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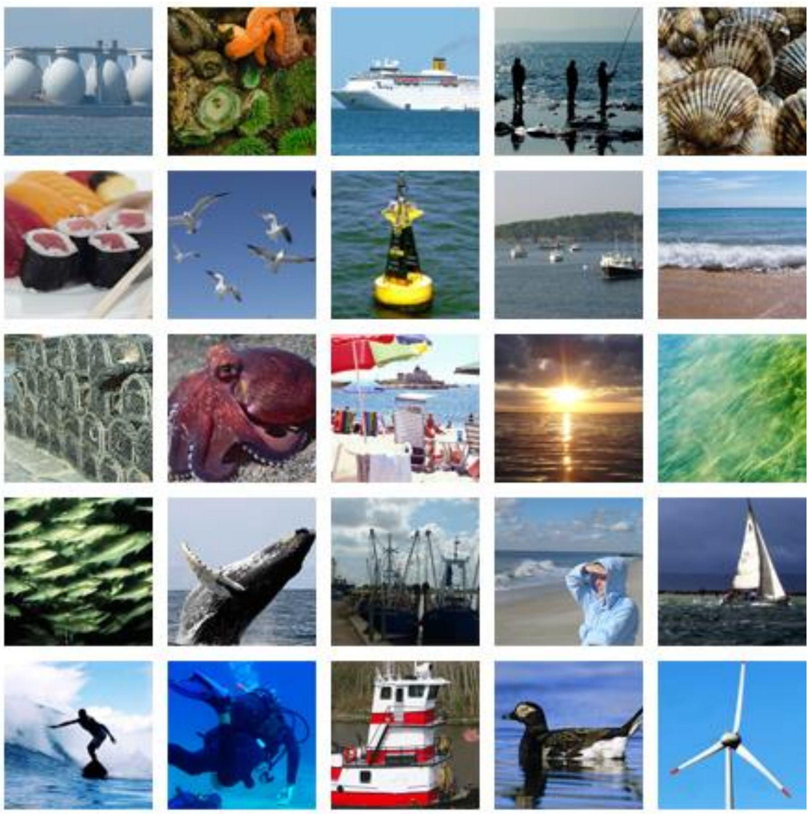

Community of Practice: Western Indian Ocean, Ocean Accounts Work Programme 2

Technical Report: November 2021

OVERVIEW

Ocean Accounts Framework applicability in Algoa Bay.

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Technical Report: November 2021

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1. Executive Summary

The rapid advancement of digital technology has resulted in an abundance of online data visualization and analysis tools which can be readily applied to marine science and the management of our marine resources. Progress in the fields of online data visualization and analysis has allowed for significant advances in marine systems monitoring. Considered the last frontier on earth for research and development, the oceans are equally a challenge in systems understanding, as well as access to its depths. By combining current technologies, the physical, biological and digital spheres can be accessed and analysed remotely as well as reported on in a framework and style that supersedes our wildest imaginings as marine research scientists working alongside decision makers.

In addition to this paradigm change in the measurement of our oceans, the ocean itself is changing and therefore our approach to managing it must also adapt. The Global Oceans Accounts Partnership is leading a worldwide shift to this inevitability through the advent of the Ocean Accounts Framework. Ocean Accounts provides an opportunity for collaborative work towards sustainable development of oceans and coasts by valuing the system and its resources (market and non-market) in a holistic and inclusive manner that goes beyond the limiting view of Gross Domestic Product valuation in monetized terms. Awareness of this shift and promotion towards a more holistic approach to monitoring our seas is advanced through the development of online data visualization and decision support-based tools which can aide management practices and decision maker's responsibility to make the most informed decisions.

South Africa is one of five countries participating in the UN Natural Capital Accounting & Valuation of Ecosystem Services Project (led by Stats SA and SANBI nationally) which aims to assist the participating partner countries to advance the knowledge agenda on environmental and ecosystem accounting and initiate pilot testing of the System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting (EA), with a view to improving the management of natural biotic resources, ecosystems and their services at the national level as well as mainstreaming biodiversity and ecosystems in national level policy, planning and implementation.

Within this, the Ocean Accounting component and the NRF Communities of Practice - 'Western Indian Ocean: Assessing the applicability of the ocean-accounts framework' aims to engage with these international programmes to develop oceans accounts in South Africa and contribute to the above mentioned initiatives.

In answer to this call an alpha version online data visualization tool has been created for viewing and interacting with Ocean Accounts development in Algoa Bay, Gqebehra, South Africa. This technical report documents progress to date.

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List of Acronyms

AODN	Australian Ocean Data Network
BGIS	Biodiversity Geographic Information System
BSU	Basic Spatial Unit
CoP	Community of Practice
CPUT	Cape Peninsula University Technicon
CSIR	Council for Scientific and Industrial Research
DEFF	Department of Environment, Forestry and Fisheries
DST	Department of Science and Technology
EA	Ecosystem Accounting
EBSA	Ecological and Biological Significant Area
EEZ	Exclusive Economic Zone
ESRI	Environmental Systems Research Institute
GDP	Gross Domestic Product
GIS	Geographic Information System
GOAP	Global Oceans Accounts Partnership
IMOS	Integrated Marine Observing System
IODE	International Oceanographic Data and Information Exchange
IORA	Indian Ocean Rim Association
MARISMA	Marine Spatial Management and Governance Programme
MBSU	Marine Basic Spatial Unit
MSDI	Marine Spatial Data Infrastructure
MSP	Marine Spatial Planning
MMU	Nelson Mandela Metropolitan University
NBA	National Biodiversity Assessment
NCA	Natural Capital Accounting
NRF	National Research Foundation
NSDI	National Spatial Data Infrastructure
OAF	Ocean Accounts Framework
OCIMS	National Oceans and Coastal Information Management System
SEEA	System of Environmental Economic Accounting
SAEON	South African Environmental Observation Network
SAIAB	South African Institute for Aquatic Biodiversity
SAMREF	South African Marine Research and Exploration Forum
SANBI	South African National Biodiversity Institute
UN	United Nations
WIO	Western Indian Ocean
WP	Work Programme

2. Introduction

Western Indian Ocean countries are steadily turning to their oceans to stimulate economic growth and ocean resource – use security in what are termed ocean economies. Governance of such resource – uses is becoming critical in ocean policy development and management, and "blue economy" approaches places sustainability and inclusivity at the centre of such governance. Because ocean policy development has an intrinsic spatial component, countries are turning to Marine Spatial Planning or Integrated Coastal Zone Management to drive the necessary trade-off decision making processes. Trade–offs require value estimations and ocean economies have in the past been largely valued as sectoral contributions to Gross Domestic Product (GDP). By providing qualifiable and quantifiable physical and monetarised values of the benefits from and costs to economic, social and environmental systems of an ocean economy, ocean accounts provide important inputs into spatial planning, economic strategy development, sustainability indicators and measures of inclusivity that are consistent and standardised across spatial and temporal domains (Findlay et al., 2020). Value metrics estimated over time provide trend data that are critical in evidence-based ocean governance and policy development, including trade-offs to balance ocean resource use, sustainability and inclusivity (Figure 2.1).

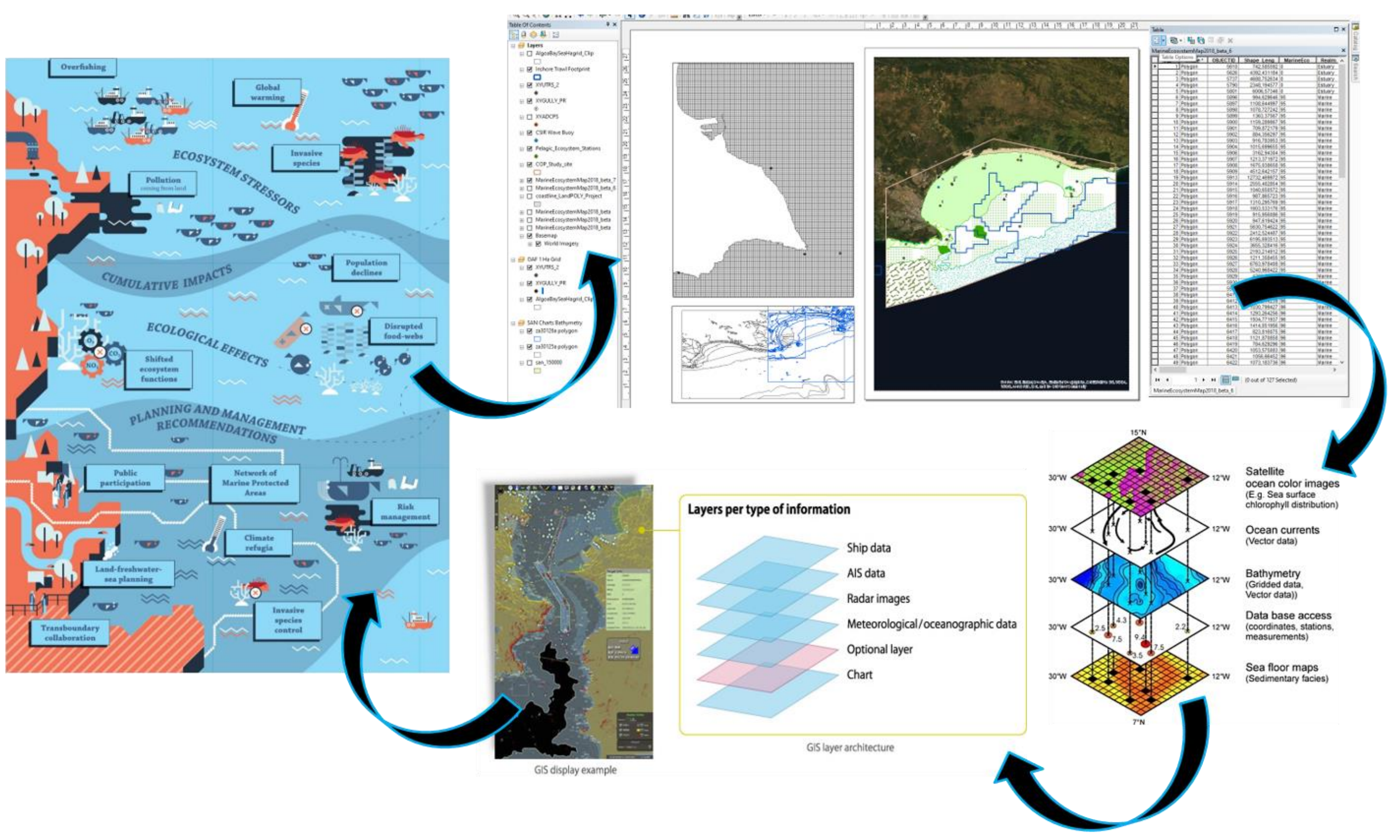


Figure 2.1 An example of Ocean Accounts Framework data flow to inform planning, management and policy makers.

Ocean Accounts forms a holistic valuation, a step in the larger process to policy and governance. Ecosystem extent accounts, along with ecosystem condition accounts, usually form the basis of the Ocean Accounts ecosystem accounting process. Below is a diagram to show OAFs position within the greater MSP process (**Error! Reference source not found.**). As our oceans change, as measurement of our oceans change, and as our use and protection of our oceans and its resources change, Ocean Accounts can support monitoring and adapting to these inherent changes.

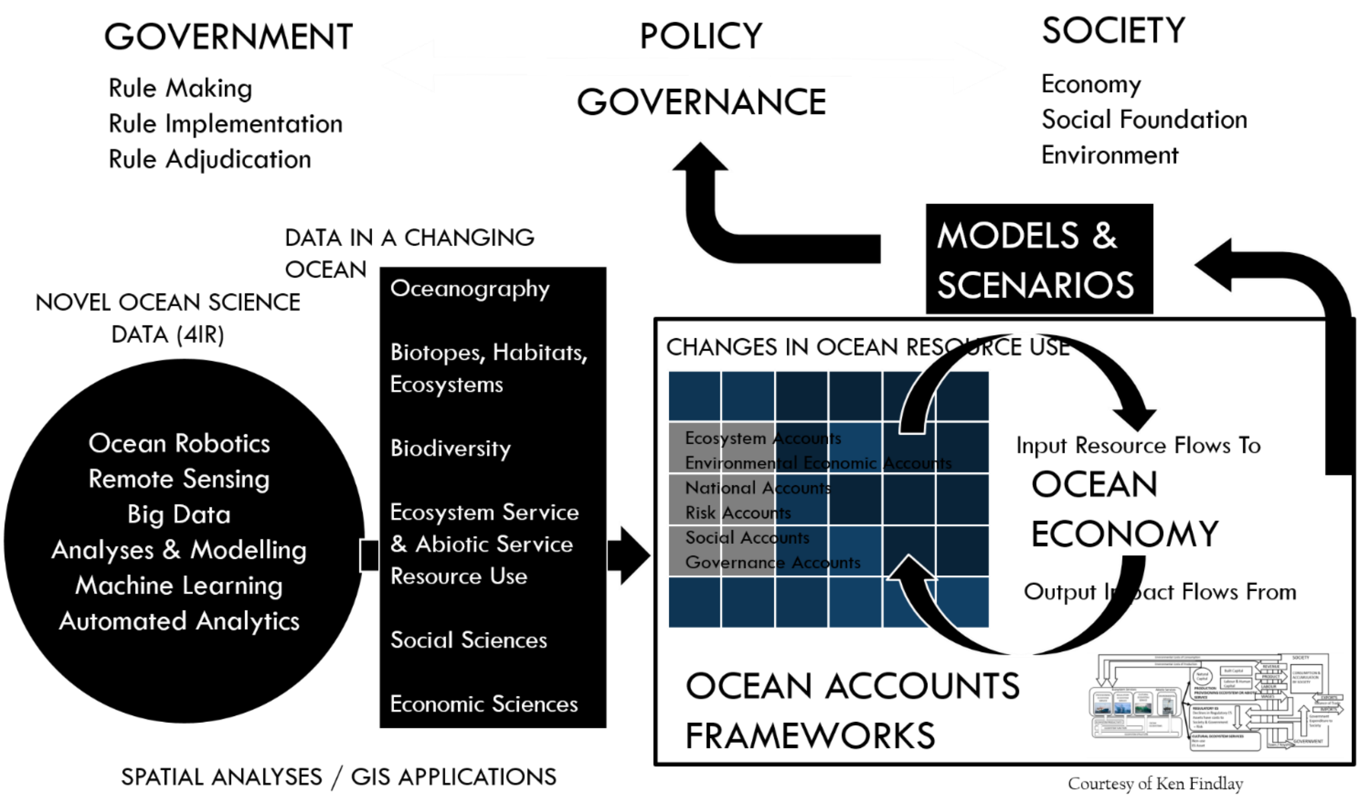


Figure 2.2 A diagram depicting a holistic approach to valuating Natural Capital and how OAF informs policy, governance, government and society and can support and assist Marine Spatial Planning processes.

The ocean accounts framework (OAF) enables countries to monitor three important trends:

- changes in ocean wealth, including "non-produced" ecosystem assets;
- ocean-related income and welfare for different groups of people; and
- ocean-based economic production.

Within South Africa, the aim of this part (Work Programme 2) of the larger GOAP Africa project is to provide an online public space easily accessible to local, national and international scientists, researchers, and decision makers involved in management and policy, where Ocean Accounts maps, layers, data and information can be viewed, manipulated and downloaded.

