# Defining ecologically or biologically significant areas in the open oceans and deep seas: Analysis, tools, resources and illustrations

A background document for the CBD expert workshop on scientific and technical guidance on the use of biogeographic classification systems and identification of marine areas beyond national jurisdiction in need of protection,

Ottawa, Canada
29 September – 2 October 2009
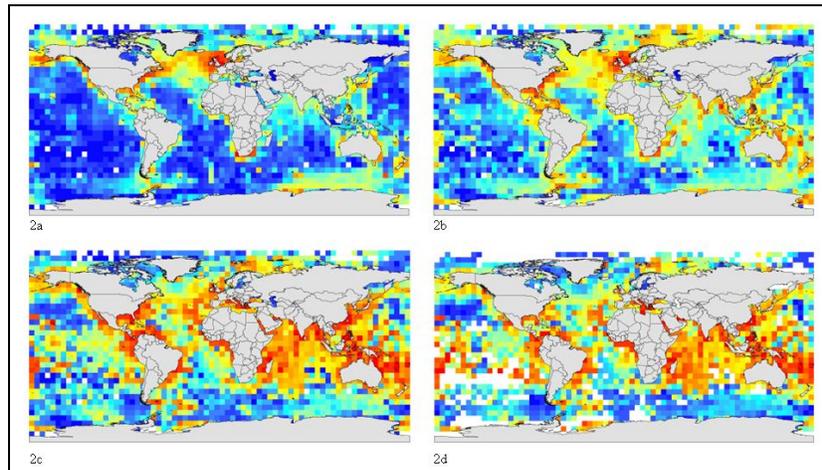
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Comments

Comments on this document are invited and may be provided at the Ottawa workshop and also directly to Kristina M. Gjerde, IUCN High Seas Policy Advisor, at kgjerde@eip.com.pl. until 10 October.

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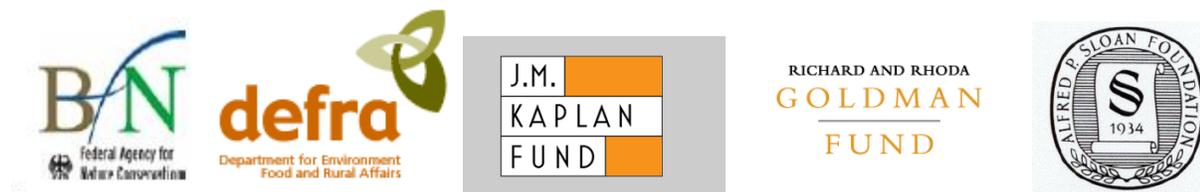
Executive Summary

The Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted in 2008 scientific criteria for identifying ecologically or biologically significant marine areas (EBSAs) in need of protection. The application of these criteria will specifically focus on the open oceans and deep seas, which encompass regions of the Earth that we have only started to explore. While much scientific discovery lies ahead, available information and current and emerging methodologies already allow us to begin identifying oceanic features that are likely of particular ecological or biological importance.

In order to facilitate this process, the CBD COP decided to convene an expert workshop to review and synthesize progress on the identification of areas beyond national jurisdiction which meet the adopted CBD scientific criteria. There are an increasing number of scientific techniques that could be used in application of each of the seven criteria (Uniqueness or rarity; Special importance for life history of species; Importance for threatened, endangered or declining species and/or habitats; Vulnerability, fragility, sensitivity, slow recovery; Biological productivity; Biological diversity; and Naturalness). This document provides a general overview of these techniques, and discusses key issues concerning the strengths, challenges and limitations in the availability of data and scientific understanding we face at this time.

This document reviews the description of each of the scientific criteria and comments on their potential applications, discusses a variety of ways in which the scientific community understands these criteria, and how they can be used as a foundation for informing future decisions regarding the marine environment of the open oceans and deep seas. An important component of the document is a set of practical illustrations (Annex 2) to increase our understanding of how the seven scientific criteria can be applied. These provide a range of examples considering species, habitats and recurrent oceanographic features using a variety of techniques ranging from field surveys, satellite tracking of tagged animals and remote sensing, to sophisticated modelling and range prediction. These illustrations are not meant as proposals for specific management measures, but are simply presented as examples of various scientific methods and techniques relevant to each criterion.

Many types of data, including both physical and biological data, are needed to fully evaluate the ecological or biological significance of a marine area. The document describes available data storage and retrieval systems, and provides an annotated list of important, publicly-available data sources. Given the paucity of data for deep seas and open oceans, it is important that all available data can be used to the greatest extent possible to facilitate the eventual identification and evaluation of EBSAs. Making data and information publicly available and easily accessible through relevant data archives and warehouses will support further research and potential management applications.

Data sharing will also support the making of robust predictions for areas that remain relatively unknown. In the absence of good broad scale survey data, limited high quality data can be used to calibrate predictive modelling of the occurrence or abundance of a species or physical ecosystem

features. While predictive models are not a substitute for observations, if adequately validated, they can make important contributions to evaluation of EBSAs.

Annex 1 of this document contains considerations for practitioners, which are more technical in nature. The annex consolidates inputs from a variety of scientific and technical experts on overarching considerations that practitioners may wish to take into account in applying the criteria. These considerations include the scale of application of the criteria and accounting for relativity, variability, and uncertainty. While the discussion is necessarily technical, this Annex provides practitioners with valuable information about how to deal with fluid ocean systems that are often data-poor and show variability on a range of spatial and temporal scales and across different levels of ecological complexity.

As the collective experience of CBD Parties in applying the scientific criteria grows, there is a need to ensure that lessons learned are made widely and rapidly available to improve overall practices and to facilitate international cooperation. In this regard, there would be great value in establishing a central repository of EBSA-related information, including documentation of expert advisory processes (from inputs to results), and any governance actions that may result from such processes. An important part of this is providing for capacity building and transfer of experience to those who lack the immediate scientific and technical capacity to apply the criteria.

Introduction

The ecological and biological importance of the open oceans and deep seas have often been underrepresented or misrepresented in discussions of global biodiversity and ecosystem function. Contrary to some popular conceptions, the open oceans and deep seas are *not* uniform, barren and relatively lifeless regions of our planet. Rather, these areas contain some of the most productive ecosystems, unique habitats, and globally rare species yet discovered. From highly productive seamounts to unique hydrothermal vent communities, to migratory pathways of endangered sea turtles, the remote oceans support an enormous wealth of ecosystem productivity, specialized habitats and individual species supporting both critical ecosystem functions and critical examples of our shared biological heritage. The open oceans (pelagic) and deep seas (benthic) represent the largest biomes of our biosphere in both surface area and volume. The dominance of the open oceans is a defining global feature and the reason why Earth is viewed from space as *the blue planet*.

There are many historic and technical reasons why open ocean and deep sea ecosystems have been relatively underrepresented for their biological and ecological significance to date. Open oceans and deep sea areas are distant from human populations and are often inaccessible without significant technological intervention. Centuries of navigation traditions have been replaced by other systems of communication. However, the accumulated assembly of new technologies and new research findings are now helping to "illuminate" the deep ocean areas of our planet and are providing a significantly more detailed and comprehensive view of these regions and ecosystems. While much scientific discovery lies ahead, the characteristics and locations of oceanic features that are of particular importance, ecologically or biologically, are already emerging.

Because the open oceans and deep seas often fall outside of national jurisdictions, an international and cooperative approach is fundamental to the characterization, location and eventual prioritization of these important features for the protection of their critical roles in ecosystem processes. While much information and many scientific methods can be extended from national surveys, international cooperation will be critical in developing a common understanding in the application of scientific criteria. The ongoing international processes convened by the Convention on Biological Diversity (CBD) under the auspices of the United Nations Environment Program (UNEP) have been serving as a forum for the development of initial criteria to define important areas in the open oceans and deep seas.

