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**THE SEAMOUNT ECOSYSTEM EVALUATION FRAMEWORK FOR NORTH ATLANTIC
AND MEDITERRANEAN SEAMOUNTS:**

PATTERNS OF KNOWLEDGE AND FUNCTIONING

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I hereby confirm that I have independently composed this Master thesis and that no other than the indicated aid and sources have been used. This work has not been presented to any other examination board.

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Abstract

The Seamount Ecosystem Evaluation Framework (SEEF) is a tool to assess our knowledge about individual seamounts. The framework includes aspects of geology, oceanography and ecology. This study applied SEEF to seamounts in the North Atlantic Ocean and the Mediterranean Sea, compiling available information from a range of sources. The degree of seamount knowledge was evaluated regarding 36 attributes, and variation between geographical areas assessed. The structure of knowledge regarding individual attributes was investigated with multivariate analyses. Ecological information available was synthesised in order to evaluate existing hypotheses of seamount productivity and endemism. Seamount knowledge in the studied areas is overall rather poor, but the variation between features is large. The focus in the Mediterranean Sea has been on geological research, while ecological seamount knowledge is higher in the North Atlantic. The structure of seamount knowledge vary additionally between geographical regions on a finer scale. Comparative research supporting a seamount effect on local biomass is scarce, and few direct studies have assessed mechanisms of seamount productivity. The notion that seamounts support a high degree of endemism is not supported for North Atlantic or Mediterranean seamounts. The reasons behind observed patterns of knowledge, and the value of an ecosystem evaluation framework for seamounts are discussed.

Introduction

Underwater mountains, also called seamounts, are distinct topographical features that do not break the sea surface (Epp & Smoot 1989). There is no 'official definition' of the term seamount, and its use depends on the field of research. Originally, only features with heights greater than 1000 meters were defined as seamounts (Menard 1964). Features below this threshold can be termed knolls or hills, from 100 to 500 meters, and under 100 meters, respectively (Yesson et al. 2011). However, as smaller features can have similar ecosystem dynamics, most ecologists today include features down to 100 meters in height as seamounts (e.g. Pitcher et al. 2007; Clark et al. 2010).

Most seamounts are of volcanic origin and found on oceanic crust (Wessel 2007). Once again, from an ecological perspective features of different nature and origin can sometimes be treated as seamounts. One example is the Eratosthenes seamount in the Eastern Mediterranean Sea, which is a carbonate platform situated on continental crust (Robertson 1998).

Recent estimates of the total number of large seamounts (>1000 meters height) range from 14,000 to 100,000, while the estimates for smaller features vary from around 100,000 to 25 million (Hillier & Watts 2007; Kitchingman et al. 2007; Wessel et al. 2010; Yesson et al. 2011). Whereas large seamounts are recognized by satellite altimetry, acoustic mapping is needed to detect smaller features (Wessel et al. 2010). Since only a fraction of the seafloor has been surveyed by echo sounders (around 10%, Becker et al. 2009) the estimates of the number of small seamounts are highly uncertain. The majority of seamounts are situated in the Pacific Ocean, while the Atlantic Ocean probably holds around 20% (Yesson et al. 2011). Around 180 large seamounts are found in the Mediterranean and Black Seas combined, a small number compared to the last

global estimates of around 33 000 features (Yesson et al. 2011).

Recently, the attention to seamount ecosystems has boosted, both from researchers (e.g. Pitcher et al. 2007; special issues in *Deep Sea Research Part II*, 2009, 56(25): *Topical Studies in Oceanography; Marine Ecology*, 2010, 31(1): *Recent Advances in Seamount Ecology*; and *Oceanography*, 2010, 23(1): *Mountains in the Sea*) and from conservation organisations (e.g. Christiansen 2001; Gubbay 2003). This accompanies the recognition that these ecosystems can be threatened by human activities, such as deep-water fishing (Clark 2009; Pitcher et al. 2010). However, as less than 300 seamounts have been biologically sampled (Schlacher et al. 2010), the distinctness of seamount ecosystems has recently been questioned, highlighting the lack of scientific evidence supporting many of the “seamount paradigms” (McClain 2007; Rowden et al. 2010).

Two main views regarding seamounts are frequently encountered in the literature, the ‘island’ and ‘oasis’ hypotheses (McClain 2007). Seamounts have long been considered unique marine habitats (e.g. Hubbs 1958; Wilson & Kaufmann 1987). This view was reinforced by reports of high levels of endemism and rare species on newly described seamounts (De Forges et al. 2000; Moore et al. 2003), leading to the image of seamounts as isolated submarine islands. On the other hand, seamounts have also been described as areas of increased abundance and biomass, ‘oases’ in an otherwise scarce deep sea environment (Genin et al 1986; Rogers, 1994; Samadi et al. 2006)

Recent research has not supported the notion of seamounts as areas of elevated endemism (e.g. Samadi et al. 2006; Hall-Spencer et al. 2007; Cho & Shank 2010), but early observation of increased biomass of seamount biota (Hubbs 1958; Genin et al. 1986) has been partly supported. There is evidence of an aggregating effect on different groups of pelagic organisms (Clarke, 2007; Holland & Grubbs, 2007; Kaschner, 2007; Litvinov, 2007; Santos et al. 2007) and reports of higher biomass of benthic organisms, such as corals, on seamounts compared to the adjacent continental slope (Rowden et al., 2010).

