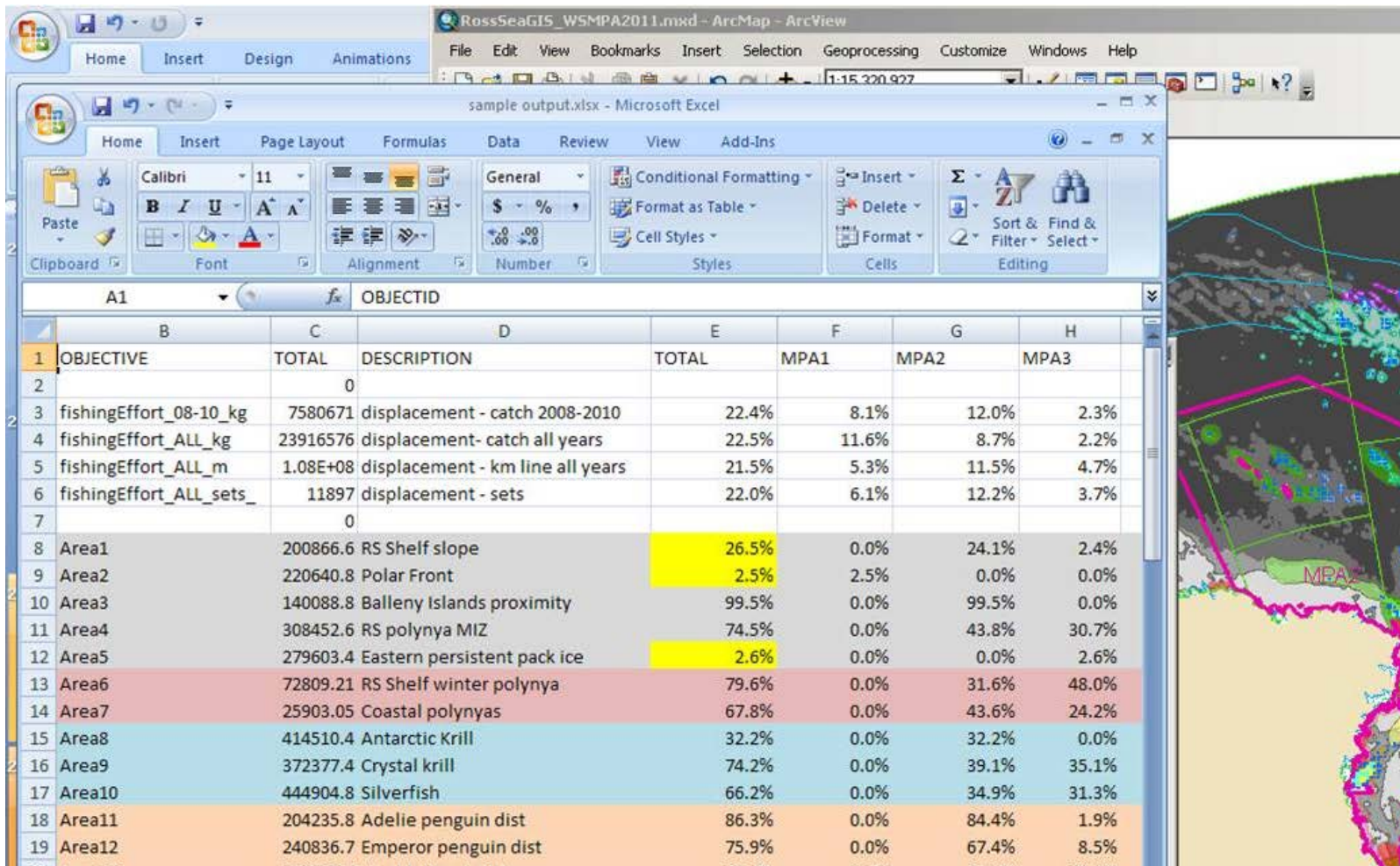
Figure 3. Screen capture of step 'E – Show Spreadsheet' with subsequent sorting and color coding by relative protection priority and conditional formatting to highlight particular outcomes of interest.