This is achieved through the integration and analysis of both spatial and non-spatial datasets within a geographic information system (GIS) and through the publication of the outputs of these studies within publicly available atlases which have been designed to enable data interpretation, exploration and download. GIS is used to make maps that communicate, perform analysis, share information, and solve complex problems. In a marine context, applications include identifying problems, monitoring change, understanding trends, managing and responding to events, performing forecasting and setting priorities. GIS data includes imagery, features, and base maps linked to spreadsheets and tables. Interactive maps are the geographic vessel for the data layers and analytics that can be easily accessible. GIS maps are easily shared and embedded in a multitude of applications. By combining an interactive mapping platform with an online data visualization tool, the power in analytics of large amounts of data can be realized and provides an invaluable resource for scientists, researchers, management bodies and decision makers alike. This sort of technology can support the development and implementation of the Global Ocean Accounts Partnership (GOAP) Ocean Accounts Framework in South Africa and the Western Indian Ocean region.

Work Package 2 of the Ocean accounts framework for South Africa utilises data sourced from the following Organisations:

- South African Environmental Observation Network (SAEON) Elwandle node,
- the Algoa Bay Project, South African Institute of Aquatic Biodiversity (SAIAB)
- South African National Biodiversity Institute (SANBI) National Biodiversity Assessment (NBA) 2018.

Additionally, the project aims to work extensively with external partners, including the Global Ocean Accounts Partnership (GOAP), the High-Level Panel for a Sustainable Ocean Economy (through GOAP), Western Indian Ocean Governance Exchange Network (WIOGEN), Indian Ocean Rim Association (IORA) Academic Groups and the African Natural Capital Accounts Working Group on Ocean Accounts as well as draw on the National and local work by SANBI NBA 2018 and The Algoa Bay Project working group, respectively. We also endeavor to engage with and share in as many additional local, regional, and national groups as feasible and willing going forward.

For the purposes of this project a combination of interactive mapping and data visualization applications have been selected and described in context and technical detail on the development and implementation of these tools provided in the following report.

2.1. Background

Introduction to GIS

Digital technology is expanding exponentially. The capacity to collect, store, analyse and manipulate data, at a global scale is unprecedented. The digital revolution is characterized by a combination of technologies that is obscuring the lines between the physical, digital, and biological spheres. This fact bodes well for the marine environment which historically has been a difficult environment to access at depth, is under monitored, and possibly underestimated in its significance to the balance it maintains and supports for earth as a functioning, importantly for humans, habitable, system. We have reached a time where transdisciplinary scientific experts working collectively will rapidly propel marine systems monitoring and understanding forward through the digital technology medium. One of many examples of this occurring is through the advent of online data analysis and visualization platforms which often centre on a geographic information system.

A geographic information system (GIS) is a system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data with all types of descriptive information. This provides a foundation for mapping and analysis that is used in many science disciplines and numerous industries. GIS helps users understand patterns, relationships, and geographic context. The benefits include improved communication and efficiency as well as better management and decision making.

Study Region

Algoa Bay is situated in Gqebehra, South Africa and is a representative area to test applicability of this framework and associated online tools because of its complex web of marine users, productive upwelling environment, dynamic oceanographic forcings in the bay, long term data availability, multi-organisation collaborations are ongoing, and topical work underway through the work of The Algoa Bay Project and the Marine Spatial Planning (MSP) strategy (under the jurisdiction of the new Marine Spatial Planning Act (Government of South Africa, 2019)).

Data types and variables used in WP2 of OAF

Basic elements of the spatial data infrastructure in an OAF should include shoreline, bathymetry and the designation of spatial units (i.e., Marine Basic Spatial Units (MBSUs or BSUs for short) based on a grid or other spatial framework) (Figure 2.3). Other elements would be overlaid as either asset types, uses or conditions.

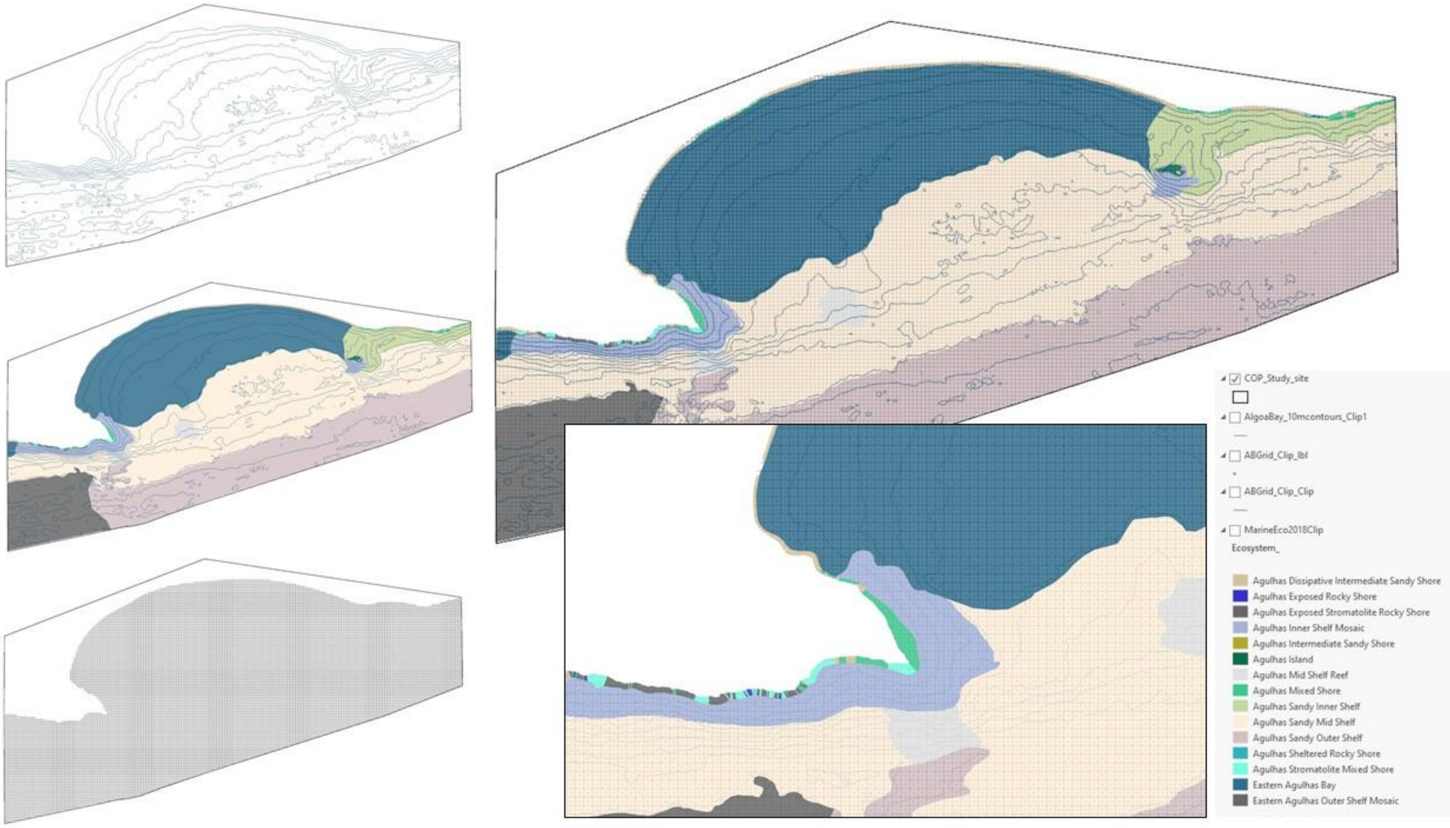


Figure 2.3 A series of maps showing the basic elements of the spatial data infrastructure for Algoa Bay (study area, 10 m contour bathymetry, SANBI 2018 ecosystems types, and bay scale grid).

The choice of condition measures will be informed by national priorities and data availability in future. For example, data on nutrient concentrations would inform concerns about algal blooms or eutrophication, chlorophyll-*a* data can give an indication of biological productivity, while sea temperature and sea height can indicate warming or cooling trends over time or sea level change. There are many approaches to "reference condition" and these should be agreed and policy relevant (e.g., pristine, sustainable, specific date in the past, pre-industrial, etc.). Generally, reference conditions should be distinct from "target conditions", which may be set by policies, but not necessarily consistent with maintaining or improving capacity to provide optimal long-term ocean services.

Some key condition variables that would inform multiple ocean-related concerns include:

- pH (acidity)
- BOD, COD, Chlorophyll-*a*, primary productivity (and / or an indicator of eutrophication)
- Species diversity, ecosystem diversity (Shannon index of diversity)
- Concentration of floating plastics

- Sea surface temperature (SST)
- Coral condition (cover, % living, %bleached)
- Seagrass and mangrove cover (%)

In the case of Algoa Bay, seagrass and mangrove cover could be replaced by kelp forest cover (% cover) for instance.

Data from the Algoa Bay SAEON Sentinel Sites, NMU, SAIAB, and Rhodes University has been utilized to inform a case study application of the OAF (Figure 2.4). Gully Temperature Probes (GTU), Underwater Temperature Recorders (UTR), Acoustic Doppler Current Profiler (ADCP), and Conductivity Temperature Depth (CTD) instruments that have been recording oceanographic conditions as a part of a long term monitoring project in Algoa Bay will be used. Oceanographic and biological variables will include depth (m), sea temperature (˚C), salinity (PSU), dissolved oxygen (ml/L), nutrients (nitrate, phosphate, silicate in μM), turbidity (NSU) and chlorophyll (Chl-*a* mg m^{-3}). While data spanning 2008 -2020 exists and will be incorporated by the end of 2021, initially data from 2018 and 2019 were used. Most of the data captured is up to 30 m depth, with exceptions up to 70m.

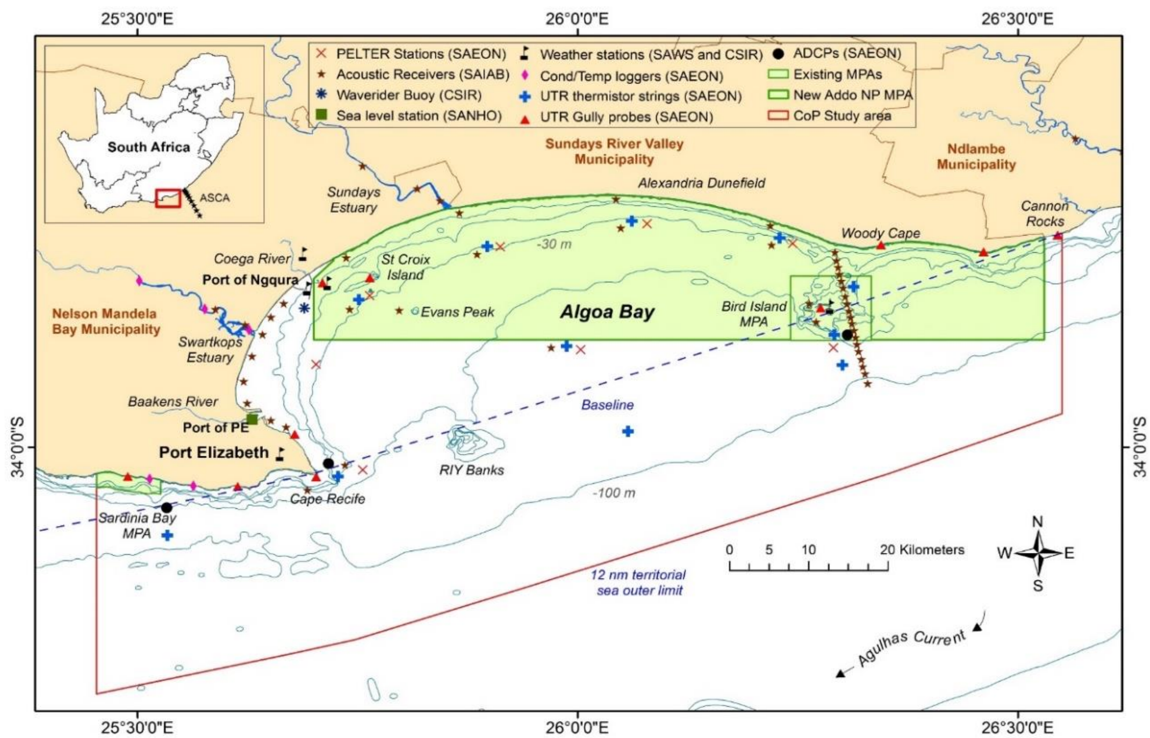


Figure 2.4 A map showing the SAEON Sentinel Site and associated instrument locations in Algoa Bay. Data from the PELTER Stations, CTDs, UTR thermistor, UTR Gully Probes and the ADCP's will be used to create a GIS database and associated spatial layers.

The ocean is large, three-dimensional, moving, much is outside national jurisdictions and spatial data are collected by many local, national and international organizations. This poses challenges to mapping; therefore, only 20 percent of the global ocean seafloor has been mapped in terms of depth (bathymetry) and less than 0.001 percent has been sampled in terms of substrate and biota (DOALOS, 2016, Chapter 33). Although remote sensing provides global data, only the surface of the ocean is visible from satellite. This requires special attention to establishing a spatial data infrastructure that will serve to integrate many types of data including from local in situ studies.

While extensive data sets do exist in this area, one of the key aims of this work is to discern which data sets and related locations, in x, y and z space, are relevant and applicable for OAF purposes.

Following a study by Sayre et al., 2017 (Figure 2.5), an ocean mesh for assessing extent and condition of oceanographic variables in x, y, z space will be used: from a global to a regional context, Algoa Bay grid zonation (Figure 2.3) will be defined as:

- 100m x 100 m grid blocks (1 ha)
- Additionally, 25m, 50m, resolution (5m when considering estuarine data) will be considered
- Discrete point data should fall within 50 m of centroid within block
- Cluster data at the centroid.
- Column of oceanographic data represented up to 70 m depth with current data sets

The WP2 group suggestions for delineating extent for oceanographic variables being considered are as follows*:

- Extent in an oceanographic context has not only x and y values, but also z values so we will look at 2D and 3D extent
- In the horizontal, Dunes, beaches and rocky shore – Onshore Zone
- High water mark to 60 m depth contour – Coastal System Zone
- 60 m depth contour to +200 m depth contour – Offshore Zone, past 200 m depth (Shelf edge –Neritic Zone)
- In z space, or vertical, 2 zones within the photic zone, 0 – 30 m through the water column, and 30 – 200 m
- Data will be batched into 5 Levels -Sea surface (0 – 2 m), Water column (WCI, 0 - 30m (in 10 m intervals initially) and WCII, 30 – 200m (I 10 m intervals initially)), Sea floor, and Sub sea floor
- Both spatial and temporal disaggregation in data will need to be flagged and tracked

*It's important to note that the MSP group have categorized horizontal extent in AB as follows: Onshore- ~50 m above the high water mark to the low water mark, Coastal System- 0 (low water mark) to 60 m depth, Offshore- 60 m to depth (presumably 500m), Marine Islands, and last, Kelp Forests and Shallow Reefs. At some stage in the near future, a standardized zoning should be agreed upon and set. We have adjusted our classifications to align with this work for the time being.

