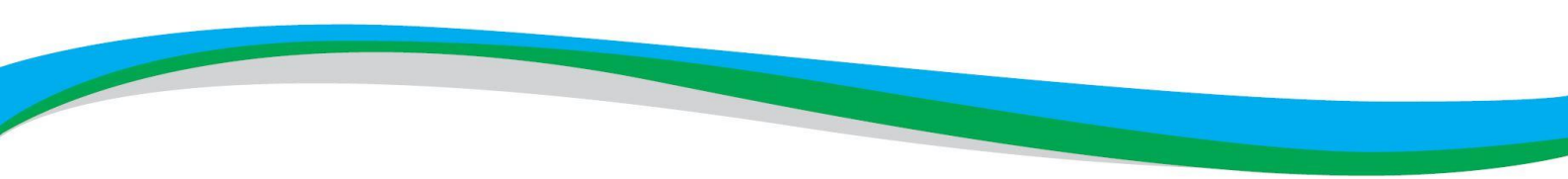


Socio-ecological assessment of the ecosystems, industries and communities of Spencer Gulf. Task 2: Interactive platform – ‘*Gulfview*’

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Executive summary

The report describes a new software platform – named ‘*Gulfview*’ – that was developed to allow stakeholders to efficiently access spatially-explicit information about the environmental characteristics, ecological assets, human activities, management arrangements and socio-economic values of Spencer Gulf. We demonstrate how this platform could be used by industry, community and decisions-makers to obtain information needed to develop and evaluate proposals for new developments, including aquaculture activities, desalination plants and ports. *Gulfview* allows users to obtain information about the characteristics of a specific location (e.g. depth, sea surface temperature, activities undertaken) and spatial overlap of environmental, ecological and economic variables. Users have control over the selection criteria used to identify parts of the gulf that may be suitable for a particular activity (e.g. aquaculture, desalination and ports). This report describes the datasets and methods used to generate the platform. The report also provides a ‘user guide’ and three example scenarios that demonstrate how *Gulfview* can be used by stakeholders to assist the development and evaluation of proposals for new developments. The platform and spatial data will be made available to stakeholders through the PIRSA-SARDI website.

Keywords: development, sustainable, environment, socio-economy, Spencer Gulf, spatial, interactive platform.

Acknowledgments

Funds for this research were provided by the Goyder Institute for Water Research, the Fisheries Research and Development Corporation (FRDC) and the Spencer Gulf Ecosystem and Development Initiative (SGEDI). SGEDI is a collaboration between a broad range of industry investors, the University of Adelaide, South Australian Research and Development Institute (SARDI) – a division of Primary Industries and Regions South Australia and Flinders University. The program aims to reduce costs, aid development and answer environmental challenges for one of South Australia's leading economic development zones.

Dr Alice Jones (University of Adelaide) provided spatial data on the human impacts on Spencer Gulf. Dr's Mark Doubell and Charles James (SARDI) provided the environmental data. Dr Simon Goldsworthy provided demographic data on seals and other marine predators. Marine parks and aquaculture zones datasets were downloaded from the 'Data.SA' website (<https://data.sa.gov.au/data/dataset>). This report was reviewed by Dr Mark Doubell and A/Prof Jason Tanner (SARDI) and Professor Bronwyn Gillanders (University of Adelaide).

1 Introduction

1.1 Background

Spencer Gulf is a key component of South Australia's Blue Economy; its marine environments contribute >\$1B per annum to the State's economy (Deloitte 2013). Almost half of South Australia's seafood comes from the gulf. It is a major gateway to the State's energy, mining and agricultural resources, and supports a wide range of fisheries, aquaculture, recreational activities and an expanding ecotourism sector. The gulf's marine ecosystems and species have global conservation significance.

The economic status and social fabric of Spencer Gulf's largest coastal communities (e.g. Whyalla, Port Augusta, Port Pirie) have been impacted by contraction and closure of important industries. There is an urgent need to develop existing and new businesses to provide alternative employment opportunities and ensure the ongoing prosperity of the region, whilst still maintaining existing industries and the environmental values that underpin them. During the mining boom, the establishment and development of new industries was impeded by: a lack of scientific tools to support marine businesses and government; delays in approval processes for major developments; lack of community confidence in industry environmental monitoring and assessments; and conflicts among existing and new stakeholders (Gillanders et al. 2016).

Industry, government and other stakeholders have identified the benefits for developing and evaluating proposals for new marine developments that would accrue from (i) collating existing spatial-information, (ii) making these data available through one or more government portals, and (iii) establishing user-friendly tools to integrate information from multiple datasets. As a key component of South Australia's blue economy, Spencer Gulf is an ideal location for a case study to demonstrate the benefits of establishing an interactive platform to allow stakeholders to access detailed spatial information on the environmental characteristics, ecological assets, human activities, management arrangements and socio-economic of a region.

Detailed spatial information on marine ecosystems are needed to support their sustainable development (e.g. Begg *et al.* 2015). In many jurisdictions, including South Australia (SA), spatial ecological, social and economic data on ecosystems, industries and communities have been historically collected by a variety of organisations for a diverse range of purposes. Currently, some of these datasets are available through several different SA Government portals. For example, Primary Industries and Regions South Australia (PIRSA) hosts the interactive mapping tool '*AgInsight*', which provides comprehensive agricultural and economic data for the State. Similarly, the Department for Environment and Water (DEW) hosts '*NatureMaps*' which provides detailed spatial information about SA's natural resources. Furthermore, "*Location SA Map Viewer*" enables users to access visual images of a wide range of datasets held by the SA Government (e.g. Land Management, Infrastructure and Utilities). These interactive tools are focused on land-based activities and on one or more of the social, economic or environmental components of the State's socio-ecological systems. None of these tools allow users to identify locations that meet specified selection criteria for multiple variables.

SARDI recently developed a software platform called '*Aquascout*' that enables users to set selection criteria (e.g. depth range, maximum mean wave height) to identify locations in Spencer Gulf that may be suitable for establishing finfish aquaculture operations (Doubell et al. 2018). '*Aquascout*' provides users with control over the selection criteria used to assess site suitability. The main limitation of '*Aquascout*' is that it was designed only to assess the suitability of sites for finfish aquaculture and only integrates bio-physical parameters relevant to that industry.

1.2 Objectives

This report describes a new interactive platform – named '*Gulfview*' – that integrates a range of existing spatial datasets for Spencer Gulf from bio-physics to economics and allows users to (i) generate maps of

individual ecological and economic variables for the gulf and (ii) set selection criteria for multiple variables to identify locations that may be suitable for a variety of activities.

The objectives of this report are to: 1) describe datasets for each spatial layer and the methods used to generate '*Gulfview*'; 2) provide a 'user guide' for the platform; and 3) present three example scenarios that demonstrate how '*Gulfview*' could be used by stakeholders to assist the evaluation of new developments proposals.

2 Methods

2.1 Data selection

Spatial data collated in the study were obtained from previous 'Spencer Gulf Ecosystem Development Initiative' (SGEDI) projects (e.g. Gillanders et al. 2016, Jones et al. 2018, Doubell et al. 2018) or existing portals (i.e. Data.SA - South Australian Government Data Directory). The selection of the variables used in this report is not exhaustive, but does include some key environmental, ecological and economic parameters for Spencer Gulf and provides a baseline from which further development can be undertaken.

Detailed descriptions of each map layer, including key features and relevant limitations and the source of the dataset are provided below. All variables were arbitrarily re-mapped to a common 2 km grid to limit the time of processing sensibly increased by finer resolution.

2.2 Environmental variables

The majority of the environmental layers were sourced from the SARDI Spencer Gulf Model (SGM, Middleton *et al.* 2013) validated for the period 1 July 2010 to 30 June 2011.

Depth

Bathymetry in metres (m) was generated from the Australian bathymetry and topography grid (June 2009, Geosciences Australia). The dataset is a merged product designed to provide broad scale information and is not suitable for navigational purposes. Re-gridding of this product to the 2 km resolution grid required spatial averaging which may result in under-estimation of actual water depth and does not necessarily resolve highly localised features (e.g. reef, shoals).

