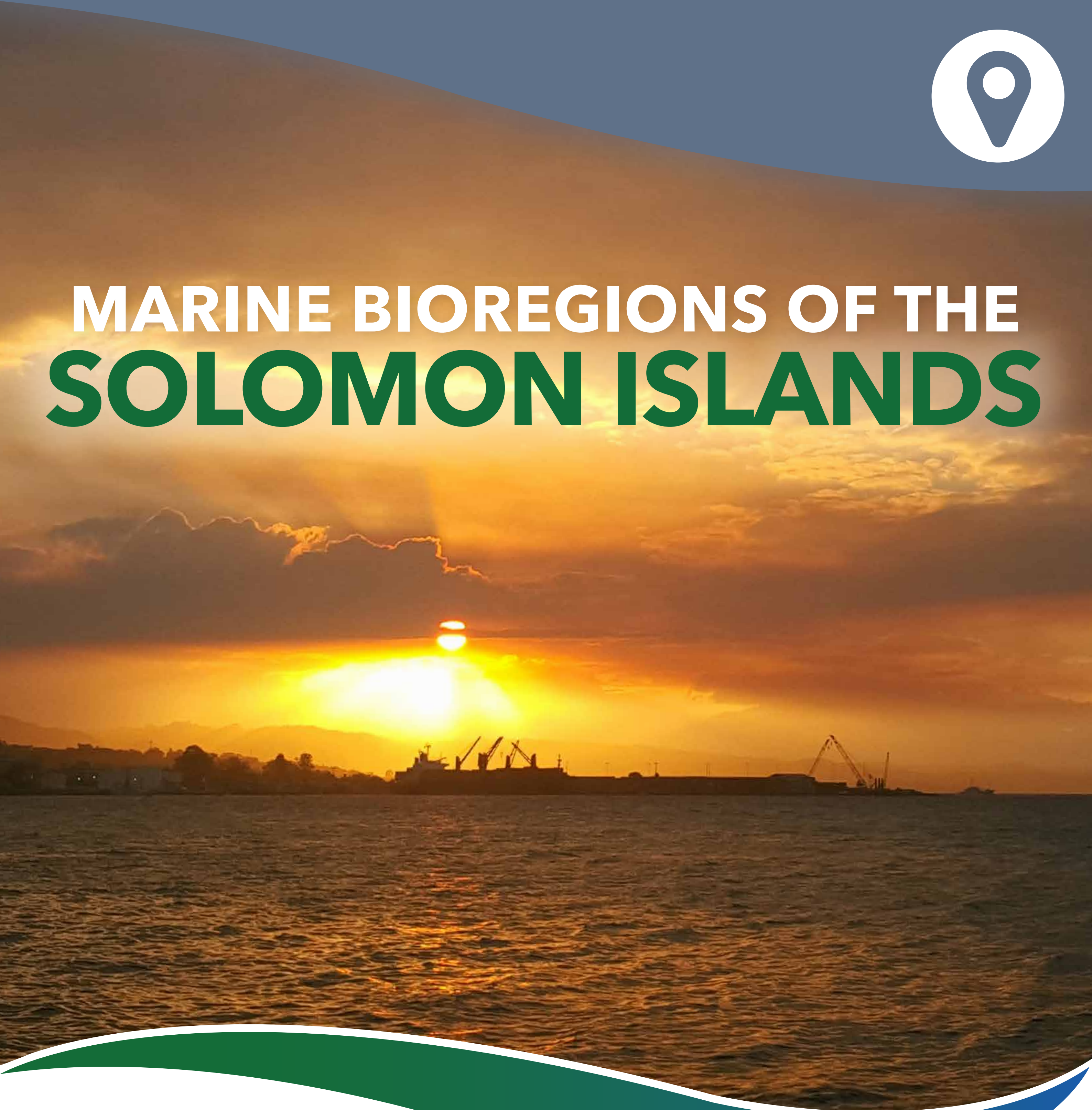
MARINE BIOREGIONS OF THE SOLOMON ISLANDS



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MACBIO

Marine and Coastal Biodiversity Management in Pacific Island Countries

MARINE SPATIAL PLANNING

Marine Spatial Planning is an integrated and participatory planning process and tool that seeks to balance ecological, economic, and social objectives, aiming for sustainable marine resource use and prosperous blue economies.

The MACBIO project supports partner countries in collecting and analyzing spatial data on different forms of current and future marine resource use, establishing a baseline for national sustainable development planning.

Aiming for integrated ocean management, marine spatial planning facilitates the sustainable use and conservation of marine and coastal ecosystems and habitats.

The report outlines the technical process undertaken to develop draft marine bioregions across the SW Pacific and the national, expert-drive process to refine the bioregions for use in the Solomon Islands. These marine bioregions provide a basis for identifying ecologically representative areas to include in national networks of marine protected areas.

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SOLOMON ISLANDS

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2018

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

SPREP Secretariat of the Pacific Regional Environment Programme

IUCN

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On behalf of Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of the Federal Republic of Germany

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Recommended citation: Wendt H, Beger M, Sullivan J, LeGrand J, Davey K, Yakub N, Kirmani SN, Grice H, Mason C, Raubani J, Lewis A, Jupiter S, Hughes A, Wini-Simeon L, Vave-Karamui A, Masu R, Ceccarelli D, Nicolay – Grosse Hokamp A, Fernandes L (2018) Marine bioregions of the Solomon Islands. MACBIO (GIZ, IUCN, SPREP), Suva, Fiji. 64 pp.

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MACBIO

Marine and Coastal Biodiversity Management
in Pacific Island Countries

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EXECUTIVE SUMMARY

Marine spatial planning is underway now, or starting, in many Pacific Island countries, including the Solomon Islands. This planning aims, amongst other things, to achieve the Convention on Biological Diversity's (CBD) Aichi Target 11 which states, in part, that at least 10 per cent of coastal and marine areas are conserved through ecologically representative and well-connected systems of protected areas.

For the Solomon Islands, means to achieve an ecologically representative system of marine protected areas is missing. There are not perfect data which describe the distribution and abundance of every marine habitat and species in the country. And certainly not at a scale that is useful for national planning in the ocean. Bioregionalisation, or the classification of the marine environment into spatial units that host similar biota, can serve to provide spatially explicit surrogates of biodiversity for marine conservation and management.

Existing marine bioregionalisations however, are at a scale that is too broad for national governments in the Pacific to use. Often whole countries are encompassed in just one or two bioregions (or ecoregions).

Recognising this, the Oceans12 Technical Working Group of the Solomon Islands asked the MACBIO project to assist them to describe the entire marine environment of the country. This report presents, for the first time, marine bioregions across the Southwest Pacific in general, and the Solomon Islands in particular, at a scale that can be used nationally, as a basis for the systematic identification of an ecologically representative system of marine protected areas.

Bioregions, of course, are just one of the important data layers in indentifying an ecologically representative system of marine protected areas. To be truly ecologically representative and comprehensive, one must also consider all available information about habitats, species and ecological processes. In addition, socio-economic and cultural considerations are vital in the spatial planning process. This report is focussed upon one important, but only one, input to marine spatial planning: the development of marine bioregions.

To take account of differing types and resolution of data, two separate bioregionalisations were developed; firstly, for the deepwater environments and secondly for reef-associated environments. For the deepwater, thirty, mainly physical, environmental variables were assessed to be adequately comprehensive and reliable to be included in the analysis. These data were allocated to over 140 000 grid cells of 20x20 km across the Southwest Pacific. K-means and then hierarchical cluster analyses were then conducted to identify groups of analytical units that contained similar environmental conditions. The number of clusters was determined by examining the dendrogram and setting a similarity value that aligned with a natural break in similarity.

For the second bioregionalisation, reef-associated datasets of more than 200 fish, coral and other invertebrate species were collated from multiple data providers who sampled over 6,500 sites. We combined these datasets, which were quality-checked for taxonomic consistency and normalised, resulting in more than 800 species that could be used in further analysis. All these species data and seven independent environmental datasets were then allocated to over 45,000 grid cells of 9x9 km across the SW Pacific. Next, the probability of observing these species was predicted, using the environmental variables, for grid cells within the unsurveyed reef-associated habitats. Hierarchical cluster analysis was then applied to the reef-associated datasets to deliver clusters of grid cells with high similarity.

The final analytical steps, applied to all the outputs, were to refine the resulting clusters using manual spatial processing and to describe each cluster to deliver the draft bioregions. This work resulted in 262 draft deepwater marine bioregions and 102 draft reef-associated bioregions across the SW Pacific, and 33 deepwater bioregions and 19 reef-associated bioregions of the Solomon Islands.

People's expertise in the Pacific marine environment extends beyond the available datasets. An important, subsequent, non-analytical step, was to review and refine the resultant draft bioregions with marine experts in the Solomon Islands prior to their use in planning. The process of review, and the resulting changes to the bioregions, are also presented in this report. The review process led to 26 deepwater and 18 reef-associated marine bioregions being finalised for use in national planning in the Solomon Islands.

By ensuring that each bioregion is represented adequately within the Solomon Islands' network of marine protected areas, the government will ensure that the network is ecologically representative as per their commitment under the National Biodiversity Strategy and Action Plan. More importantly, it will ensure a network of marine protected areas that can deliver the intended social, economic and cultural benefits.

1 INTRODUCTION

Pacific Island countries, including the Solomon Islands, are moving towards more sustainable management of their marine and coastal resources (e.g. see Pratt and Govan 2011, Pacific Island Country Voluntary Commitments at the United Nations Ocean conference), and many are also party to the Convention on Biological Diversity (CBD)[1]. Although the land area of the Solomon Islands is small, they have authority over big ocean spaces within their Exclusive Economic Zone (EEZ), with 98% of the Solomon Islands being ocean.

Pacific Island countries who are signatory to the CBD, like the Solomon Islands have committed to an ecologically representative system of Marine Protected Areas (MPAs; see box below)[2]. In addition, several leaders from the region have made commitments to better protect large parts or all of their EEZs. Many of these commitments were declared internationally and are being implemented nationally. For example, by their Cabinet Decision in 2016 (C10[2016]4) and Voluntary Commitment at the United Nations Oceans Conference (#OceanAction19754), the Solomon Islands has committed to a national marine spatial plan by 2020 including a national network of marine protected areas.

CBD Aichi Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

However, for the Solomon Islands and other Pacific Island countries where marine planning is underway to achieve Aichi targets, there is a lack of an effective way to systematically represent biodiversity. None of the previous work has provided an ocean-wide description of the marine environment at the scales needed for national marine spatial planning, and decisions about locations of ecologically representative MPAs within and across countries.

In 2016, the Oceans12 Technical Working Group (TWG) of the Solomon Islands asked the Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project to help deliver a description of the entire marine environment of the country at a scale useful for national planning.

The Oceans12 TWG is a working group of the Oceans12 itself. The Oceans12 was established by the Cabinet (Decision (C10[2016]4) to be the National Steering Committee for the Solomon Islands Integrated Ocean Governance efforts. The Oceans12 is a Permanent-Secretary-level Steering Committee co-chaired by the Ministries of Fisheries and Marine Resources, of Environment, Climate Change, Disaster Management & Meteorology and the Office of the Prime Minister and Cabinet. In total it comprises of the twelve Ministries with the most direct influence in the use and management of the Solomon Islands' ocean, the other ten being the Ministries of Mines, Energy and Rural Electrification, of Lands, Housing and Survey, of Culture and Tourism, of Foreign Affairs and External Trade, of Development Planning and Aid Coordination, of Infrastructure Development (Solomon Islands Maritime Safety Authority), of Justice and Legal Affairs, of Police, National Security and Correctional Services, of Forestry & Research and of Provincial Government and Institutional Strengthening. The Oceans12 TWG has members from the same Ministries.

The MACBIO project is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through its International Climate Initiative (IKI). The Project is helping the countries to improve management of marine and coastal biodiversity at the national level including to meet their commitments under the CBD Strategic Plan for Biodiversity 2011–2020 such as relevant Aichi Biodiversity Targets. MACBIO is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) with the countries of Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu. It has technical support from the Oceania Regional Office of the International Union for the Conservation of Nature (IUCN-ORO) and is working closely with the Secretariat of the Pacific Regional Environment Program (SPREP), see www.macbio-pacific.info.

1 https://oceanconference.un.org/commitments/, www.cbd.int/information/parties.shtml, www.cbd.int/sp/targets/ accessed 28/9/17

2 www.cbd.int/sp/targets/ accessed 28/9/17

MACBIO's objectives are to help ensure that: (1) The economic value of marine and coastal ecosystem services is considered in national development planning; (2) Exclusive economic zone-wide spatial planning frameworks are used to align national marine and coastal protected area systems with the requirements of ecosystem conservation; and (3) Best practices for managing MPAs, including payments for environmental services, are demonstrated at selected sites.

Under the second objective, the project is assisting the Solomon Island with its Marine Spatial Planning (MSP) process which aims to better manage the different uses of marine resources. The MSP process is also aiming to include a national ecologically-representative network of marine protected areas (MPAs). In principle, this requires complete and accurate spatial biodiversity data, which are rarely available. Bioregionalisation, or the classification of the marine environment into spatial units that host similar biota, can serve to provide spatially explicit surrogates of biodiversity for marine conservation and management (Fernandes et al. 2005, Last et al. 2010, Fernandes et al. 2012, Terauds et al. 2012, Foster et al. 2013, Rickbeil et al. 2014). Bioregions define areas with relatively similar assemblages of biological and physical characteristics without requiring complete data on all species, habitats and processes (Spalding et al. 2007). This means, for example, that seamounts within a bioregion will be more similar to each other than seamounts in another bioregion. Similarly, for example, seagrasses beds within one bioregion will be more similar to each other than seagrass beds in another bioregion. An ecologically representative system of MPAs can then be built by including examples of every bioregion (and, every habitat, where known) within the system. Defining bioregions across a country mitigates against ignoring those areas about which no or little data are available.

The MACBIO project has built draft marine bioregions across the Southwest Pacific for use by Pacific Island countries, including the Solomon Islands, in their national marine spatial and marine protected area planning processes. By ensuring that each bioregion is represented adequately within the Solomon Islands' network of marine protected areas, the government will ensure that the network is ecologically representative as per their commitment under the National Biodiversity Strategy and Action Plan. More importantly, it will ensure a network of marine protected areas that can deliver the intended social, economic and cultural benefits.

1.1 AIMS OF THE BIOREGIONALISATION

This marine bioregionalisation aims to support national planning efforts in the Pacific. This report describes the technical methods used by the MACBIO project to classify the entire marine environment within the MACBIO participating countries to inform, in particular, their national marine spatial and marine protected area planning efforts. The draft outputs are marine bioregions that include reef-associated and deepwater biodiversity assemblages with complete spatial coverage at a scale useful for national planning. Results for the Solomon Islands have been presented to the marine experts and government of the Solomon Islands for review (see Section 6). The resulting marine bioregions of the Solomon Islands will provide a biological and environmental basis for the nation's MSP process. Specifically, it allows for the identification of candidate sites for an ecologically-representative system of MPAs in the country.

Spatial planning for marine protected areas, including ecologically representative marine protected areas, requires much more than just holistic description of the marine environment in which one is working. Whilst marine bioregions can form an important biophysical data layer in planning, to be truly ecologically representative and comprehensive, one must also consider all available information about habitats, species and ecological processes (Lewis et al. 2017, Ceccarelli et al. in prep). Marine bioregions are useful because they offer insurance against ignoring parts of the ocean were data are incomplete or, even, absent. In the planning process overall, however, socio-economic and cultural considerations and data are also vital (Lewis et al. 2017). This report is focussed upon one important, but only one, input to marine spatial planning: the development of marine bioregions.

2 RATIONALE

The decline of marine biodiversity and ecosystem services is a worldwide problem and requires better management (Jackson et al. 2001, Worm et al. 2006, Mora 2008, Beger et al. 2015, Klein et al. 2015). This has been recognised at the global level and countries are trying to address the problem through national efforts, multi- and bi-lateral initiatives and other agreements and commitments. For example, over 1400 Voluntary Commitments to improve ocean management were made at the United Nations Ocean Conference in June 2017[3]. This includes at least 130 Pacific-specific targets. In order to achieve these targets, many nations are currently in the process of zoning their marine and coastal areas for better management and greater protection. The placement and effective designation of sites as MPAs within each country requires the full representation of marine biodiversity in conservation and management areas, whilst considering socio-economic and cultural needs.

In data-poor regions, such as the Pacific, representing marine biodiversity based on comprehensive habitat and species information is impossible. Such cases require the use of biological proxies (Sutcliffe et al. 2014, Sutcliffe et al. 2015), such as environmental conditions (Grantham et al., 2010), non-comprehensive data collected at different spatial scales (Mellin et al. 2009), surrogate species (Olds et al. 2014, Beger et al. 2015), marine classifications (Green et al. 2009), expert decision-making (Brewer et al. 2009) or some combination of these (Kerrigan et al. 2011).

Since assemblages of marine species with similar life histories, often respond similarly to environmental conditions (Elith and Leathwick 2009), these species can be grouped for biogeographical predictions or ecological modelling (Treml and Halpin 2012). The probability of occurrence of such species groupings is often determined by the unique combinations of environmental parameters that are likely to drive the distribution of these groups. The classes resulting from unique combinations of environmental parameters can thus serve as surrogates for marine biodiversity that is otherwise unrecorded (Sutcliffe et al. 2015). In the marine realm, marine classification schemes also range from global (Spalding et al. 2007, Vilhena and Antonelli 2015), regional (Keith et al. 2013, Kulbicki et al. 2013) to "local" scales (Fernandes et al. 2005, Green et al. 2009, Terauds et al. 2012), with many studies including multi-scale hierarchical classes (Spalding et al. 2007).

Many marine classification schemes are often based on specific taxonomic groups or habitats occurring in the target region. These include schemes based on shallow coral reef fishes (Kulbicki et al. 2013), or Scleractinian corals (Keith et al. 2013). Others use a mix of species distributions, environmental parameters, and expert opinion (Spalding et al. 2007, Kerrigan et al. 2011, Terauds et al. 2012). Most schemes do not explicitly classify offshore or pelagic areas, which have often been seen as largely homogeneous and have been classified into very large scale ecoregions, such as in the Pacific (Longhurst 2006, Sherman et al. 2009, Spalding et al. 2012, Watling and et al. 2013, Sutton et al. 2017).

However, the existing bioregionalisations of marine environments (both coastal and offshore) are too coarse to inform most national planning processes (Figure 1). Often entire countries in the Pacific are classified into just three, two or even one marine region. This is despite known variability within and across the marine environment within Pacific Island countries, often identified by local experts. Reef-associated marine habitats are known to vary within the scale of Pacific Island countries with changing environment and coastal morphology (Chin et al. 2011). Offshore pelagic environments are also highly variable, and are shaped by dynamic oceanographic and biophysical factors (Game et al. 2009, Sutcliffe et al. 2015) that drive pelagic population dynamics.

In offshore environments, large scale environmental dynamics drive the distributions of primary producers such as phytoplankton and consumers such as zooplankton, as well as secondary consumers such as fishes, sea-birds, turtles, jellyfish, tuna, and cetaceans. For example, sea surface temperature (SST) can be the best predictor of species richness for most taxonomic groups (Tittensor et al. 2010). By contrast, species such as pinnipeds, non-oceanic sharks, and coastal fish that are associated with coastal habitats, are predicted by the length of coastline (Tittensor et al. 2010). Furthermore, changes in thermocline characteristics affect the productivity, distribution and abundance of marine fishes (Kitagawa et al. 2007, Schaefer et al. 2007, Devney et al. 2009). For instance, the depth of the 20 degree Celsius thermocline predicts bigeye tuna catches (Howell and Kobayashi 2006). Similarly, the patterns of zooplankton distributions depend on thermoclines; however these patterns are not necessarily associated with changes in productivity (Devney et al. 2009).

[3] oceanconference.un.org/ commitments accessed 28/9/17

Zooplankton further can respond strongly to El Niño–Southern Oscillation (ENSO) patterns (Mackas et al. 2001), whereas phytoplankton abundance is predicted by the photosynthetically available radiation (PAR, i.e. a measure of light) and nitrate concentrations, depending on their functional traits (i.e. light tolerance, temp tolerance, growth rate) (Edwards et al. 2013). It follows that differing PAR and nitrate within a region are likely to support different phytoplankton assemblages. Temperature also predicts phytoplankton size, structure and taxonomic composition (Heather et al. 2003), and in some cases, models might be improved by considering SST and chlorophyll alpha (CHLa) together and to include Nitrate. Changes in diversity of plankton assemblage drives changes in the carbon, nitrogen and phosphorus (C/N/P) ratio (Martiny et al. 2013), and this corresponds to using the N/P ratio (or C/N/P ratio) as a surrogate for plankton diversity. Similarly, harmful algal bloom species (HAB) of plankton are sensitive to (and can be predicted by) temperature, phosphate, and micronutrients from land-runoff (Hallegraeff 2010).

Mega-fauna and shore-birds using the offshore habitats also follow environmental cues in search of food, which is often associated with algal blooms or indicated by changes in sea temperatures. For example, the distribution of cetaceans is predicted by primary productivity (Tittensor et al. 2010), and studies of Dall's porpoise (Phoecoenoides dalli) and common dolphins (Delphinus delphis) show that they respond to changes in SST (Forney 2000). A metric of SST, the annual SST range, predicts tunas and billfishes, Euphausids, and to a lesser degree corals and mangroves and oceanic sharks (Tittensor et al. 2010). Bluefin tuna (Thunnus maccoyii) feeding success is predicted by SST mean, SST variability, and the SS colour anomaly (Bestley et al. 2010). Similarly, the abundance and breeding success of seabirds in the tropics is influenced by environmental conditions (Devney et al. 2009), particularly the variability in productivity with season (expressed as mean annual var CHLa), but also any with upwelling changes. This shows that CHLa is a good surrogate, or a direct measure, of productivity.