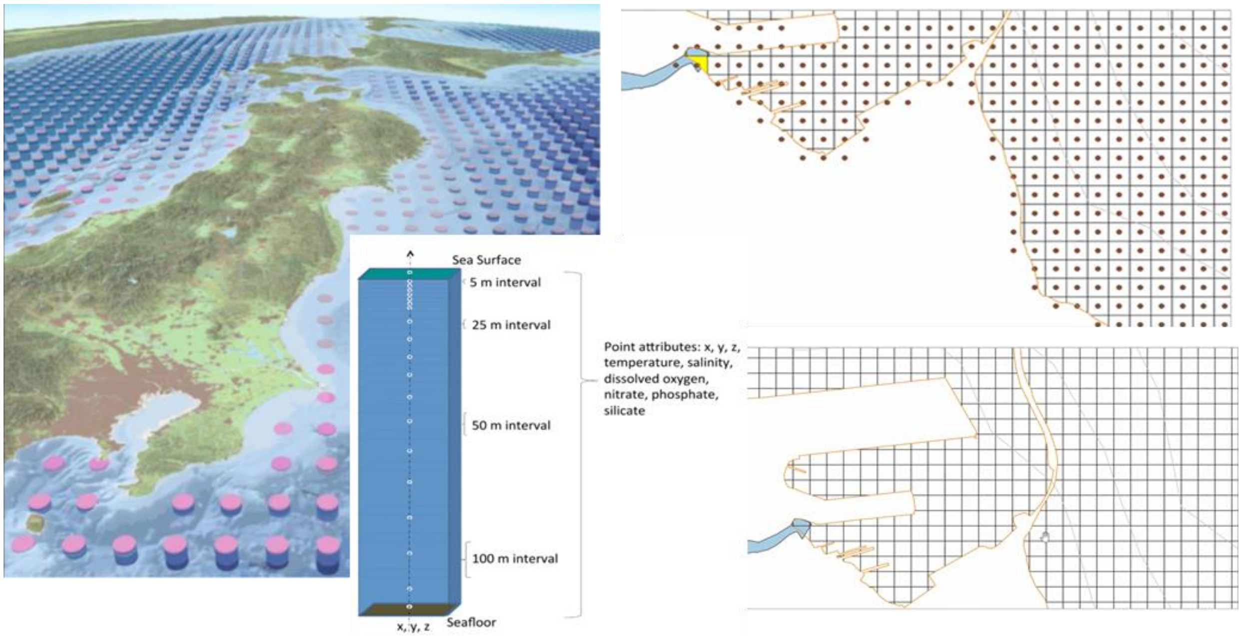


Figure 2.5 Sayre et al., 2017 global ocean mesh grid system and associated xyz water column with centroid representation, on the left. Example of Algoa Bay local scale1 ha grid system with centroid points, on the right.

The Basic Spatial Unit (BSU) may be as small as a remote sensing image pixel (30-100m), a national grid reference system (1nautical mile) or small administrative units (e.g., marine statistical area). Smaller BSUs have the advantage of being more homogenous. That is, when delineating ecosystem extent, some ecosystems, such as mangroves, or estuaries, may be in strips of 5m wide and therefore undetectable by satellite at 100m resolution. Since ecosystems tend to be more complex in coastal areas and data tends to be more generally available, some countries maintain data at finer resolution near the coast. In this case, it may be practical to distinguish between coastal units (CBSU) and marine units (MBSU).

Out of 150 SANBI (NBA 2018) ecosystem (habitat) types along the SA coastline, 15 are present and delineated in Algoa Bay (SANBI NBA, 2018). The goal is to establish extent and condition in an OAF to derive ocean ecosystem types. The two approaches are connected but different. Will biodiversity ecosystem types correlate to ocean based ecosystem types? Will there be crossover, differences, similarities? When the z factor is included as defined Levels (depth) how will the ecosystem type change or not? These are questions that will be considered through the second phase of WP2.

2.2 Spatial database

Ocean accounts can be built from maps (spatially explicit) or tables (spatially independent), but the power is in combining them. Maps can be used to generate tables and data in tables can be allocated to areas of the ocean.

The following guidance is provided in the Global Ocean Accounts Partnership, Technical Guidance on Ocean Accounting for Sustainable Development, United Nations, 1st edition, 2019. Establishing the spatial database for Ocean Accounts is an important early step that will facilitate the integration of spatial data from many sources. If the data sources already adhere to the standards of a National Spatial Data Infrastructure (NSDI) that includes coastal and marine areas (or Marine Spatial Data Infrastructure, MSDI), then spatial standards will not have to be developed specifically for the pilot. If not, then an ocean accounting pilot may be the catalyst to expand an existing NSDI to the country's EEZ. These considerations will be developed further and synchronized among all of the WPs by WP3 and to some degree in WP2.

Many pilots have begun by compiling maps as a basis for a physical ocean asset extent account. If there is no NSDI/MSDI, then standards such as shoreline vector, definition of "coastal", projections and scales will need to be established. It is possible to generate initial analytical results by overlaying spatial data in a GIS without creating an integrated spatial data infrastructure. However, this does not facilitate the production of the accounting tables. That is, to produce a physical Ocean Asset Extent Account, it is best to first align data (e.g., separate maps of mangroves, coral, seagrasses, kelp beds etc.) using the same shoreline and spatial units. Doing this will ensure validation of the data by revealing gaps and overlaps.

Although the Ocean Accounts Framework suggests spatial units and ecosystem classifications, pilot physical Ocean Asset Extent Accounts typically begin with existing national spatial units and ecosystem classifications. SANBIs NBA 2018 will be largely drawn upon as well as the work of NMUs The Algoa Bay Project Conservation Management Plan and the greater MSP group for reference and where relevant comparison.

2.3 Online GIS platforms and user tools

In an attempt to assess the applicability of the role that oceanographic data can play in the OAF a brief review of already available GIS platforms and online user tools was conducted (Figure 2.6, see Annex 2). In addition a detailed synopsis of data to be compiled, global and regional data providers and sources, and an Algoa Bay focused data catalogue have been compiled and can be viewed in Annexes 1 – 3 at the end of this report.

The novel aspects of ocean accounting means that there is considerable scope for experiential dialogue from across African case studies in the accounts refinement process as well as drawing on work already underway internationally with respect to development and implementation, and in the manner of use in decision making processes.

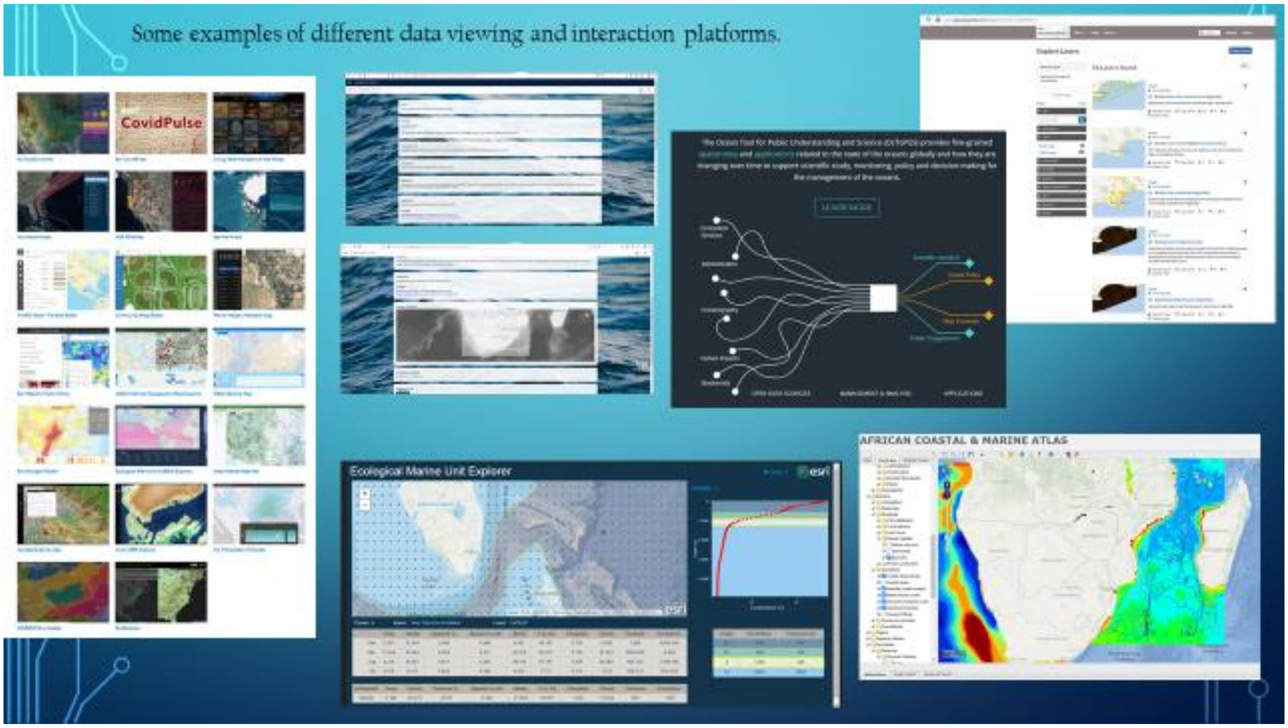


Figure 2.6 GIS based online user platforms for viewing oceanographic data (see Annexes 2 – 4 for references and more information).

2.4 Remotely sensed and modelled data

In a country like South Africa, where *in situ* data can be costly and sparse, remotely sensed and modelled data plays an important role for assessing the state of an ocean ecosystem. SAEON Egagasini node has demonstrated the advances in modelled hind and forecasted oceanographic data for Algoa Bay.

Recent work within OCIMS on bay scale modelling 'downscales' global ocean models (BRAN, HYCOM, GLORYS) to high resolution over Algoa Bay (~500 m) where hindcast simulations validated against 2.5 years of in-situ observations from ADCPs, UTRs and GTPs located in the Bay provide a snap shot of sea surface temperature (Figure 2.7 and Figure 2.8). Along with supporting various research and training objectives, uses for this type of product include scenario testing (for managers and policy makers) as well as identification and dissemination of key historical metrics and indicators.

For the purposes of Ocean Accounts, satellite data will be used to fill in any data gaps and importantly to provide wide reaching coverage when considering the EEZ and WIO region at large. Wherever possible local *in situ* data will be prioritized and can help to verify modelled data.

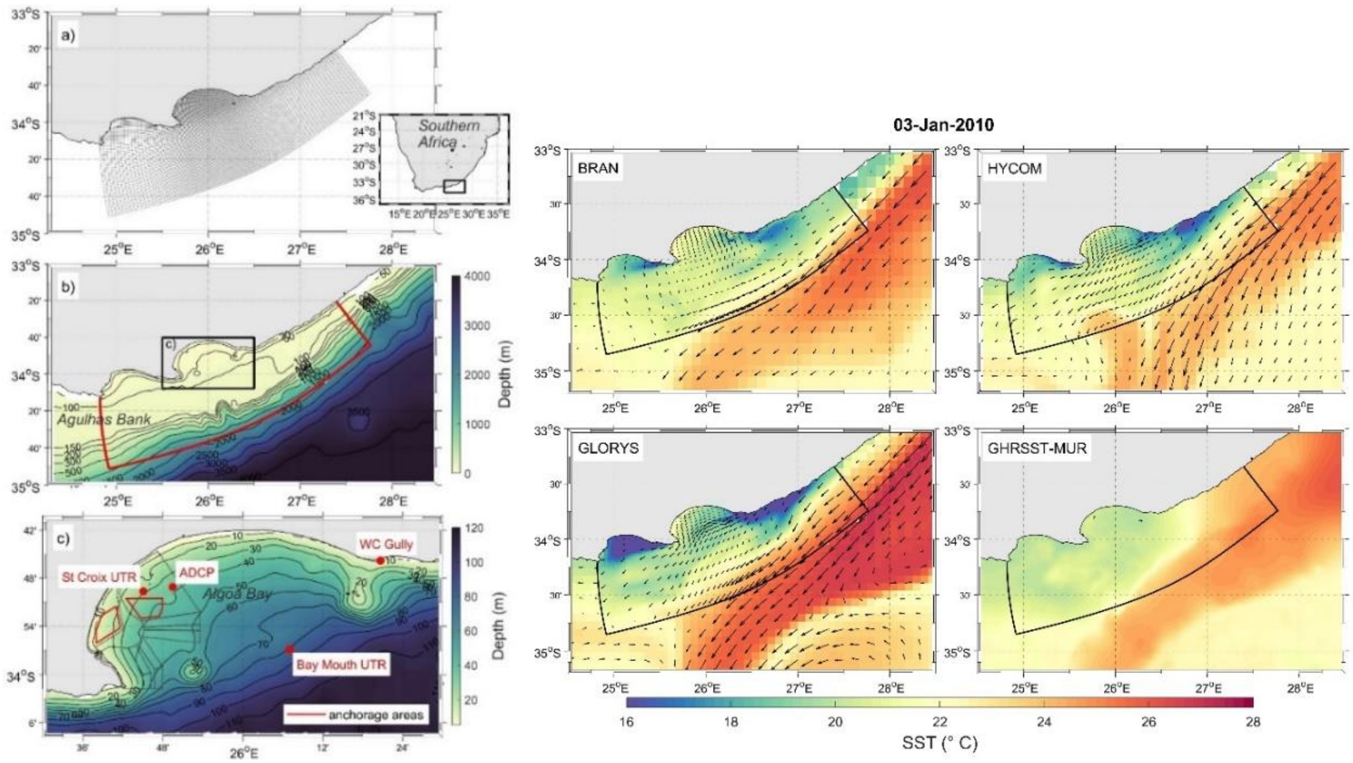


Figure 2.7 Downscaling of global ocean models, BRAN, HYCOM, GLORYS, for the purpose of high resolution hindcasting of SST over Algoa Bay.