This document provides a general overview of current and emerging techniques that could be used in the identification of ecologically or biologically significant areas (EBSAs), as well as highlighting key issues concerning the strengths, challenges and limitations in the availability of data and scientific understanding we face at this time. Annex 1 to this document presents a technical synopsis for practitioners of some considerations with regard to application of scientific criteria, including issues related to scale, relativity, variability, and uncertainty. Annex 2 provides contributed illustrations of possible ways that ecologically and biologically significant areas (EBSAs --CBD Decision IX/20 Annex1) could be identified in the open oceans and deep seas.

A brief history of the Ecologically or Biologically Significant Areas (EBSA) criteria development process

In 2007 a CBD expert workshop was convened in the Azores, Portugal, to develop, refine and consolidate scientific and ecological criteria for the identification of marine areas in need of protection and on biogeographical and other ecological classification systems. In 2008 the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted the scientific criteria (COP Decision IX/20 paragraph 14) for identifying ecologically or biologically significant marine areas in need of protection (COP Decision IX/20 Annex I) and guidance for designing representative networks of marine protected areas in open ocean waters and deep sea habitats (COP Decision IX/20 Annex II). The same decision also urged Parties and invited other Governments and relevant organizations to apply, as appropriate, the Azores scientific criteria and guidance (paragraph 18). This background document focuses on the scientific criteria in Annex I of the CBD Decision.

These criteria are based on seven general areas of consideration:

1. Uniqueness or rarity
2. Special importance for life history of species
3. Importance for threatened, endangered or declining species and/or habitats
4. Vulnerability, fragility, sensitivity, slow recovery
5. Biological productivity
6. Biological diversity
7. Naturalness

In addition, the COP Decision IX/20 (paragraph 19) included convening an expert workshop, where scientific and technical experts were to provide scientific and technical guidance on the use and further development of biogeographic classification systems, and guidance on the identification of areas beyond national jurisdiction which meet the scientific criteria in Annex I of the decision.

The central task of the CBD expert workshop (Ottawa 2009) is to provide guidance on the identification of areas beyond national jurisdiction which meet the scientific criteria in Annex 1 of decision IX/20. To do so, the workshop will review and synthesize progress on the identification of areas beyond national jurisdiction which meet the scientific criteria in Annex I to the present decision, and experience with the use of the biogeographic classification system, building upon a compilation of existing sectoral, regional and national efforts.

This background document and contributed illustrations have been developed to help inform the current expert workshop process. The materials included in this document represent contributions from a broad range of individuals and institutions with expertise in marine ecology, biogeography, mapping, visualization and knowledge management. The intention of this compilation is to help inform general discussion and provide illustrative examples of how EBSA criteria can be applied in the oceans, not to suggest specific sites to be considered for designation of protective measures.

Discussion of the EBSA criteria

In the following sections, a description of each of the EBSA criteria and comments on the potential application of these criteria are presented. The purpose of this discussion is to present a variety of ways in which the scientific community understands these criteria and how they can be used as a foundation for informing future decisions regarding the marine environment of the open oceans and deep seas. This overview is complemented by Annex 1 on Considerations for Practitioners that provides a more technical discussion concerning general issues such as scale of application of the criteria, and issues related to precision, accuracy and uncertainty and data availability, and Annex 2 with illustrations of various ways the criteria can be applied to identify significant areas.

Criterion 1: Uniqueness or rarity

Definition (from CBD Decision IX/20 Annex 1)

Area contains either (i) unique ("the only one of its kind"), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.

Comments on the definition

This criterion is established to identify unique or rare occurrences of species or habitats for consideration. The uniqueness or rarity of a given feature may be determined at a variety of scales, including the global, ocean basin, regional, or local scale. While 'uniqueness' by definition cannot be judged on a relative scale (i.e. an object is either unique, or it isn't), 'rarity' may be judged relative to other species or habitats.

Comments on the application of this criterion

Rarity and Uniqueness are strongly influenced by the scale at which the policy and management jurisdiction is functioning (the material for practitioners on Scale (Annex I) is relevant to the application of this criterion). Global rarity should be taken into account when applying this criterion at regional or local scales, such that a globally rare or unique property is identified as significant even if it is relatively common within the specific region or locality for which the evaluation is conducted. However, a feature that is depleted, rare or unique at the scale of a specific jurisdiction's evaluation should also be considered, even if the feature may be more common elsewhere.

In areas where biological information is scarce, physical data may provide the only basis for application of this criterion. Areas that have unique substrates and bathymetries may be appropriate as EBSAs based on this criterion, even without data on the biological communities present in the physically unique sites. For example, in the eastern Australian margin survey using multibeam bathymetry to map >25,000km^2 of the seabed, only 31 km^2 (0.12%) of seabed was comprised of hard substrata, while the remaining seabed comprised bioturbated soft-sediment plains. In such a circumstance it is appropriate

to assume that the biotic community supported by rare physical geography (i.e. hard substrata in this case) is also rare and should be considered as ecologically or biologically significant.

For most of the deep sea, there is an emerging consensus that many species are fairly rare, and thus that "rarity is common." If this is true, this part of the criterion for deep sea areas may pose some initial difficulties. That said, some deep sea species are likely to be *more rare* than others.

Methods

Application of the *Uniqueness & Rarity* criterion may be based on biological, ecological and oceanographic information from peer reviewed literature, technical reports and data sets. As was done in the Sargasso Sea study (see Annex 2), areas containing similar features may be compared to assess the ways in which one area is different or unique. Uniqueness or rarity can also be based on similar comparisons of survey data.

It must be noted that this criterion poses particular challenges when applied in the deep sea due to the fact that much of these ocean regions have not been well studied. Given the limited sampling that has been done on deep-sea communities, applying this criterion beyond directly surveyed areas requires the creation of predictive models using appropriate survey data.   Physical features such as rugosity, depth, and benthic complexity can be remotely sensed and are widely used in habitat modeling. Such variables have proven to be indicators of habitat for different species, and as such they are often used to classify benthic habitats and to quantify the availability of particular habitats and their obligate (directly associated) species.

There are many techniques currently used to create such predictive models (see *Predictive Modelling*, Annex 1), and the validity and usefulness of the method has been repeatedly proven. However, these techniques tend to over-estimate the possible habitat for a given species or community and hence are prone to errors of commission, which could lead to the protection of areas where the predicted species do not actually exist, unless they are followed-up with *in situ* surveys. Building on these studies, it may be possible to reliably identify unique or rare combinations of such physical features where reliable biotic survey data are not yet available.

Illustrations of how the criterion could be applied

Practical examples of how the *uniqueness or rarity* criterion could be applied can be found in Annex 2. These illustrations relate to the Saya de Malha Banks in the Indian Ocean and to the Sargasso Sea in the North Atlantic, and are based on a review of literature. It should be noted that these illustrations are presented as examples of how the criterion could be applied, and are not meant as a proposal for specific management measures.

Criterion 2: Special importance for life-history stages of species

Definition (from CBD Decision IX/20 Annex 1)

Areas that are required for a population to survive and thrive.

Comments on the definition

This criterion is intended to identify specific areas that support critical life-history stages of individual species. This is an inclusive definition which incorporates all life history stages of a species or population, but which leaves open the question of how an area can be determined to be "required" for survival and reproduction.

Comments on the application of this criterion

The application of this criterion will focus on the reliability and exclusivity of use of an area for a particular life history function of one or more species. The "significance" of an area increases as either factor (reliability over time, exclusivity relative to alternative areas) increases; i.e. "significance" increases as a greater percentage of the species use an area more regularly (in time and space) for an important life history function. It is also noted that sex, age and other biological variables can influence where these important areas exist within a single species (i.e., females with nursing offspring vs. single males), so caution should be taken when looking at this criterion across one species or population. See Annex 2: "Areas of special importance for the Antipodean Albatross in the Tasman Sea" for an example of how the significance of an area has been quantified based on this criterion.

Application of this criterion for deep sea species can be difficult because specialized sampling gears are needed to sample early life stages of deep waters species such that they are without contamination from other depths. Species identifications of immature life-history stages of deep-water species are also poorly described in many areas, making it hard to identify areas of special significance at the species level when dealing with immature stages of many deep-sea species.