Aside from patterns that may be detected in the surface waters of ocean habitats, deepwater ocean habitats can also be characterized in various ways. Firstly, there are topographic features on the sea floor such as seamounts, rises, shelf breaks, canyons, ridges and trenches, as well as oceanographic features such as currents, fronts, eddies and upwelling, which can be mapped (Harris et al. 2014). Secondly, the deep open ocean varies dramatically with depth, in physical (especially light, temperature and pressure), biological and ecological characteristics, across at least five major layers or vertical zones, known as the epipelagic or photic, mesopelagic or mesophotic, bathypelagic, abyssopelagic and hadal zones (Herring 2002).

Thirdly, within each zone there are horizontal patterns that differ in physical and biological characteristics with latitude and longitude, at various spatial scales, which may or may not overlap vertically (Craig et al. 2010, Benoit-Bird et al. 2016).

Fourth, the coupling between surface and deeper waters seems to be increasingly understood to be significant and important. So, primary productivity at the surface can influence the habitat and species that occur at much deeper oceanic layers (Graf 1989, Rex et al. 2006, Ban et al. 2014, Woolley et al. 2016).

Also, offshore species, at least partly because of the above-described features of the open ocean, do not move randomly through either surface or deep oceanic waters. Instead they tend to follow certain pathways and/or aggregate at certain sites (Ban et al. 2014).

2.1 EXISTING CLASSIFICATIONS IN THE PACIFIC REGION

There are many existing marine biogeographical regions and even smaller marine regions or provinces described for the oceans of the world (or parts of the oceans of the world) (Lourie and Vincent 2004, Brewer et al. 2009, Kerrigan et al. 2011, Green et al. 2014, Sayre et al. 2017). The countries within the MACBIO region and within the Pacific more generally, are part of some of these existing classifications (Figure 1). We review these with regard to their scale as it pertains to use by Pacific Island countries for national planning purposes and use these works as overarching guides to our current effort.

2.1.1 Coastal classifications

Classifications typically assess spatial patterns in generalised environmental characteristics of the benthic and pelagic environments such as structural features of habitat, ecological function and processes, and physical features such as water characteristics and seabed topography to select relatively homogeneous regions with respect to habitat and associated biological community characteristics. These are refined with direct knowledge or inferred understanding of the patterns of species and communities, driven by processes of dispersal, isolation and evolution. Using such data and,

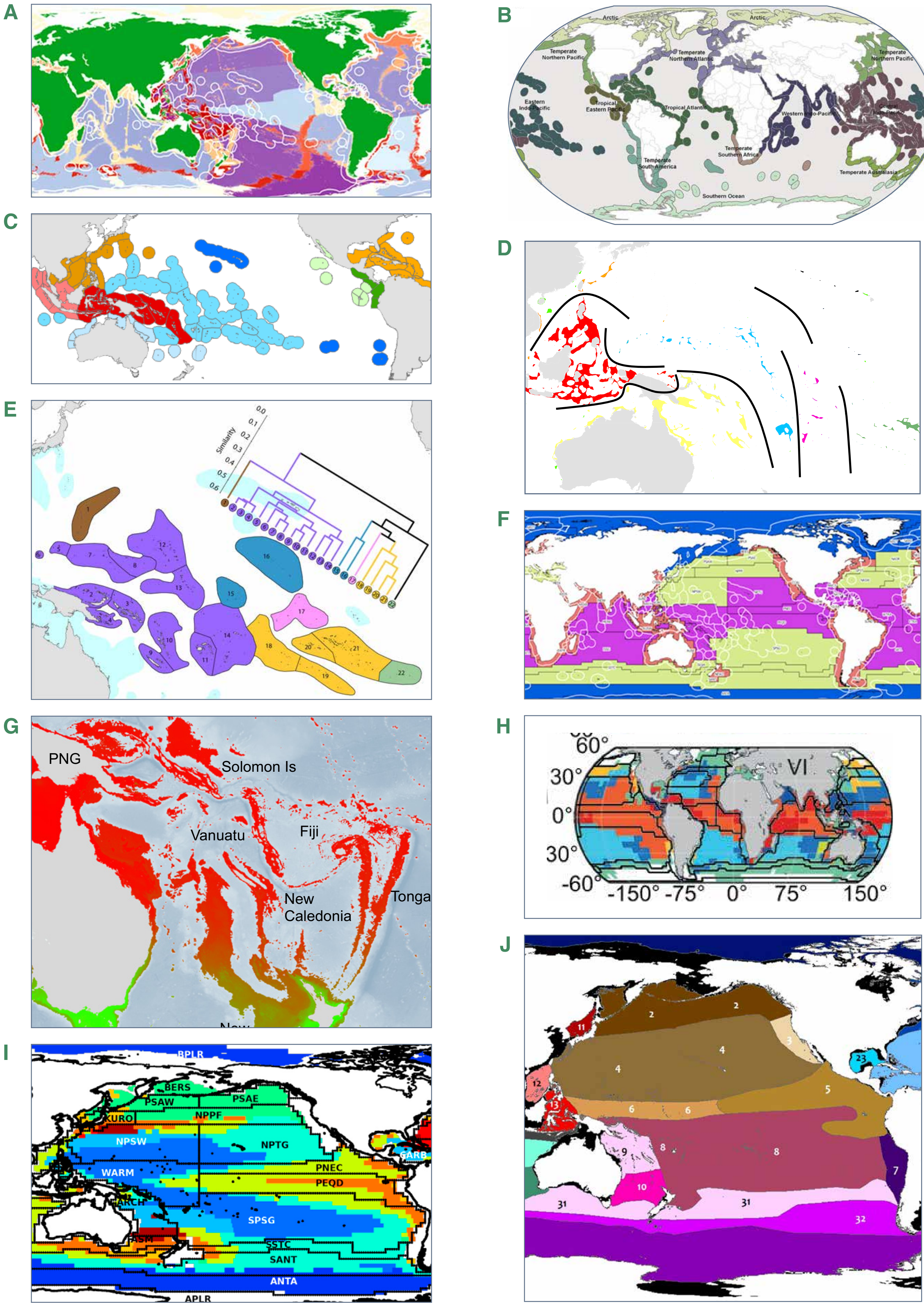

FIGURE 1: Maps of selected existing classification schemes. a) GOODS (UNESCO 2009); b) MEOW (Spalding et al. 2007); c) coral reef fishes (Kulbicki et al. 2013); d) Scleractinian corals (Keith et al. 2013); e) Veron et al. 2015; f) Biogeochemical provinces (Longhurst 2006); g) Deepwater ophiurods (O'Hara et al. 2011); h) Tuna and billfish (Reygondeau et al. 2012); i) Mesopelagic bioregions (Proud et al. 2017); j) Mesopelagic classification (Sutton et al. 2017).

often, literature reviews, experts aim to ensure, also, that biologically unique features, found in distinct basins and water bodies, are also captured in the classification. Spalding et al. (2007) applied this approach to inshore and nearshore marine environments, and delineated 232 marine ecoregions globally (Figure 1b). Of these, fifteen applied to the SW Pacific with most Pacific Island archipelagic clusters falling into their own ecoregion.

Kulbicki et al. (2013) used 169 checklists of tropical reef fish to conduct four different types of classifications; the various methods were applied to ensure robust findings despite potential limitations in the data (Figure 1c). They found that the four different classification outputs converged into a hierarchy of 14 provinces, within six regions, within three realms (Kulbicki et al. 2013). The Southwest Pacific countries were included in four provinces (Kulbicki et al. 2013). Keith et al. (2013) explored the ranges of coral species against a variety of factors to reveal that Indo-Pacific corals are assembled within 11 distinct faunal provinces, four in the SW Pacific (Figure 1d). Veron et al. (2015) also used coral data to describe the SW Pacific into 22 ecoregions within six provinces (Figure 1e).

2.1.2 Oceanic classifications

In 1998, Longhurst divided the ocean into pelagic provinces using oceanographic factors and tested and modified them based on a large global database of chlorophyll profiles (Figure 1f). Thus he defined four global provinces (three in Oceania) and 52 sub-provinces (9 in Oceania) (Longhurst 2006).

UNESCO (2009) and Watling et al. (2013) used their expertise, guided by the best available data, to divide the ocean beyond the continental shelf into biogeographical provinces based on both environmental variables and, to the extent data are available, their species composition (Figure 1a). The ocean was first stratified into 37 benthic and 30 pelagic zones. In addition, 10 hydrothermal vent provinces were delineated, for a total of 77 large-scale biogeographic provinces of which 4 were in the tropical SW Pacific (UNESCO 2009). Watling et al. (2013) then refined the deepwater provinces using higher resolution data into 14 Upper Bathyl (about four in the SW Pacific) and 14 Abyssal provinces (one in the SW Pacific) across the globe.

The biogeography of benthic bathyal fauna can be characterised into latitudinal bands of which three are in the tropical SW Pacific (O'Hara et al. 2011) (Figure 1g). The bathyal ophiuroid fauna recorded by a number of separate expeditions was found to be distributed in three broad latitudinal bands, with adjacent faunas forming transitional ecoclines rather than biogeographical breaks. The spatial patterns were similar to those observed in shallow water, despite the order-of-magnitude reduction in the variability of environmental parameters at bathyal depths.

A bioregionalisation of the ocean's mesopelagic zone (200-1,000m) was also recently developed, using information from the deep scattering layers (a biomass-rich layer of marine animals, found between 300 and 460m deep, thick enough to reflect sound waves), resulting in ten biogeographic provinces (about six in the tropical SW Pacific) (Proud et al. 2017) (Figure 1i). Ecoregions defined with a modified Delphic Method describe the mesophotic zone of the world into 33 ecoregions, of which ten are in the Pacific (Sutton et al. 2017) (Figure 1j).

Horizontal structure within the photic surface layer has been expressed biogeographically using the distribution of tuna and billfish communities (Reygondeau et al. 2012) (Figure 1h). It was found that tuna and billfish species form nine well-defined communities across the global ocean, each inhabiting a region (about four in the SW Pacific) with specific environmental, including biogeochemical, conditions. More recently, environmental data has been used to create three-dimensional maps of the ocean, resulting in a comprehensive set of 37 distinct volumetric region units, called ecological marine units (EMUs), eleven in the tropical SW Pacific (Sayre et al. 2017).

The largely biogeographic and provincial-scale descriptions of the marine environment provided above should be considered in any national-scale marine planning exercise in the nations of the tropical SW Pacific. They also provide a higher-level regionalisation within which more detailed descriptions can be developed. However, it is clear that the level of biophysical differentiation provided by these analyses is too coarse; it is too coarse to inform country decision-makers about where to locate different marine management zones or marine protected areas if aiming for ecological representativeness within their country. Our analysis provides the finer scale description needed to support these decisions.

3 TECHNICAL METHODS

Scale-appropriate, comprehensive descriptions of the marine environment of Pacific Island countries and territories remain missing. Existing higher-level marine bioregionalisations, as described above, are not sufficiently refined to effectively inform within-country planning. This impedes the implementation of ecologically representative networks of MPAs nationally, including in the Solomon Islands. Existing information on habitats and species distributions is also incomplete and not spatially continuous. To fill this gap of classifications at an appropriate spatial scale to support national planning for oceans, the methods here were designed to provide a detailed description of marine biodiversity for Pacific Island countries and territories in the Southwest Pacific.

The methods section comprises two parts: an introduction to the overarching approach of the analysis (including why the analysis was conducted across the SW Pacific), and the slightly different but complementary analyses that were applied to develop the deepwater and reef-associated bioregions. To take account of differing types and resolution of data, two separate bioregionalisations were developed; firstly, for the deepwater environments and secondly for reef-associated environments (Figure 2). These bioregions do not overlap in space, rather they are complementary to make use of different data resolutions available and represent different physical and biological features in these two environments.

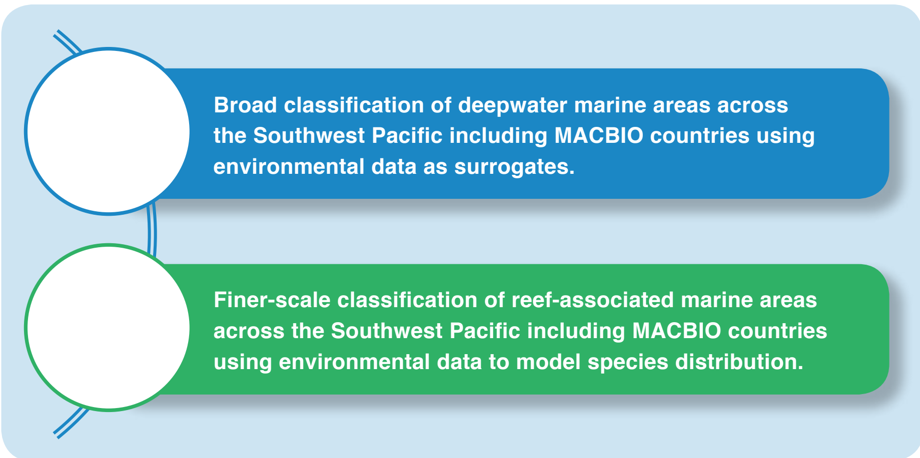

FIGURE 2: MACBIO's two-pronged integrated marine classification approach.

3.1 OVERARCHING APPROACH

As a preliminary step, we firstly defined the Area of Interest (AOI) for the analysis (Figure 3). Recognising, of course, that ecological and biological processes have no regard for jurisdictional boundaries and are operating beyond national boundaries. Therefore, any description of the marine environment within one country would be likely to "flow over" into and be relevant to neighbouring countries. So, whilst the MACBIO project focussed upon Fiji, Kiribati, the Solomon Islands, Tonga and Vanuatu, the marine systems that the project is working upon are not only contained within these country boundaries. Therefore, the AOI for the bioregion analysis was defined to include all the countries that the MACBIO project works within and all adjacent countries in the SW Pacific with the exception of Australia, New Zealand and Papua New Guinea, for which other, existing, marine regionalisations already exist or were in development (Department of the Environment and Heritage 2006, Department of Conservation and Ministry of Fisheries 2011, Green et al. 2014).

The AOI for the bioregion analyses was defined by creating a bounding box outside the EEZs of the MACBIO countries region. It extends across the Southwest Pacific Ocean, from Palau and Federated States of Micronesia to French Polynesia (130°W to 127°E, 34°S to 20°N). Except for Australia, New Zealand and Papua New Guinea (as mentioned above), all other marine areas that were not part of the EEZs of countries participating in the MACBIO project but fall within the AOI were also included in the bioregions analyses.

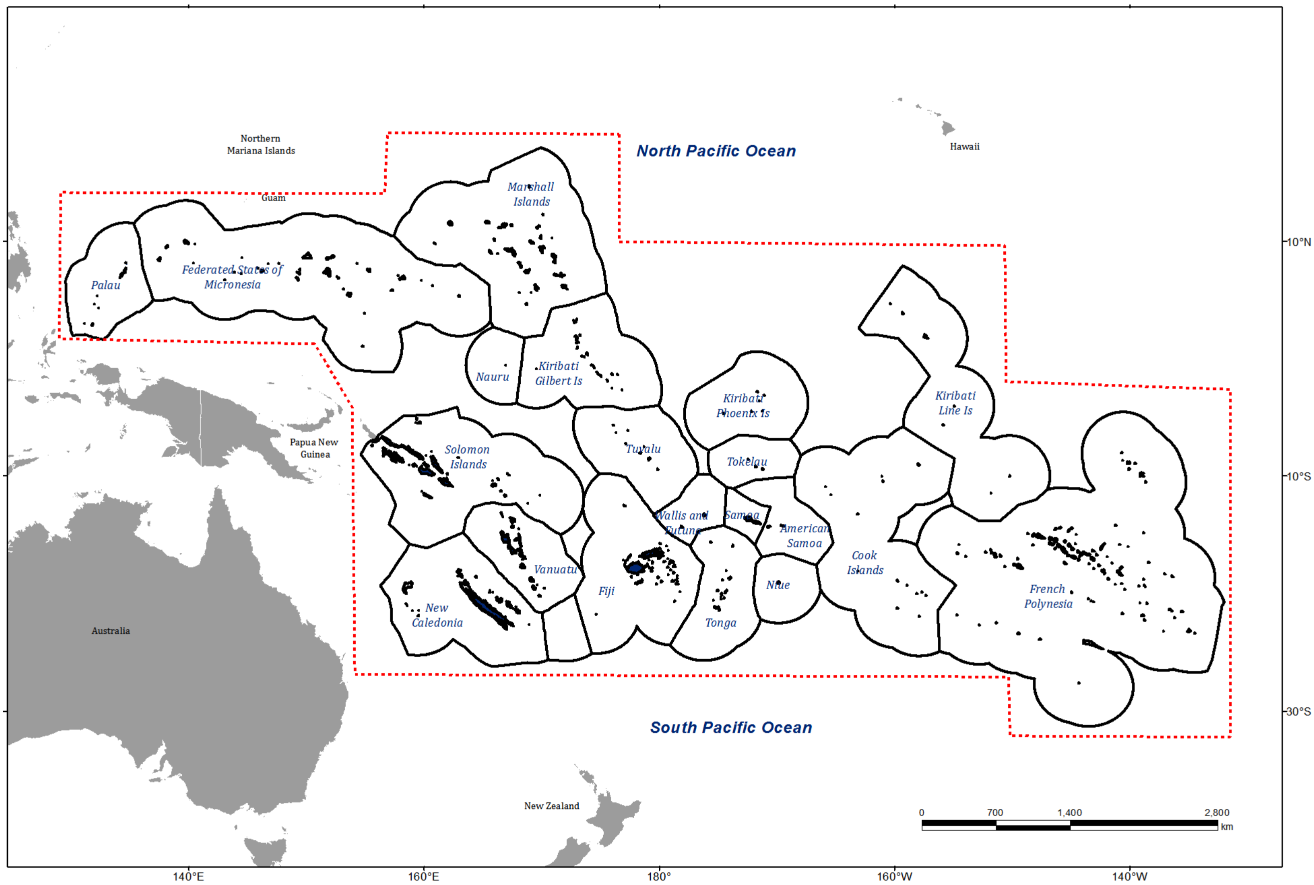

FIGURE 3: Map displaying the Area of Interest (red dotted line) and indicative provisional Exclusive Economic Zones (black solid lines).

Secondly, we chose the boundary between the deepwater versus reef-associated analysis and the size of the smallest analytical unit to be used in each bioregion analyses. Data and ecosystem considerations led to the definition of the boundary of the deepwater analysis as including areas beyond the 200 m depth or 20 km out, whichever was the furthest from land. The reef-associated analysis boundary complemented that: it was those areas within 20 km offshore or shallower than 200 m depth, whichever was furthest from land.

The appropriate resolution of the analytical units for the deepwater and reef-associated analyses was determined based upon the data resolution, purpose and scale of the analysis (i.e. to inform national planning and decision-making) and the influence on the choice of grid size on the computing time. For the deepwater analysis, 140,598 analytical grid units with a 20x20 km resolution were used and for the the shallower reef-associated areas, 45,106 analytical units with a 9x9 km resolution were used. The reef-associated areas were those that included emergent coral reef habitats, sea grasses, mangroves, and other reef-associated habitats such as sand and mudflats out to 20 km offshore or shallower than 200 m depth, whichever was furthest from land.

Third, we collated, and assessed the comprehensiveness and reliability of, environmental and biological data available from open-access sources (Wendt et al. 2018). Data were determined to be adequately comprehensive if they covered the entire AOI with sufficient resolution to enable within-country distinctions in the parameter of interest. Data were assessed to be adequately reliable if collected using methods accepted within peer reviewed literature. Of hundreds of environmental data sourced, 30 deepwater datasets were deemed adequately comprehensive and reliable for use in this classification process. Reef-associated datasets were collated from multiple data providers, but they were not comprehensive. We combined these datasets to build a comprehensive database for all reef-associated taxa. This database was quality-checked for taxonomic consistency. Then, the probability of observation was predicted to all of the unsurveyed near-shore areas with models using biological and environmental variables (see Section 3.3.3).

Fourth, hierarchical cluster analysis was conducted to identify internally homogenous clusters or groups of analytical units that are either subject to similar environmental conditions or support similar species assemblages. The number of clusters was determined by examining the dendrogram and setting a similarity value to break it up into clusters.

The fifth step was refining the resulting clusters using spatial processing and describing each cluster to deliver draft bioregions.

More detail on each of these analytical steps for the deepwater and reef-associated bioregion analysis is provided, below (Sections 3.2 and 3.3).

An important final step was to review and refine the resultant draft bioregions with marine experts in the Solomon Islands. This final review is described in Section 6, including both the process of expert review/revision and a map of the finalised bioregions which can be used in national planning in the Solomon Islands.

3.2 DEEPWATER BIOREGIONS METHODS

Marine bioregions were developed, firstly, for the deepwater areas across the Southwest Pacific. "Deepwater" for this analysis was defined at the 200 m depth or 20 km out whichever was the furthest from land.

3.2.1 Data used in analysis

The classification groups for the deepwater biological regions were driven by 30 environmental datasets including depth, salinity and sea surface temperature (Table 1) (Tyberghein et al. 2012). A more detailed description and the sources of all the data used can be found in Wendt et al. (2018). These data were served at various resolutions, requiring summary analysis to fit our 20 km resolution (see below). Comprehensive and reliable data were available at depths up to 1,000 m. At depths below 1,000 m, there were not enough data points in the acquired datasets to be reliable in the deepwater analysis. This was partly due to the sampling design used for the data and partly due to the bathymetry, which meant some places were not deep enough to have data below 1,000 m or 2,000 m (e.g. temperature at 4,000 m[4]).

