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Item 6.1 of the provisional agenda*

TRAINING MANUAL FOR THE DESCRIPTION OF ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS (EBSAS) IN OPEN-OCEAN WATERS AND DEEP-SEA HABITATS**

Note by the Executive Secretary

1. In decision X/29 (adopted in Nagoya, Japan, in 2010), the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) requested the Executive Secretary to prepare, in collaboration with the relevant international organizations, a training manual and modules in the working languages of the United Nations, subject to the availability of financial resources, which can be used to meet the capacity-building needs for identifying ecologically or biologically significant marine areas using the scientific criteria in annex I to decision IX/20 having regard to other relevant compatible and complementary intergovernmentally agreed scientific criteria as well as the scientific guidance on the identification of marine areas beyond national jurisdiction, which meet the scientific criteria in annex I to decision IX/20, taking into account the results of the Ottawa workshop.

2. Pursuant to paragraph 40 of decision X/29, draft EBSA training manual and modules, as contained in this document and associated presentation materials, were developed, with the kind financial support from the Government of Germany, to facilitate the capacity development with regard to the scientific description of areas meeting EBSAs criteria. This document also includes the user manual for the use of the EBSA prototype repository and information-sharing mechanism.

3. This document is being circulated in its draft form as information for participants at the sixteenth meeting of the Subsidiary Body.

* UNEP/CBD/SBSTTA/16/1.

** Reposted to include the following footnote: "The designations employed and the presentation of material in this note do not imply the expression of any opinion whatsoever on the part of the Secretariat concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries" as well as an editorial change on page 12.

DRAFT
Training Manual for the Description of Ecologically and Biologically Significant Areas (EBSAs) in Open-ocean Waters and Deep-sea Habitats

Introduction

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Pursuant to paragraph 40 of decision X/29, draft EBSA training manual and modules, as contained in this document and associated presentation materials, were developed, with the kind financial support from the Government of Germany, to facilitate the capacity development with regard to the scientific description of areas meeting EBSAs criteria. This document also includes the user manual for the use of the EBSA prototype repository and information-sharing mechanism. The manual is structured as follows:

MODULE 1

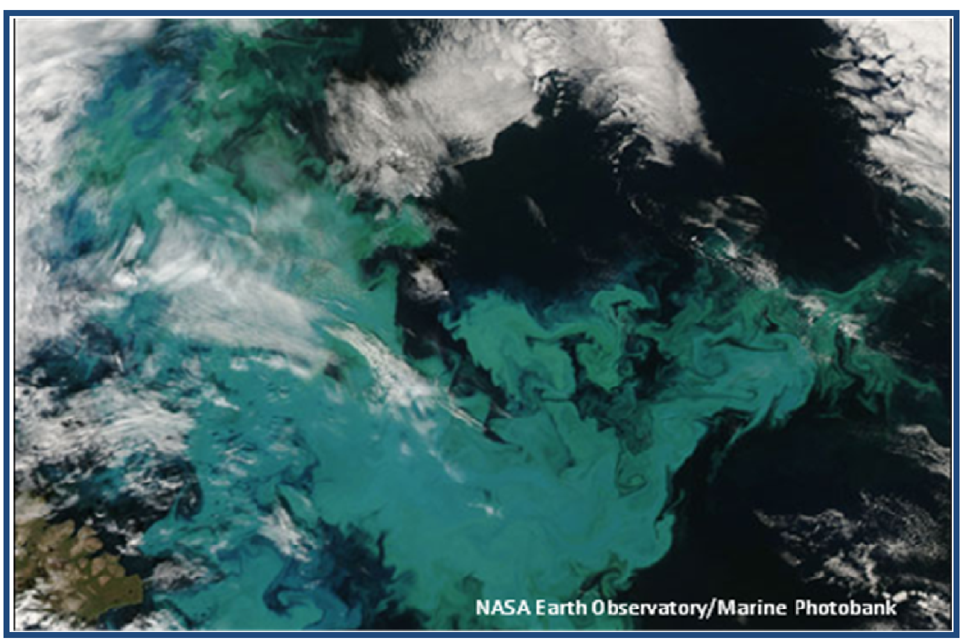
Objectives of this module:

This module will discuss the process of describing areas meeting EBSA criteria. It will provide an introduction to the CBD EBSA criteria, as well as practical guidance on how to identify areas based on each individual EBSA criterion. In addition, the module will discuss how to describe areas based on multiple EBSA criteria. Publicly available data, as well as types of tools and analyses that can be used for EBSA identification, will be described in detail.

This module will consist of the following sections:

1(a) General strategies for each EBSA criterion
1(b) The role of expert opinion
1(c) Common analytical approaches
- Kernel density estimates
- Habitat suitability modeling
- Biodiversity indices
- Productivity

1(d) Data considerations
1(e) Considerations when using multiple EBSA criteria
1(f) Systematic planning approach



1(a) General strategies for each EBSA criterion

Learning objectives:

In this section, you will go through a description of each of the EBSA criteria and consider how they can be applied. 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 open-ocean waters and deep-sea habitats.

There has been substantial experience at the national and regional level with the application of some or all of the criteria for identification of EBSAs for multiple uses, including protection. This experience was consolidated at a CBD expert workshop in Ottawa, Canada in 2009, and this discussion draws on some of that experience and material.

Each criterion is considered individually. Multi-criteria analysis will be discussed in section (e), while section (c) describes analytical approaches associated with each criterion, and section (d) addresses data requirements.

Criterion 1: Uniqueness or rarity

Definition (COP decision IX/20,annex 1)

The 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

Uniqueness and rarity are strongly influenced by the scale at which the policy and management jurisdiction is functioning. 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 a survey of the eastern Australian margin, where multibeam bathymetry was used to map >25,000km^2 of the seabed, only 31 km^2 (0.12%) of seabed comprised hard substrata, while the remaining seabed comprised bioturbated soft-sediment plains. In such a circumstance, it is appropriate to assume that the biotic community, because it is 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, many species may be fairly rare, and thus *rarity may be 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 (for more detail, see section 2(c))

Application of the *uniqueness or rarity* criterion may be based on biological, ecological and oceanographic information from peer-reviewed literature, technical reports and data sets. 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.

Approaches that seek to identify different morphological features and seascapes can also indicate unusual features which may satisfy this criterion. However, care must be taken to ensure that unusual classes that emerge from such work are not artifacts of the analysis and meaningfully reflect features in the sea.

Examples

1. The Saya de Malha Banks

The Saya de Malha Banks (fig. 15) are the largest submerged banks in the world, containing a unique seagrass biotope in the open ocean. Due to their remoteness, the Saya de Malha Banks are host to some of the least explored shallow tropical marine ecosystems globally, completely detached from land boundaries and providing an ecologically important oasis of high productivity in the Indian Ocean (M. Vierros, United Nations University Institute for Advanced Studies).

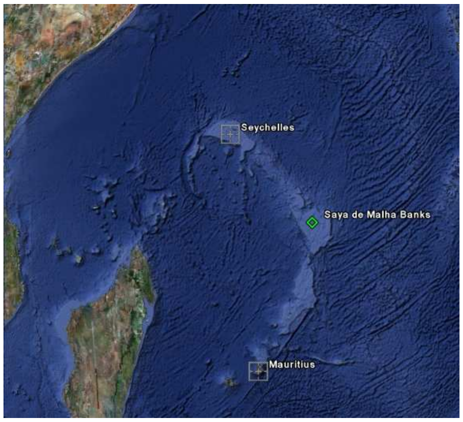


Figure 15: Location of the Saya de Malha Banks in the Western Indian Ocean
Source: xx

2. Sargasso Sea

Alone in supporting the centre of distribution for a holopelagic (continuously pelagic) drift algae (*Sargassum* spp.) community, the Sargasso Sea (fig. 16) is a globally unique marine ecosystem whose entire water column provides a range of critical services When the drift algae clumps together into mats, it provides structural habitat for a range of fauna, including endemic, threatened and commercially important species, particularly for the juveniles of the species. While *Sargassum* occurs globally, it is only in the Sargasso Sea where these characteristic large mats are found (S.A. McKenna, IUCN WCPA Marine - Caribbean Working Group, IUCN WCPA, High Seas MPA Task Force Deep Search Foundation and A. H. Hemphill, IUCN WCPA, High Seas MPA Task Force, Center for Ocean Solutions, Stanford University; S. Gulick, S. Brooke, and J. Ardron, Marine Conservation Institute).

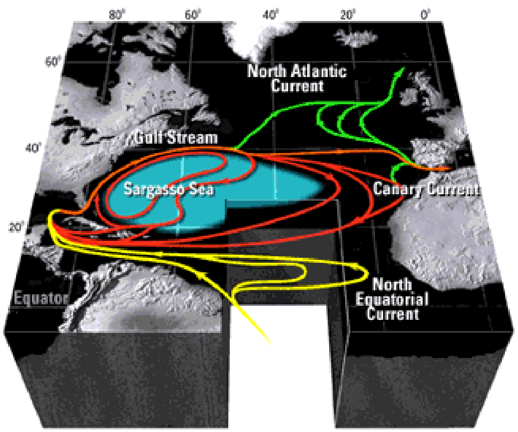


Figure 16: Location of the Sargasso Sea.
Source: xx

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

Definition (COP 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 that 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.

Application of this criterion for deep-sea species can be difficult because specialized sampling gears are needed to sample early life stages of deep-water 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.

Methods

This EBSA criterion, *Special importance for life-history stages of species*, is similar in nature to *Importance for threatened, endangered or declining species and/or habitats*, 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 data sources 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. 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 even shorter time scales. 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 (Fauchald and Tveraa 2003)
- Kernel Analyses (Laver and Kelly 2008)
- Regression, Autocovariate and other Habitat Modelling (Guisan and Zimmermann 2000, Dormann et al. 2007)
- State-Space Models (SSM) (Morales et al. 2004, Jonsen et al. 2005)

Examples

1. Areas of importance for northern elephant seals

Many wide-ranging marine animals have an amphibious life history. For example, sea turtles, seabirds, sea lions, and seals spend part of their lives feeding at sea and part of their lives on land, breeding, caring for young, or molting. In the North Pacific, the northern elephant seal is a wide-ranging top predator with such a life history. Female northern elephant seals undertake a long foraging migration in the North Pacific each year, building a reserve for subsequent months spent fasting on land while giving birth, nourishing a pup, and breeding. Using data from the Tagging of Pacific Predators project (www.topp.org), figure 17 identifies an area of high female northern elephant seal density during their annual six-to-eight-month foraging migration, indicating it is an area of special importance for life history stages of this species (A-L. Harrison, University of California at Santa Cruz,).

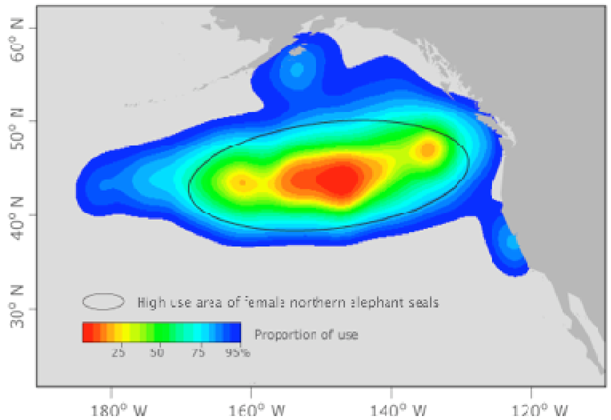


Figure 17: Area of importance for northern elephant seals
Source:

2. Area of special importance for the Antipodean albatross in the Tasman Sea

The antipodean albatross (*Diomedea antipodensis*) is one of the largest seabirds on Earth, and a member of the great albatross (*Diomedea* spp.) group. It is endemic to New Zealand, breeding on Antipodes Island, the Auckland Islands group, Adams, Disappointment and Auckland), Campbell Island, and Pitt Island in the Chatham Islands. Declines in adult survival, productivity and recruitment are largely due to bycatch in longline tuna fisheries, and the Antipodean albatross is currently listed as vulnerable by IUCN. Data from satellite tracking show that during different life-history stages birds utilize different areas (fig. 18) (Ben Lascelles and Lincoln Fishpool, BirdLife International).

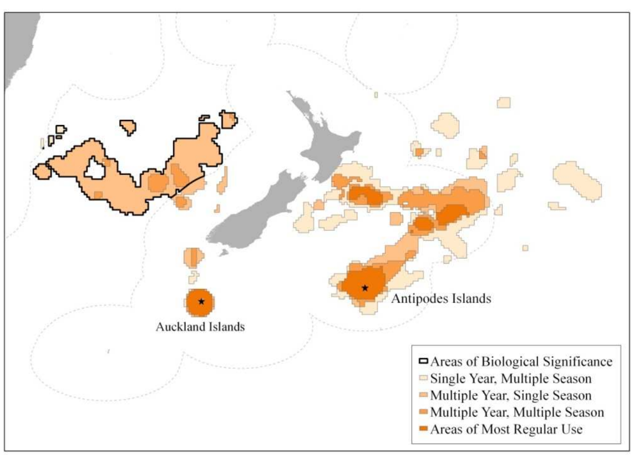


Figure 18: Map showing areas regularly used by the Antipodean albatross during different life-history stages and the location of the Tasman Sea area of biological significance.
Source:

3. Areas of importance for Pacific white sharks

Due to infrequent, yet often sensational interactions with people, white sharks have long captured the imagination of humans. Most of the studies of white sharks have centreed around pinniped (seal and sea lion) rookeries, where adult white sharks feed on elephant seals and sea lions. Off the coast of northern California, the interactions between pinnipeds and white sharks have been studied at the Farallon Islands and Año Nuevo Island for decades (Ainley et al. 1985). White sharks are present at these islands predominately in the late summer through winter when they feed on young elephant seals and sea lions. Although pinnipeds are present throughout the year, white sharks are apparently only present for a portion of the year, and their movement patterns after leaving remained a mystery for decades. With the advent of new electronic tagging technologies, it has since been possible to track white sharks for periods of up to one year and shed light on their movement patterns after departing pinniped colonies.

As illustrated in figure 19, adult white sharks were tracked travelling from several sites along the North American coast, to a region in the northeastern Pacific, equidistant between Baja California and Hawaii, where they remain for up to six months. It remains unclear whether these represent breeding or feeding migrations (A. Boustany, Duke University Marine Geospatial Ecology Lab).

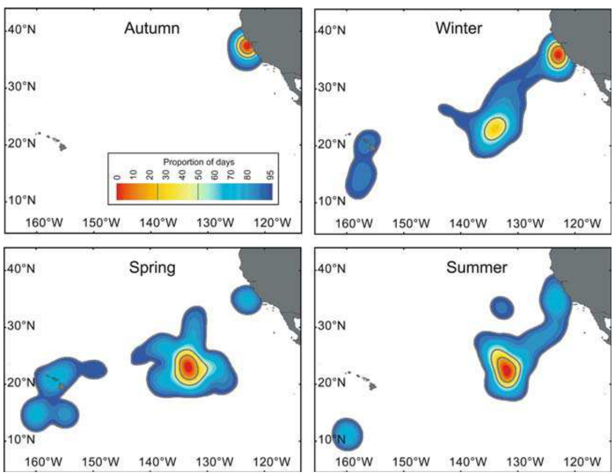


Figure 19: Seasonal densities of white sharks tagged off the northern California coast, USA
Source: Weng et al. 2007

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

Definition (COP decision IX/20, annex 1)

Area containing habitat for the survival and recovery of endangered, threatened or 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 Red List (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, *Special importance for life-history stages of species.*

Examples

1. Areas of importance for the Pacific leatherback turtle

Studying pelagic species on the high seas has traditionally been difficult. The long distances from shore, coupled with the highly mobile nature of the organisms, have precluded direct observation. Recent technological advances have permitted researchers to track highly migratory pelagic species by allowing data collection and transmission remotely (Eckert 2006). These novel electronic tags have been particularly useful for studies involving air-breathing animals in the open ocean, as frequent surfacing allows for direct uplinks to satellites, and animals can therefore be tracked in near real time. While the data these tags have returned is invaluable in shedding light on the basic biology of pelagic species, they gain even more importance when addressing questions pertaining to conservation of severely threatened and endangered species. A prime example of this is the recent electronic tracking conducted on leatherback turtles in the eastern Pacific Ocean.

Like many marine turtle species, the slow growth and low reproductive potential of leatherback turtles makes them particularly sensitive to excessive mortality during adult life stages. Leatherbacks in the eastern Pacific Ocean have suffered through illegal poaching and egg collecting on the nesting beaches, resulting in severe population declines. Figure 20 illustrates how new tracking technologies have allowed researchers to examine the movements of the critically endangered Pacific leatherback turtle. Several years of tracking have revealed a consistent foraging area for leatherback turtles in the South Pacific Gyre (A. Boustany, Duke University Marine Geospatial Ecology Lab).

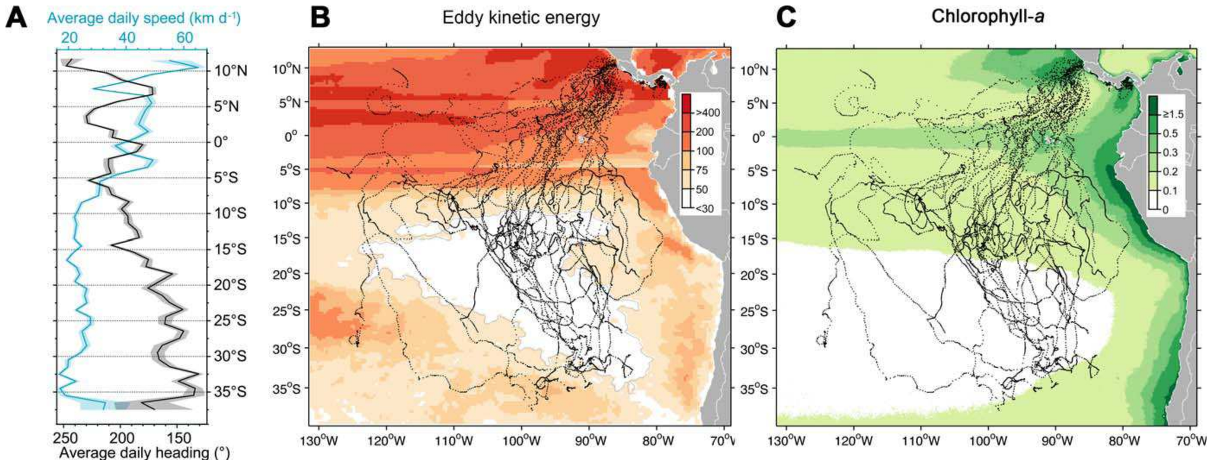


Figure 20: Colours from red to light orange show the density utilization distribution of tracked leatherback turtles; the darkest colours indicate the most intense use. The green outline highlights the region identified as having particularly low primary productivity and eddy kinetic energy. Source: Reproduced from Shillinger et al. 2008.

2. Areas of importance for the Short-tailed albatross

BirdLife International is the IUCN Red List authority for birds and conducts a comprehensive review of the status of all species every four years, with annual reviews of the most threatened. The BirdLife Important Bird Areas (IBA) Programme uses the Red List assessment to define one of the global IBA criteria for identifying IBAs (category A1), such that sites critical for the conservation of the most threatened species are identified.

The short-tailed albatross (*Phoebastria albatrus*), a threatened seabird, breeds on some islands of East Asia, and its range extends throughout the Bering Sea. Satellite tracking data and vessel survey data have been used to identify areas of importance based on habitat preferences for the albatross (fig. 21) (B. Lascelles and L. Fishpool, BirdLife International).

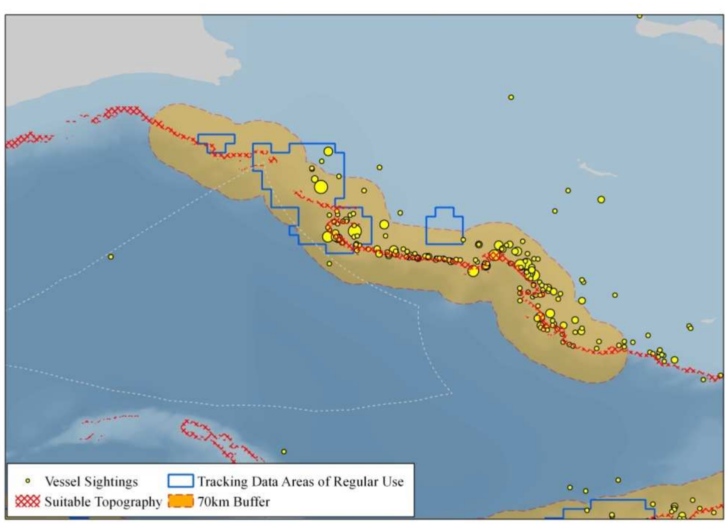


Figure 21: Map of candidate IBA for the short-tailed albatross at the Bering Sea shelf break. This map shows areas of regular use identified from satellite tracking data, vessel survey data, and a 70km buffer around suitable topography.
Source:

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

Definition (COP 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 focuses on the inherent sensitivity of habitats or species to disruption. The core concept here is that resilience to perturbations (physical or chemical) varies amongst habitats and species; for example, species with low reproductive rates exhibit an inherently higher level of risk to impacts than other species. Assessing vulnerability of benthic ecosystems in relation to bottom contact fisheries has been elaborated upon by the FAO (2009).

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 adverse impacts of any type (physical, chemical, biological). In general, maximum lifespan and age-at-first-reproduction are positively correlated, and those species that also 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. "Vulnerability" can only be evaluated relative to threats, which makes this aspect of this criterion different from all other EBSA criteria that address intrinsic properties of an ecosystem independent of threats. However, ecosystem features that are fragile, sensitive, or slow to recover are likely to be vulnerable to a wide range of threats. Viewed in that context, this criterion can be applied in the absence of information about threats. Expert advice and the literature should be sought to explain the nature of the features' properties that are considered sensitive, vulnerable, fragile or slow to recover (e.g., FAO 2009).

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

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 the 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. 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.

Example

Global habitat suitability for reef-forming cold-water corals

Reef-forming cold-water corals create structural habitat with a range of ecosystem functions in the deep sea, including promoting local biodiversity and supporting commercially important fisheries. They are known to be very sensitive to anthropogenic activities, are expected to be heavily impacted by ocean acidification, and are known to have very slow recovery rates. These scleractinian (or “stony”) corals form reef-like habitats, which are fragile and have been impacted by human activities that make contact with the seafloor, such as bottom fisheries. They are known to have very slow recovery rates, on the order of hundreds to thousands of years, if at all (Roberts et al. 2006).

Figure 22 shows global-scale predictions of habitat suitable for reef-forming corals. Using known locations of the six reef-forming cold-water coral species, amassed from research and cruise databases, coral habitat suitability predictions were made based on more than 30 different environmental conditions (J. Guinotte, Marine Conservation Institute, A. Davies, University of Bangor, Wales, and J. Ardron, Marine Conservation Institute).

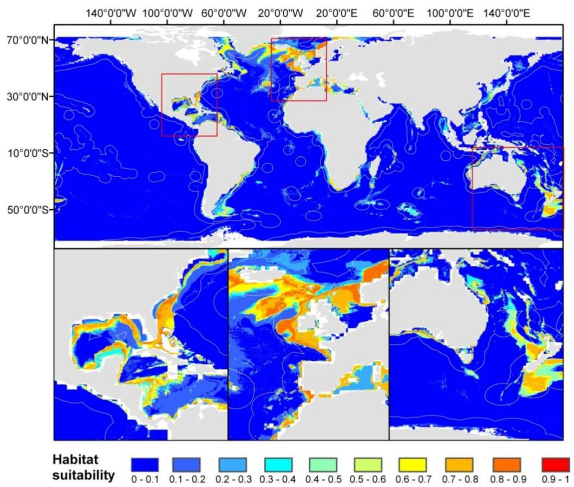


Figure 22: Habitat suitable for reef-forming corals.
Source:

Criterion 5: Biological productivity

Definition (COP decision IX/2, 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 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.

Comments on the application of this criterion

Productivity is not the same as abundance, but in many 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. Centres of high primary and secondary productivity are known to vary between years, seasonally, and on short time scales, but overall core centres can be spatially identified.

High primary productivity near the surface may not necessarily mean higher secondary 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.

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. 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.

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 and 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).

For more information on methods, see section (c) of this module.

Examples

1. Pacific Equatorial Upwelling high productivity area

Primary production does not occur uniformly throughout the ocean. The rate of production depends mainly on the quantity of phytoplankton already in the water, the availability of light and required nutrients such as nitrogen and phosphorus, and the water temperature. Light availability is regulated mainly by geographic location and the annual solar cycle. Primary production in the open ocean only occurs in the euphotic zone, the layer of the ocean that light can penetrate. Nutrient availability and water temperature are regulated by the flow of ocean currents. Patterns in light and ocean currents lead to patterns in primary productivity. Oceanographers estimate primary production worldwide from satellite observations. Using these data, we can identify one such area of high productivity around the Pacific equatorial upwelling.

In figure 23, the area identified is still very large. In order to further refine EBSA identification in this region, this criterion could be combined with other relevant criteria so as to highlight particularly significant areas (Global Ocean Biodiversity Initiative, GOBI, team).

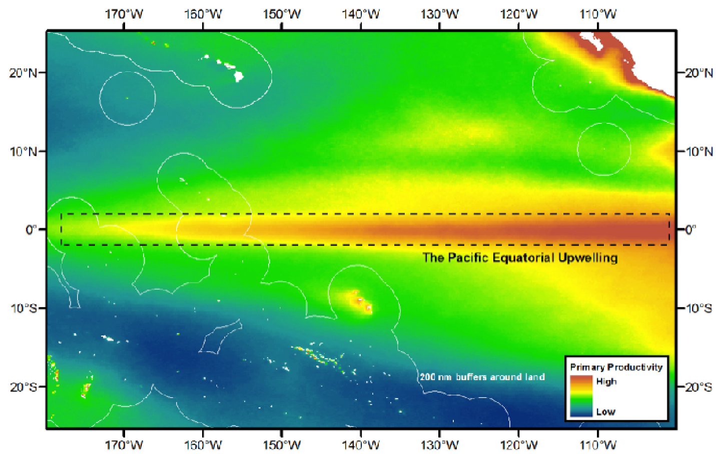


Figure 23: An area from which an EBSA could be identified in the Pacific Equatorial Upwelling. Source:

2. Sea-surface temperature fronts

Dynamic physical ocean processes, such as upwellings, currents and eddies, promote biological productivity and structure marine ecosystems by aggregating and dispersing nutrients and organisms. Phytoplankton can be detected at the ocean surface by satellites that measure specific wavelengths of reflected sunlight. But current satellite technology cannot detect animals. Until this is possible, scientists must infer the presence of animals by looking for patterns in satellite images that are correlated with the presence of animals, such as fronts visible in images of the sea surface temperature (SST). In figure 24, an algorithm was applied to estimate the frequency of SST fronts in the eastern tropical Pacific Ocean near Central America, and identify EBSAs in two zones of high frontal frequency: one south of the Gulf of Tehuantepec and one east of the Gulf of Papagayo (Jason Roberts, Duke University Marine Geospatial Ecology Lab).

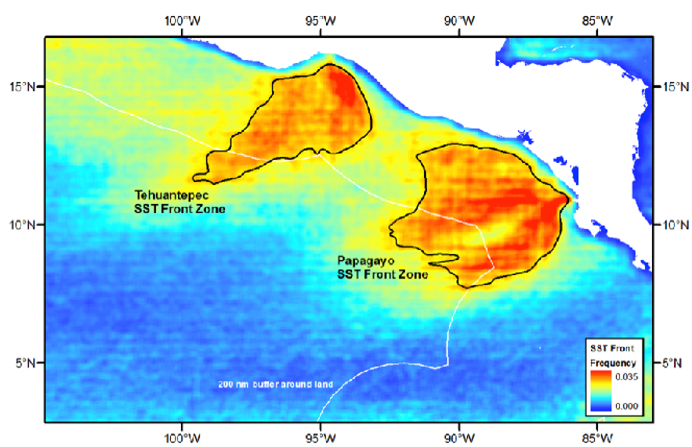


Figure 24: Sea surface temperature fronts.

Source:

Criterion 6: Biological diversity

Definition (COP 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

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 (i.e., species, communities, 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 comparing measures of species diversity among areas, sampling should be sufficient to statistically support such comparisons, for example, by ensuring that species accumulation curves (when considering richness) are saturated prior to conducting pair-wise comparisons. Otherwise there is a danger of identifying areas with more research effort.

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 and 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 that 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 by 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 and 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 and Dunston 2009)

For more information on methods, see section 2(c).

