CHAPTER 3

BIOLOGICAL VALUATION: GUIDELINES FOR A TRANSPARANT AND GENERALLY APPLICABLE PROTOCOL FOR THE MARINE ENVIRONMENT

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Abstract

Policy makers and marine managers request reliable and meaningful biological baseline maps to be able to make well-deliberated choices concerning sustainable use and conservation in the marine environment. Biological valuation maps aim at the compilation of all available biological and ecological information for a selected study area and allocate an integrated biological value to subzones. They can therefore be used as baseline maps for future spatial planning at sea. This paper gives guidelines on the practical application of the concept of marine biological valuation to a study area. All steps in the valuation protocol are described, starting from the selection of the valuation criteria over the determination of the appropriate assessment questions and practical algorithms to evaluate the criteria to the final scoring of all assessment questions. The marine biological valuation protocol is illustrated using a hypothetical study area.

Keywords: marine biological valuation, practical protocol, valuation criteria, assessment questions, scoring

Introduction

The continuously increasing socio-economic interest in marine resources and space urges the need for a decision-making framework to allocate objectively the different use functions at sea and to manage them in a sustainable way (Agardy, 1997, 1999; Tunesi & Diviacco, 1993). Policy makers therefore request clear and simple baseline maps in order to allow them to make well-deliberated policy choices (Hiscock *et al.*, 2003). Usage maps can be used to detect conflicts in the spatial distribution of human activities, whereas sedimentology and hydrodynamical maps allow the identification of suitable locations for new developments (e.g. aggregate extraction, dumping of dredged material, siting of windmill farms,…). Similarly, biological valuation maps (BVMs), compiling and summarizing relevant biological and ecological information for an area and differentiating between the intrinsic biological values of subzones within the study area, deliver indispensable information during spatial planning activities as has been demonstrated by the terrestrial BVMs in the past (e.g. in Belgium: De Blust, 1985, 1994). As such, the maps provide a useful “intelligence system” for managers and decision makers, indicating which biologically highly valuable subzones preferably to avoid when planning new developments. When such integrated biological information is lacking decision makers usually rely on the expert judgement of scientists, but such Delphic approach is rather subjective and lacks transparency which does not permit defensible, long-term recommendations (Ray, 1999; Roberts *et al.*, 2003b).

Based on a thorough literature review, Derous *et al.* (2007, in press) developed a generally applicable and transparent concept for marine biological valuation by selecting the most suitable valuation criteria (rarity and aggregation-fitness consequences). These criteria are applied to all the components of biodiversity and at two different scales (local and ecoregional scale), which should allow an objective and comprehensive biological valuation of a marine area. Marine biological valuation was defined as the determination of the value of the marine environment from a nature conservation perspective. As such, marine biological valuation aims at providing an integrated view on nature’s intrinsic value (i.e. without any reference to anthropogenic use), as opposed to socio-economic valuation aiming at the quantification of the goods and services provided by marine biodiversity (Beaumont *et al.*, 2007).

Figure 1 gives an overview of the concept of marine biological valuation as described by Derous *et al.* (2007, in press).

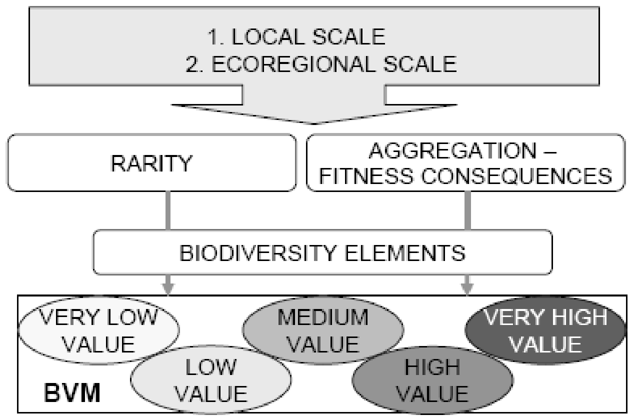

Figure 1: The concept of marine biological valuation (Derous *et al.*, 2007, in press).

The protocol for biological valuation can be designed with different levels of flexibility. The most flexible approach for biological valuation is the Delphic approach where a panel of experts is consulted to determine the value of the subzones within the area under consideration. Although this method is relatively straightforward (Roberts *et al.*, 2003b), the uncertainty and subjectivity associated with such valuation is very high. The protocol described in this paper goes beyond the use of expert judgement and provides a more objective method for biological valuation with clear guidelines. As shown in Figure 2, these guidelines can still vary according to the valuation protocol used.

