Discussion paper:

Towards a global classification of marine habitats for marine data and information exchange

Dr Mark J. Costello

Leigh Marine Laboratory, University of Auckland, New Zealand.

Direct tel. +64-9-3737599 ext 83608; Reception +64-9-422 6111; Fax +64-9-422 6113;

Email m.costello@auckland.ac.nz

Background

At first, marine habitat classifications were developed for local and regional surveys so as to help organise and describe the environment and associated assemblages of species. The scope and structure of such classifications was peculiar to the study area. More recently, coastal management, and marine conservation in particular, required standardised classifications and terminology for marine habitats to enable consistent mapping of the marine environment across all possible habitats in a country. This led to the MNCR-BioMar classification for seabed habitats and biotopes developed using both data from Britain and Ireland, and expert opinion from throughout Europe (Connor *et al.* 1997a, b, Costello and Emblow in press). This is now applied to the North-East Atlantic as part of the European Union Nature Information System (EUNIS, http://eunis.eea.eu.int). Subsequently, NOAA began development of a coastal marine habitat classification for the USA, which NatureServe now leads (Madden and Grossman 2004). Less developed marine environment and habitat classifications are being developed in Canada by DFO and WWF, in Australia by a consortium of organisations and researchers, and in New Zealand by the Department of Conservation and Ministry of Fisheries. A regional marine habitats classification system has been implemented in Europe, and this has evolved with new regulatory needs (e.g. for deep sea habitats) and in the light of new field data (e.g. new biotopes described) as classifications should. Classifications developed for marine coastal management have also been used in Australia, although not at such a fine level of ecological detail as in Europe. Although both the European, NatureServe, and Australian classifications initially focused on coastal habitats, they have widened their scope to cover “offshore” areas.

Habitat classifications imply or provide definitions of words used and show their relationships. It helps if these are hierarchical because one can then map habitats at different levels depending on the scale of the map, end-user needs, and available data. Importantly, it also means that like a classification of species, that lower levels can be aggregated into higher levels. Thus the hierarchy should be unique. For this reason the MNCR – BioMar classification did not include existing marine concepts designed for birds in the Europe, such as estuaries and inlets, because these contain the same habitats. In contrast, the NatureServe system covers a far greater range of "habitats", most notably including water column features that were excluded from MNCR-BioMar (although now included in EUNIS).

Glossary (dictionary)

Useful glossaries of terminology are included in the NatureServe, MNCR-BioMar and other authoritative sources (e.g. Lincoln *et al.* 1998, www.Wordnet.org). These could form the basis of an online dictionary of terminology. Being online it could grow in time. Alternative definitions could also be included, with 'recommended' usage where appropriate. This dictionary should be a priority for a data exchange system because it will allow future translation between terminologies and cross-mapping between classifications. To be authoritative this should be based on referenced sources and suitable authors. [Could this be a role for some members of the OBIS Editorial Board?]

Data exchange

The arrival of software that enables interoperability between databases, provides new opportunities to share and exchange data between researchers and end-users located in different cities and countries. However, data exchange requires standardised fields that form a "data schema" that is the basis of the "middleware" that connects different databases. Already, the exchange of geographic, taxonomic, and time of collection, data on marine species is underway through the Ocean Biogeographic Information System portal (www.iobis.org). However, many users are only interested in particular habitats, such as coral reefs, sea grass beds, seashores, estuaries or seamounts. Others may want to know where certain habitats occur or how much of a habitat exists in an area. To provide ecological context to marine species distribution data, OBIS needs to develop a system for exchanging data on marine habitats. The present overlays of global bathymetry, sea surface temperature, salinity, and other environmental data may have a role in mapping marine habitats. However, ground truth data associated with the species being mapped will provide the greatest accuracy. Another approach may be to relate every species or higher taxonomic group to a certain habitat; however, this will need some research to deal with different habitats for adults and larvae, how to deal with species that are exceptions within their genus or family, and perhaps other factors. The exchange of marine habitat data would be facilitated if the (word or code used to) name of a habitat automatically informed the database as to its position in the hierarchy unambiguously. This is analogous to being able to tell from a species name what family, order, class and phylum it belongs to.

Standards

Both research and environmental management benefit from the availability of standardised marine habitat classifications because alternative terminologies will be minimised, dictionaries (or glossaries) of terms available, and relationships between concepts apparent. This simpler and better definition of words used to describe and label marine habitats should improve communication between scientists and end-users, and reduce jargon.