Distance from the shoreline

Distance (km) from the shoreline was calculated from the 0m depth contour line generated from the bathymetry/topography grid.

Temperature

Sea surface temperature (SST, °C) data were derived from the MODerate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua Satellite, following the algorithm described at <https://oceancolor.gsfc.nasa.gov/atbd/>. Level 3, daily sea surface temperature (SST) data were sourced from the Integrated Marine Observing System (IMOS) portal (Australian Ocean Data Network; <https://portal.aodn.org.au>). SST data are presented as the average calculated over 15 years (from 2003 to 2017) for each grid cell. A monthly-averaged SST climatology is also presented as a graph for each grid cell by clicking on the SST map.

Salinity

Averaged salinities (PSU) for each grid cell (over 1 year) were obtained from the validated SARDI Spencer Gulf Model (Middleton *et al.* 2013). A monthly-averaged salinity climatology can be obtained as a graph for each grid cell by clicking on the salinity map.

Current Speed

Averaged current speed (m.s^{-1}) for each grid cell (over 1 years) was obtained from the validated SARDI Spencer Gulf Model (Middleton *et al.* 2013). A monthly-averaged current speed climatology can also be obtained as a graph for each grid cell by clicking on the current speed map.

Dissolved Oxygen

Averaged dissolved oxygen concentrations (mg.L^{-1}) for each grid cell (over 1 years) was obtained from the validated SARDI Spencer Gulf Model (Middleton *et al.* 2013). A monthly-averaged dissolved oxygen concentrations climatology can be obtained as a graph for each grid cell by clicking on the dissolved oxygen map.

Wave Height

Averaged wave height (H_s) for each grid cell (over 1 years) was obtained from the validated SARDI Spencer Gulf Model (Middleton *et al.* 2013). Wave models are statistical models that predict a statistical wave spectrum where H_s is the average wave height of the highest 1/3 of the wave spectrum. H_s is a universal convention to measure wave height. H_s is used in notices and forecasts of sea state such as those issued by the Australian Bureau of Meteorology. A monthly-averaged wave height climatology can be obtained as a graph for each grid cell by clicking on the wave height map.

Benthic habitats

All available data on the locations of benthic ecosystems in Spencer Gulf were combined (see Jones et al. 2018). Data were derived from aerial imagery, modelled predictions for seagrass cover through the Gulf and sediment sample data. The different data layers had varying native resolutions and confidence levels (Table 1) but were all re-gridded to a 2 km resolution grid.

Table 1: Data layer sources for marine benthic ecosystem mapping. DEW = South Australian Department for Environment and Water.

DATA LAYER	SOURCE	DATA COLLECTION YEAR	RESOLUTION
Saltmarsh and Mangrove habitats	DEW	2005	± 10 to 20 m
State marine benthic habitats	DEW	2004	± 10 to 20 m
National marine benthic habitats	SARDI		
(Edyvane 1999)	1998	± 100 to 1000 m	
Estuary habitats	DEW	2009	± 15 m
Modelled seagrass	Gillanders et al. 2015	NA	250 m
Seafloor surface sediment grab samples	O'Connell et al. 2016	Various, from 1990 onwards	NA

2.3 Fishing data

Commercial fishing data

Fishing data provided by PIRSA/SARDI are presented as the average total catch (kg or t) over a 10 year period (from 2004/5 to 2013/14) for key species (Abalone, Prawns, Rock Lobster, Sardine, Garfish, King George Whiting, Snapper, Calamari). Non-confidential data were presented by fishing areas and re-scaled/re-gridded to match the environmental data.

Fishing intensity

Fishing intensity was generated by summing the total fishing effort per spatial block and re-scaling the values between 0 and 1 (with 0 indicating no fishing activity and 1 a high fishing activity).

2.4 Human activities data (other than commercial fishing)

Shipping intensity

Shipping intensity was generated by summing the number of voyages of commercial vessels (excluding fishing vessels) per year per grid cell (from the period 1st August 2013 to 31st July 2014). The values were re-scaled between 0 and 1 (1 meaning a high shipping activity).

Coastal activities

Coastal activities were mapped using a combination of data including:

- Data on land-use from the Department of Planning, Transport and Infrastructure. These data are usually updated annually from the state-wide property cadastre.
- Data on coastal population, from the Halpern global analysis (updated data from the 2013 analysis), were used as a proxy for coastal activity (see Gillanders et al. 2016 and Jones et al. 2018). These are modelled data on the number of people living within a moving circular window of 10km.

The effect of population was limited to the onshore and intertidal areas or up to 250m offshore, whichever was furthest. Values were log-transformed. Land-use data were also log-transformed (Jones et al. 2018). These two layers were summed and re-scaled between 0 and 1 (with 1 meaning a high coastal activity).

Aquaculture zones

Data represent location of approved aquaculture zones issued under the Aquaculture Act 2001 (source: <https://data.sa.gov.au/data/dataset/aquaculture-zones>)

2.5 Pollution data

Nitrogen input

Information on nitrogen input was sourced from the National pollution inventory (see Gillanders et al. 2016 and Jones et al. 2018) and only include three point-sources:

- 1) Waste water treatment plants at Port Lincoln, Port Augusta (east) and Port Pirie, the power station at Port Augusta and the steelworks at Whyalla. Data on the specific location of the inputs were given in Gaylard (2015).
- 2) Onshore aquaculture operations with licenses that allow discharge into the environment.
- 3) Inputs from stormwater and run-off into rivers.

Each of these three sources was mapped separately and scaled to between 0 and 1 (1 meaning a likely high Nitrogen input). Then the three scaled layers were combined (summed) and re-scaled to represent relative threat from point source inputs across the Gulf.

Oil pollution risk

The 'ocean pollution' index from the Halpern analysis was used to generate this layer (Halpern et al. 2012) (see Gillanders et al. 2016, Jones et al. 2018). The layer was based on data on commercial shipping combined with modelled recreational boat use and port locations. The premise of this layer is an index of ship/boat traffic and therefore should represent the risk of ship/boat-based pollution events as these are more likely in heavily used areas. Halpern used this layer to represent the risk of all pollution events, including fuel leaks, oil discharge and waste disposal (Halpern et al. 2012). The layer uses a simple plume model for the dispersal of pollutants from port locations (max distance of 100 km) but does not specifically account for local oceanography. The Halpern global model was re-centered on the Spencer Gulf and rescaled between 0 and 1 (1 meaning a likely high Oil pollution risk).

2.6 Ecological data

Marine Park zoning

This dataset identifies the waters within the SA Marine Parks Network Zoning which is dedicated to conservation under the Marine Parks Act 2007. Internal zoning in SG includes General Managed Use Zones (GMUZ), Habitat Protection Zones (HPZ) and Sanctuary Zones (SZ) (source: <https://data.sa.gov.au/data/dataset/marine-park-zoning>).

Marine top predators spatial distribution

The spatial distribution of five species of marine predators in Spencer Gulf (Australian sea lions, *Neophoca cinerea*; long-nosed fur seals, *Arctocephalus forsteri*; little penguins, *Eudyptula minor*; crested terns, *Thalasseus bergii*; short-tailed shearwaters, *Puffinus tenuirostris*) was obtained via a modelling process detailed in Gillanders et al. (2016). We used 564 individual tracks spanning over 14 years (2000–2014) to determine the relative use of Spencer Gulf by predators. Species-specific distribution models were based on logistic regressions (binomial) implemented in a generalised linear modelling (GLM) framework. While the tracking locations reflect the presence of the individuals in the area, we generated random background locations to characterise the environment. We did not restrain the model to the Spencer Gulf region but used all tracking data available in the wider region. Therefore the probability of distribution presented for Spencer Gulf includes the potential incursion of individuals from colonies located outside of the Gulf. We then used the model to predict the probability of animals' distribution for those colonies without tracking data but where the species is known to be present during the breeding season. We finally weighted the probability of distribution around each colony by an index of individual abundance obtained from previous abundance surveys (e.g. Goldsworthy et al. 2011; Goldsworthy et al. 2015). We rescaled the probability of distribution between 0 and 1 (1 meaning a high probability of distribution)

2.7 Interaction mapping approach

Each of the variables are first represented as individual maps. When spatial information is required on a combination of variables, users can select a special map named “interactions”. From there, a function allowing the filtering of all the different variables is available. After filtering, only grid cells which share a common spatial distribution are retained; highlighting spatial zones which cumulatively satisfy the criteria selected for the variables of interest.

