Global Ocean Accounts Partnership

Cape Peninsula University of Technology







Marine Ecosystem Accounting

Table Bay, South Africa

Global Ocean Accounts Partnership African National Pilot Study Programme

Pilot Ocean Accounting of

The Table Bay Region, South Africa

Marine Ecosystem Accounting

Table Bay, South Africa

Compiled by

KP Findlay

Centre for Sustainable Oceans, Cape Peninsula University of Technology, Cape Town, South Africa, and the Global Ocean Accounts Community of Practice.

findlayk@cput.ac.za

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BACKGROUND

The Global Oceans Accounting Partnership is implementing a global Programme funded by the UK Blue Planet Fund (DEFRA-UK) to pilot and assess the implementation and uptake of their Ocean Accounts framework in six countries across sub-Saharan Africa and the Indo-Pacific region over the 2021 to 2026 period. The African component of this programme is implemented by the Cape Peninsula University of Technology (Cape Town, South Africa), in partnership with national authorities, local institutions and groups. Three Pilot Study Project Sites have been chosen from the African coast to range in terms of sectoral development from an industrialised infrastructure (Study Site - Table Bay, South Africa) to a less industrialised and largely community-based natural resource-use environment (Study Site - the Bazaruto Archipelago, Mozambique) and (a third Study Area comprising two small Study Sites in Kilifi County of Kenya). A fourth site in Algoa Bay is being investigated through a South African National Research Foundation Community of Practice project and is closely aligned with this project.

A full description of the Table Bay Piolt Study area is provided in the accompanying Scoping Report and outlined in Figure 1 below. This pilot Study Site is lies within the Table Bay coastline bounded by the 33˚30' S and 34˚ 00' S latitudes and the 18˚00' E and 18˚30' E longitudes on the southwestern Cape coast of South Africa (see **Error! Reference source not found.**).