Methods

The two EBSA criteria, *Special importance for life history stages of species* and *Importance for threatened, endangered or declining species and/or habitats*, are quite similar in nature, sharing the same examples listed in Annex I to Decision IX/20: "(i) breeding grounds, spawning areas, nursery areas, juvenile habitat or other areas important for life history stages of species; or (ii) habitats of migratory species (feeding, wintering or resting areas, breeding, moulting, migratory routes)." Due to this similarity, they will be considered together to aid understanding of the analytical techniques necessary to identify important areas related to a species or habitat.

The primary sources of data for application of these criteria are either survey data or satellite tracking data. Where coverage is adequate, survey data can be used directly to determine abundance and density of animals within a particular area. This type of data is extremely important if practitioners are interested in using the percentage of a population that exists in a particular location as a threshold (see Birdlife International's implementation of 'Important Bird Areas' (Annex 2) as well as considerations in Annex I). In evaluating whether data are adequate for direct evaluation of the functional importance of

an area, consideration must be given to how well the data capture the likely degree of natural variation in a species' distribution and behaviour. Areas of occupancy or performance of specific life-history activities may vary greatly from year to year, season to season or at an even shorter time scale. Consequently, the degree to which the available data are merely "snapshots" (i.e. representative of conditions at a single point in time) affects whether observed absences can be used as justification that an area is not used by a species, or observed presences can be used as justification that an area is *necessary* for that life history function. The less representative in space and time the available data are considered to be, the more likely it is that an evaluation should at least augment direct observational data with tested models. Where there are insufficient data or knowledge for direct estimates, models can be used to predict the likelihood of occurrence or abundance of a species from physical and biological oceanographic data.

Satellite tracking data offers more detailed information about a single organism's movement and can be used to identify core use areas for individuals or aggregated to better understand the importance of areas to a population(s). The more consistent the data are from multiple tracked animals, the more valuable such data are for identifying core use areas for individuals or populations through home range analyses, predictive habitat models or resource selection models. Some general techniques that can be used on tracking data are listed below in order from the least complex and least data-intensive, to the most complex and most data-intensive methods:

- Sinuosity Analysis (Bell 1991; Grémillet et al. 2004)
- Fractal Analysis (Laidrea et al.. 2004)
- First-Passage Time Analysis (FPT; Fauchald & Tveraa 2003)
- Kernel Analyses ((Laver & Kelly, 2008)
- Regression, Autocovariate and other Habitat Modelling (Guisan & Zimmermann 2000, Dormann et al. 2007)
- State-Space Models (SSM) (Morales et al. 2004, Jonsen et al. 2005)

Illustrations of how the criterion could be applied

Practical examples of how the criterion for special importance for life-history stages of species could be applied using some of these techniques and models can be found in Annex 2. The illustrations relate to the northern elephant seals, Antipodean albatross in the Tasman Sea, and Pacific white sharks.

Criterion 3: Importance for threatened, endangered or declining species and/or habitats

Definition (from CBD Decision IX/20 Annex 1)

Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.

Comments on the definition

This criterion targets threatened, endangered or declining species and their habitats for consideration. As in the above criterion, the linkage between the area of concern and the endangered species is one of the relative factors in the application of this criterion. The greater the persistence of use of an area, and the greater the number of individuals from a threatened population that use the area, the more important the area must be considered. The definition of a "significant assemblage" is not made explicit in the definition of the criterion.

Comments on the application of this criterion

In the deep seas, assessment of species against criteria for risk of extinction is still in early stages, and the ecological requirements of most such species are poorly known. As studies to determine the population trend of a species are long term, data intensive processes, the application of this criterion must be based on pre-existing determinations of the population status of a given species. In particular, use of the IUCN RedList (http://www.iucnredlist.org) is clearly fundamental to understanding to which species this criterion applies. In data deficient situations, the listing for organisms with similar life history traits should be used until further information on the status of the species is available.

Methods

See discussion under previous criterion, *Importance for threatened, endangered or declining species and/or habitats.*

Illustrations of how the criterion could be applied

Practical examples of how the criterion of importance for threatened, endangered or declining species and/or habitats could be applied using some of these methods can be found in Annex 2. The illustrations relate to critically endangered Pacific leatherback turtles and juvenile Atlantic loggerhead turtles.

Criterion 4: Vulnerability, fragility, sensitivity, or slow recovery

Definition (from CBD Decision IX/20 Annex 1)

Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.

Comments on the definition

This EBSA criterion is focussed on the inherent sensitivity of species, or habitats, to disruption. The core concept here is that species with low reproduction rates or habitats with slow potential recovery to perturbation, for example, exhibit an inherently higher level of risk to impacts than other species or habitats. This differs from other interpretations of vulnerability (e.g. FAO 2009) which also consider the level of exposure a species or habitat has to human disturbance. For this reason, the terms fragility and sensitivity may be more appropriate as a descriptor in the application of this criterion.

Comments on the application of this criterion

"Fragility" and recovery time can be quantified by examining the life history characteristics of a species or the inherent properties of the ecosystem features themselves in the face of perturbations. In general, species that are long-lived, have a later than average age-at-first-reproduction, and those that produce few offspring are likely to be considered sensitive and require long time periods to recover from perturbation. Structure forming organisms, or habitats that require geologic time periods to form, are also likely to be slow to recover. Expert advice should be sought to explain the nature of the ecosystem properties that are considered sensitive, vulnerable, fragile or slow to recover.

Ideally, maps of the potentially sensitive or vulnerable ecosystem features would be available. Lacking adequate data for such mapping, it would still be possible to identify the areas where ecosystem features that were sensitive, vulnerable, fragile or slow to recover were known or likely to occur, based on modeling or extrapolation of expert knowledge from better known areas.

Methods

Information on which species or biomes qualify as vulnerable, fragile, sensitive or slow to recover should be based on peer-reviewed scientific literature to the extent possible. Regardless, the fragility of certain features to certain pressures (e.g. ice-dependent communities to the effects of climate change) can be taken as self-evident, unless data indicating the contrary are produced. In some cases, expert opinion can be used where vulnerabilities or sensitivities are only just beginning to enter the peer review process. As with previous criteria, this criterion can be informed by survey data and models by using physical features known to be associated with biotic features that are sensitive or slow to recover (see below).

Application of models that extrapolate results of studies in one area to other areas of similar features will be particularly helpful for evaluating sensitivity or recovery rate. In cases of particularly sensitive benthic features such as deep-water corals, merely documenting presence of the feature using the best applicable method above may be sufficient to conclude that the area would be highly relevant to this criterion, without direct evidence of how sensitive or fragile that particular stand of coral was. Although

such inferences seem obvious for features such as corals, similar evaluations are not straightforward for some other features of marine communities, including communities composed of a range of co-existing life history strategies.   In such applications models that predict the sensitivity or fragility of particular community types would be helpful.

Additionally, there are global datasets that depict or model human impact (e.g. Halpern et al. 2008, hydrocarbon exploration leases, shipping routes fishing, undersea cables, etc.) that could be overlaid with maps of fragile or sensitive habitats or species range maps to identify areas that may be under greater risk of damage or loss.

Illustrations of how the criterion could be applied

A practical example of how the criterion for vulnerability, fragility, sensitivity, or slow recovery could be applied using predictive modeling of species distributions can be found in Annex 2. The illustration relates to global habitat suitability for reef forming cold water corals.

Criterion 5: Biological productivity

Definition (from CBD Decision IX/20 Annex 1)
Area containing species, populations or communities with comparatively higher natural biological productivity.

Comments on the definition
This criterion is specified to identify regions in the open oceans which regularly exhibit high primary or secondary productivity. These highly productive regions are here assumed to provide core ecosystem services and are also generally assumed to support significant abundances of other higher trophic level species. The phrase "comparatively higher" highlights the relative (rather than absolute) nature of this criterion. How much "higher" is left open to interpretation and is discussed further in Annex I (see *relative importance / significance*).

