CHAPTER 4

APPLICATION OF THE PROTOCOL FOR MARINE BIOLOGICAL VALUATION TO SELECTED CASE STUDY AREAS

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Abstract

Marine biological valuation integrates all biological and ecological information that is available for a study area into a relative biological value. The resulting biological valuation map (BVM) is easy to interpret and translates complex scientific data into a tool that can be used by policy makers as a baseline layer for spatial planning at sea. When such BVM is lacking, managers can only trust on the available best expert judgement to include biological aspects into their decisions, a process which lacks transparency and objectivity. The development of an acceptable and practical valuation protocol can only be established when it is iteratively applied to different test cases.

In this paper, three case study areas are biologically valuated: the Belgian part of the North Sea (BPNS), the Isles of Scilly in the UK (IoS) and the Dutch part of the North Sea (DPNS). The paper specifically explores how the methodology deals with different levels of data availability by comparing highly monitored areas like the BPNS with less data rich areas as the BPNS and the IoS. Two types of valuation maps are constructed for the IoS, one based on quantitative data and one on qualitative presence/absence data, to see whether the quality of the data has any impact on the outcome of the valuation.

The final BVMs indicated clear patterns in biological value, with coastal areas harbouring the highest biological value in all case studies. Low data quality and quantity does not seem to hamper the development of preliminary BVMs, although the reliability of these maps is low. Subzone size selection is a crucial step in the valuation protocol and relevance for the ecosystem components under consideration should always be preferred to practical considerations to obtain better valuation coverage of the area.

Despite some weaknesses of the methodology, the availability of BVMs gives the opportunity to answer policy questions related to the biological value of areas in a transparent, objective way.

Keywords: marine biological valuation, Belgian and Dutch part of the North Sea, Isles of Scilly, data quality and quantity, geographical scale

Introduction

The continuously increasing socio-economic interest in marine resources urges the need for a decision making framework to objectively allocate the different user functions in a marine area. This calls for a spatial structure plan, preferentially firmly based on the concept of sustainability, in which biological value should be carefully taken into account. Hiscock *et al.* (2003) advised that biological information should be presented to marine managers in a format that is reliable and meaningful and that translates complex scientific data into an integrated biological value. When such integrated view on the biological value of a marine area is lacking, decision makers can only rely on the available best expert judgement of scientists, but this approach can be biased due to untransparency and subjectivity. Marine biological valuation is a methodology that has been designed to overcome this problem and to summarize complex biological information in an objective and transparent manner. It can be used as a tool to call attention to areas with particularly high ecological or biological significance. It aims at providing an integrated view on nature's intrinsic value, without any reference to anthropogenic use. By determining whether areas have a high, medium or low intrinsic value, it facilitates the provision of a greater-than-usual degree of risk aversion in management of activities in such areas (Derous *et al.*, 2007).

The development of a suitable valuation protocol should be seen as an iterative process. Applying the protocol to different test cases is necessary to increase its acceptability and practical applicability.

This paper investigates how the developed marine biological valuation method performs in different case study areas. The selected case study areas are the Belgian part of the North Sea (BPNS), the Isles of Scilly (IoS) and the Dutch part of the North Sea (DPNS). These case study areas differ in the amount and quality of the available biological value, in the anthropogenic impacts on the marine environment, in the diversity and nature of the occurring habitats and in geographical scale. The fact that these case study areas are so diverse makes them ideal to test the applicability of the protocol.

Methods

The protocol for marine biological valuation was first tested on data from the BPNS, which served as a pilot area to fine-tune the assessment method. For the comparison of the results of the application of the marine biological valuation protocol in different areas, several different case study areas along the European coast have been selected in the framework Theme 3 of the European MarBEF project (European Network of Excellence on Marine Biodiversity and Ecosystem Functioning). The main objective of Theme 3 is to understand the socio-economic, biological and cultural value of marine biodiversity across Europe. Seven case study areas were selected for this exercise, with good geographical distribution across Europe: Flamborough Head area (NE of UK), Pico-Faial Channel (Azores, Portugal), the Belgian-Dutch coast (Belgium-the Netherlands), the Isles of Scilly (SW of UK), the Lister Deep area (Denmark), the Gulf of Gdansk (Poland) and the Svalbard area (Norway). In this paper the results of the biological valuation exercise of three case study areas will be discussed, being the Isles of Scilly, the BPNS and the DPNS.

A. Case study areas

The BPNS is located in the southernmost part of the North Sea and represents about 0.6 % or 3600 km² of the total North Sea surface area. It is a rather shallow area (maximum depth of 46 m) with a complex system of sandbanks and gullies. Based on their orientation and depth, four sandbank systems can be distinguished: Coastal Banks (parallel to the coastline, 0-7 km from coast), Flemish Banks (SW-NE direction, 10-30 km from coast), Zeeland Banks (parallel to coastline, 15-30 km from coast) and Hinder Banks (SW-NE orientation, 35-60 km from coast) (Degraer *et al*., 1999; Van Hoey *et al*., 2004). Strong tidal currents, which run mainly parallel to the coast line, and heavy wave action make it a high energy area resulting in a well-mixed water column and reworking of the sandbank tops. The area receives constant input of fresh water from different rivers (Somme, Canche, Authie, Ijzer, Scheldt, Meuse and Rhine) leading to a gradient from turbid nutrient rich water in the coastal zone to more transparent, nutrient poorer water offshore. The sediment diversity of the BPNS is high due to the complex bathymetry and hydrodynamics, going from very fine silt up to coarse sand. Only few gravel deposits are found in this area (Maes *et al*., 2005; Van Damme *et al*., 2007).

The IoS archipelago is situated 43 km south-west of the western extremity of the Cornish peninsula of the UK (Figure 1). The archipelago consists of five inhabited islands (St. Mary's, St. Martin's, St. Agnes, Bryher and Tresco) and over 300 smaller islands, islets and rocks. It comprises the final decayed stage of the Armorican Mountains and is now the sole European example of a Lusitanian semi-oceanic archipelago (UK Biodiversity Steering Group, 1995). The total area delimited is approximately 95 km². The area is predominantly characterised by west to east ocean currents and an almost total lack of freshwater runoff, resulting in uniform salinity, low turbidity and kelp (*Laminaria ochroleuca*) growing to a depth of 30 metres (Harvey, 1969; Kendall *et al*., 1996). The habitat diversity within the archipelago is high and all habitats occurring in the SW region of the UK are present, except for pure muddy intertidal and subtidal sediments (Marine Nature Conservation Review, 1998). Wave exposure varies from extremely exposed to very sheltered, often within a short distance (Munro & Nunny, 1998). While the BPNS and DPNS are intensively used by man (Anonymous, 2004; Maes *et al*., 2005; IBN, 2005), impacts from human activities in the IoS are minimal. There is no influence from industrial pollution, mining, dumping or dredging and the presence of potentially harmful agricultural runoff is negligible due to strict legislation in the area. The current population is 2057 and this number remains more or less static. There is a small crayfishery targeting crabs and lobsters with pots, large mesh fixed nets and one small (8 meters) trawler. The use of vessels exceeding 10 tonnes gross tonnage or 11 metres overall length for fisheries from within 6 miles around the IoS is prohibited and strictly enforced (Beaumont *et al*., 2007).

The DPNS represents 9.5 % of the total North Sea and has a relative smooth bottom topography. Locally relict glacial deposits are present (e.g. large boulders around the Cleaver Bank) (Anonymous, 2004). Depths vary between 20 and 30 m in the south up to maximum 60 m around the Dogger Bank (most northern part of DPNS). The total area of the DPNS is 57000 km². The Southern Bight, which is the southernmost part of the DPNS, is characterized by strong tidal currents, but current velocities decrease towards the northern part of the DPNS. Residual currents generally run in a north-east direction in the Southern Bight, but have no constant pattern in the north, where they are governed by the speed and direction of the wind. While the Southern Bight water column is well mixed throughout the year, stratification of the water column occurs at the Oyster Ground in summer. The Frisian Front is an area with naturally enhanced primary productivity, resulting in an enriched benthic fauna

and high fish and bird abundances (Camphuysen & Leopold, 1994; Holtmann *et al*., 1996; Arts & Berrevoets, 2005). Several mud patches are found in the DPNS of which some have anthropogenic cause (mud patches close to the coast due to input from rivers and from the Wadden Sea and due to dumping of harbour sludge), while others are natural deposits due to low current velocities in the area (mud patch around Oyster Ground) or were deposited during the last glacial period (Lindeboom et al., 2005; IBN, 2005).
Figure 1 gives an overview of the location of the case study areas which are used for this valuation exercise.

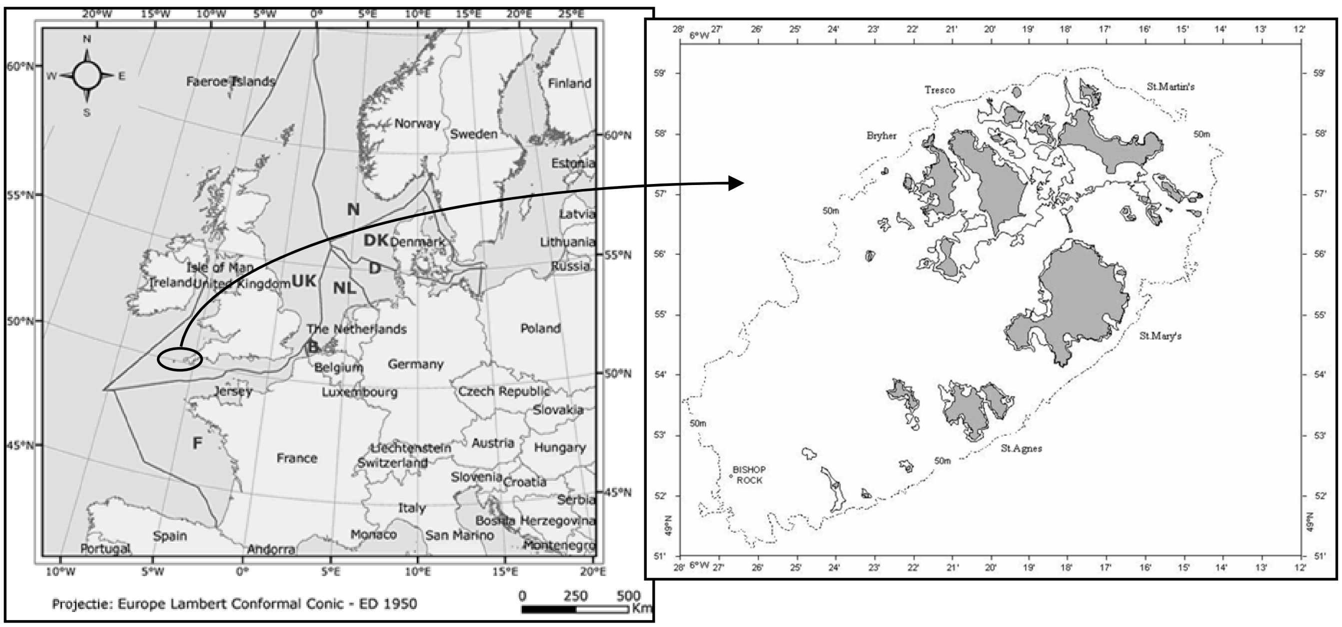

Fig. 1: Map of Europe showing the different case study areas (enlarged area = Isles of Scilly, B: Belgian part of the North Sea, NL: Dutch part of the North Sea).

B. Data availability and data treatment

A marine biological valuation map (BVM) should include and integrate information on all marine ecosystem components for which detailed spatial distribution data are available. For each case study area the amount of available data was investigated and an integrated ACCESS database was made.

The data gathering process revealed that for the BPNS detailed data are primarily available for the macrobenthos and seabirds (macrobenthos: UGent-MACRODAT database; seabirds:

IN database) for which full-coverage maps can be constructed (Table 1). To a lesser extent, but still useful from a valuing perspective, data on the spatial distribution of the demersal fish and the epi- and hyperbenthos exist. For the DPNS detailed data on phytoplankton, zooplankton, macrobenthos, demersal fish, seabirds and sea mammals were available, although the amount of data did not allow the creation of full-coverage BVMs. Data from the Isles of Scilly had to be distilled from literature as no databases existed for this area. This literature search resulted in the compilation of data for algae (both phytoplankton and macroalgae), plants (restricted to *Zostera marina*), macro-, epi-, hyper- and meiobenthos and sea mammals. Next to quantitative abundance data, the largest part of the collected data consisted out of occurrence data (presence/absence). Separate databases were made for abundance data and occurrence data and the benthos species were divided into macro-, epi-, meio- and hyperbenthos groups and into soft or hard substrates habitat groups (Table 1).

Table 1: Available datasets for the biological valuation of the selected case study areas (S: soft substrates, H: hard substrates).