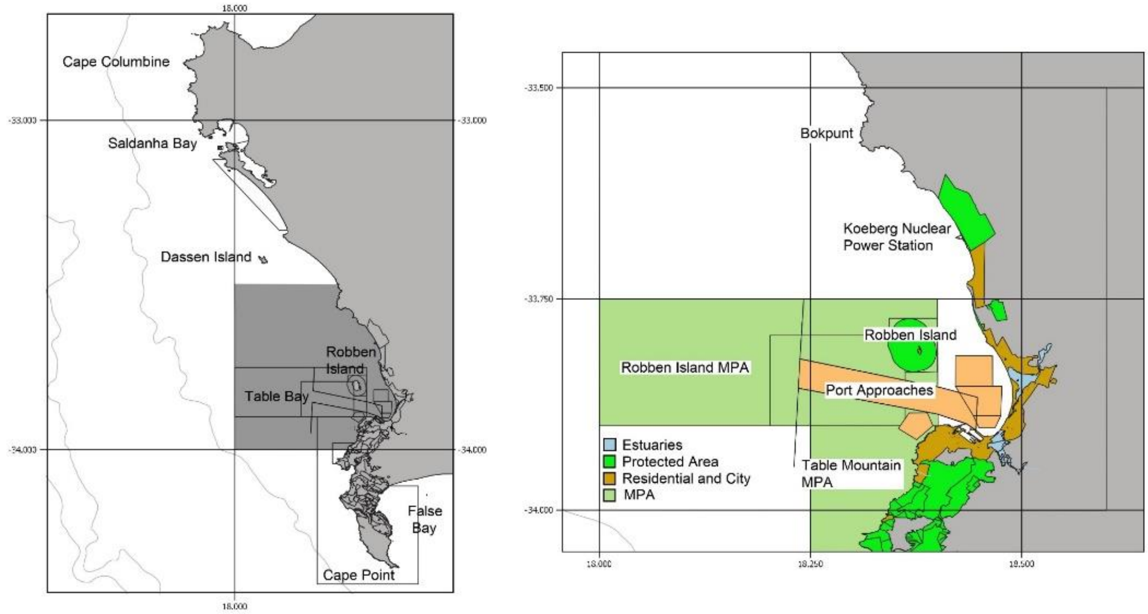

__Figure 1.__ Proposed Study Area for the pilot ocean accounting study within Table Bay, South Africa.

Marine Ecosystem Accounts

Marine ecosystem accounts (MEA) are compiled as a component (along with abiotic services accounts) of natural capital accounts describing the typologies, exents and conditions of ecosystems in a particular Study Area, that may range in scale from local sub-national, national or regional. MEA compilation methodologically draws on the System of Environmental Economic Accounts (SEEA) Ecosystem Accounts.[1] Importantly, MEA encompasses several different accounts, namely ecosystem

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extent and condition accounts, and ecosystem services accounts. The project's initial focus was aimed at the first component, extent accounts.

As outlined in the associated Roadmap document, the South African National Biodiversity Institute (SANBI) has worked in collaboration with the Department of Forestry, Fisheries and Environment (DFFE) and a range of national and sub-national stakeholders to produce a range of ecosystem accounts, including national river ecosystem accounts. SANBI's Marine Programme is developing accounts for marine ecosystems in association with the NBA 2018 output, whilst the CSIR has developed Experimental Ecosystem Accounts for South Africa's estuaries..

Through stakeholder consultation, Marine Ecosystem Accounting was identified and selected as the initial primary accounts to be developed with further expansion to blue carbon accounts (focusing on kelp forests), tourism accounts, and pressures accounts related to tourism, shipping and port infrastructure, wastewater and pollutant effluents (both within and outside of the Marine Protected Area (MPA) regions delineated by both the Table Mountain National Park and the Robben Island MPAs) (Table 4). Importantly, MEA encompasses several different accounts, namely ecosystem extent and condition accounts, and ecosystem services accounts. The project's initial focus was aimed at the first component, extent accounts. Additionally, an integral aspect of the longer-term implementation plan is the development of an ocean accounting toolkit based on experiences gained through these pilot accounts. Such a toolkit is envisaged to be transferrable across regional studies. In particular the process process to date has been investigating the role of Earth Observation remote sensing and satellite imagery analyses in the determination of the ecosystem extent accounts as outlined in the top side-bar of Figure 2 below.