A ‘User Guide’ and demonstration of how to use this feature are presented in the following section of this report.

3 User guide

3.1 Overview

'Gulfview' was created in an html format using R (2017) and can be linked to any existing website. When first started, the platform displays:

1. A map focused on Spencer Gulf.
2. A layer-control button
3. A button to measure distances and areas
4. A zoom in/out button.
5. A list of variables in the form of color-coded sliders.

Initially no layers/variables are selected so only the satellite image of Spencer Gulf is displayed as a base map (Figure 1). Note that a box at the top of the map displays the current cursor location (longitude, latitude and zoom level).

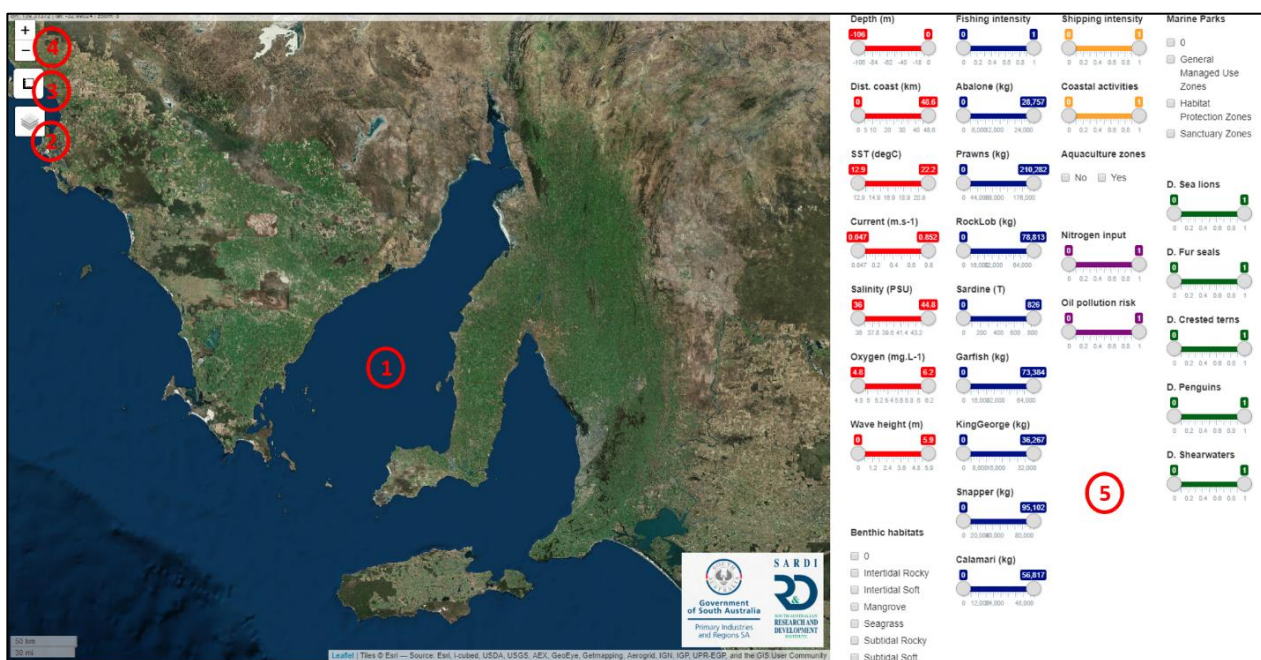


Figure 1. Esri WorldImagery default base map.

3.2 Interactive features

The platform includes several interactive features:

- **Layers selections.** When passing the mouse over the layer-control button, a layer selection panel will appear with a list of base maps and layers/variables (Figure 2).

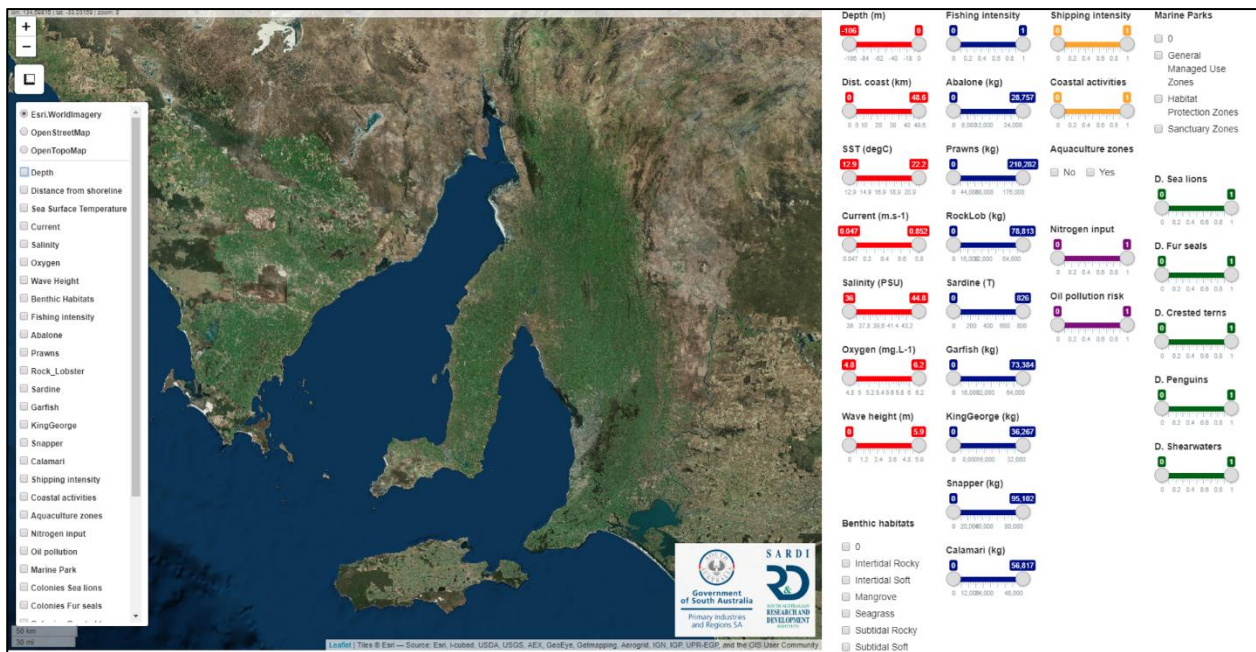


Figure 2. Layer selection panel.

The panel allows the user to change the base map (Figure 3) (we use the Esri.WorldImagery (satellite image) base map in the present document) and choose one or more layers/variables. However, the selection of more than one layer produces an overlay of the different layers and the lower layers won't be visible, especially if the last one selected has a large spatial cover (Figure 4). The colour legends for the different layers appear on the top right.