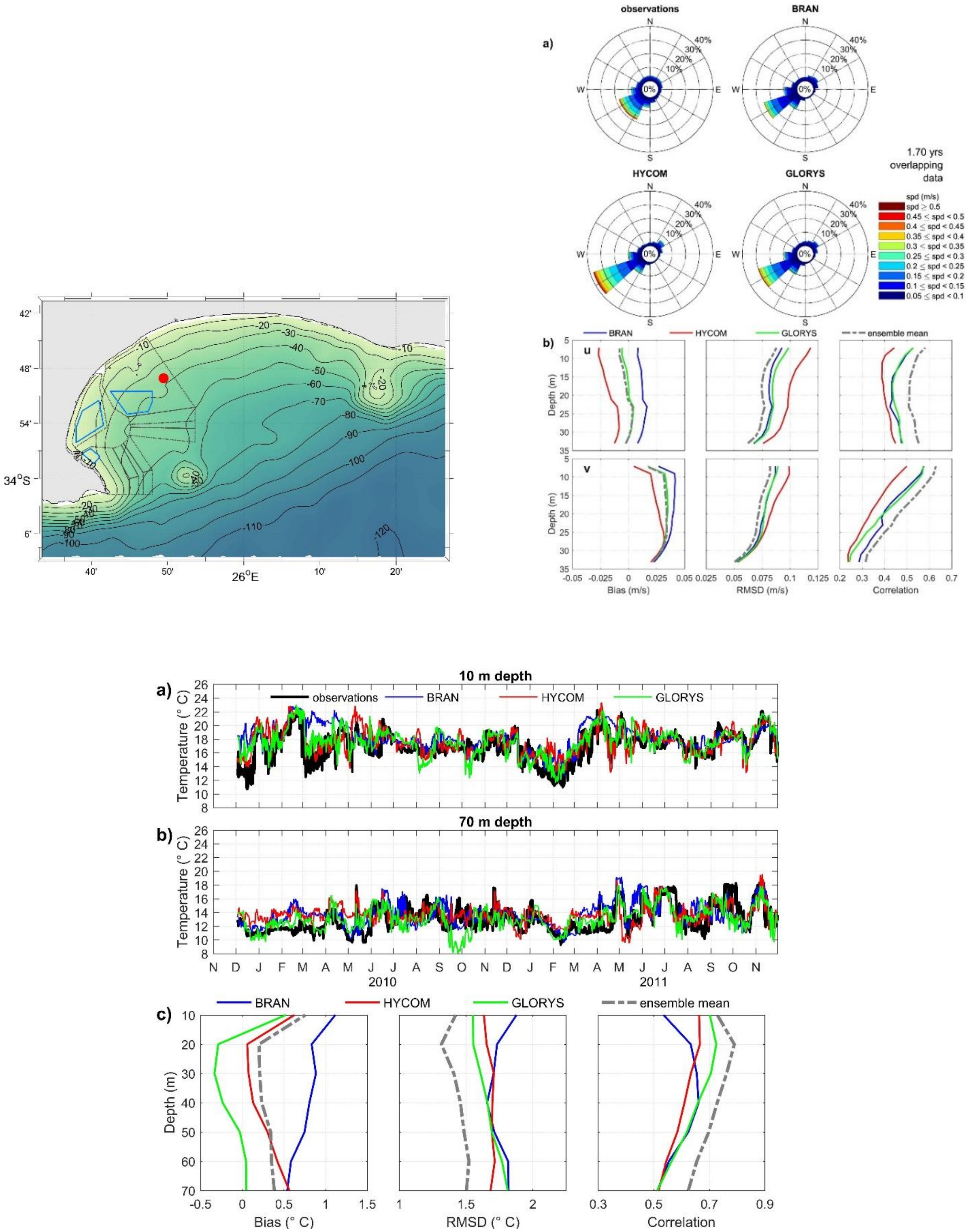


Figure 2.8 Evaluation of Algoa Bay model against in situ observations provided by SAEON eLwandle coastal node and of Lwandle Marine Environmental Services (on behalf of PetroSA).

2.5 OAF ecosystem accounting tables

Finally, examples of the associated accounting tables for Ecosystem Accounting within an Ocean Accounts Framework where stock accounts and flow accounts are broken up into physical accounts and monetary accounts respectively are an important part of the documentation (Figure 2.9). Once finalized by the WP3 team, these accounts will be linked to the GIS platform. The first step in this process is establishing streamlined ecosystem categories and associated extent accounts (see Appendix 4 for ecosystem categorization in an OAF). Achieving multiple group and organization cohesion is a challenge in this process, but not unsurmountable. The first part of this work is establishing where those misalignments are present (see Figure 2.10) and rectifying any discrepancies based on sound ecosystem assessment strategies. Engagement with SANBI and the MSP working group in Alga Bay is ongoing and issues like these are being addressed.

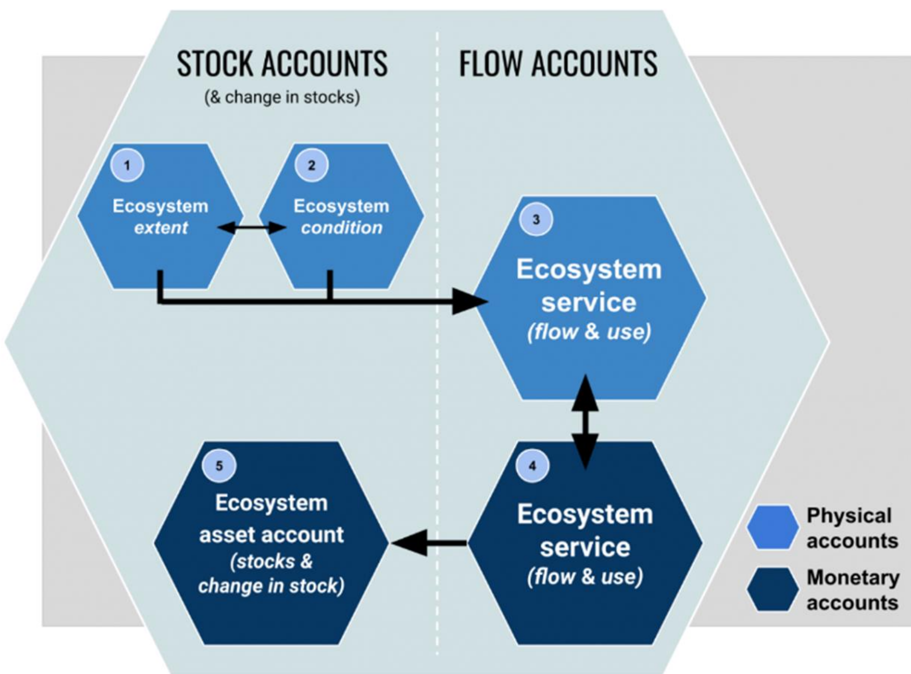


Figure 2.9 Ecosystem accounts and how they relate to one another, https://seea.un.org/ecosystem-accounting.

Ecosystem_Primary	BroadEcosystemGroup	TypeExtent_km	Totals_km
Agulhas Mixed Shore	Rocky and mixed shore	188,08	Mixed Shore 426,48
Agulhas Stromatolite Mixed Shore	Rocky and mixed shore	8,36	
Agulhas Exposed Rocky Shore	Rocky and mixed shore	89,52	
Agulhas Exposed Stromatolite Rocky Shore	Rocky and mixed shore	8,30	
Agulhas Sheltered Rocky Shore	Rocky and mixed shore	1,32	
Agulhas Dissipative Intermediate Sandy Shore	Sandy shore	116,45	
Agulhas Intermediate Sandy Shore	Sandy shore	14,45	
Eastern Agulhas Bay	Bay	1631,19	Bay 1631,19
Agulhas Island	Island	6,78	Island 6,78
Agulhas Inner Shelf Mosaic	Shallow rocky shelf	1853,57	Shallow Shelf 2375,12
Agulhas Sandy Inner Shelf	Shallow soft shelf	521,55	
Agulhas Mid Shelf Reef	Deep rocky shelf	51,89	Deep Shelf 38446,83
Agulhas Sandy Mid Shelf	Deep soft shelf	20233,09	
Agulhas Sandy Outer Shelf	Deep soft shelf	7058,51	
Eastern Agulhas Outer Shelf Mosaic	Deep rocky shelf	25966,23	

Size of ecosystems

Ecosystems					
Classification used in study:	On-shore	Coastal system (0-50m depth)	Offshore (deep sea/open ocean – 50m+ depth)	Marine islands	Coral reefs/wreckages
2018 NBA Synthesis Report classification	Sandy shore & rocky and mixed shore	Shallow soft shelf & shallow rocky shelf	Deep soft shelf & deep rocky shelf	Island	Kelp forest & shallow reef
Island Proximity				3,560	
Reefs					45,925
Agulhas Bays East		101,001			
Agulhas Mixed Shore	1,374				
Agulhas Sandy mid-self			136,209		
Total (ha)	*4,980*	*124,626*	*264,844*	*3,863*	*45,989*

Figure 2.10 Draft tables exemplifying ecosystem extent accounts from the OAF and the MSP Asset Research group. Alignment of ecosystem classification extent between working groups is critical and work is underway in addressing these discrepancies.

3. General Methodology

After investigating various options as mentioned above an online tool modeled after Sayre et al., 2017 and ESRIs Ecological Marine Unit Explorer (EMU) was selected as the overarching tool design to achieve. This decision was made in part, based on desired interactive georeferenced aspects, the need to track change over time and the idea to continuously evolve the system and tool to include biophysical, environmental, economic and social data, and the realities of data availability and permissions for access and use, at least on a local scale. It was also taken into account that the compiled information on many and varied marine aspects would be provided by contributors in several formats that would have to be integrated into a straightforward, flexible and scalable structure within the geodatabase.

3.1 Data Collection and Curation

A combination of Microsoft excel, ESRI ArcGISPro and Python were used to collect, create and build the geodatabase and map application. The geographic projection used for this project is the World Geodetic System of 1984 (WGS84) which uses the WGS 84 ellipsoid. For all associated gridded data a 1 ha grid has been used. All metadata for each data type and source has been recorded according to the SAEON Open Data Portal (ODP) requirements (see Figure 3.1 for example).

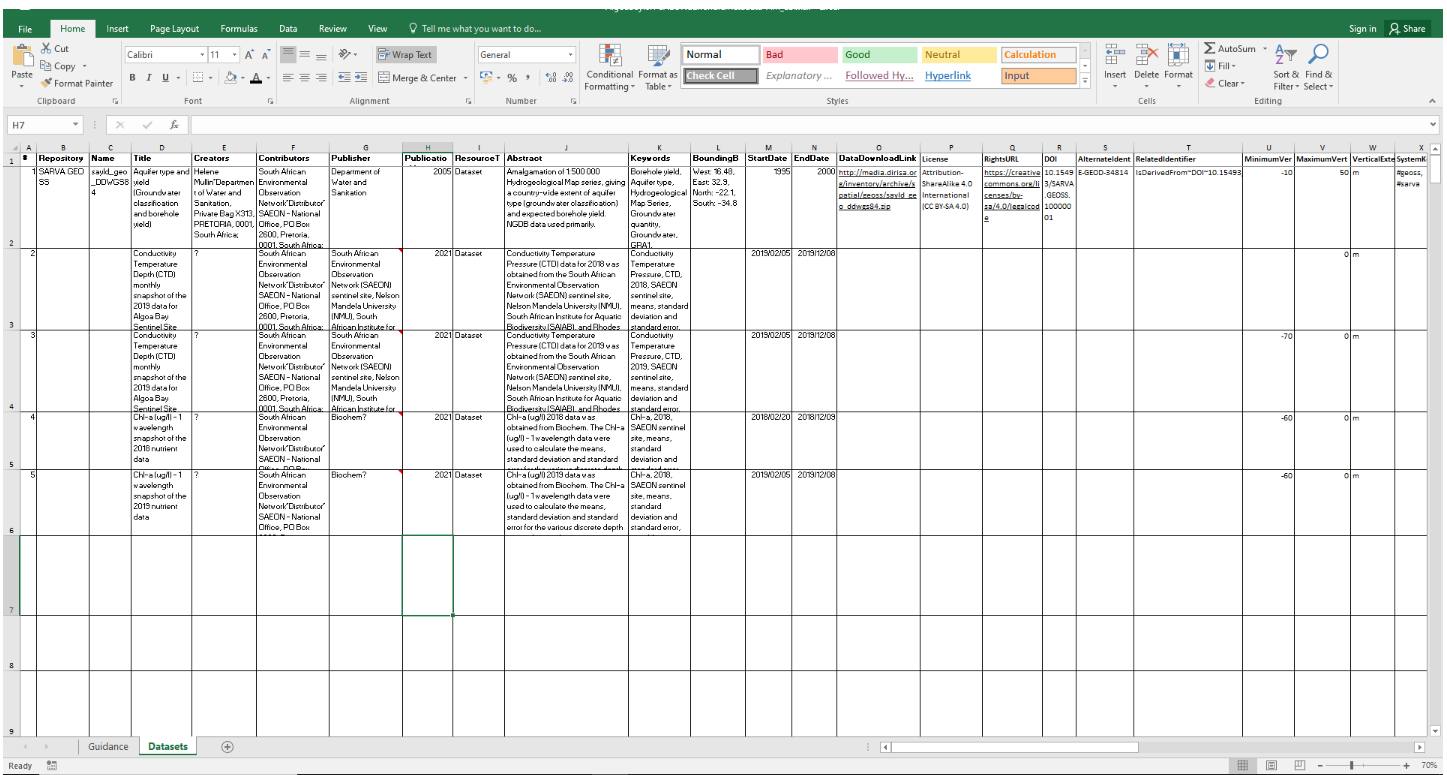
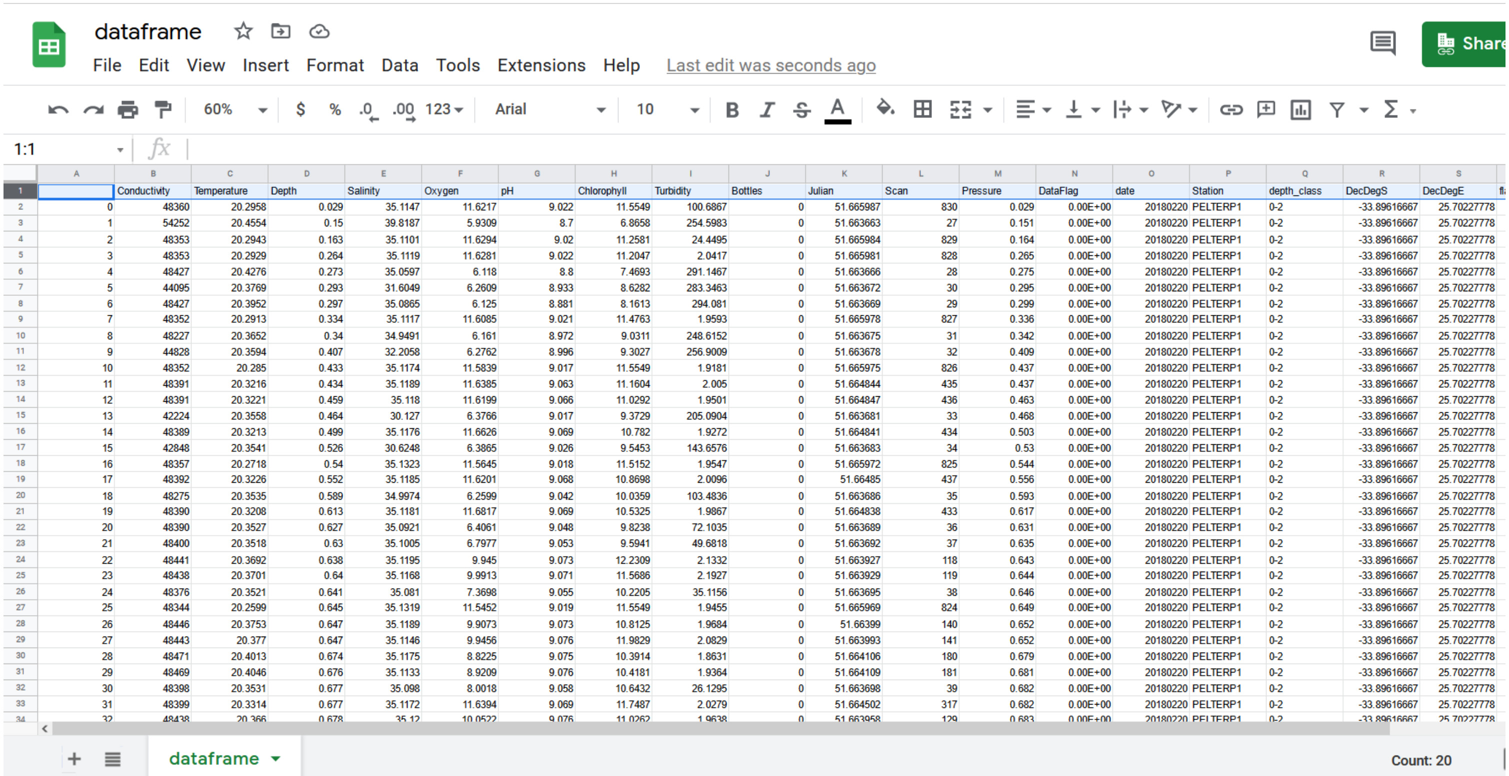


Figure 3.1 Example of SAEON uLwazi Ocean Data Portal metadata archive and formatting requirements.