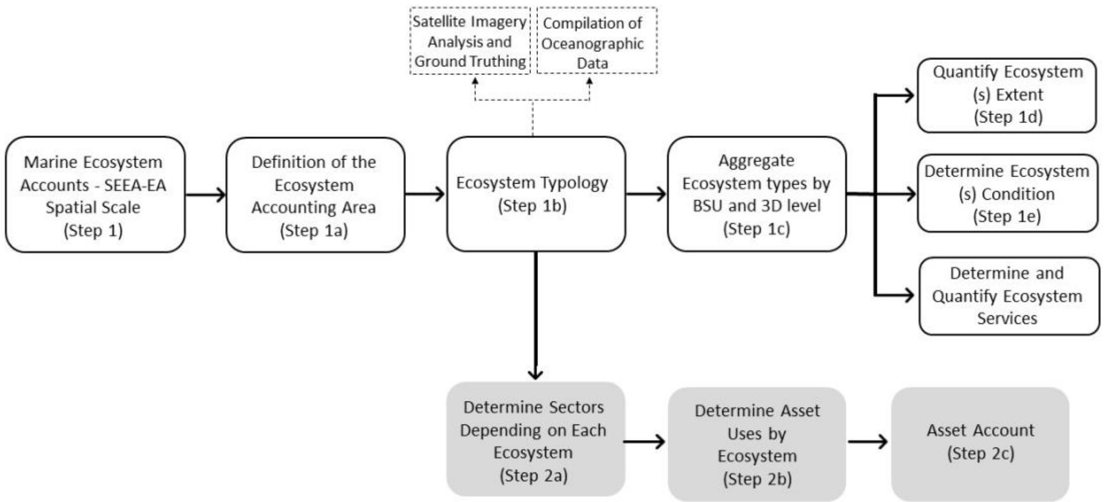

Figure 2. *Stepwise approach for the development of Marine Ecosystem Accounts. Each step is defined by a block (solid line). The dashed blocks represent potential ways of classifying ecosystem types. Grey blocks represent steps linked to the System of Environmental-Economic Accounts – Central Framework (SEEA - CF) component of Environmental accounts. System of Environmental-Economic Accounts – Ecosystem Accounts (SEEA – EA); Basic Spatial Unit (BSU). The typology and extent accounts presented in this study align with the Satellite imagery analyses of Step 1b.*

Both biophysical ocean variable and or remote sensed data data are required to compile and identify spatially resolved ecosystem typologies. The extent of each ecosystem is thereafter quantified, and condition may be assessed based on changes of the relevant criteria over time. Given potential data paucity and identification, considerable effort has been extended into remote sensing and satellite imagery-based ecosystem classification. The executed process has identified the need for bespoke marine and ocean-based ecosystem classification applications for coastal areas where both intertidal and subtidal ecosystems can be identified dependent on water clarity and light penetration.

Methodology and Results

Earth Observation analyses

Importantly, although the relativel small area of Table Bay as defined by the 33˚30' S and 34˚ 00' S latitudes and the 18˚00' E and 18˚30' E longitudes remote sensed earth observation analyses have been carried out over a broader area of 33˚30' S and 34˚ 30' S and 18˚00' E and 19˚00' E, including False Bay has been analysed to investigate application efficacy. Different resolutions have been investigated for remote sensed analyses including both the Copernicus Sentinel 2 imagery at 10 m resolution and commercial high-resolution WorldView 3 imagery. While the high-resolution imagery provides detailed interpretation, cost precludes its application if the developed methodologies are to be upscaled to broader sub-national or national scales.

Various "off the shelf" automated classification applications for Earth Observation land classification have been assessed for the Study Area including for example, the Digital Earth Africa (https://www.digitalearthafrica.org); the Remote Ecosystem Mapping and Assessment Pipeline (https://remap-app.org). Limitations in the efficacy of these applications lie in their algorithms being partly underpinned by land rather than ocean drivers.

Initially Quantum Geographic Information System's Version 3.16 was utilised in conjunction with the QGIS Semi-Automatic Classification Plugin (SCP) to assess develop marine ecosystem extent accounts through Earth Observation of single cloud free Sentinel 2 remote sense imagery (from 2020) at between 10.and 60 m resolution (dependent on spectral band resoultion). QGIS is an Open-Source Geographic Information System licensed under the GNU General Public License and is an official project of the Open-Source Geospatial Foundation (OSGeo). The QGIS Semi-Automatic Classification Plugin (SCP) is a free open-source plugin for QGIS that allows for the semi-automatic classification (also supervised classification) of remote sensing images developed by Congedo (2012).

The high "salt and pepering" in the resultant classifications and the inability of these systems to achieve suitable visual penetrationin waters deeper than 15 m maximum in the turbid temperate waters of Table Bay and associated environs as opposed to 20-30 m in similar pilot study investigations off Bazaruto, Mozambique or Kilifi, Kenya. Kelp beds and rocky shores were not clearly identifiable in the selected Sentinel 2 imagery (Figure 2). These challenges have resulted in the project turning to Object Based Image Analyses (OBIA) going forward. Seasonal late summer selection to periods of intense oceanographic upwelling of clear water, greatly improves visual depth penetration so that image selection becomes critical in these analyses.

Tiles have been overlaid with GEBCO bathymetry data and World Protected Area database extents of the Table Mountain National Park, Robben Island and Betty's Bay Marine Protected Areas as well as use-areas relating to shipping and or tourism and coastal protected area status..