Comments on the application of this criterion
Productivity is not the same as abundance, but at least in some instances abundance could be used as a surrogate for productivity. For this criterion, remote sensing data may be especially helpful, because methods for quantifying primary productivity are well developed (see Annex 2: Biological Productivity). Many of the issues discussed in the Practitioners Annex 1 on spatial and temporal variation are particularly important in the application of this criterion, because centers of high primary and secondary productivity are known to vary between years, seasonally, and on short time scales, but overall core centres in space can be identified.

High productivity near the surface may not necessarily mean higher productivity near the seafloor, as currents may transport animals and nutrients hundreds of kilometres before they settle to the bottom, and thus such transport mechanisms should be considered. Studies of benthic communities have

struggled for decades to partition productivity from standing stock of biomass, and to relate patterns in both to histories of human activities in specific areas. That very large literature base should help to guide application of this criterion.

Some ecosystems in the deep sea, such as hydrothermal vents and cold seeps, are also areas of high biological productivity through the conversion of specific chemicals into energy that directly supports complex communities and often endemic species.

Methods

A variety of pre-processed biological productivity analyses are available online. As such, little analysis needs to be performed in order to apply this criterion to specific areas. For example, global datasets are available for Chlorophyll-a, primary productivity, and secondary productivity. Analytical techniques may be required to identify the patterns of spatial gradients from areas of high productivity to areas of low productivity, or such information may be found in peer-reviewed literature. Geographic Information Systems (GIS) often include tools to identify various percentage thresholds in data sets, which can contribute to evaluating how different parts of a large area score on this criterion.

The identification of oceanographic features related to higher levels of biological productivity is a more difficult task that does require analysis of oceanographic datasets. Complex algorithms exist to identify sea surface temperature fronts (e.g., Cayula & Cornillon, 1992) and warm- and cold-core eddies (e.g., Isern-Fontanet et al. 2003). Fortunately for managers and practitioners, some of these algorithms have been implemented in a user-friendly tool package, Marine Geospatial Ecology Tools, which is freely available online (http://code.env.duke.edu/projects/mget; Roberts et al., in review).

Illustrations of how the criterion could be applied

Practical examples of how the biological productivity criterion could be applied using satellite observations and readily available tools to identify areas of 1) high phytoplankton production and 2) areas of high dynamic activity as sea surface temperature fronts can be found in Annex 2.

Criterion 6: Biological diversity

Definition (from CBD Decision IX/20 Annex 1)

Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.

Comments on the definition

This criterion identifies areas of high relative taxonomic or habitat diversity. The question of measuring biological diversity has generated a whole literature base of its own, with no single agreed-upon definition of "diversity." Hence, this criterion could be considered in a number of different ways.

Comments on the application of this criterion

Measures of diversity generally consider one or more of the following factors: 1) number of different elements (species, communities, etc., also referred to as "richness"); 2) the relative abundance of the elements ("evenness" and other related measures); and 3) how different or varied the elements are when considered as a whole (e.g. taxonomic distinctness). In applying this EBSA criterion all three factors could be taken into consideration.

When species survey data are lacking, habitat characteristics can provide indications of diversity. Owing to the greater number of possible niches, habitats of higher complexity (heterogeneity) are believed to also harbour higher species diversity. For benthic habitats this can be approximated by measuring physical topographic complexity or rugosity (e.g., Ardron 2002, Dunn & Halpin 2009). For pelagic habitats, this can be estimated by identifying convergences of differing water masses. Interactions of differing water masses generally support higher biological diversity than the individual water masses, and areas of high physical energy may also have relatively high biological diversity, consistent with the diversity-disturbance relationship than has been established for many terrestrial systems. However, because of the complexity of the concept of biological diversity, and the large variance around the often statistically significant relationships between diversity and specific features of the physical environment, application of this criterion will probably be most usefully conducted with biological data, rather than relying on physical covariates of diversity.

Methods

Analytical techniques to measure of biodiversity have been a recurrent theme in ecology for many years. A number of indices exist to examine this concept:

- Berger-Parker Index (Berger & Parker 1970, May 1975)
- Simpson's Index (Simpson 1949)
- Shannon-Wiener Index (Shannon 1948)
- Pielou's Evenness Index (Pielou 1969)
- Hurlbert (ES50) Index (Hurlbert 1971)
- Rank Abundance Curves (Foster & Dunston 2009)

Illustrations of how the criterion could be applied

Practical examples of how areas of higher biological diversity could be discerned using some of the analytical techniques identified above can be found in Annex 2. These examples relate to global patterns of species diversity using Hurlbert's index; overlaps of hotspots of marine mammal biodiversity and global seamount distributions using a species distribution model; and patterns of biodiversity richness and evenness using rank abundance curves.

Criterion 7: Naturalness

Definition (from CBD Decision IX/20 Annex 1)

Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.

Comments on the definition

This criterion measures the relative "naturalness" of open ocean areas compared to other representative examples of the habitat type. This criterion is a relative measure, and it is not required that an area be pristine in order for it to be identified as an EBSA. "Comparatively higher" highlights the relative (rather than absolute) nature of this criterion. How much "higher" is left open to interpretation, but presupposes that one has at least some information or indications on historic states of the ecosystems in the region where the criterion is being applied.

Comments on the application of this criterion

The "natural" state of ecosystems in an area is often not known, even for many well-studies areas, but inferences of this status can be gleaned from other areas. There is even less information on the "natural" state of open ocean and deep sea ecosystems. In practice, application of this criterion will probably consider the history of human activity in an area where EBSA evaluations are being conducted. Areas where there is a documented or suspected history of human activities will be considered less "natural" than areas where there has been little human activity. Application of the criterion will also require taking account of what is known of the impacts of each human activity on specific ecosystem features – such as bottom trawl impacts on benthic habitats, populations, and communities; or the effects of shipping noise and ship strikes on wildlife aggregations and migrations, collisions, and so on.

Methods

Mapping and analysing the cumulative effects of human maritime activities is a new and emerging field of research. Recent studies have paved the way for analyses of human impacts globally (Halpern *et al.* 2007, 2008a, 2008b), and regionally (Eastwood *et al.* 2007; Ban & Alder 2008; Tallis *et al.* 2008; Halpern *et al.* 2009). Though methodologies are still developing, promising approaches stratify effects according to their type (physical, chemical, biological, etc.), taking into consideration both intensity and effect-distance of the given stressor on a given habitat type (Ban et al, in review).

In most studies to date, stressors are considered additive or incremental when impacts are repeated. However, stressors can be synergistic or interactive when the combined effect is larger than the additive effect of each stressor would predict (Folt *et al.* 1999; Cooper 2004; Vinebrooke *et al.* 2004). Stressors can also be antagonistic, when the impact is less than expected (Folt *et al.* 1999; Vinebrooke *et al.* 2004). Recent meta-analyses have shown that stressor interactions are additive, synergistic, and antagonistic with little ability to predict which will occur when, and with roughly equal proportions (Crain *et al.* 2008; Darling & Côté 2008).

Given the unpredictability of effects, in the absence of additional information, assuming an additive mechanism is perhaps the best way forward, though it could in some cases underestimate effects. Bearing in mind that naturalness is a relative measure, regardless of the analytical details, the mapping of cumulative stressors should reveal overall patterns that would be useful to identify possibly (more) natural areas of a given habitat type. Stressors can be mapped using a GIS and overlaid on habitat maps to predict the 'naturalness' of an area.

Illustrations of how the criterion could be applied

A practical example of how the naturalness criterion could be applied can be found in Annex 2. This combines a global set of predicted large seamount locations with historical catch data from seamount fisheries and other anthropogenic impact to identify areas of low impact in the South East Atlantic.

Sampling and data issues, including strategies for dealing with weak or incomplete data

Sampling the ocean requires sea-going or remote sensing technologies that are usually expensive and operate under conditions of severe weather and, for deeper ecosystems, high pressure and distance-communication challenges. There can be geo-political challenges to sampling as well. Researchers and policy makers are acutely aware of the limited sampling of the open ocean and deep-sea, and that southern hemisphere oceans generally are more poorly sampled than northern hemisphere oceans, and low and high-latitude seas generally more poorly sampled than mid-latitude seas. Furthermore, the sampling which has occurred is not always comparable, making global and sometimes regional analyses difficult. In recognition of the lack of sampling, it is imperative to effectively utilize what information exists and ensure that future research efforts are aligned. Towards this end, better sharing of data must be encouraged.

