Marine Biodiversity Hub

National Environmental Science Programme

Trialling suitable indicator metrics of change for baited remote underwater video station datasets

- Progress report

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Project D3 –
Evaluating and monitoring the status of marine biodiversity assets on the continental shelf

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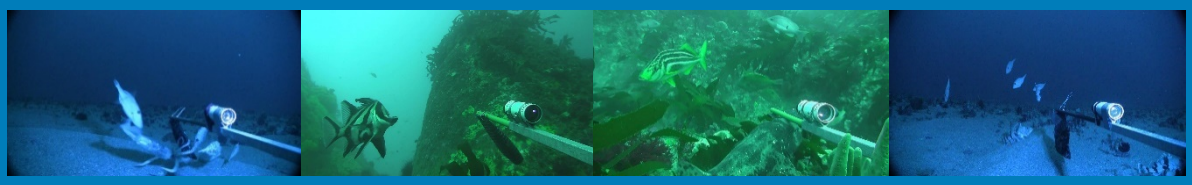

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Important Disclaimer

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EXECUTIVE SUMMARY

This report provides a progress update on the development of suitable metrics and datasets for State of the Environment (SoE) reporting and Ecosystem-Based Fisheries Management (EBFM) assessment based on Baited Remote Underwater Video stations (BRUVs). Initial work has focussed on facilitating the collation and cleaning/standardisation of an extensive range of BRUVs datasets held by research agencies around Australia. This stage has been undertaken as a collaboration with an AODN funded project to collate BRUV data and add it to the national database "Global Archive" that AODN are developing to enhance storage and analysis capabilities. While all available BRUV data has now been uploaded to Global Archive (www.globalarchive.org), nuances in the collection and annotation of data has provided considerable challenges for the standardisation necessary for analysis at the national level. Nevertheless, this process has been essential for identifying future minimum standards (standard operating protocols) we recommend in monitoring programs to ensure data generated is suitable for analysis at national, as well as local scales. The data collation has now been completed with a final "clean" dataset of 18,568 deployments now ready for trialling of potential SoE metrics. In addition to data collection and cleaning, scoping of potential metrics has also been completed, with 44 metrics identified, covering fisheries, ocean warming, community-level and life history based metrics (discussed with the BRUV research communities in workshops in WA in July 2017 and February 2018). Identification of potential covariates for spatial analysis of these metrics has also been completed (and discussed at the workshops above), with the subsequent collation and generation of spatially located (i.e. at drop level) data for 189 covariates, which are now stored in a single geodatabase. Covariates were selected based on their ability to represent human pressures (e.g. distance to township or boat ramp), habitat (e.g. distance to reef), climate (e.g. changes in sea surface temperature) and protection (e.g. distance to marine protected area). Initial trialling of effective reporting metrics is currently underway, with some elucidating key protection effects on fish communities (e.g. biomass of targeted species >20 cm).

In addition, as a part of the NCRIS funding for the Global Archive Marine RDC project, work is currently underway to turn the SoE metrics into a reporting app that will link directly with Global Archive and enable end-users to interactively explore SoE/EBFM metrics. A meeting/workshop on this SoE reporting app is being scheduled for August 2018 in Hobart.

1. INTRODUCTION

Ecosystem-Based Fisheries Management (EBFM) and State of the Environment (SoE) reporting on marine values in Australia suffers from a lack of spatially-comprehensive, long-term quantitative datasets on which to base objective assessments. Likewise, most existing datasets are local to regional in scale, and there is little opportunity to aggregate these more widely to report at greater scales, much less at national scales. Recognising this, a key recommendation from Australia's national marine science plan (http://www.marinescience.net.au), identifies the need for establishing national, integrated monitoring programs, able to report into SoE and EBFM, as well as other adaptive management frameworks. Currently, very few biologically-based programs are at a sufficiently mature stage to be able to initiate this process, particularly ones based on quantitatively comparable standard operating protocols (SOPs). Recently, Stuart-Smith et al. (2017) aggregated three major diver-based underwater visual census (UVC) programs to make the first continental scale analysis of national to regional scale trends, and identified a set of indicator metrics that may be useful for detecting trends in response to anthropogenic pressures (e.g. fishing), as well as climate change. This work combined ~1300 sites for the investigation of spatial patterns and a subset of 14 locations to assess decadal trends in assemblages between 2005-2015 (Stuart-Smith et al. 2017). This study made significant progress for SoE reporting for marine values by assessing a number of indicator metrics, and was an important contributor to SoE 2016 (Evans, K., Bax, N, Smith, D. (in review)). Enhancing the robustness of a national assessment of the marine environment. Marine Policy.). However, these data are limited to shallow water systems (i.e. < 15 m water depth) and SoE 2016 emphasized the need for similar information to evaluate the status and trend of deeper shelf systems.

A dataset that is currently being compiled and may overcome some the depth associated constraints associated with diver-based UVC is based on baited underwater remote video stations (BRUVs). Here, we summarise the work done to date in the collation of the BRUVs datasets, currently held by a wide range of researchers and institutions, for the purpose of identifying suitable metrics for reporting into SoE and EBFM frameworks.

2. SCOPING OF BRUV DATASETS OF AUSTRALIA

Since 2000 a total of 20,022 BRUV deployments has been collated from continental shelf waters around Australia. These deployments provide samples of 2,693,906 individual fish and 660,481 length measurements from 1,888 species (Figure 1). The majority of sampling has focussed on spatial replication with most datasets being collected in water depths of 0-50 m; despite specifically engineered BRUVs being capable of being deployed up to 2000 m depth (e.g. Zintzen et al 2012) (Figure 2). Accordingly, the SoE reporting will likely be constrained to depths <100 m.

These BRUV drops have been collated from 11 key contributors, including; Department of Environment and Water (South Australia), Flinders University (South Australia), Deakin University (Victoria), Institute of Marine and Antarctic Studies (Tasmania), Department of Primary Industries – Fisheries (New South Wales), University of Western Australia (Western Australia), Curtin University (Western Australia), Department of Primary Industries and Regional Development (Western Australia), Department of Biodiversity, Conservation and Attractions (Western Australia), Australian Institute for Marine Science (Western Australia, Northern Territory, Queensland), Commonwealth Scientific and Industrial Research Organisation (Western Australia, Queensland).