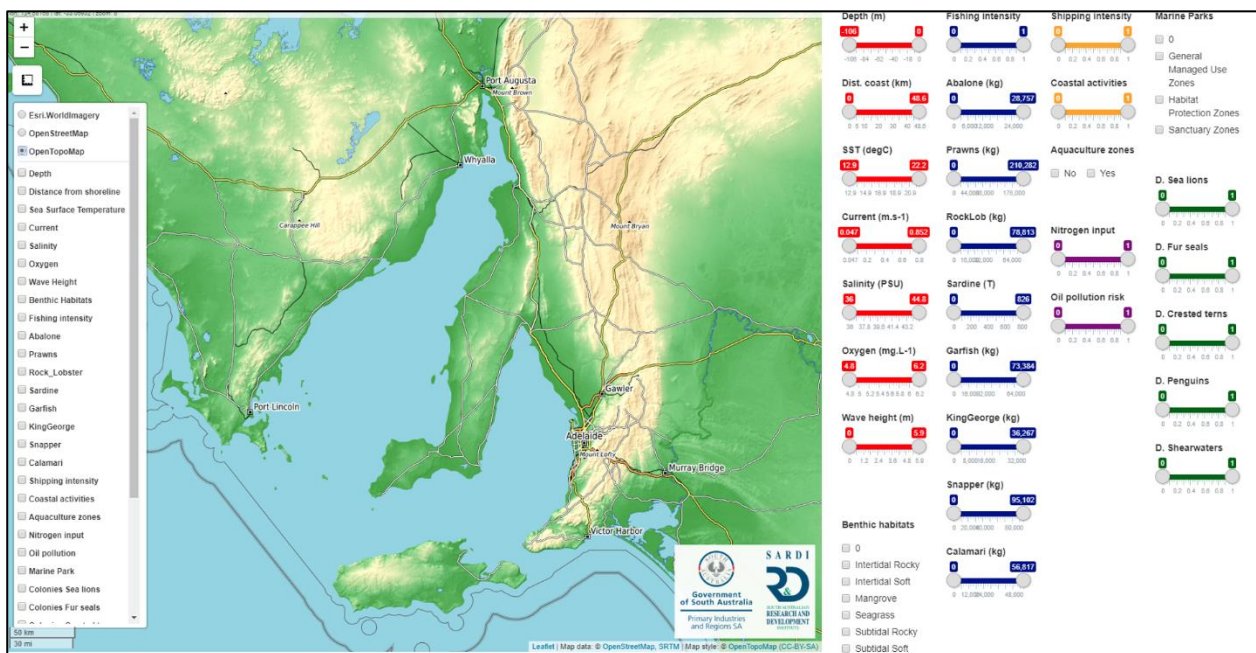


Figure 3. One of the three possible base map options (Open TopoMap).

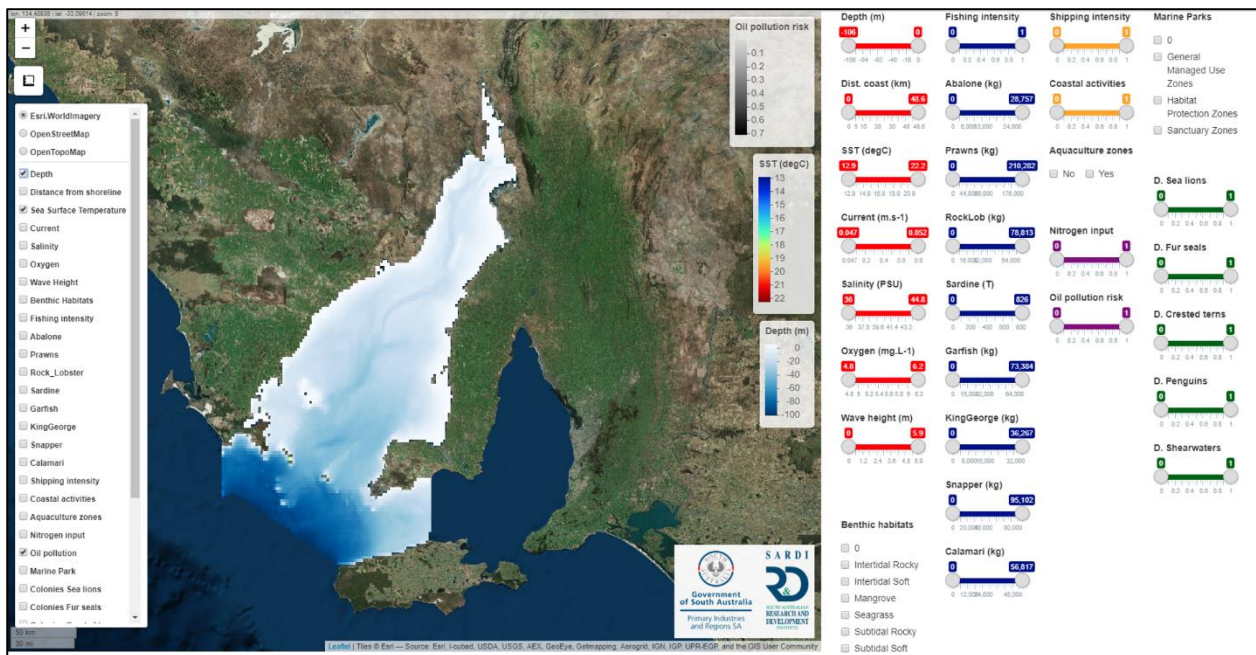


Figure 4. Selection of the 'Oil pollution risk', 'Sea surface temperature' and 'Depth' layers. The last one selected overlays the two others.

Clicking on any grid cell makes a pop-up panel appear with the value corresponding to that grid cell (Figure 5).



Figure 5. Example of a pop-up panel that displays the value of the pixel clicked.

For the seasonal variables, such as sea surface temperature, current, salinity, oxygen and wave height, while the map of annual mean is displayed (Figure 6a), a graph with a monthly climatology will appear when clicking on a grid cell (not the value of the annual mean for the grid cell) (Figure 6b).