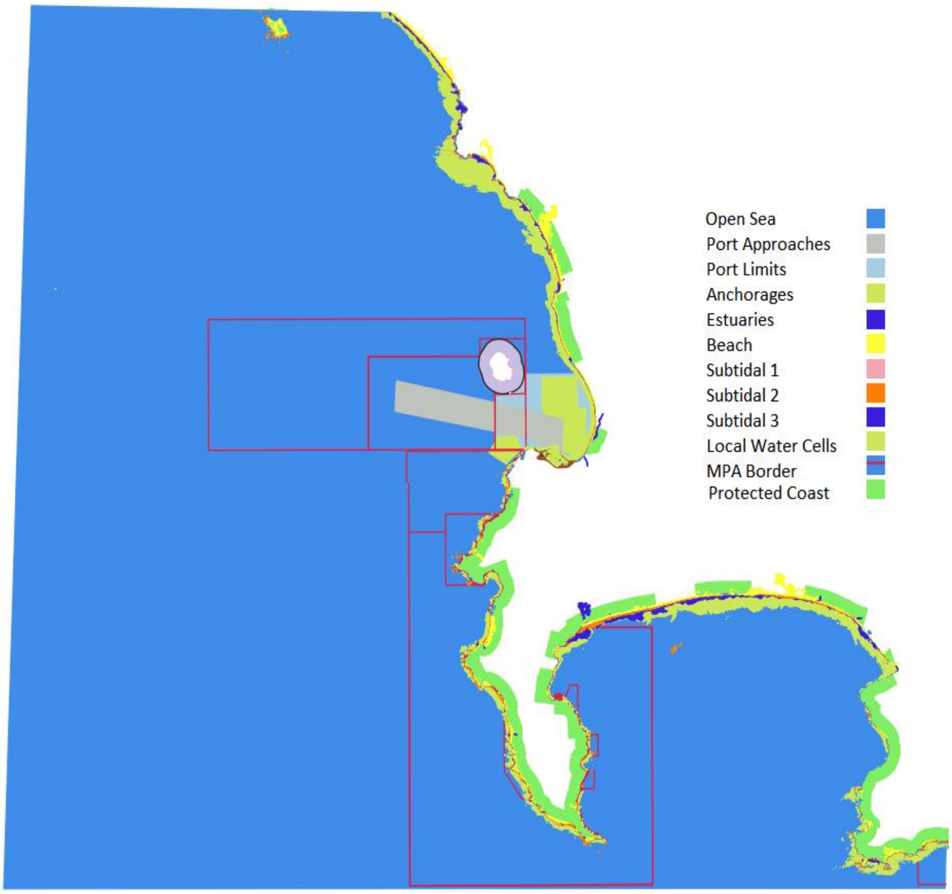

Figure 3. Results of pixel-based classification of the Table Bay Study Area overlaid with the World Protected Area database extents of the Table Mountain National Park, Robben Island and Betty's Bay Marine Protected Areas, and use areas relating to shipping or tourism as digitised from various sources.

Table 1. Typologies and extents of physical features, ecosystems, resource uses, and protected areas determined through supervised pixel-based remote sensing and investigations of digital data availability for the Table Bay Study Area.

Ecosystem or Area Typology	Extent square m	Extent square km
Beach Shore	17576672	17.58
Nearshore Surf Zone	43087037	43.09
Subtidal Region	30597221	30.60
Area 1	9902270	9.90
Area 2	956735	0.96
Area 3	19649442	19.65
Area 4	88774	0.089
Offshore Current Cells	94474854	94.47
Estuaries	1957081	1.961
Rocky Shore	TBD	
Kelp Beds	TBD	
Harbours	3248409	3.25
Port of Cape Town		
Approach	72937371	72.94
Port Roads	113992920	113.99
Anchorages		
Zone 1	16270429	16.27
Zone 2	15896064	15.90
Zone 3	3754739	3.754
Zone 4	8488231	8.49
Harbour Extent	2604050	2.60
MPAs		
Bettys Bay	1026222947	1026.22
TMNPMPA Total	955710932	955.71
Boulders Beach Restricted Zone	3630937	3.63
Cape of Good Hope Restricted Zone	10588347	10.59
Castle Rock Restricted Zone	3164998	3.165
Karbonkelberg Restricted Zone	30051899	30.05
Paulsberg Restricted Zone	2598531	2.60
St James Restricted Zone	339304	0.34
Robben Island MPA	645549383	645.55
Restricted Zone	175748421	175.75
Control Zone 1	441114201	441.11
Control Zone 2	28686761	28.69
Coastal protection	170622 m	170.62km
Study Area Extent	1243549739	12435.5
Land Extent	474927725,9	4749.28
Sea Extent	768622013,1	7686.22