Once data was collected a process to join, merge and summarize the data was undertaken and the dataframe was formatted as a .csv file to be published to ESRI ArcGIS (Figure 3.2).



	Conductivity	Temperature	Depth	Salinity	Oxygen	pH	Chlorophyll	Turbidity	Bottles	Julian	Scan	Pressure	DataFlag	date	Station	depth_class	DecDegS	DecDegE
0	48360	20.2958	0.029	35.1147	11.6217	9.022	11.5549	100.6867	0	51.665987	830	0.029	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
1	54252	20.4554	0.15	39.8187	5.9309	8.7	6.8658	254.5983	0	51.663663	27	0.151	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
2	48353	20.2943	0.163	35.1101	11.6294	9.02	11.2581	24.4495	0	51.665984	829	0.164	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
3	48353	20.2929	0.264	35.1119	11.6281	9.022	11.2047	2.0417	0	51.665981	828	0.265	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
4	48427	20.4276	0.273	35.0597	6.118	8.8	7.4693	291.1467	0	51.663666	28	0.275	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
5	44095	20.3769	0.293	31.6049	6.2609	8.933	8.6282	283.3463	0	51.663672	30	0.295	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
6	48427	20.3952	0.297	35.0865	6.125	8.881	8.1613	294.081	0	51.663669	29	0.299	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
7	48352	20.2913	0.334	35.1117	11.6085	9.021	11.4763	1.9593	0	51.665978	827	0.336	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
8	48227	20.3652	0.34	34.9491	6.161	8.972	9.0311	248.6152	0	51.663675	31	0.342	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
9	44828	20.3594	0.407	32.2058	6.2762	8.996	9.3027	256.9009	0	51.663678	32	0.409	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
10	48352	20.285	0.433	35.1174	11.5839	9.017	11.5549	1.9181	0	51.665975	826	0.437	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
11	48391	20.3216	0.434	35.1189	11.6385	9.063	11.1604	2.005	0	51.664844	435	0.437	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
12	48391	20.3221	0.459	35.118	11.6199	9.066	11.0292	1.9501	0	51.664847	436	0.463	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
13	42224	20.3558	0.464	30.127	6.3766	9.017	9.3729	205.0904	0	51.663681	33	0.468	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
14	48389	20.3213	0.499	35.1176	11.6626	9.069	10.782	1.9272	0	51.664841	434	0.503	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
15	42848	20.3541	0.526	30.6248	6.3865	9.026	9.5453	143.6576	0	51.663683	34	0.53	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
16	48357	20.2718	0.54	35.1323	11.5645	9.018	11.5152	1.9547	0	51.665972	825	0.544	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
17	48392	20.3226	0.552	35.1185	11.6201	9.068	10.8698	2.0096	0	51.66485	437	0.556	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
18	48275	20.3535	0.589	34.9974	6.2599	9.042	10.0359	103.4836	0	51.663686	35	0.593	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
19	48390	20.3208	0.613	35.1181	11.6817	9.069	10.5325	1.9867	0	51.664838	433	0.617	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
20	48390	20.3527	0.627	35.0921	6.4061	9.048	9.8238	72.1035	0	51.663689	36	0.631	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
21	48400	20.3518	0.63	35.1005	6.7977	9.053	9.5941	49.6818	0	51.663692	37	0.635	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
22	48441	20.3692	0.638	35.1195	9.945	9.073	12.2309	2.1332	0	51.663927	118	0.643	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
23	48438	20.3701	0.64	35.1168	9.9913	9.071	11.5686	2.1927	0	51.663929	119	0.644	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
24	48376	20.3521	0.641	35.081	7.3698	9.055	10.2205	35.1156	0	51.663695	38	0.646	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
25	48344	20.2599	0.645	35.1319	11.5452	9.019	11.5549	1.9455	0	51.665969	824	0.649	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
26	48446	20.3753	0.647	35.1189	9.9073	9.073	10.8125	1.9684	0	51.66399	140	0.652	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
27	48443	20.377	0.647	35.1146	9.9456	9.076	11.9829	2.0829	0	51.663993	141	0.652	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
28	48471	20.4013	0.674	35.1175	8.8225	9.075	10.3914	1.8631	0	51.664106	180	0.679	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
29	48469	20.4046	0.676	35.1133	8.9209	9.076	10.4181	1.9364	0	51.664109	181	0.681	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
30	48398	20.3531	0.677	35.098	8.0018	9.058	10.6432	26.1295	0	51.663698	39	0.682	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
31	48399	20.3314	0.677	35.1172	11.6394	9.069	11.7487	2.0279	0	51.664502	317	0.682	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778
32	48438	20.366	0.678	35.12	10.0522	9.076	11.0262	1.9638	0	51.663958	129	0.683	0.00E+00	20180220	PELTERP1	0-2	-33.89616667	25.70227778

Figure 3.2 Example of the Ocean Accounts dataframe format for integration into ESRI products.

3.2 Data Visualization

Dash (an interactive python framework for creating interactive web applications) was used for the visualization of biophysical variables.

The Dash app script below imports data, creates a list of variables to display, assigns the station names and associated dates over time and displays on the 'date slider', assigns a heading name for the app, defines the various interactions for the data and where to find associated data (e.g. drop down list for the stations (default PELTER Station 1), creates the time slider, creates the charting options, and the different variables to show in the chart (default temperature), essentially controlling the layout of the entire application. And finally, it defines how the various graphing outputs will appear (box and whisper plot or scatter plot), creates a filtered view of the .csv dataframe according to what was selected in the date slider or seasons (for example). The backend component of this work was provided by the SAEON uLwazi node.

Dash App Script:

```
#install jupyter-dash
!pip install jupyter_dash

#add some additional packages
from jupyter_dash import JupyterDash
import dash_core_components as dcc
import dash_html_components as html
from dash.dependencies import Input, Output
import pandas as pd
import plotly.express as px
from google.colab import drive
drive.mount('/content/gdrive')

#import Data into a .csv
csv_path = '/content/gdrive/MyDrive/Colab Notebooks/dataframe.csv'
df=pd.read_csv(csv_path)



#list the variables we want to display
sensor_list = ['Conductivity', 'Temperature', 'Salinity', 'Oxygen', 'pH', 'Chlorophyll', 'Turbidity', 'Pressure']

#Get a list of the Stations in alphabetical order
df = df.sort_values(by=['Station'])
stations = df['Station'].unique()

#Get a list of the dates we want to show
df['date'] = df['date'].replace('201900809', '20190809')
df = df.sort_values(by = 'date')
df['date'] = pd.to_datetime(df.date, format='%Y%m%d')
dates = df['date'].unique()
date_array = [str(i) for i in dates]
dates = [i[:10] for i in date_array]
print(dates)
date_mark = {i : dates[i] for i in range(0, 22)}

app = JupyterDash(__name__)
app.layout = html.Div([
#Heading
    html.H1("Hobo Data Visualisation App"),

#Subheading
    html.H2("Dynamic Visualisation of variables"),

# Dropdown for the Station to chart
    html.Label([
```

```
        "Station",
        dcc.Dropdown(
            id='stat-dropdown', clearable=False,
            value='PELTERP1', options=[
                {'label': st, 'value': st}
                for st in stations
            ])
    ]),

#timeslider to analyse time series
    html.Label([
        "Date",
        dcc.RangeSlider(
            id = 'slider',
            marks = date_mark,
            min = 0,
            max = 22,
            value = [0,2])
    ]),

# Chart
    dcc.Graph(id='graph'),

# Dropdown for the variables to chart
    html.Label([
        "Variable",
        dcc.Dropdown(
            id='var-dropdown', clearable=False,
            value='Temperature', options=[
                {'label': s, 'value': s}
                for s in sensor_list
            ])
    ]),

])

# Define callback to update graph
@app.callback(
    Output('graph', 'figure'),
     [Input("var-dropdown", "value"),
     Input("stat-dropdown", "value"),
     Input("slider", "value")
      ])

#define the function to update the graph based on the user selection
def update_figure(input1, input2, input3):
  #Filter the Data by station
```

```
  data = df[(df.date > dates[input3[0]]) & (df.date < dates[input3[1]])]
  #data = df.loc[df['Station'] ==input2]
  #update the plot
  fig = px.scatter(
        data.loc[data['Station'] ==input2],
         x="Depth",
         y=input1,
         color = input1,
         color_continuous_scale= "Plasma",
         title= input2
         #notched = True

  )
  return fig

# Run app and display result inline in the notebook
app.run_server(mode='inline')
```

3.3 User Interface Development

Here, goals are to learn how to build a Map Atlas using the ESRI Experience Builder and Map Atlas application then integrate the data visualizations created in the Dash app into a pop up embedded in the Experience Builder App. ArcGIS Experience Builder allows the ability to transform data into web apps without writing code, build map centric or non-map centric apps and display them on a fixed or scrolling screen, on single or multiple pages, perform a drag-and-drop operation to choose the tools you need from a set of widgets, design templates, and interact with 2D and 3D content—all within one app. With ArcGIS Experience Builder, web apps are relatively easy to create and run seamlessly on PCs, laptops or mobile devices. This phase of the project will continue to evolve as content is added over the course of 2022.

4. Results

An alpha version of an online interactive mapping platform modeled after the Sayre et al. 2017 approach and the ESRI based Ecological Marine Unit Explorer was created.

At present, physical and some biological data from 2018 to 2019 has been incorporated and the full suite of historic datasets and associated stations will be added in December 2021 (Figure 4.1). The interactive map window on the left is linked to the following viewer windows on the right, from top to bottom, the Sentinel site station name, the date slider where the users choice of dates can be displayed, the season selector (including summer Dec, Jan, Feb; spring Mar, Apr, May; autumn Sep, Oct, Nov; and winter Jun, Jul, Aug), the oceanographic and biological variable selector (including temperature, salinity, conductivity, pressure, oxygen, pH, chlorophyll-*a* and turbidity), the chart selector (scatter plot for continuous data or box and whisper plot for up to 5 different depth categories), and finally a button to download any of the relevant data desired. The charting window continually updates as the user makes their viewing selection criteria. This application is not publically available yet, but will be in 2022 and importantly can be migrated to other platforms.

The second phase of this online tool development is to embed this application (Figure 4.1) in an ESRI based web portal where a series of interactive map pages or a 'map atlas' can be viewed as well as associated charts, tables, descriptive text, and metadata (Figure 4.2 a and b). A test Dash application has been embedded in what's termed an ESRI 'experience'. 'Experience' here means that it's an online interactive platform. As mentioned above in addition to the user being able to navigate within the Dash app which allows users to view and access a suite of oceanographic and biological parameters in a continuous data format, there will also be static maps, graphs, charts and information relevant to the specific target accounts that make up the Ocean Accounts framework.

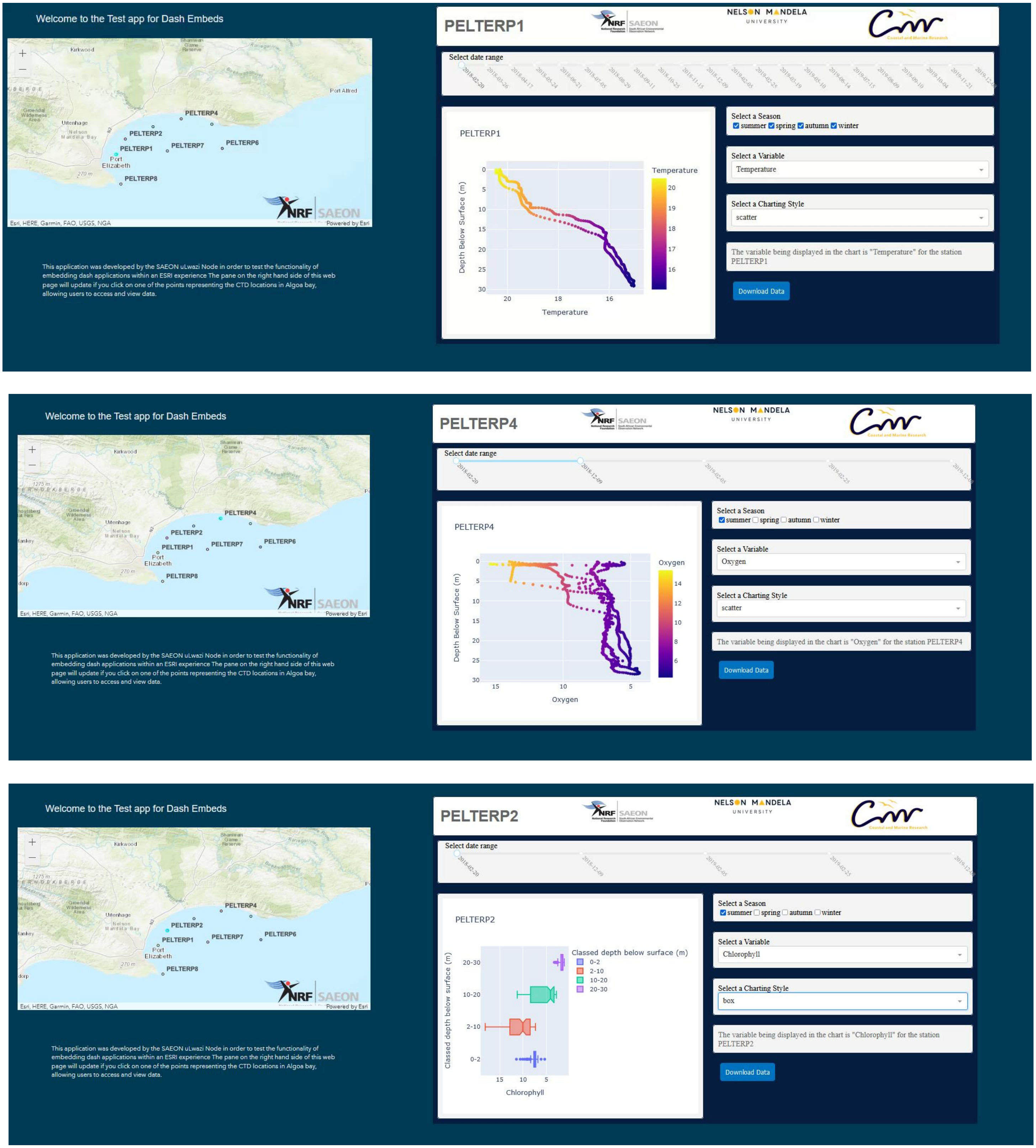


Figure 4.1 Interactive test application for data visualization in Algoa Bay. The app includes monthly data spanning 2018 to 2019, across four seasonal timeframes, eight different variables, and two different charting types for each Pelagic Ecosystem Station in the bay.