Reflecting its earlier origins and regulatory requirements, the EUNIS system is the best developed system. It is part of the EU regulatory framework for protecting marine biodiversity, such that certain habitats may be given special protection in a comparable way to listing threatened species. It is also easily accessible on the internet, and more detailed and comprehensive descriptions of its components are available from the UK Joint Nature Conservation Committee (JNCC) website. The upper levels of the classification are stable. The lower levels are called “biotopes”, namely a community of species associated with a particular habitat; where a habitat is the physical environment (including rocks, sediments, biogenic structures like reefs, salinity, etc.). One present (BioMar Ireland) and several future (from UK) OBIS data sources will be searchable using this habitat classification. The classification evolves as required, with additions of new biotopes when justified (in a similar way to describing species and adding them to a checklist).

While the upper levels of the classification may be most applicable globally, the lower biotope levels are necessary to connect to the species present. Like species, many biotopes will occur in several national and regional areas, and thus users will benefit from information being shared internationally. The NatureServe-NOAA classification is complex at the upper levels, and not a simple hierarchy. This complexity reflects the inclusive nature of its development and recognition that rationalisation may be possible following its application. It also includes several concepts that it may be useful to separate.

Requirements

The requirements of a global marine habitat classification may thus be listed in the following order of importance:

1. Facilitate data and information exchange and interoperability.
2. Comprehensive glossary of terminology.
3. Be hierarchical.
4. Enable capture of marine habitat information from existing OBIS Data Sources.
5. Enable capture of marine habitat information from potential OBIS Data Sources.
6. Relevance to end-users, including conservation, fisheries, researchers, educators.
7. Use simpler terms and avoid jargon.
8. Be consistent with existing use of terminology in marine ecology.
9. Be possible to relate to existing marine habitat classifications.

From the onset it should be recognised that few data managers will edit their databases to match a new recommended classification. Similarly, few museums rewrite the labels of specimens in their collections when species names change. Thus a translator between terminology may be required as part of the interoperability process. This could be based at the recipient portal, such that any unrecognised terms would be noticed and sent to experts for classification. OBIS is taking the lead on benthic habitats in the Marine Metadata Initiative (MMI) (www.marinemetadata.org). MMI brings experts together who special software tools to develop ontologies (relationships between words) that assist data searching and retrieval. This activity requires collaboration between experts in ontology development (typically library informatics), and domain experts (such as ecologists).

Concepts for a marine habitat classification

A global marine habitat classification needs to include benthic and pelagic environments from the intertidal to the deep sea. The development and trial application of the NatureServe classification (Madden and Grossman 2004) did consider this scope, and while the MNCR-BioMar classification was limited to the benthic near-shore (coastal) environment its application in EUNIS includes open water "habitats". The development of these USA and EU systems reviewed and built on previous approaches which were narrower in scope (Hiscock 1991, Madden and Grossman 2004). Both recognised the distinction between large regions (e.g. Atlantic and Mediterranean), physiographic features and biologically defined habitats. The EU system then focused on the latter whereas all three concepts are covered by the NatureServe classification. To these a fourth concept is proposed here because it involves commonly used terminology for groups of species that occur in certain habitats (Table 1). Note that within each concept there may be a hierarchical classification and independent sub-concepts. For example, depth and seabed type (e.g. sand, mud) are different parameters but are included in biotope definitions, and the European classification places depth zone as a higher level in the hierarchy than seabed types. Within seascapes, "estuaries" may be placed at a lower level in the hierarchy than "coastal" features. So hierarchical relationships do not imply that lower levels are unique subsets of higher levels as a taxonomic hierarchy does.

Table 1. Comparison of how four aspects associated with marine habitats are defined and the sampling methods used to collect information about them.

Concept	Defined by	Sampling method
Region	Expert opinion based on biogeography, oceanography and practical management area	Only sampled as seascapes or habitats
Seascape	Physiographic features and hydrography	Acoustic mapping, aerial photography, spectrophotometric sensing
Biotope *	Biology (characteristic species)	Visual observation, photography, sediment or water samples
Taxon group	Habitat, body size	As for biotopes

* = association of a habitat and community of species.

Regions

Several authors have suggested classifying the world oceans into major regions. A physical classification of the oceans is widely used; it includes littoral, sublittoral, continental shelf, slope, rise, plain, bathyal, abyssal, hadal. However, definitions of the depth limits of these zones can vary and biological definitions as used for coastal zonation (e.g. supralittoral, eulittoral, infralittoral) may be more useful. Further analysis of offshore zones may identify characteristic communities that provide biological definitions. The water column may be devided into nearshore (neritic, coastal) and offshore or oceanic water masses. As with depth zones, it is not possible to define these in kilometres, and biologically based definitions may be more valuable.

Zones on rocky seashores are not defined in metres because it is well-known that the limits of the zones vary with tidal range and wave exposure. The infralittoral zone is defined as the sublittoral area dominated by seaweeds, and its depth varies with water clarity. Similarly, it may be expected that the depth ranges of deeper sublittoral communities will vary according to light penetration, sea temperature and other factors. In the absence of practical biological definitions of deep-sea communities it is recommended that offshore regions be classified simply as depth zones without inferring any biological significance.