Kelp Bed and Rocky Shore extent accounts were undefined using pixel based image classification..

Given the poor performance of the supervised pixel classifiaction due to visual depth penetration, These challenges have resulted in the project turning to Object Based Image Analyses (OBIA) going forward.

Initial OBIA was carried out utilising the Orfeo ToolBox software within the QGIS platform and in association with the GDAL components thereof (see Sideris et al. 2020). Object segmentation and the thereafter classification resulted in considerable improvements in the classification results (Figure 4).

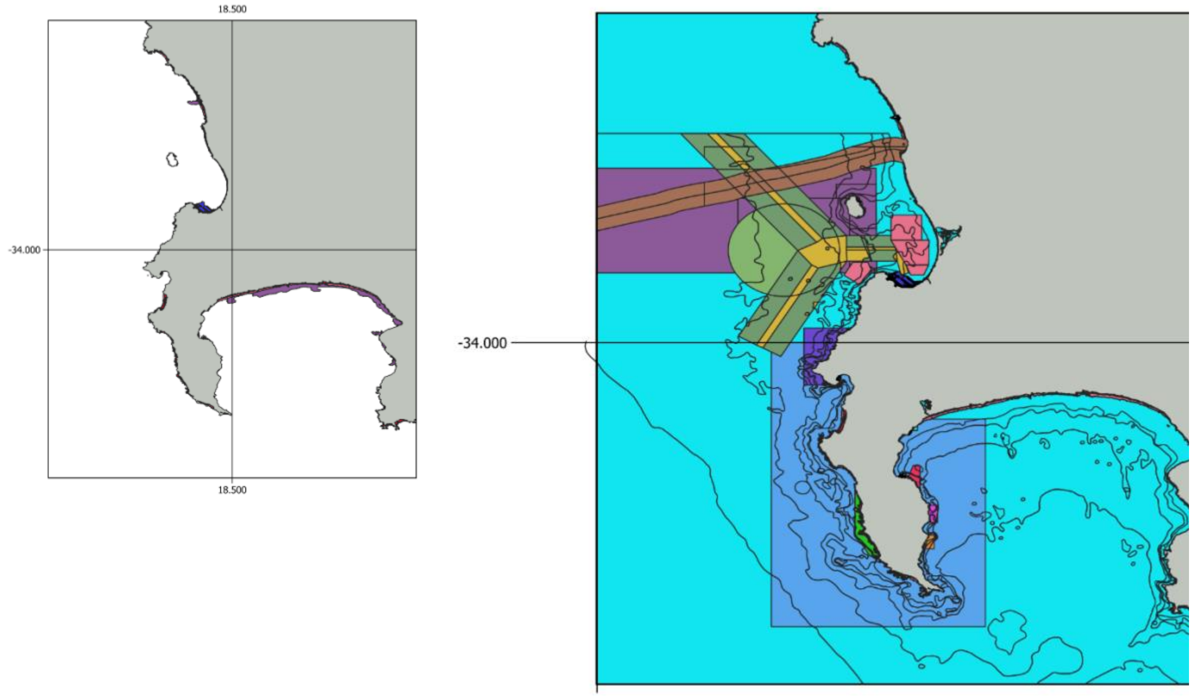

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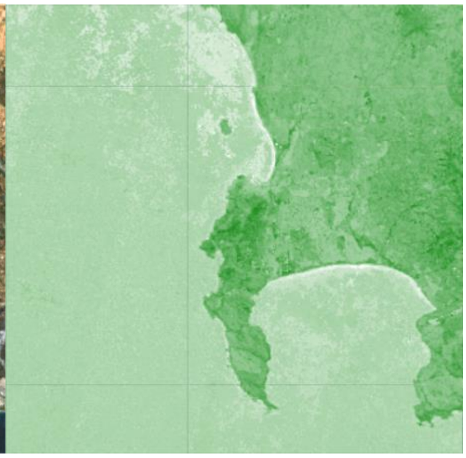
Figure 4. Results of object-based classification of the Table Bay Study Area (a). As with the supervised pixel classification results have been overlaid with the World Protected Area database extents of the Table Mountain National Park, Robben Island and Betty's Bay Marine Protected Areas, and use areas relating to shipping or tourism as digitised from various sources including the South African Hydrographers Office (Figure 4b).

Limitations with the sourcing of multiple Sentinel 2 imagery and both challenges with segmentation and supervised classification and the relatively slow and processor heavy computation has meant that both Google Earth Engine and Trimble eCognition have been further trialed for further analyses across multiple spectral band combinations, supervisory training