Examples

1. Global patterns of species diversity

Several indices measuring species diversity have been proposed. This example shows a calculation of global patterns of species diversity using one of these indices, Hurlbert’s index, for a sample size of 50 specimens. Figure 25 was based on publicly available data holdings of the Ocean Biogeographic Information System, an initiative of the Census of Marine Life and now adopted by the Intergovernmental Oceanographic Commission of UNESCO. (E. Vanden Berghe, OBIS).

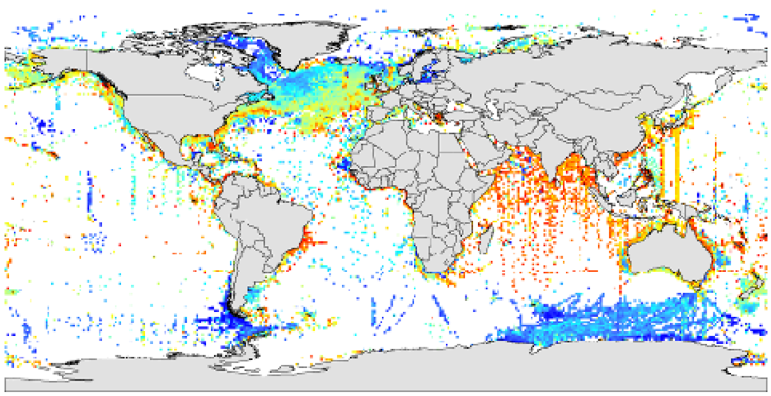


Figure 25: Global species diversity patterns.
Source:

2. Overlap between hotspots of marine mammal biodiversity and global seamount distributions

Species are not uniformly distributed on Earth. Heterogeneous physical features and community evolution drive the mix of species found in a given location. AquaMaps is a species distribution model available as an online web service that generates standardized range maps and the relative probability of occurrence within that range for currently more than 11,000 marine species from available point occurrences and other types of habitat usage information (Kaschner et al., 2006, Ready et al, accepted). Figure 26, a global map of biodiversity patterns that shows the co-occurrence of predicted hotspots of marine mammal species richness and off-shore seamounts, was produced by overlaying AquaMaps predictions for a subset of individual species (115 marine mammals) (K. Kaschner, J. Ready, E. Agbayani, P. Eastwood, T. Rees, K. Reyes, J. Rius and R. Froese).

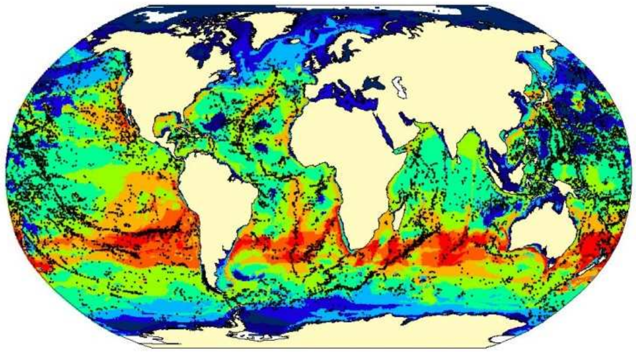


Figure 26: Co-occurrence of predicted hotspots of marine mammal species richness and off-shore seamounts.

Source:

3. Prediction of biodiversity – richness and evenness

Patterns in biodiversity can be illustrated by variation in the number of species (richness) and whether these species are evenly distributed or dominated by a minority (evenness). Combining these two properties of biodiversity leads to the identification of uncommon communities that deserve greater protection. Figure 27, from Western Australia, shows the results of a statistically rigorous analysis of species ranks combined with physical samples to predict patterns in biodiversity through the physical space. This extends our information from known biological samples to the broader environment, with measured uncertainty (Piers Dunstan, CSIRO).

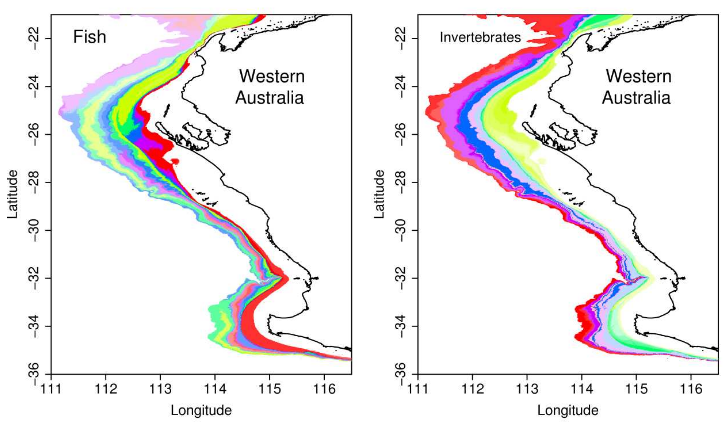


Figure 27: Analysis of species ranks combined with physical samples to predict patterns in biodiversity

Source:

Criterion 7: Naturalness

Definition (COP 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 and deep-sea 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 where the criterion is being applied.

Comments on the application of this criterion

The "natural" state of ecosystems, communities or features in an area is often unknown, even for many well-studied 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 associated with certain impacts 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 the impacts of bottom trawling on benthic habitats, populations, and communities; the effects of shipping noise and ship strikes on wildlife aggregations and migrations; and collisions.

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 and Alder 2008; Tallis et al. 2008; Halpern et al. 2009). Though methodologies are still developing, promising approaches stratify effects according to their type (i.e., physical, chemical, biological), taking into consideration both intensity and effect-distance of the given stressor on a given habitat type (Ban et al. 2010).

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 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).

Given the largely unpredictable nature of cumulative effects (Crain et al. 2008; Darling & Cote 2008), in the absence of additional information, assuming an additive mechanism is perhaps the best way forward, though it could underestimate some 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.

Example

South East Atlantic Seamounts

Seamounts have been characterized as oases of productivity and diversity in the deep sea that also influence the productivity of the water column above (White et al. 2007). Formed by tectonic and volcanic activity, seamounts may act to disrupt normal oceanographic conditions across the abyssal plain, leading to an increase in vertical mixing and circulation (Roden 1987). Such mixing, coupled with relative isolation, can encourage the development of productive and often unique ecosystems, as well as productive seamount fisheries. Beginning in the late 1960s, seamount fisheries have seen major expansions both in terms of fishing effort and their geographic range over time (Watson et al. 2007). However, many seamounts are uncatalogued scientifically and untouched by fishing gears.

As fishing is the single largest human disruption affecting most seamounts, a comparison of reported seamount fishing effort, known seamount locations, and their proximity to other anthropogenic impacts can inform the evaluation of the "naturalness" of a given seamount or seamount group. Figure 28 shows how global datasets of predicted large seamount locations (created from ocean bathymetry) were combined with historical catch data from seamount fisheries and other anthropogenic marine impacts to identify areas of low impact, including the waters around the Discovery tablemount group in the South East Atlantic (J. Cleary, Duke University Marine Geospatial Ecology Lab; A. Rowden, M. Clark, & M. Consalvey, New Zealand National Institute of Water and Atmosphere and CenSEAM).

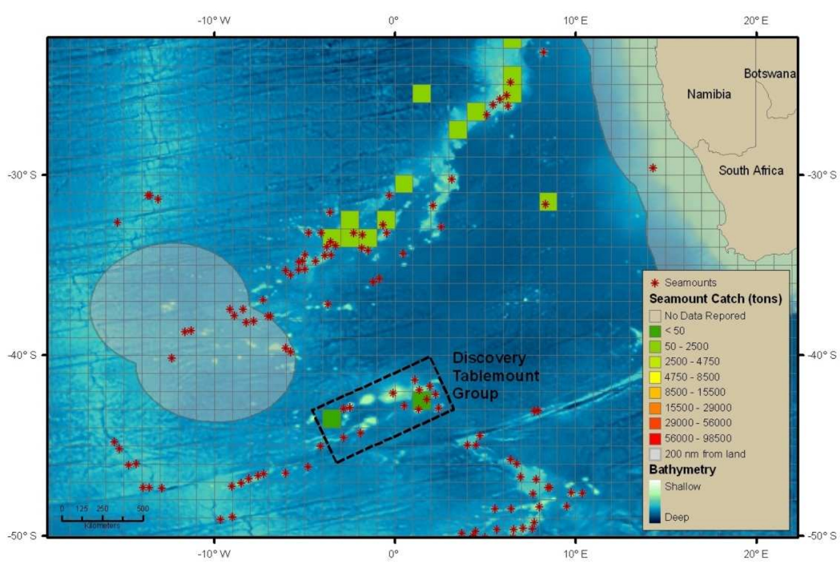


Figure 28: Seamounts with low human impact.
Source:

Summary

This section has provided an introduction to each of the seven CBD EBSA criteria and their application. The information presented is extensive, and the examples highlighting the criteria have been touched upon only in passing. In the next sections, we will go further in-depth with the methods, analytical approaches and data considerations that need to be taken into account when applying the criteria.

Check for understanding
You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. How would you define a "rare" feature?
2. What factors do measures of diversity generally consider?
3. What kinds of physical features in the oceans are generally areas of high productivity?
4. Why is the "naturalness" criterion difficult to apply?

References

Ainley DG, R. P. Henderson, H. R. Huber, R. J. Boekelheide, S. G. Allen, T. L. McElroy.1985. Dynamics of white shark/pinniped interactions in the Gulf of the Farallones. *Mem South Calif Acad Sci* 9:109–122

Ardron, J.A. 2002. A Recipe for Determining Benthic Complexity: An Indicator of Species Richness. In, *Marine Geography: GIS for the Oceans and Seas* (ch. 23, pp 196-175), Joe Breman (ed.). Redlands, CA, USA: ESRI Press.

Ardron, J., D. Dunn, C. Corrigan, K. Gjerde, P. Halpin, J. Rice, E. Vanden Berghe, M. Vierros. 2009. 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.

Aquamaps: http://www.aquamaps.org/

Ban N. and J. Alder. 2008. How wild is the ocean? Assessing the intensity of anthropogenic marine activities in British Columbia, Canada. *Aquatic Conservation: marine and freshwater ecosystems*, 18 (1). pp. 55-85.

Ban, N., H. Alidina, and J. A. 2010. Cumulative impact mapping: advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. *Marine Policy* 34: 876-886.

Bell W.J. 1991. *SearchingBehaviour: The behavioural ecology of finding resources*. Chapman & Hall.

Berger, W H; and F. L. Parker 1970. Diversity of planktonic Foramenifera in deep sea sediments. *Science* 168:1345-1347.

Cayula, J.-F. and P. Cornillon 1992. Edge detection algorithm for SST images. *Journal of Atmospheric and Oceanic Technology* 9: 67-80

Cooper, L.M. 2004. Guidelines for cumulative effects assessment in SEA of plans. In: *EPMG Occasional Paper 04/LMC/CEA*. Imperial College of London London, pp. 1-50.

Crain C.M., K. Kroeker, and B. S. Halpern. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. *Ecol Lett*, 11, 1304-1315.

Darling E.S. and I. M. Côté. 2008. Quantifying the evidence for ecological synergies. *Ecol Lett*, 11, 1278-1286.Eastwood P.D., Mills C.M., Aldridge J.N., Houghton C.A. & Rogers S.I. (2007). Human activities in UK offshore waters: an assessment of direct, physical pressure on the seabed. *ICES Journal of Marine Science: Journal du Conseil*, 64, 453.

Dormann C.F., J. M. McPherson, M. B. Araújo, R. Bivand, J. Bolliger, G. Carl, R. G. Davies, A. Hirzel, W. Jetz, W. D. Kissling, I. Kühn, R. Ohlemüller, P. R. Peres-Neto, B. Reineking, B. Schröder, F. M. Schurr, and R. Wilson. 2007. Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. *Ecography* 30(5): 609-28.

Dunn, D.C., and P.N. Halpin. (2009) Rugosity-based regional modeling of hard-bottom habitat. *Marine Ecology Progress Series* 377:1–11.

Eastwood, P. D., C. M. Mills, J. N. Aldridge, C. A. Houghton, and S. I. Rogers. 2007. Human activities in UK offshore waters: an assessment of direct, physical pressure on the seabed. *ICES Journal of Marine Science* 64: 453–463.

Eckert, S.A. 2006. High-use oceanic areas for Atlantic leatherback sea turtles (*Dermochelys coriacea*) as identified using satellite telemetered location and dive information. *Mar Biol* 149: 1257–1267

Fauchald, P., and T. Tveraa. 2003. Using first-passage time in the analysis of area-restricted search and habitat selection. *Ecology* 84 (2): 282-288.

FAO. 2009. International guidelines for the management of deep-sea fisheries in the high seas. Food and Agriculture Organization of the United Nations, Rome.

Folt C.L., C. Y. Chen, M. V. Moore, and J. Burnaford. 1999. Synergism and antagonism among multiple stressors. *Limnol Oceanogr* 44, 864-877.

Foster, S.D. and P.K. Dunstan 2010. The Analysis of Biodiversity Using Rank Abundance Distributions. Biometrics66, Issue 1: 186–195, March 2010 DOI: 10.1111/j.1541-0420.2009.01263.x

Grémillet, D., G. Dell'Omo, P. G. Ryan, G. Peters, Y. Ropert-Coudert, and S. Weeks. 2004. Offshore diplomacy, or how seabirds mitigate intraspecific competition : a case study based on GPS tracking of cape gannets from neighbouring breeding sites. *Marine Ecology Progress Series* 268: 265-279.

Guisan, A. and N. E. Zimmermann. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135: 147-186.

Halpern B.S., C. V. Kappel, K. A. Selkoe, F. Micheli, C. Ebert, C. Kontgis, C. M. Crain, R. Martone, C. Shearer, and S. J. Teck. 2009. Mapping cumulative human impacts to California Current marine ecosystems. *Conservation Letters* 2 (3): 138–148.

Halpern B.S., K. L. McLeod, A. A. Rosenberg, and L. B. Crowder. 2008a. Managing for cumulative impacts in ecosystem-based management through ocean zoning. *Ocean & Coastal Management*, 51, 203-211.

Halpern B.S., K. A. Selkoe, F. Micheli, and C.V. Kappel. 2007. Evaluating and Ranking the Vulnerability of Global Marine Ecosystems to Anthropogenic Threats. *Conserv Biol*, 21, 1301-1315.

Halpern B.S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H.E. Fox, R. Fujita, D. Heinemann, H.S. Lenihan, E.M.P. Madin, M. T. Perry, E.R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008b. A Global Map of Human Impact on Marine Ecosystems. *Science* 319 no. 5865 pp. 948-952 DOI: 10.1126/science.1149345.

Hurlbert, S.H. 1971. The non-concept of species diversity: a critique and alternative parameters. *Ecology* 52, 577–586.

Isern-Fontanet, J., E. García-Ladona, and J. Font. 2003: Identification of Marine Eddies from Altimetric Maps. *J. Atmos. Oceanic Technol*., 20, 772–778.

Jonsen, I.D., J. M. Flemming, and R. A. Myers. 2005. Robust state-space modelling of animal movement data. *Ecology* 86 (11): 2874-2880

Kaschner, K., R. Watson, A. W. Trites, and D. Pauly. 2006. Mapping worldwide distributions of marine mammals using a Relative Environmental Suitability (RES) model. Marine Ecology Progress Series **316**:285-310.

Laidre, K.L., M. P. Heide-Jorgensen, M. L. Logsdon, R. C. Hobbs, R. Dietz, and G. R. VanBlaricom. 2004. Fractal analysis of narwhal space use patterns. *Zoology*. 107: 3-11.

Laver, P. N. and M. J. Kelly. 2008. A Critical Review of Home Range Studies. *Journal of Wildlife Management* 72: 290-298.

May, R.M. 1975. Patterns of species abundance and diversity. In: M.L. Cody and J.M. Diamond, Editors, *Ecology and Evolution of Communities*, The Belknap Press of Harvard University Press, Cambridge, MA , pp. 81–120.

Morales, J. M., D. T. Haydon, J. Friar, K. E. Holsinger, and J. M. Fryxell. 2004. Extracting more out of relocation data: building movement models as mixtures of random walks. *Ecology* 85: 2436-2445.

OBIS: http://www.iobis.org/

Pielou, E.C. 1969. *An Introduction to Mathematical Ecology*. Wiley, New York.

Shannon, C.E. 1948. A mathematical theory of communication. *Bell System Technical Journal* 27: 379–423 and 623–656

Shillinger G.L., D. M. Palacios, H. Bailey, S. J. Bograd, A. M. Swithenbank, P. Gaspar, B. P. Wallace, J. R. Spotila, F. V. Paladino, R. Piedra, S. A. Eckert, B. A. Block.2008. Persistent leatherback turtle migrations present opportunities for conservation. *PLOS Biol* 6: 1408-1416.

Simpson, E.H. 1949. Measurement of diversity, *Nature* 163 (1949), p. 688.

Ready, J., K. Kaschner, A. B. South, P. D. Eastwood, T. Rees, J. Rius, E. Agbayanii, S. Kullander, and R. Froese. 2010. Predicting the distributions of marine organisms at the global scale. *Ecological Modelling* 221: 467–478.

Roden, G.I., 1987. Effects of seamounts and seamount chains on ocean circulation and thermohaline structure. Pages 335-354 in B.H. Keating et al., editors. *Seamounts, Islands, and Atolls*, Geophysical Monograph Series, Vol XXXXIII. AGU, Washington, D.C.

Tallis H., Z. Ferdana, and E. Gray. 2008. Linking Terrestrial and Marine Conservation Planning and Threats Analysis. *Conserv Biol*, 22, 120-130.

Vinebrooke R.D., K. L. Cottingham, J. Norberg, M. Scheffer, S. I. Dodson, S. C. Maberly, and U. Sommer. 2004. Impacts of multiple stressors on biodiversity and ecosystem.

Watson, R., A. Kitchingman, and W. Cheung. 2007. Catches from world seamount fisheries. Pages 400-412 in T.J. Pitcher, et al., editors. Seamounts: Ecology, Fisheries & Conservation. *Fish and Aquatic Resources Series*, 12. Blackwell Publishing, Oxford, United Kingdom.

Weng K. C. , A. M. Boustany, P. Pyle, S. D. Anderson, A. Brown, B. A. Block. 2007. Migration and habitat of white sharks (*Carcharodon carcharias)* in the eastern Pacific Ocean. *Mar Biol* 152:877–894.

White, M., I. Bashmachnikov, J. Arístegui, and A.R. Martins. 2007. Physical processes and seamount productivity. Pages 65-84 in T.J. Pitcher, et al., editors. *Seamounts: Ecology, Fisheries & Conservation. Fish and Aquatic Resources Series*, 12. Blackwell Publishing, Oxford, United Kingdom.

1(b) The role of expert opinion

Learning objectives:

In this section, you will learn about the importance and use of expert opinion, based on either scientific or local knowledge. We will review the collection, compilation and use of expert opinion for the purposes of EBSA description.

Expert opinion, whether based on scientific or local knowledge, can be an important strategy for EBSA description. Formally or informally, it can act as a foundation for further work, including the analytical approaches described in the next sections. In practise, the EBSA description process often relies on a combination of expert opinion and analytical techniques. In some cases, particularly where scientific data are lacking, inadequate or patchy, expert opinion may provide the best, or even the only, method of EBSA description.

1. Collection of all available information

The first step in the EBSA description process, whether driven by expert opinion or quantitative analysis, is the collection of all available information. Potential sources of information may include any of the following:

- Scientific publications
- “Grey literature”, including unpublished reports
- Reports from scientific cruises
- Fisheries data
- Internet-based databases and repositories (which may include bathymetric and species distribution data, as well as other GIS data)
- Conference presentations
- Indigenous and local communities and other expert knowledge

Types of knowledge that may be relevant to the process of EBSA description include:

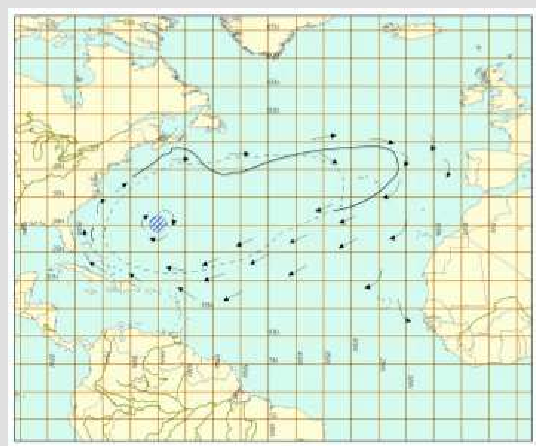
- Distribution of key physical and biogenic habitat
- The distribution of habitats of selected species, such as marine turtles, cetaceans, seabirds, sharks, fish and other species of importance
- Hot spots of benthic biodiversity
- The presence of geomorphological and oceanographic features (such as seamounts, canyons, ridges, upwelling areas and frontal systems)

Compilation of this type of information may already provide a good indication about whether an area meets one or several of the EBSA criteria. For example, compilation of all available scientific information pertaining to the Sargasso Sea demonstrates that this area very likely meets the EBSA uniqueness criterion.

Box 3: Determining the uniqueness of the Sargasso Sea

The literature search for the Sargasso Sea included peer reviewed literature, technical reports and data sets relating to biological, ecological and oceanographic features. Following the examination and compilation of the collected data, other similar regions around the world were identified. These consist of four other regions within subtropical gyres, which were compared with the defining features of the Sargasso Sea. Many similarities were found in terms of the oceanographic features or patterns of subtropical gyres and the waters they surround. For example, oligotrophic (low nutrient) waters are usually found within all the major subtropical gyres of the oceans (i.e. the North Atlantic, South Atlantic, North Pacific, South Pacific and Indian Oceans). However, the Sargasso Sea was found to be the only area in the world within a subtropical gyre that is a mass epicenter for the accumulation of vast amounts of floating *Sargassum* seaweed species, which are important for a wide variety of endemic, threatened and commercially important species. Thus, the Sargasso Sea can be said to be a globally unique area in supporting such ecologically important and significant populations of *Sargassum* spp. (McKenna et al., 2009) and its associated ecological communities.

Sargassum fluitans and *S. natans*. From http://www.tamug.edu/rooker/coastal.html.



Distribution of *Sargassum* in the Northwest Atlantic (SAFMC 2002).

2. The Delphic process

The collection of expert opinion is called the Delphic process. It usually involves convening a workshop or a panel of experts. In this setting, participants are often given a questionnaire to fill in (about, for example, which areas they think would meet the EBSA criteria and why). The answers are then discussed with the entire group.

The questionnaire may include a relatively simple scoring system, which assigns a rank of relative importance to the candidate sites depending on how well they meet the EBSA criteria. For example, a Delphic process was employed in the Mediterranean Sea for the description of EBSAs. The experts were asked to draw polygons of areas that they thought were EBSAs, and then to fill in a survey about each polygon. The survey asked the experts to score the polygons on how well they met each of the EBSA criteria, with scores ranging from 0 (not at all) to 4 (completely) (Notarbartolo di Sciara 2010).

The Delphic process can also include a mapping component. This is particularly important in the description of EBSAs, given that it is a spatially explicit process. There exist a number of geographic information systems (GIS) software packages that can be used for this purpose. Alternatively, mapping can also be done without GIS expertise by using Google Earth. Mapping expert input has the added advantage of creating a sense of ownership and common purpose, as the participants can see their collective expert opinions reflected on a map.

For example, in the Mediterranean EBSA process, 86 polygons representing expert-proposed areas of importance were collected and overlaid on a map of the Mediterranean Sea using Google Earth. EBSAs could be inferred to be recommended in locations where polygons are clustered (Notarbartolo di Sciara, 2010).

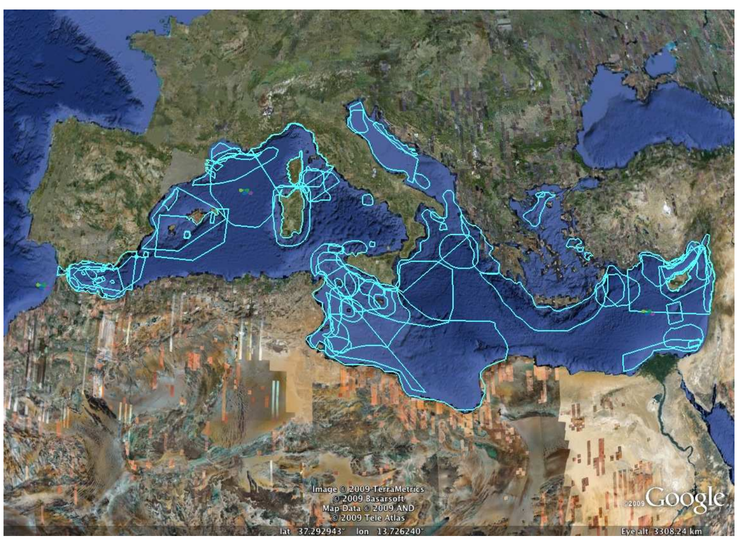


Figure 29: Expert-proposed polygons in the Mediterranean presented in Google Earth

Source: Notarbartolo di Sciara, 2010.

3. Use of local and traditional knowledge

Community engagement is often best undertaken in a less formal setting than the scientific workshops described above. In most cases, community engagement and information collection is most efficient when it is done in the community in question, respecting local cultures, norms and rules, and allowing extensive time to build trust. Respect of local authority (which may include chiefs or traditional leaders) is important. It is also paramount that the collection of traditional knowledge is done with the full and prior informed consent of the knowledge holders.

There are a number of techniques for participatory mapping that are suitable for communities. Some are available from, for example:

- Integrated Approaches to Participatory Development (IAPAD - http://www.iapad.org/);
- Participatory GIS Net (PPgis.net - http://www.ppgis.net/pgis.htm);
- EBM Tools (http://www.ebmtools.org/participatory-gis.html);
- Aboriginal Mapping Networks (http://www.nativemaps.org/); and
- The US National Oceanic and Atmospheric Administration (NOAA- http://www.csc.noaa.gov/cms/human_dimensions/participatory_mapping.pdf).

Mapping approaches may include large sketches or printed maps of the local area, which can be discussed in a group and used to gather data on local species, habitats and ecology. The technologies employed can range from hand-drawn sketches to group chalk drawings to community "3D" physical and computer models. In all of these cases, mapping comprises not just a set of tools, but the participatory process of gathering spatial information and making maps.

4. Individual interviews

In some group settings, particularly amongst concerned fishers, group solidarity can obstruct the free flow of information. In such situations, a few strong personalities can dominate discussions and the sorts of opinions that are presented. One-on-one interviews are a good way to solicit a broader range of views and information than might arise in a group setting.

When setting up interviews, it is best to find a location that feels safe and neutral to the interviewee. It is also good to present the person with materials that s/he are already familiar with; for example, while electronic maps are becoming much more common in developed countries, often paper charts, or traditional maps are still used in other parts of the world and are more appropriate for interviews there. Simple and practical advice on conducting such interviews can be found in Ardron et al. (2006).

5. Documentation

Like all data collection activities, expert opinion must be fully documented, and the methodology needs to be repeatable. Documentation should include a recording of who said what and the reasons provided. A copy of the questionnaires and draft maps should be retained. A full account of the process needs to be incorporated in a "methods" section of the report of the Delphic process.

Final results and maps produced through a Delphic process must be presented to the experts for validation, whether the experts in question are scientists or local community members. This will reduce inadvertent errors and mistakes.

6. Next steps

An expert process, while often quick and easy to apply, is always qualitative and can introduce considerable observer bias. Ideally, it is a first step in process that also incorporates some of the analytical methods described in the next section. However, where sufficient data are not available to undertake robust quantitative analysis, the Delphic process alone can provide a sufficient basis for EBSA description.

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. What are some of the considerations in organizing a delphic process?
2. How does the collection of local knowledge differ from the above?

References

Ardron, J., A. Marchand, and M. Liedkte. 2005. *GatheringSspatial Knowledge from Local Experts: A handbook for interviewing fishermen*. Version 2.0, Living Oceans Society, Sointula, BC, Canada. Online at http://www.livingoceans.org/files/PDF/marine_planning/LOS_Interviewer_Handbook_version2-2.pdf

Baldwin, K. 2009. A Summary Report for the Community Mapping Exercises of Marine

Resources, Livelihoods and Threatened Areas of the Grenadine Islands for the Grenadine Marine Resource and Space-use Information System (MarSIS). University of West Indies, Barbados. Online at http://www.grenadinesmarsis.com/uploads/Community_Mapping_Exercises_Summary_Report.pdf

Notarbartolo di Sciara, G. 2010. Methods for the Identification of EBSAs in the Adriatic Sea. 3rd International Workshop on Biodiversity in the Adriatic: Towards a representative network of MPAs in the Adriatic. Piran, 28-29 October, 2010. Online at http://www.disciara.net/documents/NotarbartolodiSciara_2010b.pdf

1 (c) Common analytical approaches

Learning objectives:

In this section you will be provided an overview of the most common analytical approaches that can be used to identify areas according to EBSA criteria. You will also learn about specific considerations you need to take into account when undertaking these analyses. While it is outside the scope of this manual to provide detailed GIS guidance, or to cover every possible analytical approach available, the manual can provide some starting points and direct the user to further resources.