Typically for EBFM and SoE reporting, temporal datasets are essential to determine the direction of change, as well as an assessment of the current state. While the BRUV dataset spans nearly two decades, temporally-replicated datasets are very restricted at present.

Western Australia contains some of the most expansive (spatially and temporally) BRUVs datasets with 10,376 deployments being collated, and some multi-year datasets in Abrolhos (9 years) and Kimberley (5 years) (Figure 1). Other sites include Jurien (3 years in deep water), Ningaloo (3 years), Canning Bioregion (2 years), Ngari Capes (2 years), Rottnest (3 years).

The Australian Institute of Marine Science BRUVs data is primarily focussed on spatial replication rather than temporal, so there is very little time series data available. The Australian Institute of Marine Science BRUVs datasets have focused primarily in north-west Western Australian and Queensland (3,317). There is some additional data associated with development projects (e.g. Scott Reef/Montarra) but these are subject to confidentiality agreements and are currently not in Global Archive, and none span more than three years.

In the Northern Territory, BRUV sampling is fairly limited with currently 73 deployments, primarily focussed around monitoring of fish protection areas, and limited to single sampling events.

New South Wales contains 2432 BRUV drops, with some of the most extensive time-series datasets including up to 4-year series samples using stereo-BRUVs in the State-water MPAs beginning in 2010 currently in Global Archive. Further to this 4-year stereo-BRUV dataset, there is a 7-year dataset of mono-BRUVs that has been identified in NSW, but this is currently not in Global Archive.

In Victoria, stereo-BRUV coverage has focussed on spatial coverage with 991 drops collated. Time-series sampling is limited to Warrnambool, where there is a 3-year dataset.

In South Australia there have been 877 BRUV deployments, with a limited series of surveys across 2 years focussed around a subset of MPAs via DEWNR. Flinders University has a limited set of data in a few locations with up to 3-years of data, and some locations with seasonal sampling.

Like other States, Tasmania has focussed on expanding spatial coverage for BRUVs with 502 drops. A single temporal (2-year) dataset off Bicheno is available.

While spatial coverage is fairly reasonable for depth between 0-50 m, there is a lack of deeper water BRUV sampling which will restrict the spatial reporting into SoE or EBFM. Temporal reporting of SoE or EBFM will likely be restricted to Abrolhos, Kimberly and Port Stephens where > 5-year datasets are available. This lack of temporal sampling will substantially reduce the utility of BRUVs datasets for SoE or EBFM reporting. A significant effort is needed to build time series for these datasets at a representative set of locations around Australia. The new National BRUVs working group may facilitate the collection of more time-series datasets, particularly in the mid-outer continental shelf waters (i.e. 50-200m), particularly those contained within, and adjacent to, Australia's newly established commonwealth Marine Parks.

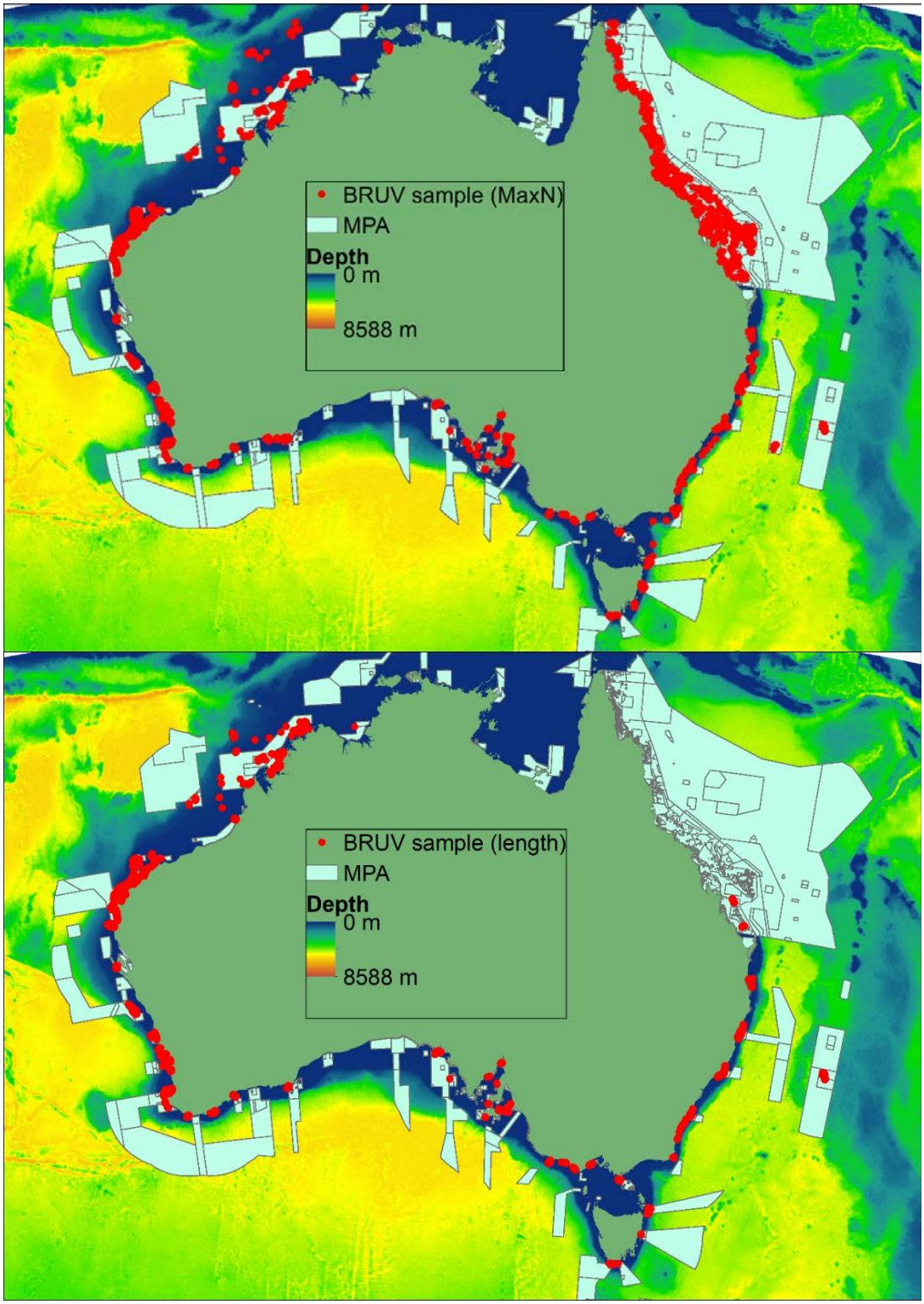

Figure 1. Spatial distribution of BRUV sampling currently collated in Global Archive for MaxN (top) and fish length (bottom) relative to Australia's network of state and commonwealth marine parks.