data and image source periods (for example, limitation of source imagery to late summer months when the probabilities of wind driven ocean upwelling means that water clarity and light penetration are optimal). Copernicus Sentinel-2 MSI: MultiSpectral Instrument, Level-2A surface relectance images from the month of February 2021 were sampled at 10m resolution . Subtidal kelp forest system classifications have been greatly enhanced by such temporal image selection using the Google Earth Engine Platform to analyse multiple images using both Normalised Difference Vegetation Index (NDVI) and Normalised Difference Water Index (NDWI) spectral band combinations (see Figure 6). Whilst both segmentation and classification were carried out in Google Earth Engine, the results shown in Figure 6 and Table 2 were analysed within the QGIS platform using GDAl, OTB and QGIS plugins.



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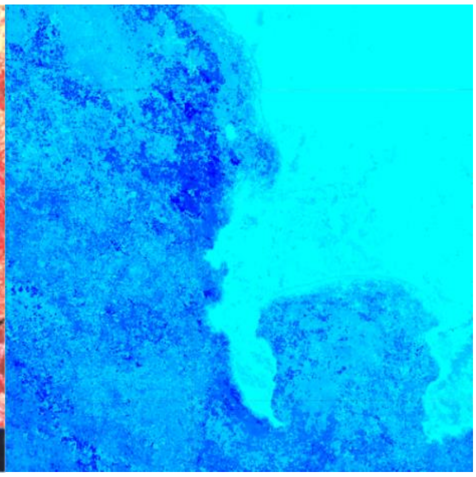

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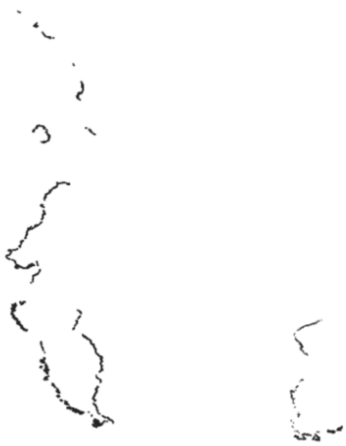

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Figure 6. Google Earth Engine analyses of the Table Bay Study Area showing the advantages of utilising different spectral bandwitdths or combinations thereof. a - visual RGB; b – NDVI; c – near infrared and d – bathymetric analyses (after Li et al. 2021), e – kelp bed systems.

Table 2. Typologies and extents of physical features determined through obect-based remote sensing for the Table Bay Study Area.