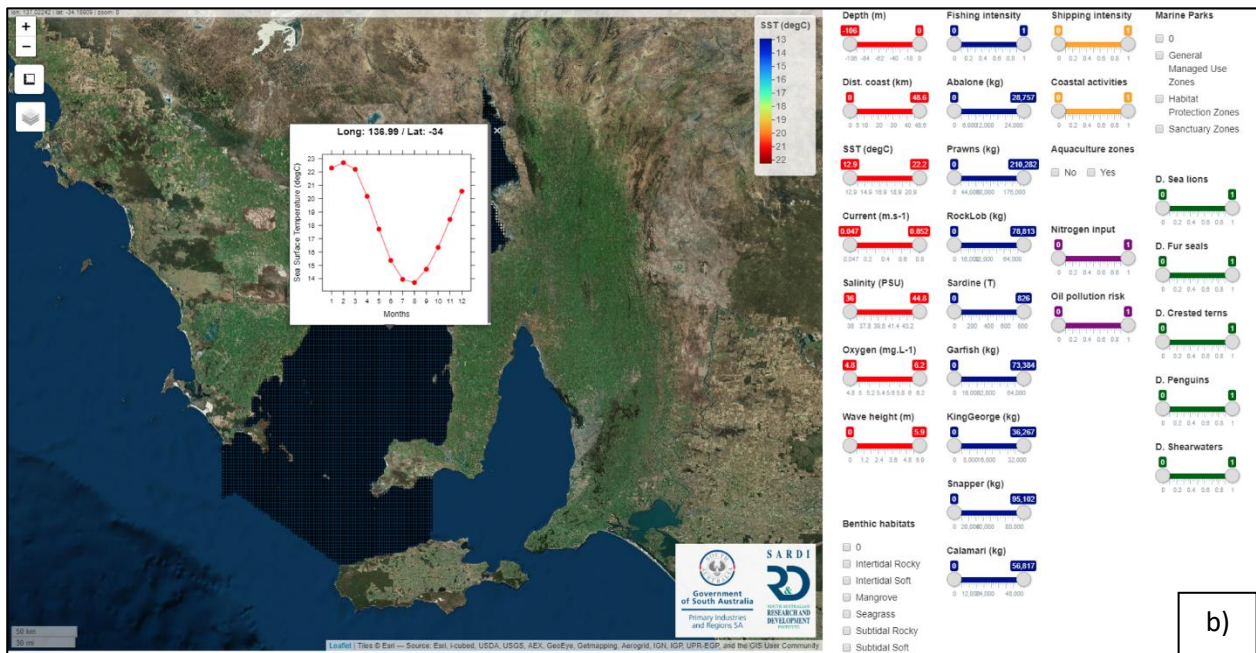
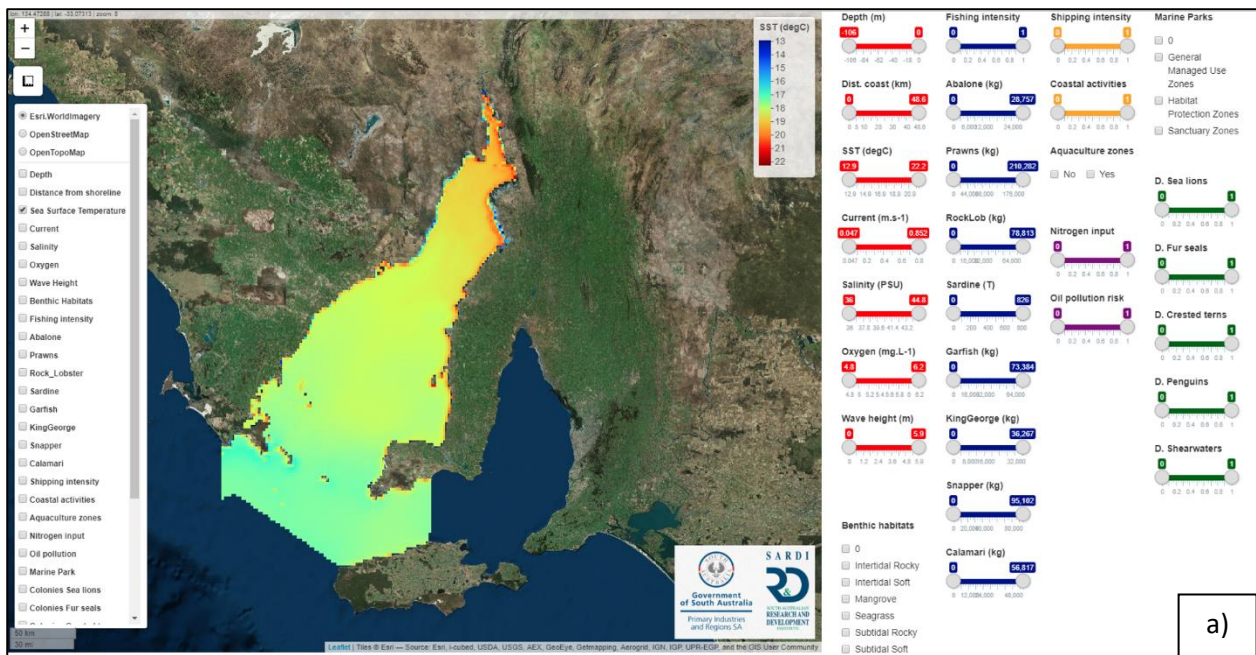


Figure 6. Special case of seasonal variables. a) Map of annual mean; b) pop-up panel that displays a local monthly climatology when one clicks on a pixel.

The selection of layer 'interactions' will be detailed in section 3.3.

- **Zoom In/Out.** The zoom in/out button in the upper left-hand corner controls the zoom magnification of the main map. The scroll wheel on the mouse achieves the same function. A click and hold on the left button of the mouse will control the selection of a region for zooming.
- **Measure control.** The measure control button can be used to display length and area results for a pre-selected zone.

Step 1: Pass the cursor over the button. The panel ‘Measure distances and areas’ will appear (Figure 7).

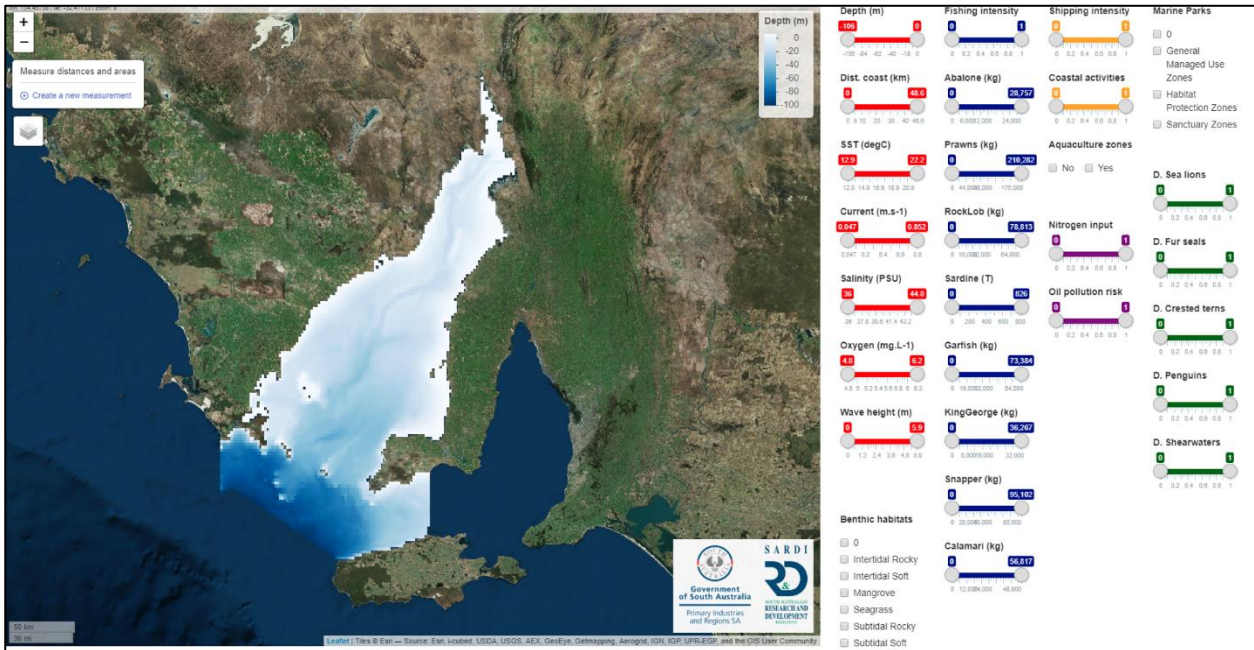


Figure 7. Selection of the measure control button.

Step 2: Click on ‘Create a new measurement’ (Figure 8).

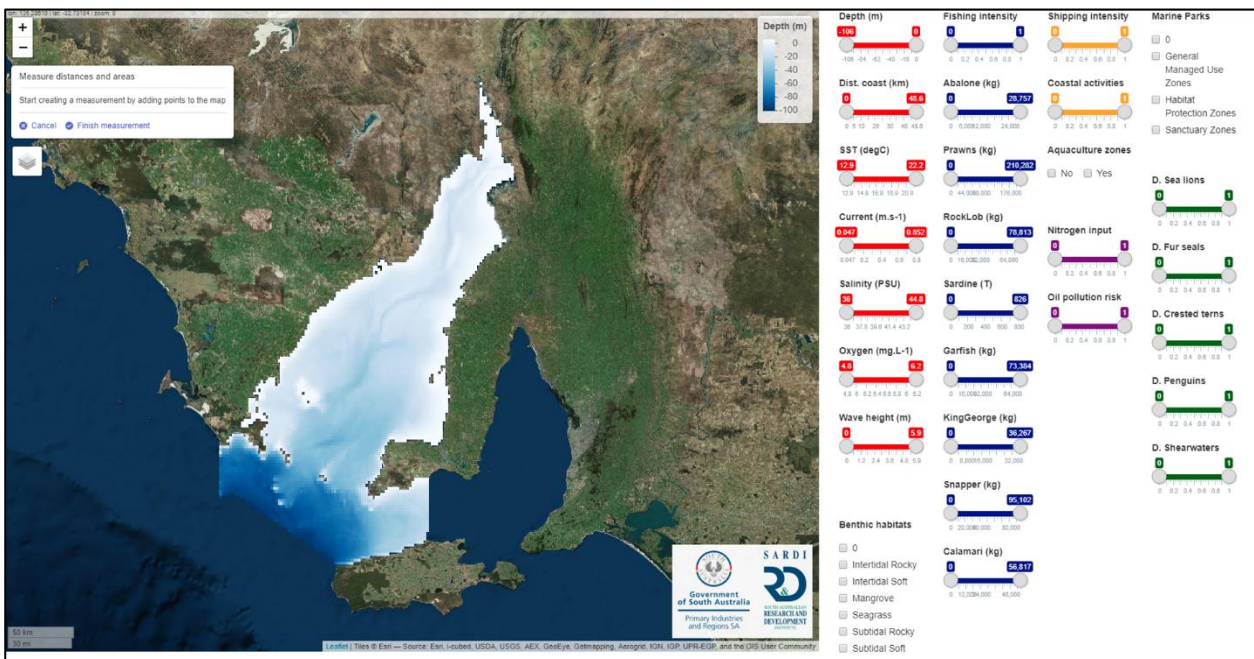


Figure 8. Setting up a new measurement.