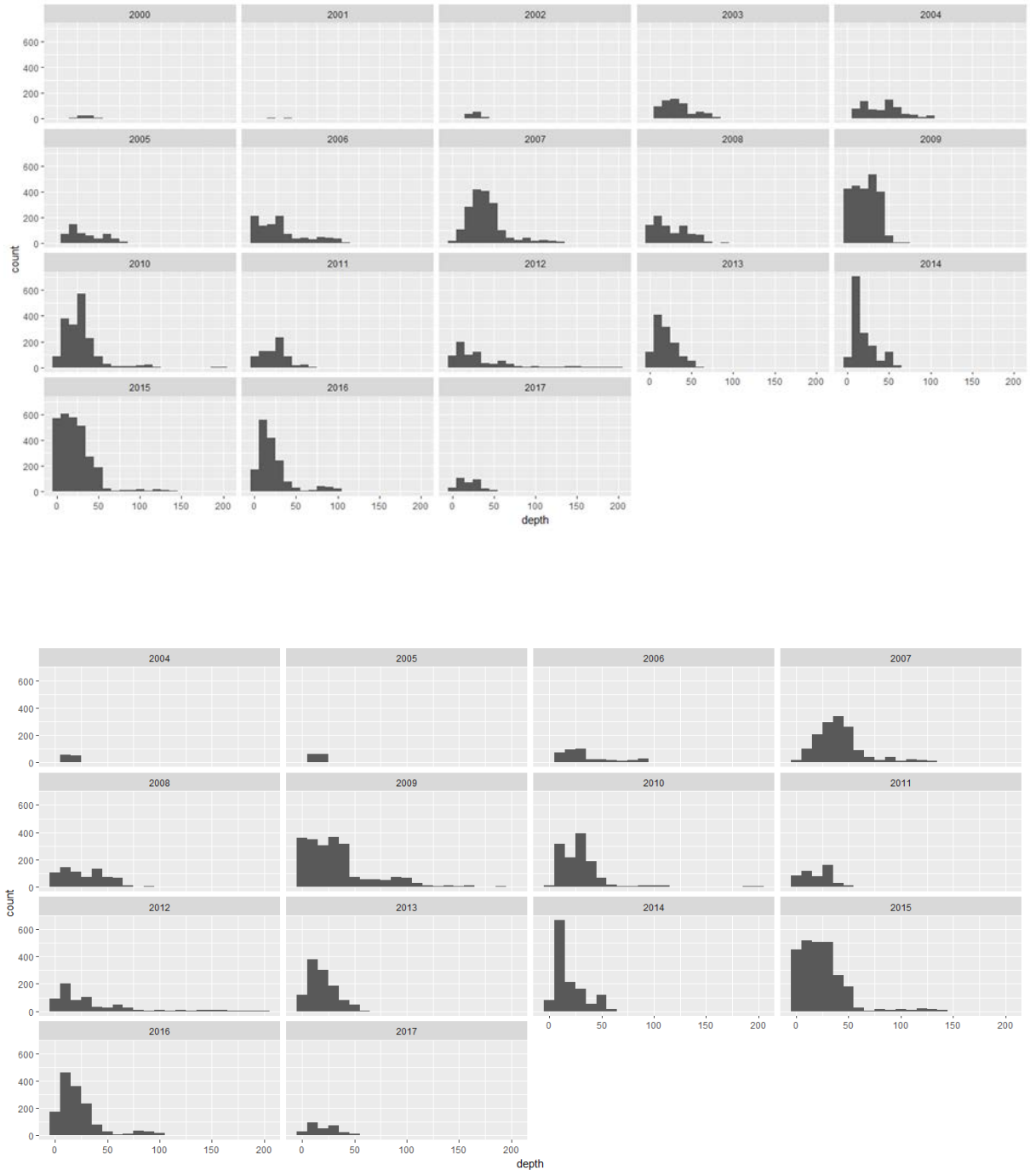

Figure 2. Change over time in the frequency of MaxN (top) and length (bottom) measurements from BRUV samples across the continental shelf depths.

3. SCOPING OF USEFUL INDICATORS/METRICS FOR SOE REPORTING

A total of 44 potential indicator metrics for national and state-level SoE and EBFM reporting has been identified (Table 1). Scoping started by reviewing a recent analysis that used long-term, UVC-based monitoring programs (Stuart-Smith et al. 2017). This study explored a wide range of metrics applicable to BRUV analysis as well, with a set of recommendations around the most effective analyses, including B20, the biomass of fish greater than 20 cm as a metric for effects of fishing pressure, and trait-based approaches, such as community thermal affinity, to detect patterns associated with warming, or ecosystem shifts. Other available metrics associated with life history and EBFM have also been identified for trialling with BRUVs datasets based on work by Nash et al. (2016) (Table 1). However, as these metrics generally require length data for each species, as well as abundance estimates for all species sighted, it may presently restrict the datasets available for use, as many do not record the full species diversity (e.g. Global FinPrint studies only record elasmobranchs) and many do not record lengths of all species sighted, rather a subset of lengths for targeted or indicator species. While this cannot easily be addressed at this stage (other than revisiting past footage if there are funding opportunities, and it is in stereo), there are alternative metrics that can be explored (such as biomass of target species) (Table 1).

Table 1. List of indicators selected for trial for SoE and EBFM reporting.