Ecosystem or Area Typology	Extent square m	Extent square km
Kelp Forests	9833846	9,833846
Estuaries	5413763	5,413763
Harbours	4264636	4,264636
Harbour Waters	3324058	3,324058
Rocky Shore	5273686	5,273686
Upper Beach	54067	0,054067
Beach	11889273	11,88927
Lower Beach	954738	0,954738
Subtidal	19467950	19,46795
Subsubtidal	403836648	403,8366
Built Surface	69077	0,069077

Extents of resource-use, infrastructure and protected areas are the same as for Table 1.

The account areas presented in this document are based on object areas rather than the areas of dissaggregated objects to Basic Spatial Units. Selection of the size of the BSU and the selection criteria for inclusion or exclusion is dependent on the sclaes at which data are available. It seems pertinent in this regard to select differnt scales of BSU dependent on the data sources. Earth observation analyses of remote sensed data are only valuable in regions where analyses are not precluded by visual depth penetration limitations. A model is consequently propsed to thus utilise visual earth observation analyses only in the near coastal region (less than 20m bathymetry dependent on water clarity), with classification of sustems in the broader neritic (less than 200m isobath) and pelagic systems (greater than 200m isobath) need to be driven on biophysical oceanographic data, so that three zones are envisaged within marine ecosystem accounts, namely coastal, neritic and pelagic, which can then be analysed at differnt spatial scales dependent on data scales.

Figure 7 shows an analysis of the effect of the selection of BSUs at 1000m and 25m resolution of a single object culled from the Table Bay object based classification, namely Table Bay harbour. The importance of both BSU scales and the selection critieria for inclusion of the system within BSUs are evident from this Figure. Presence / absence inclusion results in a large overestimation at both spatial scales, while proportional inclusion at 75% cover, 50% cover and 25% cover Such an analysis also makes an assumption of a single system assignment to a BSU and does not allow for comparisons of inclussions of multiple systems within single BSUs.