Types of data

Systematic decision-making requires a solid foundation from which information and knowledge can be extracted to inform choices among a set of options. In the case of evaluating the degree to which specific areas are ecologically or biologically significant, specific criteria (the "EBSA criteria") have been adopted. Using readily available data and objective criteria, it is possible to apply these criteria and evaluate areas to determine their ecological or biological significance. Physical and biological oceanographic data, from both remotely sensed and in-situ sources form the base of any evaluation processes. In addition, data sources such as species occurrence, surveys and satellite tracking data can be used to identify specific regions that may be of biological interest due to rarity of species or ecotype or because the region is particularly important to one or more at risk species. Such data are necessary

Figure from: UNEP World Conservation Monitoring Centre

components of the indices used to assess the importance of an area relative to these criteria (e.g., the calculation of Hurlbert's Index based on species occurrence data or range maps to describe the Biological Diversity criterion (Annex 2)). The data may be on species presences and/or abundances, seabed and substrate features, physical and biological oceanography, and may be observed directly, remotely sensed, or collected through systematic surveys or opportunistically.

Many different types of data are needed to fully evaluate the ecological or biological significance of a marine area. Two categories of data can be classified in the following way:

1. **Physical**: Physical oceanographic data include data on both static bathymetric attributes and on dynamic hydrographic attributes. Static bathymetric data (e.g. depth or rugosity) are informative about the presence of features such as hydrothermal vents, deep-sea trenches,

seamounts, cold seeps and submarine canyons. Commonly available dynamic physical hydrographic datasets include sea surface temperature and temperature at depth, various measures of sea surface height (e.g. mean sea level anomalies), geostrophic current data, wind and wave data, salinity, dissolved oxygen, and more complex derived products identifying fronts, eddies and other oceanographic features.

2. **Biological:** Biological data include measures of productivity (e.g. Chlorophyll-a measurements, or modelled estimates of primary or secondary production), biomass, carbon, as well as data from direct species observation (observer data, survey data and satellite telemetry data) and their derivatives (i.e., predictive habitat and range maps).

Although these data are fundamental to any systematic analysis of the marine environment, the time and expense required to collect many of these data types (e.g. species observation data, deep-seabed physical and biological data) greatly limit data availability. Furthermore, much data and information are still stored in formats that are not easily accessible (e.g., museum specimens, or non-digitised literature). Given the paucity of data that are available, it is imperative that existing data be used to the greatest extent possible and made publicly available for reuse by other researchers, managers, and policy makers. Data discoverability is a serious issue and systems are currently being developed to help with the process of understanding where to find and how to use relevant data.

Data storage and retrieval systems:

There are three main examples of data storage and retrieval systems:

1. **Metadata systems** – Metadata systems assist in discovery, and help to determine the fitness of the data for the applications being undertaken (e.g., is the spatial resolution adequate? Does the extent cover the area of concern?) Metadata assist in broadening the basis of information available to decision-makers and their technical advisors. There are few privacy issues or Intellectual Property Right concerns with metadata, and thus they are usually freely available. However, the creation of metadata is generally seen as a chore by the researchers who have collected the data. Examples of metadata databases are the Global Change Master Directory of NASA (general environmental), OceanPortal of International Oceanographic Data and Information Exchange (IODE) of the Intergovernmental Oceanographic Commission (IOC; specific to marine environment), World Conservation Monitoring Centre (WCMC; specific to conservation).

2. **Data archives** – Data archives assist in data preservation. Data archives have all the detail of the original datasets, as the data are stored in a manner that mimics the data originator's format as closely as possible. The major obstacle to data archives is convincing data generators (usually scientists) to contribute data to the archive. Many researchers view their data as proprietary and do not want to share them. Contribution of data to archives often also requires thorough metadata to be generated for the dataset, again raising the issue of the time required and the limited perceived benefit to the individual scientist of going through this process. Examples of data archives include the US National Oceanographic Data Center (NODC), and many other data centres of the IODE/IOC. These archives are usually supported by a data discovery tool/metadata catalogue.

3. **Data warehouses** – Data warehouses integrate data from other sources. The data stored in these warehouses are often of lesser detail than the original dataset, as data warehouses integrate data into one primary database that can only be as detailed as the least detailed dataset it incorporates.   Data warehouses apply quality control standards and, when implemented properly, provide an audit trail (i.e., data can be traced back to data originator and any change is documented). Data warehouses face the same issues relating to data submission raised in the data archives section above. Examples of data warehouses include the World Ocean Database and World Ocean Atlas, products of the US NODC as World Data Center for Oceanography (indispensable for much oceanographic work). The Global Biodiversity Information Facility (GBIF) and the Ocean Biogeographic Information System (OBIS: http://iOBIS.org) are now emulating physical oceanographers and compiling species distribution records.

Although each type of data storage and retrieval system has its own niche, all three 'systems' have to interlink. Metadata without access to data (through archives or warehouses) is informative, but of limited value as the data cannot be repurposed without extra effort by the potential additional users. Data warehouses are compilations, and so by definition are larger than the constituting individual datasets. The aggregation of datasets into a database of sufficient size makes new types of analysis possible. The greater geographic, temporal or taxonomic scope of the data warehouses allow for stronger and larger scale patterns to be observed. However, it is often necessary to go to individual datasets housed in data archives. Global databases are still relevant to the process, though, as they can be used to seed local databases, and for quality control (e.g. check on species identifications by comparison with known ranges).

Global databases also provide frameworks (e.g., standards, technology, networking) to facilitate further integration, and provide input for the modelling of a species' distribution – e.g. the use of environmental maxima and minima to characterize habitat suitability on a finer scale. Models are not a substitute for real observations, but will be necessary and important contributions to the evaluation of EBSAs if they have been adequately ground-truthed and validated. They can be a buffer against faulty conclusions caused by observer bias. For example, when survey data are not standardized by the amount of effort employed, inaccuracies or biases can result from intensity or longevity of the effort and result in higher numbers of species. In turn, these "rich areas" are an artefact of effort rather than a true estimate of species presence. If the models perform consistently well in areas where independent knowledge is high and their predictions can be tested rigorously, then they can be applied in situations where relevant local data do not exist but decisions are necessary. Predictions from good models are better than making a decision with little or no information whatsoever.

 As part of the process of evaluating EBSAs in areas beyond national jurisdictions, Parties and relevant organizations will need to support data archives and warehouses, provide data to them, and encourage the process of data recovery (i.e. digitizing historical data). These can enable the making of robust predictions based on sound models where data are sparse.

Strategies for dealing with weak or incomplete data

Predictive modelling

As indicated above, it is highly likely that practitioners will be faced with insufficient data to allow them to directly evaluate the importance of an area based solely on that data itself. Under such circumstances, the development of predictive models is a necessary step. Evaluation of any area of the open ocean or deep sea is simply not currently possible without such models. In the absence of good broad scale survey data, limited high quality data can be used to calibrate predictive models of the occurrence or abundance of a species or physical ecosystem features. Such modelling requires reliable data on the occurrence (presence-only, presence-absence, or abundance) of the ecosystem feature(s) relevant to the EBSA evaluation and possible covariates (i.e., environmental variables) which are likely to be widely available or readily measured in the areas of interest. Models linking the EBSA feature(s) to these more easily measured variables can use a variety of methods to assess relationships (e.g., Generalized Linear or Additive Models, Bayesian networks, and "entropy" machine-learning analyses (e.g., Maxent; Phillips et al. 2006)). Results of modelling approaches always have uncertainty about the predicted likelihood or abundance of an ecosystem feature, but good modelling methods include the uncertainty of the prediction as well as the most likely value.