Purpose	Indicator	Reference	Applicable for Global Archive BRUVs datasets?
Fishing indicators	Vulnerability Index (abundance weighted)	Cheung et al. (2005), Fishbase.org	Yes
	Lmax (abundance weighted)	Fishbase.org	Yes, for target and bycatch only
	Vulnerability Index (biomass weighted)	Cheung et al. (2005), Fishbase.org	Yes, for target and bycatch only
	B20	Stuart-Smith et al. (2017)	Yes, for target and bycatch only
	Total Biomass	Edgar et al. (2014)	Yes, for target and bycatch only
	Lmax (biomass weighted)	Fishbase.org, Jennings et al. (1999)	Yes, for target and bycatch only
	Gamma Scale	Thomson et al (in prep)	No
	Trophic Level	Fishbase.org, Pauly et al. (1998)	Yes
	Mean Length	Jennings et al. (1999)	Yes
	Max of Lmax	Shin et al. (2005)	Yes
	B30	Edgar et al. (2014)	Yes, for target and bycatch only
	Mean biomass	Stuart-Smith et al. (2017)	Yes, for target and bycatch only
	Biomass of exploited	Willis et al. (2003)	Yes, for target and bycatch only
	Proportion pelagic	Rochet and Trenkel (2003), Methratta and Link (2006)	Yes
	Elasmobranch biomass	Cury and Christensen (2005).	Possibly, need to look at length data
	Proportion piscivorous	Methratta and Link (2006)	Yes
	Total MaxN		Yes
	Proportion generalist carnivores		Yes
	Trophic Level (biomass weighted)	Pauly et al. (1998)	Yes, for target and bycatch only
	Biomass spectrum slope	Shin et al. (2005)	Yes, for target and bycatch only
	Large Fish Index (20 cm)	Cury and Christensen (2005)	Yes, for target and bycatch only
	Richness spectra slope	Stuart-Smith et al. (2017)	Yes
	Biomass of legal	Barrett pers. com.	Yes
	Proportion of legal	Monk et al. (2016)	Yes
	Abundance of legal	Barrett pers. com.	Yes

Purpose	Indicator	Reference	Applicable for Global Archive BRUVs datasets?
	Abundance of legal and bycatch	Barrett pers. com.	Yes
	Abundance of 20 cm target	Barrett pers. com.	Yes
	Abundance of 20 cm target and bycatch	Barrett pers. com.	Yes
	Abundance of 30 cm target	Barrett pers. com.	Yes
	Abundance of 30 cm target and bycatch	Barrett pers. com.	Yes
	Ratio of piscivores to herb biomass	Nash et al. (2016)	Yes
Ocean warming	Community Thermal Index	Stuart-Smith et al. (2017)	Yes
	Proportion herbivores		Yes
	Prop/No of out of historical range		Yes
Community	Alpha diversity metrics (e.g. relatedness, taxdis, Species richness, evenness, etc)		Yes
	Threatened, Endangered or Protected Species listed species		Yes
	Functional diversity	Nash et al. (2016)	Yes
	Functional richness	Nash et al. (2016)	Yes
Life history traits	Mean growth rate (k)	Nash et al. (2016)	Yes
	Mean lifespan (tmax)	Nash et al. (2016)	Yes
	Mean generation time (G)	Nash et al. (2016)	Yes
	Mean age at maturity (tmat)	Nash et al. (2016)	Yes
	Mean length to achieve optimum yield (Lopt)	Nash et al. (2016)	Maybe
EBFM	FROESE categories, length frequency data portioned to repro age bins		Yes, for target and bycatch only

4. SCOPING OF USEFUL COVARIATES FOR STATE OF THE ENVIRONMENT REPORTING

The majority of covariates used by Stuart-Smith et al. (2017) are highly relevant to analysis of BRUV data, including spatial distribution of human population pressure, sea surface temperatures, nutrients, proximity to fishing access points. These along with 185 other potential covariates of varying spatial (*c*. 0.3 to 44 km) and temporal (e.g. annual, decadal) resolutions have been collated or generated in a single geodatabase (Table 2). These covariates represent human pressures (e.g. distance to township or boat ramp), habitat (e.g. distance to reef), climate (e.g. changes in sea surface temperature) and protection (e.g. distance to marine protected area). Figure 5 provides some examples of the distance based covariates generated to represent potential human pressure.

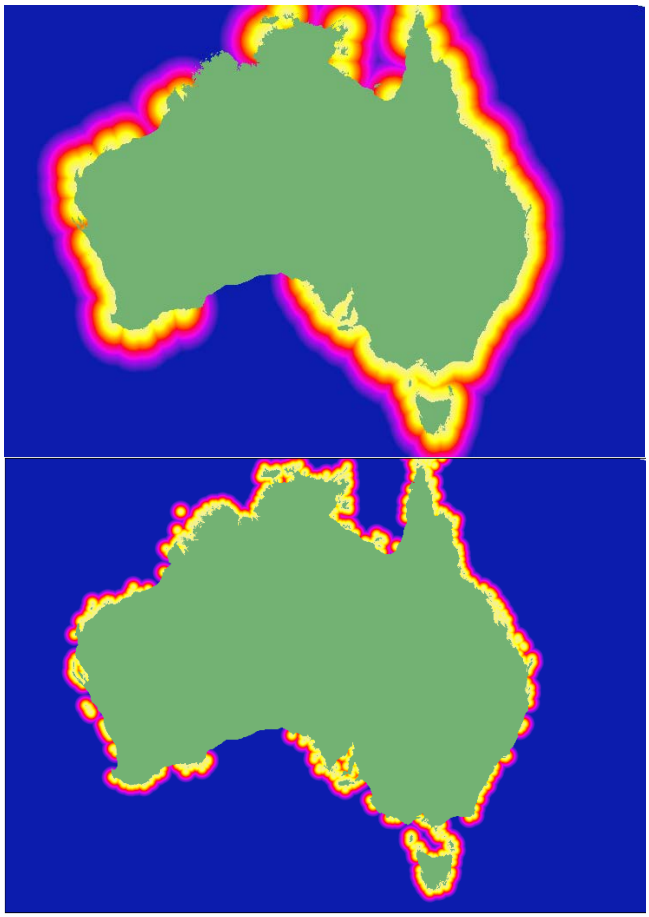

Figure 3. Euclidean distance to: (top) coastal boat ramps, (bottom) islands

Table 2. List of potential covariates for SoE and EBFM reporting.