Case study area	Ecosystem component	Available data/literature source	Sampling method	Time period
BPNS	Seabirds	Abundance, species richness	Ship counts	1992-2005
	Macrobenthos	Abundance, species richness, community information	Van Veen grabs	1994-2006
	Epibenthos	Abundance, species richness, biomass	Beamtrawls	1993-2005
	Demersal fish	Abundance, species richness	Beamtrawls	1996-2005
DPNS	Seabirds	Abundance, species richness	Airplane counts	1993-2005
	Macrobenthos	Abundance, species richness, biomass	Reineck boxcores	1991-2005
	Demersal fish	Abudance, species richness, biomass	Beamtrawls	1996-2005
	Phytoplankton	Abundance, species richness	Pump samples	1990-2005
	Zooplankton	Abundance, species richness	Pump samples	2000-2005
	Sea mammals	Abundance, species richness	Airplane counts	1993-2005
IoS	Macrobenthos S Macrobenthos H Epibenthos H Epibenthos S Fish Algae Plants Hyperbenthos Meiobenthos Sea mammals	As some authors give data on several ecosystem components, they are listed alphabetically here: Bishop (1986), Bowden *et al.* (2001), Browne & Vallentin (1904), Dipper (1981a; b), Faubel & Warwick (2005), Foster-Smith (1990), Fowler (1990, 1992), Fowler & Pilley (1991), Hiscock (1984a; b; 1985), Hocking & Tompsett (2002a; b), Holme (1983), Irving (1987), Kendall *et al.* (1996), Munro & Nunny (1998), Norton (1968), Rostron (1983; 1988), Russell (1968), Smith & Gault (1983), Summers (1974).	See literature	See literature

1. Belgian part of the North Sea

Data were provided by the Marine Biology Section of the University of Ghent (macrobenthos), the Research Institute for Nature and Forest (seabirds) and the Institute for Agricultural and Fisheries Research (demersal fish and epibenthos).

During ship-based seabird counts at the BPNS, the standardized strip-transect-method, using 10-minute tracks (Tasker *et al.*, 1984), and the snapshot method (Komdeur *et al*., 1992) were used to count both swimming and flying birds. In order to compensate for missed small and dark birds, the mean density of swimming birds was corrected with an internationally accepted correction factor (Stone *et al*., 1995). The results of these counts were transformed into densities by taking into account the speed of the research vessel. All counts were reduced to the spatial midpoints of the concerned 10-minute tracks. Since ferry counts may result in an underestimation of the densities of certain species (e.g. Alcidae and divers), because of the higher speed and the height of the observation platform, the data collected from ferries were not retained in the processed dataset. For the calculation of species per subzone all counts (including counts from ferries) were used. The seabird database of the BPNS consists of a set of midpoints where densities are known. The observer effort of these data is not evenly distributed over the study area which is due to fixed monitoring routes during the last year and to the fact that some sites are too shallow or too far away to fit in a one-day observing schedule. In order to cover the entire Belgian marine area and to resolve the bias in observer effort, a GIS-aided inter- and extrapolation was performed. To account for confounding effects of within-year fluctuations in densities and distribution of seabirds (some species occur the whole year, others only in winter or during breeding season), an *a priori* selection of the months in which a certain species occurs in the highest densities (at least 25 % of value of month with maximal density) was made. This procedure is based on the idea that the occurrence of a species in a certain density in a certain location is a reflection of the suitability of this location at that time. The final dataset was interpolated for each species separately using the Inverse Distance Weighting method of Spatial Analyst package (ArcGis 9.0). Each 500x500 m grid was given the mean density of the 24 midpoints closest to their centre. For further analysis, these grids were converted into grid cells of 3x3 km (by using the Map Calculator option in Spatial Analyst Extension), which matches best with the mean distance covered by the research vessel (2.98 km) during a 10-minutes track.

Contrary to the avifauna data, in which direct observations almost provide full-coverage information for numerous areas of the BPNS, macrobenthos data should be regarded as point data. Degraer *et al.* (2003) demonstrated that –for instance in the geomorphologically highly diverse Belgian coastal zone – even a dense grid of sampling stations (120 sampling stations in 5x5 km grids) did not allow to spatially extrapolate the macrobenthic community distribution patterns. As an alternative to obtain a full coverage spatial distribution map, a predictive model, based on the close link between the macrobenthic communities and their physical habitat (mud content and median grain size), was set up. Once this model was developed and validated, it enables the extrapolation of the spatial distribution of the habitat suitability for the different macrobenthic communities to the full BPNS. The availability of detailed abiotic habitat information allows for small-scale patchiness within the macrobenthos to be detected. The model takes into account four macrobenthic communities occurring in the BPNS: (1) *Macoma balthica* community, (2) *Abra alba-Mysella bidentata* community (or *Abra alba* community (Van Hoey *et al*., 2005), (3) *Nepthys cirrosa* community and (4) *Ophelia limacina* community (Van Hoey *et al*., 2004). Each community is restricted to a specific habitat, with median grain size and mud content of the sediment being the major structuring physical variables. The predicted habitat suitability of the communities was used in the valuation of macrobenthos next to point data on densities and species richness.

Epibenthos and demersal fish were sampled twice a year (spring and autumn) with a shrimp trawl, equipped with an 8 m beam trawl, a fine meshed net (22 m) and a boll-chain in the groundrope. The duration of each trawl was 30 minutes with an average speed of 3.5 knots (giving an average distance of 3500 m trawled). Density and biomass were standardized to an area of 1000 m², based on the trawled distance and the width of the beam trawl.

2. Dutch part of the North Sea

Data were provided by the RWS National Institute for Coastal and Marine Management (RWS RIKZ) and the Institute for Marine Research and Ecosystem Studies (IMARES).

The seabird and sea mammal datasets were obtained by an aerial counting methodology, by which individuals are counted from an airplane in a track of 100 meters width at a flight height of 150 meters during one minute. Flights are conducted along fixed routes. One complete count exists out of three flights which allows reaching a good coverage of the DPNS. Each count is conducted 6 times per season. The counts were transformed into densities per square kilometer for every species, using the speed, time and width of the track count (Arts & Berrevoets, 2005).

The demersal fish data consisted out of average density per haul (beam trawl), average weight of individuals per haul and an extrapolation of these data as density and weight per 1000 m² was possible by using the characteristics of each haul (transect).

For macrobenthos, microzooplankton and phytoplankton data were available from fixed monitoring stations, which were recurrently sampled during the year mentioned in Table 1.

3. Isles of Scilly

Both quantitative (abundance) and qualitative (occurrence) data were extracted from the literature and two separate databases were constructed to allow the creation of two types of BVMs. The units of abundance from the different literature sources were transformed to have comparable units in the final database. Macro- and epibenthos were divided into species occurring in soft or hard substrate habitats and these were valuated as separate ecosystem components.

C. Dividing the case study areas

The biological valuation protocol suggests that the division of a marine study area in workable subzones, which can be scored relatively to each other, should preferably be done by using a habitat classification system. The size of the grid cells is then ecologically meaningful for the ecosystem component and the area under consideration. However, such habitat classification cannot be performed in the case study areas due to a lack of available habitat data and an appropriate classification system, the division in subzones is done by placing a GIS (Geographic Information System) raster over the map of the case study area so that each grid cell represents a different subzone. The choice of the size of these grid cells should be ecologically meaningful for the ecosystem components under consideration. It is possible to use different grid cell sizes for different ecosystem components, because GIS allows easy transformation of data to smaller or larger grid cells. However, the boundaries of the chosen grid cells should overlap, to allow overlap between grids with different sizes.

The case study areas BPNS and DPNS are delimited by their legal coordinates (Exclusive Economic Zone – EEZ coordinates). The BPNS was divided into 250x250 m grid cells for the valuation of phyto- and zooplankton, macro- and epibenthos and demersal fish and into 3x3 km grid cells for seabirds. To determine the total biological value, values for seabirds and sea mammals in a 3x3 km grid cell are simply taken over in each of its constituent 250x250 m grid cell. The DPNS was divided into subzones according to data distribution (density and distribution of stations) of the different ecosystem components. The area was divided in grid cells of 15x15 km. For the development of the marine BVM of the IoS a rough GIS map depicting the coast lines of the archipelago has been used. The 50 meter depth line was chosen as the boundary for this case study area. The division of this case study area into subzones was done by choosing grid cells of 250x250m. The different grid size choices in the case study areas were made to see which grid sizes can be advised in the future.

The coordinates of each sampling station were included in the database. When no coordinates were available but a map of the stations was included in the literature source (IoS case study area), a procedure in ArcView was followed to acquire the corresponding coordinates. By doing so, data from the sampling stations could be linked to their corresponding subzone (grid cell). When time series or replicate data for the same station were available, these data were averaged before entering them in the database. Also, data from different stations within the same grid cell were averaged to obtain one value per grid cell. Trawl data covering multiple grid cells were treated so that every grid cell that was passed by the trawl got the density or biomass value of the entire trawl.

D. Marine biological valuation protocol

The marine biological valuation protocol as described by Derous *et al.* (submitted) was used to valuate the different case study areas. Subzones are scored at a relative scale against two biological valuation criteria: rarity and aggregation/fitness consequences. The biological valuation of a study area should preferably be done at two different scales, first at the local (study area) scale and secondly at a broader (eco)regional scale (Derous *et al.*, in press). Assessment questions relate the available biological data to the valuation criteria and to a specific organizational level of biodiversity (from the genetic to the ecosystem level, considering both structures and processes, as described by Zacharias & Roff (2000)). By developing specific mathematical algorithms for each assessment question, a quantitative assessment of the datasets becomes possible. When evaluating the subzones, a semi-quantitative scoring system is applied, using value categories of very low, low, medium, high and very high value. The scores for all the assessment questions for an ecosystem component are averaged and this average is divided into five value classes. The total biological value is determined by taking the average of the intermediate 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 the lack of data for these subzones, the total biological value should be determined by only taking into account the values that are available for the other ecosystem components. The results of the biological valuation of the case study areas are presented on marine BVMs. Each subzone within the area is assigned a colour corresponding with its value.

The reliability of the assessed intrinsic value should be noted for each BVM. Such label can either display the amount and quality of the data used to assess the criteria in a certain subzone ("data availability" level) or it displays how many assessment questions could be answered given the data available for each subzone ("information reliability" level). These reliability labels should be consulted simultaneous while using the BVMs. Data availability maps are made by analysing the number of samples taken in each subzone for each ecosystem component. The range in number of samples is sorted into three classes (level 1, level 2 and level 3). The data availability map for the total BVM is constructed by averaging the separate data availability scores for each ecosystem component and reclassifying this range into three classes. Information reliability is only determined for the total BVM by classifying the range of answered assessment questions for each subzone into three classes.

E. Comparison with expert judgement

Another, more subjective and untransparent way of determining the biological value of an area is the use of best expert judgement (Derous *et al.*, 2007; submitted). In this approach a panel of experts on the biological characteristics of an area are asked to determine the value of the subzones of an area based on their personal experience or knowledge. Such exercise was performed for the Isles of Scilly case study area. A panel of five biologists and ecologists, each with their own expertise, was consulted and each of them had to determine these values individually. These maps were then plenary discussed to come to a consensus. Comparison of the expert judgement with the BVMs can also assist in increasing the acceptability of the valuation protocol.

Results

Due to differences in the amount and quality of the available data of each of the case study areas, different sets of assessment questions could be answered (Table 2). For each of these questions mathematical algorithms were developed as described in Derous *et al.* (submitted).

Table 2: Overview of the assessment questions that could be answered per ecosystem component (MaB = macrobenthos, EB = epibenthos, HB = hyperbenthos, MeB: Meiobenthos, F = fish, P = plants, PP = phytoplankton, ZP = zooplankton, AL = algae, SB = seabirds, SM = sea mammals) for the different case study areas (BPNS = Belgian part of the North Sea, DPNS = Dutch part of the North Sea, IoS = Isles of Scilly) and according to the data type (S = soft sediments, H = hard sediments, A = abundance data, O = occurrence data).