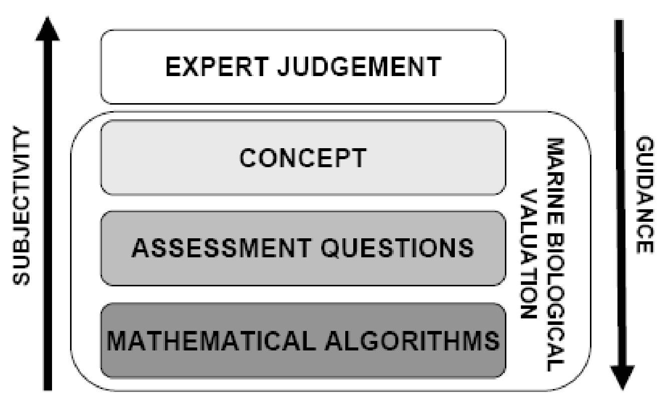

Figure 2: Different levels of complexity associated with the protocol for marine biological valuation.

The flexibility of the protocol decreases when assessment questions are linked to the valuation concept and the protocol reaches full-guidance when mathematical algorithms are determined to apply the assessment questions to a study area. Figure 2 indicates that the objectivity of the protocol increases with decreasing flexibility.

Several authors (Brody, 1998; Gilman, 2002; OSPAR, 2003; Derous *et al*., 2007) only provide a concept for biological valuation (i.e. valuation criteria which should be considered), without determining the practical methodology to apply them. This still introduces a lot of subjectivity in the protocol and could lead to different results when different users apply this concept to the same data.

Here, the concept defined by Derous *et al.* (2007) is translated and assessment questions are determined around the selected valuation criteria. These assessment questions, relating the valuation criteria to the different organizational levels of biodiversity, provide a comprehensive framework to determine the values of the subzones, but still allow some creativity by leaving it up to the valuator how to assess these questions.

The most objective valuation protocol sets clear mathematical algorithms for the interpretation of the assessment questions which can be applied to the biological datasets of the study area. Several examples of such algorithms are given below.

This paper aims at developing a generic biological valuation protocol based on the above mentioned valuation criteria. Marine BVMs need to make best use of available datasets, compiling and summarizing the biological and ecological information available for the area, and allocating an overall biological value to the different subzones. A marine BVM is an indispensable tool to make objective and scientifically-sound policy recommendations.

Developing a protocol around the concept of biological valuation

A. Concept of marine biological valuation

The two valuation criteria used in the biological valuation concept developed by Derous *et al.* (2007, in press) are ‘rarity’ and ‘aggregation/fitness consequences’, which are respectively defined as:

> *Rarity: the degree to which an area is characterized by unique, rare or distinct features (landscapes/habitats/communities/species/ecological functions/geomorphological and/or hydrological characteristics) for which no alternatives exist*, and

> *Aggregation/fitness consequences: the degree to which a subzone is a site where most individuals of a species are aggregated for some part of the year or a site which most individuals use for some important function in their life history or a site where some structural property or ecological process occurs with exceptionally high density either/or the degree to which a subzone is a site where the activity(ies) undertaken make a vital contribution to the fitness (= increased survival or reproduction) of the population or species present.*

These criteria were selected after a literature review of existing ecological criteria. While taking maximum profit of existing initiatives, Derous *et al.* (2007, in press) developed a concept to integrate the criteria towards a standarized protocol.

As visualised in figure 1, the biological valuation of a study area should be done at two different scales, first at the local (study area) scale and secondly at a broader, (eco)regional scale. This will allow putting the results at the local scale in a broader perspective, i.e. to see whether subzones scoring high at the local scale valuation are still highly valuable at the regional scale (Derous *et al.*, in press).

B. Subdividing the study area in subzones

Before the assessment of the biological and ecological value of a study area can be carried out, a division of the area into subzones (also called eco-units: Zacharias & Howes, 1998) is needed. This division should preferably be ecologically and physically meaningful (Laffoley *et al.*, 2000) and practical, allowing the comparison of the biological value between defined subzones.