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Euclidean distance to boat ramps within 1km of coast	Euclidean distance (m) to boat ramps within 1km of coast calculated by Jac Monk in ArcMap	Locations of boat ramps were compiled from State Government spatial data portals. Ramps are primarily formal ramps as opposed to beach or unrecognised launching sites.		300 m	2017
Euclidean distance to any coastline	Euclidean distance (m) to any coast calculated by Jac Monk in ArcMap.	Coastline is based on the 1:100k coastline shapefile from GA	https://data.gov.au/dataset/geodata-coast-100k-2004	300 m	2004
Euclidean distance to islands	Euclidean distance (m) to island coasts calculated by Jac Monk in ArcMap.	Coastline is based on the 1:100k coastline shapefile from GA	https://data.gov.au/dataset/geodata-coast-100k-2004	300 m	2004
Euclidean distance to mainland	Euclidean distance (m) to mainland coasts calculated by Jac Monk in ArcMap.	Coastline is based on the 1:100k coastline shapefile from GA	https://data.gov.au/dataset/geodata-coast-100k-2004	300 m	2004
Euclidean distance to any MPA	Euclidean distance (m) to edge of any MPA calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from Department of the Environment and Energy (DOEE)	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of any MPA	Euclidean distance (m) to the centre of any MPA calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Euclidean distance to MPA IUCN Ia	Euclidean distance (m) to edge of any MPA listed as IUCN Ia calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN Ia	Euclidean distance (m) to the centre of any MPA listed as IUCN Ia calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to MPA IUCN Ib	Euclidean distance (m) to edge of any MPA listed as IUCN Ib calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN Ib	Euclidean distance (m) to the centre of any MPA listed as IUCN Ib calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to MPA IUCN II	Euclidean distance (m) to edge of any MPA listed as IUCN II calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN II	Euclidean distance (m) to the centre of any MPA listed as IUCN II calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Euclidean distance to MPA IUCN III	Euclidean distance (m) to edge of any MPA listed as IUCN III calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN III	Euclidean distance (m) to the centre of any MPA listed as IUCN III calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to MPA IUCN IV	Euclidean distance (m) to edge of any MPA listed as IUCN IV calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN IV	Euclidean distance (m) to the centre of any MPA listed as IUCN IV calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to MPA IUCN V	Euclidean distance (m) to edge of any MPA listed as IUCN V calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN V	Euclidean distance (m) to the centre of any MPA listed as IUCN V calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Euclidean distance to MPA IUCN VI	Euclidean distance (m) to edge of any MPA listed as IUCN VI calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to centre of MPA IUCN VI	Euclidean distance (m) to the centre of any MPA listed as IUCN VI calculated by Jac Monk in ArcMap.	Based on the CAPAD2016 dataset and the 2018 revised zoning from DOEE	http://www.environment.gov.au/capad	300 m	2018
Euclidean distance to reef	Euclidean distance (m) to the edge of mapped "reef". Compiled as a part of NESP see Lucieer et al 2016.	NESP/Seamap australia	http://seamapaustralia.org/map/#center=-27.83935546875;132.1435546875|zoom=4|active=seamap:FINALPRODUCT_SeamapAus	300 m	2017
Euclidean distance to centre of reef patch	Euclidean distance (m) to the centre of mapped "reef" patches. Compiled as a part of NESP see Lucieer et al 2016.	NESP/Seamap australia	http://seamapaustralia.org/map/#center=-27.83935546875;132.1435546875|zoom=4|active=seamap:FINALPRODUCT_SeamapAus	300 m	2017
Euclidean distance to coastal roads	Euclidean distance (m) to mainland coastal roads calculated by Jac Monk in ArcMap.	Shapefile from GA		300 m	2006
Euclidean distance to continental shelf break	Euclidean distance (m) to continental shelf break (200m) calculated by Sam Wines (Deakin) in ArcMap.	200m contour was extracted from GA 250m bathy data		300 m	2009