The approaches covered are:

1. **Kernel density estimates**
2. **Habitat suitability modelling**
3. **Biodiversity indices**
4. **Productivity**

Each approach is covered individually and in some detail. References for further study are provided.

1. Kernel Density Estimates

There are a variety of different methods used to identify areas that are more highly used by marine organisms or to delimit a species' range. The most basic is the minimum convex polygon (MCP), in which a polygon is generated around the outermost observed locations of a given species. This can be effective for capturing the full range of the animal, but does not give any further information on the likelihood of an animal being in one area over another. Another drawback of MCP is that it is prone to overestimating the true home range because it is easily influenced by outliers (points that represent "sallies" or rare excursions from the core home range (see fig.).

Marine researchers increasingly use techniques that provide a utilization distribution: the relative frequency of locations of an animal or group of animals in a particular area during a given time frame (Van Winkle 1975). The utilization distribution describes the relative amount of time that an animal or group of animals spends in a given place and has been particularly useful for identifying areas highly used by many individuals, variably called core areas, high-use areas, and hotspots. Such core-use areas are generally areas of importance for life history stages of the species (e.g., foraging, spawning, nesting, etc.) Kernel density estimation (KDE) has emerged as the most commonly used technique to estimate utilization distributions (Worton 1989; Kernohan 2001; BirdLife International 2004; Laver and Kelly 2008). Other methods of estimating home ranges that will not be dealt with here but which practitioners might find useful are: First-Passage

Time (FPT; Fauchald and Tveraa 2003); Local Convex Hulls (LoCoH; Getz and Wilmers 2004); and Brownian bridges (Horne et al. 2007).

The primary sources of data for deriving estimates of a species home range or core use areas 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). Satellite tracking data offer 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. 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.

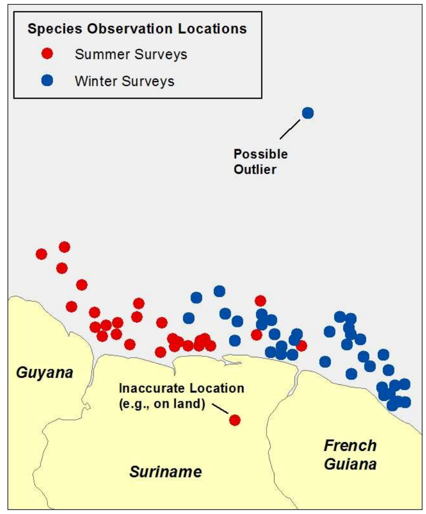


Figure 30: Data considerations: practitioners should examine the distribution of the location data AND the survey effort in time and space.
Source:

Although there are differing opinions regarding how to collect data that will be used in home range estimates, understanding how well the data capture the likely degree of natural variation in a species' distribution and behaviour is extremely important. In survey data, this pertains to the time and area covered by the survey trips, while in satellite tag data it relates to the "duty cycle" of the tag (i.e., the cycle of when the tag is on or off) and the time period covered by the tracking data. For example, in figure 1 a kernel density estimate using data collected only in summer (i.e., the red points) would fail to reveal important wintering areas around French Guiana. The accuracy of the data must also be considered. Raw satellite tag data will include a range of inaccurate positions (i.e. positions falling on land (see fig. 1), or positions farther away in distance than the animal could possibly have travelled in a given time period). Methods of processing these data to remove erroneous positions range from simple speed, distance, and angle filters, to more robust approach state-space models that account for measurement error and estimate the most probable movement pathway (Jonsen et al. 2005). Aarts (2008) summarized a number of important statistical and technical considerations when using tracking data to identify important habitats for marine predators.

Kernel Density Estimators

Kernel density estimators have been used in many tracking studies to quantify the home range or core use area of a variety of species. Generally speaking, a density estimate is simply the number of animals or sightings in a given area. The simplest form of a density estimate is to lay a grid of cells over sightings data, and calculate the number of sightings in each cell. The reason this is not used is that it generally results in a very patchy map, that overestimates true density in particular cells and underestimates it in others. This problem can be overcome with intense and long-term sampling, or by applying some method to "smooth" the data. Kernel density estimators are the most common method used to perform this smoothing.

How does kernel density estimation smooth the data? KDEs apply a function to a neighbourhood around each given point to estimate the density of the cell containing that point. To put it another way, KDEs have two main characteristics: the size and shape of the window being applied to calculate the value in a given cell. The size of the window, known as the smoothing factor and commonly noted as "h", is the search radius around a point (Fig. 2). The KDE will use this radius to determine which points (and their respective values) to include in the smoothing. Then a function is applied to that value to distribute it across the window. This is the "shape" of the window and is referred to as the kernel function. This same method has been applied to each point, and the KDE is calculated as the sum of the overlapping windows in a given cell.

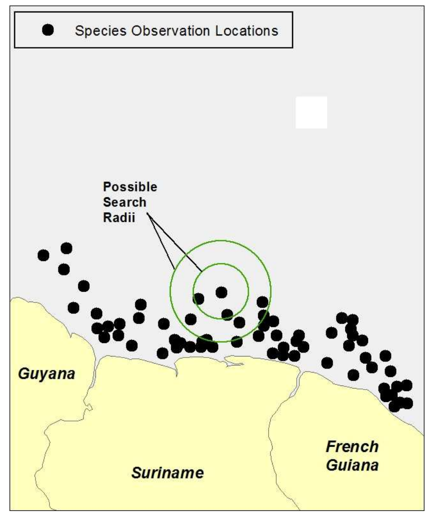


Figure 31: Examples of 2 different search radii. The smaller of the two search radii would result in values from three points being included in the kernel function, while the larger radii would include values from 7 points.

Source: xx

There are a variety of types of kernel functions (e.g., normal or "Gaussian", uniform, Epanechnikov.). While the choice of kernel type will affect the output, it is the choice of the search radius (i.e., the smoothing factor or "h") that has been shown to have the largest impact on KDE results. Different search radii can greatly affect the resulting density and range estimates (fig. 2). Choosing a search radius that is too large will result in over-smoothing of the density values – making all cells appear to be more similar than they really are. Conversely, choosing a search radius that is too small will result in under-smoothing and will exaggerate the density values (i.e., high values will appear higher, and low values will appear lower than they are in reality). The most common method for choosing a search radius is to simply use expert opinion: repeat the analysis with various smoothing factors and choose the one that results in the "best" fit based on expert opinion. This allows the user to control the level of detail shown in the density pattern. Objective methods exist for finding an optimal search radius and are often available in KDE tools such as those listed below.[1]

[1] Objective statistical methods to choose a search radius include the reference parameter (h-ref) and least-squares cross-validation (LCSV). H-ref is meant to be the optimum smoothing factor for a normally distributed data. Because most animal movement data are not normally distributed, h-ref usually ends up overestimating the home range. The LSCV method examines various smoothing parameters and attempts to minimize their estimated error (the difference between the unknown true density function and the kernel

Practitioners must also choose between the use of a fixed or adaptive kernel. A fixed kernel estimate uses the same search radius for all points, while the search radius varies in an *adaptive* kernel estimator. The choice of fixed versus adaptive is not as important as the choice of the initial search radius itself, but fixed kernel estimation is more common as the results are more easily compared and adaptive kernel analysis has been shown to overestimate the home range. Further considerations in applying kernel density estimators to tracking data were reviewed by Kernhohan et al. (2001), Getz and Wilmers (2004), and Laver and Kelly (2008).

Interpretation

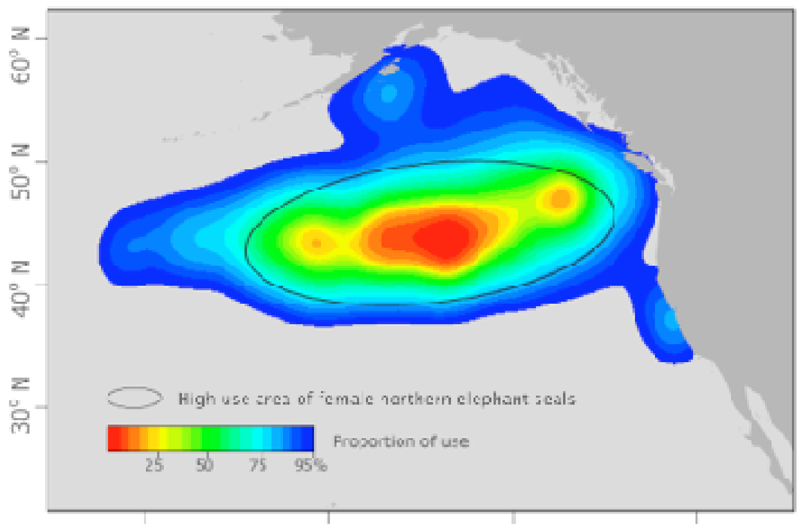


Figure 32: The utilization distribution for elephant seals tagged on the Pacific coast of the United States (see a, module 2)
Source:

Utilization distributions produce a series of volume contours encompassing the area within which the average animal spends a given percentage of time (e.g., fig 32). The 95% contour indicates the area where the animal is expected to spend 95% of its time, assuming the analysis is fully accurate. The 95% contour is often used to describe the full area used by any animal, while areas of high use are generally identified using the 50% utilization (see Fig. 32). As mentioned above, core areas are often areas of importance to different life history stages of the species. Since the marine environment is dynamic, the cues that result in the high use of one area by a species may be spatially or temporally dynamic, and thus the core area of use in any given year may change. Thus, it is important to look at the persistence of these core areas over time. BirdLife International (2009) has used kernel density estimates by season and year to identify areas of persistent use and higher conservation value. An example of this work is also available as an illustration of methods to identify areas of special importance to life history of species on the GOBI website (http://openoceansdeepseas.org).

Tools Available

- AdeHabitat package for R:
  - available @ http://cran.r-project.org/web/packages/adehabitat/index.html
  - more info @ http://www.faunalia.it/en/animove
- Geospatial Modeling Environment for R (was Hawth's Tools):

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density estimate). The LSCV method is generally preferred, though sometimes it fails to resolve an answer, and expert opinion or the h-ref value must be used.

- Available @ http://www.spatialecology.com/gme/kde.htm
- MANY OTHER R PACKAGES ALSO IMPLEMENT SOME FORM OF KDE
- ArcView 9.x & 10.x Spatial Analyst Package
  - Available @ http://www.esri.com/software/arcgis/extensions/spatialanalyst/index.html
- Animal movement extension for ArcView3.x
  - Available @ http://alaska.usgs.gov/science/biology/spatial/gistools/index.php/index.htm
- CNFER Home Range Extension (HRE) and Home Range Tools:
  - for ArcView 3.x: http://www.alanaecology.com/wildlife/Home_Range_Extension_for_ArcView_GIS.html
  - for ArcView 9.x: http://www.alanaecology.com/wildlife/Home_Range_Tools_for_ArcGIS.html#a013034
- LoCoH via the web, as an ArcMap 9.x toolbox, or an R package:
  - available @ http://locoh.cnr.berkeley.edu/

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. What are kernel density estimates used to describe? What type of data is needed to as input for a KDE? What is a "core area"?

2. What considerations do practitioners need to take into account when using data from multiple sources or multiple time periods?

3. What parameter has the greatest effect on KDE results? Why?

References

BirdLife International. 2009. Using seabird satellite tracking data to identify marine IBAs. Report of the Chize workshop, 1-3 July 2009. CNRS, Chize, France. UK: Cambridge, BirdLife International internal report.

Blundell, G. M., J. A. K. Maier, and E. M. Debevec. 2001. Linear home ranges: effects of smoothing, sample size, and autocorrelation on kernel estimates. *Ecological Monographs* 71:469–489.

Fauchald, P. and Tveraa, T. 2003. Using first-passage time in the analysis of area-restricted search and habitat selection. *Ecology* 84 (2): 282-288.

Getz, W. M. and C. C. Wilmers. 2004. A local nearest-neighbor convex-hull construction of home ranges and utilization distributions. *Ecography* 27: 489-505.

Horne, E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. *Ecology* 88: 2354–2363.

Jonsen, I.D., J.M. Flemming and R.A. Myers. 2005. Robust state-space modelling of animal movement data. *Ecology* 86 (11): 2874-2880

Kernohan, B.J., R.A. Gitzen, and J.J. Millspaugh. 2001. Analysis of animal space use and movements. in *Radio Tracking and Animal Populations* (J.J. Millspaugh and J.M. Marzluff, Eds.) pp. 125-166, Academic Press, London.

Laver, P.N., and M.J. Kelly. 2008. A critical review of home range studies. *Journal of Wildlife Management* 72: 290-298.

Seaman, D. E. and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77 (7): 2075-2085.

Van Winkle, W. 1975. Comparison of several probabilistic home-range models. *Journal of Wildlife Management* 39:118-123.

Worton, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70: 164-168.

Worton, B. J. 1995. Using Monte Carlo simulation to evaluate kernel-based home range estimators. *The Journal of Wildlife Management* 59(4): 794-800.

2. Habitat suitability modelling

The Problem

It is very seldom that we know the true extent of a species distribution in a given region. This would require complete temporal and spatial coverage of the species' range in multiple surveys—a lengthy and expensive task. Often, we rely on the combined results of surveys done over the course of years to get an idea of where that species is distributed. Fishers, for example, develop through trial and error a mental picture of where certain fish can be caught. Although they would not call this a model it actually is a mental model, built up through years of sampling; i.e. fishing. For this reason, the distribution of commercial species, especially those that have been fished for several years, is generally known. Local and expert knowledge alone, or combined with a kernel density analysis (previous section) can produce reasonable maps of the expected distribution of common commercial species.

For less commonly fished species or non-commercial species, however, there is usually much less certainty about where the species occur, because there is much less data and experience. For planning purposes (e.g., toward the goal of conserving biodiversity), a few data points widely scattered across a map will not be helpful and indeed can be misleading. For these species, it will be necessary to predict the distribution of the species across the area of interest. This is the role of habitat suitability models: converting point occurrence data into evenly mapped distributions.

Habitat suitability models aim to describe the distribution of a species by characterizing the environmental conditions that are suitable for the species, and then mapping where such suitable conditions exist. For example, certain species of fish are known to only exist in association with coral reefs in tropical climates. By identifying locations within the Tropics that contain such habitat (i.e., coral reefs), we can estimate the species' distribution. Thus, habitat suitability models are used to explain or predict the presence of an organism in a given area. Given enough information they can also be used to predict the abundance of an organism in the study area.

There are two basic approaches to developing habitat suitability models: mechanistic and correlative. Mechanistic models use pre-existing knowledge of a species' tolerance of environmental conditions to formulate an algorithm to delimit the area in which the species might exist (or prefers to exist). The level of study of a species required to develop mechanistic models is extremely high, and there are few circumstances where we have such knowledge. As such, correlative models are far more common in the literature and within resource management and conservation. Correlative models estimate the suitability of a habitat for a given species by linking known observations of the species with environmental variables. The environmental conditions in which the species has been found are thus assumed to describe its geographic distribution.

While kernel density estimates describe one type of analytical method, using only the observation data of the species itself, there are a wide variety of habitat suitability models that draw upon both species observation data and environmental variables to help predict where the species could be found. The scope of this subject cannot be covered in this document, so we encourage the reader to seek out other reviews of the subject (e.g., Guisan and Zimmerman 2000, Elith et al. 2006 and Redfern et al. 2006, or Pearson 2007).

Data Requirements and Considerations

As mentioned above, there are two general types of data required to derive habitat suitability models: (1) species occurrence records, and (2) environmental variables. Species occurrence records can be retrieved (and continually updated) from online data repositories such as the Ocean Biogeographic Information System (OBIS), OBIS-SEAMAP (a sub-node of OBIS dealing specifically with marine mammals, seabirds and sea turtles), or the Global Biodiversity Information Facility (GBIF). Most of the data in these repositories come from government agencies or academic research. Currently, the largest single contributor of marine species occurrence data to OBIS is the Census of Marine Life (CoML). The CoML website, www.coml.org, contains good background information and links to specific projects, where there is more information on how the data were collected.

Such data repositories compile point data sets from a variety of different sources (see DATA module) which can contain sampling biases including, but not limited to, non-representative coverage of habitats and species misidentifications. To correct for misidentifications or geographic misallocations of occurrence records, information about the general occurrence of species in different ocean basins should be used as a broad filter to select "good" points, i.e., excluding points that are most likely incorrect. This information can be retrieved from existing online species databases, such as FishBase and SeaLifeBase, where it is provided in the form of FAO statistical area checklists and/or bounding boxes delineating the known maximum range extent boundaries for species as described in the scientific literature.

Environmental data

The simplest and most common distinction between environmental variables used in habitat suitability models is between those variables that directly affect the species distribution and those that only indirectly affect the distribution. Direct predictors, like prey abundance, are preferred to indirect predictors, like depth. Direct predictors offer clear explanations that can be transferred to other situations where similar data are available, whereas indirect predictors are proxies (substitutes) for the real ecological relationship that we wish to describe, and often cannot be extrapolated as well in new environments (Guisan and Thuiller 2005). However, direct predictors are less common than proxies, especially at broader scales. Additionally, direct predictors at one scale may not be predictors at all at another (see below). Coastal species habitat suitability models frequently use data on the spatial distribution of physical habitats (e.g., seagrass beds) or bottom type and rugosity. However, by far the most common variables used in pelagic marine habitat suitability models are depth and sea surface temperature. In either case these data may be (1) categorical, (2) ordinal or (3) continuous. That is, they may be (1) categorized in unrelated bins, (2) ordered but not necessarily in quantifiable intervals, and (3) regular numbers (e.g. 1.1, 23.9, 4007.6, etc.). As some models cannot deal with certain types of data, the types of data available may dictate the choice of model.

Many online repositories and warehouses of environmental data exist and are freely available to modelers to download. Examples of some online resources for each of these data types are listed below:

- Sea surface temperature
    - AVHRR Oceans Pathfinder SST
    - MODerate Resolution Imaging Spectroradiometer (MODIS)
- Sea surface height, currents and wave height
    - AVISO Sea Surface Height
    - AVISO Geostrophic Currents
    - AVISO Significant Wave Height
- Primary productivity (e.g., ocean colour or derived models)
    - NASA OceanColor Chlorophyll A data (MODIS & SeaWiFS)
    - Vertically Generalized Production Model (VGPM)
- Shoreline and bathymetry

- o Global Self-consistent, Hierarchical, High-resolution Shoreline (GSHHS)
  - o ETOPO1 Global Relief Model
  - o GEBCO Global Topography
  - o SRTM30 PLUS Global topography
- Wind
  - o QuikSCAT Wind
  - o AVISO Surface Wind
- Climate and climate scenarios
  - o WorldClim
  - o Intergovernmental Panel on Climate Change (IPCC)

The environmental variables listed above range in their spatial and temporal resolution. The choice of a resolution and scale in building a habitat model is crucial, as the driving forces behind a species distribution may (will) be different at different scales. For instance, the distribution of an organism that can tolerate sea surface temperatures between 15ºC and 30ºC can be predicted at global scales using that information. However, within those temperature ranges (and there is a lot of room within those temperatures), sea surface temperature may have little to no predictive power. Hence, such models are best served by a variety of data sets that, when taken together, cover a broader range of scales than any individual data set considered alone.

The resolution and scale of the observation records are also important as they determine the scope of what can reasonably be predicted from the data. For example, if the surveys for a given species were undertaken in depths between 0 and 200 metres, extrapolation of the model to predict the species distribution in depths greater than 200 metres would be highly suspect. Thus, the concentration of global sampling effort in more accessible habitats, such as the continental shelf regions of the northern hemisphere, represents a great challenge for the application of any species distribution modeling technique.

The same caution must be taken when considering the temporal scale of the observations. Most commonly, species distribution models predict extents that often do not consider seasonal movements of animals or subspecies-level population structure and may thus potentially overlook critical habitat needed during certain life stages or for maintaining subspecies level diversity. Further, the lack of visual observation of an organism at a specific point in time and space cannot be considered a true absence, as the organism could be present but could simply have not been detected by the survey (see Data module).

One last consideration is that increases in model complexity can lead to overfitting the model and decrease the biological or ecological relevance of the model. That is, by developing a model that too closely matches the observation data, the model can lose its ability to predict the distribution of a population as a whole (i.e., it will generate an excessive number of false negatives). Model complexity should only be increased if the modeler can identify the ecological relevance of the additional complexity. That said, predictive habitat models are generally characterized more by false positive; that is, places predicted to contain species where really none exist. Both types of error point towards the need to validate models with additional survey data whenever possible. This can be in the form of directed surveys after the model has been developed, or by setting to one side a randomly selected portion of the data to test the model after it has been developed with the remaining data.[2]

Types of Habitat Suitability Models

Habitat suitability models predict either the presence/absence of a species or the abundance of a species in a given area. Of these, presence/absence models are more common, as they require less (or less detailed) data. Habitat suitability models can be further differentiated by whether they are meant to simply predict the distribution of a species, or whether they also aim to explain the relative importance of the predictors included in the model. Explanatory models require a higher level of examination for cross-correlation between variables and preclude the use of certain algorithms that combine variables in new ways to develop generally un-interpretable new axes by which to differentiate presence and absence points. Predictive models dominate the use cases outlined in these modules and conservation planning in general, as practitioners need to use the predictions to quantify biodiversity metrics or indices.

There are a wide variety of algorithms used to create habitat suitability models. They can generally be differentiated by their data requirements and their output. The most fundamental difference between model types is whether absence points are required. Often, observation data are either opportunistic or absence data are simply not recorded. Since absence data are frequently unavailable, other methods have been developed that do not require absence data. There are three types of models that do not require absence data: (1) truly presence-only models; (2) models that compare the presence points to the surrounding area in lieu of absence points; and (3) models that generate pseudo-absence points (e.g., randomly, or by random walks that simulate tracks of an individuals within a population). Table 3 (taken from an excellent summary of habitat modeling by Pearson 2007), describes several modeling algorithms and the data they require.

The most commonly used algorithms for generating habitat suitability models are multivariate logistic regression techniques. "Logistic" simply refers to the fact that the model produces a binary output (i.e., a 0 for a predicted absence, or a 1 for predicted presence). "Multivariate" simply means that there is more than one environmental variable in the model. Regression techniques attempt to understand how the response variable (i.e., the presence or absence of the species) changes across the range of values of one or more environmental variables, and to build an equation using the environmental variables that will predict the response variable. Three common multivariate regression techniques are generalized linear models (GLMs), generalized additive models (GAMs)

[2] Generally ~25% of data is set aside for testing the model, though many mechanisms exist for allowing smaller portions of the data to be set aside, including running the model many times with different combinations of the data used or left aside for testing resulting in estimates of the model parameters, variance and errors (i.e., "bootstrapping").

and classification and regression tree (CARTs). GLMs generally assume a linear relationship between the environmental predictor variables and the response variable, while GAMs allow for non-linear relationships. Unlike the other two models, CART models attempt to split the data based on the amount of deviance explained, creating a tree-like graph where the final branches cannot be split further and still explain a minimum level of deviance.

As Table 3indicates, there are many other algorithms that vary in terms of data requirements, complexity and utility for particular applications. The scope of this topic is well beyond this manual, but we would highly encourage interested practitioners to do further research on the subject, starting with the references in the table. There are also a number of online resources to help practitioners learn how to use these models and other statistics integral to the quantification and conservation of biodiversity. A few are listed below:

- Species' Distribution Modeling for Conservation Educators and Practitioners (Pearson 2007), mentioned above. Produced by the American Museum of Natural History.
- An introduction to R: software for statistical modelling and computing, course notes by Kunhert and Venables (2005). Produced by The Commonwealth Scientific and Industrial Research Organization (CSIRO).
- The Elements of Statistical Learning (Tibshirani, Hastie and Friedman, 2nd ed., 2005)

Table 3: Tools Available

Method(s)[1]	**Model/software name**[2]	**Species data type**	**Key reference**	**Associated web links**
Gower Metric	DOMAIN*	Presence-only	Carpenter et al. 1993	http://www.cifor.cgiar.org/online-library/research-tools/domain.html
Ecological Niche Factor Analysis (ENFA)	BIOMAPPER*	Presence and background	Hirzel et al. 2002	http://www2.unil.ch/biomapper/
Maximum Entropy	MAXENT*	Presence and background	Phillips et al. 2006	http://www.cs.princeton.edu/~schapire/maxent/
Genetic algorithm (GA)	GARP[3*]	Pseudo-absence[4]	Stockwell and Peters 1999	http://www.lifemapper.org/desktopgarp/
Artificial Neural Network (ANN)	SPECIES	Presence and absence (or pseudo-absence)	Pearson et al. 2002	
Regression:				
Generalized linear model (GLM), generalized additive model (GAM), and mixed models (GLMMs, GAMMs)	Implemented in R[5*]	Presence and absence (or pseudo-absence)	McCullagh and Nelder 1989; Hastie and Tibshirani 1990; Guisan et al. 2002;	http://www.unine.ch/cscf/grasp/

	GRASP*		Lehman et al. 2002	http://www.unine.ch/cscf/grasp/
	MGET*		Roberts et al. 2010	http://code.env.duke.edu/projects/mget
Classification and regression trees (CART), boosted regression tree (BRT), random forest(RF)	Implemented in R[5]		Breiman et al. 1984; Elith et al. 2008; Breiman 2001	
multivariate adaptive regression splines (MARS)	Implemented in R[5]	Presence and absence (or pseudo-absence)	Elith et al. 2006; Leathwick et al. 2006; Elith et al. 2008	
Multiple methods	BIOMOD	Presence and absence (or pseudo-absence)	Thuiller 2009	http://www.will.chez-alice.fr/Software.html
Multiple methods	OpenModeller	Depends on method implemented		http://openmodeller.sourceforge.net/

1 Method refers to a statistical or machine-learning technique. 2 Model/software name refers to a name (or acronym) given to a published model that implements the method(s) stated. Software to implement the method for species' distribution modeling is readily available at no cost for those models marked with an asterisk (*); other models are available at the discretion of the author(s). 3 The genetic algorithm for rule-set prediction (GARP) includes within its processing multiple methods, including GLM. 4 Pseudo-absence here refers to the sampling approach implemented in the GARP software; in principle, any presence-absence method can be implemented using pseudo absences. 5 R is a freely available (at no cost) software environment for statistical computing and graphics (http://www.r-project.org/).

Source: Adapted and updated from Pearson 2007

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. Why do we need habitat suitability models?
2. What are the two types of data that are used as inputs to a habitat suitability model? Give examples of some resources where they can be found.
3. Do habitat suitability models produce the same results at any scale? Why or why not? How does this affect use of the results of a habitat suitability model?

References

Breiman L, J. Friedman, C. Stone, and R. A. Olshen. 1984. *Classification and Regression Trees*. Chapman & Hall/CRC.

Breiman L. 2001. Random Forests. *Machine Learning* 45: 5-32.

Carpenter, G., A.N. Gillson, and J. Winter. 1993. DOMAIN: a flexible modeling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* 2, 667-680.

Elith, J., C. Graham, and the NCEAS species distribution modeling group. 2006. Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29, 129-151.

Elith, J. and J. R. Leathwick. 2007. Predicting species' distributions from museum and herbarium records using multiresponse models fitted with multivariate adaptive regression splines. *Diversity and Distributions* 13, 165-175.

Elith J., J.R Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. *Journal of Animal Ecology* 77: 802-813.

Guisan, A. and N. E. Zimmermann. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135(2-3): 147-186.

Guisan A, T. C. Edwards, and T. Hastie. 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling* 157: 89-100.

Guisan, A., and W. Thuiller (2005) Predicting species distribution: Offering more than simple habitat models. *Ecology Letters* 8, 993-1009.

Hastie T. and R. Tibshirani. 1990. *Generalized Additive Models*. London; New York: Chapman and Hall.

Hastie T., R. Tibshirani, and J. Friedman. 2008. *The Elements of Statistical Learning: Data Mining, Inference and Prediction.* New York: Springer-Verlag

Hirzel, A.H., J. Hausser, D. Chessel, and N. Perrin. 2002. Ecological-niche factor analysis: How to compute habitat-suitability map without absence data. *Ecology* 83, 2027-2036.

Kunhert P., and B. Venables. 2005. *An Introduction to R: Software for StatisticalModelling & Computing.* Cleveland, Australia: CSIRO.

Leathwick, J.R., J. Elith, and T. Hastie. 2006. Comparative performance of generalized additive models and multivariate adaptive regression splines for statistical modelling of species distributions. *Ecological Modelling* 199, 188-196.