Genin (2004) proposed three main mechanisms that might support the increased biomass found on seamounts: (1) nutrient upwelling along the seamounts’ flanks which leads to increased primary production, (2) trapping of vertical migrating organisms (*topographic blockage*) increasing the prey available for consumers on the seamount, and (3) alteration of the horizontal water currents by the seamount. The latter might lead to amplified fluxes of planktonic organisms and suspended organic matter supporting the benthic fauna, which in turn supports increased biomass of benthopelagic organisms. Finally, the influence of the seamount on ocean currents can lead to enhanced vertical mixing or retention mechanisms such as Taylor columns (White et al. 2007 and references therein). These oceanographic phenomena probably affect both the larval dispersal and productivity of seamounts (Beckmann & Mohn 2002; Piepenburg & Müller 2002)

The importance of these mechanisms is determined by physical factors such as depth of the seamount and steepness of its flanks (Lavelle & Mohn 2005; White et al. 2007 and references therein). Pitcher & Bulman (2007) proposed a scheme of 9 essential physical and oceanographic attributes that influence the dynamics of seamounts, and following, 21 ecological attributes that might occur as a response to the present regime (e.g. *Phytoplankton enhancement, Visiting fish predators*). Through evaluation of each attribute, a framework can be used to describe individual seamounts’ trophic functioning. This was the birth of the Seamount Ecosystem Evaluation Framework (SEEF).

In addition to describe patterns of seamount ecosystem functioning, SEEF aims to

assess the current 'knowledge status' of seamounts. This can highlight areas or individual seamounts in particular need of further research. Available seamount information will be publicised in an online database, thus allowing the general public to explore our knowledge of these marine habitats. Scientists and managers can also use SEEF for meta-analysis, ecosystem modelling, or conservational planning.

The objectives of this work are (1) to produce an overview of how well we know North Atlantic and Mediterranean seamounts today and (2) to assess patterns of seamount ecosystems. First, the degree of knowledge of North Atlantic and Mediterranean seamounts is evaluated, using a set of 36 attributes and a 4-scale knowledge score system. Spatial variation in seamount knowledge is investigated, through comparisons between seamounts in the North Atlantic Ocean and the Mediterranean Sea, and subsequently between subregions within these areas. Secondly, the ecological information gathered during the data mining process is used to evaluate the existing hypotheses of seamount ecosystem functioning.

Materials and Methods

Revision and development of the SEEF

The Seamount Ecosystem Evaluation Framework (SEEF) was initially developed by Pitcher & Bulman (2007) and Pitcher et al. (2007). By 2010, SEEF consisted of a preliminary list of 12 geological, 3 oceanographic and 25 ecological attributes (*Part A*), as well as 19 attributes describing the conservational status or threats to the individual seamount (*Part B*) (Pitcher et al. 2010). During the first period of this work the original framework was revisited and each attribute evaluated. In order to have a reasonable framework for the forthcoming process some of the original attributes were fused, while others were excluded or replaced by new attributes. An updated version of the framework with explanations for each attribute is given in Table 7 (Appendix 1). SEEF today consists of 14 geological, 3 oceanographic and 18 ecological attributes. The original *Part B* of SEEF (conservational status) has not been implemented yet.

The first stage of SEEF scores the level of knowledge for the individual seamounts regarding the 36 attributes, using four knowledge levels (*unknown, inferred, known and well known*). These categories reflect both the quantity and quality of data available. As an example, if the depth of the seamount peak is known from detailed bathymetry, this attribute is scored as *well known*. In order to keep the scoring process as objective as possible a set of scoring standards were developed through internal discussions and consultations with external experts (Table 8, Appendix 1).

The second stage of SEEF describes each attribute using categorical or quantitative values. For some of the physical attributes such as *Depth of peak* and *Age* numerical values are used, while for the remaining physical and all the ecological attributes a set of categorical values were formulated (Table 9, Appendix 1). These categories are developed to be easy-to-use during the data mining process and moreover to allow the information to be stored in a valuable manner for later analysis.

Data mining

The areas of study for this thesis work were the North Atlantic Ocean and the Mediterranean Sea. Seamounts in 8 regions were investigated: the Greenland basin; the Rockall Trough in the Northeast Atlantic; the Central East Atlantic (including the Bay of

Biscay, the Western Iberian Margin and the areas around the Madeira and Canary archipelagos); the Azores region (including the Meteor group and four features to the North of the Azores on the Mid-Atlantic Ridge); the Cape Verde Region; the New England and Corner Rise Seamounts in the Northwest; and the Mediterranean Sea's Eastern and Western basins.