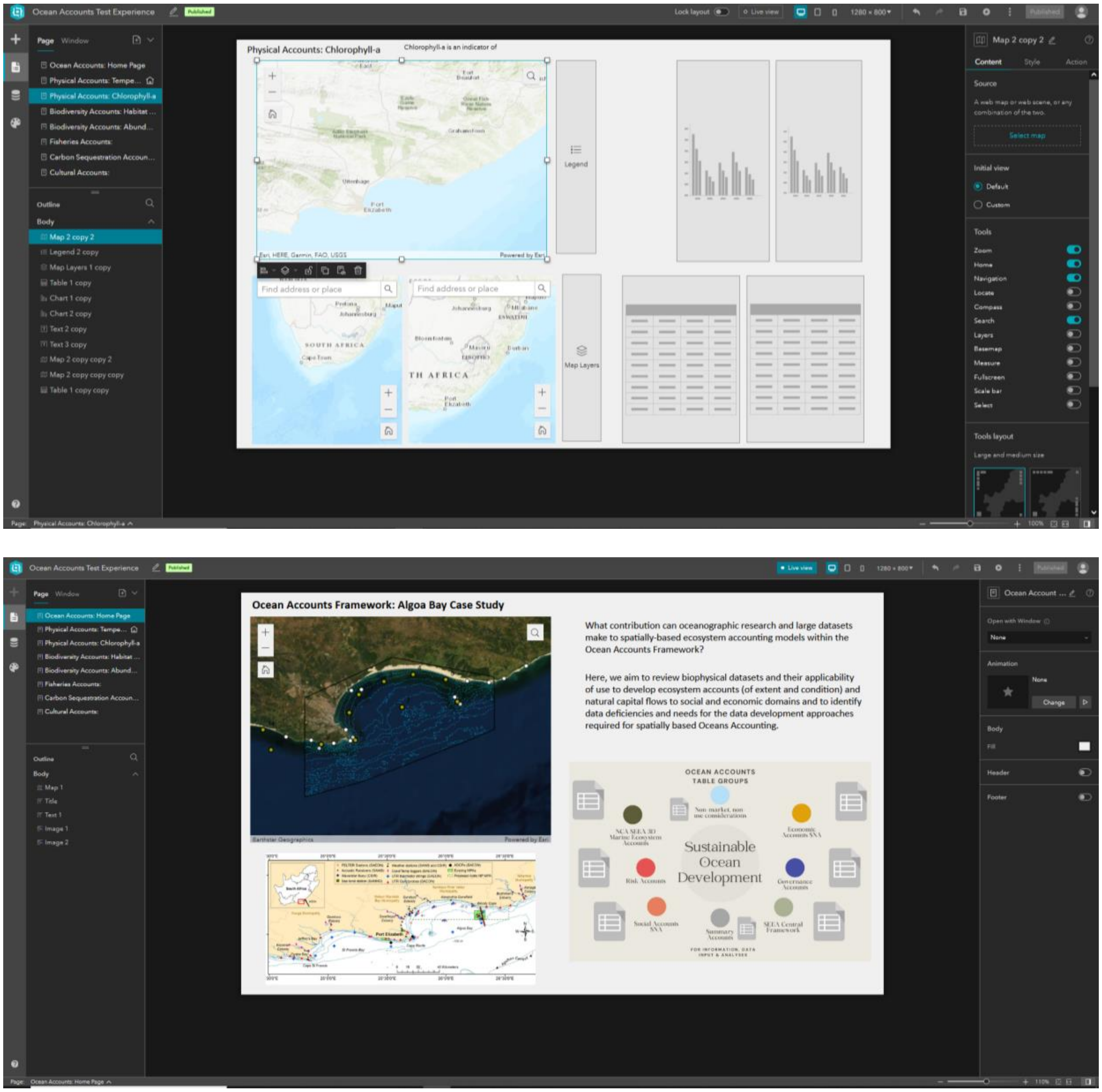


Figure 4.2 a. The ESRI hosted Experience Builder app includes web pages and an embedded version of the interactive test application for data visualization in Algoa Bay and can be custom designed to include as much or as little data, maps and information as is required.

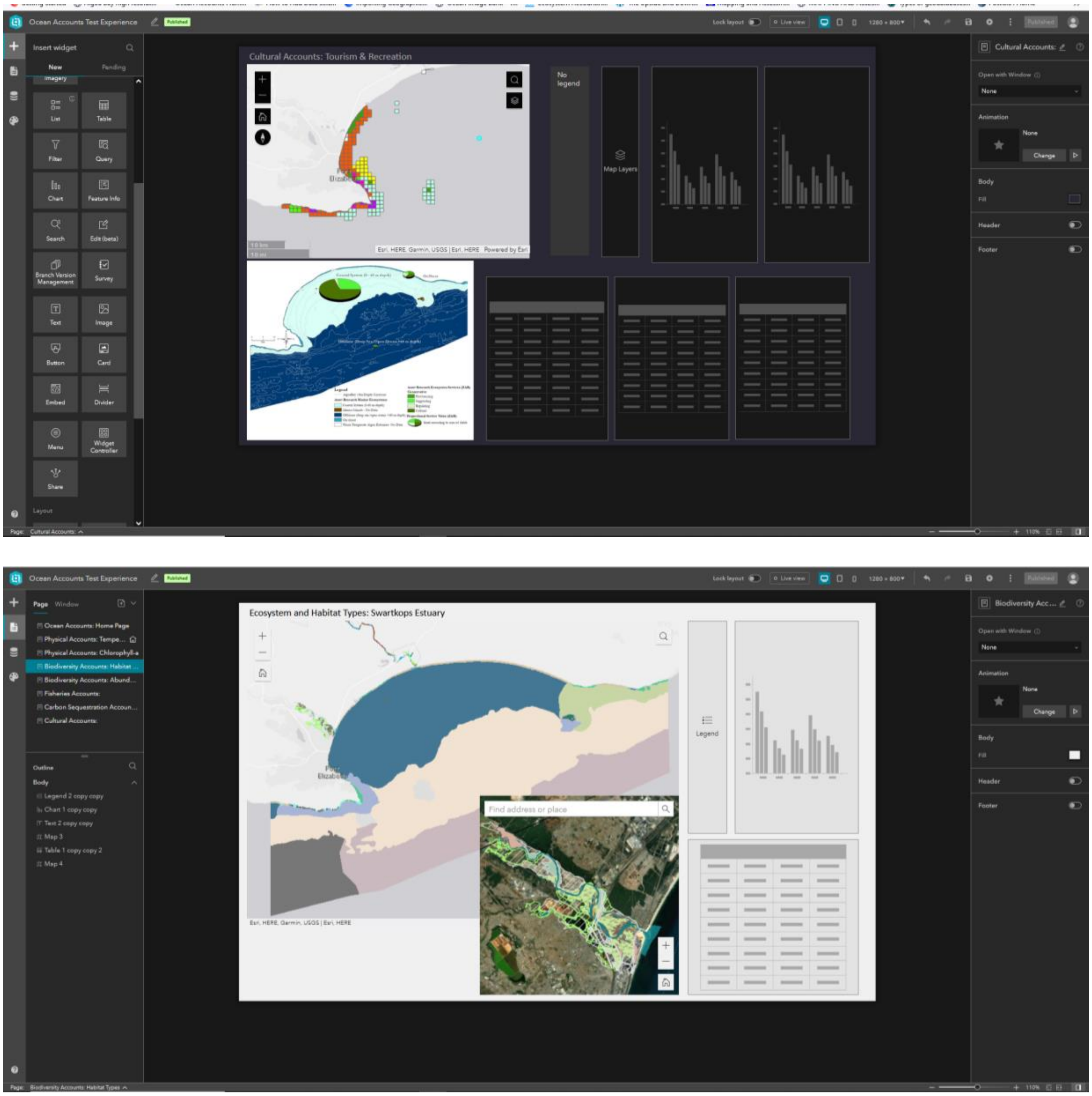


Figure 4.3 b. The ESRI hosted Experience Builder app includes web pages and an embedded version of the interactive test application for data visualization in Algoa Bay and can be custom designed to include as much or as little data, maps and information as is required.

The inclusion of various satellite products and modelled data in Algoa Bay as layers in the ESRI GIS platform were also introduced. Work from Egagasini Node's SOMISANA team into the ESRI Experience application by way of netcdf files has been initiated. The SST product used is called OSTIA, it is a reprocessed 5km SST product (SST_GLO_SST_L4_REP_OBSERVATIONS_010_011) and comes from Copernicus, a European Union earth observation programme that utilizes a suite of satellites to acquire freely accessible data. The marine based information that can be accessed here is known as CMEMS (Copernicus Marine Environment Monitoring Service). The Chl-*a* product which can be used in unison with in situ chl-*a* as a proxy for biological productivity and water quality is an example of how environmental condition will be monitored over time (Figure 4.4). Refinement of these products is still underway. The link to CMEMS data is as follows: https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=SST_GLO_SST_L4_REP_OBSERVATIONS_010_011

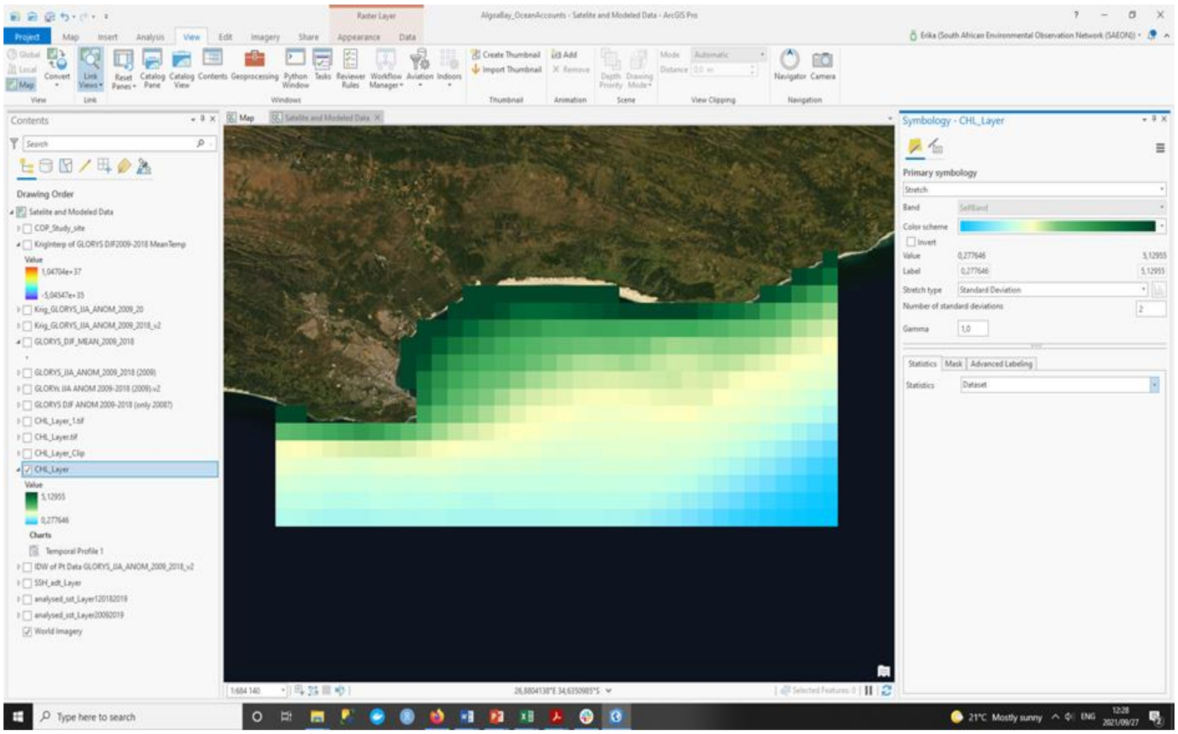


Figure 4.4A .netcdf file depicted as a raster layer in ArcGIS Pro of Chl-a monthly mean over a one year period, 2018-2019.https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=SST_GLO_SST_L4_REP_OBSERVATIONS_010_011

Finally, a layer depicting modelled winter (June, July, August) sea surface temperature anomaly over a 10 year period (2009 – 2019) in Algoa Bay was created and more work needs to be dedicated to giving an accurate depiction of this information in GIS (Figure 4.5). NetCDF (network Common Data Form) is a file format for storing multidimensional scientific data (variables) such as temperature, pressure, wind speed, and direction. Each of these variables can be displayed through a dimension (such as time) in ArcGIS by making a layer or table view from the netCDF file. The user should be able to specify a time dimension and display the associated layer representing the measurements recorded in that time (e.g. sea temperature anomaly in 2009). However, extracting this type of information proved dubious and refinement is ongoing.

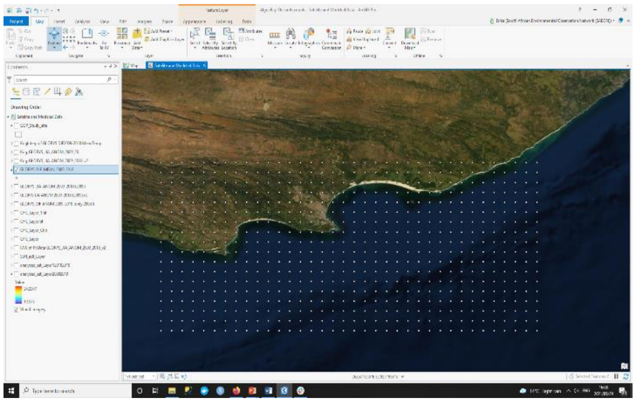
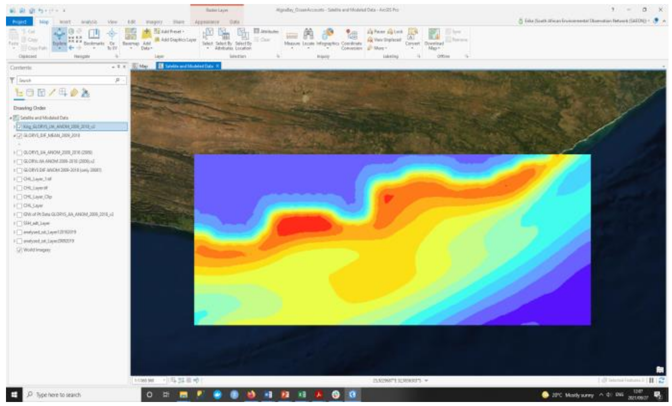
 

Figure 4.5 Modeled point data of winter SST anomaly over a 10 year period, 2009-2019, in Algoa Bay was interpolated using a krigging method in ArcGISPro.

Within an OAF concept, products like these can aid measuring change over time within the environment of focus. Additionally, elaborate simulations can be created based on local oceanographic conditions that would support risk and response scenarios and associated decisions in planning and management. An example of this is the OCIMS test platform for high resolution model forecasts for Algoa Bay and can be accessed here link where a hypothetical oil spill model simulation can be viewed.

5. Conclusions

The Ocean Accounts Framework is one approach towards promoting regional harmonization of monitoring methods, used to assess marine environmental health and to obtain complete and long-term datasets from multiple ecosystem components, ranging from microbes to large marine mammals to ocean biophysics, in one accessible space. The introduction of the alpha version of this online platform can be viewed as an exemplary attempt to initiating a multidisciplinary step towards improved ecosystem approach style management. Making a shift from structural, site specific approaches to a functional, whole sea-system monitoring program is critical, and although challenging and tedious at the start, will promote and advance sustainable development goals and the implementation of Ocean Accounts for Algoa Bay and South Africa at large.

The first iteration of this tool is largely focused towards scientists and researchers with the idea to expand on the intended audience to decision makers once the ESRI Experience application is fully operational. The addition of MSP based interactive maps, pages dedicated to the various types of accounts, environmental condition status, socio-economic and risk account data and information such as policy documents in one user space will provide a meaningful and user friendly ‘one stop shop’ for management and policy makers alike. The next version of this application will be advanced and released in 2022.

