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Identifying Ecologically or Biologically Significant Areas (EBSA): A systematic method and its application to seamounts in the South Pacific Ocean

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ABSTRACT

The Convention on Biological Diversity (CBD) has adopted a scheme of using scientific criteria for identifying '*Ecologically or Biologically Significant Marine Areas*' (EBSAs) in need of protection in open-ocean and deep-sea habitats. To date, expert opinion collated during regional workshops has been the main method to identify regional EBSAs. In this paper, we propose a new method that could complement this process by adding more objective and transparent analyses. There are four main steps: 1) identify the area to be examined, 2) determine appropriate datasets and thresholds to use in the evaluation, 3) evaluate data for each area/habitat against a set of criteria, and 4) identify and assess candidate EBSAs. The method can be applied to any habitat, but offshore seamounts were chosen as a test habitat to develop and evaluate it. Several options for various combinations of criteria are presented, with one being proposed as the most appropriate to identify a tractable number of seamounts that satisfied the EBSA criteria and which could be combined into larger areas that represent meaningful ecological and practicable management units. This option selects seamounts that meet any one of the 5 "biological" criteria (i.e. unique/rare, diverse, productive, threatened species, critical habitat) and which contain environmental features that are vulnerable to human activities but not yet significantly impacted by them. This selection process resulted in 83 seamounts being identified from over 3000 evaluated in the South Pacific Ocean. The priority seamounts group into 10 areas, consisting of 5 clusters of seamounts, and 5 individual seamounts. The primary strength of the method is the adoption of a transparent, and logically sequential, selection process that is conceptually transferrable to other habitat types and regions beyond our model system. We contend that in a global EBSA context it can be a useful tool to assist deep-sea management.

1. Introduction

The 'High Seas' – areas beyond national jurisdiction – are potentially furthest from human activities, yet human impacts are increasingly evident even in the most remote locations and deepest parts of the oceans (Ramirez-Llodra et al., 2011). The High Seas encompass extensive areas of the abyssal seafloor and contain prominent topographic features of the seascape, such as seamounts, mid-ocean ridges, and banks (e.g., Costello et al., 2010; Harris and Whiteway, 2009). These features are sites of intense commercial fishing activity where detrimental effects on target stocks and habitats can be profound and long-lasting (e.g., Althaus

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et al., 2009; Clark and Rowden, 2009; Clark et al., 2007; Norse et al., 2012; Pitcher et al., 2010; Williams et al., 2010a). Hence, these impacts have become issues of major conservation concern internationally (e.g., Gage et al., 2005; Mortensen et al., 2008; Probert et al., 2007). Other human uses of the deep sea, including mining for oil, gas, and mineral resources (e.g., Davies et al., 2007; Ramirez-Llodra et al., 2011; Roberts, 2002; Smith et al., 2008) can compound the effects of fisheries in some areas.

The breadth and intensity of current and future anthropogenic threats to deep-sea ecosystems creates a need to regulate human activities. International agreements are a critical tool in conservation efforts on the High Seas. Under the umbrella of the United Nations Convention on the Law of the Sea, a number of initiatives have focussed on ways to improve the management of fisheries (through Regional Fisheries Management Organisations or Agreements and UNGA resolutions 61/105, 64/72) to ensure sustainability of fish stocks as well as to protect deep-sea habitats (e.g., FAO, 2009). The Convention on Biological Diversity (CBD) also aims to address conservation of open ocean and deep-sea ecosystems using the concept of '*Ecologically or Biologically Significant Marine Areas*' (EBSAs). In 2008 the Parties to the CBD approved the adoption of scientific criteria for identifying EBSAs (COP decision IX/20, (CBD, 2008)). Identification of EBSAs allows prioritisation of management and conservation actions to locations seen as particularly important for the long term conservation of ecosystems.

EBSAs are defined using seven criteria (CBD, 2009a): 1.) uniqueness or rarity; 2.) special importance for life-history stages; 3.) importance for threatened, endangered or declining species and/or habitats; 4.) vulnerability, fragility, sensitivity, or slow recovery; 5.) biological productivity; 6.) biological diversity; and 7.) naturalness.

The criteria are, however, very broad, with differing levels of importance in certain situations. There is also limited guidance on how to deal with situations where multiple criteria are met to varying extents. Although EBSAs do not necessarily imply that a management response is required, they were initially intended to provide the basis for a network of protected areas (CBD, 2008). Hence it is likely that environmental managers will in the future use EBSAs to select sites for some form of management, and there is consequently a need for an objective and transparent process to assist managers if they are faced with a large number of proposed EBSAs. This need was recognised by GOBI (the Global Ocean Biodiversity Initiative: www.gobi.org) in 2010 and a workshop was held under the auspices of the GOBI Benthic Group and the Census of Marine Life on Seamounts (CenSeam) (Dunstan et al., 2011) to develop an objective method to identify "candidate" EBSAs using seamounts as a test habitat.

Seamounts are prominent features of the seafloor throughout the oceans (Costello et al., 2010; Yesson et al., 2011). Seamounts may support a large number and wide diversity of fish and invertebrates, and can be an important habitat for commercially valuable species, targeted by large-scale fisheries in the deep-sea (reviewed by Clark et al., 2010). However, seamount communities are also vulnerable to impacts from fishing, effects associated with climate change, and future seabed mining (e.g., Clark et al., 2012; Schlacher et al., 2010). The large number of seamount features (>100,000 seamounts and knolls) (Yesson et al., 2011) could result in a very large number of them fulfilling EBSA criteria: this calls for a method to select a subset of candidate seamounts to define as EBSAs that are realistic and practicable.

In this paper we introduce a new method for the selection of candidate EBSAs. It builds on an earlier method reported by Dunstan et al. (2011), refines the approach, and updates some of the datasets. In particular, we provide a worked example that illustrates in detail the method for using the CBD criteria to derive a set of candidate EBSAs. We extend the conceptual framework for the application of selection criteria leading to EBSAs (CBD, 2009a) by introducing descriptions of the *mechanics* that underlie this selection approach, using seamounts in the South Pacific as a model/test system.

2. Developing the EBSA identification method

The work presented here is the output from two workshops, held in late 2010 and early 2013, involving the authors. Three fundamental questions were considered before more detailed methodological aspects were addressed: 1) What is the appropriate spatial ambit to select EBSAs? 2) Are data of sufficient coverage and quality available for each criterion? and 3) Are the criteria equally important?

2.1. A global or regional approach?

A key decision to make at the outset is the spatial scale at which candidate EBSAs are to be identified. The spatial scale will determine the availability and resolution of data sources, and may influence how criteria are interpreted. Detailed global scale assessments are probably intractable at present. Conversely, systematic efforts at the scale of national EEZs are unlikely until the EBSA concept has become well established for the High Seas – although some countries have advanced similar concepts, such as the Australian Key Ecological Features (e.g., Falkner et al., 2009), and the Canadian Ecologically and Biologically Significant Areas (Department of Fisheries and Oceans, 2004). Large regional scales are more tractable provided that data coverage is adequate and nations collaborate. In some High Seas areas, collaboration may be through Regional Fisheries Management Organisations (RFMOs) which typically have governance over large ocean areas.

The likely biogeographic distribution of the fauna may be a useful consideration to help define the spatial scale at which the candidate EBSAs are to be identified. Working within one biogeographic province has the advantage of using the broad similarity in faunal composition to represent regional biodiversity (see Section 2.4).

2.2. What data are available on EBSA criteria?

Without data to assess the selection criteria, EBSA identification becomes very restricted: below we assess various types of data and aspects of datasets, particularly those most relevant to seamounts.

2.2.1. Criterion 1: uniqueness and rarity

This criterion defines a species that is 'the only one of its kind', or which occurs only in a few locations or populations. The same definition may be used for habitats, physical features, or ecosystems that are unique or rare (CBD, 2009a).

Evaluating this criterion requires spatially explicit data on the distribution, occurrence, or relative abundance of species, or habitats. However, while such data are available, estimates of uniqueness and rarity are often difficult to derive because of limited sampling coverage in the deep sea. Except for a few well-sampled and catalogued groups in limited regions such as ophiuroids (O'Hara et al., 2011), or for a small number of species where their restricted distribution is known such as the lobster *Jasus caveorum* (Webber and Booth, 1995), for seamount fauna it is generally not possible to determine, with confidence, whether records represent true ecological rarity (Rowden et al., 2010a). Greater confidence can be assigned to rare communities associated with some habitats, such as hydrothermal vents, which are spatially well defined and considered biologically 'unique' (e.g., Van Dover, 2000). Data on the global distribution of vents exist (http://www.noc.soton.ac.uk/

chess/database/db_home.php), although these are likely to be incomplete.