Assessment question (R: rarity / A-F: aggregation-fitness consequences)	Case study area – Ecosystem component
Number of rare species (R)	BPNS: MaB / DPNS: MaB / IoS: AL (O), HB (A,O), MaB (S/H,O/A), EB (S/H,O/A), F (O)
Abundance of rare species (R)	BPNS: MaB / DPNS: MaB / IoS: HB (A), MaB (S/H,A), EB (S/H,A)
Presence habitat-forming species (R)	IoS: AL (O), MaB (S/H,O), EB (S/H,O)
Abundance habitat-forming species (R)	BPNS: MaB / DPNS: MaB / IoS: MaB (S/H,A), EB (S/H,A)
Presence ecologically significant species (R)	IoS: AL (O), P (O), MeB (O), HB (O), MaB (S/H,O), EB (H,O), F (O), SM (O)
Abundance ecologically significant species (R)	BPNS: MaB, EB / DPNS: MaB / IoS: P (A), HB (A), MaB (S/H,A), EB (H,A), SM (A)
Distinctive/unique communities (R)	BPNS: MaB
Species richness (A-F)	BPNS: MaB, EB, F, SB / DPNS: MaB, F, SB, SM, ZP, FP / IoS: AL (O), P (O/A), MeB (O), HB (O/A), MaB (S/H,O/A), EB (S/H,O/A), F (O), SM (O/A)
High counts many species (A-F)	BPNS: MaB, EB, F, SB / DPNS: MaB, F, SB, SM, ZP, FP / IoS: P (A), MaB (S/H, A), EB (S/H, A), SM (A)
Abundance certain species (A-F)	BPNS: MaB, EB, F, SB / DPNS: MaB, F, SB, SM, ZP, FP / IoS: P (A), MaB (S/H,A), EB (H,A), SM (A)
Mutualism and/or symbiosis (A-F)	IoS: MaB (S,O/A), EB (H,O)
Highly productive (A-F)	BPNS: EB

Some of these assessment questions relate to specific keystone species, which play an important ecological role in the ecosystem ("ecologically significant species", "habitat-forming species" and "mutualistic or symbiotic species"). The species listed in Table 3 were selected as keystone species for each of the case study areas, based on references from literature.

Table 3: List of keystone species per case study area (MaB = macrobenthos, EB = epibenthos, HB = hyperbenthos, MeB: Meiobenthos, F = fish, P = plants, PP = phytoplankton, ZP = zooplankton, AL = algae, SM = sea mammals, BPNS = Belgian part of the North Sea, DPNS = Dutch part of the North Sea, IoS = Isles of Scilly).

	Ecologically significant species			
	MaB	**EB**	**AL**	**P**
BPNS	*Abra alba* *Spisula subtruncata*	*Crangon crangon*		
DPNS	*Abra alba* *Spisula subtruncata*			
IoS	*Abra alba* *Arenicola sp.* *Atelecyclus rotundatus* *Echinocardium sp.* *Odostomia sp.* *Polinices pulchellus* *Spatangus purpureus*	*Alcyonium digitatum* *Alcyonium glomeratum* *Alcyonium sp.* *Asterias rubens* *Asterina gibbosa* *Astropecten irregularis* *Crossaster papposus* *Echinus esculentus* *Henricia oculata* *Hinia incrassata* *Marthasterias glacialis* *Monodonta lineata* *Psammechinus miliaris*	*Ascophyllum nodosum* *Fucus serratus* *Fucus spiralis* *Fucus vesiculosus* *Pelvetia canaliculata*	*Zostera marina*
	MeB	**HB**	**F**	**SM**
IoS	*Haplogonaria simplex* *Pseudaphanastoma psammophilum* *Simplicomorpha gigantorhabditis*	*Astrorhiza limicola* *Halyphysema tumanowiczii* *Hippolyte varians* *Palaemon serratus* *Pandalus propinquus*	*Ctenolabrus rupestris* *Labrus bergylta* *Labrus bimaculatus* *Pollachius pollachius* *Pomatoschistus sp.* *Scyliorhinus canicula*	*Delphinus delphis* *Halichoerus grypus*
	Habitat-forming species			
	MaB	**EB**	**AL**	**P**
BPNS	*Lanice conchilega*			
DPNS	*Lanice conchilega*			
IoS	*Amphithoe sp.* *Chaetopterus variopedatus* *Janua pagenstecheri* *Lanice conchilega* *Owenia fusiformis* *Pomatoceros triqueter* *Pygospio elegans* *Sabella pavonina* *Sabellaria spinulosa* *Tubulanus annulatus*	*Balanophyllia regia* *Distomus variolosus* *Leptopsammia pruvoti* *Membranipora membranacea* *Modiolus modiolus* *Umbonula littoralis*	*Laminaria sp.*	*Zostera marina*
	Symbiotic species			
	MaB	**EB**		
IoS	*Megatrema anglicum*	*Adamsia carciniopados* *Megatrema anglicum*		

The selection of keystone species appeared to be a rather difficult process, as subjectivity cannot always be excluded. Some species, selected as keystone species for the IoS, were not selected for the BPNS or DPNS as no literature sources could be found to base the selection on. However, it seems logical that these species will play a similar role in the ecosystem of the BPNS or DPNS as they do in the IoS. As the literature on the ecological function of marine species is still very fragmentary, the selection of keystone species should be regarded as a preliminary assessment.

A. Biological valuation of the Belgian part of the North Sea

The BVM shows that the most valuable areas can be found in the coastal area of the BPNS (Figure 2), with high to very high values found for the entire coastal strip, stretching out to the Oostende sandbank in the west and to the Akkaert bank in the east. High values are also found in the area around the Thornton Bank and in the area south of the Hinder Banks. The offshore area of the BPNS is almost always characterized by a low biological value. For most areas the reliability of the valuation is rather low (Figure 3). The most reliable valuations are situated in the coastal area and in the eastern part of the BPNS.

The valuation maps for each of the ecosystem components clearly indicate the high ornithological value of the coastal zone (Appendix 1), which coincidences with results from earlier analyses (Seys *et al*., 1999; Seys, 2001; Stienen & Kuijken, 2003; Haelters *et al.*, 2004). The valuation map for seabirds, however, throws a new light on the value of more offshore sites. Where previous studies failed to identify these sites as particularly important for seabirds, the valuation method clearly pinpoints the high value of the Thorntonbank, the waters north of the Vlakte van de Raan and parts of the Hinder Banks. The highest biological value for macrobenthos is found in the coastal zone, especially near shore in the western coastal area and diverging to the Akkaert bank in the eastern coastal area. This pattern, and especially the high value in the western coastal zone, could be expected following the results of Degraer *et al*. (2002, 2003). Other valuable areas for macrobenthos are the gully above the Thorntonbank and an area between the Flemish and the Hinder Banks. The lowest values are found offshore and in the coastal area around the harbour of Zeebrugge and the mouth of the Westerschelde. The valuation map for epibenthos shows a high value of the coastal zone. The Flemish and Zeeland Banks have an intermediate to high value, whereas the offshore areas have a low to very low biological value based on epibenthos data. The demersal fish valuation map does not indicate real hot spots of high value, but rather shows an evenly distribution of different values.

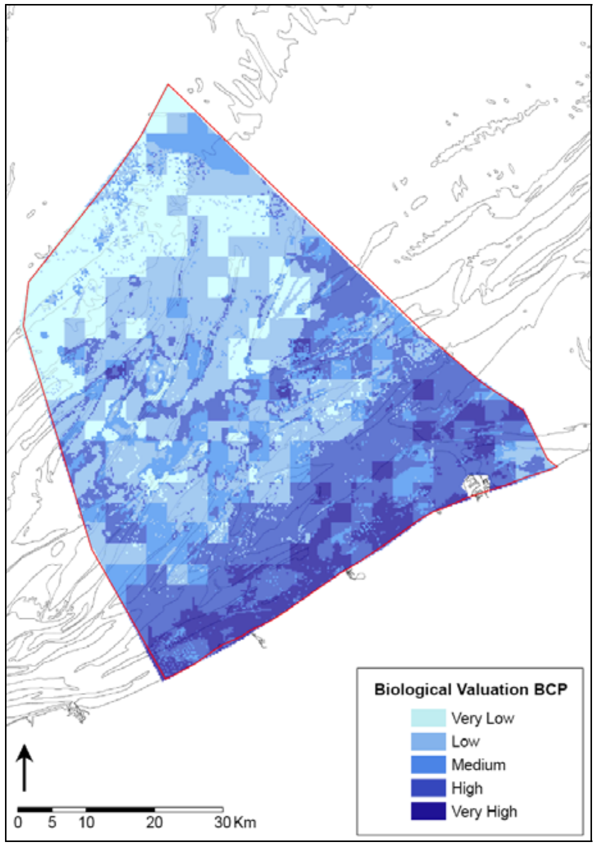

Fig 2: The marine biological valuation map of the BPNS which integrates the seabird, macrobenthos, epibenthos en demersal fish valuation maps.

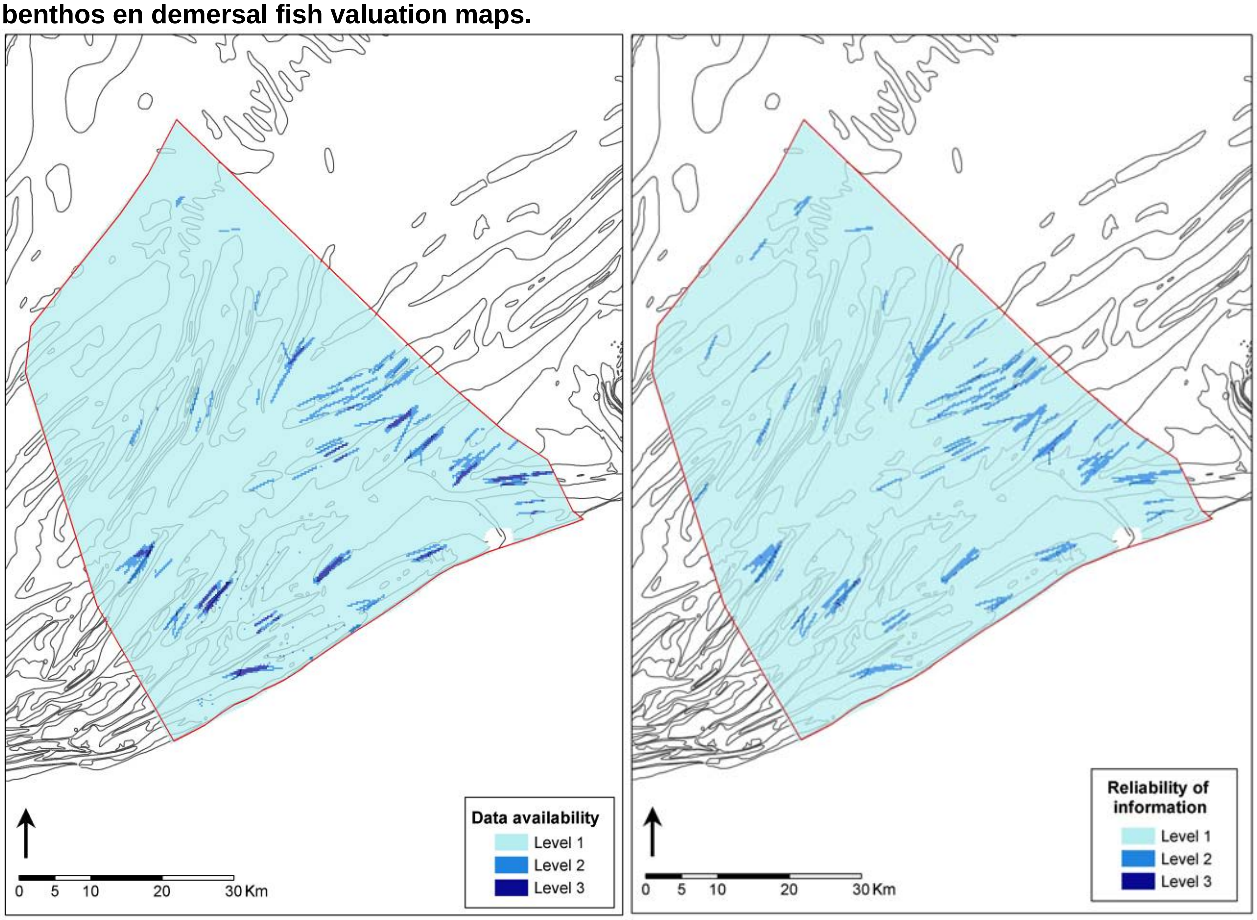

Fig 3: Data availability and information reliability of the total biological valuation map of the BPNS.

B. Biological valuation of the Isles of Scilly

Since two types of data (quantitative and qualitative data) are available for the Isles of Scilly, two separate BVMs are constructed (Figures 4 and 6). The covered area of the integrated BVMs seems restricted to the coastal region of the Isles of Scilly, which coincides with the areas where the valuation seems to be most reliable (Figures 5 and 7). Especially the open sea region in the west of the study area is very poorly sampled and surveyed. When both integrated BVMs are compared, it is noticed that the BVM based on occurrence data allows for more subzones to be valuated than the one based on quantitative data. This is due to the higher availability of occurrence data for the area. No subzones are assessed as having a very low or low biological value on both BVMs. The trends in the values of both maps are similar, with the highest biological values found south of St. Martin's, along the eastern shores of St. Mary's, in the channel between the two islands of St. Agnes and around Tresco.