TABLE 1: Datasets used to derive deepwater bioregions (for more details see Wendt et al. 2018)

	DATASET NAME (SOURCE)	PARAMETER
1	Satellite gravimetry & multibeam data (GEBCO)	Depth (m)
2	Aqua-MODIS (BioOracle)	Calcite Concentration (mol/m^3)
3	World Ocean Database 2009 (BioOracle)	Dissolved Oxygen Concentration (ml/l)
4	World Ocean Database 2009 (BioOracle)	Nitrate Concentration (µmol/l)
5	SeaWiFS (BioOracle)	Photosynthetically Available Radiation (Einstein/m^2/day) (maximum)
6	SeaWiFS (BioOracle)	Photosynthetically Available Radiation (Einstein/m^2/day) (mean)
7	World Ocean Database 2009 (BioOracle)	pH (unitless)
8	World Ocean Database 2009 (BioOracle)	Phosphate Concentration (µmol/l)
9	World Ocean Database 2009 (BioOracle)	Salinity (PSS)
10	World Ocean Database 2009 (BioOracle)	Silicate Concentration (µmol/l)
11	Global Administrative Areas (GADM28)	Distance from Land (m)
12	Aqua-MODIS (NASA)	Chlorophyll a Concentration (mg/m^3) (maximum)
13	Aqua-MODIS (NASA)	Chlorophyll a Concentration (mg/m^3) (mean)
14	Aqua-MODIS (NASA)	Chlorophyll a Concentration (mg/m^3) (minimum)
15	Aqua-MODIS (NASA)	Chlorophyll a Concentration (mg/m^3) (range)
16	Aqua-MODIS (NASA)	Sea Surface Temperature (°C) (maximum)
17	Aqua-MODIS (NASA)	Sea Surface Temperature (°C) (mean)
18	Aqua-MODIS (NASA)	Sea Surface Temperature (°C) (minimum)
19	Aqua-MODIS (NASA)	Sea Surface Temperature (°C) (range)
20	Atlas of Regional Seas (CSIRO)	Dynamic height of sea surface with regard to 2000m (m)

4 www.marine.csiro.au/~dunn/cars2009/c09_distrib_4000mA.jpg), accessed 28/9/17

	DATASET NAME (SOURCE)	PARAMETER
21	Atlas of Regional Seas (CSIRO)	Depth of 20 degree isotherm (m)
22	Atlas of Regional Seas (CSIRO)	Mixed Layer Depth (m)
23	Atlas of Regional Seas (CSIRO)	Seawater Temperature (°C) (30m)
24	Atlas of Regional Seas (CSIRO)	Seawater Temperature (°C) (200m)
25	Atlas of Regional Seas (CSIRO)	Seawater Temperature (°C) (1000m)
26	Atlas of Regional Seas (CSIRO)	Nitrate (µmol/l) (1000m)
27	Atlas of Regional Seas (CSIRO)	Dissolved Oxygen Concentration (mg/l) (1000m)
28	Atlas of Regional Seas (CSIRO)	Phosphate Concentration (µmol/l) (1000m)
29	Atlas of Regional Seas (CSIRO)	Salinity (PSS) (1000m)
30	Atlas of Regional Seas (CSIRO)	Silicate Concentration (µmol/l) (1000m)

3.2.2 Data preparation

All raster datasets were projected to a Lambert cylindrical equal-area projection with metre measurement units; this projection allowed us to split the AOI into analysis cells representing equal-sized areas.

The deepwater classification was developed across political borders, reflecting the parameters of the natural environment. For the deepwater analysis, the AOI was divided into 20 km by 20 km vector grid cells (164,430 cells). The 20x20 km cells represented the smallest unit of the deepwater regionalization. All cells that were within 20 km of land or less than 200 m depth were removed (these were classified using higher resolution data to develop reef-associated bioregions, see Section 3.3 below) leaving 140,598 cells of 20x20 km resolution in the deepwater area. The datasets were then assigned to these 20x20 km grid using the QGIS "zonal statistics plugin" algorithm to calculate the mean value of each dataset within each cell. The mean value of each input dataset for each cell were then exported for further processing (see also Wendt et al. (2018)).

3.2.3 Statistical data analysis

3.2.3.1 RAW REGIONS BASED ON CLUSTER ANALYSIS

The environmental data were processed in the R programming language using the core set of packages (www.r-project.org). The code used for this analysis can be found in Wendt et al. (2018). The data were standardised so that all values were between 0 and 1. Bathymetry is highly influential in determining both benthic ecology/seabed geomorphology as well as benthic: pelagic coupling systems (Sutton et al. 2008, Craig et al. 2010, DeVaney 2016, Vereschchaka et al. 2016). Because of this disproportionate influence of bathymetry upon deepwater habitats and species, the value of the "depth" environmental parameter weighted by a factor of two in the analysis (Dunstan et al. 2012, Brown and Thatje 2014, Piacenza et al. 2015). Due to computing limitations, we reduced the dimensionality of the 140,598 cells representing the deepwater area by clustered them into 5,000 groups using the k-means function implementing the MacQueen algorithm (MacQueen 1967). The k-means algorithm optimises the classification of items into clusters based on an initial set of randomly chosen cluster centres; the effect of this randomness was ameliorated by repeating the analysis 20 times and then using the classification with the minimum total within-cluster sum of squares: the classification with the best fit. This initial classification step reduced the dataset size to make the creation of a distance matrix possible (a distance matrix for the full deepwater environmental parameter dataset would require 80GB of RAM, which was not available).

A distance matrix was calculated using the centre of gravity of each k-means cluster using the dist function and then hierarchically clustered using the hclust algorithm with default parameters in the R programming language[5]. The hierarchical clustering tree was cut at a height of 0.4 using the cutree function, yielding 475 clusters that contained every 20 km by 20 km grid cell. The cutoff height was determined by viewing the relative variability of the clusters as displayed in a dendrogram: a "natural" break in the dendrogram (meaning that there was a greater degree of "distance" between clusters which represented differences in the groupings) (Figure 4).

[5] (www.r-project.org), accessed 28/9/17

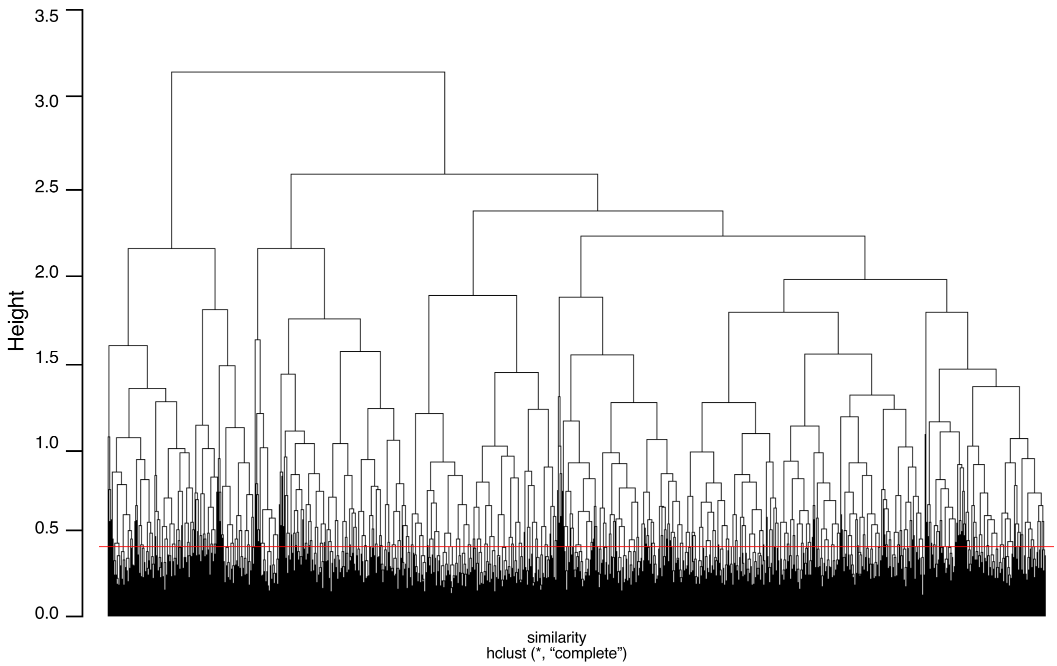

FIGURE 4: Dendrogram for offshore bioregional classification, where the red line shows the cut-off.

When plotted on a map, these clusters described the spatial variability of the SW Pacific. However, due to the necessary use of 20x20 km grid cells in the analyses, the bioregion boundaries had "square" boundaries and, in some instances, isolated irregularities arose where conflicting and intersecting data points occurred within one grid cell (e.g. at bioregion boundaries). To address these issues, a spatial smoothing and quality control step were applied.

3.2.3.2 SMOOTHING AND QUALITY CONTROL

The cluster grid had areas smaller than 4 adjacent cells which were removed using the GDAL sieve algorithm[6]. The clusters were smoothed using the GRASS generalize algorithm[7] "snakes" method with default parameters (Figure 5).

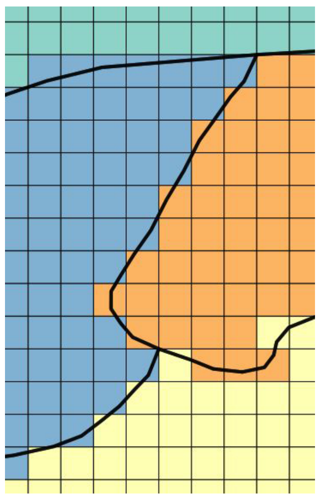

FIGURE 5: Graphic showing the 20km resolution analysis units (coloured) along with the smoothed boundaries (heavy black line).

Where the analysis identified a non-contiguous bioregion with parts that were separated by up to 1000 km, these multi-part bioregions were manually inspected to determine if their geographic locations could be explained by biological connectivity or environmental homogeneity. For example, the environmental conditions described by region 69 occurred

6 www.gdal.org/gdal_sieve, accessed 28/9/17

7 grass.osgeo.org/grass73/manuals/v.generalize, accessed 28/9/17

in two locations east and west of Fiji. If the geographic locations could be explained by biological connectivity or environmental homogeneity, then the bioregion was retained as a non-contiguous bioregion; if not they were separated into distinct bioregions as was the case for Bioregion 69 (Figure 6).

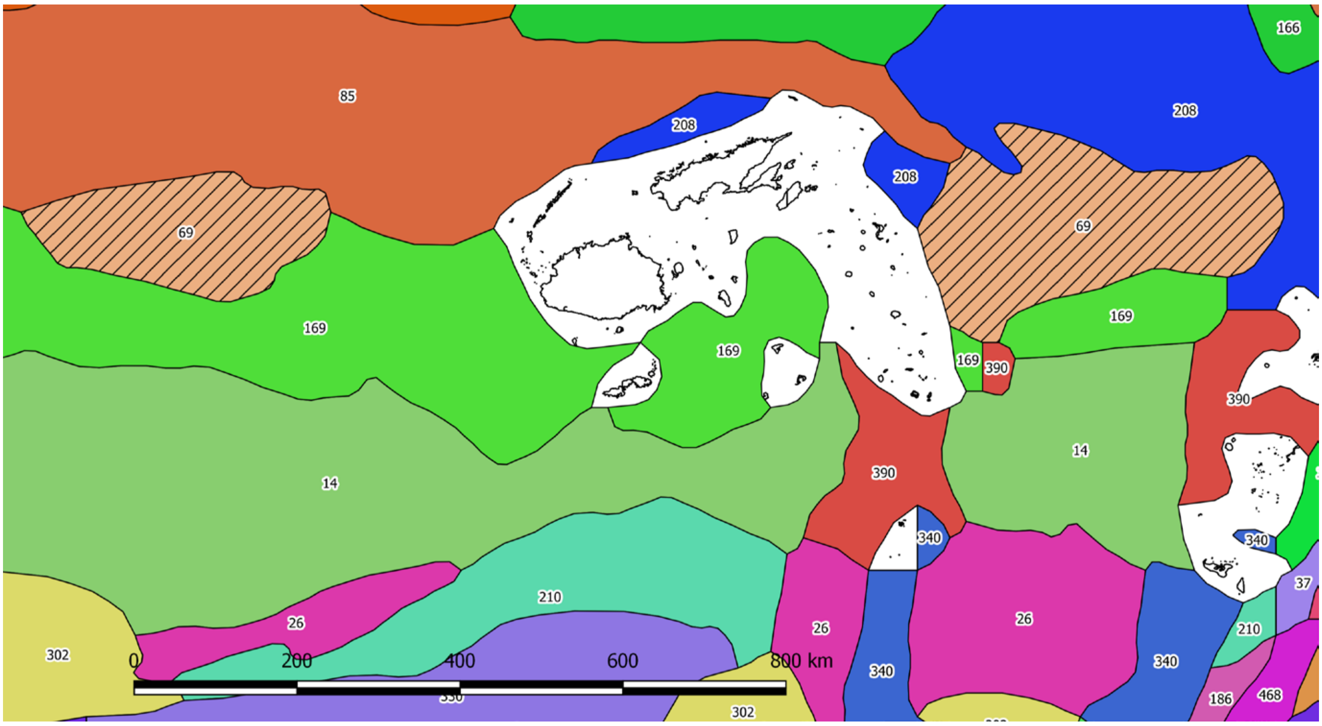

FIGURE 6: Example of post-processing decision making for non-contiguous bioregions.

3.3 REEF-ASSOCIATED BIOREGIONS METHODS

Reef-associated bioregions include shallow coral reef habitats, sea grasses, mangroves, and other reef-associated habitats such as sand and mudflats out to 20 km offshore or shallower than 200 m depth (but see Section 6), whichever was furthest from land.

The total biodiversity in these ecosystems remains largely undersampled, as in, data for reef-associated ecosystems do not exist everywhere. None-the-less, each MACBIO country, and some other Pacific Island countries, had species occurrence data, as well as environmental data, available for their reef systems. Thus, a finer-scale classification of reef-associated areas was possible in these shallower areas where both biological and environmental data were used. There were sampling sites in all MACBIO and other Pacific countries and territories, but their distribution lacked the spatial comprehensiveness and consistency needed for spatial planning (Wilson et al. 2009). Thus, survey records from these sites needed to be extrapolated in space. To provide a spatially contiguous and comprehensive coverage, the survey records were spatially modelled, producing grids of the probabilities of observation. These probability grids were then used to produce the marine coastal classification.

3.3.1 Biological data collation and standardisation

We collated biodiversity records across the study area from a variety of shallow reef-associated habitat surveys and monitoring programmes (4,804 fish sampling sites of which 863 sites had hard and soft coral data and 1,702 sites had (other) invertebrate data). The sampling methods and species targeted often differed depending on the focus of the intended research or project. Thus, the data across the studies needed to be standardised. All samples were collated to include species data, methods used by data providers, and differences in the type of data provided, for example, whether mean fish species' densities for a standardised area (250 m2) or presence/absence records. All records were standardised by conversion to presence-absence records for all taxa, which was the most common level from all providers (Table 2).

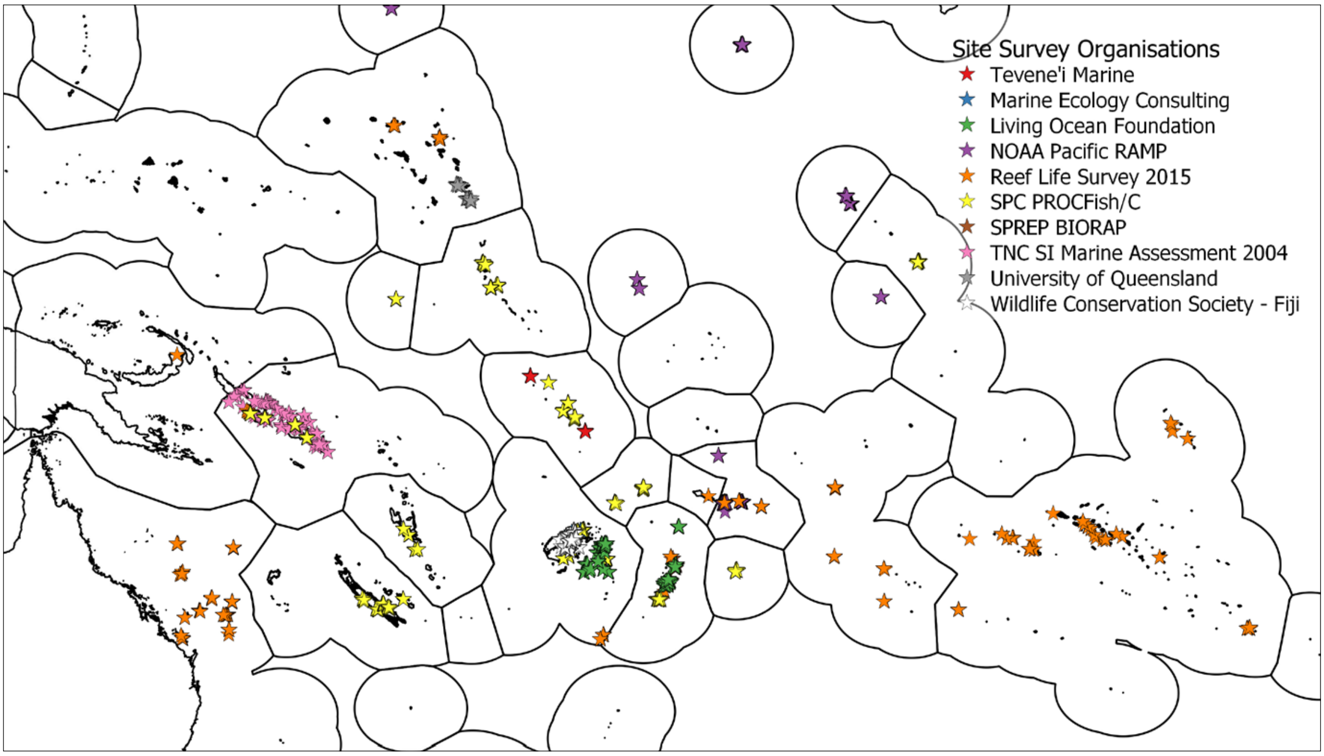

FIGURE 7: Map showing locations of fish, coral and other invertebrate surveys used.

Different numbers of species were included in the database for the three taxa. For fishes, georeferenced reef survey data for 4,804 sites were collated for 1,405 species. Most species in the dataset are only recorded a few times (Figure 8).

FIGURE 8: Ordered frequency distribution of fish species observations in the dataset, where each column represents one of the 1405 species.

For invertebrates, the database contained 300 mobile species from 1,702 sites, and 321 hard coral species and soft coral taxa (genus level) from 863 sites.

The database for fishes contained survey data from a mix of providers (Table 2), which targeted different suites of species in their work. We subset the species data into: a) species covered by all data providers with high confidence in identification (e.g. surgeon fishes); b) species covered by some data providers, but not surveyed by others; and c) species that were encountered only opportunistically by all because they are rare, cryptic, or difficult to identify. We discarded species in (c) because they are known to be difficult to identify with low numbers of sightings and/or there were inconsistencies in the sampling (either with regard to the use of less reliable-that is, not peer reviewed-or variable methods, or observers) which would lead to model uncertainty. The revised fish database contained only the species data for which we had high confidence in their correct identification and in the sampling method. This amounted to 1,014 species.

Coral and invertebrate data were all collected using reliable methods and observers. All coral and invertebrate data were either collected as presence-absence data or converted to that from abundance records, using all available records.

3.3.2 Treatment of rare species

Within the list of consistently sampled fish species, after their treatment as described above, there were still many species that were only sighted a few times. This is likely to have two main reasons: 1) they are cryptic everywhere and thus rarely recorded; or 2) they are endemic species that only occur in a limited part of the project area (and few sites were sampled within their distribution). Fish species with low numbers of records (n< 30) that might fit into these categories were listed so that the endemics amongst them can receive special consideration during the spatial planning process. Therefore, species with fewer records than 30 were not modelled, following standard procedure (Elith 2000). For hard corals and invertebrates which were undersampled across the region, we excluded species with fewer than 30 occurrences from modelling, and kept the data for selected undersampled species, again for use in the planning process but not the classification process, as per the fish data.

After this treatment of the rare, endemic, cryptic or undersampled corals and invertebrates (as described in Sections 3.3.1 and 3.3.2 above), adequate presence/absence data for the modelling remained for 435 fishes, 258 species of hard and soft corals, and 114 invertebrate taxa.

TABLE 2: Datasets used to derive reef-associated bioregions

	PARAMETER	SOURCE	COUNTRIES
1	Reef fish	Khaled bin Sultan Living Oceans Foundation	Fiji, Tonga
2	Reef fish	Marine Ecology Consulting (Ms Helen Sykes)	Fiji
3	Reef fish	National Oceanic and Atmospheric Administration	Pacific Remote Island Areas (PRIAs), Samoa
4	Reef fish	Reef Life Survey	Tonga, Cook Islands, Niue, French Polynesia, American Samoa, Solomon Islands, Pitcairn, Vanuatu, Marshall Islands
5	Reef fish	Secretariat of the Pacific Community	Fiji, Kiribati, Nauru, New Caledonia, Niue, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna
6	Reef fish	South Pacific Regional Environment Programme	Tonga, Nauru
7	Reef fish	The Nature Conservancy	Solomon Islands
8	Reef fish	University of Queensland (Dr Maria Beger)	Marshall Islands, Papua New Guinea
9	Reef fish	Dr Daniela Ceccarelli	Tuvalu
10	Reef fish	Dr Daniela Ceccarelli, Ms Karen Stone	Tonga
11	Reef fish	PIPA (Dr Stuart Sandin, Dr Randi Rotjan)	Kiribati
12	Reef fish	WCS	Fiji
13	Coral	University of Queensland, Australia (Dr Doug Fenner)	Marshall Islands
14	Coral	Dr Doug Fenner	Tonga, Nauru
15	Coral	PIPA (Dr Randi Rotjan, Dr Sangeeta Mangubhai)	Kiribati
16	Coral	University of Queensland, Australia (Dr Emre Turak, Dr Andrew Philips, Dr Zoe Richards)	Papua New Guinea
17	Coral	Dr Doug Fenner	American Samoa
18	Coral	TNC Rapid Ecological Assessment (Dr Peter Houk)	Micronesia (Chuuk)
19	Coral	The Nature Conservancy	Solomon Islands
20	Coral	University of British Columbia (Dr Simon Donner)	Kiribati
21	Coral	WCS	Fiji
22	Coral	Museum of Tropical Queensland (Dr Paul Muir)	New Caledonia
23	Invertebrate	Secretariat of the Pacific Community	Fiji, Kiribati, Nauru, New Caledonia, Niue, Solomon Islands, Tonga, Tuvalu, Vanuatu, Wallis and Futuna
24	Invertebrates	Marine Ecology Consulting (Dr Helen Sykes)	Fiji
25	Coral reefs	UNEP-WCMC, (2010).	Global distribution
26	Mangroves	Giri C, et al. (2011).	Global distribution

3.3.3 Predicting probabilities of observation for each species

All the environmental variables across the AOI available from the Bio-Oracle database were initially considered[8] (Tyberghein et al. 2012) at a resolution of 9x9 km. Data were sourced from Bio-Oracle because they were reliable and consistent throughout our AOI (Tyberghein et al. 2012). The variables available represent the four broad dimensions thought to influence the distribution of shallow-water marine organisms: (1) nutrients and dissolved oxygen, (2) cloud cover and (3) temperature and light resources associated with latitudinal patterns13 (Tyberghein et al. 2012). Some of these parameters co-vary, so to avoid over-parameterization and multicollinearity, we tested all pairs of variables for correlation. For highly correlated predictors ($r > 0.6$), one of the paired variables was excluded based by judging their ecological relevance for coral reef-related organisms. The final predictor set consisted of: calcite, mean chlorophyll alpha concentrations, mean sea surface temperature (SST), pH, maximum photosynthetically available radiation (PAR), mean PAR, and nitrate.