Different methods to classify a study area into subzones (i.e. zoning) were proposed in literature: marine biogeographical classifications can be done in several ways and at different scales (i.e. global, regional, provincial and local scale). Ideally, classification schemes that separate a study area into biogeographically similar subzones, that can then be meaningfully compared should be used (Ray, 1984), but ecologically meaningful classifications at smaller scales (e.g. within one biogeographical region) could be suitable as well. Due to the lack of distinct biogeographical boundaries at sea, there are still no generally accepted marine biogeographical classification schemes (Lourie & Vincent, 2004). At a more local scale, a detailed, hierarchical habitat classification scheme has been developed for the benthic environment in the UK, based on a combination of physical habitat data and detailed biological data (Connor *et al.*, 2004), but this classification scheme is only suitable for inshore areas with high data availability. Most marine classification schemes, however, are more broad-scale (regional/provincial), using characteristics of the local abiotic environment such as sediment characteristics, morphological features of the seabed, and water circulation, to subdivide the marine environment (Tunesi & Diviacco, 1993; Rachor & Günther, 2001; Bax & Williams, 2001; Roff *et al.*, 2003; Golding *et al.*, 2004). Ideally, both bottom habitat features and pelagic features should be incorporated into a classification scheme, because biological valuation should be done for both layers within the ecosystem (Roff *et al.*, 2003; Breeze, 2004). Such a broad-scale, physical habitat classification is based on features that are relatively easily mapped and managed, especially in data-poor situations, typical for many marine environments (Bax & Williams, 2001). Since the distribution of marine biota, and especially of macrobenthos, mirrors well the distribution of these features, this kind of division will be biologically meaningful (Rachor & Günther, 2001; Golding *et al.,* 2004). However, small-scaled conservation actions will still need a more detailed classification scheme, like the UK habitat classification scheme (Connor *et al.*, 2004), to be effective.

For the purpose of marine biological valuation a division of the study area in subzones according to a habitat classification seems most appropriate, because biogeographical classifications do not allow fine-scaled valuations and local biotope classifications demand more data to be available. If such habitat classification is impossible due to data unavailability, the study area can be divided into subzones by simply placing a raster on the map of the study area, where each grid cell represents a different subzone. In this case, care should be taken that the size of the grid cells is ecologically meaningful for the ecosystem component under consideration. For highly mobile seabirds for instance it could be advisable to use 3x3 km grid cells, while smaller grid cells of 250x250 m could be more advisable for the less mobile benthos.

C. Available data and reliability of information

Despite extensive lists of ecological criteria on value, as presented in the concept for marine biological valuation (Derous *et al.*, 2007), the majority of such criteria cannot be applied, due either to the lack of available data and/or to the urgent (usually political) need to select valuable areas (Rachor & Günther, 2001). Most efforts for the identification of valuable marine areas are hence initiated at the ecosystem level, with particular emphasis on the structuring physical parameters (e.g. bottom topography, wave exposure, depth, and substrate type), because these are the most easily observed features in marine environments and are usually well documented in large and more often full coverage databases, which does not hold true for biological population or community structures (e.g. indicator species, species diversity, community information, etc.) (Zacharias & Roff, 2001). Before the actual biological valuation of the subzones within a study area can be done, it is however necessary to collect a maximum of biological and ecological data in a database and to assign the data to the different selected subzones. Data can be clustered according to the ecosystem component (e.g. seabirds, epibenthos, phytoplankton,…) they belong to. Marine biological valuation is thus based on an integration of all available data, which is a major advantage of the methodology compared to earlier expert judgement based valuations.

While assessing each subzone, it will become obvious that there is a great deal of information for some parts of the study area and very little or none for others. It is important to recognize the different levels of data availability in interpreting the results for each subzone. Data availability can be expressed in different ways (the number of replicates per subzone, the number of sampling stations or tracks per subzone or the number of observations per subzone), depending on the ecosystem component and the type of data that the measure relates to. Attaching such data availability label to the BVMs can give a first estimate of the reliability of the values of the subzones (Breeze, 2004). Another way of reflecting the reliability of the values, mentioned on the map, is to indicate how many assessment questions (see further) could be answered given the data available for each subzone. The more assessment questions that can be answered for a subzone, the more reliable the value of this subzone will be as the value will be based on a broader variety of data. This kind of reliability is called "reliability of information" here (see table 3 and figure 3). These reliability labels should be consulted simultaneously while using the BVMs. The reliability labels also help to identify knowledge gaps, which could direct scientific research in the future.