The valuation maps for each ecosystem component show similar trends as the total BVMs although several additional hotspots for some ecosystem components can be detected (Appendices 2 and 3). The subzones south of St. Agnes are highly valuable for algae, while the zone between Bryher and St. Agnes seems to be important for both macrobenthos and epibenthos (soft substrates). The eastern part of the IoS show high values for epibenthos (hard substrates), while the southern part of the study area holds high values for fish. Several hotspots for macrobenthos occurring on hard substrates can be found around the smaller islands and rocks in the area.

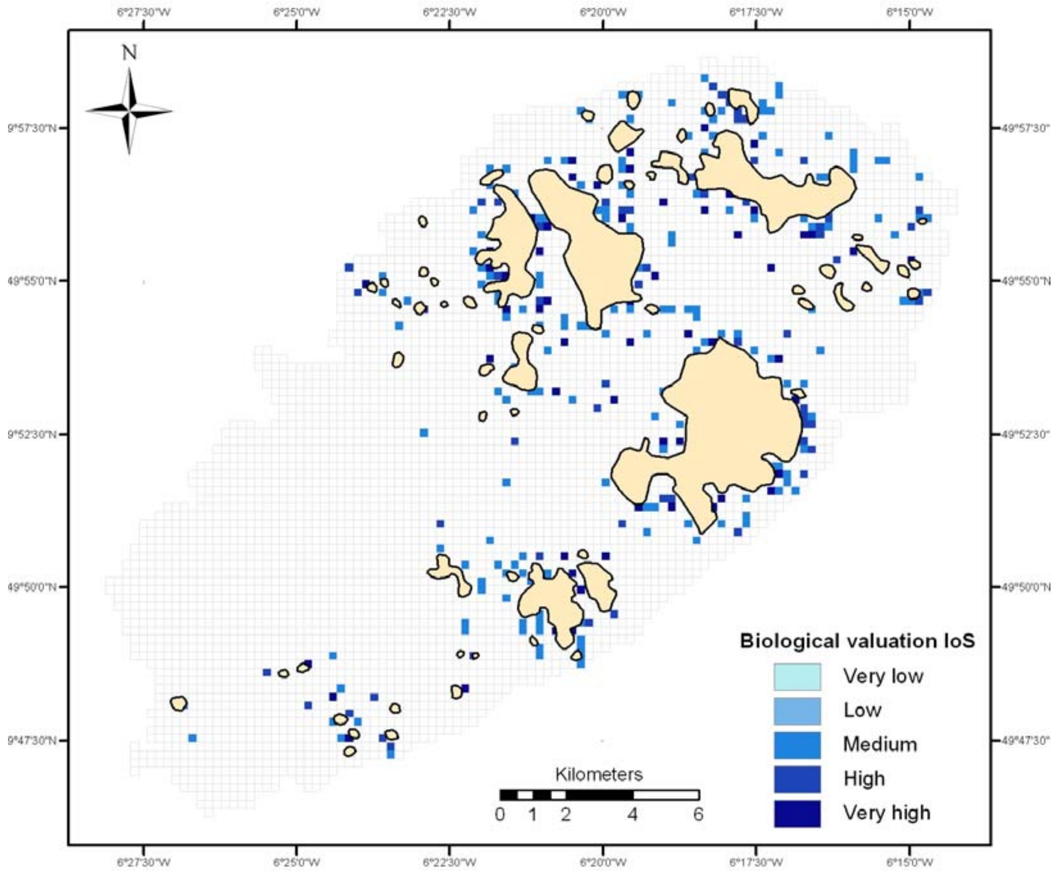

Fig 4: The marine biological valuation map of the Isles of Scilly integrating all occurrence data.

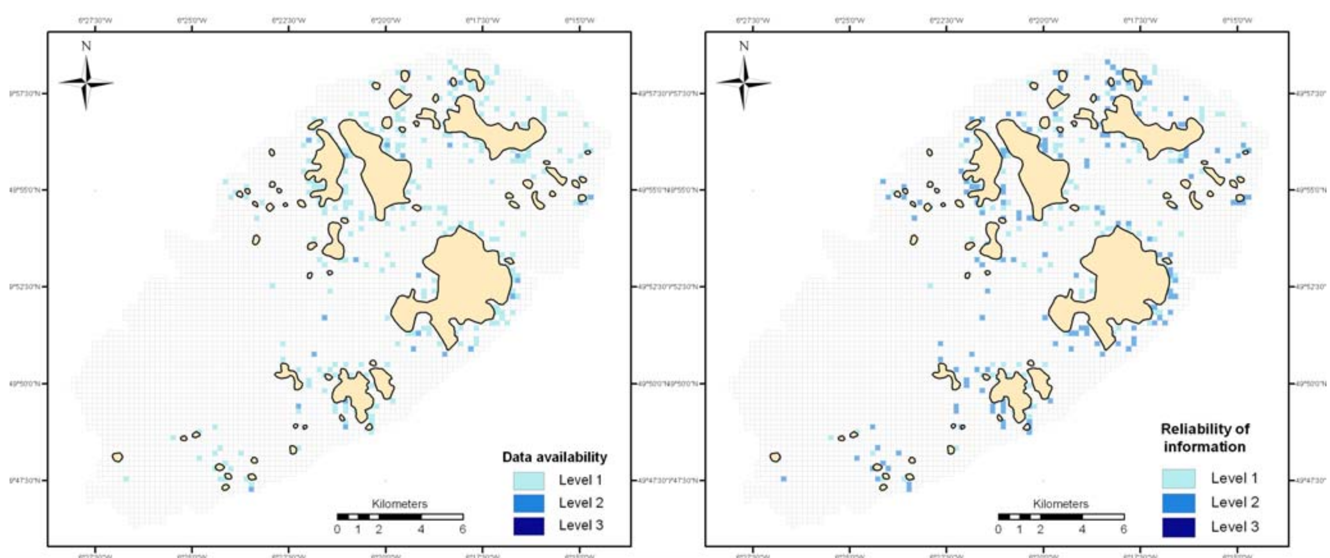

Fig 5: Data availability (left) and information reliability (right) of the total biological valuation map based on occurrence data of the Isles of Scilly.

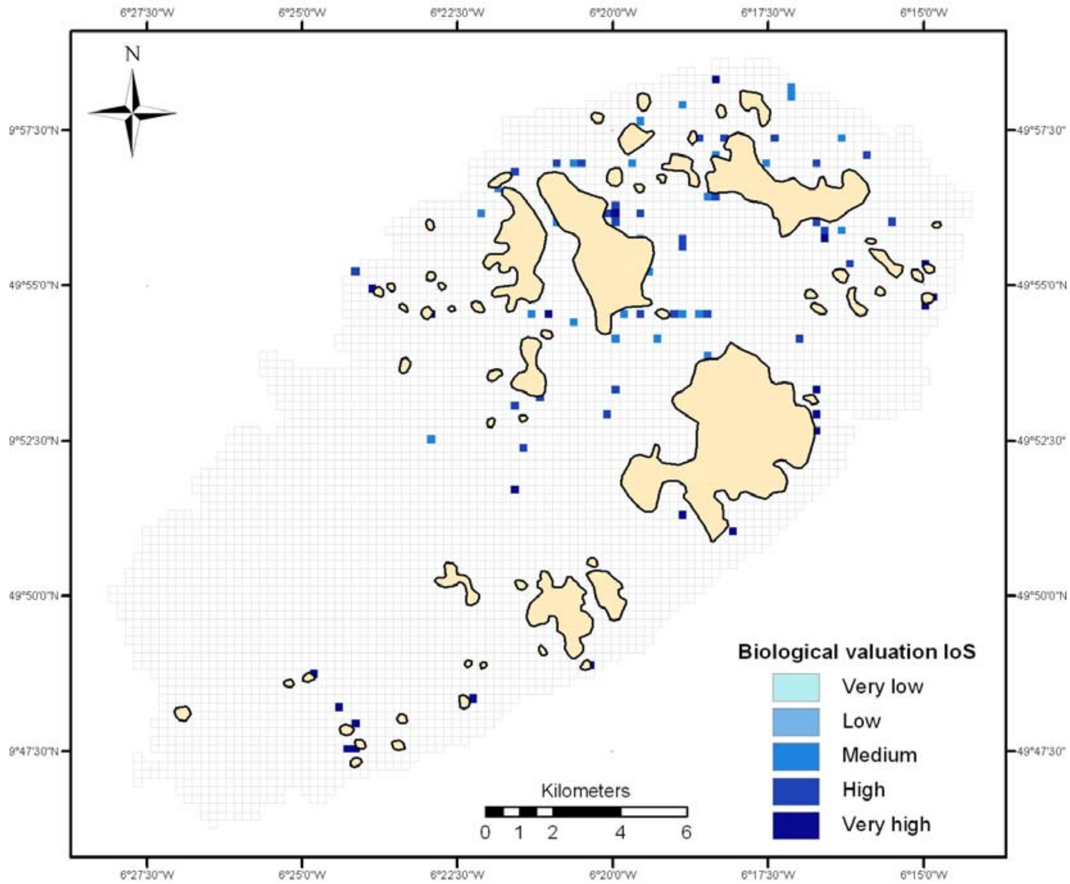

Fig 6: The marine biological valuation map of the Isles of Scilly integrating all quantitative data.

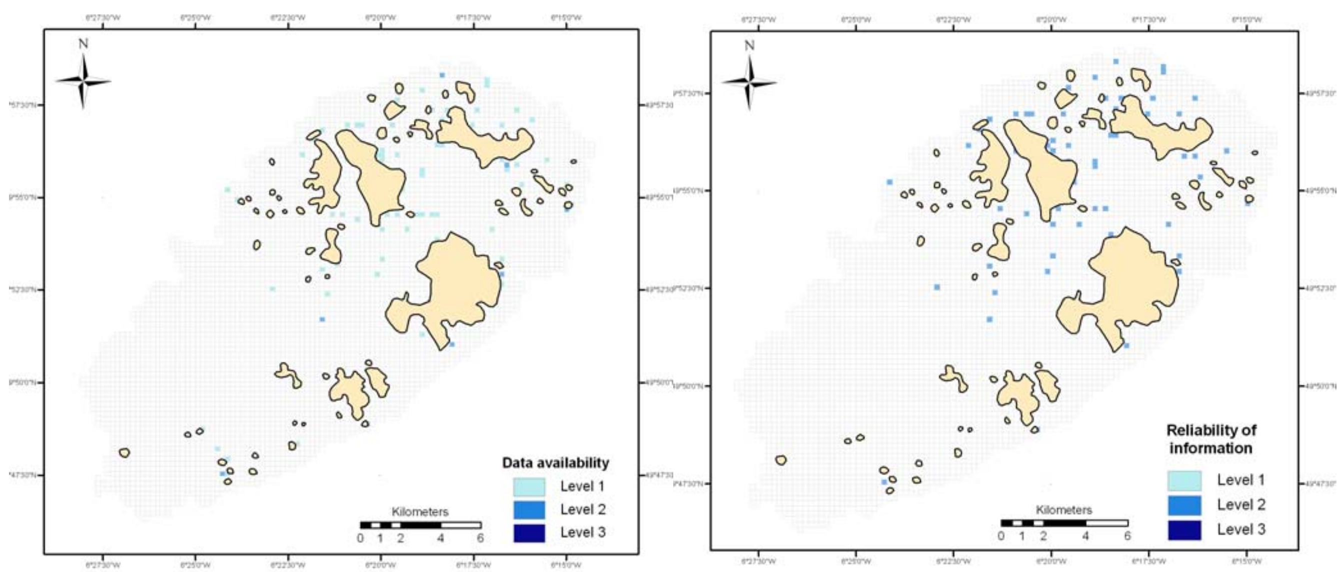

Fig 7: Data availability (left) and information reliability (right) of the total biological valuation map based on quantitative data of the Isles of Scilly.

The total BVMs were compared to the map constructed after consulting a panel of experts on the biological features of the Isles of Scilly (Table 4). The consensus of the experts was a map selecting the subzones around Darrity's Hole, Bishop Rock, St. Agnes and the area south of St. Martin's as having the highest biological value. Other areas with assumed high value were the channel between Tresco and Bryher and the area east of St. Mary's.

Table 4: Agreement between expert judgement and marine biological valuation of the IoS (NA = no data available to determine value). Highlighted values are values which agree according to both expert judgement and valuation methodology.