Criterion 1 can also be addressed in terms of habitat features that are unusual with respect to physical properties, and hence can substitute for biological uniqueness. Recent mapping of seamounts using radar topology (Yesson et al., 2011) can identify the probable location of seamounts and determine their physical characteristics. Geographically isolated seamounts or discrete chains of seamounts may be considered to have a unique physical character within a region, which could be linked to different biological characteristics. Because depth is a major determinant of species composition and turnover (McClain et al., 2010), particularly shallow or deep seamounts are likely to have very different faunal assemblages. Similarly, we may expect higher diversity (and potentially different composition) in areas influenced by particular oceanographic features, such as convergences/divergences and other frontal systems (e.g., McClatchie et al., 1997).

2.2.2. Criterion 2: special importance for life-history stages of species

This criterion defines areas that are required for a population to survive and thrive. Some geographical areas or topographic features are more suitable, or important, for particular life-stages and functions than others (CBD, 2009a).

Maps of spawning and nursery grounds, and sites where animals aggregate for feeding, are the data inputs required for evaluating this criterion. Broad-scale maps exist for some taxa such as fish (e.g., Froese and Pauly, 2013), but coverage is generally poor for seamounts. Seamounts are visited by large pelagic vertebrates like tunas, billfishes, sharks, marine mammals, turtles, and seabirds (see Pitcher et al., 2007), and are important spawning areas for deep-water fishes (Clark, 2008). Fisheries data are often available at national or regional scales, and will likely be useful for evaluating this criterion.

2.2.3. Criterion 3: importance for threatened, endangered or declining species and/or habitats

This criterion defines crucial habitats for endangered, threatened or declining species, or areas with significant assemblages of such species; conservation of these habitats supports restoration or recovery of threatened species (CBD, 2009a).

The primary data source for evaluating this criterion is the IUCN Red List (http://www.iucnredlist.org/), with additional data provided by national lists (e.g., Freeman et al., 2010 for New Zealand species). While these lists often do not include location information, they serve to identify records in global or national databases that contain geo-referenced species records (e.g., OBIS www.iobis.org, Seamounts Online seamounts.sdsc.edu/).

2.2.4. Criterion 4: vulnerability, fragility, sensitivity and slow recovery

This criterion defines areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile or with slow recovery (CBD, 2009a).

Maps of vulnerable species and habitats are the primary data for evaluating this criterion. Cold-water corals are particularly fragile and recover very slowly, and maps exist that either show the known distribution of such corals (Rogers et al., 2007), or the distribution of suitable coral habitat predicted by models (e.g., Davies and Guinotte, 2011; Yesson et al., 2012). Other data sources include FAO or RFMO records of taxa that may characterise Vulnerable Marine Ecosystems (VMEs) (which often include corals as defining species) (FAO, 2013), and the sensitivity of corals to aragonite saturation depth (e.g., Tittensor et al., 2010). Habitat suitability models for corals have been used with specific reference to seamounts (Tittensor et al., 2009) and for assessments of the vulnerability of seamounts to fishing impacts (Clark and Tittensor, 2010).

2.2.5. Criterion 5: biological productivity

This criterion defines areas containing species, populations or communities with comparatively higher productivity (CBD, 2009a).

Oceanographic conditions, depth, and topography can play important roles in determining the location and magnitude of productivity. Areas of current mixing (e.g., frontal zones) and upwelling can increase surface productivity (Rivas, 2006), as can particular topographic features that may alter circulation characteristics locally, trap plankton, and attract predators (e.g., Genin and Dower, 2007; Kaschner, 2007; Thompson, 2007).

Maps of surface chlorophyll and modelled estimates of the vertical flux of particulate organic carbon (POC) through the water column are publically available (e.g., MODIS (http://modis.gsfc.nasa.gov/; SeaWIFS http://oceancolor.gsfc.nasa.gov/SeaWiFS/; Global surface productivity models http://www.science.oregonstate.edu/ocean.productivity). Flux of surface productivity that reaches the seafloor is particularly important for benthic assemblages, and global maps of POC flux at the seafloor exist (e.g., Alvarez et al., 2009; Lutz et al., 2007; Yool et al., 2007). Productivity data are, however, rarely available at the scale of individual seamounts and hence spatial interpolations from coarser-grained models must be used when evaluating this criterion.

2.2.6. Criterion 6: biological diversity

This criterion defines areas that contain a comparatively higher diversity of ecosystems, habitats, communities or species, or have higher genetic diversity (CBD, 2009a).

Data on biological diversity include maps of common indices of diversity (e.g., http://www.iobis.org/maps). The species composition of deep-sea fish faunas is reasonably well known, and diversity maps have been made from predictive models of fish species distributions at global (e.g., Froese and Pauly, 2013) and regional scales (e.g., Leathwick et al., 2006). Knowledge is less complete for invertebrates, although coarse-scale predictions of species richness for some taxa are beginning to be made (e.g., Tittensor et al., 2010).

Robust estimates of biological diversity are very rare for seamounts even at a regional scale, although species richness data for some taxa (e.g., ophiuroids, galatheid decapods) have been collected from a number of seamounts (e.g., O'Hara and Tittensor, 2010; Rowden et al., 2010b). Globally, OBIS provides diversity estimates at a coarse resolution of 5° (http://www.iobis.org/maps), and may be the most comprehensive data source when more detailed regional information is unavailable. However, caution is needed using such global data as they are incomplete, and subject to biases from, for example, uneven sample sizes and sampling effort between locations (see Fig. 4 of Williams et al., 2010b).

2.2.7. Criterion 7: naturalness

This criterion defines areas with a comparatively higher degree of naturalness as a result of the lack of, or low levels of, human disturbance or degradation (CBD, 2009a).

The main threatening processes for the deep-sea are bottom trawling and imminent seabed mining (Ramirez-Llodra et al., 2011; Smith et al., 2008). There are global and regional maps of fishing pressure (e.g., Halpern et al., 2008), and marine protected areas (MPAs) within national boundaries may also be a promising useful proxy of 'naturalness'. The impacts of fishing on seamounts have been well documented (e.g., Clark and Koslow, 2007), and the possible effects of seabed mining on seamounts are being evaluated (Schlacher et al., 2013; Van Dover et al., 2012). There are detailed estimates of fishing pressure for seamounts (Clark and Tittensor, 2010; Clark et al., 2007).

2.3. Are all EBSA criteria equally important?

Each EBSA criterion may be used individually or in combination with others. The original CBD decision (CBD, 2008), the criteria descriptions (CBD, 2009a), as well as EBSA identification efforts since then (CBD, 2009b), suggest that each criterion is of equal importance. Simple additive applications of unweighted criteria can, however, create problems in producing large numbers of candidate areas; this situation is likely in data-sparse situations such as the deep sea.

Here we consider three possible solutions to address this issue: 1) to define thematic groups within the full set of criteria, 2) to rank the criteria, or 3) to combine them in non-additive ways. We propose that the full list of criteria can be thematically split into those that primarily describe biological characteristics (criteria 1, 2, 3, 5 and 6), and those that primarily relate to anthropogenic threats (criteria 4 and 7); this separation is a similar interpretation to that suggested by a CBD working group (CBD, 2011). In the case of seamounts, specifically the benthic fauna, we also considered that greater emphasis on criteria 1–3 would, theoretically, provide a more ecologically informative outcome (Table 1). However, it must be stressed that this ranking may need to be different for different ecosystems. Finally, we explored methods of combining criteria by comparing the number and spatial distribution of candidate EBSAs resulting from different permutations of criteria.

2.4. A proposed method to identify EBSAs

Without prejudging the future development and refinements of the process to identify EBSAs under the CBD, we have identified a sequence of four steps to identify EBSAs (Fig. 1), which are described below.

(1) Identify the area to be examined

We anticipate that the EBSA identification method will be used over a range of spatial scales extending from smaller areas within EEZs to extensive High Seas regions. As an initial step in the process, existing biogeographic information can be examined to identify underlying regional patterns in biodiversity. Understanding the biogeography of an area is particularly important at ocean-basin scales and when it is envisaged that representative EBSAs may be selected to be part of a network of MPAs.

The most recent and comprehensive benthic-based biogeographical classification is that of Watling et al. (2013), which is an update of the “Global Open Oceans and Deep Seabed (GOODS) biogeographical classification” (UNESCO, 2009). This classification identifies benthic biogeographical regions in all world oceans and can be used to spatially partition the benthic realm, including by depth. It covers lower bathyal (800–3 500 m), abyssal (3500–6000 m) and hadal (>6 000 m) depth zones, but does not include the upper bathyal (200–800 m). The latest biogeography of the shallow pelagic realm (<200 m) is the one produced by Spalding et al. (2012) which is based largely on the earlier GOODS (UNESCO, 2009).