Biogeographic classifications

Another possible way to address data limitations in specific areas is to apply experience from application of the criteria in other areas with similar physical, chemical and biological characteristics. In addition to input from experts, biogeographic classifications such as the Global Open Ocean and Deep Sea (GOODS) may assist in identifying similar areas. Where there are places where no alternative areas are considered similar enough to provide even coarse analogous information, this may itself be indicative of rarity or uniqueness (see discussion of the Uniqueness and Rarity criterion and illustrations in Annex 2), and further study should be encouraged to ground truth this assumption. Over time, knowledge of the open ocean and deep seas will increase, as will experience with the use of these and possibly additional criteria. Therefore any process for application of these criteria should include periodic reviews of results.

Expert processes

Expert processes relying on people experienced with the use of data and their transformation into information and knowledge can help to address data limitations, provided the processes are impartial, as empirical as the information allows, and inclusive of the range of expertise available in the region. Because the evaluations will almost inevitably require judgments by the experts, it is important that the expert processes be transparent, and fully document the reasoning behind their evaluation. As Parties begin to take the results of the expert evaluations and begin to design management measures to protect EBSAs, certain types of evaluations may prove more (or less) useful in supporting policy and management actions. To ensure these lessons are made widely and rapidly available to improve overall practices, there would be great value to a central repository of EBSA-related actions, including documentation of both expert advisory processes (from inputs to results), and governance actions with the results of the expert processes.

Annotated list of important data sources

Government agencies typically maintain archives of environmental data, often the result of monitoring activities. Each agency is responsible for their own type of data. Fisheries agencies are a prime source of information for landing statistics of fish catch, and often also for monitoring data. Environmental protection agencies are in charge of data on environmental quality. In many countries, a National Oceanographic Data Centre (NODC) is providing facilities to archive many data types related to marine sciences (e.g. NODC in the United States: http://www.nodc.noaa.gov. These NODCs work together in the framework of the Intergovernmental Oceanographic Commission (http://ioc-unesco.org/) of UNESCO. Specific examples of online resources for downloading oceanographic data are:

- Bathymetry:
  - SRTM30_Plus (see http://topex.ucsd.edu/WWW_html/srtm30_plus.html)
  - ETOPO1 (see http://www.ngdc.noaa.gov/mgg/global/etopo1sources.html)
  - GEBCO (see http://www.gebco.net/data_and_products/gridded_bathymetry_data/)
- Sea Surface Temperature:
  - AVHRR Pathfinder (see http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/)
- Ocean Color/Primary Productivity
  - NASA OceanColor Chlorophyll (see http://oceancolor.gsfc.nasa.gov/)
  - Vertically Generalized Production Model (VGPM; see http://www.science.oregonstate.edu/ocean.productivity/)
- Sea Surface Height[1]:
  - AVISO sea surface height (SSH) data
  - AVISO geostrophic current data
  - AVISO significant wave height data
- Sea Surface Wind:
  - Quikscat (see http://podaac.jpl.nasa.gov/PRODUCTS/p109.html)
  - AVISO Surface Wind data (http://www.aviso.oceanobs.com/en/data/products/wind-waves-products/mswhmwind/processing-gridded-wind-wave-products/index.html)

Many science and fisheries advisory organisations are national, but some are regional and encompass large areas of open ocean and deep sea, such as the International Council for the Exploration of the Sea (ICES http://www.ices.dk/) in the Northern Atlantic and the North Pacific Marine Science Organization (PICES http://www.pices.int/) in the Pacific. Also the UN Food and Agriculture Organization (FAO,

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[1] All available from AVISO at (http://www.aviso.oceanobs.com/en/data/products/sea-surface-height-products/global/index.html)

http://www.fao.org/) holds large amounts of data, but often aggregated to a level of detail that becomes too coarse-grained to be used for purposes other than fisheries management.

Museums are traditionally the keepers of biodiversity information, storing physical specimens since centuries. The progress in databases and communications via Internet has prompted many museums to digitise specimen data, and make this information available through the World Wide Web (e.g. Smithsonian, California Academy of Sciences, some European examples, Australia). The standards on which both GBIF and OBIS were built were created with museum specimen data in mind.

A number of marine laboratories, such as the Sir Alistair Hardy Foundation for Oceanographic Studies (SAHFOS, http://www.sahfos.ac.uk/) and the Scripps Institute of Oceanography (http://www.sio.ucsd.edu/), have geospatially referenced collections of plant and animal specimens, and related environmental data that span decades.

International scientific programmes such as the Joint Global Ocean Flux Study (JGOFS http://ijgofs.whoi.edu/); Global Ocean Ecosystem Dynamics (GLOBEC http://www.globec.org/) and InterRidge (http://www.interridge.org/) generate large datasets, which are typically available on line. The Census of Marine Life (CoML http://www.coml.org/) deals specifically with marine biodiversity, on a global scale; OBIS (http://iOBIS.org) was created as its data integration component, and combines data generated by CoML field projects with other sources.

Conservation organisations hold species information to support their conservation programmes, and often work closely together with environmental managers. Examples include UNEP-WCMC species databases (www.unep-wcmc.org/species/dbases/about.cfm), IUCN RedList (http://www.iucnredlist.org/) and the Global Marine Species Assessment (GMSA, http://sci.odu.edu/gmsa/). Increasingly, industries are holders of useful information based on direct observations of species occurrences from their transport systems during business operations.

Capacity building

Many developing countries, Small Island Developing States, and countries with economies in transition may lack the scientific and technical capacity required for ready identification of EBSAs, particularly in deep and open ocean areas. This lack of capacity may have to do with inadequate scientific data, or access to equipment and technologies necessary to compile such data, relating to physical and biological patterns, such as the distribution of species, habitats and ecosystems within national EEZs or beyond; lack of knowledge and training relating to the best processes, methods and tools to use in identifying EBSAs and moving from single sites to networks; limited hardware, software, or connectivity; and inadequate human or financial resources to dedicate to the task. CBD decision IX/20 recognizes the need to increase capacity and to exchange experiences, lessons learned and good practices related to the identification of EBSAs.

There are a number of ways in which these capacity-related issues could be addressed. In the short to medium-term, the following options exist:

– **Making information readily available regarding what data exists in the public domain and how it can be accessed**. International research programs, such as the Census of Marine Life, have collected a great deal of scientific data from all regions of the world. These publicly available data may fill some national information gaps in EBSA identification. Some of these are listed above and more can be found in Annex II.

– **Implementing short training courses on the process of identifying EBSAs, including the use of methods and tools**. Such short courses are particularly useful for practitioners who are not able to arrange for a lengthy leave of absence to pursue university studies.

– **Undertaking exchange visits between practitioners to learn first-hand the process of identifying and designating EBSAs**. These types of information visits can be arranged bilaterally, or can be part of a broader learning network.

– **Sharing experiences and case studies through a dedicated web portal and/or a web-mapping tool**. The web portal and web mapping functions developed by Duke University and UNEP-WCMC provide a platform for information sharing. In order for the information portal to become widely used, it will need to be actively promoted at CBD and other international/regional meetings, as well as through other means.

In the longer term, the following options might be explored:

– **Longer term degree programs and training courses to enhance scientific capacity,** not only relating to EBSAs, but to marine conservation biology, spatial ecology and other related disciplines.

– **Development of a knowledge sharing network that provides professional expertise and advice to governments wishing to identify EBSAs.** This network would allow international experts to

work directly with practitioners to address issues specific to that country's situation. A useful model for a knowledge sharing network might be provided by the Cooperative Initiative on Invasive Alien Species on Islands ("The Cooperative Islands Initiative" or CII), which provides capacity building and technical support for on-the-ground projects relating to the management and eradication of invasive species on islands (http://www.issg.org/cii/).

Future work

Sharing information and progress

The present document has provided an overview of some of the methods, analyses, tools and data available for assessing areas that may meet the EBSA criteria. In addition, the document has shown a number of illustrations regarding how such areas could be selected. While this is a good starting point, work relating to the identification and eventual selection of EBSAs will continue in the long term and will require the involvement of a large number of stakeholders, including scientists, governments, international and non-governmental organizations, and industry. As improved data and methodologies become available in the future, our capacity for evaluating and selecting EBSAs will improve.