BVMs should not be seen as unchangeable, rigid, and fully explanatory maps depicting the relative intrinsic value of subzones. A detailed database, covering all data and information used for the value assessment, should be attached to the maps, and this should be consulted whenever the maps are used to guide advice or when used as a warning system in management decisions. It should be noted that a BVM gives the relative values of different subzones given the available data at that time. This requires that BVMs need to be revised on a regular basis to meet the dynamics of the marine ecosystem (e.g. climate change effects) and whenever new relevant data become available (e.g. on other ecosystem components).

D. Assessment questions

As suggested by Derous *et al.* (2007), as many ecosystem components as possible should be included in the biological valuation of a study area. Although the concept of biodiversity is not treated as a valuation criterion, it still overarches the biological valuation concept by assessing all other selected valuation criteria on all levels of biodiversity (as far as biological data are available for doing this). Zacharias and Roff (2000) visualised the various components of biodiversity in their ‘marine ecological framework’ (going from the species to the ecosystem level and including both biodiversity structures and processes). Their framework was further developed, including more components of structure and process/functions at the different levels. Another level which could be included in this scheme is the genetic level. However, in most of the world’s marine environments, genetic diversity is poorly understood (Attrill *et al.*, 1996; Roberts *et al.*, 2003a, 2003b) and, although being acknowledged to be important, the genetic structures and processes are therefore excluded from this valuation protocol for practical reasons.

By answering a set of possible assessment questions, related to the different structures and processes of biodiversity and coupled to the proposed valuation criteria, all aspects linked to biological and ecological valuation are visualized (see Table 1).

This question-driven approach is similar to that used by Smith and Theberge (1986) to evaluate natural areas according to a set of criteria. Detailed questions about structures and processes of biodiversity can lead to a more objective valuation, because experts could otherwise score a criterion from their own individual perspective and comparison among valuations would be difficult. When applying this framework to a given study area, experts are forced to select the appropriate questions by examining the available data and the presence of certain processes and structures in the area.

Table 1: Assessment questions relating the valuation criteria to the different organizational levels of biodiversity.

Organizational level of biodiversity	Valuation criteria	
	Rarity	Aggregation-Fitness consequences
Species/ population level – structure	- Is the subzone characterised by many **rare species**? - Is the subzone characterized by high abundances of **rare species**? - Are there habitats formed by **keystone species** present in the subzone? - Are there certain **indicator species** or **indicator conditions** present in the subzone? - Is the abundance of an **umbrella species** high in the subzone? - Are there ecologically significant **(keystone) species** with a controlling influence on other species present in the subzone?	- Is a **high percentage of a species population** located within the subzone? - Is the **abundance** of a certain species very high in the subzone (= is there a concentration/ aggregation of the species in the subzone)? - Is the subzone characterised by **high counts of many species**? - Is a **species** (with an otherwise restricted **distribution** within the study area) present in high densities within the subzone? - Is the abundance of **focal species** (as a surrogate for biodiversity in general?) high in the subzone?
Species/ population level – processes	- Is the species **retention** high in the subzone?	- Are there important **migration routes** for certain species located within the subzone? - Are there sites present in the subzone that provide **refuge** during adverse conditions? - Are there **wintering/resting/ feeding sites** located in the subzone? - Are there critical (key) **sites for reproduction (spawning/breeding)** present in the subzone? - Are there critical (key) **sites for recruitment (nursery/rearing)** present in the subzone?
Community level – structure	- Are there **distinctive/unique communities** present in the subzone (with respect to their species richness and abundance)? - Are there **endemic species** present in the subzone? - Are there unique **biomes** present in the subzone? - Is there a high level of ecological **heterogeneity** present in the subzone?	- Is the **species richness** in the subzone high? - Are there species living in **symbiosis** with each other present in the subzone? - Is the total **biomass** high in the subzone?
Community level – processes		- Are there species living in **mutualism** with each other present in the subzone? - Is the natural **productivity** in the subzone high?
Ecosystem level – structure	- Is the subzone characterized by a **complex topography** or **seabed morphology**? - Is the **substrate diversity** in the subzone high? - Is the subzone an outstanding example representing **significant geological processes** in the development of landforms? - Are there **distinctive/unique ecosystems** located in the subzone? - Are there subzones present which are critical for **nutrient cycling**? - Are there any **unique/distinctive oceanographic features** (with respect to temperature, salinity, stratification, anoxia, natural boundaries,…) located in the subzone?	- Are there oceanographic features located in the subzone, which are causing species to aggregate (e.g. **natural refugia**)?
Ecosystem level – processes	- Are there **upwelling** sites located in the subzone? - Are there any **unique/distinctive oceanographic processes** located in the subzone (e.g. unique tidal systems, gyres, entrainment, natural erosion and deposition, other natural disturbance…)?	- Are there oceanographic processes occurring in the subzone, which are causing species to aggregate (e.g. **nutrient retention**, **upwelling**,…)?