(2) Determine appropriate datasets and thresholds to use in the evaluation

A decision to focus on either benthic or pelagic ecosystems, in some cases motivated by the needs of marine management in the area, will be the first step in determining the most appropriate datasets to use. Analysis of multiple datasets will be necessary to cover the full set of criteria, and to assess the information content for some individual criteria. The relative importance of each dataset is likely to be established by expert opinion. Datasets will almost certainly be at different spatial scales, and vary in their robustness

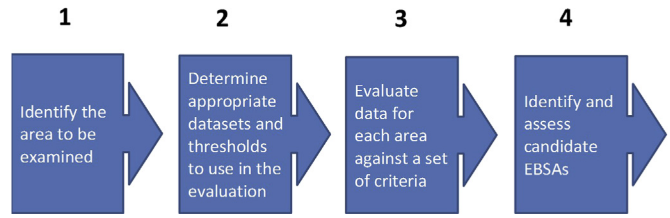

Fig. 1. Method for identifying potential EBSA candidates.

Table 1
Example of how EBSA criteria can be ordered according to their importance to the biome or habitat being assessed – in this case for seamount benthos.

Criterion title	Theme	Rank order of importance	Rationale for relevance level
C1 – Uniqueness or rarity	Biological	1	Seamounts can support unique and rare benthic biodiversity (e.g., hydrothermal vent communities) which contributes to larger-scale biodiversity in the deep sea.
C2 – Special importance for life-history stages of species	Biological	1	Some seamounts have special importance for life history stages of benthic species (e.g., fish spawning or nursery grounds).
C3 – Importance for threatened, endangered or declining species and/or habitats	Biological	1	Some seamounts form habitat for species that are already threatened by human activities (e.g., sharks, deep-sea stony corals), and that can occur on seamounts in relatively high numbers.
C5 – Biological productivity	Biological	2	While seamounts can occur beneath areas of high surface water productivity, the coupling between pelagic primary production and benthic secondary production is not well documented for many seamounts.
C6 – Biological diversity	Biological	2	Seamounts with varying levels of biodiversity are valuable where they add species or complement larger-scale biodiversity pools in the deep ocean.
C4 – Vulnerability, fragility, sensitivity, or slow recovery	Threatening process	1	Many seamounts are vulnerable to human impacts (i.e. direct impacts such as fishing and indirect impacts from likely effects associated with climate change) and are habitat for species that are fragile, sensitive, and slow to recover (e.g., stony coral reefs)
C7 – Naturalness	Threatening process	1	Many seamounts have not yet been significantly disturbed by human activities and can provide refuges and propagule/larval sources for seamount and non-seamount biota.

and coverage. Datasets mapped either at a global scale or amalgamated from regional-scale sources are likely to be necessary to provide comprehensive coverage of an area. It is important to be aware that datasets with broad areal coverage may contain sub-areas of low underlying data density, and/or sub-areas in which data values have been predicted using information from similar or adjacent areas. A check of underlying data should prevent misinterpretations, and indicate where high data density would support more detailed analysis if the management scale was smaller than the candidate EBSA identified. Where data are missing for certain criteria or where there are gaps in geographical coverage, the dataset or the criterion can be removed from consideration, or alternative options used to fill in the gaps (e.g., extrapolate from neighbouring areas, use proxy variables as a substitute, expert opinion). These options will need to be evaluated on a case by case basis.

As well as gathering appropriate datasets, it may be necessary to set thresholds that reflect the intentions of the criteria. Whether an area meets the EBSA criteria mostly depends upon it exhibiting a comparatively "higher" value of diversity, productivity, vulnerability etc. than other areas. Determining the thresholds for each criterion requires an examination of the properties of the data being used. For example, the distribution of the data values may be such that exceptional sites will naturally stand out from others on histogram plots, and particular clusters or modes of data can be used to set a threshold. Expert knowledge should be used to interpret and justify the ecological validity of such data values, and in some instances statistical techniques can be used to identify the precise threshold value. For example, if the data distribution corresponds to standard models such as a normal distribution, sites can be identified using cut-offs at common statistical boundaries like quartiles, 95 percentile, or one or two standard deviations from the mean (Ardron et al., 2009).

Data for the deep sea are generally sparse, and so pragmatic decisions will need to be made when determining appropriate datasets and thresholds. Notwithstanding any limitations, it is important that the properties of the datasets are fully described, and that threshold values are documented.

(3) Evaluate the data for each area against a set of criteria

The data evaluation stage should be carried out as objectively as possible, and ideally should be automated so that the process is transparent and can be easily repeated should new data become available. Datasets can be mapped in a GIS and evaluated as spatial layers which helps visual interpretation of candidate EBSA criteria.

Candidate EBSAs can be identified by meeting a single criterion, but it is likely that an impracticably large number of areas on the High Seas would be identified using this approach. Combining a number of criteria is more practical, particularly when candidate EBSAs are being considered for protection as part of a wider MPA network (i.e. when decisions have to be made about which areas are more worthy of protection, and which areas have properties that make them particularly suitable to include in a network). There are many ways in which the seven EBSA criteria can be combined, depending upon the objective/s of the identification process. The most appropriate combination of criteria can be determined *a priori*, or the results of different multi-criteria combinations can be assessed to see how well each combination meets the objective of the identification process.

(4) Identify and assess candidate EBSAs

Identification of candidate EBSA areas will, in many cases, be based on an evaluation of several or all criteria. Whether a particular area meets all or just a few of the criteria is a simple way to contribute to assessing the relative value or worth of a potential EBSA candidate. The relative contribution of each criterion can also be compared. For example, one area might have much higher levels of biological diversity than another area which also exceeds the threshold to satisfy this criterion.

Once identified, there is an established process for formally submitting candidate EBSAs to the CBD, and for their ratification. Candidate EBSAs (and associated data and metadata) are submitted to the EBSA Repository via Regional Workshops; then submissions undergo an initial validation by the SBSTTA which submits a report detailing EBSA recommendations to the Conference Of Parties (COP), which can endorse the recommendation and pass it to the UNGA Ad Hoc Open-ended Informal Working Group on Biodiversity Beyond National Jurisdiction for ratification (Dunn et al., 2011).

3. A worked example: South Pacific Ocean seamounts

Following the development of the four-step method described above, we conducted a practical test of the method using data on seamounts in the South Pacific Ocean.

3.1. Identify the area to be examined

The area to be examined was defined as the High Seas in the South Pacific Ocean, from the boundaries of the Australian EEZ to the Chilean EEZ and latitudes 20° S to 60° S. This region was selected for the practical test because the majority of the GOBI-CenSeam workshop participants were familiar with the seamounts and biota of this region. Yesson et al. (2011) predict a total of 3412 seamounts in this region with summit depths ranging from 52 to 4995 m. The seamounts within this region are found within 5 lower bathyal and 4 abyssal biogeographic provinces (Watling et al., 2013) (Fig. 2).

3.2. Determine appropriate datasets and thresholds to use for the evaluation

Section 2.3 introduces data that are considered appropriate for assessing the EBSA criteria for seamounts, and, for the worked example, Table 2 lists the data sources and summarises the thresholds applied to individual datasets for evaluating the criteria (see Section 3.3).

3.2.1. Criterion 1: uniqueness or rarity

Three sets of data were used for this criterion: 1) very shallow and deep seamounts, 2) the presence of a lobster species endemic to seamounts, and 3) the presence of vent communities. Shallow seamounts that extend into the photic zone (<200 m) are rare (1.3%) in the region and likely to support species and assemblages that are dissimilar to deeper habitats (Carney et al., 1983; Gage and Tyler, 1991). Deep seamounts below 4000 m are also rare (2.5%; Fig. 3a), and based on the known strong influence of depth on faunal composition and structure (Carney et al., 1983) we predicted that they would also support species and communities that are significantly different. The distribution of lobster species is better known than that of many other benthic taxa (largely due to their commercial importance). Hence, we have used records of *Jasus caveorum* endemic to one cluster of seamounts in the region (Webber and Booth, 1995) as an indicator of seamount uniqueness. The presence of a vent community was used as a further indicator of potentially unique benthic species assemblages being present on the seamounts.