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Euclidean distance to coastal townships	Euclidean distance (m) to edge of mainland coastal towns calculated by Jac Monk in ArcMap.	Shapefile from GA		300 m	
Euclidean distance to centre of coastal townships	Euclidean distance (m) to centre of mainland coastal towns calculated by Jac Monk in ArcMap.	Shapefile from GA		300 m	
Euclidean distance to freshwater input	Euclidean distance (m) to any freshwater input (e.g. river) calculated by Sam Wines (Deakin) in ArcMap.	Shapefile from GA		300 m	
GA 250m bathy data	Depth	Raster from GA		300 m	2009
Sea air flux	Sea air energy flux	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	9km	
Seabed aspect from authbath	Bathymetry derived topographic aspect grid	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76991	300 m	
Bottom velocity autumn mean	Bran 3.5 Bottom Current Velocity Data - Autumn Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
Bottom velocity spring mean	Bran 3.5 Bottom Current Velocity Data - Spring Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Bottom velocity summer mean	Bran 3.5 Bottom Current Velocity Data - Summer Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
Bottom velocity winter mean	Bran 3.5 Bottom Current Velocity Data - Winter Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
cdom mean	MODIS-derived Coloured Dissolved Organic Matter Data (2009-2011) - Mean	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	2009-2011
cdom stdev	MODIS-derived Coloured Dissolved Organic Matter Data (2009-2011) - Standard Deviation	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	2009-2011
east-west velocity	east-west current velocity	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	9km	
geofeature	Geomorphic Features 2006	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_69797	1km	2006
geomacs ed	Ecological disturbance index	GA	https://data.gov.au/dataset/ecological-disturbance-index	10km	
geomacs exceed	Percentage Exceedance of the Geomacs out	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/71995/	1km	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
geomacs pe	Percentage of time the Shields parameter exceeds 0.25	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_77000	10km	
geomacs r	The integrated Shields parameter exceeding 0.25 divided by the integrated total Shields parameter	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_77001	10km	
geomacs ri	Average time between events when the Shields parameter exceeds 0.25	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_77002	10km	
percent gravel	Seabed Gravel Content Across the Australian Continental EEZ, 2011	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/71981/	1km	
Turbidity (k490) mean	MODIS-derived K490 Data (2009-2011) - Mean	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	2009-2011
Turbidity (k490) stdev	MODIS-derived K490 Data (2009-2011) - Standard Deviation	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	2009-2011
mars co3	Interpolated from MARS points using ArcMap by Jac Monk and Dan Iero	GA	http://dbforms.ga.gov.au/pls/www/npm.mars.search	300m	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
mld 1	Mixed layer depth - definition 1	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	9km	
mld 2	Mixed layer depth - definition 2	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	9km	
percent mud	Seabed Mud Content Across the Australian Continental EEZ, 2012	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/71977/	300m	
no3 mean	Bottom Water Nitrate Data - Mean	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
no3 range	Bottom Water Nitrate Data - Seasonal Range	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
no3 stdev	Bottom Water Nitrate Data - Standard Deviation	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
north-south velocity	north-south current velocity	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	1km	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
o2 mean	Bottom Water Oxygen Data - Mean	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
o2 stdev	Bottom Water Oxygen Data - Standard Deviation	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
po4 mean	Bottom Water Phosphate Data - Mean	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
po4 stdev	Bottom Water Phosphate Data - Standard Deviation	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
poc mean	MODIS-derived Particulate Organic Carbon Data (2009-2011) - Mean	GA	not published/GA/CSIRO	1km	2009-2011
poc stdev	MODIS-derived Particulate Organic Carbon Data (2009-2011) - Standard Deviation	GA	not published/GA/CSIRO	1km	2009-2011
present benthic mean depth chlorophyll Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth chlorophyll Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth chlorophyll max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth chlorophyll mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth chlorophyll min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth chlorophyll range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth current velocity Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth current velocity Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth current velocity max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth current velocity mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth current velocity min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth current velocity range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth dissolved oxygen Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth dissolved oxygen Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth dissolved oxygen max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth dissolved oxygen mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth dissolved oxygen min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth dissolved oxygen range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth iron Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth iron Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth iron max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth iron mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth iron min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth iron range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth light bottom Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth light bottom Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth light bottom max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth light bottom mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth light bottom min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth light bottom range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth nitrate Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth nitrate Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth nitrate max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth nitrate mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth nitrate min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth nitrate range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phosphate Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth phosphate Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phosphate max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phosphate mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phosphate min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phosphate range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phytoplankton Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth phytoplankton Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phytoplankton max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phytoplankton mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phytoplankton min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth phytoplankton range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth primary productivity Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth primary productivity Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth primary productivity max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth primary productivity mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth primary productivity min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth primary productivity range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth salinity Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth salinity Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth salinity max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth salinity mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth salinity min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth salinity range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth silicate Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth silicate Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth silicate max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth silicate mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth silicate min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth silicate range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth temperature Lt max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
present benthic mean depth temperature Lt min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth temperature max	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth temperature mean	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth temperature min	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
present benthic mean depth temperature range	A full description of data can be found at https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1466-8238.2011.00656.x	Bio-oracle	http://bio-oracle.org/	~10km	Decade +
seabed relief from ausbath	Bathymetry derived topographic relief grid	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76993	300m	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
Bottom Water Salinity Data - Mean		GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
Bottom Water Salinity Data - Standard Deviation		GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
percent sand	Seabed Sand Content Across the Australian Continental EEZ, 2013	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/71982/	1km	
Bottom Water Silicate Data - Mean		GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
Bottom Water Silicate Data - Standard Deviation		GA	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
slope of seabed calc from ausbath	Bathymetry derived topographic slope grid	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76992	300m	2009
Sea Surface Height	Sea Surface Height	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	1km	
SST velocity 1862-1871	Change in SST over decade	Mary Young (Deakin)		44km	1862-1871

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
SST velocity 1872-1881	Change in SST over decade	Mary Young (Deakin)		44km	1872-1881
SST velocity 1882-1891	Change in SST over decade	Mary Young (Deakin)		44km	1882-1891
SST velocity 1892-1901	Change in SST over decade	Mary Young (Deakin)		44km	1892-1901
SST velocity 1902-1911	Change in SST over decade	Mary Young (Deakin)		44km	1902-1911
SST velocity 1912-1921	Change in SST over decade	Mary Young (Deakin)		44km	1912-1921
SST velocity 1922-1931	Change in SST over decade	Mary Young (Deakin)		44km	1922-1931
SST velocity 1932-1941	Change in SST over decade	Mary Young (Deakin)		44km	1932-1941
SST velocity 1942-1951	Change in SST over decade	Mary Young (Deakin)		44km	1942-1951
SST velocity 1952-1961	Change in SST over decade	Mary Young (Deakin)		24km	1952-1961
SST velocity 1962-1971	Change in SST over decade	Mary Young (Deakin)		24km	1962-1971
SST velocity 1972-1981	Change in SST over decade	Mary Young (Deakin)		24km	1972-1981
SST velocity 1982-1991	Change in SST over decade	Mary Young (Deakin)		24km	1982-1991
SST velocity 1992-2001	Change in SST over decade	Mary Young (Deakin)		24km	1992-2001

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
SST velocity 2002-2011	Change in SST over decade	Mary Young (Deakin)		24km	2002-2011
SST velocity 1871-1960	Change in SST over 50s	Mary Young (Deakin)		24km	1871-1960
SST velocity 1961-2010	Change in SST over 50s	Mary Young (Deakin)		24km	1961-2010
surface rugosity of seabed calc from ausbath	Bathymetry derived topographic rugosity grid	GA	http://www.ga.gov.au/metadata-gateway/metadata/record/gcat_76994	300m	2009
Bottom Water Temperature Data - Mean	Bottom Water Temperature Data - Mean	GA/CSIRO	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
Bottom Water Temperature Data - Standard Deviation	Bottom Water Temperature Data - Standard Deviation	GA/CSIRO	http://www.ga.gov.au/metadata-gateway/metadata/record/70439/	1km	
2003-2013 autumn mean chl oc3	2003-13_autumn_mean_chl_oc3	MODIS-derived Chlorophyll a Data (2003-2013) - Autumn Mean	not published/ GA/CSIRO	1km	2003-2013
2003-2013 autumn mean sst	2003-13_autumn_mean_sst	MODIS-derived SST Data (2003-2013) - Autumn Mean	not published/ GA/CSIRO	1km	2003-2013
2003-2013 spring mean chl oc3	2003-13_spring_mean_chl_oc3	MODIS-derived Chlorophyll a Data (2003-2013) - Spring Mean	not published/ GA/CSIRO	1km	2003-2013
2003-2013 spring mean sst	2003-13_spring_mean_sst	MODIS-derived SST Data (2003-2013) - Spring Mean	not published/ GA/CSIRO	1km	2003-2013