Given the long-term nature of this work, there is a need to provide for support and coordination in the process of identifying EBSAs. This support might include the sharing of experiences in regards to new data, methods, decision-making tools, experiences and lessons learned. An important part of this support would be in the form of capacity building activities, as described in the previous section. Another vital component would allow scientists to share best available information, address technical questions, and make information broadly available. As new potential EBSAs are identified, a central register of proposed EBSAs would allow the scientific evaluation of such proposals to be undertaken in a transparent and coordinated manner.

At a most basic level, coordination might be provided for through a common access point to EBSA-related information. Information and experiences could be shared through the development of a website portal on open oceans and deep seas. One such portal is already being tested by the Duke University Marine Geospatial Laboratory, as part of their work on the Census of Marine Life project. This portal aims to eventually provide for data and information exchange, collaborative processing and outreach. The prototype portal will be on-line at http://openoceansdeepseas.org/.

Another linked component involves mapping habitat features, species information and proposed EBSAs through an interactive web-mapping facility. UNEP-WCMC is currently developing a web-based map viewer of marine areas beyond the limits of national jurisdiction, which would incorporate geographically referenced data layers. In its initial form, the map viewer would contain web-based GIS data for the presentation of static EBSA case studies. Later refinement of the map viewer could include possible interactive capacity, allowing the user to perform basic analyses with available data layers.

Together, these two linked websites would provide for the sharing of data, methodologies and experiences relating to deep and open oceans, as well as the capacity to map proposed EBSAs and make available the GIS files. They would also provide for scientific and technical collaboration, as well as capacity building, with the aim to ensure that policymakers will be able to access best available scientific information for the management of remote and shared ocean areas.

Other outstanding work

Most of the examples presented in this document illustrate the application of single criterion to help identify an EBSA. However, some areas could meet multiple EBSA criteria. For example, some seamounts could be considered ecologically or biologically significant because they are of special importance to life-history stages of species; un-fished seamounts may meet naturalness criterion; and some seamounts have high productivity and uniqueness values. Hydrothermal vents may also meet multiple EBSA criteria. An area might be designated for any one of these criteria or for meeting multiple criteria. Using multiple criteria becomes particularly important once the process moves from identifying individual EBSAs to networks. Once this stage is reached, there is a need to develop further guidance for considering multiple EBSA layers as members of possible networks. In this regard, annexes II and III of CBD decision XI/20 provide a basis on developing representative networks of marine protected areas. However, as this document elaborates upon IX/20 Annex 1, further guidance will likely also be required for Annexes 2 and 3, including the development of illustrative examples.

Consideration of EBSAs in the near future

While this document has been developed for use in the CBD Expert workshop in Ottawa, the scientific work to help identify areas that may meet the EBSA criteria will continue well beyond 2009. Proposed work includes capacity building, possibly in the form of future regional workshops, as well as bringing together regional oceans and fisheries management agencies.

A number of international meetings during the coming years will be relevant to the EBSA work detailed in this document, and may provide further direction for this work. These include the following:

- January 2010: the Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction (New York).
- 3-7 May 2010: The Global Conference on Oceans, Coasts and Islands (Paris)
- 13-21 May 2010: CBD SBSTTA-14 (Nairobi, Kenya)
- 4-7 October 2010: Launch of the Census of Marine Life results
- 18-29 October 2010: CBD COP-10 (Nagoya, Japan)
- 2013: Marine mammal protected areas meeting with France hosting

Annex I

Additional Considerations for Practitioners

In order to identify additional considerations in application of the EBSA criteria, we requested input from a variety of scientific and technical experts. These experts identified a common set of overarching considerations that practitioners may wish to take into account in applying the criteria. Many of these considerations arose from the fact that research—and thus knowledge -- of the open oceans and deep seas is for the most part still in its infancy; data are few and sparse, and understanding of the underlying ecosystem drivers and emergent processes is incomplete. Application of, and extrapolation from, the existing information would therefore benefit from addressing, *inter alia*:

1. issues related to **scale** of application of each criterion;

2. evaluation of the **relative importance / significance** of an area for a given criterion;

3. accounting for **spatial and temporal variability**; and

4. **precision, accuracy, and uncertainty**;

This Annex provides guidance for practitioners for addressing each of these considerations, to aid in consistent and objective application of the criteria by appropriate expert groups where information is available to commence such work.

Scale

 Scale is a major concern in ecological applications (Levin 1992, Scheiner et al 2000). In this document it is used broadly, to include the scale of patterns in space and time, shown by data about either structural (criteria like fragility or uniqueness) or functional (criteria like special importance to life history stages) ecosystem properties. Scale generally refers to the extent of the property being measured relative to the unit of measurement, or "grain" (Schneider 2001). It reflects the amount of ecologically meaningful detail available for any given analysis. It is influenced by both the accuracy and particularly the precision, of sampling relative to the natural variability of the property being sampled. With regard to application of the EBSA criteria, scale is relevant from both the ecological perspective and from the implementation perspective.

From the ecological perspective, systems generally show characteristic variability on a range of spatial and temporal scales and across different levels of ecological complexity (Levin 1992). At the species level, an appropriate scale of study for one life history stage (e.g. larval) may be inappropriate for another (e.g. juvenile). Consequently application of the criterion regarding importance to life history stages of a species could require considering several different scales to capture the requirements of the species. For such reasons there is no one right or correct scale for application of any of the criteria. This is not a shortcoming of the EBSA criteria per se, but rather a general issue when studying ecological systems (Thrush et al 1997). However, in applying the criteria it is often necessary to determine how

results can be translated from one scale to another, guided by the linkages among elements in the system. When applying criteria of biological diversity and productivity, experience from terrestrial ecology can sometimes provide guidance on making such translations among scales (e.g. the scaling up of quadrat-plot results using species-area curves to predict regional species richness –Stohlgren et al 1997), including lessons about the risk of becoming lost in a myriad of arcane considerations (Scheiner et al 2000). In general, for any of the criteria, if *specific* questions can be posed, appropriate scales are usually fairly self-evident, such as the range of an individual, the distribution of a species, or the persistence of an upwelling event.

Modern GIS technology allows users to work a multiple scales and often zoom in and out depending upon what is of interest. This may result in GIS products that are not matched to any particular intended scale, or vary in scale across a series of related products. Likewise, the results of modelling (such as predictive habitat or biogeographic classifications) are not actually of uniform scale, with some places reflecting better input data and confidence (less uncertainty) than others. Users who receive the analysis or modeling products without explanation about the quality of information in space or time can choose among unsatisfactory alternatives. For example, they might assume all the results are only as good as their weakest components, thus sacrificing greater accuracy and precision in identifying EBSAs and limiting their prioritization to the better known areas. Alternatively they may erroneously use all the results as if they reflect as much information as the best cases, and overestimate the importance of certain areas without accounting for the uncertainty in the model prediction.

Good practice for addressing scale in the application of EBSA criteria will require the creation of indices of confidence such as estimated confidence layers to accompany analysis and modelling results. By "confidence," in this context we mean how certain one can be that the results reflect the true situation, taking into account the many uncertainties associated with sound scientific analyses; that is, for a good scientist, very little is 100% certain, but some things are more certain than others. Although it is very difficult to take all uncertainties into account, practitioners should take account of as many factors as possible, particularly the more readily available factors such as sampling design and density, measurement accuracy, and so forth. Such factors are especially relevant if input GIS layers or data series were aggregated or appended together from various disparate datasets of varying scales. Estimated confidence layers in GIS analyses allows for better informed decisions and is highly recommended when dealing with maps and data of varying scales. Even though methods for producing such confidence layers are still evolving, decisions regarding the identification of EBSAs will be more likely to succeed when estimated confidence is taken into account.