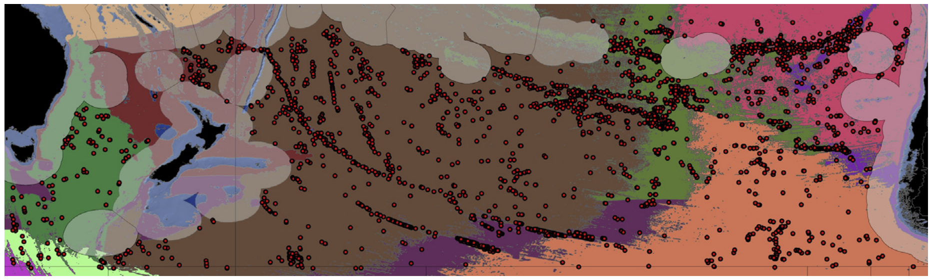

Fig. 2. Map showing predicted seamounts (red dots) and biogeographic regions in High Seas area of the South Pacific study region (20°–60° S latitudes, 150° E – 60° W longitude). EEZ boundaries are shown, but not data inside these areas, nor outside the study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.2.2. Criterion 2: special importance for life-history stages of species

Few robust data exist on this criterion in the South Pacific with the exception of spawning areas for orange roughy (*Hoplostethus atlanticus*). We consequently used records of the New Zealand Ministry of Primary Industries Scientific Observer Programme. Seamounts were considered spawning areas if more than half of female fish sampled had eggs in the latter stages of development, indicating spawning would occur there. The observer programme operates on New Zealand commercial fishing vessels, mainly on the Louisville Seamount Chain (Clark, 2008), and thus it was only possible to identify spawning areas for seamounts that are fished.

3.2.3. Criterion 3: importance for threatened, endangered or declining species and/or habitats

We used OBIS to obtain records of 51 IUCN Red list species at 420 locations in the region. We matched these records to known or predicted seamount locations with a 55 km radius buffer (an area roughly equivalent to 1° of latitude/longitude square), centred on the summit position of the seamount. This buffer compensated for positional inaccuracies and incomplete physical sampling of many seamounts.

3.2.4. Criterion 4: vulnerability, fragility, sensitivity and slow recovery

Modelled global habitat suitability for six species of stony corals (*Enallopsammia rostrata*, *Goniocorella dumosa*, *Lophelia pertusa*, *Madrepora oculata*, *Oculina varicosa* and *Solenosmilia variabilis*) that are known to form reef frameworks in the deep sea was used to assess this criterion (Davies and Guinotte, 2011). A 70% probability of habitat suitability was used as the minimum threshold to identify seamounts likely to support corals. Seamounts within these areas were deemed vulnerable to fishing or mining if their summit depths were shallower than 2000 m – the depth to which we considered effective fishing or mining is likely to occur in the near future.

3.2.5. Criterion 5: biological productivity

High flux of POC to the seafloor was the information used for this criterion, based on Lutz et al. (2007). POC values that were comparatively 'high' across the region were determined at or above the 95 percentile (i.e. 2.07 g C m^{-2} yr^{-1}) of all values calculated for 5° grid cells across the region (Fig. 3b). Seamounts within areas of POC flux above the threshold were deemed to receive a comparatively higher amount of carbon derived from surface primary productivity, some of which was assumed to translate into high secondary productivity for the seamount (Genin and Dower, 2007; Pitcher and Bulman, 2007).

3.2.6. Criterion 6: biological diversity

Biological diversity was assessed using Shannon diversity index values provided by OBIS for 5° latitude/longitude cells across the region. We used values greater than one standard deviation above

Table 2
Data and thresholds used for assessing EBSA criteria for seamounts in the South Pacific.

Criterion	Data and thresholds used	Data source
Biological criteria		
C1 – Uniqueness or rarity	Summit depth of seamounts – seamounts with summits in the photic zone (<200 m) and the deepest seamounts (>97.5%, >4250 m).	Yesson et al. (2011)
	Distributional records for known vent communities – known vent communities within 5 km of a seamount.	http://www.noc.soton.ac.uk/chess/
	Distributional records for lobster *Jasus caveorum* – presence of seamount endemic lobster species.	Webber and Booth (1995)
C2 – Special importance for life-history stages of species	Gonad condition of orange roughy caught on seamounts – spawning areas where >50% of samples of female orange roughy have eggs in latest stage of development.	Anderson (2006), Clark (2008)
C3 – Importance for threatened, endangered or declining species and/or habitats	IUCN Red List Species found in OBIS database – IUCN Red List species within 55 km of seamounts.	http://iobis.org/ http://www.iucnredlist.org
C5 – Biological productivity	POC flux to the seafloor – seamounts in areas with highest relative values of POC flux (top 5%, >2.07 g C m^{-2} yr^{-1}).	Lutz et al. (2007)
C6 – Biological diversity	OBIS estimate of Shannon diversity – seamounts in 5° cells with relatively high values of diversity (value > mean + 1SD, 3.853).	http://www.iobis.org
Human impact criteria		
C4 – Vulnerability, fragility, sensitivity, or slow recovery	Habitat suitability for stony corals and seamount summit depths –high probability (>70%) of stony coral habitat on seamounts vulnerable to fishing (summit depth <2000 m).	Davies and Guinotte (2011) Yesson et al. (2011)
C7 – Naturalness	Trawl fish catch records for seamounts – seamounts in 1°cells without known fish catch.	Clark and Tittensor (2010)

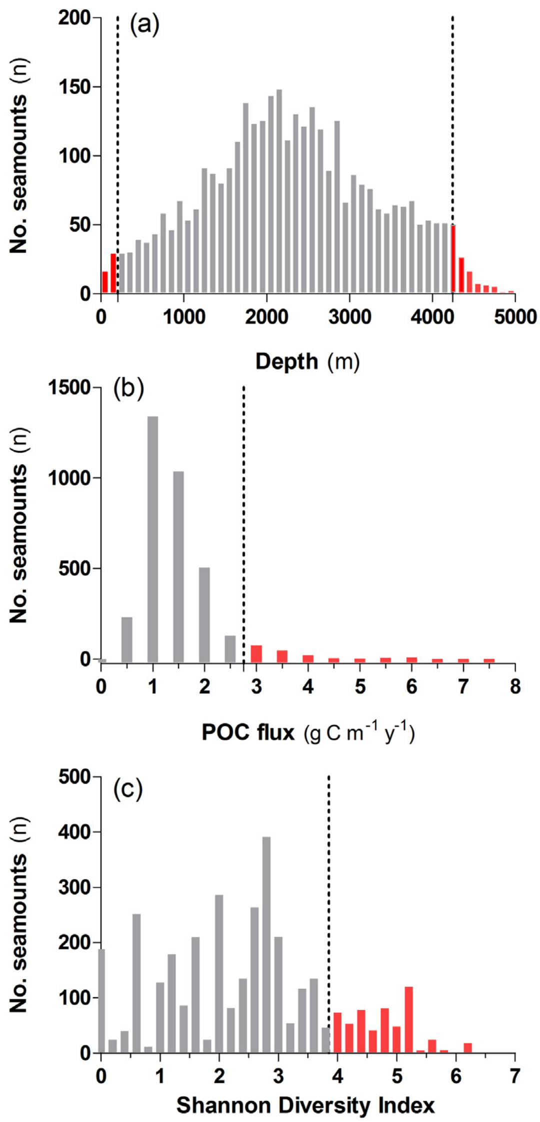

Fig. 3. Histograms of data for (a) depth of seamount summit, (b) POC flux to summit depth of seamount, (c) seamount diversity, marked with thresholds used to identify seamounts satisfying EBSA criteria 1, 5 and 6, respectively. See text for data sources and explanation of how thresholds were determined.

the mean to denote grid cells of comparatively higher diversity in the region (Fig. 3c). No attempt was made to correct for differences in sample sizes across the region.

3.2.7. Criterion 7: naturalness

Naturalness was evaluated as lack of known bottom-contact fishing for individual seamounts. Data on the distribution of bottom trawling was sourced from a number of national databases, and from scientists that had access to unpublished data (Bensch et al., 2008; Clark et al., 2007). Where it was not possible to resolve catches to individual seamounts, data were amalgamated for 1° latitude/longitude cells (after Clark and Tittensor, 2010). Seamounts within a cell that had no catch data were deemed to have not been fished.

3.3. Evaluate the data for each seamount against a set of criteria

Each of the criteria were evaluated independently for each individual seamount: seamounts were assigned a score of 1 if they met an EBSA criterion, or 0 if they did not (Appendix A).

There is no unique solution for weighting and combining the criteria to derive possible candidate EBSAs. We therefore evaluated combinations of criteria that broadly reflect decreasing order of stringency (Table 3). The overarching objective was to identify a tractable number of seamounts that satisfied the EBSA criteria and which could be combined into larger areas that represent meaningful ecological and practicable management units.

For seamounts, we consider criteria 1, 2 and 3 to be of greater biological importance for selecting a seamount as a candidate EBSA compared with the biological criteria 5 and 6 (see Section 2.3 above). We therefore included three scenarios (Options 2–4, Table 3) that reflect a greater emphasis on uniqueness/rarity, life history stages, and threatened species. Both criteria relating to human threats (C4 and C7) were included in all options because an EBSA should, logically, contain biological entities that respond to human stressors (C4 – vulnerable), and be largely in a natural state (C7 – naturalness) if they are ultimately to be considered for protection.