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
2003-2013 summer mean chl oc3	2003-13_summer_mean_chl_oc3	MODIS-derived Chlorophyll a Data (2003-2013) - Summer Mean	not published/ GA/CSIRO	1km	2003-2013
2003-2013 summer mean sst	2003-13_summer_mean_sst	MODIS-derived SST Data (2003-2013) - Summer Mean	not published/GA/CSIRO/CSIRO	1km	2003-2013
2003-2013 winter mean chl oc3	2003-13_winter_mean_chl_oc3	MODIS-derived Chlorophyll a Data (2003-2013) - Winter Mean	not published/GA/CSIRO	1km	2003-2013
2003-2013 winter mean sst	2003-13_winter_mean_sst	MODIS-derived SST Data (2003-2013) - Winter Mean	not published/GA/CSIRO	1km	2003-2013
2003-2013 mean chl oc3	2003-13mean_chl_oc3	MODIS-derived Chlorophyll a Data (2003-2013) - Mean	not published/GA/CSIRO	1km	2003-2013
2003-2013 mean sst	2003-13mean_sst	MODIS-derived SST Data (2003-2013) - Mean	not published/GA/CSIRO	1km	
Mean total suspended material	MODIS-derived Total Suspended Material Data (2009-2011) - Mean	GA/CSIRO	not published/GA/CSIRO	1km	
Standard deviation total suspended material	MODIS-derived Total Suspended Material Data (2009-2011) - Standard Deviation	GA/CSIRO	not published/GA/CSIRO	1km	
upwelling bottom mean autumn	Bran 3.5 Bottom Upwelling Data - Autumn Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling bottom mean spring	Bran 3.5 Bottom Upwelling Data - Spring Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
upwelling bottom mean summer	Bran 3.5 Bottom Upwelling Data - Summer Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling bottom mean winter	Bran 3.5 Bottom Upwelling Data - Winter Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean autumn	Bran 3.5 Upwelling to Euphotic Zone Data - Autumn Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean spring	Bran 3.5 Upwelling to Euphotic Zone Data - Spring Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean summer	Bran 3.5 Upwelling to Euphotic Zone Data - Summer Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean winter	Bran 3.5 Upwelling to Euphotic Zone Data - Winter Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean autumn	Bran 3.5 Upwelling to Mixed Layer Depth Data - Autumn Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean spring	Bran 3.5 Upwelling to Mixed Layer Depth Data - Spring Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
upwelling euphotic mean summer	Bran 3.5 Upwelling to Mixed Layer Depth Data - Summer Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	

Covariate	Explanation	Source	URL	Spatial resolution	Temporal resolution
upwelling euphotic mean winter	Bran 3.5 Upwelling to Mixed Layer Depth Data - Winter Mean	CSIRO	http://wp.csiro.au/bluelink/global/bran/	12km	
v velocity	Vertical current velocity	GA/CSIRO	http://www.ga.gov.au/metadata-gateway/metadata/record/75846/	9km	
zeu l mean	Mean euphotic depth	MODIS-derived Euphotic Depth Data (2009-2011) - Mean	not published/GA/CSIRO	1km	
zeu l sd	Standard deviation euphotic depth	MODIS-derived Euphotic Depth Data (2009-2011) - Standard Deviation	not published/GA/CSIRO	1km	
human pop	Density of human population. Reflects human population density from nearest point on land in 2010	ABS	http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1301.0~2012~Main%20Features~Geographic%20distribution%20of%20the%20population~49	1km	2010
cyclones	Cumulative cyclone paths in decade, 50 and 100 year time periods. Calculated by Jac Monk.	NOAA	https://www.ncdc.noaa.gov/ibtracs/index.php?name=ibtracs-data		

5. EXAMPLES OF INDICATORS/METRICS FOR SOE REPORTING

The SoE reporting is quite conservative from report to report to retain consistency and comparability between the 5-yearly reports. However, it is also important for the rigour of SoE (and EBFM) reporting that these summary metrics are based on well-developed quantitative metrics representing the best scientific approaches. The trialling of these latter metrics is currently underway, with completion scheduled for the end of August. Initial work suggests that some show clear temporal patterns. For example, biomass of targeted fish greater than 20 cm shows clear protection effects over time for Port Stephens Great Lakes Marine Park in New South Wales State waters (Figure 3). Our ongoing work will identify further informative metrics.