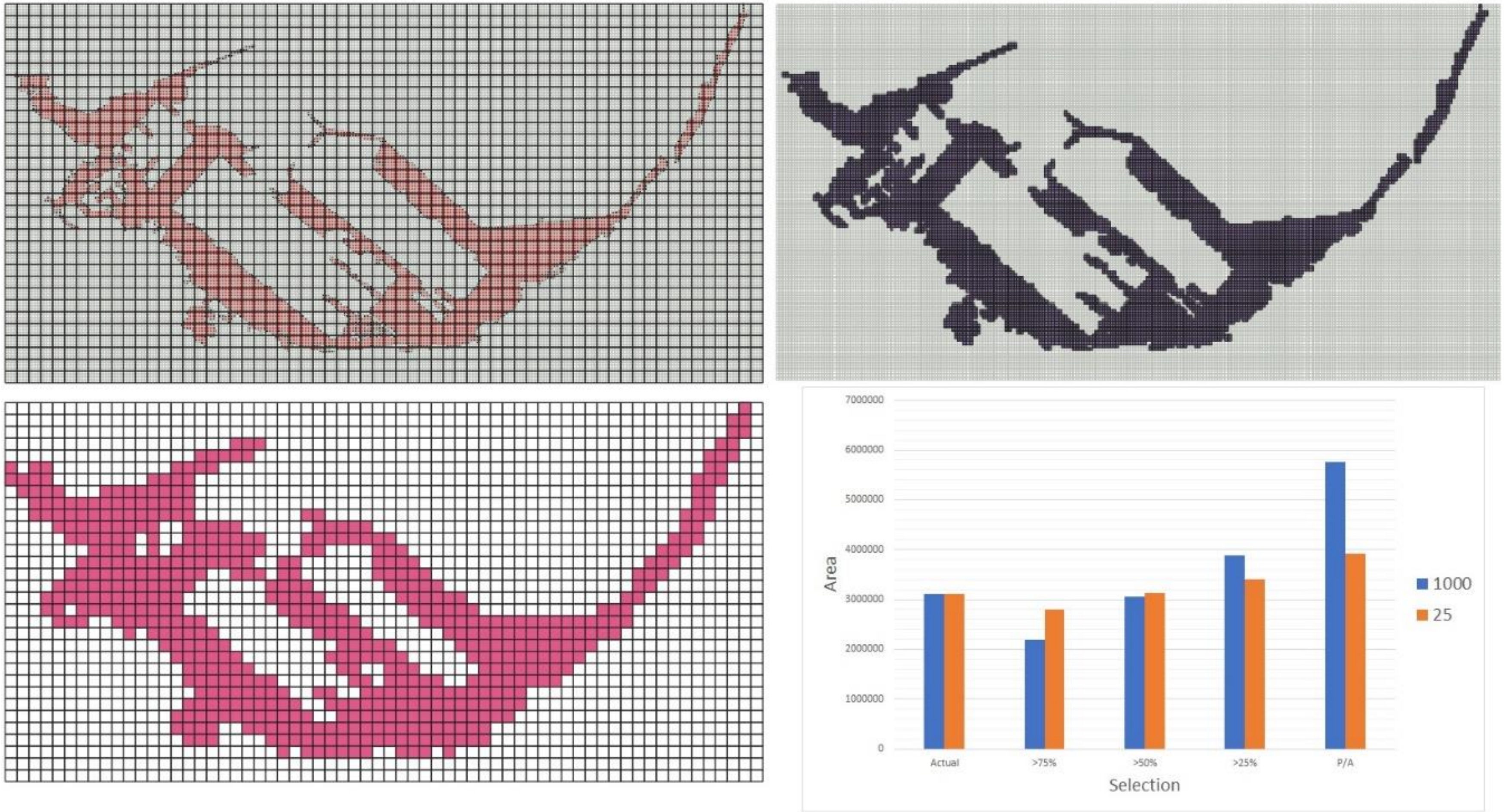

Figure 7. The importance of both BSU scales and the selection critieria for inclusion of a system within BSUs. A. A single system (Table Bay harbour) has been analysed at both 100m x 100m (1 ha) and 25m by 25m scales. B and C show the presence absence selection within these grids identifying the marked overestimation of the object size at both spatial scales (albeit less so at the 25m scale). Selection of inclusion at 75%, 50% and 25% cover underestimates object area, aligns with object area and overestimates object area respectively.

DISCUSSION

Despite challenges with water clarity and penetration, the analysis of remote sensed imagery provides considerable advantages for relatively low-cost development of marine ecosystem accounts that once verified, allow for scaling across much broader geographic ranges. Challenges with depth penetration may be overcome by the selection of adequate imagery and mosaicking and appropriate analytical bandwidths.

Although these accounts have identified considerable value in the use of remote sensed products for the compilation of marine ecosystem accounts, there is a need for the further development of spatial accounts using remote sensed applications that are driven by ocean physical, biogeochemical and biological data. These include for example the setting of thresholds of inter alia Salinity, Temperature, Nutrients and Oxygen, Faunal abundance and distribution and biodiversity patterns.

The remote sensed accounting processes utilised have identified the utility of earth observation analyses within the extreme nearshore region for marine ecosystem classification. The accounts produced within this study are single period snapshots. The developed methodology within Google Earth Engine however makes the analyses imagery across mutliple periods relatively easy and aligns well with analyses of extent change. Condition change requires investigation through ground truthing processs.

This accounting process has also identified the need for

a) A ground truthing programme to assess the veracity of the classification results. This project is utilising the CPUT UAV systems (both fixed wing and quadcopter) with onboard multispectral cameras to sample at low altitudes.
b) A bespoke image classification tool for earth obsevation analyses in the nearshore environment that is transferable across regions and that aligns directly with ocean accounting needs across regions. The extent of this nearshore environment will be study site specific dependent on visual depth penetration or penetration of associated spectral bandwidths. In this regard Google Earth Engine software has been investigated to determine bathymetric features using remote sensed imagery (see Figure 6).

Both of these needs are discussed further in the associated roadmap document.

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