Step3: Go to the map and click to select a section or area (Figure 9).

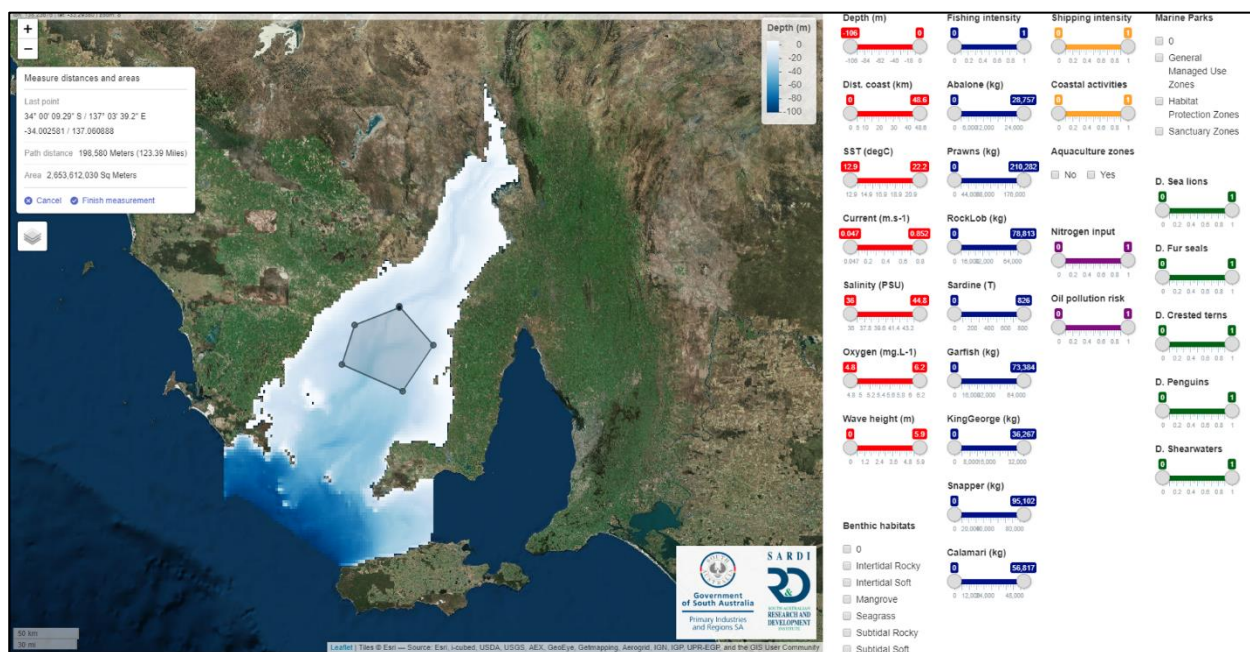


Figure 9. Selection of a section or area of interest on the map.

Step4: Go back to the panel and click on 'Finish measurement' (Figure 10).

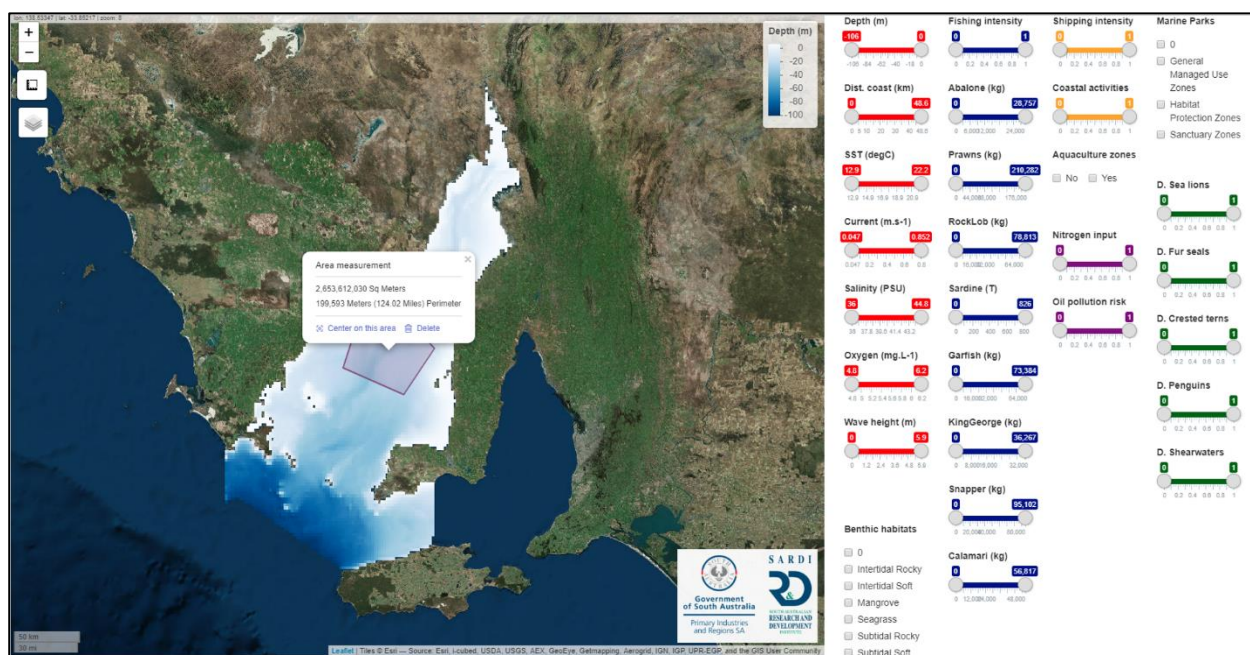


Figure 10. Finalising measurement.

3.3 Multiple variables interaction

When the 'Interactions' layer is selected, a grey map corresponding to the entire domain will be displayed (Figure 11). Initially no variables are filtered so every point in the domain is highlighted with grey cells showing that there are currently no limiting criteria for cell eligibility.