E. Mathematical algorithms

When all biological and ecological data of a study area are collected the different subzones of that study area can be valuated by selecting the applicable assessment questions from table

1. By developing specific algorithms for each assessment question the value of the subzones can be quantitatively assessed relatively to each other. Examples of such mathematical algorithms are given for several ecosystem components in Table 2.

Similar algorithms can be defined for the other assessment questions mentioned in table 1. Such algorithms can be developed for different types of data, ranging from presence/absence data to detailed density or biomass data. The more detailed and abundant the available data are, the more assessment questions can be answered, which will increase the reliability of the valuation (see further). But even simple presence/absence data will allow the application of some algorithms, for instance the ones dealing with species richness and rare or ecologically significant species. Also maps, giving information on spawning or nursery areas of certain species, can be incorporated in the protocol, by indicating the overlap of these areas with the selected subzones. Several subzones will be completely covered by the spawning or nursery area, while others will not or only partially be covered. The percentage of coverage can then be used to construct value classes for these assessment questions.

Table 2: Examples of algorithms which can be used to apply the assessment questions to data of different ecosystem components. If there are no data available for a certain subzone within a study area, this subzone is labeled "NA" and is not incorporated when the algorithm is applied.

	Assessment question (criterion)	Algorithm
Seabirds	High counts of many species (A-F)	1. Determine the species which are regularly occurring in your study area (i.e. species occurring in more than 5 % of the subzones). This is done to exclude rare species from the species list. 2. Determine the average density of every regularly occurring seabird species per subzone. 3. Create 5 density classes with values from 1 to 5, based on the range of the densities. 4. Assign values to data for all species and sum the values in every subzone. 5. Divide the resulting summed values again in 5 classes, based on the range of the summed values.
Macrobenthos	Habitats formed by keystone species (R)	1. Select habitat structuring species from species list (e.g. *Lanice conchilega* is a tubeworm occurring on the Belgian Continental Shelf, which is known to build small reefs on the seabed. These reefs give structure to the habitat, which attracts other species). 2. Create 5 density classes for this species with values between 1 and 5, using the density range. 3. If there are several habitat structuring species present in the study area, then create different density classes for each species separately and average the values afterwards.
	Distinctive/ unique communities (R)	1. Determine the different macrobenthic communities in the study area and calculate the average species richness (#sp/m²) and density (ind/m²) for each community (= $SPR(comm_x)_{avg}$, $DENS(comm_x)_{avg}$). 2. Determine the average species richness and density occurring in the whole study area (= SPR_{avg} and $DENS_{avg}$). 3. Calculate the ratios $SPR(comm_x)_{avg}/SPR_{avg}$ and $DENS(comm_x)_{avg}/DENS_{avg}$ for every community. 4. Multiplying the 2 ratios of each community gives unique values which can be divided into 5 value classes based on their range. 5. Assign these values to each subzone according to the community that was characterized in this subzone.
Epibenthos	High species richness (A-F)	1. Determine the epibenthic species richness of each subzone. 2. Create 5 species richness classes with values from 1 to 5, based on the range of the species richness. Assign the corresponding value to the different subzones.
Hyperbenthos	Ecologically significant species (A-F)	1. Select ecologically significant species from species list. Such species could be species which constitute important food sources of certain seabirds (e.g. *Mesopodopsis slabberi* in the coastal zone of the Belgian Continental Shelf) or species which are important for recruitment of fish stocks (e.g. fish larvae on the Belgian Continental Shelf). 2. Create 5 density classes for this species with values from 1 to 5, based on the range of the densities. 3. If there are several ecologically significant species present in the study area, then create different density classes for each species separately and average the values afterwards.
Ecosystem processes	Upwelling sites (R)	1. Determine the percentage coverage of upwelling sites in each subzone. 2. Create 5 coverage classes with values from 1 to 5, based on the range of the coverage. Assign the corresponding value to the different subzones.