6. References

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7. Annex 1: List of Data To Be Compiled

Table 3. Types and themes of data to be collected.

Ecological data	Physical data	BioGeoChem Data	Human / socio-economic data	Others
Coastal Ecosystems	Bathymetry	Productivity/Chl-a	Fisheries	Administrative Boundaries
Marine Ecosystems	Temperature	Nutrients (Phosphate, Silicate, Nitrate)	Aquaculture	Population Distribution
Estuarine Ecosystems	Depth Zones	Dissolved oxygen	Tourism	Maritime/marine related policies/acts/laws
Areas of High Biodiversity	Waves		Recreation	
Areas of High Endemism	Wind		Maritime Transportation	
Areas of High Productivity	Turbidity		Ports	
Aggregation Sites	Salinity		Offshore Oil & Gas	
Spawning / Breeding Areas	Ocean Acidification/pH		Offshore Renewable Energy	
Feeding / Foraging Areas	Flood Risk		Telecommunication Cables	
Nesting Areas	Seismic Threat		Mining concession areas	
Nursery Areas	Sediment type		Sand & Gravel Mining	
Migration Routes / Migration Stopover	Benthic habitat type		Dredged disposal site	
Environmental Health	Tide		Seabed Mining	
Ecozones	Current Direction		Desalination Plants	
Eco Regions	Current Velocity		Carbon Sequestration Sites	
			Military Areas	
			Maritime and Underwater Cultural Heritage	
			Scientific Research	
			Marine Protected Areas	
			EBSAs	
			CBAs	
			Effluent Outfall Pipes/Areas	

8. Annex 2: Potential data sources and providers

A Spatial Data Infrastructure (SDI) is a framework of technologies, policies and institutional arrangements that combined enable the creation, exchange and use of geospatial data and related information across an information-sharing community. SDI extends a Geographic Information System (GIS), ensuring geospatial data and standards are used to create official datasets linked to policies (ESRI, 2010), which can aid administration of current policies, as well as the development of new policies.

SDIs are particularly useful in the context of todays ‘big data’, when large volumes of geospatial data and web services are readily available (Hu and Li, 2017). A successful SDI interconnects leadership, people, computer networking, publishing and access software, data, policies, and metadata into a framework that helps put the appropriate tools and rules in place to maintain data and turn them into useful information products to support operations and decision-making (Jafari, 2014, IOC Technical Series, 161, 2021). Building an SDI not only sets a precedent to allow free access to spatial data for governmental authorities, stakeholders and citizens, but also provides many benefits to it’s users (Table 4) (Chafiq et al., 2013, IOC Technical Series, 161, 2021).

Table 4. Benefits of Spatial Data Infrastructures (Adapted from Chafiq et al., 2013 and IOC Technical Series, 161, 2021).

Financial	Strategic	Social	Users
Reduces the costs of spatial data collection, avoiding duplication	Improves data authorship	Improves working relationships between stakeholders and public administrators	Improves access to data
Reduces the costs of data access and sharing	Improves data privacy	Improves relationships between citizens and public administrators	Facilitates data use
Reduces the costs of data maintenance	Improves partnerships through efficient data sharing agreements	Improves understanding about relevance of spatial data	Improves services to users
Reduces the time of integration of data and interoperability	Improves data quality	Improves understanding about the issues related to the data	Improves users’ responsiveness
Reduces the risks and the costs of development of new applications	Improves documentation of metadata	Reduces redundancy in available applications	Improves data standards and expectations
Refocuses funding streams	Improves transparency about data collection, processing and updating		Attracts participation

The aim of this annex is to review the current SDIs available at different levels (global and regional) in order to identify potential data sources and providers that could contribute to the development of the OAF pilot area in Algoa Bay, South Africa, as well as contribute to a regional process going forward. A systematic analysis of global and regional SDIs was carried out to identify functional status and relevance to the OAF process in the pilot project based on an adaptation of the European "MSP Data Study" (European Commission, 2016).

The criteria considered are:

A. Type of infrastructure (SDI Type)

- Data Catalogue: a data list, its availability and how to source
- Data Portal: online direct access to datasets
- Data Viewer: service to display spatial data
- Information Service: service which aggregates data into information product (e.g., factsheets)
- Decision Support Tool: method or specialised tool to support further analysis and interpretation

B. Scale

- Global
- Regional

C. Goal

- Describe the marine area: state of the environment and distribution of maritime activities
- Describe interactions in the marine area: pressures and impacts of maritime activities
- Integrated management: integrated assessments, including monitoring and evaluation

D. Scope

- Marine
- Terrestrial

E. Data type

- Ecological
- Physical
- Socio-economic

Review of SDIs with relevance to Algoa Bay

A total of 19 SDIs that could be useful for OAF purposes were identified (Table 5).

Table 5. Overview of Spatial Data Infrastructures identified with potential relevance to the OAF development process in South Africa and for this case study within Algoa Bay.

Name	URL	SDI type	Scale	Goal	Scope	Data type
The Algoa Bay Project	http://www.algoabaydata.com/	Data Portal, Data Viewer, Information Service	Regional	Describe the marine area and uses	Marine	Ecological, Socio-economic
South African National Biodiversity Institute	http://bgis.sanbi.org/	Data Portal, Data Viewer, Information Service	Regional	Describe the marine area	Marine & Terrestrial	Ecological
The Marine Information Management System	https://data.ocean.gov.za/about/	Data Information Service	Regional	Describe the marine area and uses	Marine	Physical
The National Oceans and Coastal Information Management System	http://ocimstest.ocean.gov.za/aloga_bay_model/	Data Viewer, Information Service	Regional	Describe the marine area	Marine	Physical
Ecologically or Biologically Significant Marine Areas	https://cmr.mandela.ac.za/Research-Projects/EBSA-Portal/South-Africa	Data Viewer, Information Service	Regional	Describe the marine area	Marine	Ecological
Gov.UK	https://explore-marine-plans.marineservices.org.uk/	Data Viewer, Information Service	Regional (UK)	Describe the marine area and uses	Marine	Ecological, Physical, Socio-economic
Symphony for MSP in Sweden	https://www.havochvatten.se/en/eu-and-international/marine-spatial-planning/sympho	Data Viewer, Information Service	Regional (Sweden)	Describe the marine area	Marine	Ecological, Physical, Socio-economic

	ny---a-tool-for-ecosystem-based-marine-spatial-planning.html					
ESRIs Ecological Marine Unit Explorer	https://livingatlas.arcgis.com/emu	Data Viewer, Information Service	Global	Describe the marine area	Marine	Physical
Copernicus Marine Service	https://myocean.marine.copernicus.eu/data	Data Portal, Data Viewer	Global	Describe the marine area	Marine	Physical
Ecologically or Biologically Significant Marine Areas	https://www.cbd.int/ebsa/	Data Portal, Data Viewer, Information Service	Global	Describe the marine area	Marine	Ecological
Ocean Data Viewer	https://data.unep-wcmc.org/	Data Portal, Data Viewer, Information Service	Global	Describe the marine area	Marine	Ecological
The General Bathymetric Chart of the Oceans	https://www.gebco.net/data_and_products/gridded_bathymetry_data/	Data Portal, Data Viewer	Global	Describe the marine area	Marine	Physical
Marine Important Bird Areas (IBA) e-atlas	https://maps.birdlife.org/marineIBAs/	Data Viewer, Information Service	Global	Describe the marine area	Marine	Ecological
Ramsar	https://rsis.ramsar.org/	Data Viewer, Information Service	Global	Describe the marine area	Marine & Terrestrial	Ecological
Submarine Cable Map	https://www.submarinecablemap.com/	Data Catalogue, Data Viewer	Global	Describe the marine area	Marine	Socio-economic
Information Integration System for Marine	https://instaar.colorado.edu/~jenkinsc/dbseabed/	Data Portal, Data Viewer	Global	Describe the marine area	Marine	Physical

Substrates (dbSEABED)						
Ocean Color Web	https://oceancolor.gsfc.nasa.gov/	Data Portal, Data Viewer	Global	Describe the marine area	Marine	Ecological
IW:LEARN Spatial Lab	http://geonode.iwlearn.org/	Data Portal, Data Viewer	Global	Describe the marine area	Marine	Physical
Ocean Tool for PUblic Understanding and Science, University of Oxford	https://octopus.zoo.ox.ac.uk/	Data Portal, Data Viewer, Information Service	Global	Describe the marine area	Marine	Ecological, Physical, Socio-economic

9. Annex 3: Algoa Bay data catalogue to date

Table 6. Ocean Accounts Framework related data acquisition for Work Programme 2, 2021.

Dataset	Contact/Owner	Acquisition Status	Visualisation Ready?	Publication to ODP ready?	Type of additional Analysis	Responsible Person	Published to ODP	Metadata Link	Published to ESRI	Published to Living Atlas?
Sea Temperature	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Salinity	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Dissolved Oxygen	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
pH	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Chl-a	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Turbidity	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Nutrients (Phosphate)	SAEON Tommy Bornman or Shaun Deyzel	Acquired	N							
Nutrients (Silicate)	SAEON Tommy Bornman or Shaun Deyzel	Acquired	N							
Nutrients (Nitrate)	SAEON Tommy Bornman or Shaun Deyzel	Acquired	N							
Currents	SAEON Tommy Bornman or Shaun Deyzel	Acquired	N							
Waves	SAEON Tommy Bornman or Shaun Deyzel	Acquired	N							
Bottom Temperature	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Sentinel Site Biological and Physical Station Locations	SAEON Tommy Bornman or Shaun Deyzel	Acquired	Y							
Algoa Bay 1 hectare grid	CPUT Ken Findlay	Acquired	Y							
Algoa Bay Study Area	SAEON Tommy Bornman	Acquired	Y							
SANBI 2018 layers	SANBI Kerry Sink, Prideel Majiedt	Acquired								
Ecosytem Types 2018	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							
Benthic and coastal habitat Types	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							
Pelagic Threat Status	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							
Pelagic Protection	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							
EcoRegions and EcoZones	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							

Benthic and Coastal Condition	SANBI Kerry Sink, Prideel Majiedt	Verbally Approved	Y							
Combined Pressures	SANBI Kerry Sink, Prideel Majiedt	Verbally Approved	Y							
Coastline	SANBI Kerry Sink, Prideel Majiedt	Acquired	Y							
Algoa Bay Project layers	ABP NMU Hanah Truter, Victoria Goddall	Acquired								
Bathymetry 10 m contours	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
SAHRA Terrestrial Middens	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
SAHRA Terrestrial Heritage Sites	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Marine Heritage Sites	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Subsistence Fishing Intensity	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Squid Spawning Areas	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Shark distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Top Predator distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Algoa Bay Priority Conservation Areas	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Reef Distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Recreational Activities	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Recreational Spearfishing	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Rec SkiBoat Fishing Intensity	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Rec Shore Fishing Intensity	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Planning Units for Systematic Conservation Plan	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Linefish distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Kayak fishing areas	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
EBSAs	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Algoa Bay Dive Sites	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Commercial Shark Longline Fishing	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Commercial Linefishing Effort	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Commercial Inshore Trawling	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Commercial Squid Fishing	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Coastal Birds (Terns) Distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
South African Dive Sites	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Cetacean Sitings	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Bird Abundance and Richness	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							

Algoa Bay Islands	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Abelone Reefs	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Fish Distribution	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
SAWS weather stations	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Kelp harvesting intensity	ABP NMU Hanah Truter, Victoria Goddall	Acquired	N							
Shipping Lanes Mariculture Anchors	ABP NMU Hanah Truter, Victoria Goddall	Acquired	Y							
Wind	SAWS	Needed	N							
Tides	SA Hydrographers Office	Needed	N							
Estuarine habitat types	SAIAB, NMU Taryn Ridin	Acquired	Y							
Estuarine functional zone (5 m contour)	SAIAB, NMU Taryn Ridin	Acquired	Y							
Estuarine physical data	NMU SAIAB Janine Parker-Nance	Needed	N							
Ecosystem Services Valuation	Asset Research, James Lignaut	Acquired	N							
Socio-Economic Data	Industry/Muncipality/WPs	Desired	N							
Mining Concession Areas	Private or DMR	Desired	N							
Mining Application Areas	Private or DMR	Desired	N							
Estuarine carbon sequestration data	NMU SAIAB Janine Parker-Nance	Desired	N							
Effluent outfalls	Muncipality	Desired	N							
Telecommunication cables	Muncipality	Desired	N							
Aquaculture concession areas	Private	Desired	N							

10. Annex 4: Ocean Accounts Ecosystem Types

Ecosystem Type: Open Ocean

Category	Statistic
Ocean Assets	
Condition	***Overall Condition Statistics***
Biodiversity	Megafauna Abundance/Diversity Fish Diversity Plankton Abundance (Phyto + Zoo)
Ecosystem Fitness	Chlorophyll-*a* concentration Biological Pump Rate Turbidity/ Light Availability
Biogeochemical Cycling	Thermocline Pycnocline Vertical Profile: Oxygen Vertical Profile: Nitrate, Phosphate, Silicate Vertical Profile: pH Vertical Profile: DIC
Physiochemical Quality	Sea Surface Temperature Sea Surface Salinity Mean Sea Level
Greenhouse Gas Retention	Plankton Abundance Chlorophyll-*a* Concentration Dissolved Inorganic Carbon Profile Average Sea State
Stock	***Overall Stock Statistics***
Ecosystem Extent	Total area defined as open ocean (satellite)
Stock of Natural Aquatic Resources (Vertebrates)	Gross pelagic fish catch Gross piscivorous fish catch
Stock of Natural Aquatic Resources (Invertebrates)	Gross prawn/shrimp catch Gross squid catch Gross chokka catch
Stock of Cultivated Aquatic Resources (Vertebrates)	Gross pelagic fish grown
Stock of Cultivated Aquatic Resources (Invertebrates)	Gross shelffish grown Gross prawn/shrimp grown
Stock of Abiotic Resources	Oil/Petroleum Harvested Energy Generated
Ocean Services (Flows to the economy)	
Regulating	*Conditions affecting flow of services*
Greenhouse Gas Sequestration	Average Sea State

Ecosystem Type: Open Ocean

Category	Statistic
	Chlorophyll a (Satellite) SST (Satellite)
Coastal Protection	Mean Sea Level Hydrodynamic Barrier Area
Erosion Control	Water Column Sedimentation Rates
Water Purification	Plankton Abundance Chlorophyll *a* Concentration
Nutrient Cycling	Biological Pump Rate Chlorophyll a Concentration (satellite) Dissolved Inorganic Carbon Profile
Waste Remediation	Water Column PON Water Column POC Plastic Pollutant Load Terrestrial Runoff Rate
Pollutant Remediation	Fertilizer Concentrations Microplastic Concentrations Large Plastic Concentrations
Provisioning	*Conditions affecting flow of services/economic values*
Maintenance of Fisheries	Fish Catch and Value Catch Per Unit Effort
Cultivated Resources Extracted	Value of Cultivated Vertebrates Value of Cultivated Invertebrates
Raw Materials Extracted	Energy Generated Oil/Petroleum Extracted
Cultural	*Service levels and values*
Tourism/Recreation	Accessible Area for Recreation Water Quality Tourism Generated Income Recreation Generated Income
Education/Research	Net Expense on Research Net Expense on Education
Religious/Spiritual/Indigenous	Cultural Heritage Area
Ocean Governance	***Activities, status, expenditures, and value statistics***
Regulation	License Fees/Taxes Taxes on Cultivated Resources Taxes on Nautral Resources
Enforcement	Permit Income Penalties/Fines
Restoration/Conservation	Area Conserved (no take)