	Expert judgement	Marine biological valuation (quantitative)	Marine biological valuation (qualitative)
North of St. Martins	Medium	High	Medium to high
East of St. Martins	High	High	Medium
South of St. Martins	Medium	High to very high	Medium to very high
West of St. Martins	High	Medium	High
North of St. Marys	Medium	Medium	Medium to high
East of St. Marys	High	Very high	High
South of St. Marys	High	Very high	Medium to very high
West of St. Marys	Low	NA	Medium
North of St. Agnes	Medium	NA	Medium
East of St. Agnes	Medium	NA	Very high
South of St. Agnes	High	NA	Medium
West of St. Agnes	High	NA	Medium
North of Tresco	High	Medium to high	Medium to very high
East of Tresco	Medium	High	High
South of Tresco	Low	Medium	Medium
West of Tresco (= channel between Tresco and Bryher)	High	Very high	High to very high
North of Bryher	High	High	Medium
South of Bryher	Medium	Medium	Medium to very high
West of Bryher	Medium	Medium	Medium to high
Darrity's Hole	High	High	High
Bishop Rock	High	NA	Medium
Southern part of IoS	Low	Very high	Medium to high
Eastern part of IoS	Low	Very high	High
Western part of IoS	Low	NA	NA

The experts based their valuation mainly on their knowledge of the presence of special habitats (e.g. seagrass beds, rock pools, exposed shores) or specific species (e.g. seals) in a certain location, without performing any data analyses. It should be noted that the experts were asked to express their value estimate by using only three value classes (rather than five, as is done in the valuation of the IoS). The subzones indicated by the experts to have a high biological value largely overlapped the ones depicted as having a (very) high value on the BVMs, although most areas indicated by the experts were larger. This is due to the restriction of samples to the inshore areas, which are easily accessable to take samples. No samples are available for a lot of subzones further from the coasts, disabling the determination of their biological value. However, where data are available for these offshore areas, the biological value seems to be higher than expected by the experts.

C. Biological valuation of the Dutch part of the North Sea

The total BVM of the DPNS shows that, due to the choice of large grid cells (15x15 km) a good coverage of the DPNS (74% of the grid cells valuated) was achieved (Figure 8). Highest values are found in the coastal area but also subzones more offshore (e.g. around Frisian Front, northern part of DPNS) were assessed as having a high biological value, based on the six ecosystem components under consideration. It should be stressed that very little were available for the Wadden Sea and its biological value can therefore not be evaluated based on the BVM. From the data availability map (Figure 9) it can be seen that the high coastal values coincide with the areas for which most data are available, rendering the valuation of this zone as reliable.

The valuation maps for each ecosystem component indicate that the DPNS seems to share its high ornithological value of the coastal zone with the Belgian case study area, although results could be biased by the higher data availability for this zone (Appendix 4 and Figure 9). Due to time restrictions, no spatial extrapolation of seabird data, as was done for the BPNS, was performed to reduce the observer bias towards the coastal area. The largest part of the DPNS seems to have medium to high value for fish, with the exception of the offshore area. The highest macrobenthic values are found in the central and northern part of the study area, which contrast with the results for sea mammals where high values are mainly found in the coastal area around the Wadden Sea. Data for microzooplankton and phytoplankton are too scarce to be able to show trends in their valuation.

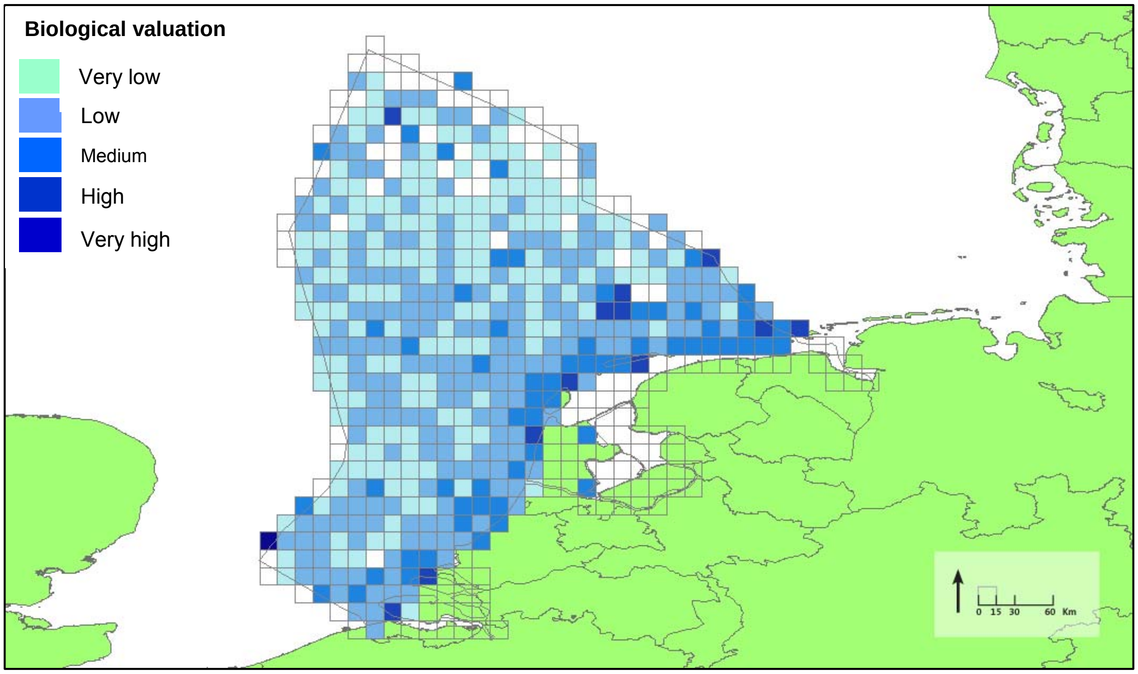

Fig 8: The marine biological valuation map of the DPNS.

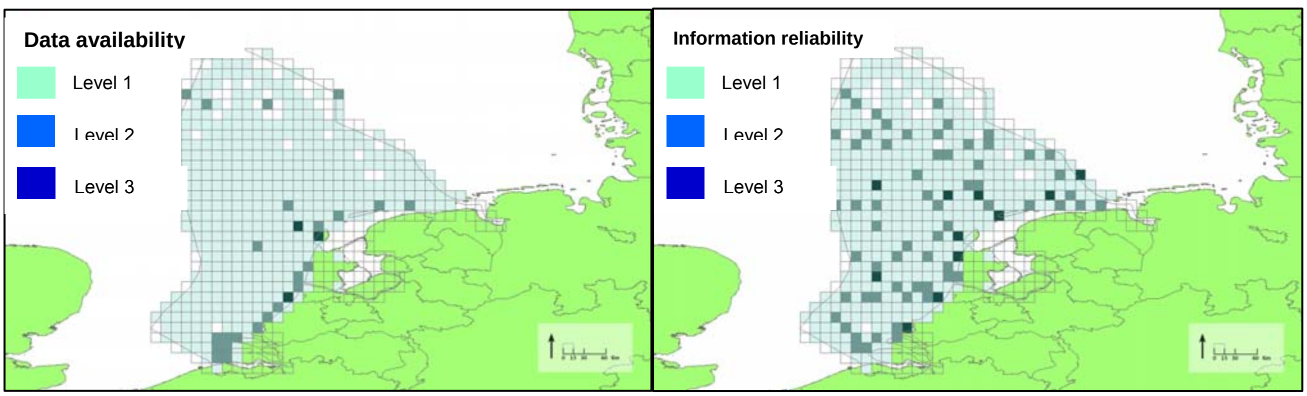

Fig 9: Data availability (left) and information reliability (right) of the total biological valuation map of the DPNS.

Discussion

A. Comparison with previous studies

The BPNS is, despite its relatively small surface area, a highly important area for seabirds, not only for wintering birds but also for migrants and breeding birds (e.g. Seys *et al*., 1999; Seys, 2001; Stienen & Kuijken, 2003). Being a bottleneck area for seabirds migrating from the northern breeding areas to the southern wintering areas, more than 5 % of the biogeographical population of 12 species migrates through the southern part of the North Sea (Seys, 2001, Stienen & Kuijken, 2003; Stienen *et al*., 2007). Also, the BPNS functions as a major feeding area for the internationally important tern colonies in the harbour of Zeebrugge (Alvarez, 2005; Stienen *et al*., 2005). The importance of the BPNS for birds was acknowledged by the designation of three Marine Protected Areas under the Birds Directive in 2005 (Dienst Continentaal Plat, 2005). The delineation of these areas was based on a selection of species, listed in Annex I of the Bird Directive and occurring frequently and with high densities (Sandwich Tern, Common Tern and Little Tern) or having more than 1 % of their biogeographical population situated in the BPNS between 1992 and 2002 (Great-Crested Grebe, Little Gull, Common Scoter and Great Skua) (Haelters *et al*., 2004). Although the study of Haelters *et al.* (2004) was very important in terms of conservation of threatened species, unlike this study it did not aim to valuate the broader ornithological importance of the BPNS. The valuation exercise of the BPNS also takes into account non-threatened and more widely distributed seabird species. The final valuation map of seabirds gives a good view of the relative ornithological importance of the different subzones of the BPNS.

Results from the DPNS valuation were compared to an earlier biological analysis by Lindeboom *et al.* (2005), who identified five zones of high ecological importance being (1) the Dogger Bank, (2) the Cleaverbank, (3), the central Oyster Grounds, (4) the Frisian Front and (5) the Coastal Sea (Figure 10). Two sites in the Coastal Sea zone (Voordelta and coastal sea north of Petten) are also designated as Special Conservation Areas under the Bird Directive and proposed as Habitat Directive areas due to their importance for benthos, birds, fish and sea mammals (Camphuysen *et al*., 1994; Arts & Berrevoets, 2005; Lindeboom *et al*., 2005; IBN, 2005). Several of these areas (or parts of these areas) coincide with high value subzones from this exercise (e.g. coastal subzones, parts of the Dogger bank area in the north and the central Oyster Grounds). It is striking that the Frisian Front does not harbour a lot of high valued grids, both on the total BVM (Figure 8) and the birds BVM (Appendix 4b). This is in contrast to the results of Camphuysen *et al*. (1994), who described the high significance of this area for seabirds (e.g. thousands of Common Guillemots use this area to moult). Because the valuation of the DPNS was done by a scientist without a background on this area and its specifications, these particular aspects were neglected (could be addressed by additional assessment questions dealing with ‘aggregation-fitness consequences’) and the ecological importance of the Frisian Front is not reflected by the valuation. The importance of the Dogger Bank, Oyster Grounds, Frisian Front and Cleaverbank for macrobenthos (Lavaleye, 2000; Lindeboom *et al*., 2005) seems to be reflected relatively well by the valuation results (Appendix 4a).

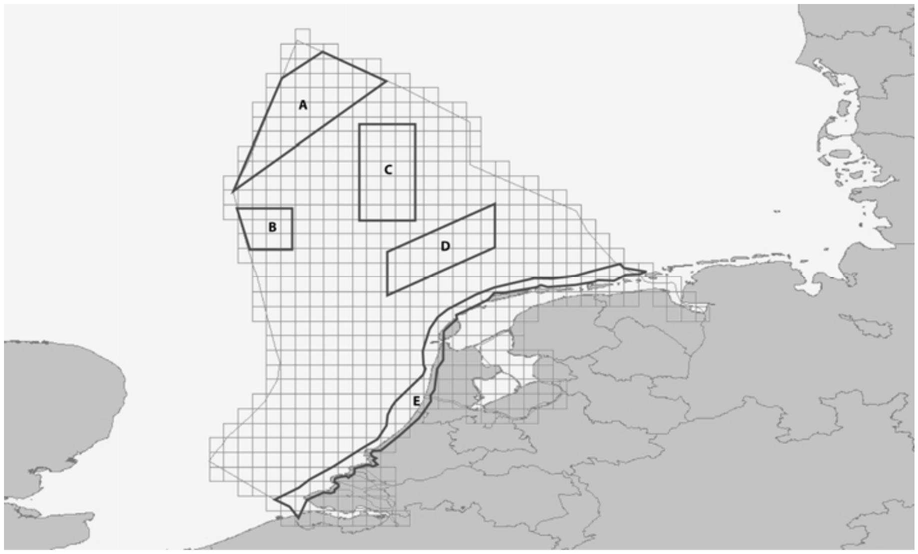

Fig. 10: Areas with high ecological importance as reproduced from Lindeboom et al. (2005). (A) Dogger Bank, (B) Cleaverbank, (C) Central Oyster Grounds, (D) Frisian Front, (E) Coastal Sea.

For the IoS archipelago, different clusters of high to very high value could be determined and these all overlap with areas which are being protected under different national and international designations (e.g. Area of Outstanding Natural Beauty, Heritage Coast, Ramsar sites, Bird and Habitat areas,…) (IoS-AONB, 2007; JNCC, 2007). This is not surprisingly as almost the entire coastal region of the IoS, where most biological data were available, is being protected by one or more designations. The results from the valuation exercise also agreed well with the results from the expert judgement. But the BVM is objectively developed by applying the valuation protocol, while the maps provided by experts will always include some subjectivity as they are based on the knowledge of scientists of specific features or species in the area, while neglecting information on other biological aspects. It should also be noted that the IoS BVMs for plants, hyperbenthos and sea mammals show a very high biological value for most of the grid cells and this is due to the fact that the amount of species under consideration is very low. For plants there is only one species being considered, namely *Zostera marina*. For hyperbenthos (only five species) and sea mammals (only two species) a similar output can be seen. These maps can be regarded as distribution maps of the corresponding ecosystem component and should be considered carefully for valuation purposes.