F. Scoring

When evaluating subzones with the selected criteria, a scoring system needs to be applied. Due to the inherent complexity of marine ecosystems and unavailability of detailed biological data, quantitative scoring is often impossible and the subzones are weighted qualitatively against each other (Levings & Jamieson, 1999; Breeze, 2004). An alternative is to work with a semi-quantitative scoring system (i.e. ranking subzones in categories of high, medium or low value), a method that could even be used when data are incomplete and expert judgement is used to complete the information (Croom & Crosby, 1998 (cited in Brody, 1998); Levings & Jamieson, 1999; WWF, 2000; Breeze, 2004). One thing that should be noted is that there could be problems with scoring systems if the amount of information for each subzone is not equal, because the ranking scheme may undervalue unique features for which little is known and overvalue features or processes for which a lot of information is available (Breeze, 2004). This bias should be recognised and could be reflected by the reliability labels attached to the BVMs. A semi-quantitative scoring system was also used in the development of the terrestrial BVMs of Belgium (De Blust *et al*., 1985; 1994). Although the inclusion of expert judgement in a semi-quantitative scoring system makes the valuation process less objective, it could also be the only possible scoring system in marine environments, where full-coverage biological data are lacking. Hockey and Branch (1997) suggested that the scoring system should be kept as flexible as possible so that it can be modified to be more sensitive or emphasize particular objectives if there are substantiated biological reasons for doing so. However, chosing such flexible scoring system would hamper the objectivity of the valuation process.

Other authors have used mathematical selection methods, like SITES and MARXAN to score the criteria for a certain study area (Freitag *et al.*, 1997; Pressey *et al.*, 1996, 1997; Ardron *et al.*, 2002; Gladstone, 2002; McDonnell *et al.*, 2002; Stewart and Possingham, 2002; Beger *et al.*, 2003; Roberts *et al.*, 2003b; Breeze, 2004, Lieberknecht *et al*., 2004). Because these methods require quantitative biological data for every evaluated subzone, they will not be applicable in every marine environment.

In the proposed scoring system (Table 3), all ecosystem components are first valuated separately by summing the scores for the used assessment questions. The total biological value of the subzones is determined by averaging the values for the different ecosystem components. Each assessment question has an equal weight in the total score. When the values of certain subzones cannot be determined for an ecosystem component (due to a lack of data for these subzones), then the total biological value of these subzones should be determined by only taking into account the values that are available for the other ecosystem components. Five value classes are used in the proposed scoring system (very low, low, medium, high and very high biological value), because these classes allow a better detection of value patterns without losing too many details.

Other scoring systems could be used to determine the total biological value (e.g. addition or multiplication with weighing factors). The scoring approach, used in the terrestrial biological valuation of Belgium, is to label a subzone with ‘high’ intrinsic value if it scores high on only one criterion (De Blust *et al.,* 1985; 1994). These alternative scoring options are still open for discussion and should be explored in the future.

It seems impossible to set uniform thresholds which would be applicable to all marine ecosystems, so this needs to be done on a case by case basis. When all relevant questions are scored for the different subzones within a study area, all criteria (with respect to all organizational levels of biodiversity) are assessed. This will lead to subzones with different biological and ecological values (e.g. low, medium, high value) and the highly valued subzones can then be considered ‘hotspots’ that reflect the highest biological value within a study area, considering all possible aspects of biodiversity and habitat diversity. Thus, in our approach ‘hotspots’ are seen as subzones which have or are perceived to have ‘more’ intrinsic biological value because of their combinations or greater numbers of biodiversity attributes. This is similar to the hotspot theory of Ray (1999), but extended to the full spectrum of biodiversity attributes. In this way the hotspot approach, based on species richness or rarity, is now coupled to an extended set of other criteria and assessment questions, and the whole framework can be used to assess the intrinsic value of the different subzones within a study area.

Table 3: Example of the proposed scoring system for a hypothetical study area with 6 subzones. The individual scores for every assessment question are also hypothetical and only used to illustrate the scoring process. After each assessment question the criterion it relates to can be found (R=rarity, A-F=aggregation-fitness consequences). When no biological data are available for a certain subzone, this is indicated by NA. The values are given by the following codes (VL=very low, L=low, M=medium, H=high, VH=very high).