Lehman, A., J.M. Overton, and J.R. Leathwick. 2002. GRASP: generalized regression analysis and spatial prediction. *Ecological Modelling* 157, 189-207.

McCullagh P. and J. A. Nelder. 1989. *Generalized Linear Models*. New York Chapman and Hall.

Pearson, R.G., T.P. Dawson, P.M. Berry, and P.A. Harrison. 2002. Species: A spatial evaluation of climate impact on the envelope of species. *Ecological Modelling* 154, 289-300.

Pearson, R.G. 2007. *Species' Distribution Modeling for Conservation Educators and Practitioners.* Synthesis. American Museum of Natural History. Available at http://ncep.amnh.org.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190, 231-259.

Redfern J.V., et al. 2006. Techniques for cetacean-habitat modeling. *Marine Ecology-Progress Series* 310: 271-295.

Roberts J.J., B.D. Best, D. C. Dunn, E. A. Treml, P. N. Halpin. 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. *Environmental Modelling & Software* 25: 1197-1207.

Stockwell, D.R.B. and D.P. Peters. 1999. The GARP modelling system: Problems and solutions to automated spatial prediction. *International Journal of Geographical Information Systems* 13, 143-158.

Thuiller, W., B. Lafourcade, R. Engler, and M. B. Arau´jo. 2009. BIOMOD: a platform for ensemble forecasting of species distributions. *Ecography* 32: 369-373 (Version 0).

3. Biodiversity indices

What is biological diversity?
One of the more intuitive criteria on which conservation efforts are based is "diversity" – but measuring diversity is not straightforward.

The CBD's definition of biodiversity

> "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
>
> Article 2, the Convention on Biological Diversity

Measures of diversity generally consider one or more of the following factors: 1) the number of different elements (e.g., species or communities) also referred to as "richness"; 2) the overall abundance of elements; 3) the relative abundance, or "evenness", of the elements (and other related measures); and 4) how different or varied the elements are when considered as a whole (e.g., taxonomic distinctness; Warwick and Clarke 1995; Clarke and Warwick 1998). In applying this EBSA criterion, all four factors could be taken into consideration. Many biodiversity indices have been proposed, often differing in the weight attached to each of the four components. However, many of the more commonly used indices are mathematically related (see Hill 1973). Several publications give a good overview of diversity indices and their respective advantages and drawbacks (e.g., Magurran 1988; Grassle et al. 1979; Heip et al. 2001). Readers are encouraged to seek out these publications.

The diversity indices outlined below rely on observational data. 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 and 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 by relying on physical covariates of diversity.

A word on marine indicator projects

Indices should not be confused with *indicators.* Biodiversity indices rely on the direct measurement of data to determine a mathematical component of biodiversity, whereas biodiversity indicators are used more broadly to provide an indication of the health of a component of an ecosystem, usually through aggregated trends. For example, *Trends in the extent of selected biomes, ecosystems, and habitats* (http://www.twentyten.net/marinehabitats) is one of ten composite indicators being used in the Biodiversity Indicators Partnership which seeks to address biodiversity reporting for the CBD and other bodies (http://www.twentyten.net/). Some other broad initiatives to track marine biodiversity include:

- The UN's Regular process for global reporting and assessment of the state of the marine environment, including socio-economic aspects (http://www.un.org/Depts/los/global_reporting/global_reporting.htm);
- The indiSeas project (http://www.indiseas.org/), which is a global assessment of ocean ecosystems and trends, particularly fisheries;
- TWAP-LME (Transboundary Waters Assessment Programme-Large Marine Ecosystem; http://www.unep.org/regionalseas/globalmeetings/12/wp05-transboundary-waters-assessment.pdf) under development by UNEP;
- The European Union's *Streamlining European 2010 Biodiversity Indicators* (SEBI2010; http://ec.europa.eu/environment/nature/knowledge/eu2010_indicators/index_en.ht

m) which has published terrestrial and marine trends for Europe (http://www.eea.europa.eu/publications/assessing-biodiversity-in-europe-84);

Biodiversity Indices

For some, biodiversity equates to species richness, i.e. how many species are found in a given area (or per unit of sampling effort). The problem with this measure is that it is very sensitive to sampling effort and that it does not take into account relative abundances or taxonomic groupings. Hence 98 herring, pilchard, and 1 capelin (richness = 3) is considered the same as 33 herring, 34 black-footed albatrosses and 33 blue whales (richness = 3). Something seems wrong here, as we intuitively know that the first grouping is less diverse, both because it is dominated by one species (i.e., herring) and because the species come from lower order taxa that are generally much more abundant than the high order taxa in the second grouping. As we can see then, measuring only species richness may yield misleading results. One problematic assumption inherent in the approach of many diversity indices is that species are interchangeable. This is obviously not true – due to their ecological role, or economic or conservation status. For example, diversity mainly consisting of invasive species is generally not a desirable situation; endangered and/or endemic species clearly should rank higher when making conservation decisions. Thus, analyses of biodiversity should take into consideration the actual species composition and possible implications for ecosystem functions and services.

Species richness is not the only measure of biodiversity that can be deceptive when looked at in isolation. In fact, any of the other individual measures can also yield unreliable results. If we compared "evenness" in two samples in which one contained 1 herring, 1 pilchard, and 1 capelin (high evenness), and the other contained 100 herring, 10 black-footed albatrosses, and 1 blue whale (low eveness), we would also fail to get an accurate accounting of biodiversity in the area sampled. The lack of any measure of the overall abundance of the species or a relative weighting for less abundant species decreases the utility of such a measure used on its own.

Phylogenetic concerns (i.e., concerns pertaining to the evolutionary relatedness of species) have also been raised, suggesting that it is better to have an area with species that are more distantly related than an area with only closely related species (e.g., Humphries et al. 1995). Indices that include relatedness exist (e.g. Warwick and Clarke 1995, Clarke and Warwick 1998), but they require additional work on calculating distances across species in the tree of life, before they can be calculated on large global datasets.

To combat these issues, biodiversity indices have been developed to include multiple factors and to be relatively insensitive to sampling biases. They include:

- Simpson's Index (Simpson 1949)
- Shannon-Wiener Index (Shannon 1948)

- Pielou’s Evenness Index (Pielou 1969)
- Berger-Parker Index (Berger and Parker 1970; 1975)
- Hurlbert (ES50) Index (Hurlbert 1971)
- Rank Abundance Curves (Foster and Dunston 2009)

Three of the more common biodiversity indices are described below.

Simpson’s Index is a measure that accounts for both species richness and the relative abundance of species abundance in a sample. It does this by calculating the probability that two randomly selected individuals from the sample will not belong to the same species. To make the results more intuitive (i.e., to make larger values equal more diversity), the sum of all probabilities calculated for each species is subtracted from 1. The simplicity of Simpson's Index has led it to be used frequently, regardless of its drawbacks. For instance, the index is weighted toward the more abundant species, and thus rare species have a disproportionately small influence on the result, which is completely counter-intuitive to the objective of most biodiversity conservation efforts.

One of the most popular diversity indices is the Shannon-Wiener index (Shannon 1948), which is considered a measure of evenness. This index is more sensitive to the inclusion of rare species than Simpson’s Index. Unfortunately, this benefit is offset by the assumption that all species of the community are present in the sample. Obviously, this will only be true if the number of sampled individuals is very large. This index is also very sensitive to sampling effort. Further, it assumes a logarithmic relationship across species, which, while more realistic than simply counting species as per richness, is still problematic in that higher or lower taxonomic levels are not directly accounted for.

A measure of biodiversity that is both intuitive and relatively insensitive to observation bias is Hurlbert’s Index (Hurlbert 1971), which is calculated as the number of distinct species expected to be present in a random sample of, for example, 50 individuals from an area. Hurlbert’s index, commonly referred to as “es(50)”, is calculated for the OBIS dataset using 5 degree squares in figure 33.

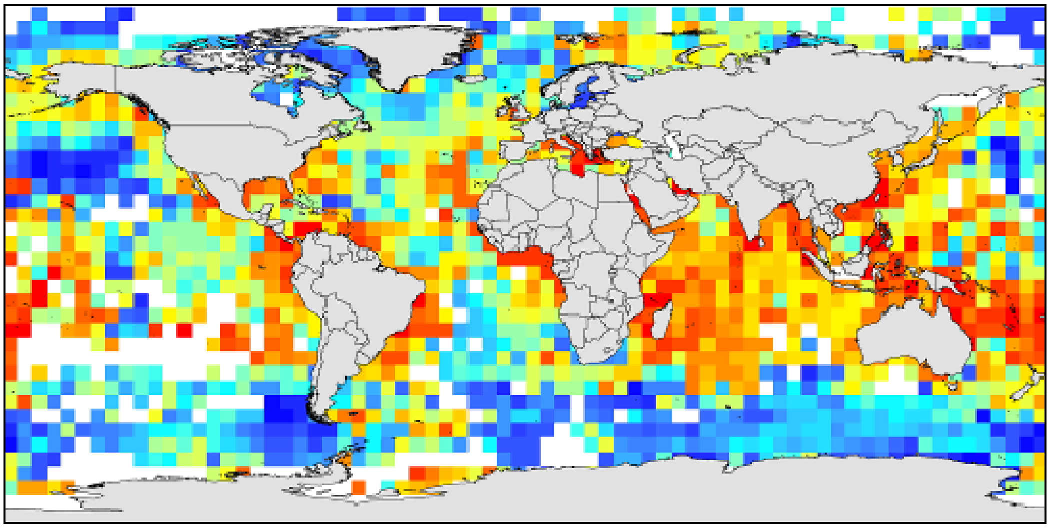


Figure 33: Hurlbert's Index, es(50), applied to the OBIS dataset of ~30 million records. Source:

Data Requirements and Considerations

The primary sources of data for deriving biodiversity indices are species observation data or habitat models derived from such data. Raw species observation data are available from many sources, such as large museums, national monitoring programmes, fisheries data, and individual datasets. The challenge is that these data are not always easily accessible, and that individual datasets are usually collected on a limited scope – geographic, taxonomic and temporal. The Ocean Biogeographic Information System (OBIS; http://www.iobis.org/) was initiated to create a data warehouse to integrate this multitude of data in one comprehensive, quality-controlled system. OBIS is currently housed under the International Oceanographic Commission (IOC) of UNESCO. OBIS continues to grow, steadily increasing the quantity and quality of the data available through its portal. The content of OBIS is becoming suitable for the study of broad patterns of t biodiversity distribution, though the content is generally insufficient to allow detailed analyses on regional scales, or to study the distribution patterns of individual taxa. OBIS does provide a framework for capture and re-use of existing data, and is expected to continue to grow. It has also been an integral mechanism for data sharing and data repatriation from the developed to developing nations and small island developing states.

A quick exploration of OBIS indicates that there are significant differences in the intensity with which the oceans are studied (fig.

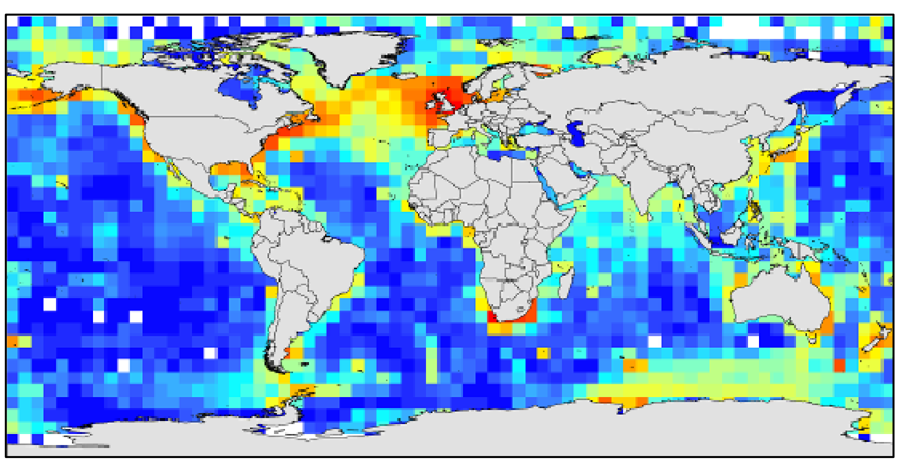


Figure 34: caption
Source:

34). Many more data are available for coastal areas than for the open ocean. In the open ocean, surface waters are more intensively sampled than the bottom, and even fewer data are available for the mid-waters. Some large datasets, such as a long-line fisheries dataset from South Africa, with a great many records (more than 3 million) for very limited number of target species, result in low estimates of certain biodiversity indices because longline fisheries data swamp other biodiversity surveys of the same region. This spatial sampling bias also affects the quantification of species richness: more observations generally result in more species being discovered in a given area. Thus if the sampling number is not accounted for, the more highly sampled areas (often also those in or near developed countries) will result in higher measured levels of biodiversity. Sampling bias is a significant problem for open oceans and deep seas, where sampling effort has concentrated on discrete areas, while other areas or entire regions remain largely unexplored. There are several possible methods to remedy this situation, including the use of raw observation data as input for predictive range and habitat models (e.g., AquaMaps; Ready et al. 2010; *Predictive Habitat Modelling*) instead of raw occurrences.

Tools Available

- The "vegan" and "vegetarian" packages for R provide access to biodiversity metrics:
    - vegan: http://cc.oulu.fi/~jarioksa/softhelp/vegan.html
    - vegetarian: http://cran.r-project.org/web/packages/vegetarian/
- BiodiversityR package for R provides a GUI for biodiversity analysis:
    - http://www.worldagroforestry.org/resources/databases/tree-diversity-analysis
- FD package for R computes functional diversity metrics:
    - http://cran.r-project.org/web/packages/FD/
- Marine Geospatial Ecology Tools (MGET) for ArcView 9.x and ArcView 10
    - http://code.env.duke.edu/projects/mget
- Examples of online or downloadable biodiversity calculators
    - http://alyoung.com/labs/biodiversity_calculator.html
    - http://www.columbia.edu/itc/cerc/danoff-burg/MBD_Links.html

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. What is biodiversity? What is the difference between biodiversity indices and

biodiversity indicators?

2. What are the four common factors considered in biodiversity indices? Why do biodiversity indices generally account for more than one of these factors?

3. What are some issues with the use of Simpson's Index and the Shannon-Wiener Index?

References

Clarke K.R. and R.M. Warwick. 1998. A taxonomic distinctness index and its statistical properties. *J Appl Ecol* 35:523–531

Grassle, J.F., G.P. Patil, W. Smith, and C. Taille (eds). 1979. Ecological diversity in theory and practice. Volume 6 in G.P. Patil (ed) *Statistical Ecology*. International Cooperative Publishing House, Fairland, MD.

Heip, C.H.R., P.M.J. Herman, and K. Soetaert. 2001. Indices of diversity and evenness. *Oceanis* 24: 61-87.

Hill, M.O. 1973. Diversity and evenness: a unifying notation and its consequences. *Ecology* 54: 427-431.

Hurlbert, S.H. 1971. The non-concept of species diversity: a critique and alternative parameters. *Ecology* 52: 577-586.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Chapman & Hall.

Ready, J., K. Kaschner, A.B. South, P.D. Eastwood, T. Rees, J. Rius, E. Agbayani, S. Kullander, and R. Froese. 2010. Predicting the distributions of marine organisms at the global scale. *Ecological Modelling* 221(3): 467-478.

Shannon, C.E. 1948. A mathematical theory of communication. *Bell System Technical Journal* 27: 379–423 and 623–656.

Warwick, R.M. and K.R. Clarke. 1995. New 'biodiversity' measures reveal a decrease in taxonomic distinctness with increasing stress. *Marine Ecology Progress Series* 129: 301-305.

4. Measures of Productivity

Primary productivity

At the bottom of many marine food chains are phytoplankton, single-celled, microscopic plants.. Through the process of photosynthesis, phytoplankton use chlorophyll and the sun’s energy to convert carbon dioxide and water to organic compounds for growth and reproduction. The generation of new plant material by photosynthesis is called primary production. Oceanographers use estimates of primary production as the most basic measure of the biological productivity of the ocean.

Primary production does not occur uniformly throughout the ocean. The rate of production depends mainly on the quantity of phytoplankton already in the water, the availability of light and required nutrients such as nitrogen and phosphorus, and the water temperature. While sunlight availability is related mainly to geographic distance from the equator and the annual solar cycle, nutrient availability is governed by complex, dynamic circulatory processes such as upwellings, currents, and eddies. Unable to resist the flow of ocean currents, phytoplankton drift passively and are subject to the same circulatory processes that control the flow of nutrients. Currents and eddies can entrain drifting organisms and carry them far from their points of origin. As distinct water masses flow past each other, they aggregate drifting organisms along their boundaries, called fronts. These frontal aggregations of drifters attract mobile predators such as fish, turtles, birds, and marine mammals. These processes disperse nutrients unevenly and create patches of high and low phytoplankton productivity.

The physical phenomena that produce these patches of low or high primary productivity operate across a range of space and time scales. Fronts, eddies and other small-scale dynamic processes can stimulate productivity for days to months (Willett et al. 2006). The annual solar cycle drives distinct seasonal patterns in productivity (Behrenfeld and Falkowski 1997), especially in regions poleward of the tropics. Large-scale episodic phenomena such as the El Niño Southern Oscillation (ENSO) can force regional episodes of high or low productivity (Behrenfeld et al. 2001). Finally, global climate trends influence primary productivity on a global scale (Behrenfeld et al. 2006). When describing an EBSA on the basis of primary productivity, it is important to understand the phenomena that affect primary productivity in the given region of interest.
Phytoplankton can be detected at the ocean surface by satellites that measure specific wavelengths of reflected sunlight. The NASA OceanColor Chlorophyll A dataset is one common source of information on estimates of Chlorophyll-a in the ocean. However, there are other, more complex models of primary productivity. The Vertically Generalized Production Model (VGPM) by Behrenfeld and Falkowski (1997) estimates the net primary productivity for a “euphotic volume of water” as a function of surface chlorophyll concentration, surface temperature, length of the day, quantity of photosynthetically active radiation (sunlight important for plant growth), and depth of the euphotic zone (the layer of the ocean penetrated by light, which is used in photosynthesis). Because these parameters can be estimated by high resolution satellite sensors, detailed maps of the VGPM can be calculated for the entire planet on a daily basis. Oceanographers are continually improving methods for estimating primary productivity. While the VGPM represents the current “industry standard” (MJ Behrenfeld, personal communication), newer models may provide more accurate estimates. Behrenfeld provides two alternative models on his website (http://www.science.oregonstate.edu/ocean.productivity/).

It is important to note that high primary productivity is not always a positive indicator. Nutrient loading in rivers from agricultural run-off and other sources can result in large dead zones, areas of very high productivity a river delta. This primary productivity can result in eutrophication and areas of extremely low oxygen. These anoxic environments, referred to as cannot support the marine life normally found in the area, resulting in large fish kills. Thus it is extremely important to understand the wider context surrounding areas of high productivity.

Secondary productivity

Regions with high primary productivity do not always have high productivity of animals higher in the food chain, such as fish or marine mammals. Phytoplankton drift passively with the currents. When a phytoplankton bloom occurs, days or weeks may pass before grazing animals multiply to significant numbers or arrive from elsewhere to consume it. Many of these grazers are zooplankton, which can drift both actively and passively. Efforts are underway to model the distribution of zooplankton biomass. Although spatial and temporal resolution and model validation remain issues, such global estimates of zooplankton biomass do exist (see Stromberg et al. 2010). By the time these grazers have themselves been consumed by predators further up the food chain and the density of these predators has reached its peak, the food web may have drifted quite far from the bloom's original location. Such areas, generally fronts or eddies, tend to be locally and regionally important for ecosystem functioning. Algorithms are available to identify these areas from satellite images. For example, fronts can be delineated in satellite images of sea surface temperature (SST) and chlorophyll-a (CHLA), and eddies in images of sea surface height (SSH). Global images of SST on a variety of spatial and temporal scales down to daily images with a 4-kilometre resolution can be found at the AVHRR Oceans Pathfinder SST website (http://www.nodc.noaa.gov/SatelliteData/pathfinder4km/) and the MODerate Resolution Imaging Spectroradiometer (MODIS) website (http://podaac.jpl.nasa.gov/pub/sea_surface_temperature/modis/doc/modis_sst.gd.html). Sea-surface height and data on currents can be found at AVISO's website (http://www.aviso.oceanobs.com/en/data/products/sea-surface-height-products/global/index.html).

Oceanographic data are often difficult to import into GIS programmes. Marine Geospatial Ecology Tools (Roberts et al. 2010), a collection of free tools published by Duke University Marine Geospatial Ecology Lab, assist with the download and display of oceanographic data. For best results when addressing these considerations, consult oceanographers and biologists familiar with the given region and species of interest.

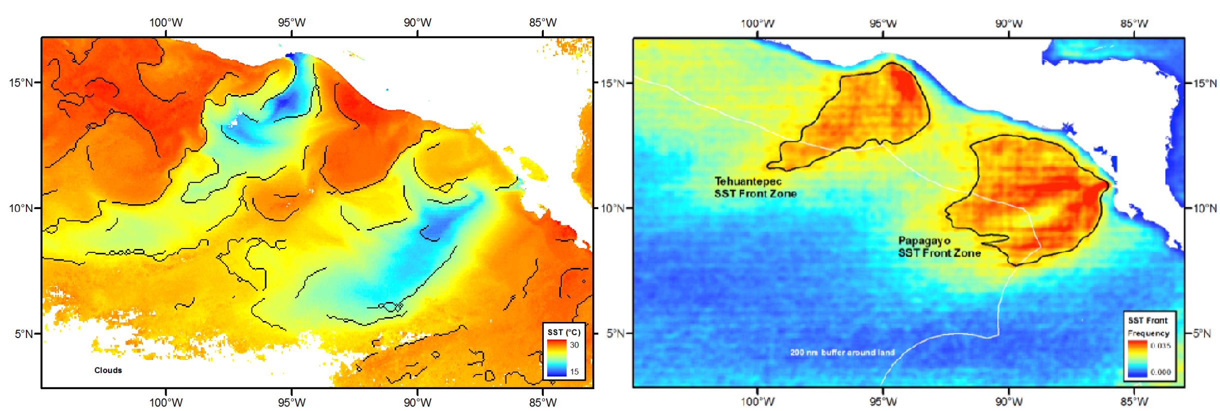
Benthic export productivity

In most areas of open-ocean waters and deep-sea habitats, the benthos (seafloor ecosystem) relies upon the rain of organic matter from the upper layers of the water column. This export of productivity is not easy to measure, and often surface production, calculated from satellite data (see above) is used as a starting point for estimating how much food material is delivered to the seafloor in various regions of the ocean. The major problem with these kinds of estimates is that it is difficult to determine what fraction of surface production actually reaches the seafloor. Yool et al. (2007, 2009) have developed a model to estimate the amount of organic carbon that, on average, is likely to be exported from the surface, and so will be available as food to organisms on the seafloor. This model provides a useful starting point for quantifying the export of organic matter in different parts of the deep ocean. Clark et al. (2010) used this measure as part of their global classification of seamounts.[3]

Example of methods

There are several methods available to identify areas of high primary productivity. One basic method is to simply visually estimate the boundary of the high productivity area based on a map of mean annual primary production using a geographic information system (GIS). This method is easy to implement and to interpret. An alternative is to use a GIS to identify areas that exceed a specified threshold value based on ecological considerations. Another is to review the scientific literature and look for definitions of oceanographic features that correspond to regions of high productivity.

The identification of physical phenomenon that aggregate productivity is more complicated. One option is to create a map showing the long-term mean frequency of SST fronts, generating "climatologies" (i.e., averages of oceanographic data over a specified period of time). For example, figure 35 depicts a map of comprising 15,340 SST images generated between 1985 and 2005 (two per day). For each image, Cayula and Cornillon's single-image edge detection (SIED) algorithm (Cayula and Cornillon 1992) was used to identify fronts in the image using the implementation of this algorithm, available in Marine Geospatial Ecology Tools (MGET; Roberts et al., 2010). Finally, the mean frequency of fronts for each cell was estimated by dividing the number of times that it contained a front in the 15,340 images by the number of times that the algorithm could be executed.



[3] In that seamount classification system, the following classes of export productivity were used: "Low"(<1 mol m^{-2} d-^{1}), "Medium" (1 to <5 mol m^{-2} d^{-1}), and "High" (≥5 mol m^{-2} d^{-1})

Figure 35a & b: (a) Surface temperature fronts (black lines) identified by Cayula and Cornillon's SIED algorithm in the NOAA NESDIS GOES L3 6 km Near Real-Time SST image for 5 January 2009; and (b) the mean frequency of sea surface temperature (SST) fronts off the Pacific coast of Central America, 1985-2005, detected by applying Cayula and Cornillon's SIED algorithm to 15,340 twice-daily SST images from the NOAA NODC 4 km AVHRR Pathfinder 5.0 database. Pixels show the 5x5 cell focal mean of SST front frequency. Black outlines show the smoothed 0.025 frequency contours that enclose two zones of high frontal frequency
Source: adapted from Roberts 2009.

Although there are alternative algorithms for identifying SST fronts, the SIED algorithm provides several advantages. It was shown to be as good at finding large fronts, such as the Gulf Stream northern boundary, as the simplest alternative, manual classification, by which a trained GIS operator draws the fronts on the image by hand. It was shown to be better than or comparable to several other simple automated methods (Cayula and Cornillon 1992; Ullman and Cornillon 2000). It has been validated against fronts identified at sea with oceanographic instruments**Error! Bookmark not defined.**. Finally, although alternatives and improvements have been suggested (see Belkin and O'Reilly, in press, for a review), SIED is the only freely-available, GIS-integrated algorithm.

Dynamic regions of the ocean can also be identified by looking for other types of physical features in other types of satellite data. Using data from satellites that measure the height and roughness of the ocean surface with radar, oceanographers are able to estimate the velocity and direction of surface waters and the winds immediately above the surface. From this, major currents and features such as eddies can be identified. MGET includes a tool for identifying eddies using the Okubo-Weiss algorithm, which was used in a recent global census of eddies (Chelton et al., 2007).

Upwellings occur when winds or currents draw cold, nutrient-rich water from the depths to the ocean surface. These influxes of nutrients into the sun-lit surface layer produce large phytoplankton blooms, which often lead to high productivity of fish and other animals. Scientists have developed methods for identifying upwellings in satellite images of SST and chlorophyll concentration (e.g., work done at the Observatorio Oceanográfico Digital de Venezuela, http://ood.cbm.usb.ve/wiki/, by E. Klein and J.C. Castillo. See also Klein and Castillo 2009).

Tools available

- Marine Geospatial Ecology Toolshttp://code.env.duke.edu/projects/mget

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. Why do we measure primary productivity?

2. What are some oceanographic features associated with productivity?

3. What is benthic export productivity, and what part of the ocean ecosystem relies on it?

References

Behrenfeld, M.J. and P.G. Falkowski. 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration. *Limnology and Oceanography* 42: 1-20. Data available online: http://www.science.oregonstate.edu/ocean.productivity/

Behrenfeld, M.J., R.T. O'Malley, D.A. Siegel, C.R. McClain, J.L. Sarmiento, G.C. Feldman, A.J. Milligan, P.G. Falkowski, R.M. Letelier and E.S. Boss. 2006. Climate-driven trends in contemporary ocean productivity. *Nature* 444: 752-755.

Behrenfeld, M.J., J.T. Randerson, C.R. McClain, G.C. Feldman, S.O. Los, C.J. Tucker, P.G. Falkowski, C.B. Field, R. Frouin, W.E. Esaias, D.D. Kolber and N.H. Pollack. 2001. Biospheric Primary Production During an ENSO Transition. *Science* 291: 2594-2597.

Belkin, I. 2002. New challenge: ocean fronts. *Journal of Marine Systems* 37: 1-2.

Belkin I.M. 2009. Observational studies of oceanic fronts. *Journal of Marine Systems* 78: 317-318.

Belkin I.M., Cornillon P.C. and Sherman K. 2009. Fronts in Large Marine Ecosystems. *Progress In Oceanography* 81: 223-236.

Belkin I.M. and O'Reilly J.E. 2009. An algorithm for oceanic front detection in chlorophyll and SST satellite imagery. *Journal of Marine Systems* 78: 319-326.

Casey, K.S. and R. Evans. 2009. Global AVHRR 4 km SST for 1985-2007, Pathfinder v5.0, NODC/RSMAS. NOAA National Oceanographic Data Center, Silver Spring, Maryland. Available online: http://pathfinder.nodc.noaa.gov/. Accessed June 2006.

Cayula, J.-F. and P. Cornillon. 1992. Edge Detection Algorithm for SST Images. *Journal of Atmospheric and Oceanic Technology* 9: 67-80.