B. Weaknesses and threats of the developed valuation protocol

It has to be emphasized that the BVM for macrobenthos of the BPNS is strongly biased by the output of the assessment question on 'distinctive communities', which was answered with the use of a predictive model, as this is the only question which could be answered for most of the grid cells. Where the macrobenthic value of a grid cell is based on more than one question, this value will be more reliable as this value integrates both predicted community information and information from samples. Another important consideration concerning the model results, is the fact that each grid cell was assigned a certain (community) habitat suitability based on the probability which was highest for this grid cell. When the probabilities for different communities differed only slightly (e.g. 0% for community 1 - 30% for community 2 - 34% for community 3 - 36% for community 4), then the grid is assigned to the community with the 36% probability, which is rather artificial and could be a wrong interpretation of the information since three communities could occur in such habitat.

The data availability maps of the BPNS and DPNS show that, in contrast to seabirds and sea mammals, data availability for macro- and epibenthos, phyto- and zooplankton and demersal fish was mostly restricted to certain areas. This is due to the fact that sampling the latter ecosystem components is more time consuming than counting seabirds or sea mammals, which can be done by observations. Despite the large databases which are already available for macro- and epibenthos and demersal fish, they can not be extrapolated to create full-coverage valuation yet, although this was done for the habitat suitability of the macrobenthic communities of the BPNS through the use of predictive modelling. When the BVMs of the DPNS are considered, it can be recommended that in this case extrapolation of the data for seabirds should have been possible, given the good distribution of the observations. Next to that, it could be advisable to exclude the plankton data from the valuation analysis since very little data are available for plankton. Including such insufficient information could lead to bias in the development of the reliability maps.

When the case study area of the IoS is investigated, where no ready-to-use data archive was available, it should be noted that it was impossible to integrate all existing biological data in this valuation assessment due to time restrictions and the maps described above should therefore be seen as preliminary maps based on a fraction of the existing data. It should also be noted that the data abstracted from literature are sometimes very old, which seriously decreases the reliability of the outcome as marine areas are dynamic systems where changes in biological communities can happen very fast. This is certainly true for the exposed coast of the archipelago.

The use of these BVMs could be misleading, as managers should always keep in mind that the maps show the biological values of the subzones relatively to each other. No comparison between the map of the IoS can be made with the map of the BPNS or DPNS because their subzones were not compared to each other. The fact that no grid cells with low or very low value appear in the IoS archipelago does not necessarily mean that this is an area of special biological value. To investigate this further the IoS should be valuated at a broader geographical scale, for instance the entire UK coastline, to know its relative value at a more regional scale.

It was not possible to exclude some subjectivity from the protocol as it stands now, as some assessment questions are still difficult to assess due to the lack of appropriate data or information sources. This was particularly the case for the selection of keystone species (habitat-forming species or other ecologically significant species). The literature on the ecological functions of most marine species is still fragmentary, so the choice of keystone species for the case study areas should also be seen as a first step towards more objective selections once the literature on this subject has grown.

The scoring method which was used for the valuation of the case study areas is only one of the possible scoring systems. Here, the value is based on the range of values for a certain parameter (species richness, density…). Five value classes are determined based on this range. The total value is the average of the individual values for the different ecosystem components. One could easily suggest other scoring or integrating methods, for instance that subzones automatically get a (very) high value when they scored (very) high for one of the ecosystem components. This could increase the values of the obtained BVMs. As can be seen, by chosing another scoring system, other BVMs could be produced. Again, this could introduce subjectivity in the protocol as scientists could apply different scoring systems to the data and chose the one that best suits their personal hypotheses. More strict rules concerning the scoring system to be used are therefore necessary. In the future, these alternative scoring systems should be tested on other case study areas to see which one is best suited for the valuation protocol.

C. Opportunities and lessons learned for the future

Due to different sampling methodologies used in the IoS, two BVMs were created, one based on quantitative data and one on qualitative (occurrence) data. Since all ecosystem components can be easily surveyed by recording their presence or absence, the map based on occurrence data would seem like a more likely candidate for the outcome of a worldwide applicable marine biological valuation method. However, a BVM should not only indicate whether some species is there or not, but indications on its number of individuals present adds a lot of valuable information (e.g. aggregation of species) to such maps. It could be possible that some rare species was only counted once at five different subzones in the entire archipelago, but information on the fact that it appeared 4 times with a high density and one time with only one individual gives more details on this species and will give a more diverse picture on these subzones. So, although BVMs based on quantitative abundance data require more time-consuming sampling campaigns and data treatment, their outcome will be more reliable and give a better representation of the intrinsic value of the subzones within the study area. However, the methodology seems to be flexible enough to make BVMs based on occurrence data and such preliminary maps can be used while more quantitative data are being gathered.

Since BVMs provide the relative values of different subzones given the available data at that time, managers should keep in mind that BVMs will need to be revised on a regular basis to meet the dynamics of the marine ecosystem and whenever new relevant data become available. The inclusion of new data will not only make the BVM more reliable but can also increase the coverage on the maps, which allows a better relative comparison between subzones.

The choice of the grid cell size is very important and should always be ecologically relevant for the ecosystem component under consideration. Smaller grid sizes (e.g. 250x250 m) should be chosen for benthic ecosystem components which are relatively immobile, while such small grid sizes are not appropriate for the valuation of highly mobile groups like seabirds or sea mammals, as was shown for the IoS case study. Grid sizes should also not be too small, to allow for good coverage of the study area, while too large grid cells could result in the loss of site-specific information, which is most relevant to marine decision makers and managers. The implications of the geographical scale of a study area can be seen when the BVMs of the BPNS and DPNS are compared. For the DPNS, which is a substantially larger area than the BPNS, a grid cell size of 15x15 km was chosen. Although this did allow having better coverage, it is questionable whether sampling data for macrobenthos or phytoplankton can be extrapolated to such large grid cells. It is therefore recommended not to use such large grid sizes for sessile ecosystem components in the future. The resolution of the BVM for the BPNS is much higher, allowing for more detailed valuation information for a specific location. Despite these different grid sizes, the overall trend of higher biological value in the coastal zone is visible on both maps.

The choice of the grid sizes can also lead to conflicts in the biological valuation of neighbouring areas. This is illustrated in Figure 11, where the BVMs of the BPNS and DPNS are plotted next to each other. An integrated valuation of both areas, or an increase in the similarity of grid cell sizes, would be a usefull exercise to indicate more realistic biological values near the shared border of both areas.

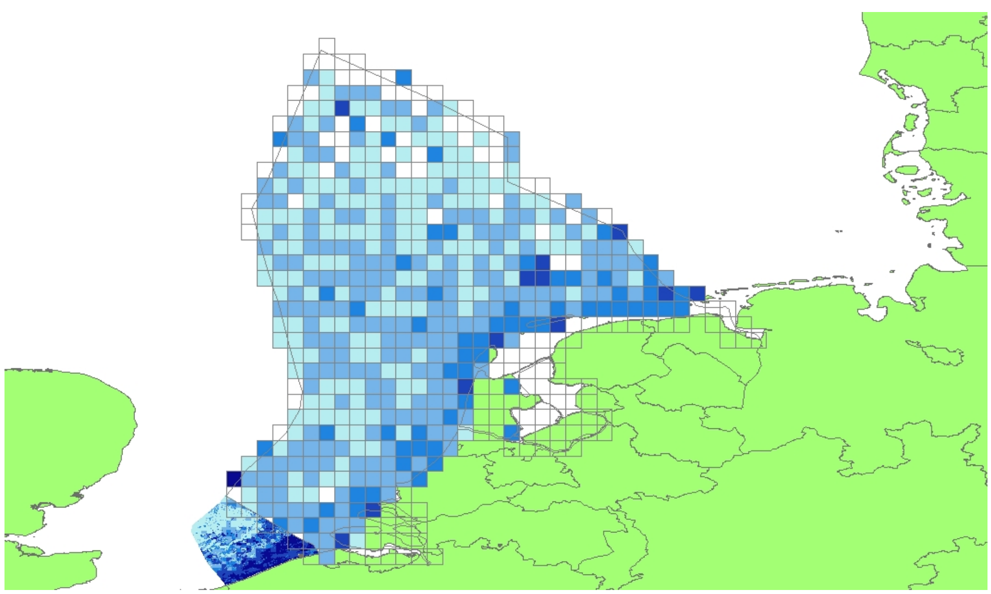

Fig. 11: BVMs of the Belgian and the Dutch parts of the North Sea plotted next to each other to illustrate border issues.

Another point worth mentioning is the fact that, instead of chosing GIS grid cells as working units for the valuation, in the future attempts should be made to use marine landscapes as ecologically relevant subzones. These are now available for the BPNS (Schelfaut *et al*., 2007).

The BVMs developed in this paper show the integrated value of a selected set of ecosystem components. Other ecosystem components are not included in the assessments because there are not enough data available for a valuation. However, the methodology is flexible and allows the incorporation of new data when these become available in the future. Data can easily be added to the integrated database and similar assessment algorithms could be developed for these new ecosystem components as well.

Application of the protocol to future test areas should always be done by marine scientists who are familiar with the area and the ecosystem components which are included in the valuation, or at least after consultation of such experts. This was particularly proven by the case study area of the DPNS, where the valuator was not aware of the significance of the Frisian Front area for seabirds, which led to the neglection of certain assessment questions dealing with 'aggregation-fitness consequences' in the protocol.

BVMs are baseline maps showing the relative values of the different subzones of a study area. As such, the values are linked to the scale of the area which is valued. This means that a subzone of the BPNS given a 'high' value cannot be compared to a subzone of the IoS with the same value, although the same methodology has been used to determine the values. Comparing the values of subzones of different areas can only be done when a new valuation assessment is done where all subzones are assessed against each other. In the future more case study areas should be valuated on a regional scale to see how this higher level valuation compares to the valuation on a local scale. The combination of the BPNS and DPNS would be an ideal test case for such regional valuation.

Conclusions

As many marine areas (such as the BPNS and DPNS) are heavily exploited, there is an ever increasing awareness that it is necessary to use their resources and space in a sustainable matter. Policy makers who want to implement sustainable policy actions need good decision support systems (DSS). Such DSS should not only provide information on the socio-economic value and impacts of the BPNS but should also integrate biological and ecological information. To objectively allocate the different user function of marine areas, a spatial structure plan, which is based on the concept of integrated marine management, is needed. One of the baseline maps needed for such spatial structure plan is a BVM, which indicates the biological value of each of the subzones of the area on a relative basis. BVMs that compile and integrate all available biological information of an area are therefore promising tools for future spatial planning activities. The development and use of these maps will prevent the inclusion of subjective, untransparant expert judgement in the preparation of management decisions, an approach that was used frequently in the past.

The final BVMs indicate clear patterns in biological value. Some areas which were estimated as highly valuable in the past (mainly based on expert judgement of ecosystem components analysed separately), like the coastal areas of the BPNS or DPNS, were also assessed highly valuable with this marine biological valuation protocol.

Next to the final BVMs, the underlying valuation maps and integrated database are also valuable end products. These can also be consulted when managers have more specific questions about one or more ecosystem components.

A lot of quantitative data were available for the development of the biological valuation map of the BPNS and DPNS. In contrast to other countries, these are well-studied areas (both biologically and geologically) and large databases are available for certain ecosystem components. The high data availability for seabirds in the BPNS allowed a (statistically significant) spatial interpolation of the data to create full-coverage maps for this component. The same thing was possible for the distribution of the habitat suitability of the macrobenthic communities of the BPNS, by using full-coverage sediment information and a predictive model. Most data available for the IoS are qualitative data (presence/absence data), but the data availability for this case study area was substantially lower than that of the other two study areas. This was largely due to the lack of data archiving and integration for this area and the poor geographical distribution of the sampling locations (mainly restricted to the coastal strip around the isles). The BVM of the IoS should therefore be seen as a preliminary map, indicating future sampling opportunities.