		Subzone					
	Assessment question (criterion)	**1**	**2**	**3**	**4**	**5**	**6**
Seabirds	high counts of many species (A-F)	2	5	NA	1	4	1
	high abundance certain species (A-F)	5	4	NA	4	3	2
	high % species population (A-F)	1	4	NA	1	3	1
	high species richness (A-F)	3	4	NA	2	3	2
	Total score (sum)	11	17	NA	8	13	6
	Value for seabirds *(see (*1))*	**M**	**VH**	**NA**	**VL**	**H**	**VL**
Macrobenthos	high counts of many species (A-F)	3	NA	2	NA	4	2
	high abundance certain species (A-F)	2	NA	4	NA	5	3
	presence of rare species (R)	1	NA	5	NA	3	2
	abundance of rare species (R)	2	NA	2	NA	2	2
	habitat formed by keystone species (R)	1	NA	5	NA	3	2
	distinctive/unique communities (R)	2	2	2	1	5	1
	ecologically significant species (R)	2	NA	3	NA	3	2
	high species richness (A-F)	3	NA	4	NA	5	1
	high biomass (A-F)	2	NA	NA	NA	2	NA
	Total score (sum)	18	2	27	1	32	15
	Value for macrobenthos *(see (*1))*	**M**	**VL**	**VH**	**VL**	**VH**	**M**

*(*1) Determination of the value*	**Range of total score (sum)**		**Value classes (numerical)**
	Min	**Max**	
X = (MAX – MIN)/5	MIN	MIN + X	VL (1)
	MIN + X	MIN + 2X	L (2)
	MIN + 2X	MIN + 3X	M (3)
	MIN + 3X	MIN + 4X	H (4)
	MIN + 4X	MAX	VH (5)

	1	**2**	**3**	**4**	**5**	**6**
Value seabirds	M	VH	NA	VL	H	VL
Value macrobenthos	M	VL	VH	VL	VH	M
Average total (numerical) value *(see (*1))*	3	3	5	1	4.5	2
Average total value *(see (*2))*	**M**	**M**	**VH**	**VL**	**VH**	**L**
Data availability for seabirds	H	L	NA	H	H	H
Data availability for macrobenthos	M	L	M	L	H	M
Total #Q answered per subzone (max total #Q = 13)	13	5	8	5	13	12
Reliability of information (in terms of #Q answered) *(see (*3))*	H	L	M	L	H	H

*(*2)Determination of total value (using the numerical equivalents of the intermediate values)*	**Range of average total numerical value**		**Total value**
	Min	**Max**	
	1	1.8	VL
	1.8	2.6	L
	2.6	3.4	M
	3.4	4.2	H
	4.2	5	VH

*(*3) Determination of reliability of information*	**Range of total #Q**		**Reliability level**
	Min	**Max**	
Y = (MAX – MIN)/3	MIN	MIN+Y	L
	MIN+Y	MIN+2Y	M
	MIN+2Y	MAX	H

G. Presentation of BVM

The results of the biological valuation of a study area can now be presented on a map, where each subzone within the area is assigned a colour corresponding with its value. Figure 3 presents a road map for the application of the valuation protocol, which is illustrated here for a hypothetical study area, eventually leading to a BVM for the area. The values given are purely indicative as they are based on the fictive data of Table 3 above. Reliability can be indicated by using different intensities of a colour or other markings.