We applied generalised additive modelling (GAM) to create models that use major environmental predictors of species observations to generate spatial predictions of the probabilities to observe species across the entire region. For sites with no species data, these models predict the probability of observing the species using environmental factors thought to influence the suitability of an area for a species (Elith et al. 2006). Using 9x9 km analytical spatial units, we modelled species with a binomial distribution and the best model identified, and predicted species probability for all coastal analytical units, including un-surveyed ones. This analysis used the gam function in the “mgcv” package in “MuMIn” in R v.3.2.5. These models were created for 807 species in total, with 435 fishes, 258 hard and soft corals, and 114 invertebrates.

3.3.4 Clustering to create reef-associated bioregions

For all the shallow water sites, we took the species observation probabilities from the models and used hierarchical clustering with Ward (Clarke 1993) to identify clusters of sites with similar assemblages as raw reef-associated bioregions (Figure 8). Cells consisted of a 9 km by 9 km vector grid within 20 km from shore or shallower than 200 m depth, whichever was furthest from land.

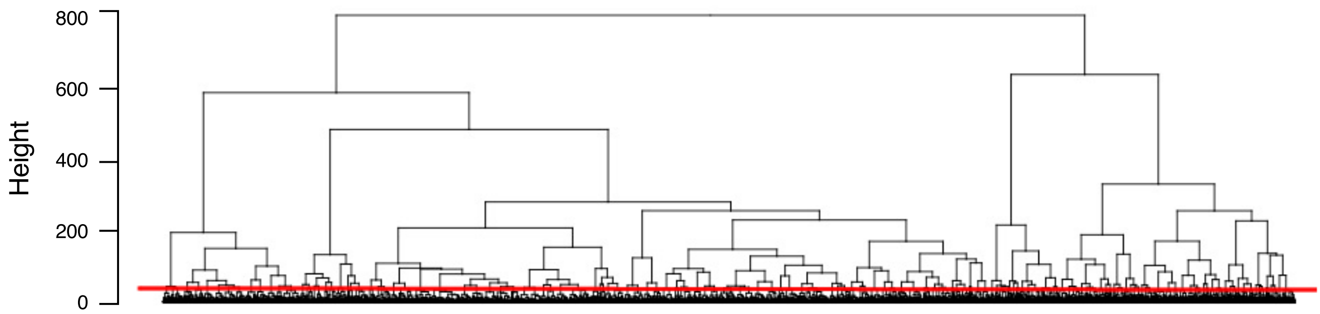

FIGURE 9: Dendrogram for reef-associated bioregional classification

3.3.5 Smoothing and categorising reef-associated bioregions

As in deepwater bioregions, the raw regions derived from clustering were smoothed using the GRASS generalized algorithm “snakes” method with default parameters[9]. Further manual editing was conducted to finalise the smoothing in areas where bioregion boundaries were not adequately smoothed through automated processing.

[8] www.oracle.ugent.be, accessed 28/9/17

[9] grass.osgeo.org/grass73/manuals/v.generalize.html, accessed 28/9/17

3.4 BIOREGION NAMES AND DESCRIPTIONS

Finally, the resulting draft bioregions were assigned unique code identifiers, draft names and initial descriptions. Whilst codes and names were assigned to bioregions across the AOI, descriptions were only provided for deepwater bioregions since knowledge of these offshore environments is less well known. Descriptions for the less-well-understood deepwater bioregions were provided to draw attention to habitats and environmental variables that influenced the delineation of each bioregion. These bioregions are now ready to be reviewed and, as necessary, revised based upon in-country marine expert input.

The draft naming system for the bioregions was created based on the following factors:

1. existing geographic place names;
2. geomorphic feature types within each cluster;
3. environmental variables that influence the delineation of each cluster; and
4. notable key underwater features.

Careful consideration was given when assigning names to the deepwater bioregions since most boundaries extend beyond the EEZs of countries.

4 TECHNICAL RESULTS

4.1 DRAFT MARINE BIOREGIONS ACROSS THE SOUTHWEST PACIFIC

The technical bioregionalisation analysis resulted in the division of the entire AOI into draft deepwater and reef-associated bioregions across the Southwest Pacific including the Solomon Islands. A total of 262 deepwater bioregions and 102 reef-associated bioregions were defined. Most were contiguous but some had multiple, non-contiguous parts. Many deepwater bioregion boundaries extended beyond countries' EEZs and also into areas beyond national jurisdiction. A majority of the deepwater bioregions share boundaries with neighbouring countries as did many reef-associated bioregions. Names and descriptions of bioregions are provided in Wendt et al. (2018). Note that whilst in-country knowledge of reef systems is relatively high, knowledge of the deep-sea environments is lower. For this reason, we have offered some information about each deepwater bioregion (Wendt et al. 2018).

Final numbers of bioregions, per country, is provided in Table 3. Because many bioregions cut across national boundaries they are listed in more than one country. The numbers of bioregions in the table reflect the technical results before in-country expertise is used to refine and revise the bioregions.

TABLE 3: Number of draft deepwater and reef-associated bioregions described per country as an output of this analysis.

COUNTRY NAME	NUMBER OF DEEPWATER BIOREGIONS	NUMBER OF SHARED DEEPWATER BIOREGIONS	NUMBER OF REEF-ASSOCIATED BIOREGIONS	NUMBER OF SHARED REEF-ASSOCIATED BIOREGIONS
American Samoa	9	9	2	2
Cook Islands	30	27	6	4
Fiji	23	23	12	3
French Polynesia	52	23	16	5
Kiribati	54	47	11	2
Marshall Islands	34	19	9	2
Micronesia	41	32	19	4
Nauru	6	6	1	1
New Caledonia	31	24	8	1
Niue	6	6	2	2
Palau	19	18	4	0
Samoa	6	6	1	1
Solomon Islands	33	26	19	6
Tokelau	8	8	2	2
Tonga	35	27	4	3
Tuvalu	13	13	4	3
Vanuatu	20	18	7	3
Wallis and Futuna	9	9	3	3

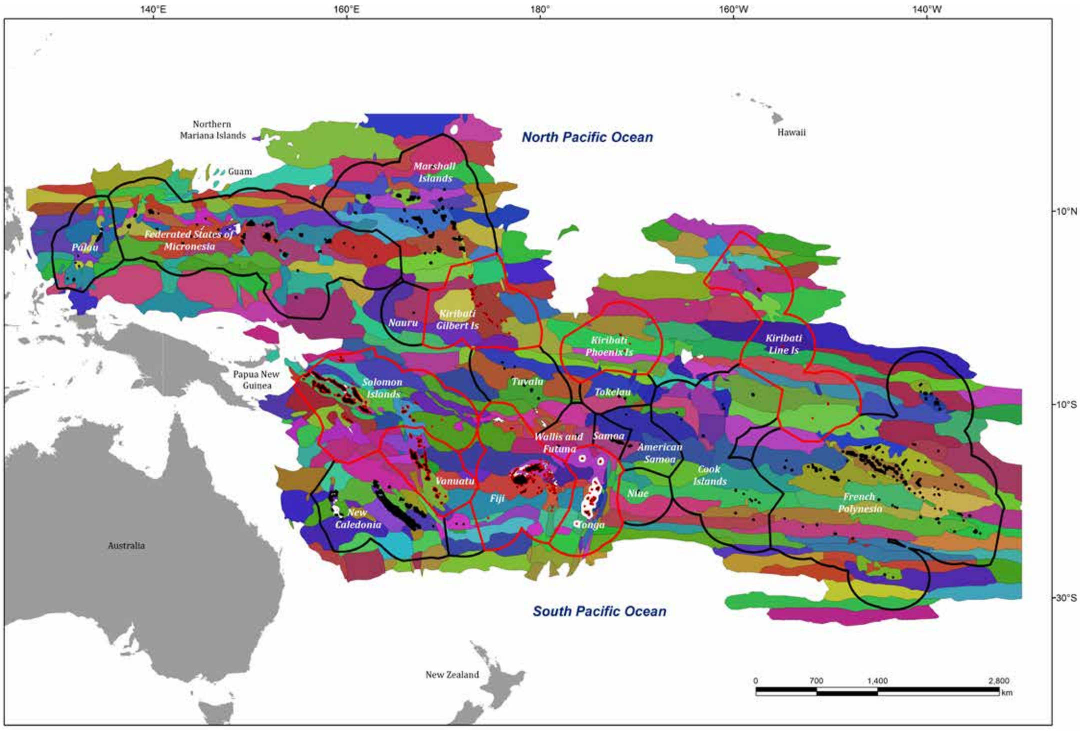

FIGURE 10: Draft deepwater bioregions for the Southwest Pacific including MACBIO countries (red solid line).

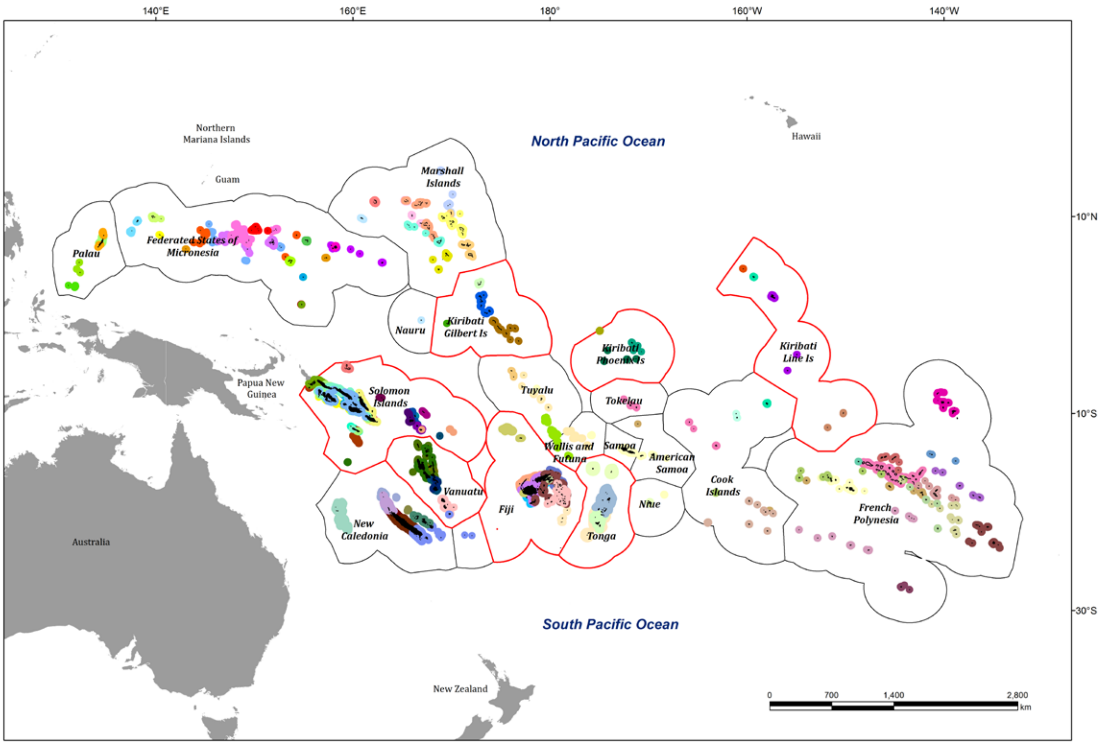

FIGURE 11: Draft reef-associated bioregions for the Southwest Pacific including MACBIO countries (red solid line). Reef areas are exaggerated in this figure for ease of viewing.

In both figures above, the different coloured areas represent different bioregions. Because the colour palette available to both was not sufficient, some different bioregions may appear to be the same colour. Bioregions specific to the Solomon Islands are presented in Section 6.

5 DISCUSSION

This work was done to support national marine planning efforts in Pacific Island countries and territories. It provides value-neutral, sub-national descriptions of the marine diversity within Pacific Island countries and territories. Whilst spatial planning for ecologically representative marine protected areas in the Solomon Islands requires much more than this, our marine bioregions form an important biophysical data layer in the process (Lewis et al. 2017). However, true ecological representativeness also requires using the information you have about habitats, species and ecological processes (Lewis et al. 2017). Additionally, most natural resource managers have social, economic and cultural objectives they wish to achieve so consideration of human uses and values is pivotal to achieving these multiple objectives (Lewis et al. 2017).

Big ocean states in the Pacific, including Fiji, Kiribati, the Solomon Islands, Tonga and Vanuatu, are aiming to do better, in terms of protecting their ocean (e.g. United Nations Ocean Conference Voluntary Commitments[10]). Many Pacific Island Countries, including the Solomon Islands, are party to the Convention on Biological Diversity and committed to meeting the CBD goals in implementing an ecologically representative network of marine protected areas[11]. Until now, a mechanism to systematically implement ecologically representative networks of Marine Protected Areas at national scales, within Pacific Island countries, had not been available.

The bioregions resulting from this technical analysis provides, for the first time, marine bioregions across the Southwest Pacific at a scale, which can be used as a basis for comprehensive, in-country consideration of what a representative network of Marine Protected Areas could look like. The methodology is repeatable, statistically robust and based on many sets of comprehensive and reliable data available across the Southwest Pacific.

Even so, the marine bioregions presented here are termed “draft” bioregions because they still require in-country input from Solomon Islands experts (see Section 6). Local marine experts, can, review and revise (as appropriate) the bioregion names, boundaries and descriptions to better reflect their local knowledge of their marine ecosystems. This coupling of technical analysis and expert input ensures a solid basis for future marine planning at a national scale and is a relatively unique approach to the creation of bioregions which normally rely on either one approach or the other – albeit always informed by spatial data (Longhurst 2006, Spalding et al. 2007, UNESCO 2009, O’Hara et al. 2011, Reygondeau et al. 2012, Keith et al. 2013, Kulbicki et al. 2013, Green et al. 2014, Proud et al. 2017).

Even after expert review, the authors acknowledge that the analysis and methods upon which the bioregions are based will still not be perfect, because they are based upon available information, which is incomplete. As more information comes to light the bioregions presented here can be improved and refined.

In particular, it is acknowledged that the epiphotic (or photic), mesophotic, bathyl, abyssal, hadal and benthic ocean zones host asssemblages of organisms that may not vertically align. Sayre et al. (2017), for example, used environmental data to create three-dimensional maps of the ocean, resulting in a comprehensive set of 37 distinct volumetric region units, called ecological marine units (EMUs) at various depths in the oceans, globally. Eleven of these are in the tropical SW Pacific (Sayre et al. 2017); this differentiation in the Pacific is not sufficient to support national planning processes. Thus, in an ideal world, one would describe marine bioregions within each vertical ocean “zone” at a scale useful for national management; however, this was not possible given the data constraints at the time of this work. It is also conceptionally difficult to establish protected zones for different depth zones (Venegas-Li et al. 2017), and the scope of current marine spatial planning work in the region does not include such an approach.

Alternatively, different methods can be used to describe bioregions (see Section 2.1 above). For example, Last et al. (2010) present a framework of ten hierarchical layers of “regions” that describe the seabed only, but at different scales from the ocean basin-scale (biogeographic) to the genetic level. Its in-country utility for national-planning purposes in the Pacific has yet to be explored. The clustering of the reef-associated species data could also have been conducted with other methods, for example where species assemblages are tracked together probabilistically (e.g. Foster et al. 2013), or with a network approach (Vilhena and Antonelli 2015). Each of the many types of methods available has pros and cons; we chose approaches that we considered would best match Pacific Island ocean planning requirements and data constraints.

10 oceanconference.un.org/commitments, accessed 28/9/17

11 www.cbd.int/information/parties.shtml, accessed 28/9/17

In national planning, of course, many other considerations and data should inform decisions about where to locate marine protected areas – both biophysical and socio-economic. For example, at the finer scale, habitat and species distribution information within bioregions, where available, should be used to complement bioregions to ensure networks of MPAs that represent the entire range of biodiversity within countries (see Ceccarelli et al. in prep). Further, social, economic and cultural management objectives will obviously require consideration of human uses and values as well as biophysical data in decision-making (Lewis et al. 2017).

The marine environment and the organisms that live in the ocean do not respect national boundaries. As such, the data used in these analyses and the resulting draft marine bioregions extend beyond national boundaries (ABNJ) and can contribute, also, to management of the high seas should an ecologically representative approach to planning be desired.

Overall, our results provide a first, unique and essential step to supporting Pacific Island countries and territories, and beyond, to deliver national, ecologically representative networks of marine protected areas.

6 FINALISING MARINE BIOREGIONS OF THE SOLOMON ISLANDS

6.1 INTRODUCTION

As discussed (Section 1.1), marine conservation work in a number of Pacific Island nations will benefit from outlining bioregions at a scale appropriate for national marine spatial planning. The previous sections of this report present draft marine bioregions across the Southwest Pacific and the technical methods used to derive them. The original technical analysis (in 2016) resulted in 19 draft reef-associated marine bioregions and 33 draft deepwater bioregions in the Solomon Islands' EEZ (see Figure 12 and Figure 13).

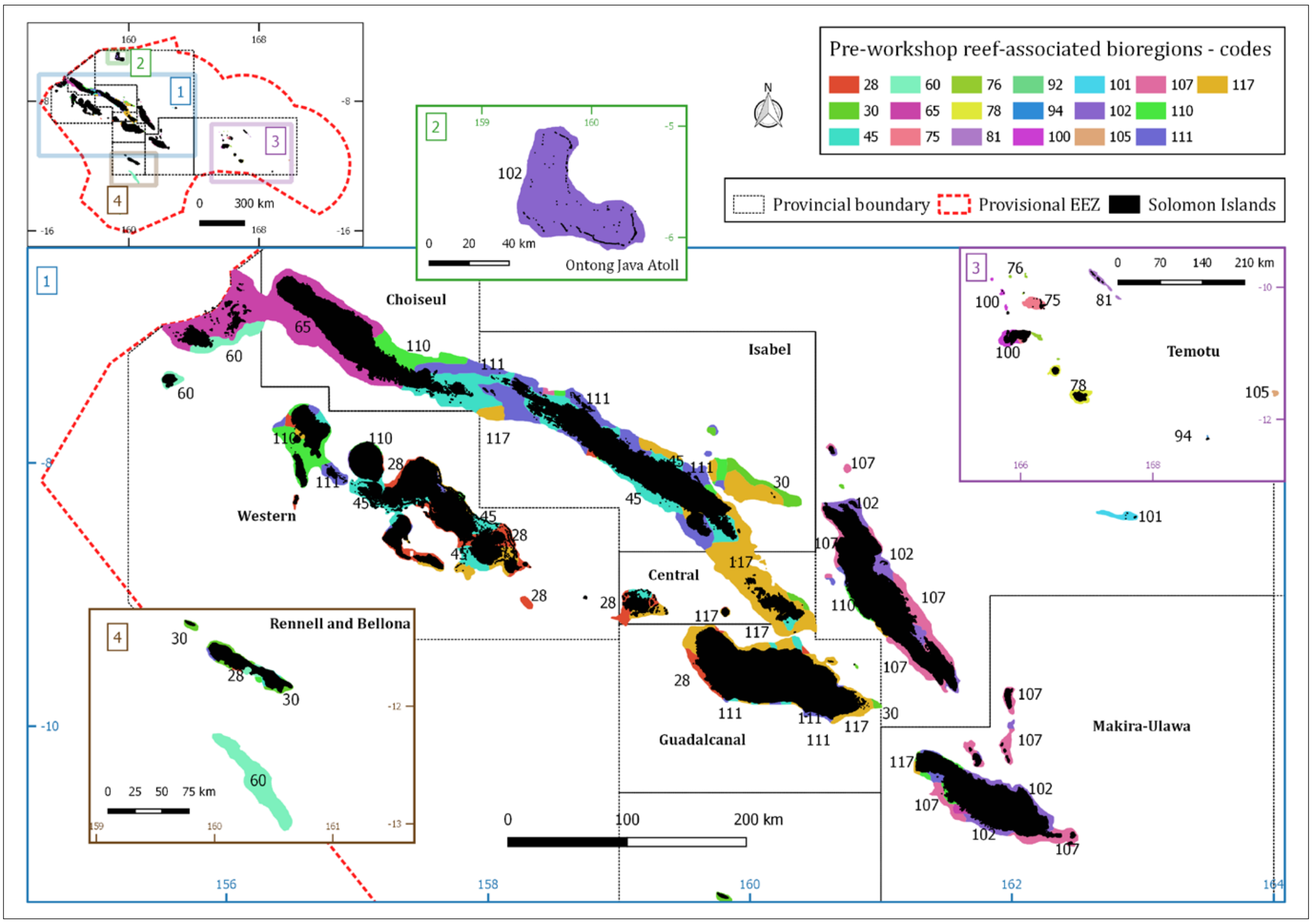

FIGURE 12. Draft reef-associated bioregions of the Solomon Islands. These were the outcome of the original preliminary technical analysis in 2016. Each colour and code represents a different marine bioregion.