Chai, F., R.C. Dugdale, T.-H. Peng, F.P. Wilkerson and R.T. Barber. 2002. One Dimensional Ecosystem Model of the Equatorial Pacific Upwelling System, Part I: Model Development and Silicon and Nitrogen Cycle. *Deep-Sea Research II* 49: 2713-2745.

Chelton, D.B., M.G. Schlax, R.M. Samelson and R.A. de Szoeke. 2007. Global observations of large oceanic eddies. *Geophysical Research Letters* 34 L15606.

Clark M.R., L. Watling, A.A. Rowden, J.M. Guinotte and C.R. Smith. 2010. A global seamount classification to aid the scientific design of marine protected area networks, *Ocean & Coastal Management*; doi:10.1016/j.ocecoaman.2010.10.006

Fielder, P.C. 2002. The annual cycle and biological effects of the Costa Rica Dome. *Deep-Sea Research I* 49: 321-338.

Klein E. and J.C. Castillo. 2009. Observatorio Oceanográfico Digital del Mar Venezolano. Laboratorio de Sensores Remotos, Centro de Biodiversidad Marina INTECMAR-USB. Available online: http://ood.cbm.usb.ve

Palacios, D.M., S.J. Bograd, D.G. Foley and F.B. Schwing. 2006. Oceanographic characteristics of biological hot spots in the North Pacific: A remote sensing perspective. *Deep-Sea Research II* 53: 250-269.

Pennington, J.T., K.L. Mahoney, V.S. Kuwahara, D.D. Kolber, R. Calienes and F.P. Chavez. 2006. Primary production in the eastern tropical Pacific: A review. *Progress in Oceanography* 69: 285-317.

Roberts, J.J. 2009. Sea Surface Temperature Fronts. *in* Ardron, J., D.C. Dunn, C. Corrigan, K. Gjerde, P.N. Halpin, J. Rice, E. Vanden Berghe, M. Vierros. Defining ecologically or biologically significant areas in the open oceans and deep seas: Analysis, tools, resources and illustrations. Report to 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.

Roberts, J.J., B.D. Best, D.C. Dunn, E.A. Treml and P.N. Halpin. 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software. Available online: http://mgel.env.duke.edu/tools

Ullman, D.S. and P.C. Cornillon. 2000. Evaluation of front detection methods for satellite-derived SST data using in situ observations. *Journal of Atmospheric and Oceanic Technology* 17: 1667-1675.

Willett, C.S., R.R. Leben, and M.F. Lavín. 2006. Eddies and Tropical Instability Waves in the eastern tropical Pacific: A review. *Progress in Oceanography* 69: 218-238.

Yool A., Martin A.P., Fernandez C. and Clark D.R. 2007. The significance of nitrification for oceanic new production. *Nature* 47:999e1002.

Yool A., Shepherd J.G., Bryden H.L. and Oschlies, A. 2009. Low efficiency of nutrient translocation for enhancing oceanic uptake of carbon dioxide. *Journal of Geophysical Research* 114(C08009). doi:10.1029/2008JC004792.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1(d) Sampling and data issues, including strategies for dealing with weak or incomplete data

(Parts of this module have been adapted from Alidina et al. 2008 and Ardron et al. 2009)

Learning objectives

In this section you will be introduced to issues related to sampling and data, including types of data, data storage and retrieval systems, data evaluation and preparation, and how to deal with incomplete data.

Our scientific knowledge of the ocean is limited by how much, and what kinds of, data we have managed to collect. 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. For these and other reasons, our knowledge of the oceans is uneven. Southern hemisphere oceans generally are more poorly sampled than northern hemisphere oceans, and low and high-latitude seas are generally more poorly sampled than mid-latitude seas. Furthermore, the sampling that 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.

1. The need for 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. Parties to the CBD have been asked to apply these criteria and evaluate areas to determine their ecological or biological significance. For this task, physical and biological oceanographic data, from both remotely sensed and in-situ sources, will form the base of the evaluation processes. In addition, data sources such as species occurrence surveys and satellite tracking data can be used to identify specific areas that may be of biological interest due to rarity of species or ecotype or because they are particularly important to one or more at risk species. Indices used to assess the importance of an area relative to the EBSA criteria all rely on such data (e.g., the calculation of Hurlbert's Index based on species occurrence data or range maps to describe the biological diversity criterion discussed earlier in this document).

2. Types of data

Many different types of data are needed to fully evaluate the ecological or biological significance of a marine area. The data may be on the presence and/or abundance of species, seabed and substrate features, physical and biological oceanography, may be observed directly or remotely sensed, and may be collected through systematic surveys or opportunistically. Two categories of data can be classified in the following way:

1. **Physical**: Physical data include both fixed topographical features (e.g., canyons, seamounts), and dynamic oceanographic attributes (e.g., temperature, salinity). Bathymetric data identify depth and can be processed to measure rugosity / topographic complexity, as well as 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), 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 (e.g., 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-digitized 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 an ongoing issue, and systems are currently being developed to help with the process of understanding where to find and how to use relevant data.

3. 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), and the 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 archives and other sources. The data stored in these warehouses are often less detailed than the original dataset. Warehouses need to focus on attributes commonly found across many datasets and are limited by the least detailed datasets, i.e., "the lowest common denominator". 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 (http://www.nodc.noaa.gov/General/NODC-dataexch/NODC-wdca.html), which areindispensable for much oceanographic work. The Global Biodiversity Information Facility (GBIF) and the Ocean Biogeographic Information System (OBIS) contain compiled 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 accessed directly. If not available in an archive or warehouse, a specific data request to the data originator is required, which can be time-consuming, and is not always successful. Data warehouses are compilations. 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 allows for stronger and broader-scale patterns to be observed. For more detailed analysis, 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., to 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.

As part of the process of evaluating EBSAs, 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.

4. Data evaluation and preparation

There are a number of important issues regarding the use and interpretation of data and models that must be addressed in preparation for any data analysis. There is a common phrase that is frequently used when data are being analyzed: "Garbage in, garbage out". The utility and validity of any analysis is fundamentally related to the accuracy and appropriate use of data. If an analysis is based on poorly collected data or if the data are insufficiently understood, the results will be highly suspect. Data might be deemed to be poor for one of two reasons: a) lack of quality or b) insufficient sample size (i.e., not enough data). A variety of methods exist to deal with both issues of data quality and quantity, but the data being used must be assessed before analyses begin to understand their limitations. Alidina et al. (2008) offer a checklist (Table 4) for assessing data, which should be followed when analyzing any dataset for potential use in an analysis. The authors suggest that the information requested in the checklist is frequently part of the metadata associated with any dataset and that it is advisable "to consult with data owners, thematic experts and others such as statisticians on any of these items." Finally, we must consider how to incorporate data from multiple sources which are bound to have inconsistencies. The most important factor when incorporating multiple datasets is to document all the work done to integrate the data so that the analysis is transparent and repeatable. Transparency is supported by a firm foundation of meticulous data management. Common formats and standards should be followed to ensure ease of repeatability and use by other practitioners.
Table 4: Checklist for Assessing Data

ITEMS TO CHECK	THINGS TO LOOK OUTFOR	IMPLICATIONS
Data Origin Source Compilation	Are the data from a first hand source (raw data), or are they a secondary compilation or value-added product, from several other sources? If they came from different sources were the sampling methods comparable and have the data been standardised?	Inconsistencies mean data may not be comparable, may require standardisation, or error correction
Reason for Data Collection Sampling Strategy Spatial and Temporal Coverage	Understand the reason and purpose data were collected for, and the method of data collection. What was the sampling protocol? Was there adequate and consistent sampling across space and time? Has data collection been biased toward one area, time period or by the collector? How comprehensive are the data relative to the project area? Are they representative, e.g., a random sample? If there was differential sampling effort then the data should be corrected for effort and should be reported per unit of effort.	Data collected for different purposes might not be appropriate for your specific analysis There may be Spatial or Temporal biases in the data such as survey effort and sampling protocol
Data Representation Data Classification Data Generalisation	How are the data reported and spatially represented? Are they in the form of continuous data or have they been generalised or grouped into classes or categories. What is the variability in the data reported (are there error bars associated with them)? How were the classes derived, and what is the classification accuracy? Is the way the data are represented appropriate for the purpose you require?	Data may require reclassification, normalisation or other treatment
Spatial Resolution Spatial Scale and Accuracy	How are the data represented spatially? Are they vector or raster features? At what scale (resolution and extent) were the features observed or compiled? What is the spatial resolution and accuracy for the features being represented? Are they comparable with the scale for the analysis?	Data may or may not be at a coarser or finer scale than that of the analysis
Data Currency	How current are the data? If they are dated by several years are they expected to offer an adequate representation of reality at current time? Is the feature being represented change rapidly or it is relatively stable? Are long-term means provided and with a metric of variability, e.g., standard variation, min-max?	Dated data for specific times and seasons may or may not be appropriate for present distributions.

Source: Alidina et al. 2008

5. Strategies for dealing with weak or incomplete data

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 use of proxy datasets or predictive modeling is a necessary step.

Predictive modeling

See also: kernel density and predictive habitat 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) that 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). 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 in addition to the predicted likely value. More about the topic of uncertainty is available in section 2(e).

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 seabed (GOODS; http://unesdoc.unesco.org/Ulis/cgi-bin/ulis.pl?catno=182451&set=4A462B44_3_6&gp=1&lin=1&ll=1) 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 or rarity criterion), 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 (see also section b, module 2 on expert knowledge)

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 use the results of the expert evaluations and design management measures to protect EBSAs, certain types of evaluations may prove useful in supporting policy and management actions. To ensure these lessons are made widely and rapidly available to improve the overall selection and management of EBSAs, there is great value in the submission of these experiences to the central repository of EBSA-related actions, including documentation of both expert advisory processes (from inputs to results), and management actions arising from the results of the expert processes.

6. 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 fish landing statistics 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 available under Habitat Suitability Modelling, in section (c) of this module.

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, 1 All available from AVISO at (http://www.aviso.oceanobs.com/en/data/products/sea-surface-heightproducts/ 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 for centuries. The progress in databases and communications via Internet has prompted many museums to digitize specimen data and make this information available through the World Wide Web (e.g., Smithsonian, California Academy of Sciences, some European examples, Australia). Both GBIF and OBIS were built according to standards 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 that 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 organizations 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 hold useful information based on direct observations of species occurrences from their transport systems during business operations.

7. Accounting for Observation Effort
(adapted from Alidina et al. 2008, box 7.1)

It is important to distinguish between presence/absence data and presence only data (these are data that usually consist of opportunistic presence records and which lack "confirmed absence"). A feature is considered absent from a particular area because it was sampled for and not found, and not because no sampling occurred there. These are crucial distinctions. One should emphasize here that all of the data above are virtually a function of search effort. Ideally, such data should be corrected for equal search effort in space and time.

Data biases are often created where one area is more closely observed and sampled than another. Datasets that show species abundances may be misleading if they do not account for the time or effort spent observing the data. If used in an analysis the results may be skewed and will raise questions on the reliability of the analysis.

Table 5:

Observations corrected for sampling effort (→ Average number of YRWA/visit)

	Number of times site visited/sampled	Number of YRWA observed	Average number of YRWA/visit
SITE A	10	45	4.5
SITE B	5	35	7

Source: xx

Consider a simple example of two sites that are each sampled a number of times each season. One of the sites (site A) is more accessible (e.g., near a road and in flat terrain) and thus more frequented by researchers than the other site (site B). Each time a site is visited a standard observation protocol (a 30 min transect walk) is employed and the number of birds per species observed are recorded. The observations for one species of seabird (YRWA) are summarised in the table above, with and without correction for sampling effort.

Although site A has a greater number of YRWA observations recorded, when both are considered with a correction for sampling effort, site B yields a greater density of YRWA. These results are not only found for the abundance but also for the spatial patterns of occurrences. For instance, a very rare bird can be found at a given site after 20 observers search intensely for 10 hours, whereas another site can be mislabeled "absence" after 10 minutes of fruitless searching by just one observer. Although a simple example, interpreting the data without a correction of effort would have been misleading and led to site-selection biases. Many spatial datasets suffer from lack of information on the underlying search effort, and if this detail is not provided in the metadata, enquiries should be made.

8. Spatial and temporal variability

It is 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 summer may present very different patterns of area utilization than tracking data from those same animals tracked in the winter (see the example used in the section on Kernel Density Estimation). 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 section (a) of this module, as well as the GOBI EBSA illustrations (available at www.gobi.org). Similarly, it is necessary to consider variability and trends induced by climate change and other global processes. These can affect oceanographic processes and thereby species ranges, migration patterns, and resource availability into the future.

9. 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, or detectability of an animal in survey data). 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.

Uncertainty contributes to two types of possible errors in evaluating data relative to the EBSA criteria; false negatives ("misses")—when it is erroneously concluded that an area does not meet a criterion when in reality it does; and, false positives ("false alarms") 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 ground-truthing, this can lead to the selection 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 false negatives. Thus, failure to find evidence of an EBSA in incomplete datasets should not be taken as strong evidence that the area has no special requirements for conservation.

10. Further information

For further information we recommend the two sources from which this text was adapted: Alidina et al. (2008) and Ardron et al. (2009).

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. What are some examples of the two main categories of data described in this module?
2. What are the main differences between the three examples of data storage and retrieval systems given in this module?
3. What are some issues that you need to consider when evaluating data? Why is data evaluation important?
4. What are some strategies for dealing with weak or incomplete data?

References

Alidina, H.M., D.T. Fischer, C. Steinback, Z. Ferdana, A.V. Lombana and F. Heuttmann (2008) Assessing and Managing Data *in* Ardron, J.A., Possingham, H.P., and Klein, C.J. (eds). *Marxan Good Practices Handbook*, *Version 2*. (2010.). Pacific Marine Analysis and Research Association, Victoria, BC, Canada. www.pacmara.org.

Ardron, J., D.C. Dunn, C. Corrigan, K. Gjerde, P.N. Halpin, J. Rice, E. Vanden Berghe and M. Vierros. 2009. Defining ecologically or biologically significant areas in the open oceans and deep seas: Analysis, tools, resources and illustrations. Report to 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.

1(e) Considerations when using multiple EBSA criteria

Learning objectives

In this section you will learn about some of the considerations when making decisions based on more than one EBSA criterion, and how sets of EBSAs (i.e., more than singular sites) can help alleviate many of the difficult issues.

1. Introduction

Previous sections, when discussing how to identify potential EBSAs, have mostly focussed on a single criterion. In practice, it will be necessary to assemble information on areas that meet multiple EBSA criteria, and consider how to identify the best EBSA sites amongst them. Typically, this will involve evaluations at both the site and network level: a) how sites compare with each other; and b) how well a given site advances the overall objectives of a given region, which likely includes a network of other EBSAs, some perhaps protected, and others not.

This section discusses some of the things to keep in mind when trying to select sites that satisfy many criteria. While this learning manual is focussed on EBSAs, the principles are general and can be applied to any sets of criteria, including things like economics, community values, practicality, and so forth. It may come as a surprise to some readers that this is not an easy thing to do, and that a whole academic literature has grown up around *multiple criteria decision-making* (MCDM; also known as *multiple criteria analysis*, and other variants). Unfortunately, the more one studies this topic, the more one begins to see that there are no easy or right answers, which means that there may be more than one suitable solution to match to stakeholder needs. Much depends on local ecological circumstances, the context of other decisions, and planning objectives. That said, there are still many ways to go wrong!

2. Why do we need MCDM to describe EBSAs?

The definitions of EBSAs are justifiably broad. However, in a region where relatively little is known, many areas can potentially meet one, many or all of the CBD criteria that define an EBSA. There is a need to assess individual nominations for candidate EBSAs against the full suite of CBD criteria and balance individual nominations across the full set of nominated or existing candidate EBSAs in the region. Categorizing, prioritizing and recommending EBSAs is a complex process that requires an approach that can be justified at an international level. The suite of decision-making tools and experience available through MCDM can greatly assist in this process. Towards the end of this module, we consider some ways to do this.

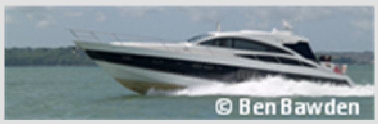
Box 4: Some boats are hard to build...

Multiple criteria problems are not just limited to EBSAs or protected areas. Imagine you want to buy a boat that is:

- fairly fast (>10 knots, say)
- fairly comfortable (allowing weekend trips, sleeping on board overnight)
- fairly economical (both to buy and to operate)

Even though the request sounds reasonable (you carefully used the word "fairly" to show just how reasonable and flexible you are), boat sales people just shake their heads sadly. "No such boat exists," they tell you. Instead, they show you the following:

You can have fast and comfortable, but not economical;



You can have fast and economical, but not very comfortable;

Or, you can have comfortable and economical, but not fast.

The moral of this story is: *some multiple criteria problems are very hard to solve, and compromises, if they exist, will make everyone unhappy*. In such situations, it is better for parties to reconsider the criteria one by one for a given place. If the criteria are truly irreconcilable, it is a better compromise to focus on some criteria in one place and the other criteria in another, and design a network of complementary EBSAs.

3. Common approaches and why they don't work very well

First, let's take a look at some of the common ideas that first come to mind and their limitations. The next three approaches are sometimes found in planning exercises;

however, for reasons that we outline below, *they are not recommended*. We use them to illustrate why sorting through differing criteria, “apples, oranges and monkeys,” is harder than it first appears.

Ranking

It might seem like a good idea to rank order the EBSA criteria. Having been distilled from a wide variety of existing criteria systems, the CBD EBSA criteria have some, but not a lot, of overlap. In other words, they are largely independent of one another—statistically orthogonal. They are not ranked, and their order in CBD documents has no meaning whatsoever, but imagine this was a ranking:

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

In this fictitious example, we would describe all EBSAs first for uniqueness/rarity, then for life history importance, and so on. The problem with this approach is that:

- **Ranking assumes some ecological characteristics are more important**. However, most ecologists are very uncomfortable with this assumption and prefer to point out that ecosystems rely on a suite of characteristics. Just as a mechanical watch relies on an assembly of various moving parts, it is hard to argue that gears are more important to keeping time than springs.
- **Ranking assumes that all places can be compared.** Assuming fruit is a personal preference, how can we say an apple is more important than an orange? Actually, different ecological characteristics will come to the fore in different places. In some places biodiversity could be a defining characteristic, and it would make no sense to put rarity above that; whereas in others, it could be something else.
- **Ranking assumes categorical yes/no answers** (it is rare or is not), but cannot account for the shades of grey. For example, would the habitat of a somewhat rare species take priority over a place characterised by very high productivity? (You may think the answer to this problem is setting up a scoring system, but that approach is covered in the next example, below.)
- **Ranking assumes that the rank will remain fixed, no matter how many other areas get protected**. Even if a ranking system could be developed that took all the above concerns into account, it would still assume protecting rarity, say, was more important than biodiversity, even if 100 places had been protected for rarity and none for biodiversity. This is a problem shared with other common approaches, like scoring, below.

Scoring

In the latter half of the twentieth century, if a systematic approach to conservation site selection was taken (and oftennone was!), probably the most common approach was to use some sort of scoring system. Imagine that for each of the EBSA criteria, a score of 0-5 could be assigned, where 0 is none, 1 is very low and 5 is very high. Adding these scores certainly sounds like a reasonable idea... however, it does not actually help select good EBSA sites, for several reasons:

- **Fallacy of addition**: Many “1” scores for various features can add to a single high score. Hence a place with a score of five 1s (remember, 1 means very low) is now considered as important as a place that has a single score of 5 (very high). But we know that protecting many weak features is not as useful as protecting one excellent example.
- **Unclear**: There is no indication what a high score means, i.e., which EBSA criteria are being captured. EBSA criteria are not evenly distributed over space, and it is very likely that using a scoring system would lead to protecting many examples of some criteria, but none of others.
- **Unsystematic**: Since we cannot say from the scores alone what criteria are being considered, getting a comprehensive set of sites that cover all criteria becomes trial and error. After picking the first site, based on a high score, for every selection after that, each individual higher-scoring site needs to be examined to see if it fills in a remaining criteria gap or not. After a few selections, soon the user is simply trying to find a site that fulfills some criterion or other, and the scoring system is no longer being used anyway!
- **Inefficient**: collecting only high scores can lead to spatially inefficient solutions in the end. Most times, a collection of good sites will take up less space (and cost) than selecting the highest scores and then trying to fill in gaps. This is why site selection tools, such as:
    - Marxan http://www.uq.edu.au/marxan/ or
    - Zonation http://www.helsinki.fi/bioscience/consplan/software/Zonation/index.html or
    - others http://www.uq.edu.au/ecology/index.html?page=101951 ; http://www.consnet.org/

  address network-level solutions, producing several efficient options.
- **Uncertainty**: it is difficult to include uncertainty in a simple scoring system, but in the ocean and especially in areas beyond national jurisdiction, where our knowledge is limited, what we don’t know may be as important as what we think we do.

Overlay mapping

Prior to the advent of geographic information systems (GIS) data and software, planners would sometimes use clear plastic sheets overlaid on maps to draw important features for conservation. These clear plastic pages could be piled on top of one another to find the spot where they most often overlapped. This was slow, tedious work, and GIS was seen as a great way to speed this up. However, as more and more GIS layers were overlaid, seldom was much thought given as to why overlapping the many different features was thought to be important. While some areas of overlap can indeed represent good choices, many will not. Consider figure 36, in which the ovals represent different EBSA criteria being mapped. The arrow shows the area of highest overlap. Is this the most valuable EBSA? Probably not, for the reasons provided below.

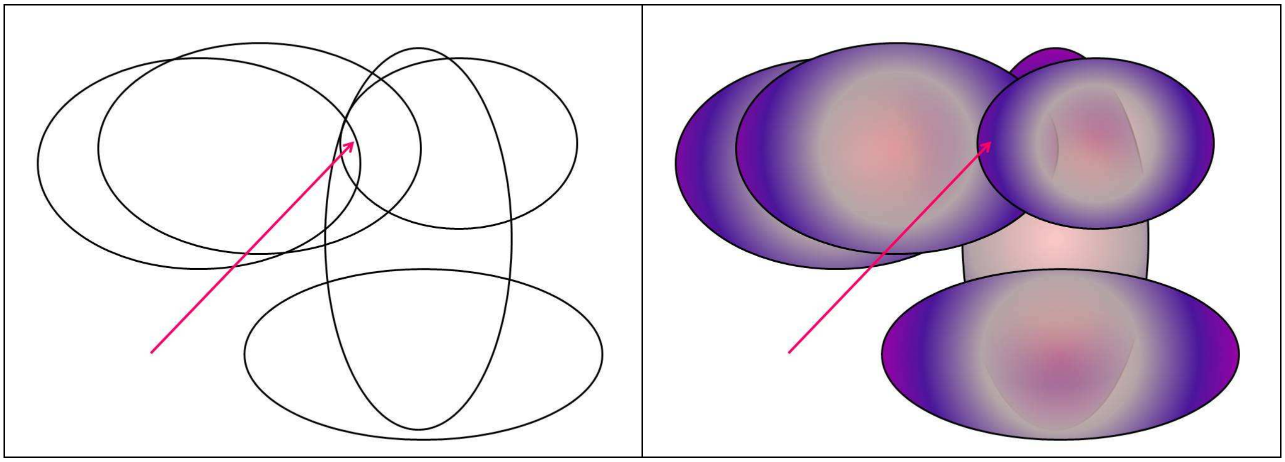


Figure 36: a) overlapping mapped conservation features within an imaginary study area, where the ovals represent five different possible EBSA criteria; b) the same criteria considered with regard to spatial uncertainty, whereby the lighter areas in the middle are more certain and the darker areas towards the edges represent greater uncertainty. The arrow shows the area of highest overlap, hence greatest uncertainty.
Source:

Issues with using overlapping GIS layers to identify high value areas:

- **Overlaps miss core areas**. It is the nature of overlaps that core areas can often be excluded, as illustrated in figures 36a and 36b. This situation gets worse as more and more layers are added. Presumably it is the core areas that are of greater interest than their fringes, as these areas are likely to be the key habitat, the source of young and larvae propagules to fringe areas, and are more resistant to future environmental change.
- **Edges represent areas of greater uncertainty**. This is related to the problem above and is a reflection of the fact that most ecological lines on maps are somewhat arbitrary, in that there is some spatial uncertainty about where the ecological feature exactly begins or ends. There are good and poor mapping practices to deal with this issue, but the fact remains that the lines on maps are less certain than the cores within them and may include transition zones between core areas. In figure 36b, the dark purple areas represent those of greater uncertainty. As can be seen, this is exactly where the overlap method would suggest protection! However, it is unlikely that, once this is understood, either stakeholders or decision-makers would support protecting a place where it is very uncertain that the values actually exist.
- **Overlaps are usually small and fragmented. U**sually overlaps are too small and incomplete to viably support the species or habitat(s) in question. Unless you are in the lucky situation where everything overlaps everything else exactly (in which case you don’t need GIS!), all overlaps will be smaller than the given distributions of the species and habitats being mapped. The more features that are mapped, the

smaller and more fragmented the overlaps will be. It is generally accepted that small fragmented places are not good candidates for protection (unless the thing they represent cannot be found anywhere else).

- **Overlaps may not always be meaningful**. Is overlapping the range of a seabird with a fish ecologically meaningful? Probably not, unless the seabird happens to be likely to eat that fish. It makes more sense to examine overlaps of similar guilds of species. Some overlaps might be worse than meaningless; they could even be bad. In highly biodiverse places, for example, rare species might be under greater competition for habitat and food, and/or greater threat of being eaten.

4. MCDM approaches

Having examined the weaknesses of some common approaches, we now turn our attention to a selection of more promising approaches.

Site selection / optimization tools

Sorting through more than five or six GIS layers quickly gets complicated and beyond the realm of intuition. Provided the data are available, planning tools like Marxan, C-Plan, and others can help (see section e, module 1, *Planning tools*). However, all of the caveats around data (above) still apply. In many regions where quantitative data are scarce, Marxan-like tools are inappropriate and if used will favour the few areas with quantitative data (including “arbitrary” lines on maps). In these data-scarce situations it is better to use discussions with locals and other experts, as well as ecologists and biologists, to sort through multiple criteria problems. It is our opinion that well-facilitated discussions can do a better job of sorting through multiple criteria than either simplistic systems (like scoring) or poorly run software tools. However, when the data and technical know-how are available, these tools are very powerful and are recommended as part of the preferred approach to dealing with multiple criteria. There is still a need for experts and stakeholders to check results and discuss options, especially as there will be practical considerations that cannot be included in these software tools. An effective way to use these tools (as followed in rezoning the Great Barrier Reef) is to set initial expectations concerning the possible size and extent of network solutions, and subsequently to use the tools to check revisions to network designs, as proposed by stakeholders and experts, against the agreed targets and objectives.

Use explicit methods for prioritisation

Even if tools like Marxan or ConsNet (http://www.consnet.org/) are used, there is often a need to prioritize further, to narrow down the available network options, and/or to prioritise or schedule site-by-site actions. Post-analysis software tools for this also exist (e.g., MultCSync; http://uts.cc.utexas.edu/~consbio/Cons/ResNet.html). However, for simple problems, these tools may not be worth the necessary effort of setting up data and files, etc. As with any software tool, multi-criteria tools have underlying assumptions that can be hard to see.

If prioritization is required, users must be clear about how they are going to prioritize sites, whether using software tools or not.

For example, they could be scored according to vulnerability (threat of damage / loss) and irreplaceability (if there are other sites like it in the region). The same concerns expressed above about scoring still apply; however, for some considerations ("dimensions"), this is usually acceptable. That said, unlike common practice, scores of independent measures *should not be added together*. Rather, they should be treated as "orthogonal", like in a right-angled triangle, whereby the total value (the hypotenuse) is the square-root of the sum of their squares (i.e., the Euclidian distance). Indeed, authors sometimes plot such dimensions as x and y axes on a graph, but then, paradoxically, add them together as though they were not at right angles to one another.

If measures are similar to one another (i.e. not orthogonal), their average value (arithmetic mean) can first be calculated to create one aggregated orthogonal measure. For example, human coastal population, shipping traffic volume, invasive species, and pollution are all anthropogenic-related threats with spatial similarity and overlap (correlation), and could probably be averaged in many cases to come up with a single threat layer to be used in a prioritization exercise.

For the example above, the math would be: protection priority = $(v^2 + i^2)^{0.5}$ where v and i are standardised measures of vulnerability and irreplaceability, respectively. Though they may be initially derived using different scales, the range of the v and i values should be the same (e.g., 0-5), assuming equal weighting. Although sometimes it is possible to come up with more detailed and accurate assessments, be careful to not misuse large ranges, as these can overstate the accuracy of the underlying data. In many cases, simpler is better! Uncertainty is cruel to false accuracy, and so it is better to be approximately right than exactly wrong.