Even if an absolute value of uncertainty cannot be estimated, it is usually possible to estimate *relative confidence;* i.e. Area A is considered to have more uncertainty than Area B. Simple relative confidence scores (e.g. 1=lower; 2=moderate; 3=higher) for each input layer can go a long way towards producing an overall relative confidence layer that is helpful for planning. Even qualitative guidance on the varying scale (and quality) of the information, can guide the varying scale of decision-making from place to place. Practitioners may prefer to focus their efforts on better understood areas rather than highly uncertain ones, and/or to have some areas given larger buffers than others, in order to maintain a consistent degree of risk aversion in face of varying levels of uncertainty.

Relative importance / significance

All of the EBSA criteria (except for "Uniqueness") are *relative* measures; i.e., they comparatively order places that are more "significant" than surrounding areas based on the *ecological or biological* role played by the area within the larger region where an evaluation of EBSAs is occurring. The properties of marine ecosystems vary widely from region to region, so global absolute thresholds (i.e. measurement 'X' must exceed 'a' units) are not appropriate. Instead, the evaluation process must sort out the relative importance of specific features or places in a given ecological region on each of the criteria. In the best cases the ecological knowledge of the area can be used to establish and justify a particular threshold value above which any area would be an EBSA on the given criterion. This is the ideal approach, but also the most demanding of both data and ecological knowledge of an area.

Often there may be enough information to map the pattern of how a biological feature varies with regard to a single variable, such as abundance, across an area.   In these cases the patterns in the available data may help inform how possible "significance" varies with the "abundance" (or other attribute) of a feature. With comprehensive quantitative data, two general approaches can be used for investigation of such patterns:

1. **Identify natural break point(s) in the data**: The underlying assumption of this approach is that with some types of data exceptional features will naturally stand out from all others. This approach works well with data that have multiple modes or clusters, such as infrequent dense concentrations of features that usually are thinly distributed. Plots of frequency histogram (fig. 1) will bring out this nature of the data when it is present. Analytical methods applied to

Figure 1. An example of a histogram showing two clusters of values and the optimal threshold to differentiate between those clusters.

such data can use the cumulative frequency distribution rather than the histograms, although both methods of presentation display the same patterns in the data. "Steps" that appear in the cumulative frequency distribution show how the data are clustered into groups that are similar on the feature of interest. Many statistical techniques can be applied to make steps appear larger or smaller, and to isolate the steps (places) at the high and low end of the distribution. When applying these techniques, however, it is necessary to take care to avoid circularity and confirmatory bias of making differences in the data look larger than they really are. Ecological knowledge is still necessary to interpret the ecological or biological "significance" of the various steps, and (when one is needed) justify a threshold value – that is, the value above (or below) which areas are considered significant. If such knowledge is very weak, arbitrary choices can be made about the use of a threshold value, but it is often sufficient to provide the numerical rankings of sites as increasing in "significance" and highlight where the steps in the distribution
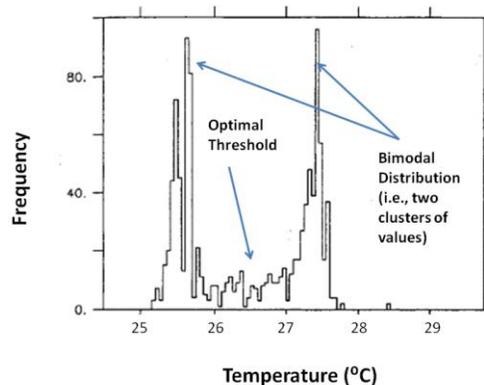
are, as input to the dialogue on how the degree of ecological or biological significance varies among areas.

2. **Select a cut-off based on standard deviations**: If the data about the occurrence of the ecological feature of interest are smooth and continuous, then analyses of their frequency distribution will not reveal any discontinuities or steps. In such cases the sites at the high (or low for the "rarity" criterion) end of the smooth distribution are more significant that ones closer to the centre. There is a long statistical history of considering cases more than two standard deviations from the mean to be "significant", and such an arbitrary rule can be applied to identify a threshold above or below which sites might be considered significant. However, it is important to note that in this statistical convention, "significance" has traditionally had a different meaning from that of 'biologically or ecologically *significant.' The assumption that a feature that is statistically unusual ("significant") in its class is also biologically significant may or may not be true, though it does suggest further investigation is warranted.* In many circumstances data may need to be transformed to better approximate a normal distribution before this method can be applied.

Spatial and temporal variability

It is important to recognize that most aspects of the marine environment are highly dynamic. Thus, when evaluating the ecological or biological significance of an area based on a particular criterion, the spatial and temporal variability of a feature (e.g. a sea surface temperature front) or an organism's behaviour (e.g. migration routes) must be taken into account. For many criteria, some places will have substantial variation in how they would be evaluated from year to year, season to season, or on even shorter time periods.   The science advice identifying the likely EBSA and suggesting appropriate boundaries should include as much information as possible about the magnitude and time-scale of these variations.   How variability is incorporated into evaluations of an area is largely dependent on the type of data being analyzed. When looking at oceanographic features (e.g., sea surface temperature fronts, eddies, or upwelling events) practitioners can use threshold values to differentiate 'persistent' features from temporary features using climatologies (i.e., average values over extended time periods). One good example of this is the aggregation of daily sea surface temperature front data into a climatology representing the likelihood that a front will exist in a given area (see Annex II: "Sea Surface Temperature Fronts"). Such a dataset could then have threshold values applied to it to delineate important areas of higher frontal activity.

It is equally important to examine spatial and temporal (spatio-temporal) variability in survey or tracking data. Although it is tempting to aggregate data from different surveys or tracked animals together to better understand population level processes, it is important to first consider how the data overlap in time and space. For instance, tracking data from animals tracked in the fall may present very different patterns of area utilization than those same animals tracked in the spring. To ensure that all areas relevant to an organism's life history are taken into account, temporal variations in these data should be understood and incorporated into evaluations of an area's importance. Generally, good data over a number of years are necessary to meet this objective. For further discussion and examples of how to incorporate spatio-temporal variability in survey and tracking data see Annex II.

Finally, it is necessary to consider variability induced by climate change and other global processes (Fuller et al. 2008). These can affect oceanographic processes, and thereby species ranges, migration patterns, and resource availability. As such, it is important to understand if there are temporal trends in the data used to evaluate an area.

Precision, accuracy, and uncertainty

Discussions of scale and spatial/temporal variability inevitably lead to discussions of precision, accuracy, and uncertainty. These three properties of data are inter-related but not interchangeable. Evaluations of the ecological or biological importance of an area require that practitioners accommodate the uncertainty in the available information, which in turn requires understanding the factors that contribute to the uncertainty. Uncertainty may enter evaluations of an area through several means, but most commonly it is due to the use of predictive models, or through factors inherent in the sampling method used (e.g., uncertainty in locational data recorded by tags used to track animals). For many marine features it is difficult to take exact measurements, regardless of the precision of the scale of measurement. Benthic sampling gears do not necessarily capture every individual in the location being sampled; towed nets do not always cover exactly the distance that is recorded as "distance towed". Such measurement error contributes to uncertainty in the data as well. There is a large body of scientific literature on survey, sampling, and experimental design which addresses how to deal with potential bias and variance in research and surveys, and this literature should be consulted for guidance on a case by case basis. Large sample sizes of repeated measurements can go far in addressing measurement uncertainty, for example.

Uncertainty contributes to two types of possible errors in evaluating data relative to the EBSA criteria; "misses" – when it is erroneously concluded that an area does not meet a criterion when in reality it does, and "false positives", when it is erroneously concluded that an area does meet one of the criteria, when in reality it does not. Misses are likely when data are incomplete and/or sampling coverage at the wrong scale (generally too coarse), so features are present in an area (or ecological functions served) but they simply are not recorded in the available data. False positives also reflect incomplete knowledge of an area, such that limited sample data are treated as typical, and a model is built around them predicting a broader distribution of a feature than actually exists. Without groundtruthing, this can lead to the protection of sites that do not actually have the desired feature. Both types of errors decrease as ecological knowledge increases and sampling becomes more complete. With high uncertainty in data and information, the precautionary approach would support a relatively higher tolerance for false positives than misses. Thus, failure to find evidence of an EBSA in incomplete data sets should not be taken as strong evidence that the area has no special requirements for conservation.

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