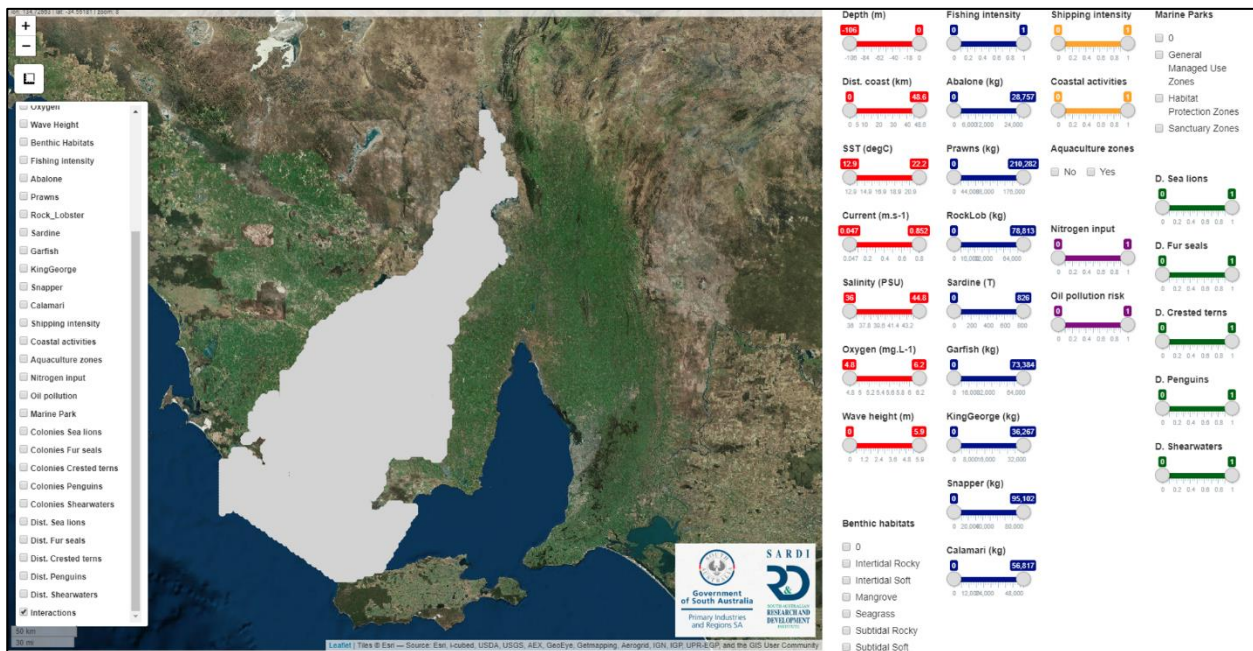


Figure 11. Selection of the 'interactions' layer.

The different variables are either in the form of classes of factors or numerical with a minimum and maximum limiting criteria which can be adjusted by the user thanks to the color-coded sliders on the right. Colors are used to make the different categories of variables easy to read: red= environmental variables; blue= commercial fishing activities; yellow= human activities; purple= pollution; green= ecological variables.

Note that all the variables can potentially interact together.

3.3.1 Example 1: Identifying areas suitable for finfish aquaculture farms

In this example, we investigate the areas where environmental conditions may be potentially suitable for finfish aquaculture. The different variables were arbitrarily (*i.e.* not necessarily realistic) set as follows. Note the order of filtering the data does not matter as the final result will be the same (Figure 12):

- Within the aquaculture zones = yes
- Depth range: 20 – 45 m
- Maximum average current speed: 0.4 m.s^{-1}
- Maximum average wave height: 2 m

Average annual temperature range: 17 – 19 °C

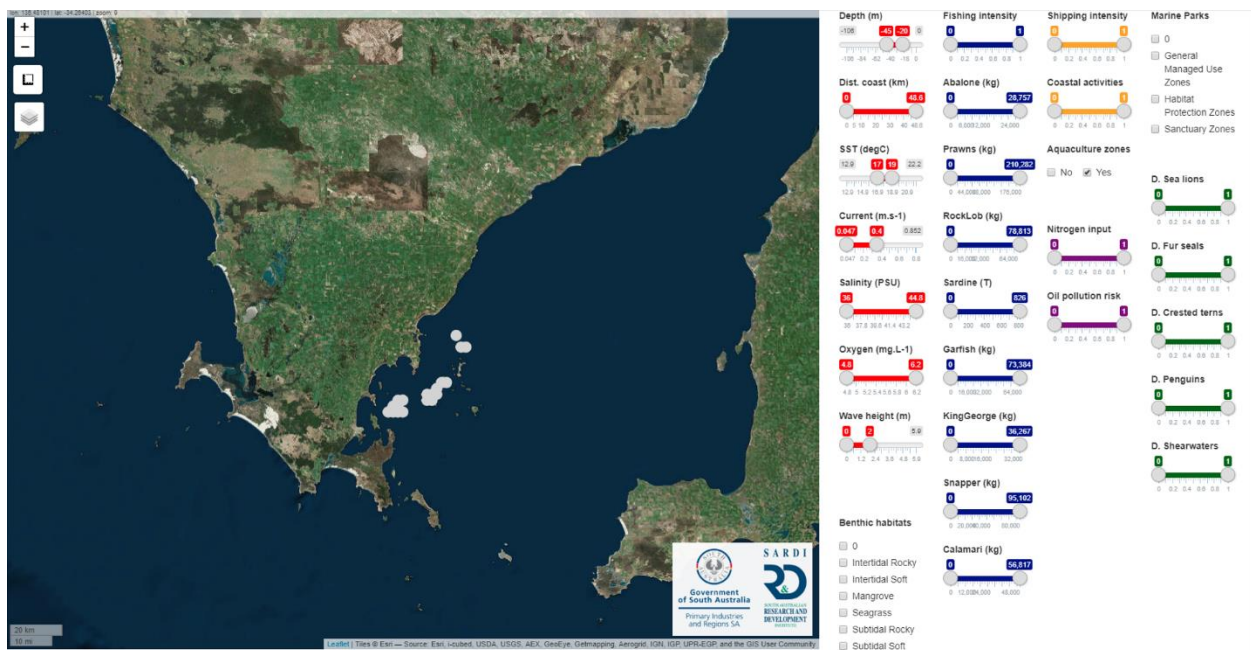


Figure 12. Example 1 – Delineation of areas potentially suitable for finfish aquaculture. Suitable grid cells according to the specified criteria on the right appear as grey points.

When clicking on one of the remaining grid cells, a panel summarising all the information available at that location will appear (Figure 13).

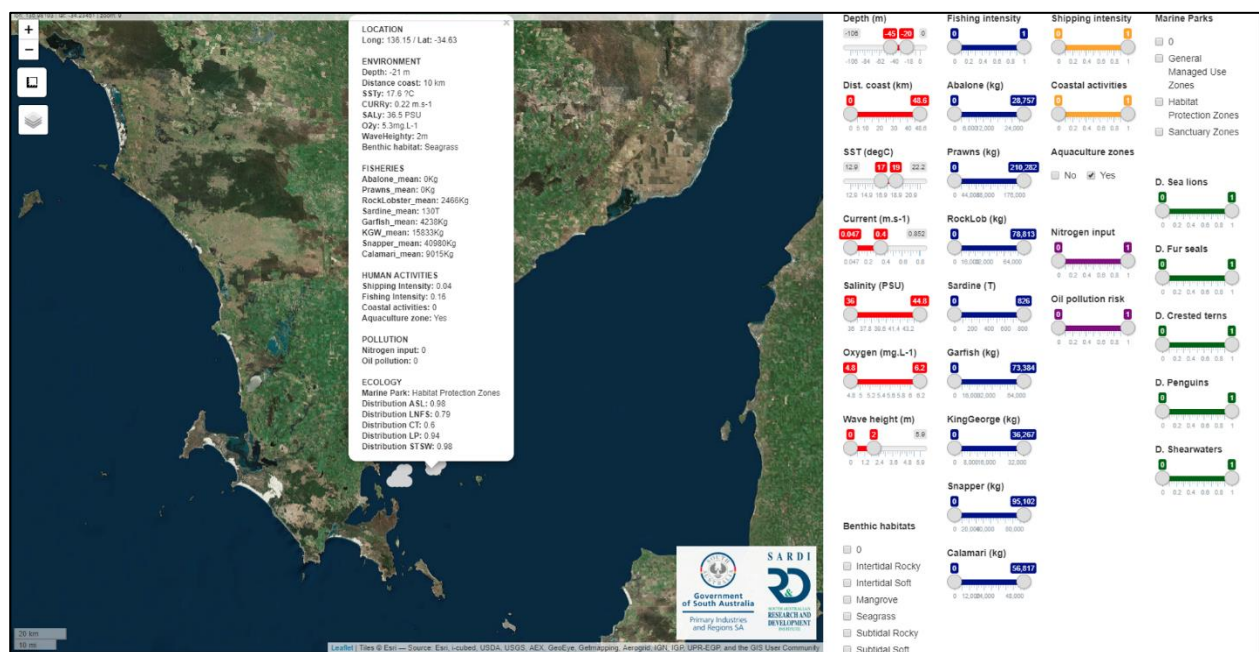


Figure 13. Pop-up panel that displays all the information available at that location when one clicks on a pixel of the 'interactions' layer.