No seamounts were identified as candidate EBSAs by Options 1 and 2. Options 3, 4, and 5 identified 43, 65 and 83 seamount EBSAs, respectively. The CBD default Option 6 (any criterion) identified 3 374 seamounts as candidate EBSAs from a total of 3412 seamounts in the study region (Table 3). The distributions of the seamounts identified by multi-criteria options 3, 4 and 5 are shown in Figs B.1, B.2 and B.3 in Appendix B.

3.4. Identify and assess candidate EBSAs

Options 3 to 5 produced tractable numbers (n = 43–83) of candidate EBSAs (Table 3). Each of these options includes at least one of the biological criteria in the selection, but Option 5 is the one which gives equal weight to all biological criteria. It is thus the most parsimonious solution, while still resulting in a number of seamounts that is practicable in a conservation context. It has the advantage of being consistent with the CBD implied approach of equal criteria weighting. It also identifies seamounts that contain biological systems likely to be vulnerable to human threats (evaluated by using fishing impacts on stony corals as the metric) and which are likely to show a high degree of naturalness. This combination of EBSA criteria is also appropriate for identifying groups of seamounts in areas that could be considered for protection as part of a wider network of High Seas MPAs in the region. The 83 seamounts identified by this combination of criteria were distributed across the South Pacific region, with clusters of five or more seamounts in five areas (Nazca Ridge and Sala y Gomez Seamount Chain, Three Kings Ridge, Foundation Seamounts, Louisville Seamount Chain, North Colville Ridge) as well as pairs or single seamounts at other locations (Karasev Bank, East Chatham Rise, Eltanin Fracture Zone, Gascoyne Seamount, Geracyl Ridge) (Fig. 4).

The selection process using Option 5 can include seamounts that meet any of the biological criteria (Table 4), and hence it can be useful to identify the prevalence of single criteria which contribute to this process or how broadly a candidate EBSA fulfils the criteria. This is a complementary analysis that does not replace the selection algorithms, and is intended to answer specific questions that environmental managers may have about the candidate EBSAs' 'performance' against the criteria or the influence of individual criteria (Fig. 5). For example, most seamounts in the Nazca and Sala y Gomez area meet most of the criteria. The exceptions are C1, which was met by only 10% of seamounts included in this candidate EBSA, and C2, which was not satisfied by any seamount in any area (Fig. 5). Conversely, if it were deemed important to select an area that would afford greater protection to unique or rare characteristics of an ecosystem, then Foundation Seamounts would be a better candidate area; many seamounts in this area perform poorly, however, against the other criteria (Fig. 5).

Table 3
Multi-criteria combination options evaluated to identify candidate EBSAs. The boxes represent parentheses in selection statements, colour-coded to reflect separate versus combined criteria, and whether biological or human-impact criteria.

Option:	1	2	3	4	5	6
Criterion						
Biological						
C1 - Uniqueness/rarity*	C1	C1	C1	C1	C1	C1
	and	and	or	or	or	or
C2 - Life-history*	C2	C2	C2	C2	C2	C2
	and	and	or	or	or	or
C3 - Endangered species*	C3	C3	C3	C3	C3	C3
	and	and	and	or	or	or
C5 - Productivity	C5	C5	C5	C5	C5	C5
	and	or	or	and	or	or
C6 - Biodiversity	C6	C6	C6	C6	C6	C6
Human Impact	and	and	and	and	and	or
C4 - Vulnerability	C4	C4	C4	C4	C4	C4
	and	and	and	and	and	or
C7 - Naturalness	C7	C7	C7	C7	C7	C7
No. seamounts selected:	0	0	43	65	83	3374

* considered of higher biological importance/relevance

4. Discussion

The CBD process for identifying candidate EBSAs has revolved around a series of Regional Workshops held to cover areas of the northeast Atlantic (2011), western South Pacific (2011), south-eastern Atlantic (2012), Caribbean and western Mid-Atlantic (2012), southern Indian Ocean (2012), eastern tropical and temperate Pacific (2012), and North Pacific (2013). These workshops have identified several hundred benthic and pelagic candidate EBSAs, based largely on eliciting expert opinion for each area. Regional workshops have generally comprised one expert nominated from each country in the region, plus additional experts from Non-Governmental Organisations (e.g., Birdlife International). Observations by several of the current authors involved in this process were that the experts tend to emphasise the areas or features they know best. Without a structured method for data input and evaluation, future workshops may potentially miss locations that are under-sampled (such as those in remote and High Seas areas), and may also expose the EBSA process to criticism from stakeholders with competing objectives (e.g., resource use versus conservation), or those not involved in the selection, evaluation and submission process. Thus, we contend there is a need for a method that can be used across multiple regions to identify candidate EBSAs in a comparable and robust manner. The proposed method presented in this paper was developed for seamounts, but is likely to have broader applicability to identify candidate EBSAs for a wide range of benthic and pelagic systems.

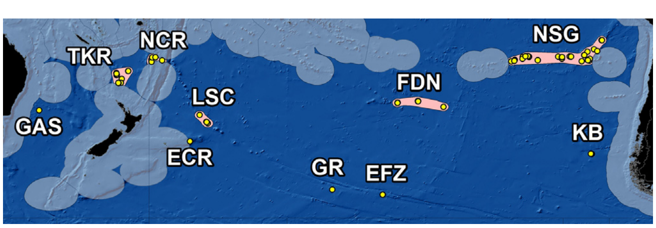

Fig. 4. Map of the South Pacific study region showing seamounts and seamount areas identified as candidate EBSAs. Areas shown are Nazca Ridge and Sala y Gomez Seamount Chain (NSG), Three Kings Ridge (TKR), Foundation Seamount (FN), Louisville Seamount Chain (LSC), North Colville Ridge (NCR), Karasev Bank (KB), East Chatham Rise (ECR), Eltanin Fracture Zone (EFZ), Gascoyne Seamount (GAS), and Geracyl Ridge (GR). See text for detail about what data and combination of criteria were used to identify candidate EBSAs for seamounts.

4.1. The proposed method

The method we have developed is based on a logical sequence of actions. The identification and collation of information is followed by the creation of data layers and the setting of thresholds for each criterion. The method uses a combined criteria approach to identify candidate EBSAs from a large number of sites that could potentially qualify for EBSA status based on meeting one or a few of the criteria. It systematically structures the criteria and subsequent analysis of relevant datasets to score the criteria. Data with potential to inform EBSA identification are selected first, as opposed to identifying areas and then using data to justify their selection. The method, importantly, allows the contribution of individual attributes (e.g., diversity, rarity, vulnerability) to be transparent. It also identifies the types of data considered, and highlights where major data sources are limited or lacking. The methodology, and especially the data sources that can be integrated, can be modified by regional knowledge on smaller spatial scales than considered here. It can also be nested within a regional or national process, as a globally consistent framework for identifying ecologically important sites. A habitat-by-habitat approach can be taken, whereby results from several habitats can be combined into a more comprehensive assessment of global EBSAs. The method, however, addresses solely the criteria for identifying candidate EBSAs, and is not designed to identify networks of protected areas on large ocean-basin scales (covered in Annex II of Decision IX/20).

Table 4
Number of seamounts within each candidate EBSA that meet criteria C1 to C7 (NB – all features had to meet both criteria related to human impacts, C4 and C7). Blank cells denote that no feature within a candidate area met a criterion.

Potential candidate area	No. seamounts selected	C1 uniqueness/ rarity	C2 life-history	C3 endangered species	C5 productivity	C6 biodiversity	C4 vulnerability	C7 naturalness
Nazca Ridge and Sala y Gomez Seamount Chain (NSG)	40	4	–	31	20	33	40	40
Three Kings Ridge (TKR)	12	–	–	10	12	12	12	12
Foundation Seamounts (FN)	10	6	–	–	4	–	10	10
Louisville Seamount Chain (LSC)	5	–	–	–	5	–	5	5
North Colville Ridge (NCR)	5	1	–	–	5	5	5	5
Karasev Bank (KB)	5	5	–	–	3	–	5	5
East Chatham Rise (ECR)	2	–	–	–	–	2	2	2
Eltanin Fracture Zone (EFZ)	2	–	–	–	–	2	2	2
Gascoyne Seamount (GAS)	1	1	–	–	1	1	1	1
Geracyl Ridge (GR)	1	–	–	–	1	–	1	1

4.2. *Data issues*

The analyses we undertook were intentionally limited to using data immediately to hand, and used sample data rather than model data wherever possible. Such data were used because the emphasis of the study was to develop an overall *method*, not to generate specific results. In a number of instances, other data could have been used (such as longline fishing, other data on spawning or nursery grounds). If the method is to be used for a formal assessment in the future, then improved information on the composition of biological communities (especially endemic or highly vulnerable species) and the extent of threats from fishing or mining is necessary to make the application of the criteria more robust. However, the worked example demonstrates the applicability of the method across datasets that are variable in their quantity and quality – a common situation in conservation planning.