When the BVMs are used it is recommended to consult the underlying valuation maps and the maps explaining the data availability and information reliability of the different grid cells. The data availability maps clearly show which areas did not get a lot of attention during past research efforts and should be focus points in future sampling campaigns. Collecting new data will only improve the reliability of the maps by increasing both the data availability and the number of assessment questions which can be answered (information reliability). Misinterpretations of the valuation maps could occur when the values on the maps are used without consultation of the underlying maps, the documentation of the valuation or the integrated database. Such consultation should be done to check the data which were used to determine the integrated biological value and the methodology that was used to assess the values. In this way users of the map will get a better idea of the reliability of the values. It is also necessary to clearly state for which purposes the developed marine biological valuation can be used. The map can only be used to determine the biological value of subzones. As such they can be considered as warning systems for marine managers who are planning new threatening activities at sea, and can help to indicate conflicts between human uses and high biological value of a subzone during spatial planning. It should be explicitly stated that these maps give no information on the potential impacts that any activity could have on a certain area, since criteria like vulnerability or resilience were not included in the valuation protocol. They cannot be used for site-specific management (e.g. selection of marine protected areas or impact assessments) as such activities also require the assessment of other criteria (representativeness, integrity, socio-economic and management criteria). However, the BVMs could be used as a framework to evaluate the effects of certain management decisions (implementation of MPAs or new quota for resource use), but only at a more general level when BVMs are revised after a period of time to see if value changes occur in subzones where these management actions were implemented. However, these value changes cannot directly be related to specific impact sources, but only give an integrated view on the effect of all impact sources and improvement measures taken in the subzone.

Despite the threats and weaknesses which are recognised above, the availability of marine BVMs gives the opportunity to answer policy questions related to the biological value of certain subzones of the areas under consideration in a transparent, objective way. When future spatial planning activities (e.g. installation of new windmill parks or selection of low valuable sites for new developments) require information on the integrated value of a subzone these maps could prove to be an excellent tool. Of course improvements of the maps are possible (integrating more data, filling in sampling gaps,…), but waiting for these improvements and neglecting the maps as they stand now, only leaves the alternative of returning to the use of best expert judgement when new policy questions are posed. Because such expert consultation process is very untransparent and subjective, relying on the marine biological valuation maps and simultaneously consulting the data availability and underlying valuation maps will give a more reliable and objective answer.

Acknowledgements

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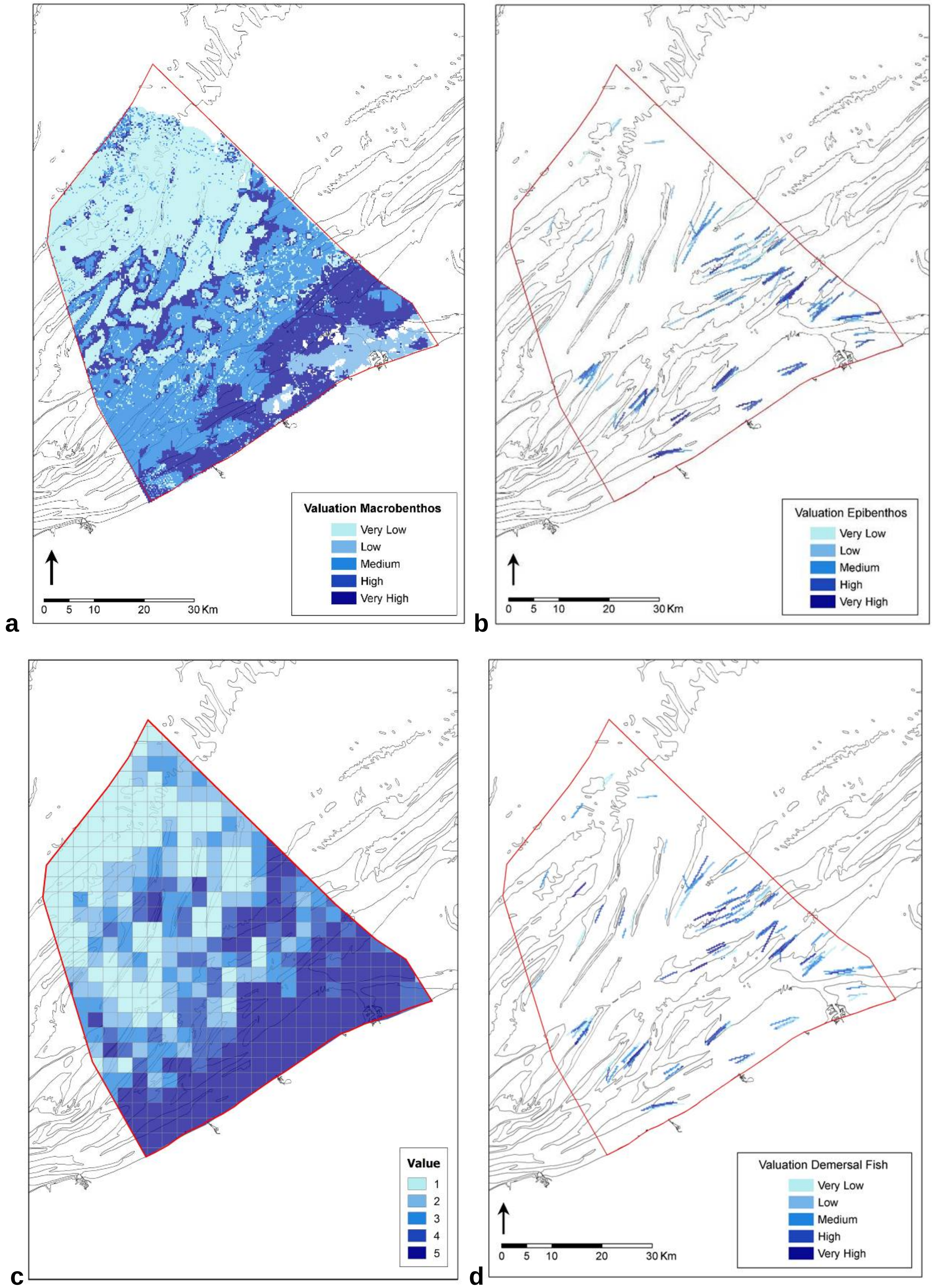
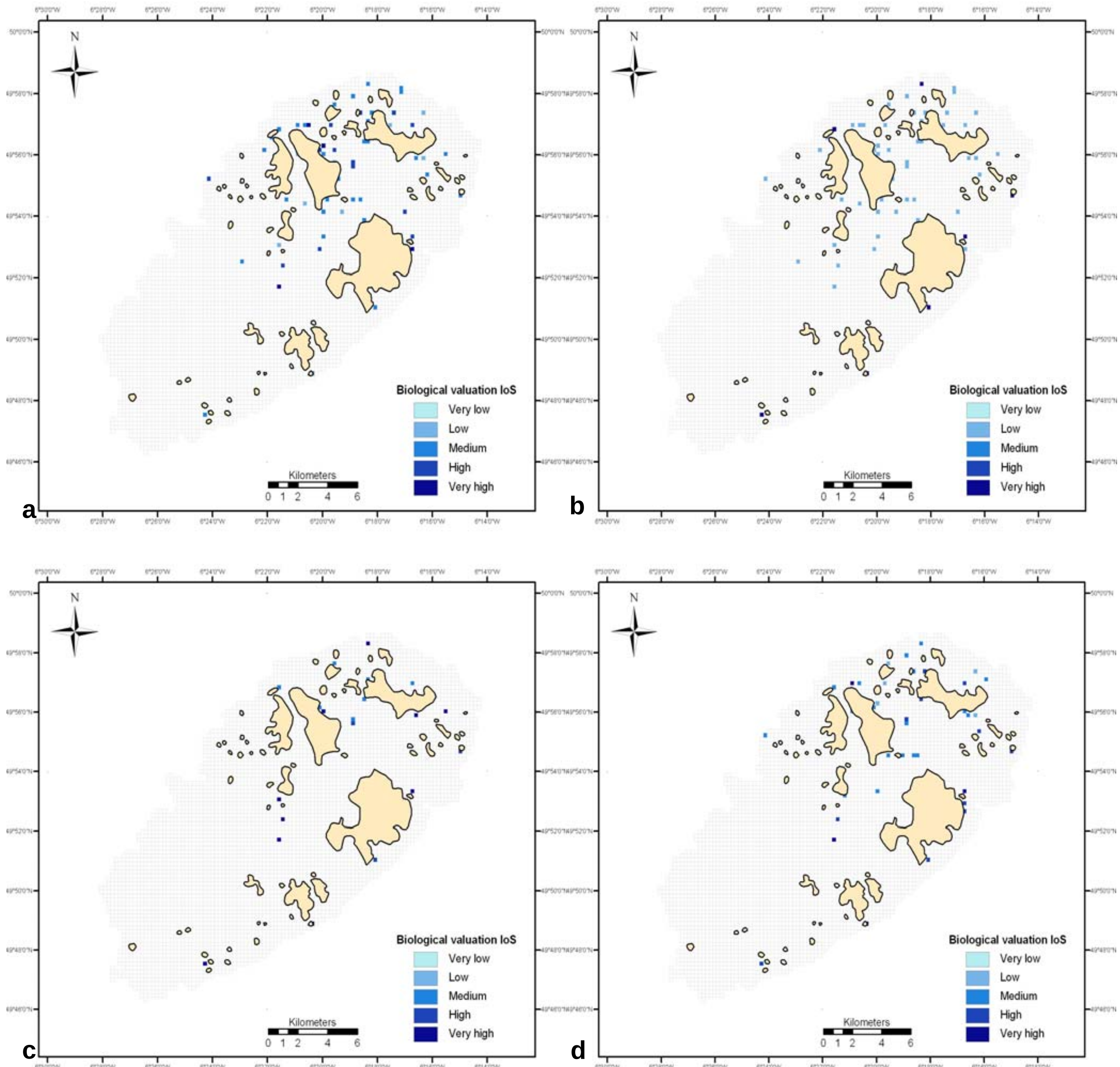
Appendix 1: Biological valuation maps for macro- and epibenthos, seabirds and demersal fish of the BPNS.

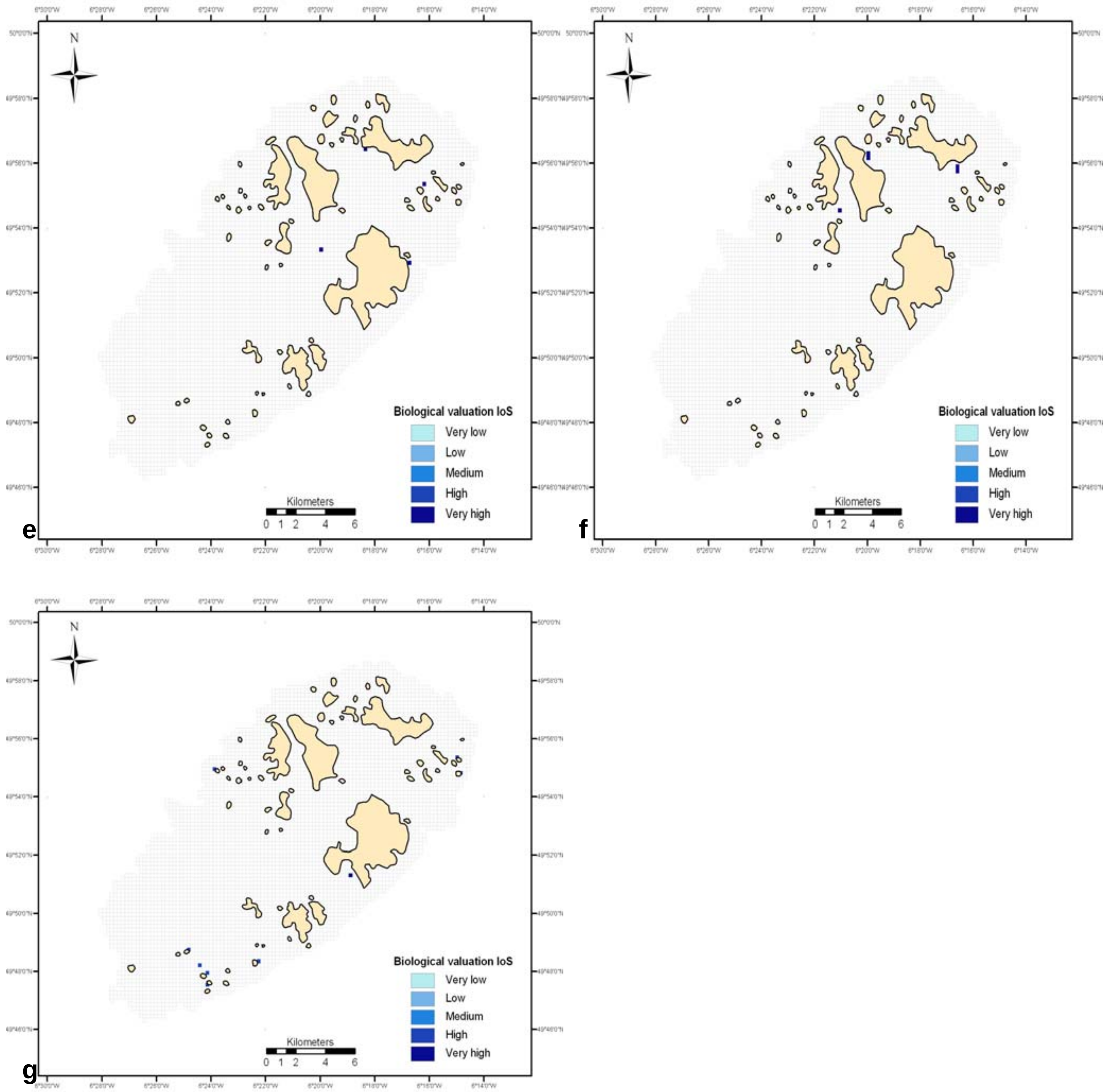
Figure a: macrobenthos – figure b: epibenthos – figure c: seabirds – figure d: demersal fish



Appendix 2: Biological valuation maps based on quantitative data for macro- and epibenthos (soft and hard sediments), hyperbenthos, plants and sea mammals of the Isles of Scilly.