Vulnerability: a mix of threat and resilience

In a traditional risk assessment, two components are multiplied together: 1) the damage that could occur if the event occurred, and 2) the likelihood that it will occur. Translating these terms into an ecosystem approach, the damage is determined by considering the affected habitats and organisms within an ecosystem and their resilience to the activity in question. Considerations can include structural fragility, as well as life history characteristics that reflect low resilience (e.g., low reproductively). Threat can be composed of the intensity of the occurrence multiplied by the likelihood of its occurrence. For example, some places are currently too deep to fish, and so the likelihood of the occurrence is currently low. Such models can become very sophisticated, taking into account uncertainty, lack of data, and plausible worst case scenarios (see, for example, Smith et al. 2007).

5. How this might fit into a larger process

Figure 37 indicates one possibility of how multi-criteria considerations could fit within an EBSA description process. This is not meant to be prescriptive, but rather an illustration to help visualise some of the possible considerations.

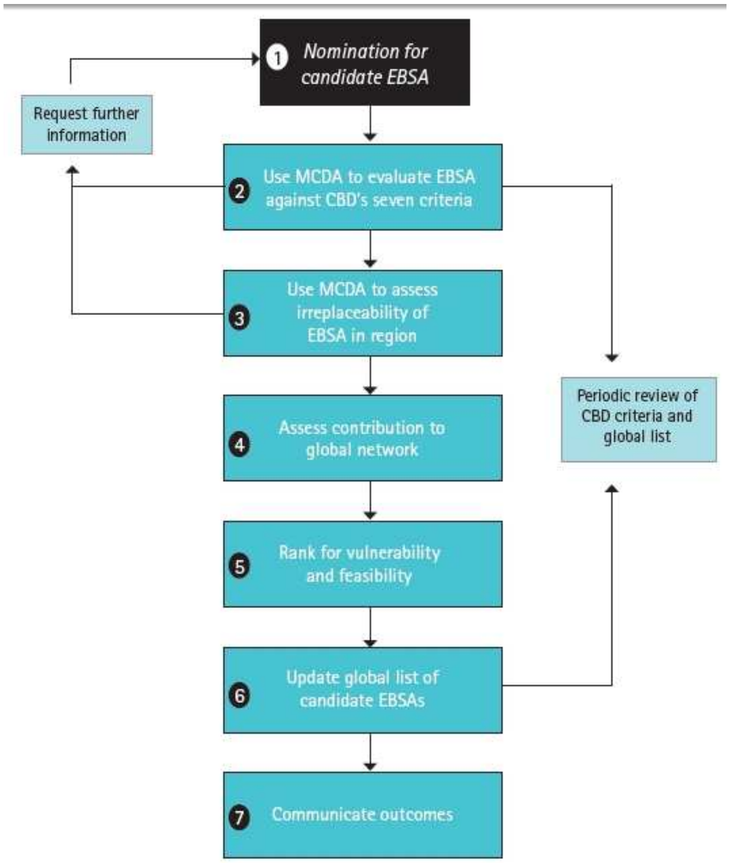


Figure 37: An example of possible steps in a multi-criteria EBSA description process (courtesy the Global Ocean Biodiversity Initiative (GOBI.org)). In the case of a regional process, steps 4 and 6 would be regional, rather than global.
Source:

6. Good practices in preparing for a MCDM process

This section is intended to provide an overview of some good practices in preparing for MCDM analyses and processes.

Map areas that are already recognized for their outstanding ecological values

Not all areas are alike, and the exceptional places are almost always already known. Within these ecologically exceptional places many EBSA criteria will often be fully or partially met. Usually these areas of multiple EBSA criteria are also well-studied, and hence scientific data exist to reinforce their selection. However, even when the scientific data are lacking, such places should still be given serious consideration, based on local expert knowledge.

Focus information gathering on features that are of central relevance to ecosystems in that region

Note that we are not suggesting that all species or habitats be mapped, or that even all EBSAs be listed! That would not only be an impossible task, but it would take more time and money than we can afford while the EBSAs suffer. In this recommended initial accounting, we suggest narrowing the search to key ecological features (species and habitats mostly, but also ecological functions) that best define a given region. Once that is done, attributes that would provide information on EBSAs related to those core features can be collected and mapped. As noted above (section b in this module, *The role of expert opinion*), local expert knowledge should be considered as well as scientific knowledge, and the same standards should apply, whereby local knowledge is attributed and collected in a defensible and consistent manner. Often it is the locals who have a more holistic view of their local ecosystems and can better identify key elements, rather than the biologists who are often focussed only on their particular species of interest. In this way, we know that the multiple EBSAs produced reflect areas central to that region. They are all likely to be important, and sorting through them becomes more an exercise of prioritization and their regional contribution (discussed below), than valuation.

Map EBSA criteria information as separate layers, not merged together

For many of the same reasons given under the discussion on scoring, above, merging GIS layers of different features results in a loss of information. In some cases this is justified, but in many cases it is not, and it becomes very difficult to see what is being protected and what is not. For example, if all of the species that met the “uniqueness or rarity” criterion were mapped into one big layer, it would be impossible to know whether more than just one or two species would be protected if 50% of that layer were protected,. Imagine if a “rare” layer were then mapped with a “biodiversity” layer—it would be very difficult indeed to understand what was going on. It is better to keep ecological values mapped separately and to allow software tools to sort through them later (as discussed above).

Group like together, but keep unlike features apart

Pay attention to when different pieces of information related to more than one EBSA criterion should be considered together or not. In general, if it is simply “fruit” you are after, then EBSAs for apples and oranges can be mapped together, but not monkeys. Each case is unique, but always ask yourself the same questions: by combining the information, what is gained? What is lost? If more is lost than gained, keep them apart. So in our simplistic example, adding the monkey layer allows us to map all living things, but now we can’t tell the difference between animals and fruits. It is important to document these decisions and the associated data, so that future planning work can consider and build on earlier results.

Map spatial uncertainty, if possible

While it is very difficult to take all uncertainties into account, it is not so difficult to note some of the more readily available factors, such as sampling density and statistical variance. This can be especially relevant if input layers were stitched together from various disparate datasets. Although an absolute value is difficult to determine, 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. (For example, a 1-5 rating system was developed to assess the reliability of fish identifications gathered from historical surveys and other data in Western Australian waters over the continental slope (Williams et al. 1996.) Such a layer indicates the varying quality and scale of the information. Ideally, uncertainty should be reflected in the approach to decision-making from place to place, with some areas having larger buffers (precaution) against uncertainty than others, wherethings are more certain.

Areas that may have appeared to have been important but that have low confidence scores will perhaps not appear as attractive to planners as areas with moderate importance; but higher confidence scores; i.e., when given the opportunity, many managers would prefer to base their decisions on well known factors than uncertain ones. Thus, an estimated confidence layer allows for better informed decisions and is a valuable strategy to deal with maps and data of varying scales. In light of this, it is perhaps surprising that confidence layers are seldom generated and thus the GIS techniques to generate them are still evolving.

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. Describe why scoring systems are not very effective when sorting out many sites with more than one EBSA criterion.
2. Describe how sets of sites can work together to be 'greater than the sum of their parts.'

References

Smith, ADM, E. J. Fulton, A. J. Hobday, D. C. Smith, and P. Shoulder. 2007. Scientific tools to support the practical implementation of ecosystem-based fisheries management. *ICES Journal of Marine Science*, 64: 633–639.

Williams A., P. R. Last, M. F. Gomon, and J. R. Paxton. 1996. Species composition and checklist of the demersal ichthyofauna of the continental slope off Western Australia (20-35^{0}S). *Records of the Western Australian Museum* 18: 135-155.

Further reading

Evans, S.J.M., Jamieson, G., Ardron, J., Patterson, M. and Jessen, S. 2004. Evaluation of site selection methodologies for use in marine protected area network design. Canadian Science Advisory Secretariat Research Document.

Margules, C.R. and R.L.Pressey. 2000. Systematic conservation planning. *Nature* 405: 243-253.

Margules, C. and S. Sarkar. 2007. *Systematic Conservation Planning* (Ecology, Biodiversity and Conservation). Cambridge University Press.

Moffett, A. and S. Sarkar. 2006. Incorporating multiple criteria into the design of conservation area networks: a minireview with recommendations. *Diversity and Distributions* 12: 125–137. DOI:10.1111/j.1366-9516.2005.00202.x.

Moilanen A, K. Willson, and H. Possignham (eds.) 2009. *Spatial Conservation Prioritization: Quantitative methods and computational tools*. Oxford University Press.

Sarkar, S., Pressey, R.L., Faith, D.P., et al. 2006. Biodiversity Conservation Planning Tools: Present Status and Challenges for the Future. *Annu. Rev. Environ. Resour.* 31: 123–59. DOI:10.1146/annurev.energy.31.042606.085844.

1(f) Systematic planning approach

Learning objectives

In this section you will learn about some of the key elements in taking a systematic planning approach.

As discussed in the previous section, multi-criteria problems can become very complex quite quickly. In order to fulfill multiple EBSA criteria for multiple species and habitats, a single-site solution is most often not possible. The solution appropriate for a given region will almost always involve *collections of sites*. This section will examine the steps that are typically required to arrive at solutions that contain such collections of candidate sites and how these sites can become *networks*.

Box 5: Scientific guidance for selecting areas to establish a representative network of marine protected areas (excerpted from CBD decision IX/20 annex 2)

Required network properties and components:

1. **EBSAs** (with seven site-level criteria): Ecologically and biologically significant areas are discrete areas that provide important services to one or more species/populations of an ecosystem or to the ecosystem as a whole, compared to other surrounding areas or areas of similar ecological characteristics.
2. **Representativity** is captured in a network when it consists of areas representing the different biogeographical subdivisions of a region that reasonably reflect the full range of ecosystems, including the biotic and habitat diversity of that region.
3. **Connectivity** in the design of a network allows for linkages whereby protected sites benefit from larval and/or species exchanges, and functional linkages from other network sites. In a connected network individual sites benefit one another.
4. **Replication** of ecological features* means that more than one site shall contain examples of a given feature in the given biogeographic area.
5. **Adequacy / viability**: all sites within a network should have size and protection sufficient to ensure the ecological viability and integrity of the feature(s)* for which they were selected.

**Features* means species, habitats and ecological processes that naturally occur in the given biogeographic area.

The decision of whether or not to protect EBSAs as MPAs,[4] or not, this decision will still involve multiple criteria at the site and network level. Fortunately, the guidance for identifying networks of MPAs also applies more generally to identifying collections of any sorts of sites requiring enhanced management and protection, such as EBSAs. It is all part of systematic conservation planning, which has a growing literature and community of practice. While details may vary, the following elements collectively define the characteristics of SCP:

- Structured step-wise approach
- Developing goals, objectives, targets
- Determining existing gaps
- Identifying (possible) conservation sites
- Selecting (possible) conservation networks /collections
- Refining decisions with feedback, revision, reiteration

Replacing the word "conservation", in the fourth and fifth element, above, with "EBSA" is justifiable in the context of CBD processes. Note that these two elements focus on the description of EBSAs, a task that should be seen as nested within a larger structured step-wise approach. Without clear goals, objectives and targets, information gathering and EBSA description is likely to be unfocussed and ad hoc, leading to confusion. Without refinement and feedback, decisions are likely to be poorly suited for the realities of maritime uses and the nuances of regional ecosystems. There are several recommended sets of planning steps, one of which was listed above (section a of module 1). Table 6 provides four examples. Note that they are all fairly similar and contain the above-listed elements of SCP. As a last step, many also include a monitoring and adaptive management component, which, while not part of planning per se, is certainly critical once sites and protection have been established.

A fuller analysis of SCP steps has been undertaken by the Pacific Marine Analysis and Research Association (PacMARA.org) in British Columbia, Canada (http://pacmara.org/wp-content/uploads/2011/02/MSP-Steps-Summary.pdf).

Table 6:

Four examples of steps used in systematic conservation planning

[4] MPAs are just one solution to managing EBSAs (section c of module 1); nonetheless, they are often an appropriate solution, particularly in places where capacity to implement other more management-intensive solutions is limited. MPAs form an important part of the CBD's programme of work on marine and coastal biodiversity.

1 Compile data on the biodiversity of the planning region 2. Identify conservation goals for the planning region 3. Review existing conservation areas 4. Select additional conservation areas 5. Implement conservation actions 6. Maintain the required values of conservation areas *(Margules & Pressey 2000)*	1. Identify stakeholders 2. Compile, assess, refine data (bio-physical, and S-E) 3. Identify biodiversity surrogates (indicators) 4. Establish conservation goals, objectives, targets 5. Review existing conservation network (gap analysis) 6. Prioritize new areas for possible conservation 7. Assess persistence 8. Refine the possible networks 9. Examine feasibility using multi-criteria analysis 10. Implement a conservation plan 11. Periodically reassess network *(Margules & Sarkar 2007)*
1. Identify and involve stakeholders 2. Identify goals and objectives 3. Compile data 4. Establish conservation targets and design principles 5. Review existing protected areas and identify network gaps 6. Select new protected areas 7. Implement conservation action 8. Maintain and monitor protected area network *(Possingham et al. 2008)*	1. Identify and involve stakeholders and others 2. Compile ecological and socio-economic data 3. Set network objectives for each bioregion 4. Set specific conservation targets and apply design principles 5. Review existing areas and existing proposed areas, and perform gap analysis 6. Identify jurisdictions to establish priority areas 7. Undertake site-specific planning and implementation 8. Manage and monitor the MPA network *(Canada 2010)*

The CBD does not advocate any one particular set of steps in a planning process. The key is simply to have such a set of steps agreed upon early in the process. The CBD has, however, provided some advice on the steps that can lead from describing EBSAs to achieving networks of protected places (see box 6). Scientific description of EBSAs should be complemented with network-level considerations, like representativity, in which a biogeographic classification system can be very helpful (see step 2, box 5). While a discussion of network design lies outside the scope of this manual, it is good to keep in mind that after an initial set of EBSAs is described, the work is not over! Spatial tools created for multicriteria analyses (discussed in section (e), above) come into their own in step 3.

Box 6: Four initial steps to be considered in the development of representative networks of marine protected areas (CBD decision IX/20, annex 3)

1. *Scientific identification of an initial set of ecologically or biologically significant areas.* The criteria in annex I to decision IX/20 should be used, considering the best scientific information available, and applying the precautionary approach. This identification should focus on developing an initial set of sites already recognized for their ecological values, with the understanding that other sites could be added as more information becomes available.

2. *Develop/choose a biogeographic, habitat, and/or community classification system.* This system should reflect the scale of the application and address the key ecological features within the area. This step will entail a separation of at least two realms – pelagic and benthic.

3. *Drawing upon steps 1 and 2 above, iteratively use qualitative and/or quantitative techniques to identify sites to include in a network.* Their selection for consideration of enhanced management should reflect their recognised ecological importance or vulnerability and address the requirements of ecological coherence through representativity, connectivity, and replication.

4. *Assess the adequacy and viability of the selected sites.* Consideration should be given to their size, shape, boundaries, buffering, and appropriateness of the site-management regime.

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. How is a systematic approach different from an ad hoc approach? What are some of the key elements of a systematic approach?

2. How do the CBD EBSA site criteria fit within the suggested CBD planning steps? When do network considerations come into play?

References

Canada. 2010 (draft). National Framework for Canada's Network of Marine Protected Areas. http://www.isdm-gdsi.gc.ca/oceans/publications/dmpaf-eczpm/docs/framework-cadre-eng.pdf

Margules, C.R. and R.L. Pressey. 2000. Systematic conservation planning. *Nature* 405, 243-253.

Margules, C.R. and Sarkar, S. 2007. *Systematic Conservation Planning*. New York: Cambridge University Press.

Possingham, H.P., J.L. Smith, K. Royle, D. Dorfman and T.G. Martin. 2008 / 2010. Introduction to: *Marxan Good Practices Handbook*, *Version 2*. J. A. Ardron, H. P. Possingham, and C. J. Klein (eds). Pacific Marine Analysis and Research Association, Victoria, BC, Canada. www.pacmara.org.

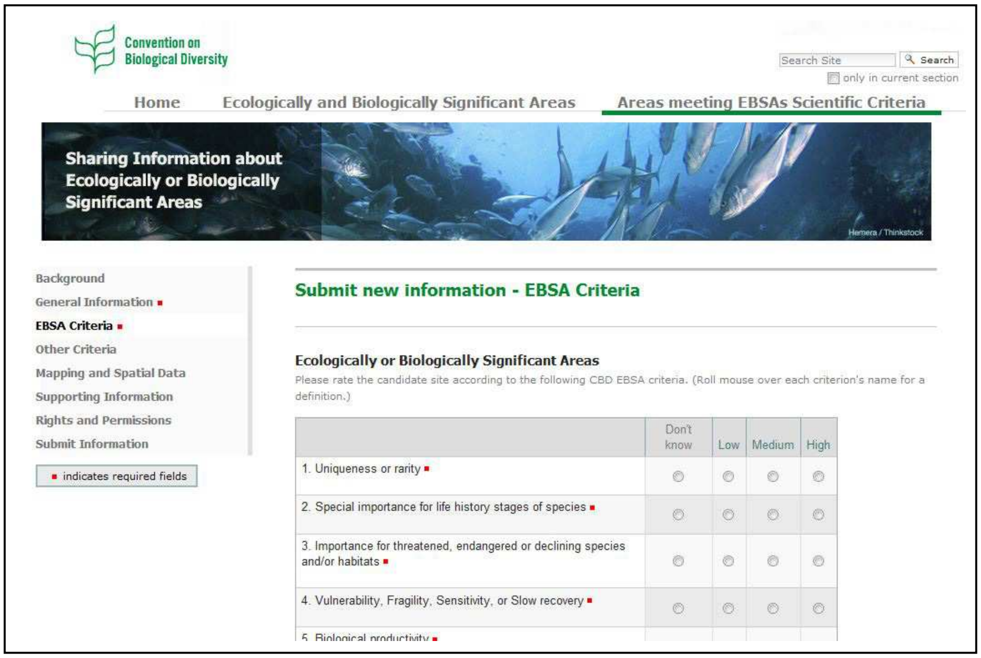
MODULE 2

Objectives of this module:

This module will introduce the CBD repository for EBSA scientific and technical information, and information-sharing mechanism. The contents of the repository, including available technical and scientific information, support, tools and data will be discussed. The user will also be shown how to upload information relating to EBSAs, and to access information and experiences provided by others.

This module will consist of the following sections:

2(a) Introduction to the user interface
2(b) Relative ranking of areas
2(c) Other relevant criteria



2(a) Introduction to the user interface

Learning objectives

This section will introduce the EBSA user interface, including the mapper and upload tools. A brief overview of the CBD decisions leading to the development of this tool will also be provided.

1. What is the web-based input tool?

The CBD's web-based input tool and database have been developed to assist countries and organizations to compile information and experiences relevant to the identification of EBSAs, allowing users to share data, information, tools and lessons learned. The web-based tool also allows for the upload of information relevant to the regional identification of EBSAs.

Information uploaded to the repository will go through a thorough CBD quality assurance process, which involves several steps. As part of this workflow, uploaded content is not publically available until it has gone through initial CBD review procedures. Subsequent reviews will occur at the regional level, as well as by the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and the CBD Parties. As information progresses through these quality control and assurance stages, it can be revised and improved.

The database and repository use technical standards that are well-recognized, open and designed to allow for dynamic links to other databases, as required. At the time of writing, the prototype can link to the OBIS (Ocean Biogeographic Information System) to load biodiversity indices and to search for data on species. Additional linkages and features are anticipated.

The EBSA user interface with its associated repository and mapping tool were developed as a result of decisions made by the CBD Parties at their eighth, ninth and 10th meetings in 2006, 2008 and 2010, respectively. In appendix 1 to this section, we briefly review the history of this tool, which began with the development of another related tool, the IMap/ Ocean Data Viewer.

2. Using the CBD EBSA repository

The primary purpose of the CBD EBSA repository is to store information about potential ecologically or biologically significant areas (EBSAs). At this stage the EBSA repository is a place for adding, storing and modifying data and information. There is a sophisticated workflow, security and permissions system that allows for varying degrees of access, visibility, and editing. Information can be contributed at any time, without being made available to the general public or even other site members.

All information will undergo an initial review for spam and nonsense by the CBD Secretariat to ensure that the submission is legitimate and potentially of interest. The formal review process will begin in regional workshops. Eventually, the site could be officially recognized by the CBD Conference of Parties (COP). The repository is a central place for both collection and review, and eventually for distributing relevant and approved information to the public.

The repository can hold many different types of information, but there are two main types:

1. Submission reports; and
2. documents and data supporting description of EBSAs.

The first type, submission reports, contains the information about the seven EBSA criteria (see p. xxx) and may contain supporting documents. Additional documents and data submitted with the Submission will remain associated with the its report as it is developed and reviewed.

Note that not all data and information will lead to EBSAs being described by the CBD regional workshops; hence there will be much more information in the repository than there will be officially endorse scientific description of EBSAs.

3. Navigating to the EBSA repository

The following instructions explain the basics of how to get around the CBD EBSA repository website. They offer information about the different pages, how to move from section to section, and the various links provided.

Access to the CBD EBSA repository website is available through a link on the CBD website. (At the time of writing, it is a prototype, and a public link is not yet available.) Users can navigate through the site using the menu across the top of the page. From the top menu users can access the following links from anywhere on the site:

- **Home**: Listing of the most recent updates to the EBSA Repository
- **Areas meeting EBSA Scientific Criteria**: Entry point to the heart of the CBD EBSA repository. This is where users can add, store, modify, and review information about potential biologically and ecologically significant areas.
- **Regional EBSAs**: Submitted reports organized according to geographic region
- **Events**: Information on upcoming and past events and workshops relevant to the CBD process for the description of EBSAs.

- **EBSAs**: Areas recognized by the CBD (currently empty).
- **How to**: Provides links to additional information on using the CBD EBSA repository, creating an EBSA report, and workflow and visibility information.

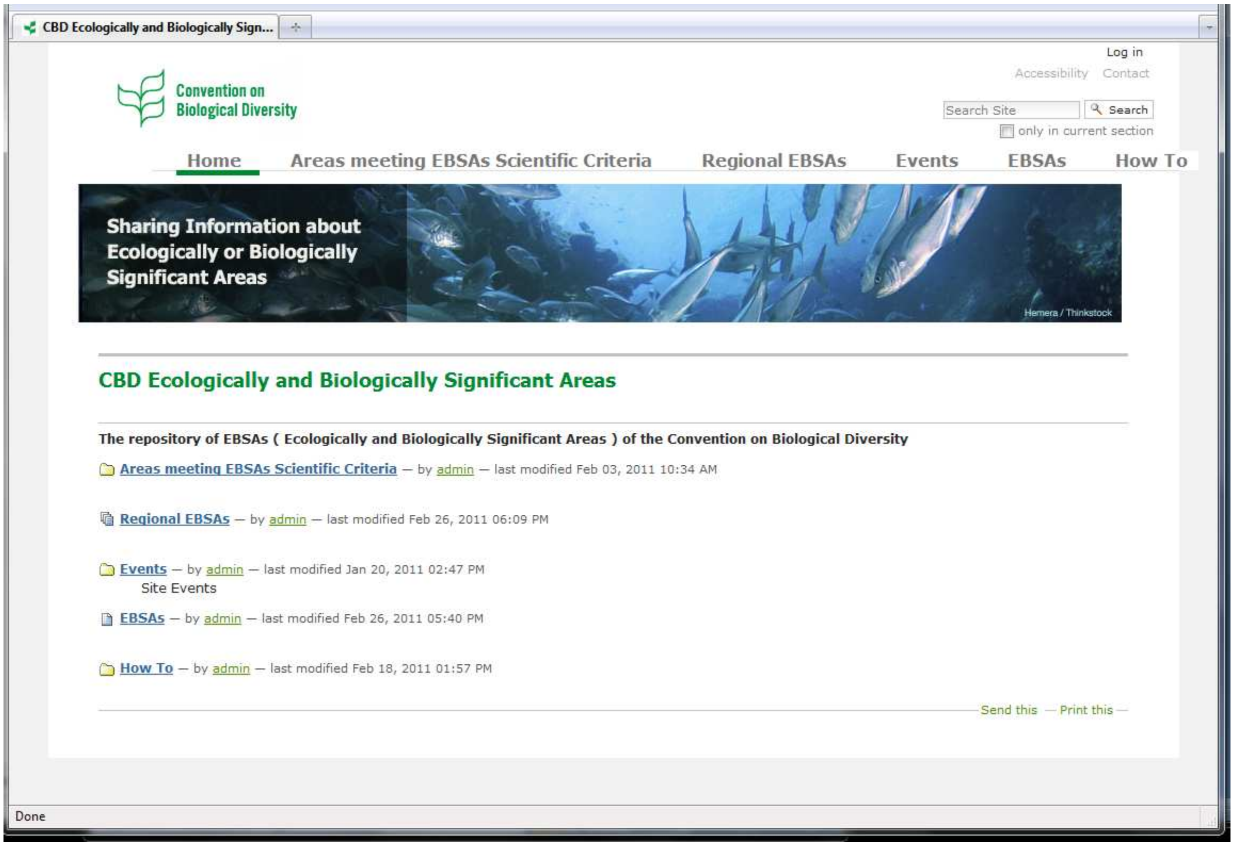


Figure 38: CBD EBSA Repository (*Note that the final site may be may appear slightly different than these images taken from the prototype*.)

4. Areas Meeting EBSAs Scientific Criteria page

The **Areas Meeting EBSAs Scientific Criteria** page is the entry point for adding, saving, modifying, and reviewing all EBSA-related information on the site. From this page any user is able to view reports that have been submitted to the site and have undergone initial review procedures. Submission reports in draft form are not visible to the general public. Users are able to browse through reports in three different ways:

1. From the left-hand **Navigation**, menu, which lists all submitted reports;
2. EBSA reports organized by the status of the potential EBSA in the CBD review process; and
3. By clicking on **Regional EBSAs** in the top menu bar to see the EBSA reports organized by region.

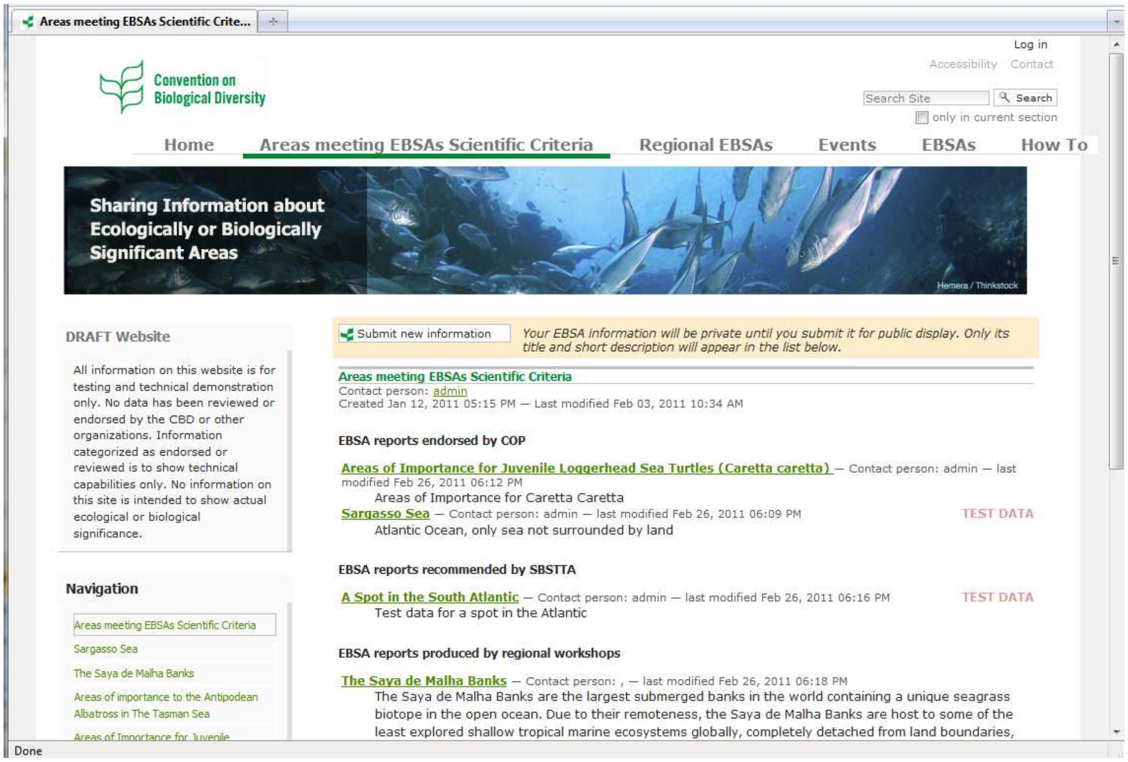


Figure 39: Areas Meeting EBSAs Scientific Criteria page

5. Creating a login account

A login account is needed to submit information. Request an account by clicking **Submit new information** in the pink box on the **Areas Meeting EBSAs Scientific Criteria** page. A pop-up box will appear advising users that they need to log in to submit information. New users will be taken to a simple registration page (fig. 40). Once a user completes the form (the blanks with the little red boxes next to them are required) and clicks **Register**, an email will be sent to the address provided during registration. Follow the link in the email to reach a page where you can change your password and complete the registration process.