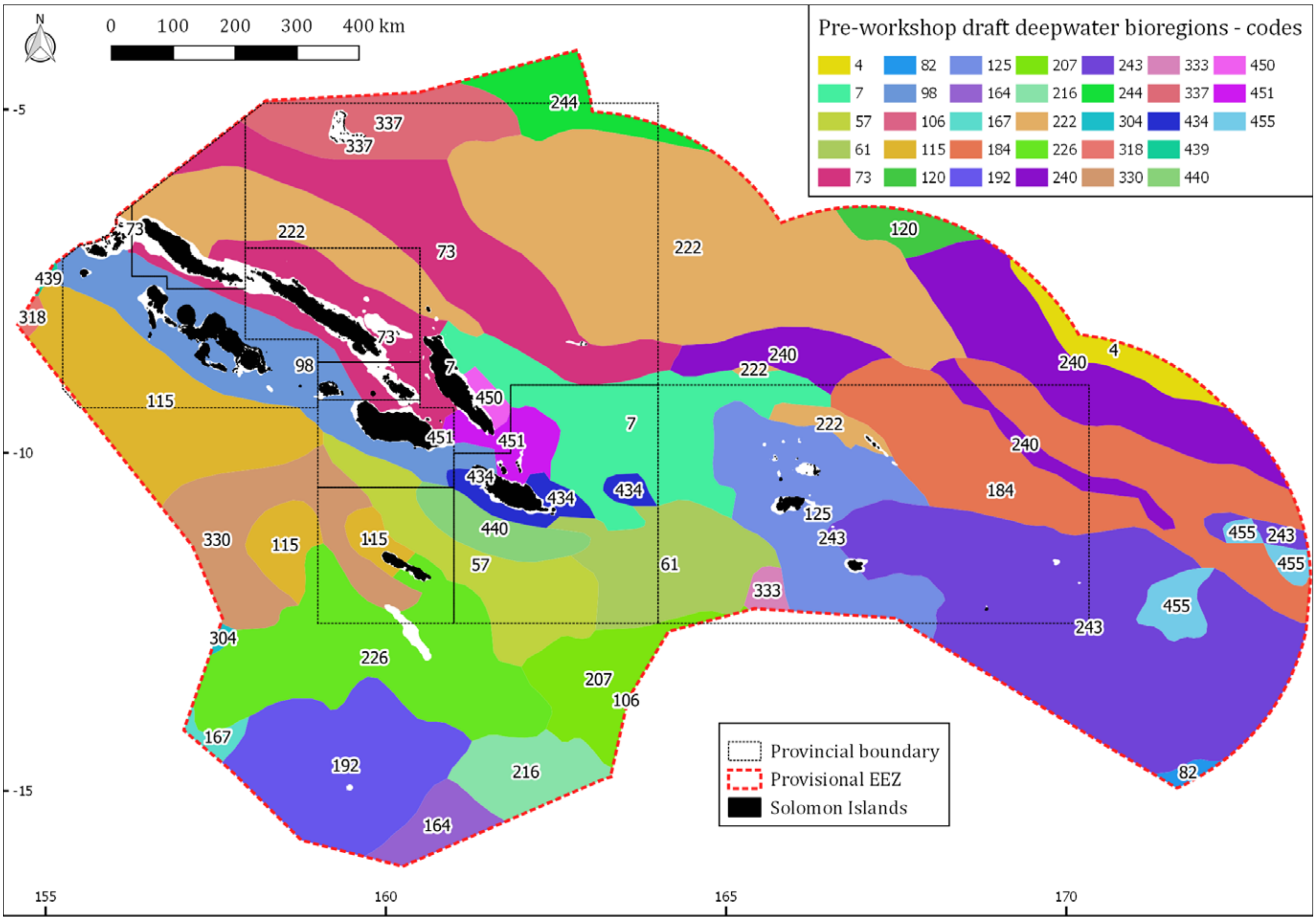

FIGURE 13. Draft deepwater bioregions of the Solomon Islands.
These were the outcome of the original preliminary technical analysis in 2016.
Each colour and code represents a different marine bioregion.

However, this process would be incomplete without input from experts within the Solomon Islands. An important, subsequent, non-analytical step, presented here, was to refine the resultant draft bioregions with marine experts in the Solomon Islands prior to their use in national planning.

This chapter describes the process and outcomes of the workshop, and follow-up discussions and research, during which the marine bioregions of the Solomon Islands were finalised for use.

6.2 METHODS

The workshop to refine the draft bioregions in the Solomon Islands was hosted and chaired by the Ministry of Fisheries and Marine Resources (MFMR) and the Ministry of Environment, Climate Change, Disaster Management and Meteorology(MECDM). It occurred on February 28 2018, in the Solomon Kitano Mendana Hotel, Honiara. The aim of the workshop was specifically to gather marine expertise in the Solomon Islands to review the draft bioregions identified by the process described above. The workshop agenda (Appendix 1) was circulated to all participants (Appendix 2) and clarified with a Powerpoint presentation at the start of the workshop (Appendix 3).

The workshop initially reviewed the reef-associated bioregions, since it was understood that these areas were more familiar to, and better understood by, the participants. Then the participants reviewed the deepwater bioregions. They were asked to consider each bioregion's:

- Location;
- Boundaries;
- Name; and
- Description.

The format in which the information was gathered from participants can be seen in Appendix 4. The 31 participants (Figure 14) were divided into three working groups for the reef-associated bioregions and three for the deepwater bioregions; at both scales, participants were split according to central, western and eastern regions. Each working group had a rapporteur, facilitator and GIS technician.

TABLE 4. Participants assigned to each group

GROUP	GEOGRAPHIC AREA	NAME	MINISTRY/AFFILIATION
Brown	Central Region	Agnetha Vave-Karamui	MECDM – ECD
		Wilson Eta	Isabel Province Government
		Malachi T	MFMR – Central Province
		Rosemary Apa	MECDM – ECD
		Debra Kereseka	MECDM – ECD
		Duta Bero	MFMR – CBRM
		Ivory Akao	MFMR
		Henry Kaniki	TNC
		Lysa Wini-Simeon	Macbio PLO SLB
Blue	Western region	Cozzirieh Posala	SICCP
		Harold Vilia	MFMR
		Rachel Bare- Anita	MID
		Alec Hughes	WCS
		Nelly Kere	MECDM
		Tingo Leve	WWF
		Mirriam Lidimani	MFAET
		Veira Pulekera	SICCP
		Julianna Manusalo	MFMR
		Zelda Hilly	WWF
Pink	Eastern Region	Paul Jay Tua	MFMR
		Jeremiah Kisi	MMERE – Geology Division
		Samson Maeniuta	MFMR
		Joshua Lavisi	MMERE – Petroleum Division
		Jonatha Wara	FFA
		Sebastian Misiga	MFMR
		Marsh Maebiru	MFMR

FIGURE 14. Workshop participants during the 2018 review of the Solomon Islands' bioregions.

Supporting material available to the workshop participants included maps of the draft bioregions (at various scales) for each working group to draw upon, hardcopy maps of biophysical data posted on a "resource wall" and biophysical data available in a GIS (see Appendix 5). The data available were in two groups: data used in developing the bioregions and other biophysical data not used to develop the bioregions but still providing useful biophysical data to inform the refinement of the bioregion boundaries and descriptions.

The participants and working groups were divided/merged in two ways: people with more knowledge about a particular area were allocated to the group dealing with that area; people with more general knowledge chose which group they could work with. Some participants were extremely knowledgeable about more than one area – these individuals were asked to move around the groups which were working on specific geographies.

6.3 RESULTS

6.3.1 Reef-associated

Most reef-associated bioregions were maintained, except 94 and 105; these were excluded from the revised bioregions.

The five reef-associated bioregions of Guadalcanal Province were initially labelled 28, 30, 45, 111 and 117. After the workshop, the five different bioregions remain, but with different configurations, and a new bioregion (200) was created for the coastal areas around Honiara as a result of discussions within one of the working groups (Brown Group). The new bioregion represents the waterfront off and near Honiara, where corals and fishes are more affected by pollution, and lower diversity may be expected. For southern Guadalcanal, Bioregions 45, 111 and 117, were combined into one longer Bioregion (code 111). The western side of Guadalcanal, previously represented by Bioregions 28 and 117, was considered to be mostly Bioregion 28. In northern Guadalcanal there were slight changes to the boundaries of Bioregions 28, 45 and 117, but all three bioregions were retained. Along the eastern side of Guadalcanal (Bioregions 30, 111, 117), Bioregion 30 was merged with 117 and part of Bioregion 111 was changed to 45.

Major changes were made to the reef-associated bioregions of the Central Province: on the eastern side of the Province Nggela Islands, Bioregion 117 was split into three (30, 111, 117) and Bioregion 45 was merged with 117.

In Isabel Province, the total number of bioregions was reduced by two, as Bioregions 28 and 107 were both merged with Bioregion 45. In northeastern Isabel Island, Bioregions 45 and 117 were merged with 111.

In Western Province, the number of bioregions (28, 45, 60, 102, 110, 111 and 117) remained the same, but a number of configuration changes were made. Most notably, Bioregion 28, which originally cut across the south of New Geogia Island to Vangunu Island, and then to Mbulo Island, was significantly reduced in size, with most parts merged with Bioregion 45. The part of Bioreion 28 that encompassed reefs of Rendova and Tetepare Islands was also significantly reduced, with most parts merged with Bioregion 117.

Choiseul Province originally had four bioregions (45, 65, 110 and 111); during the workshop, the Blue Group merged Bioregion 110 with Bioregions 65 and 111 on the northern side of Choiseul Island.

In Malaita Province, all bioregions (30, 101, 102, 107, 110, 111 and 117) were retained, with changes to their boundaries. On northern Malaita Island, Bioregion 107 was merged with 102. In western Malaita, the offshore reef between Auki Harbour and Indispensable Strait (Bioregion 107) was merged with 111 to show that the whole reef system is a single bioregion instead of two.

In Temotu Province, the Pink Group added Bioregion 28 to the existing seven bioregions (75, 76, 78, 81, 94, 100 and 105). The offshore reef north of Tinakula Island was changed from Bioregion 100 to 28. On Tinakula Island itself, reef-associated Bioregion 100 was changed to 103. Bioregion 105, on the far eastern side of Temotu Province on Anuta and Fatutaka Islands was changed to Bioregion 78.

One working group (Brown) made no changes to Bioregions 102, 107 and 117 around Makira Ulawa Province, and another (Pink) suggested no alterations to Bioregions 28, 30 and 60 in Rennell and Bellona Province, partly through lack of knowledge.

The revised, and final, reef-associated bioregions for the Solomon Islands are shown in Figure 15.

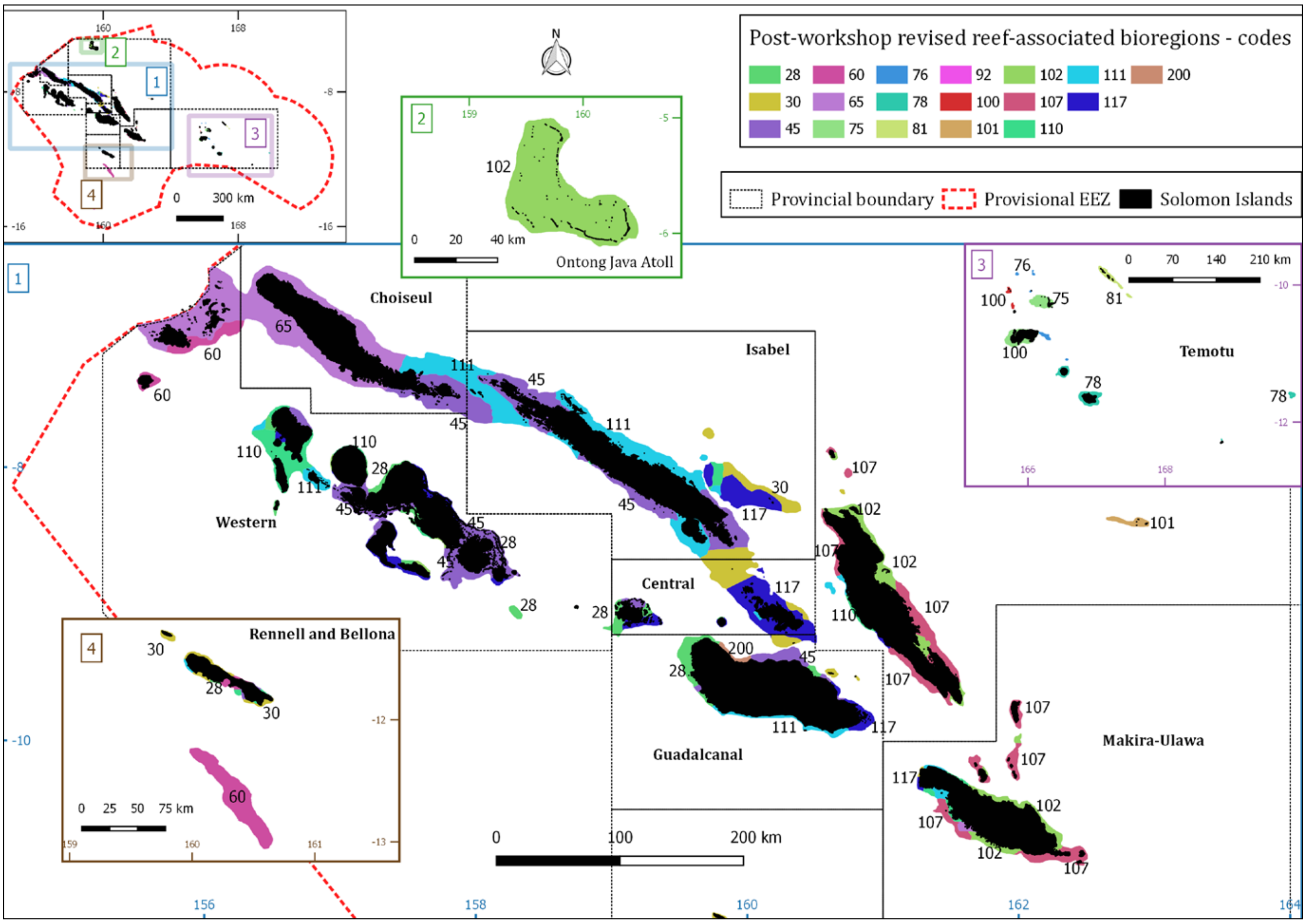

FIGURE 15. Revised reef-associated bioregions of the Solomon Islands.

6.3.2 Deepwater

During the workshop, the 33 deepwater bioregions for the Solomon Islands were condensed into 26 bioregions. The major changes were made to the northwestern side of the Solomon Islands EEZ; there was general agreement about the deepwater bioregions in the southeastern half of the country. Bioregions 120, 164, 167, 192, 244, and 304 were merged with Bioregion 222. Bioregion 226 was split into two halves, and one part of the non-contiguous Bioregion 240 (the part closer to the islands) was merged with 222. The lower part of the non-contiguous Bioregion 115 was merged with Bioregions 330 and 318 to become Bioregion 439. To the north of the islands, parts of Bioregions 222 and 73 were merged, and also included within Bioregion 439. The parts of Bioregion 73 closest to the islands were merged with Bioregion 98.

The revised, and final, deepwater bioregions are shown in Figure 16.

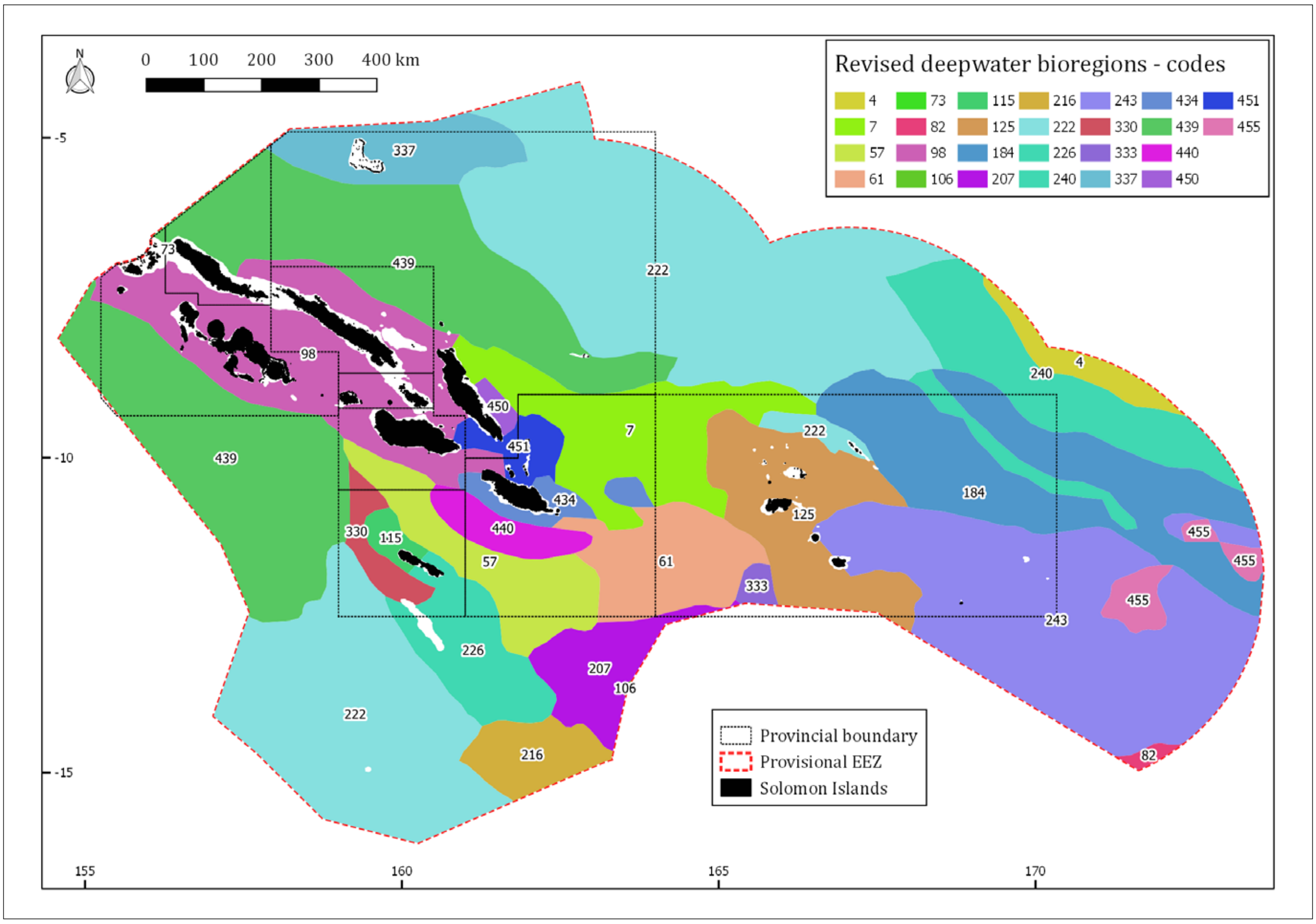

FIGURE 16. Revised deepwater bioregions of the Solomon Islands.

6.4 CONCLUSIONS

Most bioregions were subject to comments and suggested changes during the 2018 workshop, based on the workshop participants' knowledge.

As a result, all the reef-associated bioregions boundaries were changed, except those around Makira-Ulawa and Rennell and Bellona Provinces, where very little information was available. Two reef-associated bioregions were dropped and one was added; the additional bioregion was a reflection of reef environments close to dense human habitation and the influence this is likely to have on biodiversity. Almost all bioregions were subject to boundary changes. Of the original 19 reef-associated bioregions, revision during the workshop resulted in 18 reef-associated bioregions.

A previous bioregionalization of the Solomon Islands had already separated just the inshore habitats into three groupings: the main island chain; the reefs of the Ontong Java Plateau; and Rennell, Bellona and the Indispensable Reefs (Green and Mous 2008). These were all embedded within the "Bismarck-Solomon Seas Ecoregion" of the Coral Triangle. The Santa Cruz Islands were excluded from the bioregionalization (Green and Mous 2008). The new regionalisation, presented in this report, discerns a finer scale and more comprehensive differentiation for Solomon Islands' reef-associated habitats. This therefore, better reflects the reality of the Solomon Islands as being in the centre of global marine diversity as well as being at a scale much more useful for national marine planning.

The deepwater bioregions were all modified, mostly by combining bioregions according to biophysical similarities. The majority of changes occurred in the northwestern portion of the EEZ; deep-water bioregions in the southeastern portion were left largely intact. This resulted in a simplification of the bioregions from 33 to 26.

These marine bioregions now form a robust and technically sound framework upon which, together with other data, to base marine spatial planning decisions in the Solomon Islands. In particular, by including adequate MPAs within each bioregion, the Solomon Islands can ensure an ecologically representative network of MPAs which can help their effectiveness and ability to achieve social, economic and cultural objectives. The final bioregion names and/or descriptions for the Solomon Islands are in Appendix 6, and spatial data for these can be downloaded at: http://macbio-pacific.info/macbio-resources/ under the "Planning" tab or under http://macbio-pacific info/categories/solomon-islands/.

None-the-less, we acknowledge that marine data for the Solomon Islands remain imperfect, and the bioregions should be subject to further review as more data are made available.

7 ACKNOWLEDGEMENTS

This project was supported and embraced by the country partners of the MACBIO project. The work has been guided by the Oceans12 and the Oceans12 Technical Working Group of the Solomon Islands especially the Chairs: the Ministry of Fisheries and Marine Resources, Ministry of Environment, Climate Change, Disaster Management and Meteorology and the Prime Minister's Office. We would like, particularly, to thank the many scientific experts in Solomon Islands who provided their time at the national workshop and beyond, to review the draft marine bioregions for the country. Significant assistance, particularly with data provision, was rendered by the following people and institutions: Daniela Ceccarelli; David Feary; Doug Fenner; Peter Houk; Khaled bin Sultan Living Oceans Foundation (Kate Fraser, BR Samaniego, J Eyre); Marine Ecology Consulting (Helen Sykes); Marine Conservation Consulting (Maël Imirizaldu), Museum of Tropical Queensland (Paul Muir); National Oceanic and Atmospheric Administration; Phoenix Islands Protected Area (Stuart Sandin, Randi Rotjan, Sangeeta Mangubhai); Reef Life Survey; Secretariat of the Pacific Community (SPC); Secretariat of the Pacific Regional Environment Programme (SPREP); Vava'u Environmental Protection Association (Karen Stone); The Nature Conservancy (TNC); UNEP-WCMC; University of British Columbia (Simon Donner); WCS (Fiji); WorldFish Centre; World Resources Institute (WRI). We are further grateful to the University of Queensland for assistance with contract administration, to Geoscience Australia for releasing Mr Sullivan for this project. The report benefitted from the input of Mark Spalding and Piers Dunstan.

The Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO) project was the main source of funding for this work. MACBIO is funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety's (BMU) International Climate Initiative (IKI). It is being implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) with the countries of Fiji, Kiribati, Solomon Islands, Tonga and Vanuatu. It has technical support from the Oceania Regional Office of the International Union for the Conservation of Nature (IUCN) and is working in close collaboration with the Pacific Regional Environment Program (SPREP).

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9 APPENDICES

9.1 APPENDIX 1 WORKSHOP AGENDA

TIME	AGENDA ITEM	LEAD
8:30 – 9:00	Registration Prayer Welcome Remarks	Ms Rosalie Masu
9:00 – 9:05	**Agenda item 1: Introductions** ▪ Overview of meeting & expectations ▪ Introductions of participants and resource walls	Ms Agnetha Vave-Karamui
9:05 – 9:15	**Agenda Item 2:** *Objective: Reviewing Solomon Island's marine spatial planning process*	
9:15 – 9:25	**Presentation:** ▪ Review of the current process to achieve a national marine spatial plan	Ms Rosalie Masu
9:25 – 9:40	**Agenda item 3:** *Objective: Review status of report on Solomon Island's special and unique marine areas (SUMA)*	
9:40 -10:00	**Presentation:** ▪ Key outcomes of the Special and or Unique Marine Areas workshop which identified special, unique marine areas	Ms Lysa Wini-Simeon
10:00-10:30	TEA BREAK	
10:30 – 10:40 10:40 – 10:50 10:50 – 11:10 11:10 – 11:20	**Agenda item 4:** *Objective: Introduction of approach used to describe Solomon Island's marine environment and results* **Presentations:** ▪ Introduction to the concept of different marine biological regions (bioregions) for Solomon Islands, how a description of the entire marine environment of Solomon Islands differs from special, unique marine areas ▪ Methods and data used to create draft preliminary marine biological regions (bioregions) for Solomon Islands ▪ Marine data including seabed geomorphological features found in Solomon Islands ▪ Introduction to Solomon Island's draft preliminary marine bioregions	Mr Hans Wendt Mr John Kaitu'u
11:20 – 13:00	**Agenda Item 5:** *Objective: Review the reef-associated marine bioregion boundaries and descriptions* ▪ Description of group work and breakout into groups ▪ Expert review and revision of Solomon Islands' reef associated marine biological region boundaries and descriptions ▪ Feedback from each group	Dr Leanne Fernandes Break-out groups Group rapporteurs
13:00 – 14:00	Lunch	
14:00 – 15.15	**Agenda Item 6:** *Objective: Review the deep-water bioregion boundaries and descriptions* ▪ Expert review and revision of Solomon Islands' deep-water marine biological region boundaries and descriptions	Break-out groups
15:15-15:30	Afternoon tea	
15:30 – 16.30	**Agenda Item 6: cont.** ▪ Feedback from breakout groups	Group rapporteurs
16.45 – 17.00	**Agenda Item 7:** ▪ Next steps	O12 TWG Chairs

9.2 APPENDIX 2 WORKSHOP PARTICIPANTS

PARTICIPANT NAME	AGENCY
Agnetha Vave-Karamui	MECDM – ECD
Wilson Eta	Isabel Province Government
Malachi T	MFMR – Central Province
Rosemary Apa	MECDM – ECD
Debra Kereseka	MECDM – ECD
Duta Bero Kauikona	MFMR – CBRM
Ivory Akao	MFMR
Henry Kaniki	TNC
Lysa Wini-Simeon	MACBIO
Hans Wendt	MACBIO
Anja Nicolay-Grosse Hokamp	MECDM – ECD /MACBIO
Cozzirieh Posala	SICCP
Harold Vilia	MFMR
Rachel Bare- Anita	MID
Alec Hughes	WCS
Nelly Kere	MECDM
Tingo Leve	WWF
Mirriam Lidimani	MFAET
Veira Pulekera	SICCP
Julianna Manusalo	MFMR
Zelda Hilly	WWF
John Kaituu	MACBIO
Paul Jay Tua	MFMR
Jeremiah Kisi	MMERE – Geology Division
Samson Maeniuta	MFMR
Joshua Lavisi	MMERE – Petroleum Division
Jonatha Wara	FFA
Sebastian Misiga	MFMR
Marsh Maebiru	MFMR

9.3 APPENDIX 3 WORKSHOP PRESENTATION

MACBIO

Identifying marine biological regions to describe Solomon Islands' marine environment

Mendana Hotel, Wednesday, 28th February 2018

SPREP Secretariat of the Pacific Regional Environment Programme

IUCN

giz

On behalf of: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of the Federal Republic of Germany

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MACBIO

Welcome

Ms Rosalie Masu

Co-Chair Oceans12 TWG

MACBIO

Agenda Item 1: Introduction

Ms Agnetha Vave-Karamui

Co-chair Oceans12 TWG

- Government has made several high-level commitments to improving ocean governance – in Cabinet, national legislation & internationally (e.g. United Nations Ocean Conference)
- Commitments are being implemented through the Ocean12 and the *Ocean12 Technical Working Group (TWG)*

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Agenda Item 1: Introduction

- The workshop today is part of implementing more integrated ocean governance – particularly through participatory marine spatial planning
- A Marine Spatial Plan is a management tool that distributes human activities in marine areas within spatially and temporally defined zones to achieve identified ecological, economic, cultural and social objectives – such as those defined by the Ocean12 for the Solomon Islands.

MACBIO

Agenda Item 1:

Introductions & meeting expectations

MACBIO

Agenda Item 2: Background MSP

Ms Rosalie Masu

- 2015: Inaugural intra-government Ocean Summit hosted by the Prime Minister
- 12 Ministries (Ocean12)
- Finding: potential for synergies, conflicts, complementarity, coordination
- Decision: integrated ocean governance needed, including spatial planning

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Integrated ocean governance

The way that organizations or countries manage the ocean at the highest level, and the systems for doing this.

A policy approach by a responsible authority to achieve integration of one or all of the following:
. Spatial e.g. across jurisdictions & ecosystems);
. Different interests and uses by different sectors;
. Social, economic and environmental objectives.

Fully integrated ocean governance applies to all aspects of ocean use, whether public or private, and includes planning through to decision making, management, implementation, enforcement and performance monitoring.

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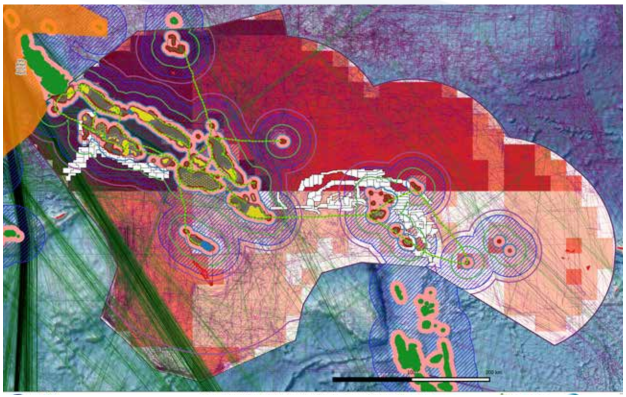
Integrated Ocean Governance

- Why does the government want to do integrated ocean governance including marine spatial planning?



Vision

A healthy, secure, clean and productive ocean which benefits the people of the Solomon Islands and beyond

Initial steps

- In April 2016: Cabinet decision to support more integrated ocean governance
- In August 2016: Ocean12 meeting:
  - Established an Ocean Technical Working Group
  - Developed roadmaps for the types of interventions needed, including for spatial ocean planning
  - Is reaching out to partners

IOG

Integrated Ocean governance has many aspects:

1. Legal
2. Policy/strategies/plans
3. Institutional
4. Decision-making
5. Knowledge
6. Compliance
7. Capacity (both skills and numbers of people)
8. Marine spatial planning
9. Financial
10. Jurisdictional
11. Consultation/participation

Marine Spatial Planning

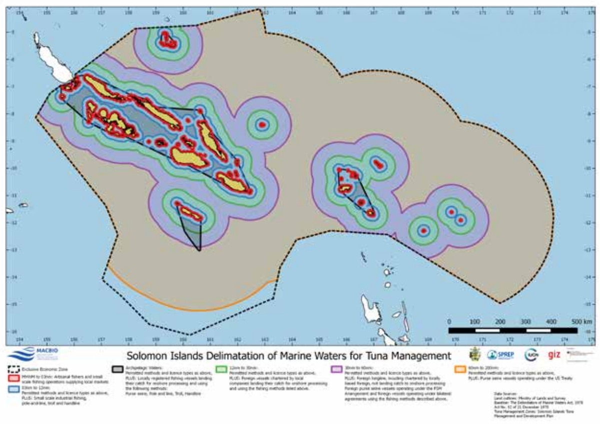
- Marine spatial planning is one of those aspects
- Government has decided that this is one of its priorities (the others include an Ocean Policy, legislation, sustainable financing and capacity development)
- This workshop contributes to marine spatial planning

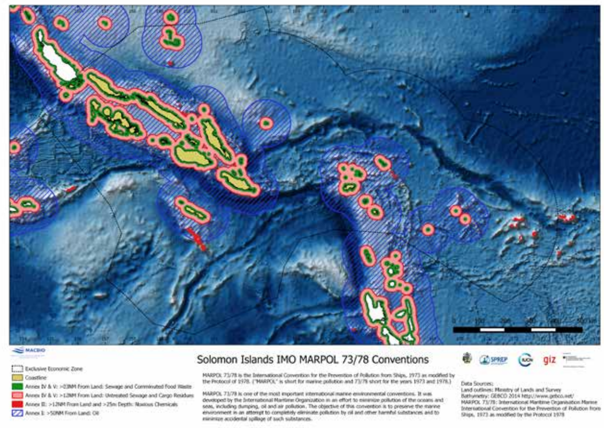
What is marine spatial planning?

- On land spatial planning happens all the time to decide where to put: industry; schools; ports; protected areas; rubbish dumps; etc
- Done to: promote certain activities in some areas; limit uses in other areas; separate conflicting uses; protect special places;
- Often this is codified into an holistic spatial plan
- In the ocean, one can do the same thing

What is marine spatial planning?

- "Marine Spatial Planning" is, in fact, already happening in the Solomon Islands in a way
  - Within Arnavons Community Marine Park
  - Fisheries management areas
  - IMO zones
  - LMMAs





MSP Workplan

MACBIO

- **Legal review - done*** **2015**
- **Develop IOG objectives – done*** **2015**
- **Build consultation/communication plan - done** **mid-2017**
- **Identify biologically special ,unique marine areas - done*** **mid-2017**
- **Build draft zone typology*** **mid - 2017**
- Develop **bioregions for Solomon Islands's ocean*** NOW
- Design zone placement guidelines* early-2018
- Public consultation – what uses/protection where? 2018
- Draft marine spatial plan late 2018
- Preparation for consultation late 2018
- National/public consultation on draft spatial plan 2019
- Revise and finalise draft spatial plan late 2019
- Informal consultation within government/stakeholders 2019
- Formal Government Gazette 2020
- Inform public of new Ocean Plan 2020

Review of work to date

MACBIO

1. Identification of government-articulated objectives that integrated ocean governance can help achieve
2. Review of legislative support for integrated ocean governance
3. Collation of >100 datasets (physical, biological, uses, risks)
4. Identification of Special, Unique Marine Areas
5. Draft ocean zone typology

1. Objectives

MACBIO

Analysis of documents to identify government-articulate objectives that integrated ocean governance can help achieve:

- **Sustainable development and use**
- **Food security**
- **Climate change resilience and adaptation**
- **Environmental protection and rehabilitation**
- **Protection from natural disasters and**
- **Conservation of biodiversity**

2. Legal review

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Review of legislative support for integrated ocean management

- 58 instruments reviewed
- Many of the necessary legislative and policy settings already exist
- There are gaps
- Could address harmonisation & gaps through new overarching policy/legislation

3. Data

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Open source/freely available spatial data collated so far:

- Physical: 67
- Biological: 36
- Uses: 10
- Risks: 3

4. Special, unique marine areas

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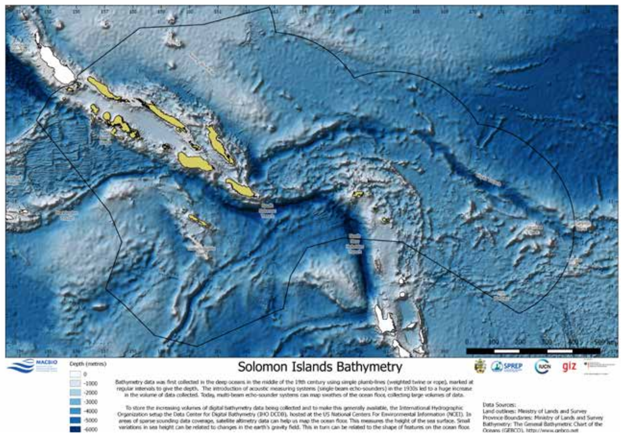
To be addressed in Agenda Item 3

5. New ocean zones to be mainly beyond reefs

- Communities have traditional knowledge and management systems that apply inshore
- A marine spatial plan will reinforce and support these systems
- If communities wish, and only if they wish, they can codify their community management plans in formal legislation within an MPA or MSP
- This will remain the case within an MSP



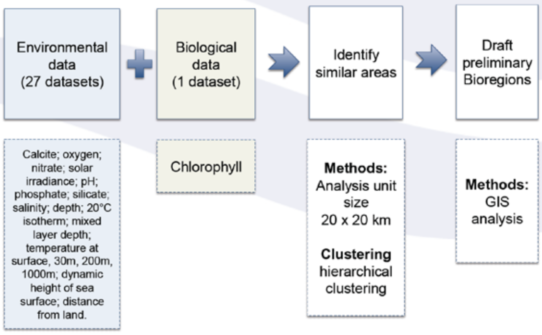
5. New ocean zones will be comprehensive*

- Ocean zones should:
  - Help achieve the Integrated Ocean Governance vision and objectives (which are also the vision and objectives of the Marine Spatial Planning)
  - support existing uses and values
  - ensure sustainability of the ecosystems which provide the goods and services that people want
  - be comprehensive (*beyond the reef edge)

5. Draft Ocean Zone names

- General Use Zone
- Locally Managed Marine Zone/Cultural Zone
- Sustainable Use Zone
- Limited Use Zone
- No-take Zone
- Special Zone

Building Deep Water Bioregions



5. Draft Ocean Zones & objectives

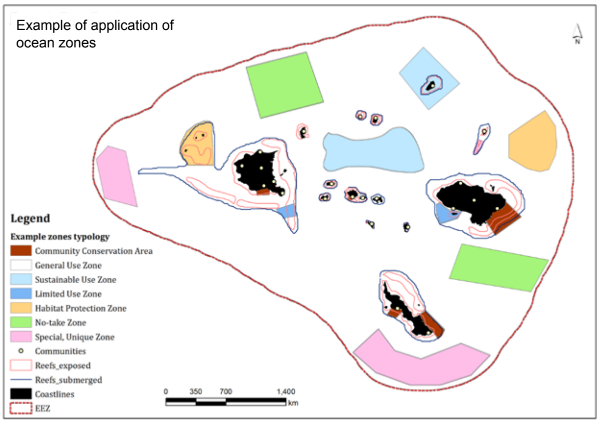
- **Sustainable Use Zone: To allow for sustainable use of Solomon Islands' renewable marine resources including non-artisanal commercial fishing**
- **Limited Use Zone To protect the integrity of habitats, biodiversity, food security and livelihoods by allowing limited fishing, including non-artisanal fishing as well as non-extractive activities that do not directly impact habitats.**

5. Draft Ocean Zones & objectives

- **No-take Zone:To protect natural biodiversity along with its underlying ecological structure, support natural environmental and fisheries processes and replenishment, and to promote education and recreation by restricting all extractive uses.**
- **Special Zone To protect, conserve and restore specific species, habitats or cultural value of concern by eliminating the key threats.**

5.Ocean Zones & activities allowed and not allowed

Activities	General Use Zone	Localy Managed Marine Zone/Cultural Zone	Sustainable Use Zone	Limited Use Zone	No-take[6] Zone/Marine Protected Zone	Speci
Mining - (other than non-commercial sand, gravel and aggregate minng) incl exploration, prospecting[1]	Yes	No	No	No	No	No
Benthic disturbance (trawling/ dredging, weighted lines)	Yes	No	Yes	No	No	tbd per site[4]
Industrial Fishing [1,2]	Yes	No	Yes	No	No	tbd per site[4]
Other non-artisanal fishing[1, 3]	Yes	tbd per site[4]	Yes	No	No	tbd per site[5]
Non-commercial sand, gravel and aggregate mining	Yes	tbd per site[4]	Yes	No	No	tbd per site[6]
Fish Aggregating Devices (FADs)	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Sea Cucumber harvesting	Yes	tbd per site[4]	Yes	No	No	tbd per site[5]
Anchoring/walking/standing	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Traps or Fish Fences	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Gleaning	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Hand spearing	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Netting (mesh, gill, cast, etc)	Yes	tbd per site[4]	Yes	No	No	tbd per site[4]
Hand-line Fishing	Yes	tbd per site[4]	Yes	Yes	No	tbd per site[4]
Tow-line fishing	Yes	tbd per site[4]	Yes	Yes	No	tbd per site[4]
Non-extractive uses (diving, swimming, snorkelling, kayaking, sailing, boating, canoeing, etc)	Yes	tbd per site[4]	Yes	Yes	Yes	tbd per site[4]
Mariculture	Yes	tbd per site[4]	Yes	No	No	No
Works (dredging, reclamation, building, laying cables)[1]	Yes	tbd per site[5]	Yes	No	No	No
Artificial modification (e.g. beach nourishment, restocking[5], artificial reefs[9)]	Yes	tbd per site[4]	Yes	No	No	No
Ecosystem restoration (e.g. coral or clam re-introduction, stock enhancement[8], removal of crown-of-thorns starfish)	Yes	tbd per site[4]	Yes	Yes	Yes	Yes
Research	Yes	tbd per site[5]	Yes	Yes	Yes	Yes
Dumping of solid and liquid waste including sewage and ballast water from marine vessels beyond 12nm[7]	Yes	No	No	No	No	No



Agenda Item 3
Special, unique marine areas report

MACBIO

Ms Lysa Wini-Simeon

Expert workshop held 26 July 2017

Aim: To describe special, unique marine areas in the Solomon Islands for use in national planning, in permit and licencing decisions, in EIAs, etc.

Agenda Item 3: Criteria

MACBIO

- Justification
- Geographic explicitness
- Type of information source(s)
- Number of information sources
- National or international obligations

- Scoring system: 3 = very good; 2 = good; 1 = minimal
- Assess on a RELATIVE basis

Justification

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- Amount, detail and nature of justification
- Consider whether there are:
  - rare, vulnerable or unique habitats or species
  - species of concern
  - important life stages of key species (feeding, breeding, nesting, migration),
  - physically or biologically outstanding attributes e.g. unique geomorphology or high species diversity
  - habitats of high complexity or size
- Score 3 = if more than 5 justifications; 2 = 3-4 justifications; 1 = two or less justifications

Geographic explicitness

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How well-defined and well-justified are the boundaries of the site?

Score 3 = the boundaries exactly match the biophysical features identified as important

2 = the boundaries broadly match the features

1 = the boundaries are quite loosely defined

Type of information sources

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Type of information sources:
- Are the information source(s) reliable and verifiable?

Score 3 = at least one peer reviewed scientific paper or report discusses this site

2 = no peer reviewed papers are available but there are good reports and expert advice available

1 = mainly anecdotal and inferred information

Number of information sources

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Number of information sources
- information is more likely to be correct and can be cross-referenced and triangulated if multiple information sources are used.

Score 3 = if four sources or more

2 = two to three sources

1 = just one source

National/International obligations

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Are the areas associated with species or habitats for which the country has:
- national obligations (e.g. under law) &/or
- international obligations (e.g. under Conventions) or

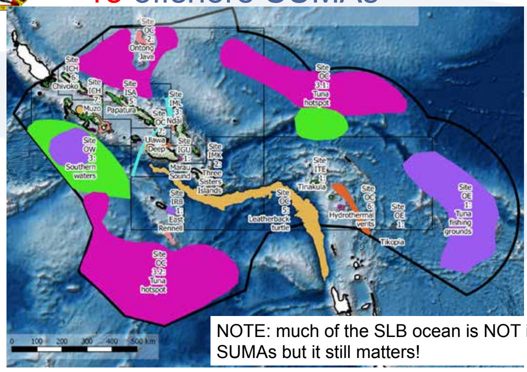
Score 3 if more than one species/habitat with obligations

2 = one species/habitat; 1 = nil known

Results

- 55 inshore special, unique marine areas defined
- 15 Offshore special, unique marine areas defined
- Draft report prepared & available NOW
- Need to seek out further clarification on some site boundaries (on the side of this workshop)

Results - 55 inshore & 15 offshore SUMAs



MSP Workplan

- **Legal review - done* 2015**
- **Develop IOG objectives – done* 2015**
- **Build consultation/communication plan - done mid-2017**
- **Identify biologically special ,unique marine areas - done*mid-2017**
- **Build draft zone typology* mid - 2017**
- Develop **bioregions for Solomon Islands's ocean*** NOW
- Design zone placement guidelines* early-2018
- Public consultation – what uses/protection where? 2018
- Draft marine spatial plan late 2018
- Preparation for consultation late 2018
- National/public consultation on draft spatial plan 2019
- Revise and finalise draft spatial plan late 2019
- Informal consultation within government/stakeholders 2019
- Formal Government Gazette 2020
- Inform public of new Ocean Plan 2020

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

Agenda item 4.1: Describing Solomon's entire marine environment – expert workshop - Hans Wendt

28 February 2018

SPREP IUCN giz

What are bioregions and why do we care?