In developing the method, we made use of large global as well as regional biological datasets and substituted physical environmental proxies for some of the biological criteria. This meant that we were able to evaluate all of the CBD criteria. In some situations, however, it may not be possible to find adequate data for each criterion. Options then are to exclude the particular criterion, use available data (even if incomplete), or use an environmental proxy for the biological attribute. We considered excluding a criterion to be undesirable, as all the criteria are regarded by the CBD as important components of defining an EBSA. In a review of the Canadian experience with EBSAs, (Department of Fisheries and Oceans, 2011) it was noted that incomplete scientific data should only be rejected if they were collected using poor methods, or their use could be misleading. When data are very patchy or of highly variable quality, outputs could be misleading by only selecting those areas/sites for which data exist, or sites that are poorly sampled will have 'estimates' that are downwardly biased. Thus, unless these issues are carefully evaluated, it may be better to use proxies. In our worked example, one of the measures of unique/rare was described by seamount depth, where the extreme depth ranges (very shallow or very deep) were used to represent rare habitat. In our view there would be very few instances where an environmental proxy could not be used to evaluate the EBSA criteria. For example, factors such as depth, substrate, water mass, and dissolved oxygen are known to be major drivers of faunal community composition in the sea (e.g., Rex and Etter, 2010), and local circulation patterns can enhance recruitment (e.g., Mullineaux and Mills, 1997).

The results of the worked example for the southern Pacific Ocean were, invariably, driven by the selection of datasets and the way criteria were combined in the selection process (Table 3). The forcing of all multi-criteria options to meet the threshold values of the EBSA criteria Vulnerability (C4) and Naturalness (C7) meant that seamounts identified by all options are always shallower than 2 000 m (because of the use of reef-building stony corals as the data set to define C4) and those that have not been subject to bottom fishing (the global trawl data used for C7). If we had used different data to assess "vulnerability" (e.g., distribution of very low productivity species), and "naturalness" (e.g., distribution of longline fishing), then seamounts at depths >2 000 m and those without known fisheries other than trawling could have been identified as candidate EBSAs. Note that Gascoyne Seamount, which was selected as a candidate EBSA, has been subject to extensive non-trawl fishing. In addition, by identifying only untrawled seamounts, we effectively excluded the criterion for important life history stages (C2) from the identification process, because that data set was limited to the spawning grounds of orange roughy. This is a commercial species, and the spawning sites are all fished. With more data on non-commercial species, this situation would not occur, although we did not feel that it was a major limitation because the absence of strong human impact (as indexed by the fishing data) is an important condition for a candidate EBSA. However, areas that have been lightly fished can still be identified as EBSAs (Weaver and Johnson, 2012). Nevertheless, this result underlines the importance of having a transparent method, whereby the influence of all criteria on the identification of candidate EBSAs can be easily evaluated.

Most criteria were evaluated using only one set of data, and the maximum we used was three. Well-sampled regions will have many more datasets that can be applied to each criterion. This is unlikely in the High Seas, but inside EEZs there may be many sources of information which might require some rationalisation. While the proposed method itself is independent of the number of datasets, emphasis should be placed on using robust, high quality, data sources. Decisions can be made in individual situations whether to include all or a subset of datasets, or to weight some sources over others. These decisions could be made with reference to the reliability associated with each dataset.

Uncertainty was not considered in the worked example, but the degree of certainty associated with the data used should be quantified. For example, a higher confidence would typically be attributed to information derived from direct measurements relative to modelled data. Conversely, modelled results may be more appropriate if applied over large areas. It would be relatively straightforward to assign a subjective confidence score (such as low-medium-high) to each data set as an indication of their reliability. The certainty score could be used to weight criteria, or datasets within a criterion when multiple data are available.

It would be useful to apply the proposed method at a range of spatial scales, and with various levels of data quality and quantity. This procedure would ensure that the method performs as expected with both data-rich situations (such as where detailed regional datasets are available) as well as at a global level, where

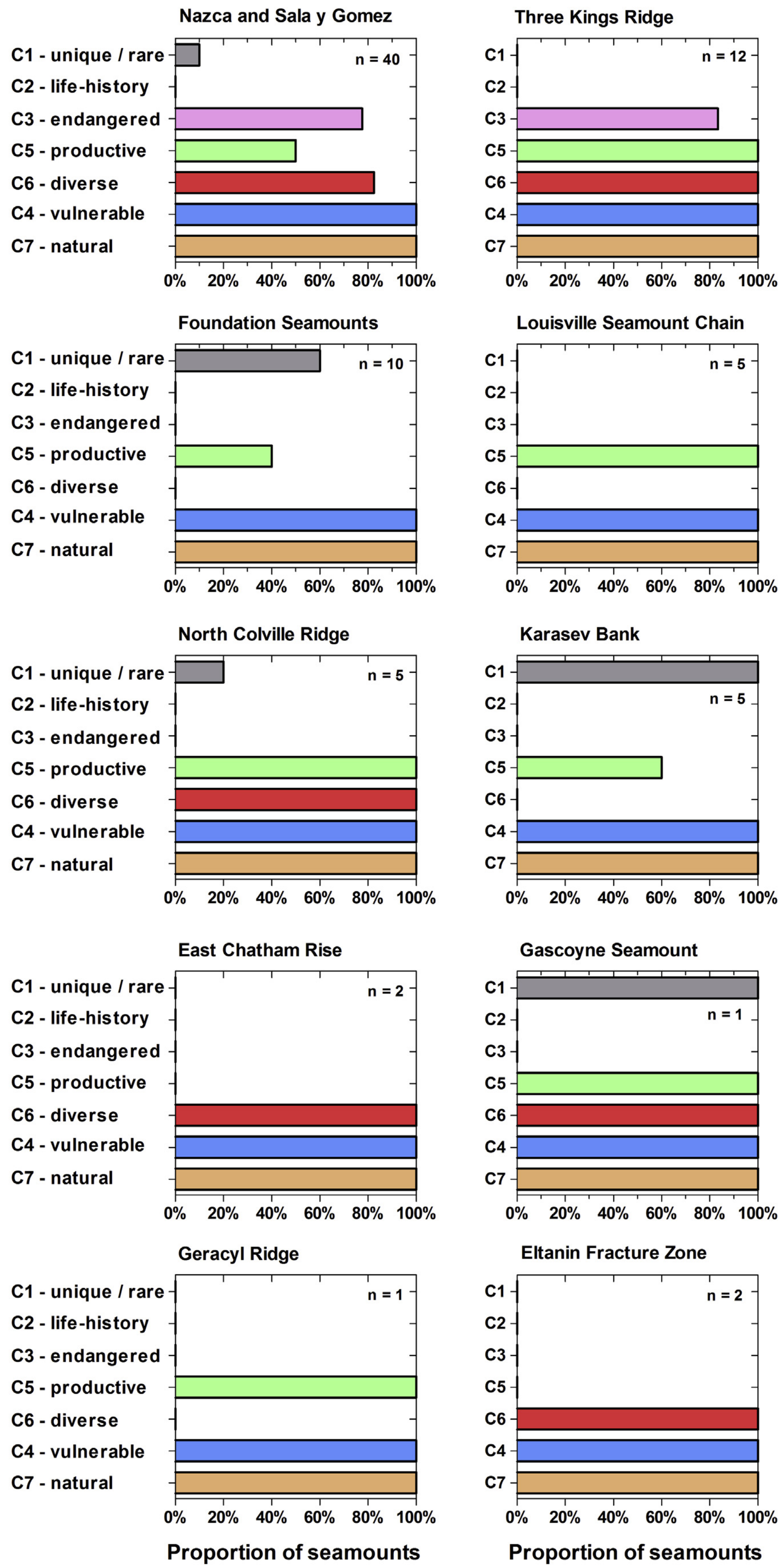

Fig. 5. Bar charts showing the relative contribution of each EBSA criterion to the overall identification of candidate EBSAs for seamounts.

the approach could give valuable insight into the relative merits of candidate EBSAs in different ocean basins which are currently assessed independently in CBD Regional Workshops.

4.3. The approach

We have suggested that when selecting the area of interest within which EBSAs are to be identified, available biogeographic classifications should be considered. In ocean-basin scale deliberations, a broad classification such as that of Watling et al. (2013) can be used. If candidate EBSAs are to be part of a global network, then it would be advantageous to conduct the analysis within each biogeographic area to generate a suite of representative EBSAs across a large region with multiple biogeographic units. Gregr et al. (2012) summarised a number of marine habitat classification methods and schemes that operate at different spatial scales, and can be useful in helping define the location or characteristics of EBSAs.