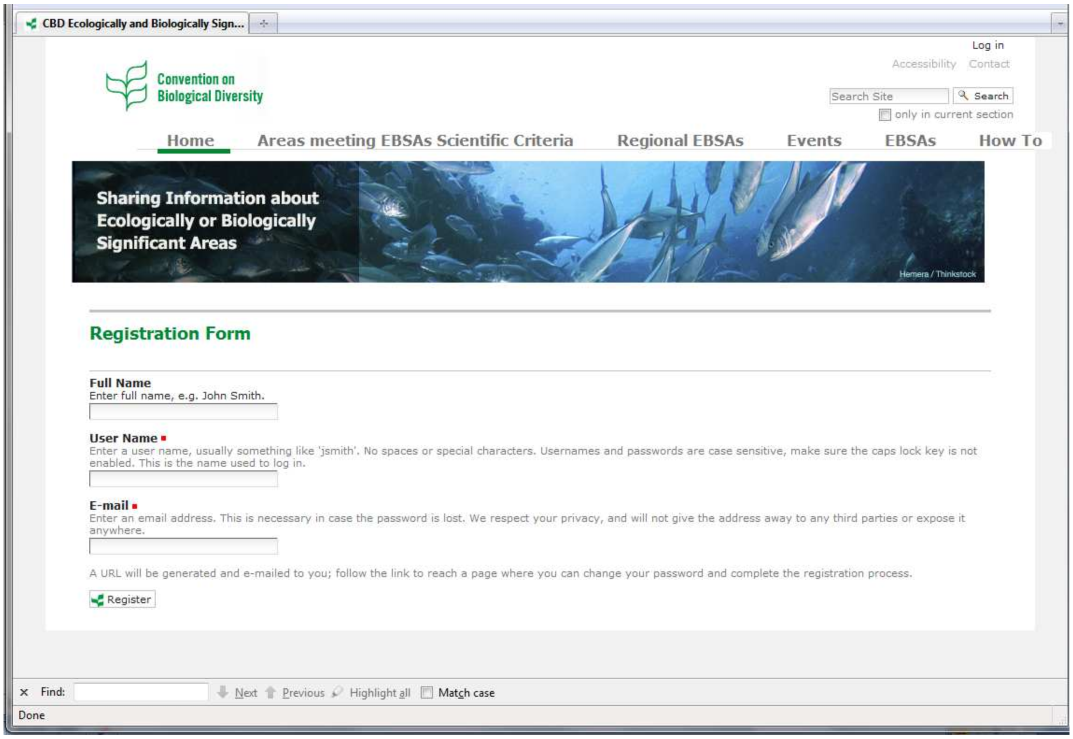


Figure 40: Registration form

Users who already have login names and passwords can access the **log in** page from the top right of any page on the website. Once logged in, users can log out of the site at any time by clicking **log out** at the top right of any page within the website.

6. Creating a new submission

The process of contributing to the site begins with initiating a new EBSA submission report. Supporting documents are not required at first. Indeed, the only required information is a description of the area's significance, a measure of its relative relevance to the EBSA criteria, and its geographic location. Supporting images, articles, geographic information system files, and datasets can be added later.

Users who have logged in can access the EBSA report survey pages by clicking on **Submit New Information** in the pink box under the fish banner at the top of the **Areas Meeting EBSAs Scientific Criteria** page. At first, the user will be taken to the **Submit New Information – Background** page, which contains information on CBD EBSA criteria and how the CBD repository online submission tool came to be. From this page, users also can find links to more information on the CBD criteria (enter url), examples of how the CBD criteria have been applied (enter url), and can access the learning manuals and modules (enter url). Users can submit comments and concerns on the online submission tool at the bottom of the page by clicking on the highlighted words **This website's Contact form** or by going to this link (enter url).

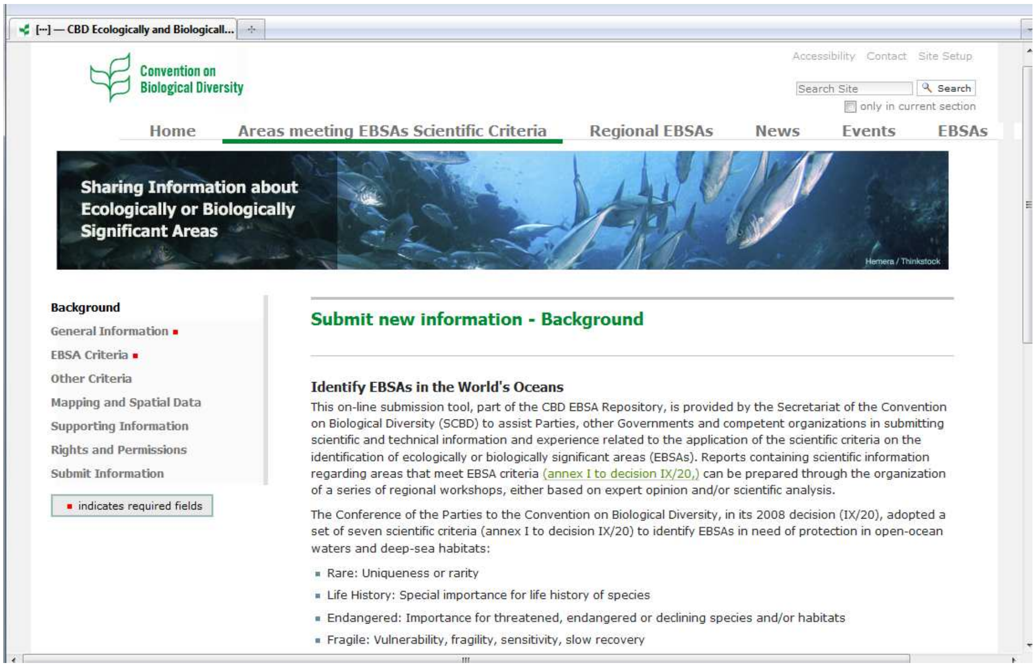


Figure 41: Background page.

Once users are within the survey part of the website, they will be able to navigate within the survey using the menu on the left-hand side.

An EBSA submission report has the following subsections. Once you've filled out the **General Information** and **EBSA Criteria**, you can save the report for later editing. You can also click between each subsection without losing what you've added.

- **General Information** (required): The name, ocean basin and general description of the site.
- **EBSA Criteria** (required**)**: A simple questionnaire ranking the site's significance in relation to the EBSA criteria.
- **Other Criteria** (optional): A similar questionnaire that has other non-CBD criteria which may also be used.
- **Mapping and Spatial Data** (optional, but highly recommended): an interactive tool for identifying the area geographically.
- **Supporting Information** (optional): tools to upload supporting PDFs, spreadsheets, and other files.
- **Rights and Permissions** (optional): for storing contact information and detailing contributors to the report.

7. Procedures for creating a new EBSA report — section by section

General Information (required)

General Information is one of the two sections authors must fill out in order to save a draft report. Authors are asked to designate whether or not the information is test data or an actual submission and provide a name for and a short description of the site, which will appear in the list of submissions. On the general information page, authors can also select the oceanic region(s) to which the site belongs, whether or not the area is in international waters or crosses into an exclusive economic zone (EEZ). A space is also provided where authors can explain in general terms why they are selecting the area.

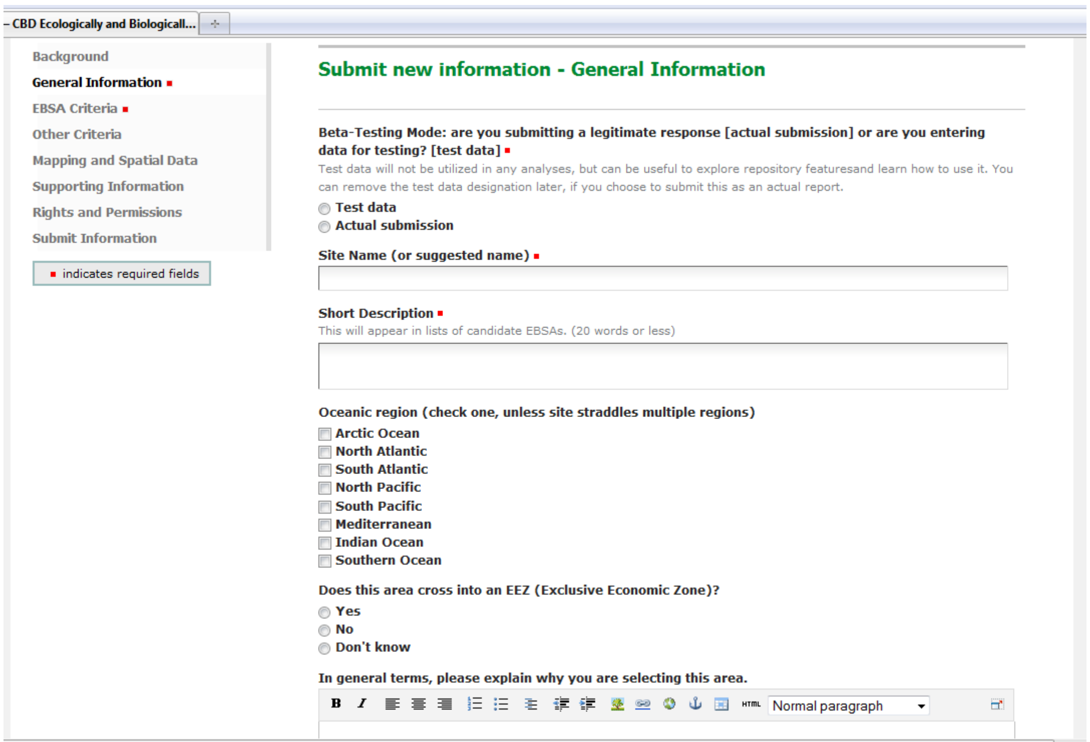


Figure 42: General Information. Note that red squares denote required fields.

Note that:

- *Users can identify a submission as "test data" to become familiar with using the system. No one will take further action on a submission in this state. (Though you can subsequently change a test submission to a real submission.)*
- *The main text area will allow you to embed images once you've saved the whole report, but only accepts text initially.*

EBSA Criteria (required)

In this section, authors are asked to rate the submission according to the seven EBSA criteria. Users can scroll the cursor over each criterion to see a pop up of the relevant definitions. (More information on EBSA criteria, their application, and guidance on the rating system can be found on the CBD website, as well in the previous sections of this manual.)

To help address some of the EBSA questions, the interactive mapping tool on the **Mapping and Spatial Data** page can help users explore the biological diversity and presence of species in a given area (more information on the interactive mapping tool in the **Mapping and Spatial Data** page below.

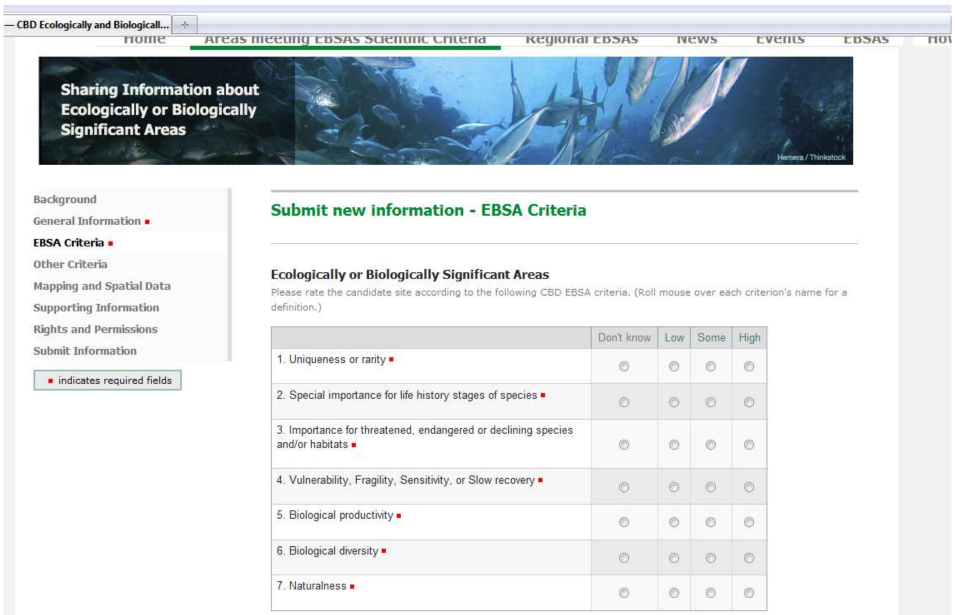


Figure 43: **EBSA Criteria** page. Note that the red squares denote required fields.

*Note on saving your report: Once an author has completed the **General Information** and **EBSA Criteria** sections, a report can be saved in draft form by clicking the save button at the bottom right of the page. If a user tries to save a draft of their report prior to having filled out all of the required information, an error message will pop up advising the user of the missing parts.*

<u>Other Criteria</u>

Authors can also rate the candidate site according to the following other criteria: Dependency, representativeness, biogeographic importance, structural complexity, natural beauty, Earth's geological history. Definitions are included for each criterion. In some cases authors might like to apply a national, regional, or international criterion that is not listed in either the **EBSA Criteria** list or the **Other Criteria** list. There is a final "freeform" criteria where an additional criterion can be described and rated.

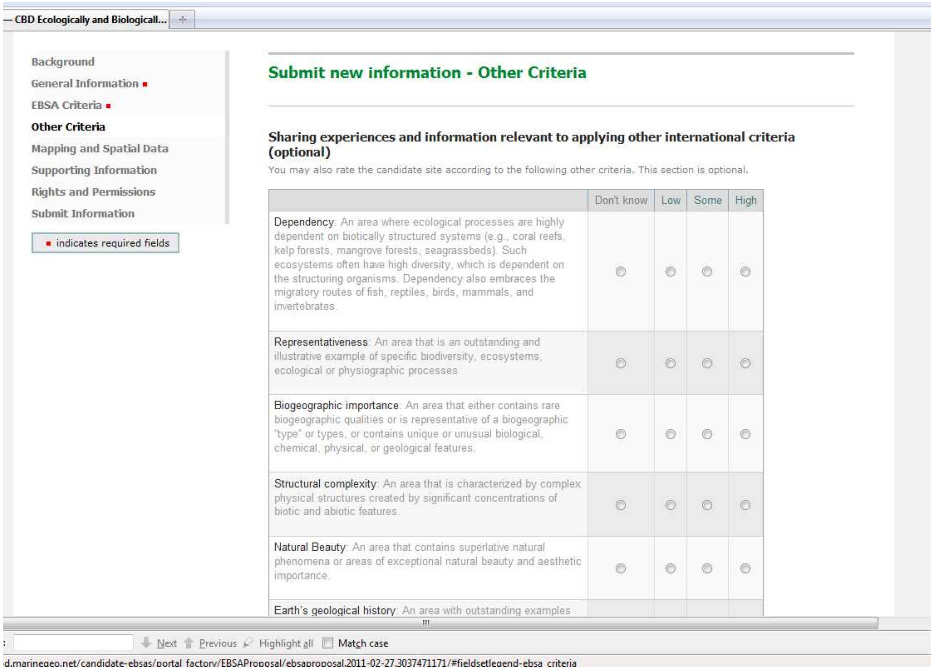


Figure 44: **Other Criteria** page

Mapping and Spatial Data

In this subsection, authors are asked to provide mapping and spatial information about their area. At the top of the page a text box is provided where authors can provide a written description of the site, including latitude/longitude coordinates, if available. If a user has exact coordinates, exact latitude and longitude can be entered after creating a rough shape on the map.

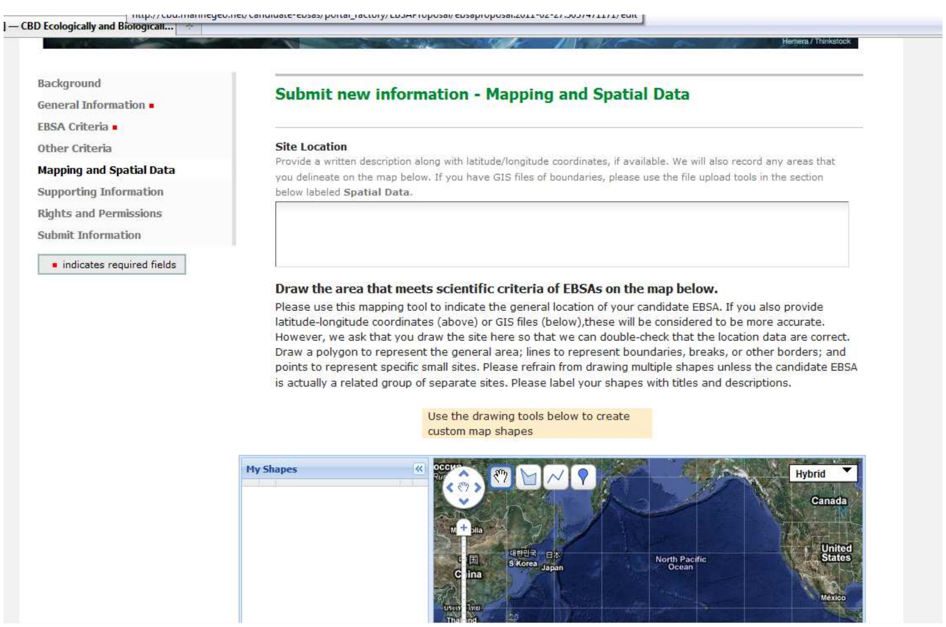


Figure 45: **Mapping and Spatial Data** page (top part).

Below the text box described above, users are presented with an interactive map editor. We strongly encourage users to draw a rough sketch of the area using the tools providing in the interactive map editor.

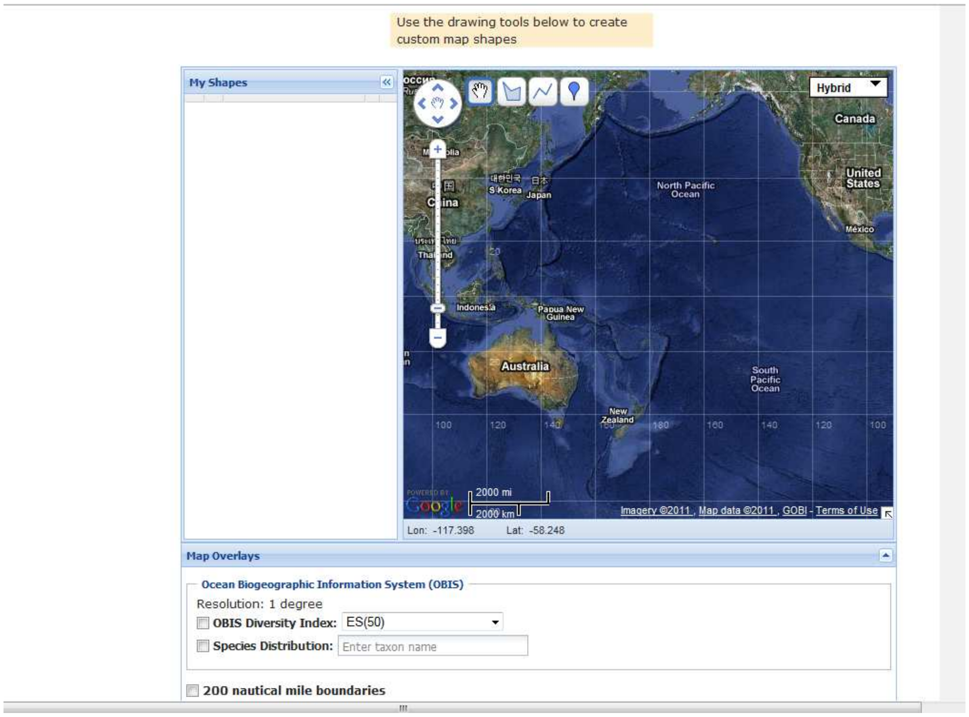


Figure 46: Interactive Mapping tool (bottom part of **Mapping and Spatial Data** page).

If this is a new submission, it will initially display a blank world map. If this is an existing submission with user-drawn map data, the map will show all previously drawn shapes. This map will display any areas demarcated by the user while creating and editing the shape. (Note: Only spatial data drawn by the user via the map-editing interface will appear here. Spatial data files submitted via the file upload tool are saved but not mapped. More information on uploading spatial data files is provided below.)

The map will display any points, lines, or polygons drawn by the submitters. Clicking on a shape will pop up a window with the name and description of the feature. Navigating the map is done by clicking and dragging on the map or using the map control overlays on the left side of the map window.

To add a new shape to the map, click on one of the map editing tool buttons along the upper left edge of the map. You will see instructions for each tool as you move your mouse over the icons.

- **The hand tool** is activated by default and is used for normal map navigation. It does not create map features.
- **The polygon tool** allows users to draw filled shapes on the map.
  - After selecting the polygon tool button, the tooltip by the mouse cursor will present the user with step-by-step instructions. Click once on the map to set the first vertex of the polygon, then continue to click to add

additional vertices. When finished adding points, double clicking will add a vertex and connect it to the first vertex, ending the edit session. The same can be accomplished by clicking on the first vertex directly.

- **The line tool** allows users to draw lines on the map.
    - Drawing a line is almost identical to drawing a polygon except that the line does not need to return to the first vertex. On-screen instructions are provided during the process.
- **The point tool** allows users to draw place markers on the maps.
    - After selecting the point tool, clicking anywhere on the map will drop the place marker.

Once a shape of any type has been drawn, the user will be asked to provide a name and description for the shape. An entry will also be shown in the **My Shapes** list to the left of the map. Clicking on the entry in the list or clicking on the shape on the map will pop up the name and description window.

Clicking on the red "x" next to the shape entry in the **My Shapes** list will delete the shape from the map.

Clicking on the "+" button to the left of the shape entry in the My Shapes list will show all of the longitude/latitude coordinates of the shape vertices. These vertices can be deleted individually or edited manually by clicking on the coordinates.

Below the map pane are optional map layers that can be overlaid along with the user-defined EBSA shapes. Checking the box for the EEZ layer displays marine areas within 200 nautical miles of shore. Checking the box for the OBIS Diversity Index will display a global overlay of the biodiversity index selected in the dropdown menu. There are two layers that query data directly from the Ocean Biogeographic Information System (iobis.org). To view the distribution of observations of a particular taxon or taxa grouping, check the box for species distribution and then begin typing the taxon name (e.g., genus and species, genus, family). As you type, a list of matching taxa will be displayed. Select the taxon of interest to view its distribution on the map. Only one OBIS layer can be viewed at one time.

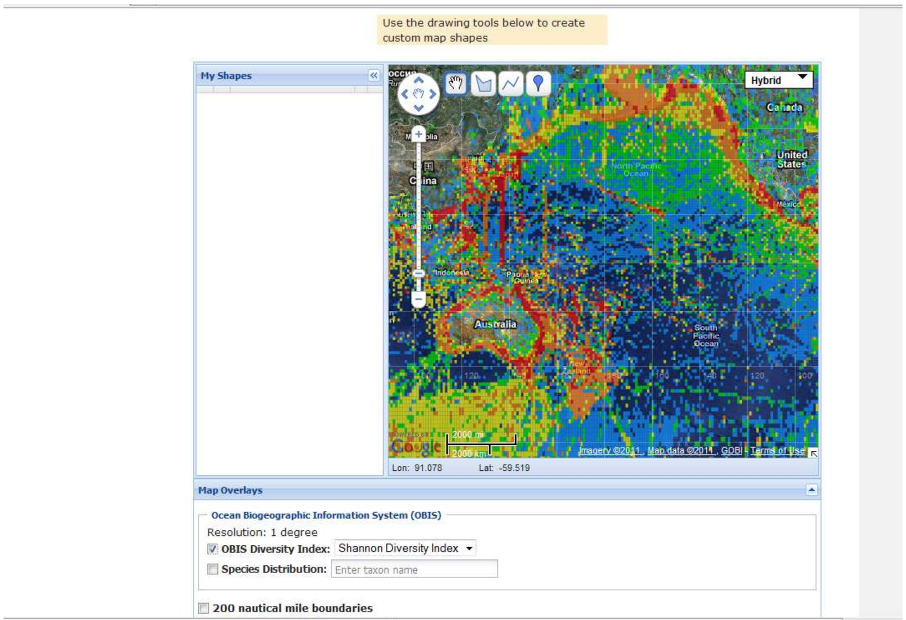


Figure 47: Interactive mapping tool with OBIS Diversity Index layer turned on (Shannon-Wiener Diversity Index).

Uploading spatial data

While creating a new submission report or editing an existing one, users have the ability to provide spatial data to help define the area. A file uploading tool allows for multiple spatial data files in any format to be uploaded. Uploaded files are then associated with the submission. These uploaded files are not currently interpreted by the EBSA web application and are not viewable on a map on the website.

Supporting Information

If users have other datasets, related documents, or media they would like to submit relevant to the areas that meet scientific criteria for EBSAs or other criteria (optional), they are welcome to submit any scientific and technical supporting information in the form of publications, maps, and relevant data products. Additionally, photographs and audio/visual media can further clarify the description of such areas. The tools embedded in the **Supporting Information** page can also be used to submit supporting documentation and media, providing references where they are known and uploading data and media files if they are in the public domain.

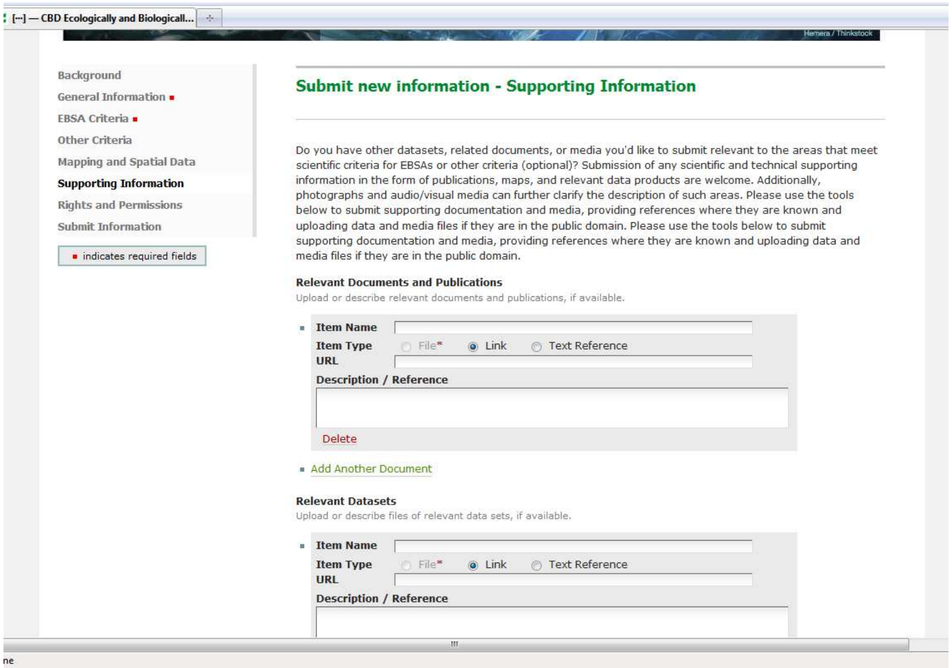


Figure 48: **Supporting Information** page.

Rights and Permissions

Users are asked to provide contact information for the contributors to the report in this subsection. If the author would like to submit information regarding copyrights statements or other rights information a text box is provided. Users also are asked to read and acknowledge that

- by submitting this information, it will appear on this CBD website and may be shared with Parties and other relevant competent organizations, unless separate arrangements are made with the Secretariat; and
- give permission to publish the information in CBD publications.

Tick boxes are provided.