Old paradigm

– Protect areas where we know there is high biodiversity

– Protect areas with endemic species

NOW we know

a) Protecting these areas is important BUT not enough to protect the ecosystems AND

b) We have imperfect information about these anyway

New Paradigm

Ecologically representative network of marine protected areas

- Convention on Biological Diversity (CBD)
- Includes examples of all habitat types

We don't have complete information about biodiversity in the marine environment so how do we choose "ecologically representative" (versus special, unique) areas to protect?

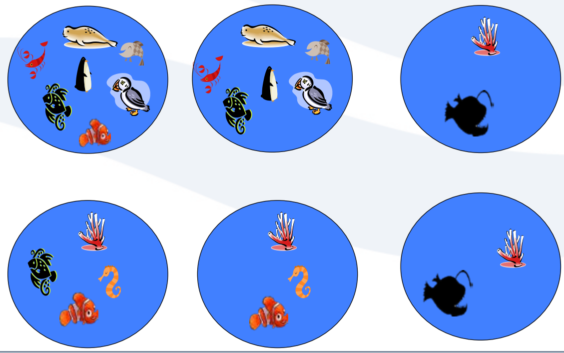
Solution: use bioregions

- It is a value-neutral way to describe the entire marine environment of Solomon.
- Bioregions can be described using comprehensive layers of environmental data: surrogates for imperfect biological information.
- Every part of Solomon's marine environment belongs to one bioregion or another.
- No bioregion is more important than any other.

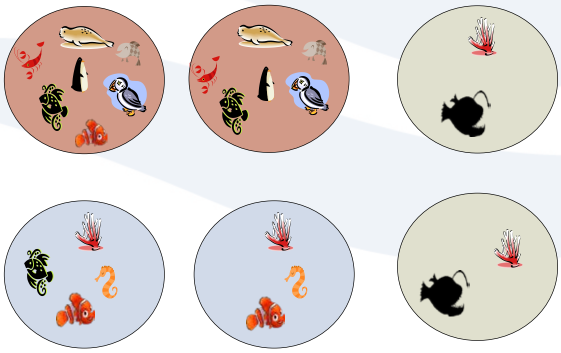
But what are bioregions?

- Areas of relative similarity
  - Habitats, communities, and physical features within a bioregion (e.g. seamounts, coral reefs, fish, invertebrates) are more similar to each other than those same features in a different bioregion.
- A way to represent the full range of biodiversity
- A classification of habitat and environmental types

Example of Species Assemblages



"Bioregions" with similar (not exactly the same) species

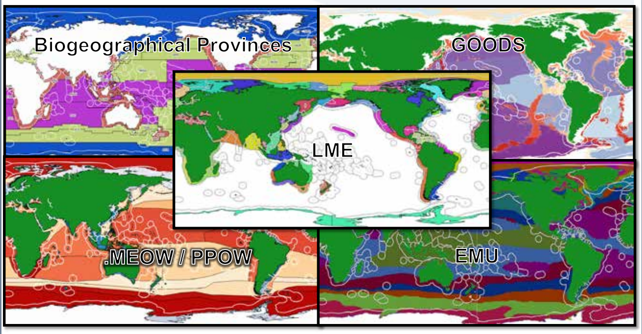


Bioregions as a planning tool

If one objective is an ecologically representative network of marine protected areas covering a minimum percentage (10% or 30%) of the marine environment with the goal of enhancing biodiversity

Then a protected area target of this percent for each bioregion will help meet that objective

Existing global bioregions



Longhurst, 2010. Biogeographical Provinces

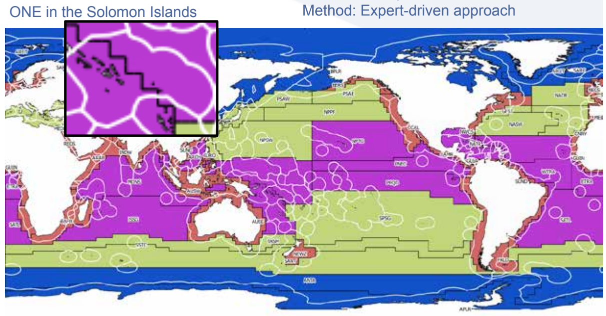
4 global provinces: 3 in Oceania

52 sub-provinces: 9 in Oceania

ONE in the Solomon Islands

Factors: Based on biophysical proxies: phytoplankton abundance, mixed layer depth, currents, clarity.

Method: Expert-driven approach



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Bioregions as a planning tool

- The MACBIO project is working with 5 countries to support Marine Spatial Planning within their EEZs.
- Global-scale bioregions are not useful for national scale marine planning and management.
- Solomon needs finer scale descriptions of its entire marine environment

Questions?

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

Agenda Item 4.2. Methods used to create bioregions for Solomon Islands (& SW Pacific) Hans Wendt

SPREP IUCN giz On behalf of: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of the Federal Republic of Germany

2 Types of Bioregions

- Deep water bioregions
- Reef-associated bioregions (shallow)

NOTE: in working across the five MACBIO countries it was realised that building five different sets of bioregions didn't make biological sense: so we built one set of bioregions across the entire SW Pacific

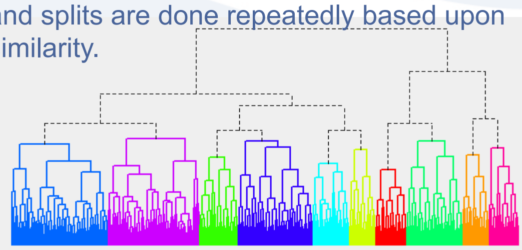
Can then also support OTHER countries doing national MSP

Building deepwater bioregions

Environmental data (30 datasets)	+ Biological data (1 dataset)	→ Identify similar areas	→ Draft Bioregions
Calcite; oxygen; nitrate; solar irradiance; pH; phosphate; silicate; salinity; depth; 20°C isotherm; mixed layer depth; temperature at surface, 30m, 200m, 1000m; dynamic height of sea surface; distance from land.	Chlorophyll	**Methods:** Analysis unit size 20 x 20 km **Clustering** hierarchical clustering	**Methods:** GIS analysis

Clustering Algorithm

Hierarchical Clustering: a hierarchy of clusters; all observations start in one cluster and splits are done repeatedly based upon similarity.



Building Reef-Associated Bioregions

Remotely sensed data	Site-specific survey data			
Environment + Biological data (7 datasets)	+ Fish, Coral, Invert groups	→ Combine survey data with remotely sensed data	→ Identify similar areas	→ Draft Bioregions
Calcite, nitrate concentrat'n solar irradiance pH, sea temperature + chlorophyll	3,846 sites 435 fish 258 hard and soft corals, 114 inverts	General Additive Models of the probability of observing each species	**Methods:** Analysis unit size 9 x 9 km **Clustering** hierarchical clustering	**Methods:** GIS analysis

Data Contributors

AquaMaps, Convention on Biological Diversity, SPREP, MACBIO, CSIRO, Sea Around Us, Western and Central Pacific Fisheries Commission, Oregon State University, VLIZ, USF University of South Florida, USGS science for a changing world, WCS, InterRidge, ZSL Institute of Zoology, GEBCO, Pacific Community Communauté du Pacifique, NASA, Institute for Marine Remote Sensing, WWF, GRID Arendal, NOAA

MACBIO
Marine and Coastal Biodiversity Management in Pacific Island Countries

Agenda Item 4.3. Data and maps (Resource wall) and introduction to Solomon's seabed geomorphology – John Kaitu'u

SPREP IUCN giz On behalf of: Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety of the Federal Republic of Germany

Agenda Items 4.3: Data and maps

a) Resource wall: two groups of data on maps
   i) some of the 30-odd datasets used in technical analysis just described and
   ii) over 20 other datasets that might be useful in this workshop

Here we present more information about one key dataset: seabed geomorphology – "habitats" of the seabed

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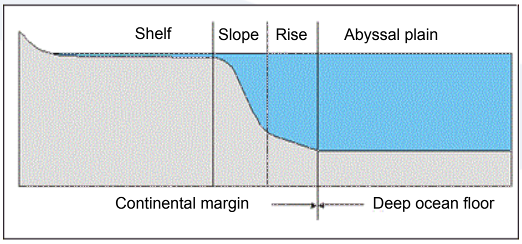
Geomorphological features of the ocean floor

MACBIO

Abyssal plains

- Generally flat, level or gently sloping
- Thick deposits of sediment



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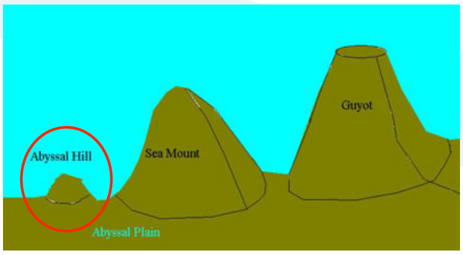
Abyssal hills

- Small elevations
- Peak height between 300 – 1000 m above seafloor



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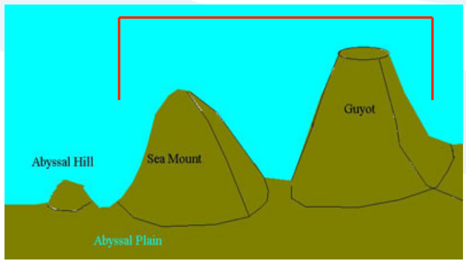
Abyssal mountains

- Submarine mountains
- Peak height greater than 1000 m
- Includes seamounts and ridges



http://bclearningnetwork.com/LOR/media/es11/unit8/U08L02/hillmountguyot.JPG

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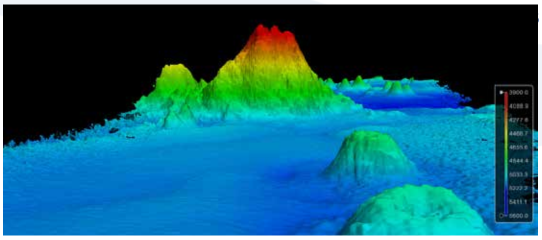
Seamounts

- Large conical shaped mountains
- Peak height greater than 1000 m from seafloor
- Isolated or in groups



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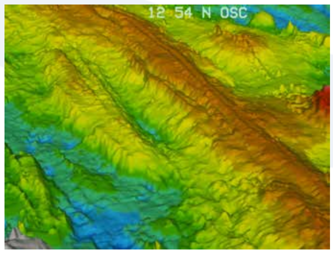
Ridges

- Long, narrow elevations with steep sides
- Peak height greater than 1000 m from seabed



http://www.livescience.com/images/i/000/073/788/original/east-pacific-rise.jpg?interpolation=lanczos-none&downsize=*:1000

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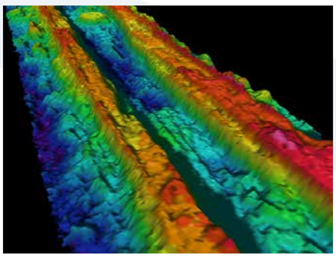
Rift valleys

- Long valleys
- Found between spreading ridges



http://oceanexplorer.noaa.gov/explorations/05galapagos/logs/dec5/media/multibeam_ridge_600.jpg

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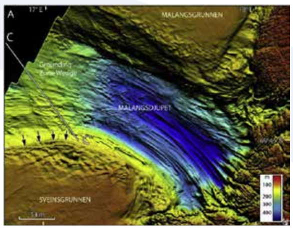
Troughs

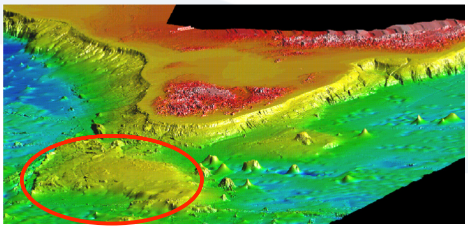
- Large deep areas
- From 100 m to over 1000 m depth



https://www.researchgate.net/profile/Martin_Jakobsson2/publication/282377233/figure/fig5/AS:281937424994341@1444230529290/Fig-6-a-Multi-beam-bathymetric-data-showing-a-submarine-palaeo-ice-stream-bed-ice-fl.png

Plateaus

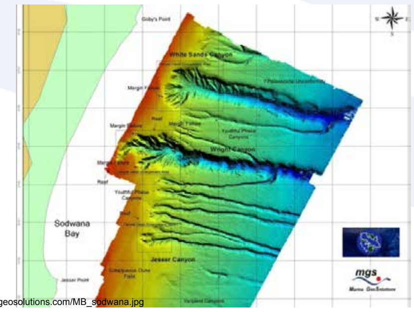
- Mostly flat, large, elevated areas
- Sudden drop off on one or more sides



https://www.researchgate.net/profile/Peter_Harris14/publication/284032480/figure/fig5/AS:297399898656781@1447917069918/Figure-613-Bathymetric-image-from-Geoscience-Australia-showing-a-three-

Submarine canyons

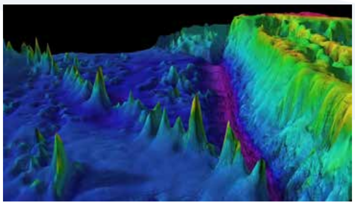
- Steep-walled, winding valleys over 1000 m deep
- Associated with high biomass and biodiversity
- Relatively high productivity



https://www.marinegeosolutions.com/MB_sodwana.jpg

Trenches

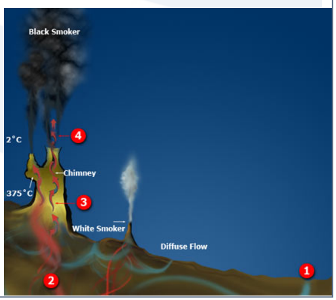
- Very deep (6 – 10 km), long and narrow depressions of ocean floor
- Part of the Hadal zone (depths of 6000 m or more)
- Highly specialised and often endemic fauna



https://www.whoi.edu/cms/images/kermadec_trench_x_415673.jpg

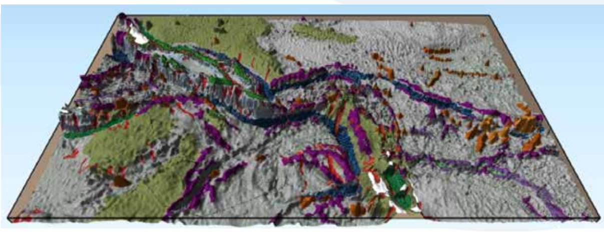
Hydrothermal vents

- Mineral rich, geothermally heated seawater rises towards ocean crust, cools and forms vent structures
- Unique biodiversity



http://www.divediscover.whoi.edu/images/vent-smoker.jpg

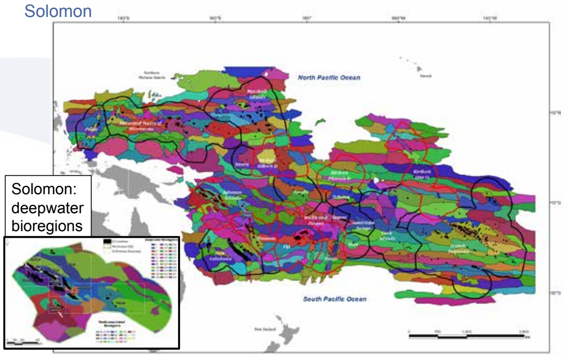
3-D Geomorphology



Agenda Item 4.3
Results - draft marine bioregions across the SW Pacific INCLUDING the Solomon Islands – Hans Wendt

Result: Deepwater Bioregions

262 Deepwater Bioregions in SW Pacific; **33** Deepwater Bioregions in Solomon



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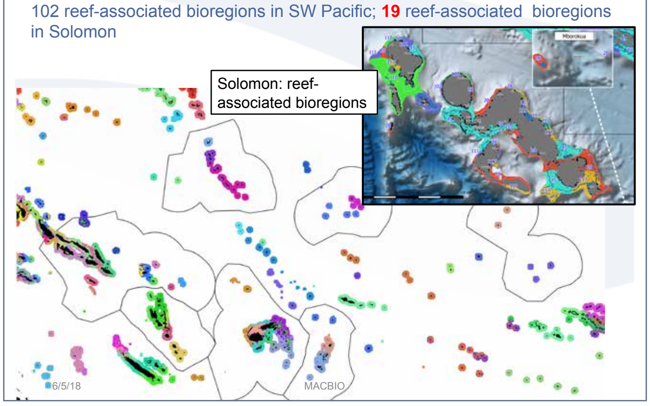
Result: Reef-associated (shallow) bioregions

102 reef-associated bioregions in SW Pacific; **19** reef-associated bioregions in Solomon



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Agenda Item 5: Review reef-associated bioregions
Leanne Fernandes

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Agenda Items 5: Break-out groups

Resources:

a) Resource wall (hard copy maps posted on the wall of (i) some of the 30-odd datasets used in technical analysis and (ii) over 20 other datasets that might be useful
b) Hard copy maps and input forms on tables to guide discussions
c) GIS data (with GIS person to drive it) per table – can pull up any of 140 datasets relevant to Solomon including draft bioregions

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Agenda Item 5. Review the draft reef-associated bioregion boundaries and descriptions

Breakout groups: nominate a rapporteur

All groups to consider:
1. Boundaries and location of the bioregions
2. Names for the bioregions
3. Description of the bioregions

Feedback from breakout groups

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Agenda Item 6. Review the draft deep-water marine bioregion boundaries and descriptions

Breakout groups: nominate a rapporteur

All groups to consider:
1. Boundaries and location of the bioregions
2. Names for the bioregions
3. Description of the bioregions

Feedback from breakout groups

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Agenda Item 7: Next steps
Agnetha Vave-Karamui & Rosalie Masu

- Digitise the boundary changes
- Verify clarity about suggested bioregion name changes and descriptions
- Prepare bioregions report for Solomon Islands
- Distribute draft report back to participants
- Review/discuss participant expectations

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Agenda Item 7: MSP Workplan
Next steps more broadly

- **Legal review - done* 2015**
- **Develop IOG objectives – done* 2015**
- **Build consultation/communication plan - done mid-2017**
- **Identify biologically special ,unique marine areas - done*mid-2017**
- **Build draft zone typology* mid - 2017**
- Develop **bioregions for Solomon Islands's ocean*** NOW
- Design zone placement guidelines* early-2018
- Public consultation – what uses/protection where? 2018
- Draft marine spatial plan late 2018
- Preparation for consultation late 2018
- National/public consultation on draft spatial plan 2019
- Revise and finalise draft spatial plan late 2019
- Informal consultation within government/stakeholders 2019
- Formal Government Gazette 2020
- Inform public of new Ocean Plan 2020

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Summary - expectations

1. Bring information back to communities
2. Improve understanding of resource mgt planning in SLB
3. Know more about marine environment/bioregions
4. Know more about marine spatial planning (MSP), integrated ocean governance (IOG) & the proposed Ocean Policy for SLB
5. Know how to use bioregions in planning
6. How bioregions contribute to IOG & MSP
7. Improve policy coordination across sectors/ministeries
8. Gather information that may be useful for sector planning
9. Complement project work (e.g. WCS) with national planning
10. Understand how offshore observer work related to bioregions
11. See how policy/legal work and bioregions inter-relate
12. Consider reef-associated bioregions vs special, unique areas
13. Consider bioregions against DSM

9.4 APPENDIX 4 WORKSHOP INFORMATION GATHERING

NATIONAL EXPERT WORKSHOP ON THE ESTABLISHMENT OF BIOLOGICAL REGIONS TO DESCRIBE SOLOMON ISLANDS MARINE ENVIRONMENT

EXPERT INPUT FORM

GROUP: ____

BIOREGION NUMBER: ______________________________________

Are there annotations on a hardcopy map associated with this input form? YES / NO

PLEASE CODE THE ASSOCIATED MAP WITH YOUR GROUP COLOUR

SUGGESTIONS (on bioregion location, name, boundary, descriptions)

____

____

____

____

____

____

____

9.5 APPENDIX 5 DATA AVAILABLE TO WORKSHOP PARTICIPANTS

LIST OF BIOREGIONS MAPS, RESOURCE WALL AND E-COPY MAPS AND GIS DATA

Note: RED fonts include some of the data that were used to derive the draft bioregions. The fonts in black indicate data that were NOT used to derive bioregions but directly related to the environmental conditions and how species are distributed in the ocean.