Our method involved a simple combination of criteria using a straight-forward procedure. We used a binary outcome for each seamount against each criterion (i.e. meets or fails the criterion) without an explicit weighting of criteria in the selection process. Taranto et al. (2012) used an Ecosystem Evaluation Framework method to examine the likelihood of a seamount constituting an EBSA as well as its level of human impact. An interesting difference in the methodology applied by Taranto et al. (2012) and ours is the weighting that they gave to different EBSA criteria and datasets. The presence (actual or implied) of, for example, cold-water corals, was given a weight of 3, because it was applied to three EBSA criteria (C3, C4, and C6), whereas depth had a weight of 1 as it was used only as an indicator of criterion 5. In our worked example, an individual dataset was used only to evaluate a single EBSA criterion. Whether a dataset is used across criteria matters more when relative EBSA selection is based on a scoring system (as in Taranto et al., 2012), but not if it is a yes/no categorical situation.

The separation of criteria into biological and threat categories was an important step in terms of structuring the method for future management, and the phrase "in need of protection" stated in the CBD Decision IX/20 (CBD, 2008). This division also recognises that ecosystem vulnerability can be due to natural (climate) change as well as a number of direct human-induced factors. Taranto et al. (2012) also tended to separate concepts of threat from the biological attributes of an EBSA. However, they included naturalness as a biological parameter, and then separately evaluated human impacts. The latter considered the type of fishing method or mining operation, as well as the perceived relative impact to different components of the ecosystem. The worked examples provided by Taranto et al. (2012) cover 8 seamounts for which a large amount of data are available and which enable a very thorough examination. Their approach is appropriate when there are good data on human activities at a detailed scale, which is typically not the case in the High Seas (e.g., Clark et al., 2010). The human-induced threats analysis by Taranto et al. (2012) was covered under our evaluation of naturalness as a simple categorical fished/not-fished, which can be modified with more categories, or with different thresholds, where more information is available such as number of tows, or magnitude of catch.

An important concept in our method was identifying candidate EBSAs over a wider area than a single point habitat. This recognises the likelihood that a single site is part of a larger ecosystem. For example, a group or chain of seamounts may vary in their individual characteristics, and taking a more extensive area will include a greater range of the variability which is desirable for protecting higher diversity as well as ecosystem function.

Consideration of large areas was also a recommendation from an equivalent pelagic workshop to our initial benthic (seamounts) workshop in 2010. Dunn et al. (2011) identified five general guidelines which can apply equally to defining EBSAs in benthic environments: (1) think big (large areas), (2) consider time (environments are dynamic and change over time), (3) think deep (consider all depths), (4) be dynamic (take into account spatial and temporal variability), and (5) quantify uncertainty (recognise that data may be poor, and be adaptive).

4.4. Future developments

The CBD has committed to holding at least one further round of Regional Workshops following the current round. The method outlined here would facilitate candidate EBSA identification based on a data-focussed approach in these future workshops, and define areas that might not be picked up through solely expert opinion.

A data-driven process has the potential to complement an expert approach. Two of the areas identified by our worked example have also been identified through the Pacific regional workshops in 2011 and 2012: the Louisville Ridge, and the Nazca Ridge and Sala y Gomez Seamount Chain. Both these areas have been identified partly based on their benthic features. This concordance suggests that adopting a data-driven approach could potentially replace more subjective expert opinion, and consequently strengthen the justification of candidate EBSA selection, reduce possible criticism from conflicting stakeholders and improve uptake of the results by environmental managers.

The Aichi targets 6 and 11 of the CBD (CBD, 2011) contain several commitments to ensure sustainable use and conservation of biodiversity on the High Seas. Linking these targets to ensure that management objectives do not conflict and that the goals can be integrated is important. The EBSA concept under the CBD should be considered alongside a number of other types of important marine areas, and the associated processes of other agencies. These include Areas of Particular Environmental Interest (APEI) of the International Seabed Authority; World Heritage Sites under UNESCO; Vulnerable Marine Ecosystems (VME) which are covered under FAO and RFMOs; and Particularly Sensitive Sea Areas (PSSA) identified under the International Maritime Organization. Ban et al. (2013) note that fisheries and conservation goals in High Sea areas can be harmonised provided that the goals and objectives of management are clearly described and they outline a "Systematic Conservation Planning" approach to improve the sustainable use of resources by all stakeholders. The structured method outlined here to identify and assess candidate EBSAs against selection criteria is, we hope, a potentially important tool to help nations effectively manage areas of significant marine biodiversity.

Acknowledgements

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Appendix A. Figures of the distribution of seamounts satisfying EBSA criteria

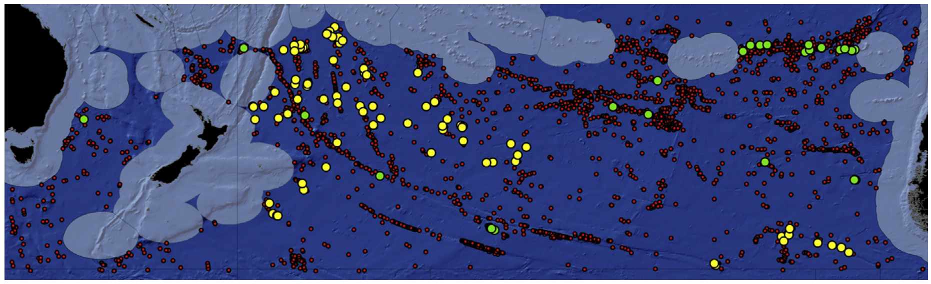

Fig. A.1. Seamounts in the study region satisfying EBSA criterion 1 (uniqueness or rarity) using data for very shallow (green dots) and very deep seamounts (yellow dots).

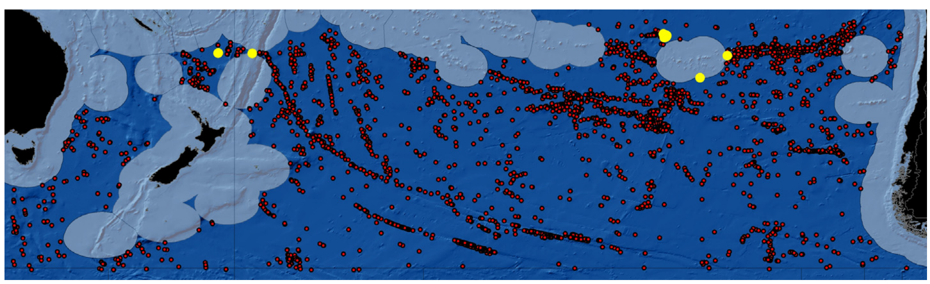

Fig. A.2. Seamounts in the study region satisfying EBSA criterion 1 (uniqueness or rarity) using data for known vent communities.

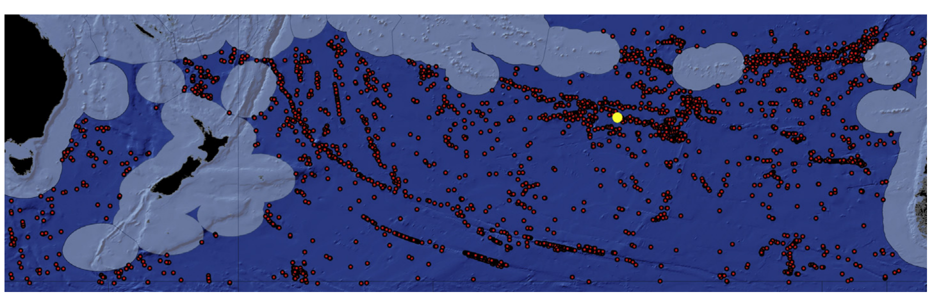

Fig. A.3. Seamounts in the study region satisfying EBSA criterion 1 (uniqueness or rarity) using data for the presence of a seamount endemic lobster (*Jasus caveorum*).

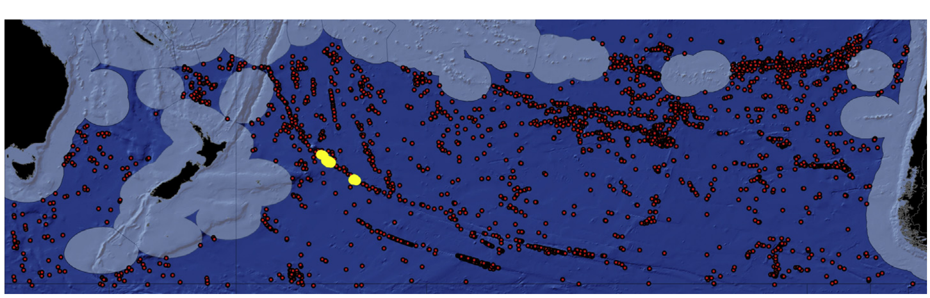

Fig. A.4. Seamounts in the study region satisfying EBSA criterion 2 (special importance for life-history stages of species) using data for spawning areas of orange roughy (*Hoplostethus atlanticus*).