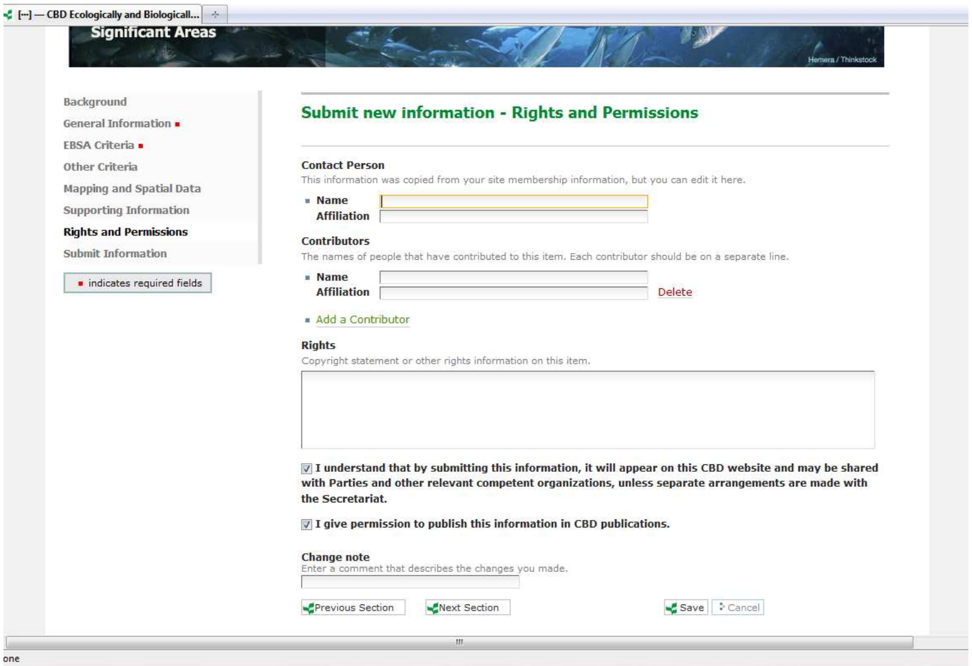


Figure 49: Rights and Permissions page

Submit Information

When users are ready to submit their information, they can press the save button on the **Submit Information** page and carefully review the **Summary** page. When they are happy with the **Summary** page, they can click the **Submit to Workshops** button at the top of the summary page.

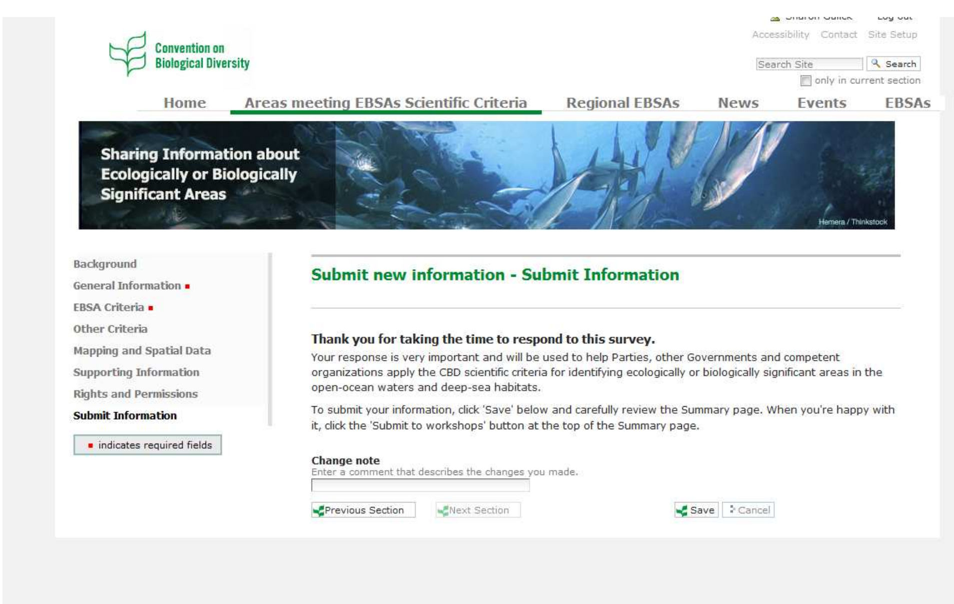


Figure 50: **Submit Information** page.

8. Workflow and Visibility of information

The web-based repository and information tool is open to all users, and anyone may register to make a submission. However, log-on and security measures have been put in place to ensure that submissions are not tampered with, and that they flow through the approved CBD work processes.

New data in the repository begin in a private state. While in draft state, before a submission is submitted, the information is only available to the user making the submission. If the submission is held in draft state, only the title of the report is visible to site members. To share the full content of the report, the author may publish their submission internally, before formally submitting. Once, submitted, the information will flow through the CBD quality control and assurance process, beginning with an initial 'spam and nonsense' review. Subsequent reviews will occur at the regional level, as well as by the CBD's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) and the CBD Parties. As information progresses through these quality control and assurance stages, it can be revised and improved.

Figure 51: **History** icon.

The history of a Submission can be tracked near the bottom of the page. Clicking on the [+] icon will reveal the site member who advanced the Submission and the time at which its state changed.

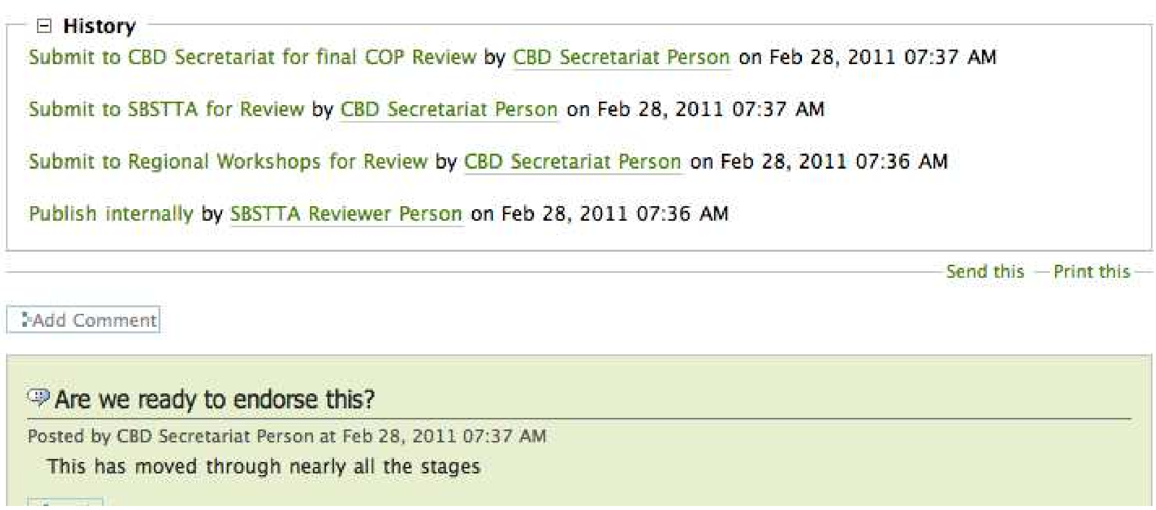


Figure 52: Sample **History** view

Comments can be attached to a submission and appear at the bottom.. The visibility of the comments follows the visibility of the submission.

The site administrator can bypass the visibility/invisibility of the workflow and correct an item's position in the workflow if the item is categorized incorrectly. Administrators can remove comments, as can the owner of a comment.

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. **What are the required steps to submit information about an EBSA to the CBD repository?**
2. **What are the quality control and assurance stages for submitted information? When is information made public?**

2(b) Relative ranking of areas

Learning objectives

In this section you will learn about some of the ways to consider the relative ranking (low – high) of sites based on the EBSA criteria.

> *The [EBSA] criteria function to rank areas in terms of their priority for protection, and not as an absolute "significant – not significant" choice. As such, an application of absolute thresholds for most criteria is inappropriate.*
>
> –Report of the CBD expert workshop on ecological criteria and biogeographic classification systems for marine areas in need of protection (2009 UNEP/CBD/EW-BCS&IMA/1/2, http://www.cbd.int/doc/?meeting=EWBCSIMA-01).

In this section we will discuss why the EBSA criteria should be seen as *relative* and strategies for determining their ranking when using the CBD EBSA repository tool.

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 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 determine relative importance of specific features or places in a given ecological region on each of the criteria. In the best cases, ecological knowledge of the area can be used to establish and justify a particular threshold value above which any area would qualify as 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.

The CBD repository tool requires the user to input information to rank the area/feature in question for each of the seven EBSA criteria (fig. 54). The user is given a choice ranging from low (1) to very high (5). There is also an option to indicate "Don't know". For an area to be seriously considered as an EBSA, it is expected that it should rate highly on at least one criterion. That said, it can be difficult to know how to do this ranking. While it is inherently subjective, there are quantitative techniques that can help inform and defend ranking decisions.

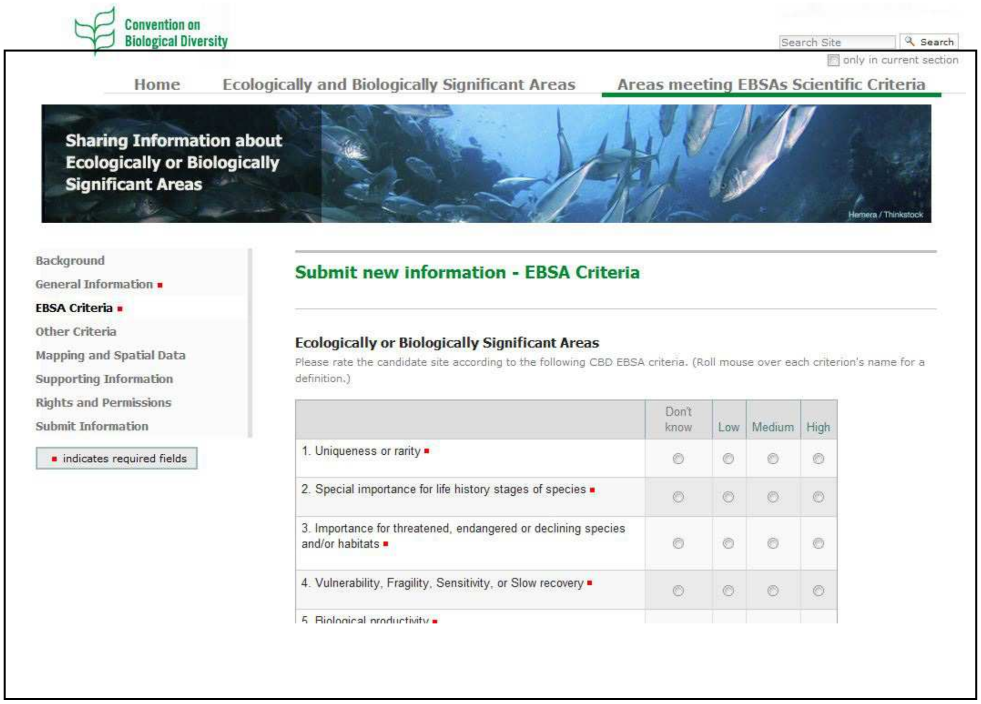


Figure 54: CBD EBSA repository tool.

1. Strategies to determine relative rankings

Most strategies will require comparing the place/feature in question to others in the same bioregion. If the feature is dominated by a single EBSA criterion (e.g., special importance for life history stages of species, such as a spawning site), then it makes sense to compare it to other known sites of that type. However, if there are secondary characteristics (e.g. a spawning site with significant biodiversity also), then the comparison for that secondary characteristic should focus on other places that are known for that criterion (e.g. other areas of biodiversity) in the region. If no relevant data exist, comparisons can be subjective based on local expert opinion. It is better, however, if corroborating evidence can be produced, such as fisheries catch data or historical accounts. Using the expert opinion approach, a good place to begin is to develop a few regional benchmarks of well-known places that illustrate a range of possibilities from low to moderate ('average') to high. Once these benchmarks are established, then it is easier to place the feature in question into this continuum.

Sometimes there may be enough directly relevant data to map the pattern of how a biological feature varies with regard to a single variable, such as abundance, across a region. In these fortunate cases, patterns in the available data may help inform how to rank a feature in the context of other like features in a region (i.e., above or below an average—moderate—ranking). With comprehensive quantitative data, two general approaches can be used to investigate 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. Histograms of frequency (fig. 55) will bring out this nature of the data when present. Analytical methods applied to such data can use the cumulative frequency distribution rather than histograms, although both methods of presentation display the same patterns in 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 ends of the distribution. When applying these techniques, however, it is necessary to avoid circularity and confirmatory bias by 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 weak, arbitrary choices can be made about the use of a threshold value (e.g., exhibiting certain relevant characteristics found in fewer than half of such sites in the region). However, it is often sufficient to first relatively order the sites amongst themselves, and then to use this relative ordering as input to the dialogue on how the ecological or biological significance varies among areas, and if a cut-off threshold is required.

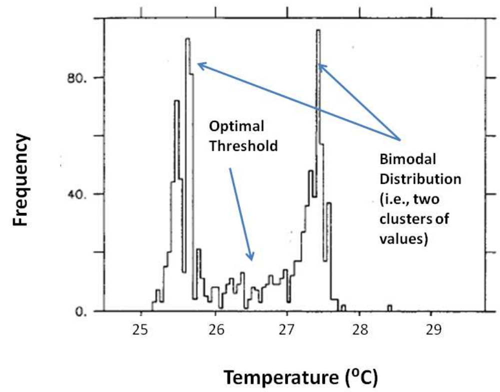


Figure 55: An example of a histogram showing two clusters of values and the optimal threshold to ???

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 would warrant a higher relative ranking than those 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 that further investigation is warranted. In many circumstances, it may be best to transform data, so that it better approximates a normal distribution, before this method can be applied.

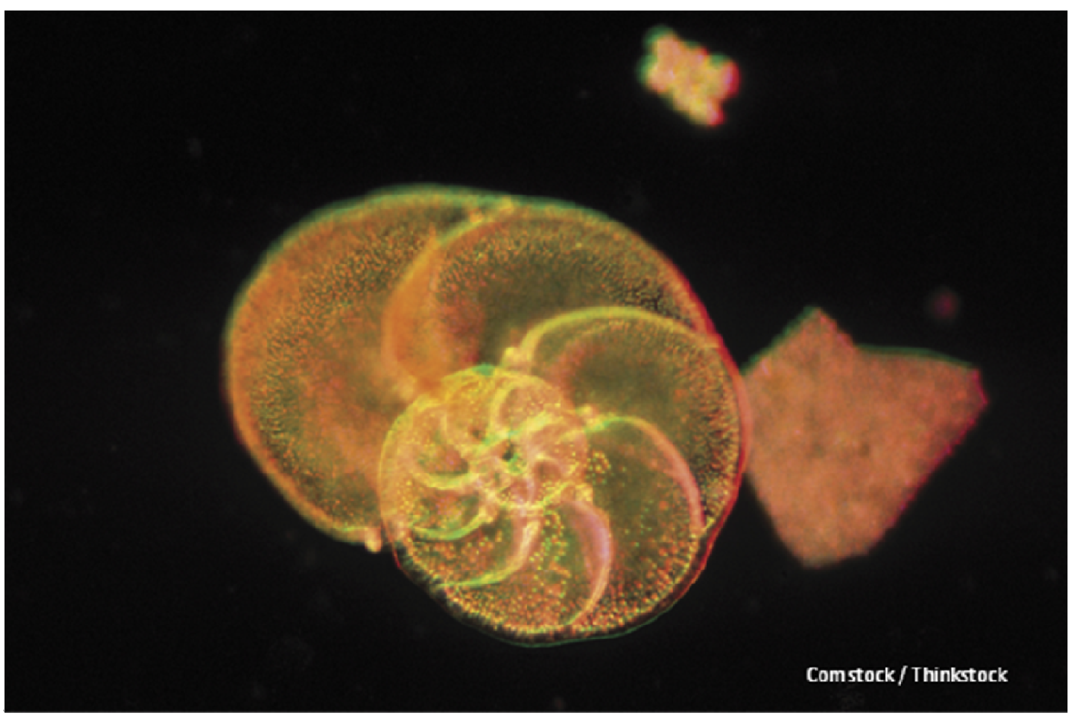
All methods, be they qualitative or quantitative, should be clearly documented so that these decisions can be explained/defended, and revised, if necessary, as new information comes available.

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. Is there a fixed rule for determining when something is ecologically or biologically significant? Explain.

2. How might relative ranking in one region differ from that in another region? Choose at least one EBSA criterion to illustrate how these could be ranked differently in different regions.



2(c) Other relevant criteria

Learning objectives

In this section you will learn about other criteria for selecting marine sites for enhanced management and protection. In particular, we will discuss other international criteria (such as those adopted by the FAO and IMO) and compare them to the CBD EBSA criteria. We also look at regional and national site selection criteria.

1. International criteria

In addition to the CBD, other international and regional processes have adopted criteria for selecting areas of the ocean for enhanced management or conservation. They include the FAO criteria for the identification of vulnerable marine ecosystems (VMEs) and the IMO criteria for selecting particularly sensitive sea areas (PSSAs). Though designed for specific human activities (fishing and shipping, respectively), these criteria systems largely overlap the EBSA criteria. The CBD web-based input tool allows for the optional input of information and experiences related to other criteria, as appropriate, as well as the CBD EBSA criteria.

The FAO criteria for the identification of VMEs are intended to prevent negative impacts from deep-sea fishing activities on vulnerable habitats and ecosystems on the sea floor. Species groups, communities or habitats that are easily damaged and take a long time to recover are considered vulnerable to bottom-fishing activities. According to the FAO, the vulnerability of an ecosystem is related to the vulnerability of its constituent populations, communities or habitats. Features of an ecosystem may be *physically vulnerable* (i.e., structural elements of the ecosystem may be damaged through direct contact with fishing gear) or *functionally vulnerable* (i.e., selective removal of a species may change the manner in which the ecosystem functions). The most vulnerable ecosystems are those that are both easily disturbed and slow to recover. Ecosystem components identified as particularly vulnerable include, for example, sponge-dominated communities, cold-water corals, and seep communities. These are often associated with topographical, hydrophysical or geological features such as summits and flanks of seamounts, or in the case of cold seeps, the margins of continental shelves.

The IMO PSSA designation can be used to protect an area from damage by international maritime activities. According to the IMO, an area can be designated a PSSA if it fulfills a number of criteria, including: ecological criteria, such as uniqueness or rarity of the ecosystem, diversity of the ecosystem or vulnerability to degradation by natural events or human activities; social, cultural and economic criteria, such as significance of the area for recreation or tourism; and scientific and educational criteria, such as biological research or historical value. When an area is approved as a PSSA, specific measures can be used to control the maritime activities in that area, such as routing measures, application of MARPOL discharge and equipment requirements for ships, such as oil tankers; and installation of vessel traffic service (VTS) devices.

Table xx summarizes the criteria systems and illustrates the overlap amongst them.

Table 7: Comparison of CBD, FAO and IMO criteria systems

Type of criteria	CBD EBSA	FAO VME	IMO PSSA
Uniqueness or rarity	**Uniqueness or rarity** – 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	**Uniqueness or rarity** – An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include: habitats that contain endemic species; habitats of rare, threatened or endangered species that occur only in discrete areas; or nurseries or discrete feeding, breeding, or spawning areas.	**Uniqueness or rarity** – An area or ecosystem is unique if it is “the only one of its kind”. Habitats of rare, threatened, or endangered species that occur only in one area are an example. An area or ecosystem is rare if it only occurs in a few locations or has been seriously depleted across its range. (...) Nurseries or certain feeding, breeding, or spawning areas may also be rare or unique.
Special importance for life history stages of species	**Special importance for life history stages of species** – Areas that are required for a population to survive and thrive. (...) Areas containing: (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).	**Functional significance of the habitat** – Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.	**Spawning or breeding grounds** – An area that may be a critical spawning or breeding ground or nursery area for marine species which may spend the rest of their life-cycle elsewhere, or is recognized as migratory routes for fish, reptiles, birds, mammals, or invertebrates.
Importance to threatened or endangered species	**Importance for threatened, endangered or declining species and/or habitats** – Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.	**Functional significance of the habitat** – Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.	**Critical habitat** – A sea area that may be essential for the survival, function, or recovery of fish stocks or rare or endangered marine species, or for the support of large marine ecosystems.
Vulnerability, Fragility, sensitivity, or	**Vulnerability, fragility, sensitivity, or slow recovery** – Areas that contain a relatively high proportion of sensitive	**Fragility** – An ecosystem that is highly susceptible to degradation by anthropogenic activities.	**Fragility** – An area that is highly susceptible to degradation by natural events or by the activities

slow recovery	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.	**Life-history traits of component species that make recovery difficult** – Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: slow growth rates; late age of maturity; low or unpredictable recruitment; or longlived.	of people. (…)
Productivity	**Biological productivity** – Area containing species, populations or communities with comparatively higher natural biological productivity.	NA	**Productivity** – An area that has a particularly high rate of natural biological production. Such productivity is the net result of biological and physical processes which result in an increase in biomass in areas such as oceanic fronts, upwelling areas and some gyres.
Biological diversity	**Biological diversity** – Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.	NA	**Diversity** – An area that may have an exceptional variety of species or genetic diversity or includes highly varied ecosystems, habitats, and communities.
Naturalness	**Naturalness** – Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.	NA	**Naturalness** – An area that has experienced a relative lack of human-induced disturbance or degradation.
Structure		**Structural complexity** – an ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.	**Dependency** – An area where ecological processes are highly dependent on biotically structured systems (e.g. coral reefs, kelp forests, mangrove forests, seagrass beds). Such ecosystems often have high diversity, which is dependent on the structuring organisms. Dependency also embraces the migratory routes of fish, reptiles, birds, mammals, and invertebrates.

Source: Courtesy of D. Dunn

As illustrated above, the three criteria are very similar, though there are small variations in definitions. The FAO VME criteria do not include productivity, biodiversity and naturalness, while the CBD EBSA criteria do not include structural complexity. Regardless, there is a high level of compatibility between the criteria.

Other relevant international selection criteria that can be applied in open ocean waters and deep-sea habitats include the IUCN criteria for marine protected area networks, the International Seabed Authority guidance for preservation reference areas and UNESCO criteria for World Heritage sites. As was the case with the FAO and IMO criteria, each set of criteria was designed with a specific management objective in mind, and each is to a large extent compatible with the CBD EBSA criteria.

2. Regional criteria

Many regional processes, in particular Regional Seas Programmes, have adopted criteria for selecting areas to be included in regional marine protected area networks. Such criteria exist, at least, for the Mediterranean Region, the Wider Caribbean Region, the Baltic Sea (HELCOM) and the North-East Atlantic (OSPAR). These criteria are also generally compatible with the CBD EBSA criteria. For example, box 7presents the OSPAR criteria for identification of areas to be included in their regional MPA network, which include most of the same elements as the CBD EBSA criteria.

Box 7: Ecological Criteria for Identification and Selection of Marine Protected Areas, Adopted by the Convention for the Protection of the Marine Environment of the North-east Atlantic (OSPAR Convention)

Ecological criteria/considerations[5]
An area qualifies for selection as an MPA if it meets several but not necessarily all of the following criteria. The consideration and assessment of these criteria should be based on best available scientific expertise and knowledge.

1. Threatened or declining species and habitats/biotopes

The area is important for species, habitats/biotopes and ecological processes that appear to be under immediate threat or subject to rapid decline as identified by the ongoing OSPAR (Texel-Faial) selection process.

2. Important species and habitats/biotopes

The area is important for other species and habitats/biotopes as identified by the ongoing OSPAR (Texel-Faial) selection process.

[5] The OPSAR Convention also adopted a set of practical considerations for MPA designation, which have no counterpart in the CBD.

3. Ecological significance

The area has:

- a high proportion of a habitat/biotope type or a biogeographic population of a species at any stage in its life cycle;
- important feeding, breeding, moulting, wintering or resting areas;
- important nursery, juvenile or spawning areas; or
- a high natural biological productivity of the species or features being represented.

4. High natural biological diversity

The area has a naturally high variety of species (in comparison to similar habitat/biotope features elsewhere) or includes a wide variety of habitats/biotopes (in comparison to similar habitat/biotope complexes elsewhere).

5. Representativity

The area contains a number of habitat/biotope types, habitat/biotope complexes, species, ecological processes or other natural characteristics that are representative for the OSPAR maritime area as a whole or for its different biogeographic regions and sub-regions.

6. Sensitivity

The area contains a high proportion of very sensitive or sensitive habitats/biotopes or species.

7. Naturalness

The area has a high degree of naturalness, with species and habitats/biotope types still in a very natural state as a result of the lack of human-induced disturbance or degradation.

3. National criteria

In addition to the international and regional criteria for identifying sites for enhanced management and protection, many countries have adopted their own criteria for this purpose to be used in their national waters. In general, many of these country criteria are very similar to the CBD EBSA criteria, with some differences to account for the special circumstances, biodiversity, and ecosystem management goals of each country. For example, box 8 shows criteria used by Trinidad and Tobago to identify marine areas for protection.

Box 8: TRINIDAD AND TOBAGO

Principles of Environmentally Sensitive Area (ESA) Rules of 2001 are used in selection of marine areas for protection.

- Uniqueness, rarity or important biological features
- Good representation of naturally-occurring ecological system or type

- Particularly good representative of an ecosystem characteristic of one, or common to more than one biogeographical region
- Critical importance to the survival or recovery of endangered, endemic or vulnerable species/communities of plants and animals
- An appreciable or significant assemblage of endangered, or threatened species of plants or animals
- Special value as a habitat for plants or animals at a critical stage of their biological cycle
- Provision of appreciable social, recreational or economic benefit to local communities or to wider areas
- High in aesthetic value
- Regarded by the scientific community as having significant value for non-destructive research
- Potential for fostering environmental awareness, appreciation or education
- Performing an integral role in the functioning of the wider ecosystem
- Representative example of all coastal and marine ecosystems
- Representative example of all wetland types

Many other criteria systems group site criteria (e.g., naturalness) with network criteria (e.g., representativity), however the CBD has divided these into sets, found in: decision IX/20, annex 1 and annex 2, respectively.

4. Using other criteria to input sites using the CBD web-based input tool

Given the high degree of compatibility between the various criteria used internationally, regionally and nationally, information on areas that have been selected based not only on the CBD criteria, but also other compatible criteria can be entered into the CBD web-based input tool and repository. The input tool has a page called **Submit New Information – Other Criteria**, which includes criteria not covered by the EBSA criteria. Figure 56 is a screenshot of this page. The other criteria included are dependency, representativeness, biogeographic importance, structural complexity, natural beauty and Earth's geological history. Definitions are included for each criterion. If other criteria used are not on the list, it is possible to add information about the criteria using the blank entry line at the bottom of the form.

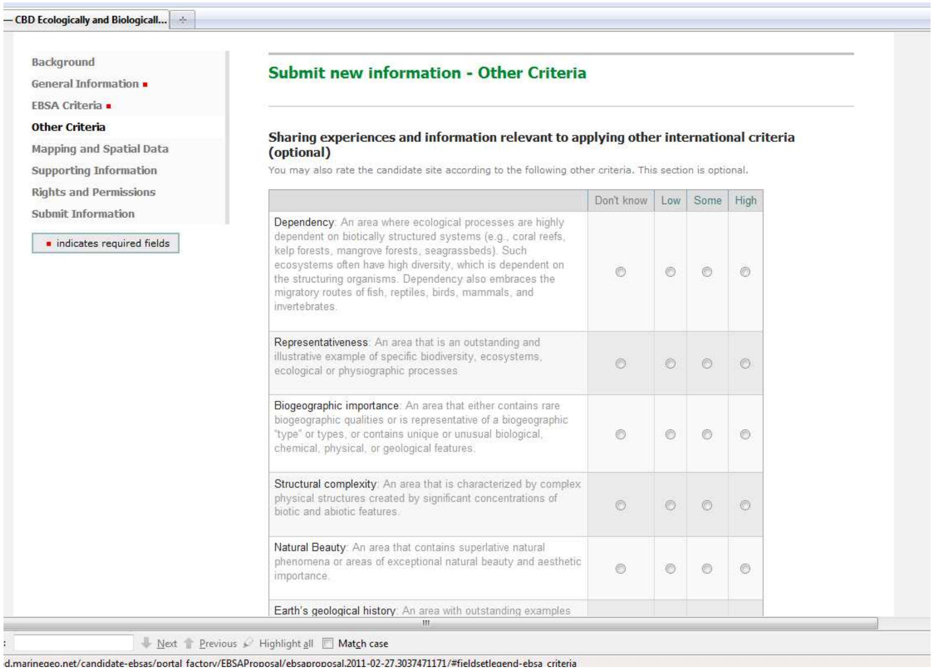


Figure 56: **Other Criteria** page

Check for understanding

You can check your understanding by answering the following questions, the answers for which can be found in the text above:

1. What are some of the similarities and differences between the CBD EBSA criteria, the FAO VME criteria and the IMO PSSA criteria?
2. How do the criteria used in your country/region compare to the CBD EBSA criteria?

References:

FAO International Guidelines for the Management of Deep-sea Fisheries in the High Seas (criteria relevant to the identification of a VME): http://www.fao.org/fishery/topic/4440/en

IMO Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas: http://www.gc.noaa.gov/documents/982-1.pdf

Operational Guidelines for the Implementation of the World Heritage Convention: http://whc.unesco.org/archive/opguide08-en.pdf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