DRAFT BIOREGIONS MAP USED FOR FEEDBACK

1. FOR THE DRAFT PRELIMINARY REEF-ASSOCIATED BIOREGIONS MAPS

Central Province reef-associated bioregions
Choiseul Province reef-associated bioregions
Guadalcanal Province reef-associated bioregions
Isabel Province reef-associated bioregions
Makira_Ulawa Province reef-associated bioregions
Malaita Province reef-associated bioregions
Rennell and Bellona Province reef-associated bioregions
Temotu Province reef-associated bioregions
Western Province reef-associated bioregions

2. FOR THE DRAFT PRELIMINARY DEEP-WATER BIOREGIONS MAPS

Offshore EEZ scale deepwater bioregions
Offshore Western deepwater bioregions
Offshore Central deepwater bioregions
Offshore Eastern deepwater bioregions

RESOURCE WALLS (HARDCOPY MAPS POSTED ON THE WALLS)

1. Solomon Islands Overview Map
2. Solomon Islands bathymetry (depth)
3. Solomon Islands silicate concentration
4. Solomon Islands sea surface temperature
5. Solomon Islands chlorophyll a-concentration
6. Solomon Islands mixed layer depth
7. Solomon Islands nitrate concentration in the ocean
8. Solomon Islands dissolved oxygen
9. Solomon Islands photosynthetically available radiation
10. Solomon Islands phosphate concentration
11. Solomon Islands marine species richness all species from aquamaps
12. Solomon Islands benthic marine species richness from aquamaps
13. Solomon Islands pelagic marine species richness from aquamaps
14. Solomon Islands cold water corals
15. Solomon Islands coral species richness
16. Solomon Islands currents
17. Solomon Islands cyclone tracks
18. Solomon Islands upwelling
19. Solomon Islands downwelling diffuse attenuation coefficient
20. Solomon Islands downwelling eddy frequency
21. Solomon Islands ecologically and biologically significant areas (EBSA)
22. Solomon Islands important bird areas (IBAs)
23. Solomon Islands front count
24. Solomon Islands geomorphology
25. Solomon Islands hydrothermal vents
26. Solomon Islands mangroves, reefs
27. Solomon Islands particulate organic carbon flux
28. Solomon Islands reefs at risk
29. Solomon Islands seamounts and seamount morphology classification
30. Solomon Islands historic tsunami location
31. Solomon Islands ocean productivity
32. Solomon Islands Seamounts pelagic classification
33. Solomon Islands depth classification GEBCO

DATA AVAILABLE TO PARTICIPANTS IN GIS

All of the hardcopy maps listed above were also available on the GIS. In addition, the following data were available on Q-GIS

1. BASE LAYERS

a. Solomon Islands Provisional EEZ
b. Solomon Islands Coastlines
c. Bathymetry data
d. Underwater feature names

2. ENVIRONMENTAL VARIABLES

a. Temperature at 1000 meters depth
b. Temperature at 200 meters depth
c. Temperature at 30 meters depth
d. Depth of 20 degree isotherm
e. Salinity
f. pH
g. Calcite

3. BIOPHYSICAL DATA

a. Mangroves, reefs and seagrasses

b. Geomorphological features

i. Escarpment
ii. Basin
iii. Bridge
iv. Guyot
v. Seamount
vi. Rift valley
vii. Trough
viii. Ridge
ix. Spreading ridge
x. Terrace
xi. Trench
xii. Plateau
xiii. Slope
xiv. Hadal
xv. Shelf classification (high, medium, low)
xvi. Abyssal classification (mountain, hill, plain)

9.6 APPENDIX 6 DESCRIPTION OF REVISED BIOREGIONS OF THE SOLOMON ISLANDS

Descriptions of bioregions are not constrained to national boundaries, and most therefore these descriptions relate to entire bioregions which may span across two or more EEZs.

HABITAT	CODE	NAME	DESCRIPTION
Deepwater	4	Solomon Seamounts	Bioregion consists of a chain of deeper and larger seamounts formed on abyssal mountains and sloping abyssal hills and underlying abyssal plains. SST is high and stable, Chlorophyll-a concentrations are low and stable. Salinity and dissolved oxygen are low. Temperature at 1000m is low, 20°C isotherm is deep, Mixed Layer Depth (MLD) is low and pH is high. Solar irradiance is moderate, silicate, phosphate, nitrate and calcite are low. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak); 4 seamounts type 2 (small with deep peak, most common type); 4 seamounts type 7 (small and short with very deep peaks, shortest); 17 seamounts type 8 (small and short with very deep peaks, deepest type); 2 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). The upper depth is 4500m and the lower depth is 5500m.
	7	Cape Johnson & Solomon Trench	Deep bioregion that contains the Solomon Trench and Cape Johnson Trough. Underlying basin, abyssal hills and mountains and deep seamount ridges, and canyons on the northwestern side. SST moderate and stable, Chlorophyll-a concentrations are low and stable. Salinity and dissolved oxygen are low. Temperature at 1000m is moderate, 20°C isotherm, pH, and solar irradiance are moderate. Silicate, phosphate, nitrate and calcite are low. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak); 2 seamounts type 3 (intermediate size, large tall and deep); 2 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Contains 9 blind canyon types. Contains 1 active, confirmed and 2 active, inferred hydrothermal vents. The upper depth is 2500m and the lower depth is 4500m.
	57	Hammondsport Seamount and Basin	Solomon Islands bioregion just northeast of Rennell and Bellona. Includes Hammondsport Seamount and part of the San Cristobal Trench with abyssal plain, hill, ridge, a seamount and basin. SST moderate and stable, Chlorophyll-a concentrations, DO and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and PH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Contains 1 seamount type 10 (large and tall with shallow peak: shallow); 1 seamount type 11 (intermediate size, largest basal area and deepest peak depth). Includes 1 blind canyon type. The upper depth is 3500m and the lower depth is 5000m.
	61	South Solomon Trench	Includes the South Solomon Trench which is the dominant feature. Also includes ridges, canyons and abyssal features. SST moderate and stable, Chlorophyll-a concentrations, DO and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and PH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Contain no seamounts. Includes 7 blind canyon types. The upper depth is 1500m and the lower depth is 6000m. Has southwest to west ocean currents. Highly fished area for albacore. The area is also described to have a healthy shark population as tuna catches show signs of shark bites (e.g. cookie cutter sharks).
	73	Bradley Deep	Four non-contiguous parts of this bioregion lie within the Solomon Islands. Mainly contains canyons and escarpments on slopes. The most eastern part includes mainly plateaus. SST moderate and stable, Chlorophyll-a concentrations are low, but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate, 20°C isotherm is deep, MLD is shallow. Solar irradiance and pH, silicate, phosphate, and nitrate are low. Calcite is moderate. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak) and 2 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); includes 27 blind canyon types and 23 shelf incising canyon types. The upper depth is 0m and the lower depth is 2500m. Highly fished area for bigeye and yellowfin tuna (incudes vessels operating out of Fiji). The area is also descried to have a healthy shark population as tuna catches show signs of shark bites (e.g. cookie cutter sharks).

HABITAT	CODE	NAME	DESCRIPTION
Deepwater	82	Ambae Trough	Contains trough and abyssal features with basin and plateau that extends into the Solomon Islands EEZ. Also includes spreading ridge and ridge with escarpments. SST moderate, mildly variable. Chlorophyll-a concentrations are low, with scattered blooms around Maewo Island. Mid-depth temperatures very high while temperature at 1000m is low. 20°C isotherm is exceptionally low. Silicate and phosphorous levels are high. PH is high. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak); 1 seamount type 3 (intermediate size, large tall and deep); 3 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); 1 seamount type 7 (small and short with very deep peaks, shortest); 2 seamounts type 10 (large and tall with shallow peak: shallow); includes 10 blind canyon types and 1 shelf incising canyon type. Contains 3 active, inferred and 1 inactive, hydrothermal vents. The upper depth is 2500m and the lower depth is 3500m.
	98	Santa Isabel Slope	Consists of canyons on ridge and slope bottoms. Escarpment is also well featured. SST moderate and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is deep, MLD is shallow. Solar irradiance and pH, silicate, phosphate, and nitrate are low. Calcite is moderate. Intersect 1 seamount type 3 (intermediate size, large tall and deep); includes 21 blind canyon types and 10 shelf incising canyon types. Contains 2 active, inferred hydrothermal vents. The upper depth is 0m and the lower depth is 3000m. Good fishing ground for domestic vessels. History of turtles migrating through the bioregion. Presence of yellowfin and skipjack tuna. Known bycatch are rainbow runners.
	106	Torres Rise	Contains plateaus, ridges and canyons and the northern New Hebrides Trench. Chlorophyll-a concentrations are moderate, stable. Salinity and dissolved oxygen are low but higher in east of region. Mid-depth temperatures very high while temperature at 1000m is low. 20°C isotherm is exceptionally low. Solar irradiance is quite high. Contain no seamounts. Includes 20 blind canyon types and 11 shelf incising canyon types. The upper depth is 500m and the lower depth is 3500m.
	115	Solomon Sea Spread	Contains the northern tip of the South Solomon Trench, medium size seamounts, Solomon Sea spreading ridges and rift valleys, basin canyons and the Rennell and Bellona Plateau, SST moderate and stable, Chlorophyll-a concentrations, dissolved oxygen and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and PH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Contains 3 seamounts type 1 (small with deep peak, short with moderately deep peak); 3 seamounts type 3 (intermediate size, large tall and deep); 1 seamount type 7 (small and short with very deep peaks, shortest); 1 seamount type 10 (large and tall with shallow peak: shallow); 5 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 28 blind canyon types. Contains 2 active, inferred hydrothermal vents. The upper depth is 2500m and the lower depth is 4000m. Good fishing ground for domestic vessels for yellowfin, albacore and skipjack tuna. Known bycatch are barracuda, sharks and dolphinfish.
	125	Temotu Cluster	Contains the Solomon Plateau and large ridges with escarpments. Canyons and seamounts run through the region with deep water basins on abyssal features. SST very high and stable. Chlorophyll-a concentrations are moderate, with large bloom in southern region. Salinity, dissolved oxygen, silicate and phosphorous levels are low. Solar irradiance is high. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak); 5 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); 1 seamount type 10 (large and tall with shallow peak: shallow); 3 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 22 blind canyon types and 2 shelf incising canyon typess. Contains 1 active, confirmed; 2 active inferred hydrothermal vents. The upper depth is 1000m and the lower depth is 3500m. High productivity around seamounts, eddies present.

HABITAT	CODE	NAME	DESCRIPTION
Deepwater	184	East Temotu	Mostly abyssal with several seamounts and ridges. Deep abyssal mountains form the base of the seamounts. The Vityaz Trench bisects the two ridges and connects to the Cape Johnson Trough with steep escarpments. SST moderate and stable, CHL low and variable, salinity increases eastward and stable, dissolved oxygen low and stable, deepwater temperature is moderate, 20°C isotherm is shallow, mixed layer depth is shallow closer to land, solar irradiance is moderate, pH level is moderate and variable, silicate level is low, phosphate level is low, nitrate level is low, calcite is low. Contains 1 seamount type 1 (small with deep peak, short with moderately deep peak); 3 seamounts type 2 (small with deep peak, most common type); 3 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); 1 seamount type 9 (Large and tall with shallow peak, larger); 3 seamounts type 10 (large and tall with shallow peak: shallow); 2 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 3 blind canyon types and 1 shelf incising canyon type. The upper depth is 3000m and the lower depth is 4500m.
	207	Torres Canyons Deep	Region dominated by canyons and deep basin. Other features include a seamount and steep escarpment. SST mildly variable and relatively high. Chlorophyll-a concentrations are moderate, stable. Salinity and dissolved oxygen are low. Mid-depth temperatures are very high while temperature at 1000m is low. MLD is high. Silicate and phosphorous levels are low. pH is very low. Contains 1 seamount type 4 (small with deep peak, most isolated type); 2 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 13 blind canyon types. The upper depth is 3000m and the lower depth is 4500m.
	216	Loyalty Basin	Mostly deep abyssal hills and mountains with overlying basins, and cuts across few seamounts, ridges and trench. SST moderate, variable. Chlorophyll-a concentrations are high to moderate, variable. Salinity and dissolved oxygen are low. Temperature at 200m is low. Solar irradiance is quite high in the north. Contains 1 seamount type 2 (small with deep peak, most common type); 3 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 2 blind canyon types and 3 shelf incising canyon types. The upper depth is 3500m and the lower depth is 5000m.
	222	North of Solomon and Cape Johnson Troughs	Contains part of a trench and trough in the north Solomons including Cape Johnson Trouch as well as Duff Islands, to the south of Rennel. It contains plateaus and canyons, steep escarpments and abyssal features. SST high and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is deep, MLD is shallow. Solar irradiance and pH, silicate, phosphate, and nitrate are low. Calcite is moderate. Contains 3 seamounts type 1 (small with deep peak, short with moderately deep peak); 1 seamount type 2 (small with deep peak, most common type); 1 seamount type 7 (small and short with very deep peaks, shortest); 4 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 19 blind canyon types and 3 shelf incising canyon types. The upper depth is 2500m and the lower depth is 4000m. Highly fished area for tuna by longliners and purseiners, a tuna migratory route. Bycatch includes turtles, sharks and marlin.
	226	Rennell Troughs	Bioregion in two parts with trough, canyons, plateau, ridges, basin, escarpments, and abyssal mountains. SST moderate and stable, Chlorophyll-a concentrations, dissolved oxygen and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and pH is moderate. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Contains 1 seamount type 4 (small with deep peak, most isolated type); includes 13 blind canyon types. The upper depth is 2500m and the lower depth is 4000m.
	240	South East Solomon Islands abyssal plain, seamounts	Very deep bioregion with abyssal plains, Vityaz Trench and ridges with few chains of seamounts. SST high and stable, Chlorophyll-a concentrations are low and variable, salinity is moderate and stable, dissolved oxygen is low and stable, deepwater temp is moderate, 20°C isotherm is deep, mixed layer depth is shallow, solar irradiance is moderate, pH level is variable, silicate level has a left to right gradual increase, phosphate level is low, nitrate level is low, calcite is low. Contains 4 seamounts type 2 (small with deep peak, most common type); 3 seamounts type 7 (small and short with very deep peaks, shortest); 4 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 4 blind canyon types. The upper depth is 4000m and the lower depth is 5000m.

HABITAT	CODE	NAME	DESCRIPTION
Deepwater	243	East Temotu andBanks	Contains large spreading ridge in the western part and a number of seamounts in the northern and eastern part of the bioregion. SST high and stable. Chlorophyll-a concentrations are low, except for high concentration in the northwestern corner. Mid-depth temperatures very high while temperature at 1000m is low. M LD is high. Silicate and phosphorous levels are high. pH is high. Contains 7 seamounts type 1 (small with deep peak, short with moderately deep peak); 1 seamount type 2 (small with deep peak, most common type); 8 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); 1 seamount type 7 (small and short with very deep peaks, shortest); 1 seamount type 9 (Large and tall with shallow peak, larger); 7 seamounts type 10 (large and tall with shallow peak: shallow); 6 seamounts type 11 (intermediate size, largest basal area and deepest peak depth). Includes 18 blind canyon types and 1 shelf incising canyon type. Contains 2 inactive hydrothermal vents. The upper depth is 2000m and the lower depth is 3500m.
	330	Hammondsport Seamount and Rennell Ridge	Bioregion in two parts. Western side contains ridge, seamounts and canyons. Eastern side contains plateau, large ridge and canyons. SST moderate and stable, Chlorophyll-a concentrations, dissolved oxygen and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and pH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Intersects 2 seamounts type 10 (large and tall with shallow peak: shallow). Includes 14 blind canyon types. The upper depth is 1500m and the lower depth is 3000m.
	333	North New Hebrides Trench	Includes the northern New Hebrides Trench. SST very high and stable. Chlorophyll-a concentrations are moderate, stable. Salinity and dissolved oxygen are low. Mid-depth temperatures very high while temperature at 1000m is low. MLD is high. Silicate and phosphorous levels are low. pH is very low. Contains no seamounts. Includes 3 blind canyon types. The upper depth is 4500m and the lower depth is 8000m.
	337	Ontong Java Atoll	Bioregion in two parts, eastern side contains plateau and the western part contains ridges, slope with canyon on escarpments and abyssal mountains. SST high and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is moderate; MLD and solar irradiance are low. pH is moderate. Silicate, phosphate, and nitrate are low. Calcite is high. Contains no seamounts. Includes 14 blind canyon types and 5 shelf incising canyon types. Contains 1 active, confirmed; 2 active, inferred and 1 inactive hydrothermal vent. The upper depth is 500m and the lower depth is 2000m.
	434	Makira/Ulawa Deep	Contains canyons on slopes and escarpments with a ridge. SST moderate and stable, Chlorophyll-a concentrations, dissolved oxygen and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and pH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Intersects 1 seamount type 11 (intermediate size, largest basal area and deepest peak depth). Includes 7 blind canyon types and 1 shelf incising canyon type. The upper depth is 0m and the lower depth is 3000m.
	439	Solomon Border	Contains the New Britain Trench. SST moderate and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is moderate; MLD and solar irradiance are low. pH is moderate. Silicate, phosphate, and nitrate are low. Calcite is high. Contains no seamounts. Includes 3 blind canyon types. The upper depth is 4000m and the lower depth is 7500m.
	440	San Cristobal Trench	Contains the San Cristobal Trench with few canyon features. SST moderate and stable, Chlorophyll-a concentrations, dissolved oxygen and salinity are low. Temperature at 1000m is high, 20°C isotherm is deep, MLD is shallow, and pH is low. Solar irradiance, silicate, phosphate, nitrate and calcite are low. Contains no seamounts. Includes 2 blind canyon types. The upper depth is 4000m and the lower depth is 7000m.

HABITAT	CODE	NAME	DESCRIPTION
Deepwater	450	Southeast Malaita and Maramasike	Contains slopes, basin and escarpment on deep abyssal mountain area and part of ridge. SST moderate and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is deep, MLD is shallow. Solar irradiance and pH, silicate, phosphate, and nitrate are low. Calcite is moderate. Contains no seamounts. The upper depth is 0m and the lower depth is 3000m.
	451	Ulava Deep	Contains canyons, ridges and deep Cape Johnson Trough and Trench. SST moderate and stable, Chlorophyll-a concentrations are low but high around the islands. Salinity and dissolved oxygen are low and variable. Temperature at 1000m is moderate. 20°C isotherm is deep, MLD is shallow. Solar irradiance and pH, silicate, phosphate, and nitrate are low. Calcite is moderate. Contains no seamounts. Includes 3 blind canyon types and 2 shelf incising canyon types. The upper depth is 1500m and the lower depth is 6000m.
	455	East Temotu	Deep bioregion containing large seamounts, ridges and canyons and part of the Vityaz Trench. SST is high and stable, Chlorophyll-a concentrations are low and stable, salinity is moderate, dissolved oxygen is low and stable, deepwater temperature is medium, 20°C isotherm is deep, mixed layer depth is medium, solar irradiance is moderate, pH level is moderate, silicate level is moderate, phosphate level is moderate, nitrate level is low, calcite is low. Contains 3 seamounts type 3 (intermediate size, large tall and deep); 6 seamounts type 5 (intermediate size, small, moderately tall and shallowest peak depths of this group); 1 seamount type 9 (Large and tall with shallow peak, larger); 3 seamounts type 10 (large and tall with shallow peak: shallow); 1 seamount type 11 (intermediate size, largest basal area and deepest peak depth). Includes 7 blind canyon types and 2 shelf incising canyon types. The upper depth is 1500m and the lower depth is 3000m. Highly fished area for tuna by longliners. The area is also described to experience intense swells.
Reef-associated	28	Western Munda and Atonn island	Barrier type coral reefs with low coral cover. Seagrasses and mangroves are present but only in small patches. Mongroves present but in small patches. Known for green and hawksbill turtles and dugongs. Freshwater influence.
	30	Rennell Bellona and Isabel oceanic influenced	Exposed reef edges, islands far from the coast. Minimal to no mangroves or seagrasses in the area.
	45	Kolobangara Island	Big rivers with high sedimentation and turbidity due to logging and coastal erosion. Mangroves (Rhizophora spp.), seagrasses and crocodiles present, but no coral reefs. Breeding ground for bumphead parrotfish, crown-of-thorns starfish and other echinoderms. High current areas. In central Isabel Island area barrier reefs and fringing reefs are present. Feeding ground for turtles. Further west: River and land influence, soft bottom, turbid, land influenced. Shallow reefs are present (same as Choiseul and Anavans).
	60	Indispensable Reef and Treasury Islands	East Kapingamarangi Atoll and Indispensable and Shortland reefs fringing reefs with steeply sloping banks into deep (~30m) water. Geomorphology: plateau areas.
	65	Shortlands Islands	Kapingamarangi, South Bougainville and North Choiseul Reefs. Fjord-like coastlines. Very diverse fish community. There is a good cross section of habitat, including mangroves (one of the largest mangrove areas in the Solomon Islands), seagrass beds, shallow reef flats, rich coral areas, and an abrupt slope to relatively deep water. Small island fringing reef with sand and bommies. Exposed outer reef. Geomorphology: high shelf areas.
	75	Bougainville and Santa Cruz Islands	Bougainville and Lord Howe Islands Cluster. Large volcanic islands, Reef Islands are upraised reef characterized by a typical limestone soil. Steep cliffs that continue vertically into the sea reaching depths of about 40 to 50 m where a gentle sandy slope takes over.
	76	Lord Howe, Nukapu, Temotu	Lyra Reef and Lord Howe Islands Cluster. Submerged low lying reef islands, wide fringing reefs, medium shelfs on slopes above pleateaus.
	78	Utupua and Banie Island	South Tafea Island with steep cliff edges, ragged, weather coasts, deep waters, medium shelfs on plateaus.

HABITAT	CODE	NAME	DESCRIPTION
Reef-associated	81	Duff Islands	Mapua and Treasures Islands Cluster stark volcanic islands, slopes on south side of ridges.
	92	South Rennell	South Rennell Bellona, located in abyssal region, believed to be the top of a seamount.
	100	Ndeni and Tinakula Islands	Volcanic Islands. Surrounding water is good habitat for deep water snapper (red snapper).
	101	Sikaiana	Three islands with fringing reefs.
	102	Ontong Java and Eastern Solomon	Freshwater influence. Steep dropoff.
	107	Malaita and Makira cluster	Ndai Island and the southern region of Malaita have active logging areas. Extensive mangrove areas towards the southern end, well known for mud crabs and nautilus shells.
	110	Solomon shallow coral	Well-flushed shallow coral reef and good coral cover.
	111	Solomon-wide influenced	South Guadalcanal - Asimauri area with strong winds and rough seas due to being on the exposed “weather” coast with high wave action. Throughout bioregions, very narrow fringing reefs with steep drop-offs and strong currents. Big rivers with evidence of logging. Leatherback nesting grounds and crocodiles. Presence of parrotfish, feeding ground for leatherback, green and hawksill turtles. Seagrass present.
	117	Marau Guadalcanal	Mangroves, seagrass and coral reefs vulnerable to tradewinds. High threat of sedimentation from logging and sea level rise. Seagrass meadows are foraging and nesting areas for dugongs and turtles, especially leatherback turtles. In the western area the reef flat is exposed and more prominent, with good coral cover.
	200	Honiara	Fringing reefs affected by coastal pollution and run-off, presumably decreased biodiversity.

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