Figure a: macrobenthos soft – figure b: macrobenthos hard – figure c: epibenthos soft – figure d: epibenthos hard – figure e: hyperbenthos – figure f: plants – figure g: sea mammals

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0 1 2 4 6
g
N
Biological valuation IoS
Very low
Low
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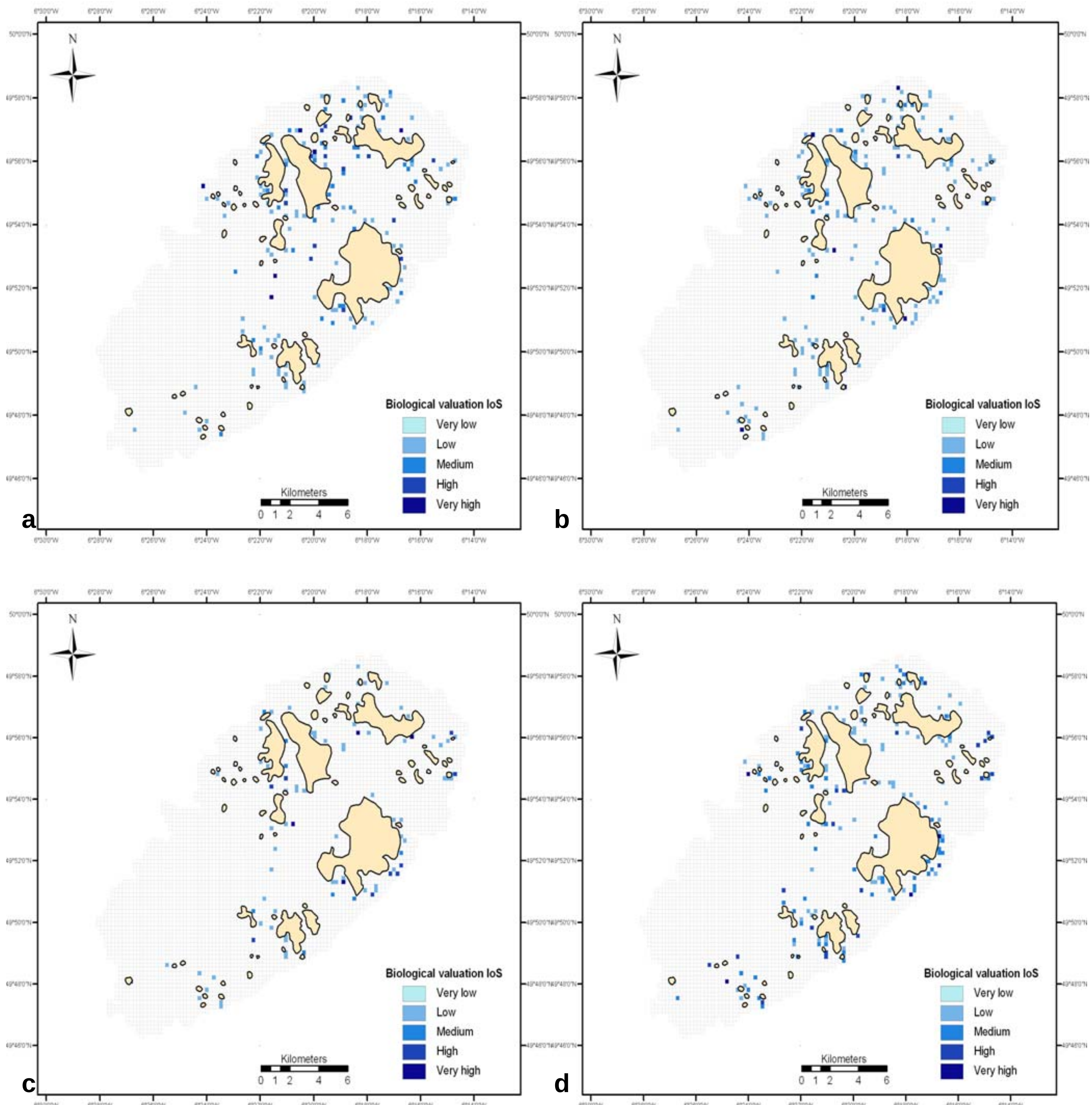
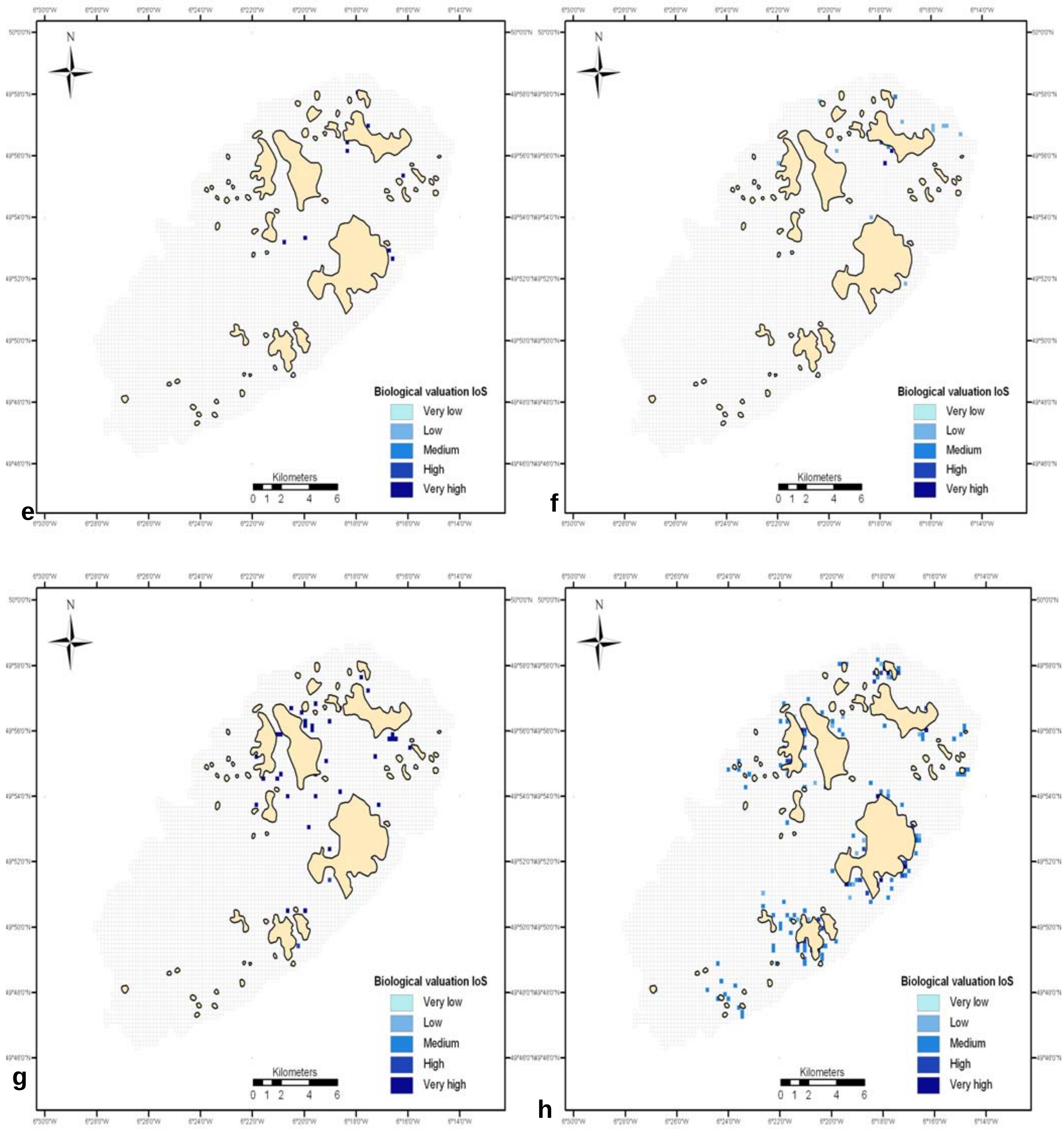
High
Very high
Kilometers
0 1 2 4 6

Appendix 3: Biological valuation maps based on occurrence data for macro- and epibenthos (soft and hard sediments), hyper- and meiobenthos, plants, algae, demersal fish and sea mammals of the Isles of Scilly.

Figure a: macrobenthos soft – figure b: macrobenthos hard – figure c: epibenthos soft – figure d: epibenthos hard – figure e: hyperbenthos – figure f: meiobenthos – figure g: plants – figure h: algae – figure i: demersal fish – j: sea mammals

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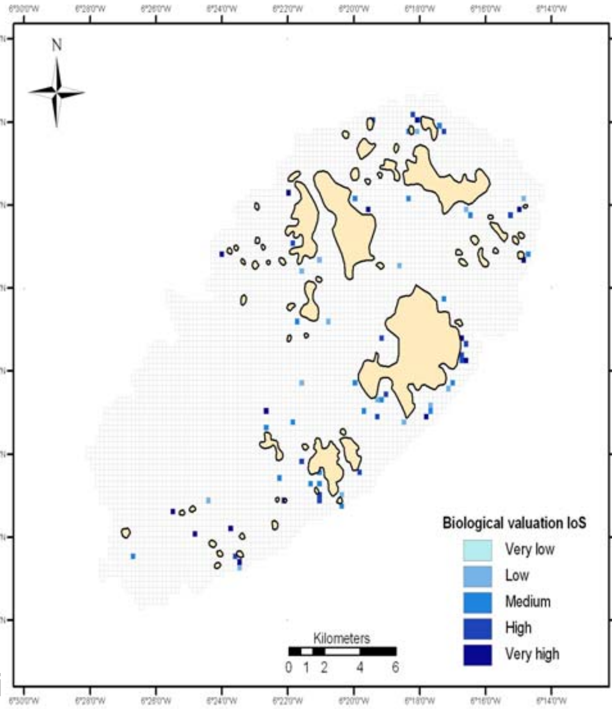
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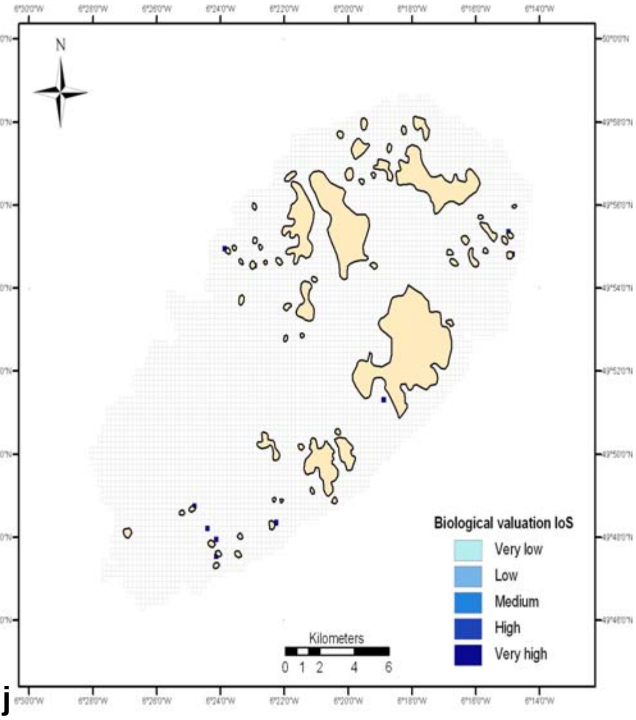
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Biological valuation IoS
Very low
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Kilometers
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j

Appendix 4: Biological valuation maps for macrobenthos, seabirds, demersal fish, sea mammals and phyto- and zooplankton of the DPNS.

Figure a: macrobenthos – figure b: seabirds – figure c: demersal fish – figure d: sea mammals – figure e: phytoplankton – figure f: zooplankton