Marine biogeographic regions (e.g. Ekman 1953, Briggs 1974), pelagic regions (Longhurst 1998) have been combined in world “Bioregions” by IUCN, and WWF uses similar “Ecoregions”. How these correspond to NatureServe’s “Ecological Regions” remains to be determined. Other global organisations have well established global regions, such as FAO, ICES, and UNEP (Large Marine Ecosystems) have other regions. Individual countries may have their own regions based on practical biogeographic and/or political boundaries (e.g. Australia). Most of these regions have been developed for practical (data) management purposes and with varying oceanographic and biological justification, but are already in use. Each may be applied as a series of polygons in a similar way to Exclusive Economic Zones (EEZ) for countries.

Seascapes

The term seascapes has been used to refer to underwater landscapes defined by their physiographic features. Examples include estuaries, seamounts, fjords, canyons, lagoons. Their occurrence can be identified from coastline shape and bathymetric data. The NatureServe classification refers to these as geoforms and macrohabitats.

It is also possible to define water column (pelagic) “seascapes” by their hydrographic features, including fronts, pycnoclines, salinity and temperature characteristics. The NatureServe classification refers to these as regimes, systems and hydroforms.

A particular seascape may occur in all or a few of the global marine “regions” and thus no simple (uni-directional) hierarchical relationship can be applied. Because seascapes are defined using physical features, they are distinct from regions (defined by a mix of geographic, biological, and/or political boundaries), and habitats (defined by species present). A separate classification and dictionary of seascapes is thus necessary, and would include levels 2 (regime), 3 (system), 4 (hydroform/geoform), 5 (zone), and 6 (macrohabitats) of the NatureServe classification. Trials in using this classification found the same data defined these levels, indicating that they form the same concept.

Habitats and biotopes

The separation of benthic marine habitats by vertical zonation, substrata, and for rocky seashores by wave exposure, are well established in the scientific literature. They form the upper levels of the marine habitat classification in MCNR-BioMar, and level 7 (habitat) in NatureServe’s. All classifications aim to provide a basis for defining communities associated with particular habitats (i.e. biotopes). The lowest levels of a benthic marine, or pelagic, classification would thus be a distinct group of species know to occur under specified environmental conditions in different places. It does not need to be stable in time, and may change with for example, season or successional events. The middle levels of a hierarchy may be arranged in different ways, and the time is ripe to see if the merits of any differences between the NOAA-NatureServe and EUNIS systems outweigh the benefits of having more congruent classifications.

Oceanographers have long defined water masses by characteristic species, and although neither the NatureServe nor EUNIS classifications presently define water column biotopes this may be possible. Such analysis may find that these are synonymous with open water seascapes.

Taxon groups

Marine animals and plants are commonly grouped according to where they live and their body size, largely reflecting the sampling methods used and sub-disciplines in ecology. For example, in the water column there are pico-, phyto-, zoo-, mero-, and holo-plankton, and nekton. On the seabed there are macro-, meio-, epi- and in- fauna; as well as microphytobenthos, and epibiota. Near the seabed occur demersal (benthopelagic or hyperbenthic) species, and parasites use other species as habitats. Major groups of organisms can be related to these concepts, and most species can be classified into these categories. Clearly these are useful concepts in ecology and can provide a connection from the habitat to taxonomy without needing information on other species in the assemblage.

Four key concepts

Both (1) regions, (2) seascapes, (3) habitats and biotopes, and (4) taxon groups may have hierarchical classifications with them. However, it is suggested that these concepts should be kept separate in a global habitat classification because it is not practical to nest them within each other. For example any combination of biotopes may occur in a seascape, and any combination of seascapes in a region. A more limited variety of taxon groups may occur in a biotope, depending on the biotope concerned. If regions have been distinguished biogeographically, then each should have its own unique set of biotopes. It remains to be determined whether this will be the case.

Next steps (not necessarily as part of this project)

1. Modify if required, and then agree, rationale above.
2. Agree on classification requirements and priorities.
3. Review global and regional “regions” (IUCN, WWF, NatureServe, Australia, New Zealand, other?) to see how many will need to be used (e.g. as separate polygon layers).
4. See how MNCR-BioMar (EUNIS) and NatureServe-NOAA systems match requirements.
5. Develop dictionary.
6. Adopt a common set of recommended standards for the glossary and classification.
7. Design how these will fit into the OBIS schema.
8. Expand OBIS schema to include habitat fields.
9. Enable data exchange using recommended standards.
10. Develop translators (ontologies) to enable exchange of data using other terminology and classifications.
11. Label taxa in OBIS hierarchy by habitat where possible.

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