Ecosystem Type: Open Ocean

Category	Statistic
	Area Conserved (recreational take only) Biomass Restocked (vertebrates) Biomass Restocked (invertebrates)
Mitigation	Length of Engineered Coastal Barriers Area of Hydrodynamic Barriers
Gross value added by sector	Gross value added of all Ocean Services by sector
Expenditure	Expenditures on environmental protection and maintenance

Ecosystem Type: Kelp Forest

Category	Statistic
Ocean Assets	
Condition	***Overall Condition Statistics***
Biodiversity	Predator Reef Fish Abundance Kelp Canopy Biomass (Landsat) Benthic Macroinvertebrate Diversity
Ecosystem Fitness	Availability of Drift Algae Turf Algae Abundance Urchin Grazing Intensity Ratio of Invasive: Natural kelp species Juvenile Kelp Recruitment Rate
Biogeochemical Cycling	Nitrate Concentration Ammonium Concentration Kelp Growth Rate Dissolved Oxygen Concentration C13 Stable Isotopes N15 Stable Isotopes
Physiochemical Quality	Sea Temperature Salinity Light Availability
Greenhouse Gas Retention	Light availability Carbon Storage Kelp Forest Biomass
Stock	***Overall Stock Statistics***
Ecosystem Extent	Kelp Canopy Biomass (Landsat) Total Kelp Forest Area (Satellite)
Stock of Natural Aquatic Resources (Vertebrates)	Fish Stocks
Stock of Natural Aquatic Resources (Invertebrates)	Urchin abundance Abalone abundance

Ecosystem Type: Kelp Forest

Category	Statistic
	Lobster abundance
Stock of Cultivated Aquatic Resources (Vertebrates)	Gross Piscivorous Fish Grown Gross Planktivorous Fish Grown
Stock of Cultivated Aquatic Resources (Invertebrates)	Gross Shellfish grown Gross Macroalgae Available for Harvesting
Stock of Abiotic Resources	Alginate Available for Extraction
Ocean Services (Flows to the economy)	
Regulating	*Conditions affecting flow of services*
Greenhouse Gas Sequestration	Light Availability Kelp Biomass Kelp Canopy Cover
Coastal Protection	Coastal geomorphology Kelp Canopy Density Wave fetch Abundance of Urchins (and removed) Storm Frequency
Erosion Control	Localized Hydronamics Distance to Metropolitan Area Kelp Canopy Cover
Water Purification	Kelp/Macroalgae Abundance Light Availability
Nutrient Cycling	Kelp Growth Rate Standing Stock of Carbon Light availability
Waste Remediation	Ratio of Turf:Macroalgae Kelp Canopy Cover
Pollutant Remediation	Fertilizer Concentrations Fish Farm Runoff Effluent discharge volumes, content and concentrations??
Provisioning	*Conditions affecting flow of services/economic values*
Maintenance of Fisheries	Fish Catch and Value Catch Per Unit Effort Kelp Cover
Cultivated Resources Extracted	Value of Cultivated Vertebrates & Invertebrates Value of Cultivated Macroalgae
Raw Materials Extracted	Alginate Extracted
Cultural	*Service levels and values*
Tourism/Recreation	Kelp Persistence

Ecosystem Type: Kelp Forest

Category	Statistic
	Scuba Diving & Snorkeling Frequency Spatial coverage of Marine Protected Area Recreational Fisheries
Education/Research	Net Expense on Research Net Expense on Education
Religious/Spiritual/Indigenous	Cultural Heritage Area
Ocean Governance	***Activities, status, expenditures, and value statistics***
Regulation	License Fees/Taxes Taxes on Cultivated Resources Taxes on Nautral Resources
Enforcement	Permit Income Penalties/Fines
Restoration/Conservation	Transplant costs Invasive Species Abundance Fish Biomass Number/Size of Marine Protected Areas
Mitigation	Area/Abundance of Urchins Removed Area Restored with Kelp
Gross value added by sector	Gross value added of all Ocean Services by sector
Expenditure	Expenditures on environmental protection and maintenance

Ecosystem Type: Coral Reef (Shallow Reef/Wreckages)

Category	Statistic
Ocean Assets	
Condition	***Overall Condition Statistics***
Biodiversity	Coral coverage (satellite data) Hermatypic coral abundance (in-situ) Hermatypic coral diversity (in-situ)
Ecosystem Fitness	Production: Respiration Ratio Net Accretion Rate Total Alkalinity/DIC Slope Reef water flow velocity
Biogeochemical Cycling	Nitrate concentration Total Alkalinity Offshore:Inshore DIC ratio Aragonite Saturation State Dissolved Oxygen pH (total scale)
Physiochemical Quality	Temperature

Ecosystem Type: Coral Reef (Shallow Reef/Wreckages)

Category	Statistic
	Mean Sea Level Salinity
Greenhouse Gas Retention	Dissolved Inorganic Nutrient Concentration Carbon Dioxide Flux Coral coverage (satellite data) Sediment: Hard Coral Ratio
Stock	***Overall Stock Statistics***
Ecosystem Extent	Coral coverage (satellite data) Total reef area (satellite data)
Stock of Natural Aquatic Resources (Vertebrates)	Stocks of Subsistence Fish Stocks of Recreational Fish Stocks of Commercial Fish Stockes of Ornamental Aquarium Fish
Stock of Natural Aquatic Resources (Invertebrates, Algae, Plants)	Stocks of Echinoderms Stocks of Gastropods Stocks of Ornamental Aquarium Coral for Export Stocks of Bivalves
Stock of Cultivated Aquatic Resources (Vertebrates)	Gross Pelagic Fish Reared Gross Reef Fish Reared
Stock of Cultivated Aquatic Resources (Invertebrates)	Gross Coral Cultured Gross Algae Grown
Stock of Abiotic Resources	Calcium Available for Harvest Minerals/Oils Available for Extraction
Ocean Services (Flows to the economy)	
Regulating	*Conditions affecting flow of services*
Greenhouse Gas Sequestration	Coastal geomorphology Sediment deposition rate Light availability Coral Cover
Coastal Protection	Coral Species Reef length/distance Water depth Mean Wave Height Storm Frequency
Erosion Control	Sea Level Rise Rate Terrestrial Sediment Deposition Rate Reef slope to lagoon sediment deposition rate
Water Purification	Sediment Organic Carbon:Nitrogen Ratio Benthic coral:algae cover ratio

Ecosystem Type: Coral Reef (Shallow Reef/Wreckages)

Category	Statistic
Nutrient Cycling	Benthic algae cover Sediment cover Ratio of Nitrate:Ammonium
Waste Remediation	Sediment Organic Carbon Content Sediment Organic Nitrogen Content Plastic Pollutant Load Terrestrial Runoff Rate
Pollutant Remediation	Fertilizer Concentrations POC/PON Concentrations Ciguatera Presence
Provisioning	*Conditions affecting flow of services/economic values*
Maintenance of Fisheries	Fish catch and value Coral Cover
Cultivated Resources Extracted	Value of Cultivated Vertebrates Value of Cultivated Invertebrates
Raw Materials Extracted	Value of Coral Sand Extracted Value of Guano Extracted
Cultural	*Service levels and values*
Tourism/Recreation	Swimmable Area (Lagoon Size) Underwater Tourism Nautical Tourism Surfing/Recreational Tourism
Education/Research	Net Expense on Research Net Expense on Education
Religious/Spiritual/Indigenous	Cultural Heritage Area
Ocean Governance	***Activities, status, expenditures, and value statistics***
Regulation	License Fees/Taxes Taxes on Cultivated Resources Taxes on Nautral Resources
Enforcement	Permit Income Penalties/Fines
Restoration/Conservation	Area Conserved (no take) Area Conserved (recreational take only) Biomass Restocked (vertebrates) Biomass Restocked (invertebrates)
Mitigation	Length of Engineered Coastal Barriers Area Geoengineered
Gross value added by sector	Gross value added of all Ocean Services by sector
Expenditure	Expenditures on environmental protection and maintenance

Ecosystem Type: Sediment

Category	Statistic
Ocean Assets	
Condition	***Overall Condition Statistics***
Biodiversity	Benthic Microbial Community Fish Diversity Infaunal Invertebrate Diversity
Ecosystem Fitness	Production: Respiration Ratio Sulfate Reduction Rate Sediment Oxygen Profile Nitrification Rate
Biogeochemical Cycling	Nitrate Concentration Sulfate Concentration Sediment Redox Potential Particulate/Dissolved Organic C:N Dissolved Oxygen pH (total scale)
Physiochemical Quality	Water Temperature Salinity Mean Sea Level
Greenhouse Gas Retention	Benthic Production:Respiration Ratio Sediment Permeability Light Availability/Turbidity Average Sea State
Stock	***Overall Stock Statistics***
Ecosystem Extent	Total Area of Soft Bottom/Sediment (Satellite)
Stock of Natural Aquatic Resources (Vertebrates)	Gross benthal fish stock Gross infaunal fish stock
Stock of Natural Aquatic Resources (Invertebrates)	Gross Sea Cucumber Stock Gross Shellfish Stock
Stock of Cultivated Aquatic Resources (Vertebrates)	Gross Piscivorous Fish Grown Gross Planktivorous Fish Grown
Stock of Cultivated Aquatic Resources (Invertebrates)	Gross Shellfish grown
Stock of Abiotic Resources	Sand or Gravel? Available for Harvest
Ocean Services (Flows to the economy)	
Regulating	*Conditions affecting flow of services*
Greenhouse Gas Sequestration	Coastal geomorphology Sediment deposition rate Sediment Permeability

Ecosystem Type: Sediment

Category	Statistic
	Light availability
Coastal Protection	Coastal geomorphology Tidal Range Water Table Height Storm Frequency
Erosion Control	Fluvial sediment deposition Sea level rise Area of physical structure
Water Purification	Microphytobenthic composition
Nutrient Cycling	Nitrification Rate Biological Oxygen Demand Sulfate Reduction Rate
Waste Remediation	Sediment Organic Carbon Content Sediment Organic Nitrogen Content Plastic Pollutant Load Terrestrial Runoff Rate
Pollutant Remediation	Fertilizer Concentrations Fish Farm Runoff Effluent discharge volumes, content and concentrations??
Provisioning	*Conditions affecting flow of services/economic values*
Maintenance of Fisheries	Fish Catch and Value Catch Per Unit Effort Kelp Cover
Cultivated Resources Extracted	Value of Cultivated Vertebrates & Invertebrates Value of Cultivated Macroalgae
Raw Materials Extracted	Alginate Extracted
Cultural	*Service levels and values*
Tourism/Recreation	Kelp Persistence Scuba Diving & Snorkeling Frequency Spatial coverage of Marine Protected Area Recreational Fisheries
Education/Research	Net Expense on Research Net Expense on Education
Religious/Spiritual/Indigenous	Cultural Heritage Area
Ocean Governance	***Activities, status, expenditures, and value statistics***
Regulation	License Fees/Taxes Taxes on Cultivated Resources Taxes on Nautral Resources
Enforcement	Permit Income

Ecosystem Type: Sediment

Category	Statistic
	Penalties/Fines
Restoration/Conservation	Transplant costs Invasive Species Abundance Fish Biomass Number/Size of Marine Protected Areas
Mitigation	Area/Abundance of Urchins Removed Area Restored with Kelp
Gross value added by sector	Gross value added of all Ocean Services by sector
Expenditure	Expenditures on environmental protection and maintenance

Ecosystem Type: Salt Marshes & Estuaries

Category	Statistic
Ocean Assets	
Condition	***Overall Condition Statistics***
Biodiversity	Seagrass/Vegetation Cover Prey Fish Abundance Healthy Predator Populations
Ecosystem Fitness	Vegetation Type Seagrass Abundance/Cover Plant Height
Biogeochemical Cycling	Sediment Redox Potential Hypersalinity Inundation Depth C:N Sediment ratios Submerged Plant Growth Form
Physiochemical Quality	Water Temperature Light Availability Salinity
Greenhouse Gas Retention	Nitrification Rate Carbon Dioxide Flux Total Water Storage Total Organic Carbon
Stock	***Overall Stock Statistics***
Ecosystem Extent	Seagrass/Vegetation Cover Total Area of Saline High Tide Extent (satellite)
Stock of Natural Aquatic Resources (Vertebrates)	Stock Available for Artisinal Fishery Stock of Commercial Fish Stock of Recreational Fish
Stock of Natural Aquatic Resources (Invertebrates)	Stock of Shellfish Available for Harvest

Ecosystem Type: Salt Marshes & Estuaries

Category	Statistic
	Stock of Shrimp/Prawns Available for Harvest Stock of Crab Available for Harvest
Stock of Cultivated Aquatic Resources (Vertebrates)	Gross Planktivorous Fish Grown
Stock of Cultivated Aquatic Resources (Invertebrates)	Gross Shellfish grown
Stock of Abiotic Resources	Minerals/Fertilizers Available for Extraction
Ocean Services (Flows to the economy)	
Regulating	*Conditions affecting flow of services*
Greenhouse Gas Sequestration	Coastal geomorphology Sediment deposition rate Vegetation Cover Aquatic Plant Leaf Size
Coastal Protection	Coastal geomorphology Tidal Range Water Table Height Rooted Plant Cover Storm Frequency
Erosion Control	Fluvial sediment deposition Sea level rise Growth Form: Submerged
Water Purification	Aquatic Plant Leaf Size Sediment/Nutrient Load Root Type
Nutrient Cycling	Nitrification Rate Biological Oxygen Demand Sulfate Reduction Rate
Waste Remediation	Sediment Organic Carbon Content Sediment Organic Nitrogen Content Terrestrial Runoff Rate
Pollutant Remediation	Fertilizer Concentrations Sewage Waste Concentrations Effluent discharge volumes, content and concentrations??
Provisioning	*Conditions affecting flow of services/economic values*
Maintenance of Fisheries	Prey Fish Abundance Hydrodynamic Conditions Primary Productivity Rate (Chl a) Vegetation Cover
Cultivated Resources Extracted	Value of Cultivated Vertebrates Value of Cultivated Invertebrates
Raw Materials Extracted	Agricultural Products Extracted

Ecosystem Type: Salt Marshes & Estuaries

Category	Statistic
Cultural	*Service levels and values*
Tourism/Recreation	Accessible Area for Recreation Water Quality Marine Mammal Tourism Abundance of Visually attractive flora Recreation Generated Income
Education/Research	Net Expense on Research Net Expense on Education Habitat quality and area
Religious/Spiritual/Indigenous	Cultural Heritage Area
Ocean Governance	***Activities, status, expenditures, and value statistics***
Regulation	License Fees/Taxes Taxes on Cultivated Resources Taxes on Nautral Resources
Enforcement	Permit Income Penalties/Fines
Restoration/Conservation	Area Conserved (no take) Area Conserved (recreational take only) Biomass Restocked (vertebrates) Biomass Restocked (invertebrates)
Mitigation	Length of Engineered Coastal Barriers Area Geoengineered
Gross value added by sector	Gross value added of all Ocean Services by sector
Expenditure	Expenditures on environmental protection and maintenance