3.3.2 Example 2: Identifying areas suitable for seawater desalination plants

In this example, we investigate the areas where environmental conditions may be potentially suitable for desalination plant. The different variables were arbitrarily (*i.e.* not necessarily realistic) set as follows (Figure 14):

- Depth range: 0 – 20 m
- Maximum distance from coast: 10 km
- Average annual temperature range: 15 – 18 °C
- Maximum average current speed: 0.5 m.s⁻¹
- Average annual salinity range: 36 – 40 PSU
- Average annual dissolved oxygen range: 5.5 – 6.2 mg.L⁻¹

Maximum average wave height: 2 m

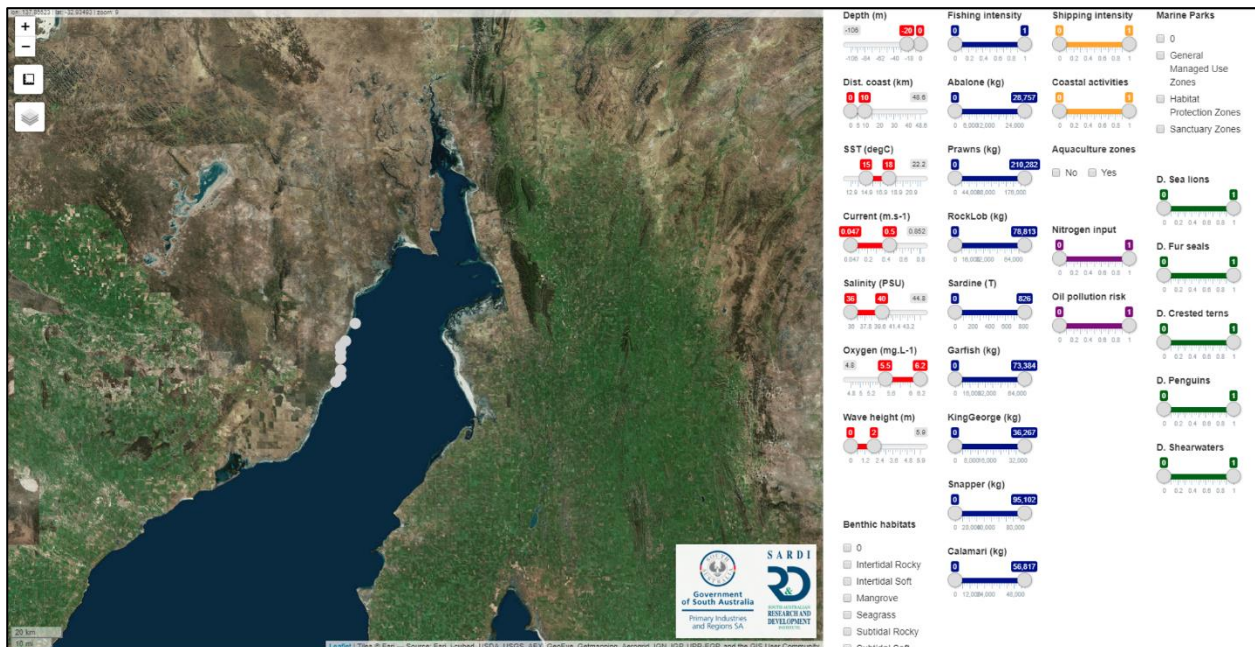


Figure 14. Example 2 – Delineation of areas potentially suitable for desalination plants.

Again, when clicking on one of the remaining grid cells, a panel summarising all the information available at that location will appear (see example 1).

3.3.3 Example 3: Identifying areas of ecological significance

In this example, we determine the potential areas of ecological significance, simplistically defined for the purposes of demonstration as areas where all five predator species overlap with seagrass benthic habitats. The different variables are set as follows (Figure 15):

- Distribution Sea lions $\neq 0$
- Distribution Fur seals $\neq 0$
- Distribution Crested terns $\neq 0$
- Distribution Penguins $\neq 0$
- Distribution Shearwaters $\neq 0$

Benthic habitats = Seagrass

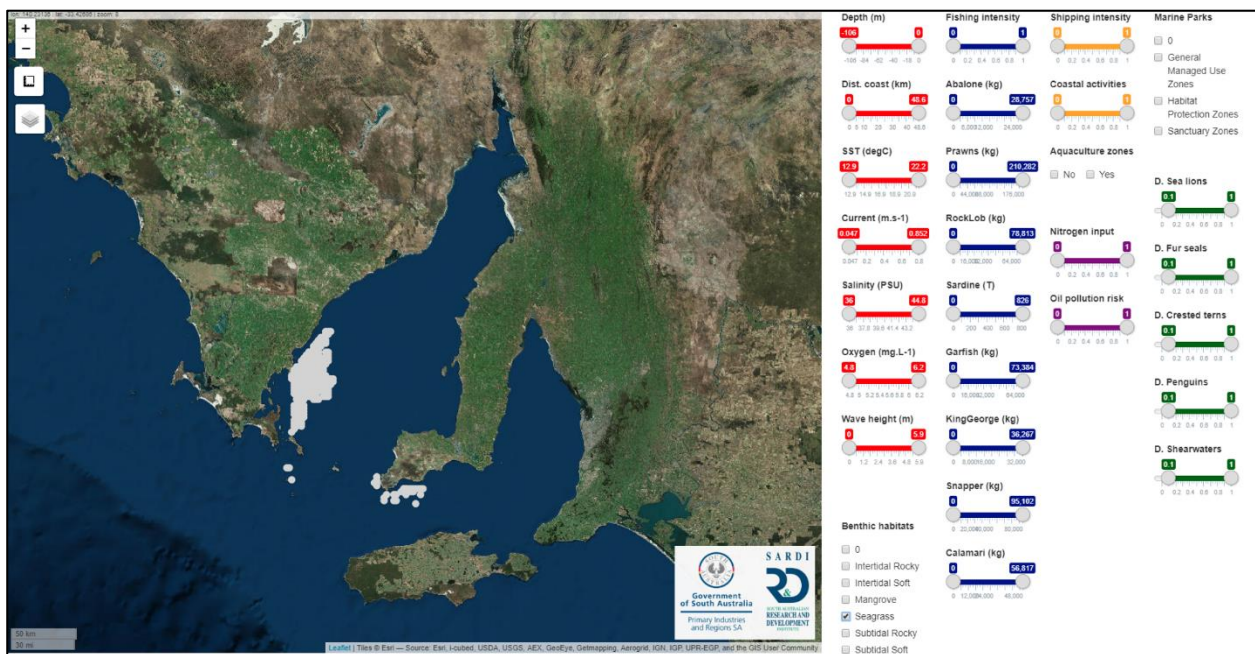


Figure 15. Example 3 – Delineation of areas of ecological significance in SG based on the overlay of distribution at sea of five species of marine predators and seagrass benthic habitats.

4 Conclusion

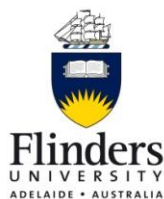
The new platform '*Gulfview*' presented in this report allows users to control criteria selection and combine spatial datasets for Spencer Gulf. '*Gulfview*' provides a tool to identify areas that may be suitable for particular activities, based on user-specified criteria. '*Gulfview*' and spatial data will be made available to stakeholders through the PIRSA website. A business case is about to be developed to incorporate into AgInsight a refined version of the platform that covers all marine waters off South Australia out to the 200 nautical mile limit of Australia's Exclusive Economic Zone.

Further development of the platform within AgInsight could include a greater focus on the temporal component of some environmental variables. For example, variables currently presented as an annual mean could also be presented on a monthly or seasonal basis or as an annual maximum/minimum. Additional variables could also be incorporated into the tool to make it more useful to a broader range of stakeholders. Data will need to be updated regularly, according to availability, to prevent the platform becoming obsolete.

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