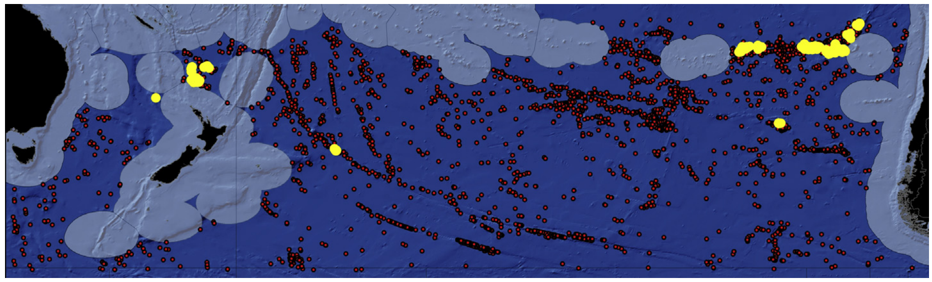

Fig. A.5. Seamounts in the study region satisfying EBSA criterion 3 (importance for threatened, endangered or declining species and/or habitats) using data for IUCN red list species from OBIS records.

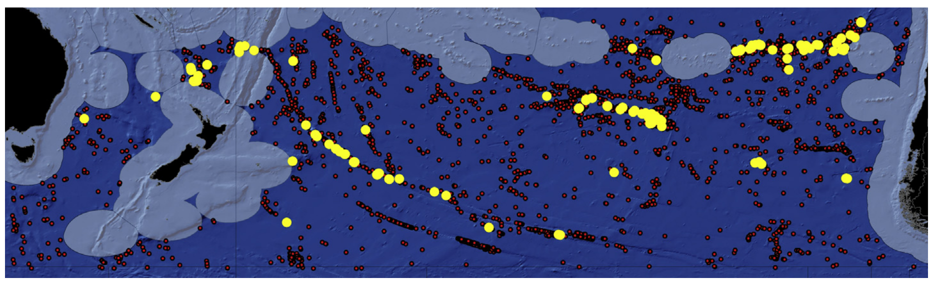

Fig. A.6. Seamounts in the study region satisfying EBSA criterion 4 (vulnerability, fragility, sensitivity and slow recovery) using data for high probability of habitat suitability for stony corals.

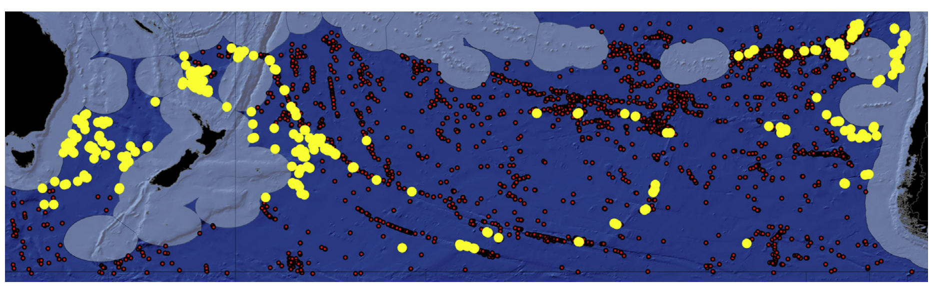

Fig. A.7. Seamounts in the study region satisfying EBSA criterion 5 (biological productivity) using data for POC flux to the summit depth of a seamount.

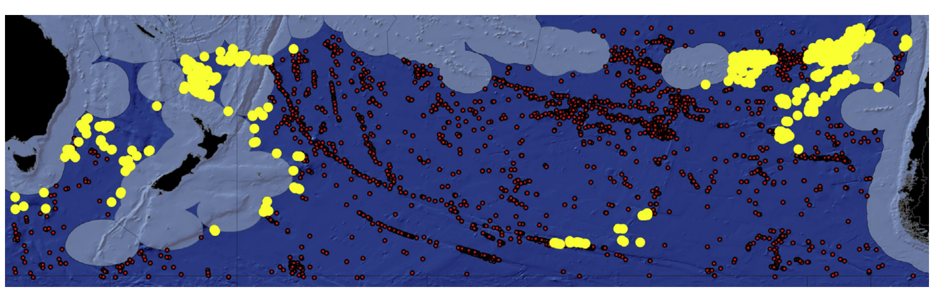

Fig. A.8. Seamounts in the study region satisfying EBSA criterion 6 (biological diversity) using data for high Shannon diversity.

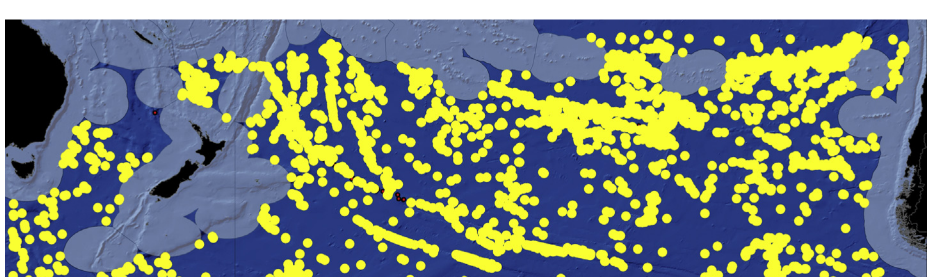

Fig. A.9. Seamounts in the study region satisfying EBSA criterion 7 (naturalness) using data for seamount trawling distribution and fishery catch data.

Appendix B. Figures of the distribution of seamounts satisfying various EBSA selection criteria.

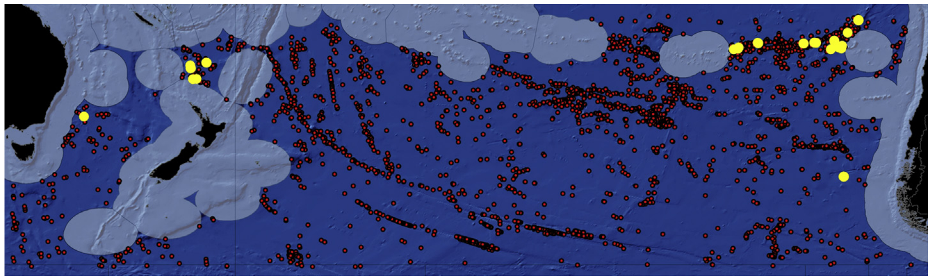

Fig. B.1. Distribution of seamounts in the Study area satisfying Selection option 3 (43 seamounts)

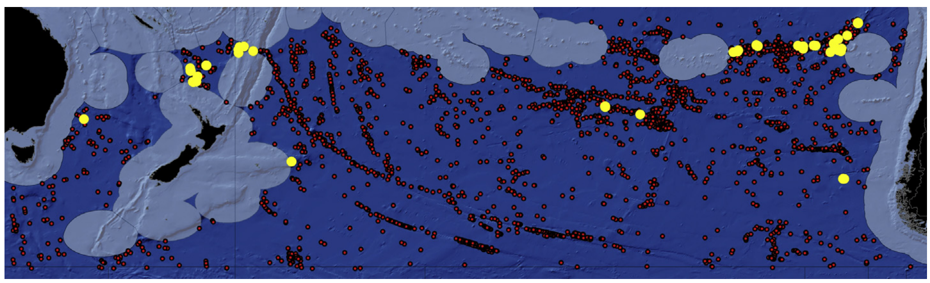

Fig. B.2. Distribution of seamounts in the Study area satisfying Selection option 4 (65 seamounts)

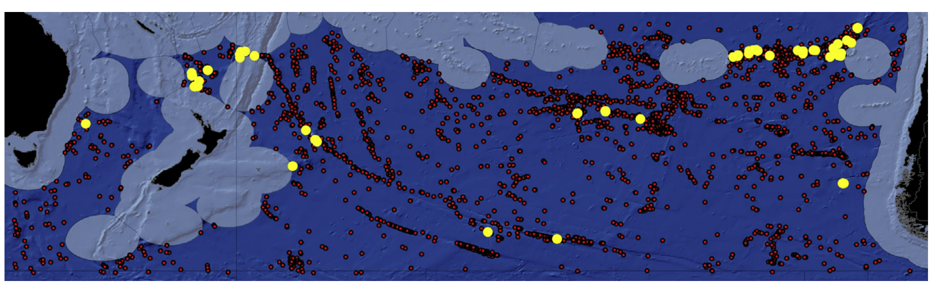

Fig. B.3. Distribution of seamounts in the Study area satisfying Selection option 5 (83 seamounts)

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