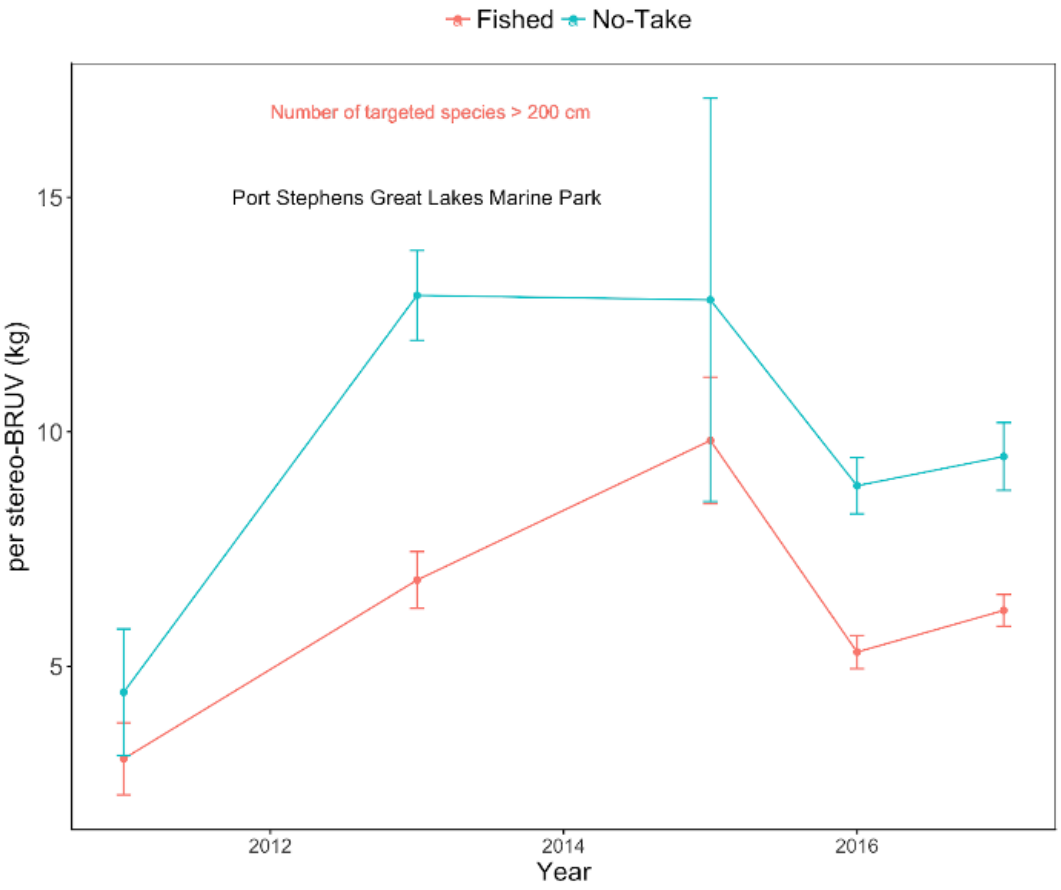

Figure 4. Biomass of targeted fish greater than 20 cm over time for Port Stephens Great Lakes Marine Park in New South Wales State waters

6. MOVING FORWARD

After initial set-backs with BRUVs data collation and fixing of unforeseen inconsistencies between datasets, the trialling of all metrics with the national BRUVs dataset is set to be completed by the end of June. Further to this as a part of the NCRIS funding for the Global Archive Marine RDC project, a meeting/workshop on Global Archive and SoE reporting app is being scheduled for August. The SoE reporting app (Figure 3) will link directly with Global Archive and enable end-users to interactively explore SoE/EBFM metrics.

Importantly, the process of working towards reporting metrics for SOE, as well as the understanding of national BRUV datasets generated by the collation process and two national BRUV workshops in 2017/18 has significantly enhanced the understanding of the importance of this process to the national BRUV research community. In doing so it has identified a range of areas that need to be enhanced where possible to improve the ability to share information on platforms like Global Archive, as well as make the data most valuable to national integrated programs. This includes identification of all species where possible (rather than a subset of species of interest), recording counts to at least a Max N value (index of relative abundance) and estimation of length across all species. Where this is not possible due to funding/time constraints, ideally the raw video can be added to Global Archive, Squidle + (https://squidle.com.au/) or similar so that other researchers have the opportunity to complete the missing data in the future. With such information (species level, abundances, and sizes), all identified metrics for SOE reporting would be able to be generated, and these have been identified as the core Essential Environmental Measures (EEMs) for reef associated fishes by the Department of the Environment and Energy (DoEE) as part of the trial EEM program in 2017 (of which this project and agencies associated with it were key contributors).

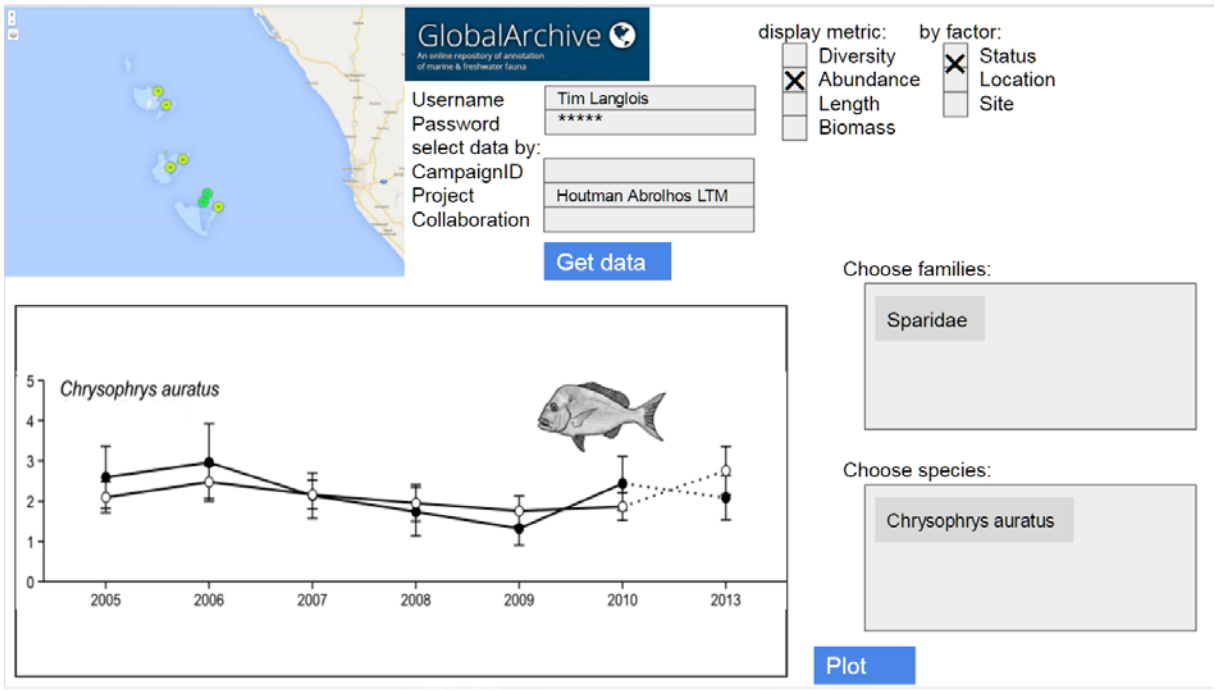

Figure 5. Example concept for SoE reporting app associated with Global Archive.

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