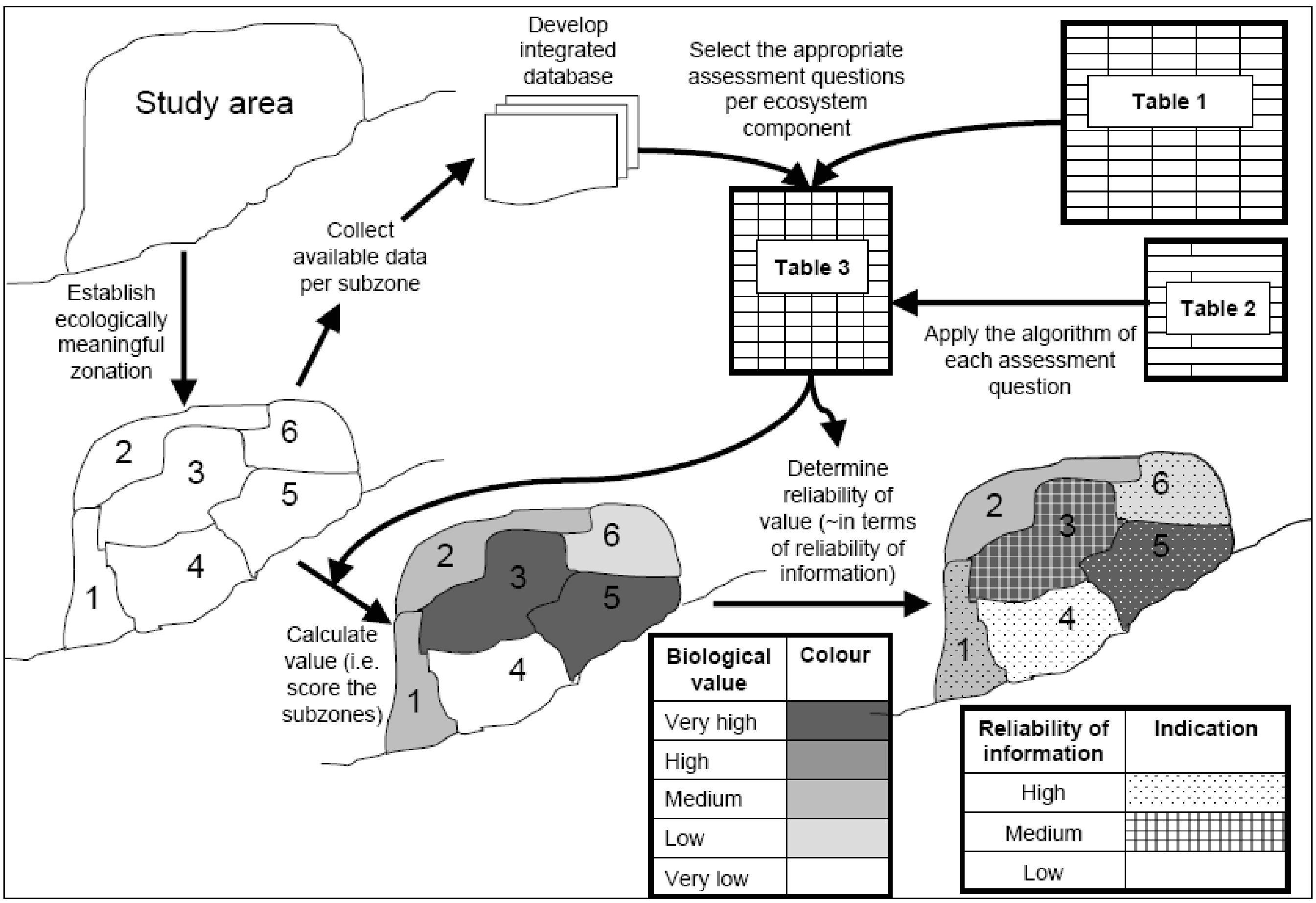

Figure 3: Example of the application of the marine biological valuation protocol to a hypothetical study area with 6 subzones. The values and reliability labels are also hypothetical and only used to illustrate the protocol.

Conclusion: a road map for marine biological valuation

To allow an objective biological valuation of marine areas, generally applicable and transparent guidelines for the practical application of the marine biological valuation concept are needed. After dividing the study area into subzones and collecting the available biological data, the applicable assessment questions should be selected, which relate the valuation criteria to the different organizational levels of biodiversity. To develop a protocol which is as objective as possible, several mathematical algorithms are defined which can be used for the practical application of the assessment questions to an existing biological dataset. This protocol allows assessing the biological value of subzones, relatively to each other, based on the proposed criteria in study areas with various levels of data available.

A major benefit of the proposed marine biological valuation protocol is the fact that all available biological and ecological data are integrated for each subzone, which makes the comparison between subzones easier for the users of the BVMs.

Several scoring systems could be used for this integration and one example is explained in the paper by using fictive values of a hypothetical study area.

The reliability of the assessed intrinsic value should be noted by attaching a label to the different subzones. This label can display the amount and quality of the data used to assess the value of a certain subzone or it can display how many assessment questions could be answered given the data available for each subzone (reliability of information). These reliability labels should be consulted simultaneously while using the BVMs. Next to that, they help to identify knowledge gaps which could direct future scientific research.

The biological valuation protocol, presented here, is developed to be as objective and flexible as possible, which should allow the inclusion of multiple ecosystem components, the use of different levels of data availability and the application to a broad range of marine environments.

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