Data mining was done by scanning available literature and online databases such as SeamountsOnline (Stocks 2010), FishBase (Froese & Pauly 2003), and Seamount Biogeoscience Network (<http://earthref.org/SBN/>). A total of 166 references were consulted for the North Atlantic and Mediterranean Sea, including scientific publications, reports, online databases, posters and personal communications. Information was continuously compiled in a Microsoft Access (2007) database. Each entry in the database holds information regarding one attribute (with an associated knowledge score), per individual seamount and reference. One attribute can thus be scored multiple times for the same seamount, but from different references and with possibly different knowledge scores.

In addition to the original SEEF, a separate framework was developed to keep track of taxonomic information when available. For ichthyofauna the species level was used, applying the same nomenclature as FishBase (Froese & Pauly 2003), and only including fish with complete Latin name in the reference. Data on air-breathing visitors (mammals, turtles and sea-birds) were also kept at the species level. Because of time limiting factors it was not feasible to keep track of species of demersal invertebrates; instead higher taxonomic levels were applied. The groups of seamount fauna presented by Stocks (2001) were used as a basis (generally going to the class level), while for corals the information was kept at the order level when available (Table 7, Appendix 1).

The Access database was constructed with 9 connected tables that keep track of seamount names and position, alternative names, seamount chains, SEEF knowledge scores and quantitative values, taxonomic information as well as all references.

Data analyses

Mapping the knowledge of seamount ecosystems

To assess the patterns of knowledge regarding seamounts in the North Atlantic Ocean and the Mediterranean Sea various descriptive statistics were employed. The *quantity* of knowledge was summarized on different levels: (1) for the total collection of seamounts ((a) the count of seamounts scored per attribute; (b) the average proportion of attributes scored per seamount; and (c) the total number of entries in the database), and (2) for individual seamounts (the proportion of attributes scored). The employment of geological versus ecological attributes was also assessed. (The oceanographic attributes were excluded since only one of these has been implemented at this stage.) To investigate whether the patterns of quantitative knowledge differed spatially between the seamounts in the North Atlantic Ocean and the Mediterranean Sea the non-parametric Mann-Whitney one-way analysis of variance was used. Possible associations between the knowledge (in terms of proportion of attributes scored) and physical factors (*Depth of the peak* and *Height of seamount*) were tested with the Spearman rank correlation coefficient (r_s).

Secondly, the *quality* of the data was summarized. This was done based on the SEEF knowledge score (1: inferred, 2: known, 3: well known) regarding each data entry, and compared between the two geographical areas.

To visually display the patterns of seamount knowledge ArgGIS 10 software

(ESRI 2011) was used. Additionally, we implemented a GoogleEarth application (version 6.0.2, 2011) to create interactive maps where the information on individual seamounts can be explored. Kml files were generated to display information about seamount name, position, depth of peak, height of peak, total proportion of attributes scored and proportion of attributes scored in the four fields Geology, Oceanography, Ecology and Threats.

Multivariate analyses

The structure of seamount knowledge in terms of the individual SEEF attributes was investigated using multivariate statistical methods in the Primer v6 (Clarke & Gorley 2006). A data matrix was constructed of the maximum knowledge scores for each attribute per individual seamount. Attributes which knowledge score never constituted over 6% of the summed scores for any seamount were excluded. Nonmetric multidimensional scaling (nMDS) was used to visualize the structure of the seamounts in 'attribute space'. This analysis was based on the triangular Euclidean distance matrix. The Euclidean metric was chosen for the ordination since similarities in terms of *lack of knowledge* (zeros) were also of interest to this analysis. Transformations of the knowledge score data did not affect the structure of the resemblance matrix significantly: the RELATE Spearman rank correlation analysis showed significant correlation between the resemblance matrix from original data and from square root transformed data ($R = 0.968$, $p: 0.1\%$), 4th-root transformed data ($R = 0.933$, $p: 0.1\%$); log-transformed data ($R = 0.977$, $p: 0.1\%$); and presence/absence data ($R = 0.88$, $p: 0.1\%$). The original data matrix was therefore used as basis for the analyses.

By applying cluster-analysis, with group-averages, and PRIMER's SIMPROF routine (1000 permutations, $p < 5\%$), the statistical significance of the groups emerging from the multivariate analysis could be tested. Clusters which structure was statistically supported was added to the MDS plot in order to further visualize the natural groups of seamount knowledge.

One-way analyses of similarities (ANOSIM, 999 permutations) were employed to test the null hypotheses that there were no differences in the structure of knowledge between a priori designed areas. The analysis was run for the Atlantic Ocean and Mediterranean Sea, and afterward for the following 7 subregions: the Rockall Trough; the Central East Atlantic, including the Bay of Biscay, the Western Iberian Margin, and the seamounts around the Madeira and Canary archipelagos; the Azores/Meteor Seamounts, including features to the north of the Azores on the Mid-Atlantic Ridge; the Cape Verde/West Saharan seamounts; the Northwest Atlantic, including the New England and Corner Rise seamounts; the Eastern Mediterranean basin, including the Levantine Basin and the Ionian Sea; and the Western Mediterranean basin, including the Tyrrhenian Sea, Balearic and Alboran Sea. (The Vesterisbanken seamount was excluded, as this is the single seamount from the Greenland Basin in the database.)

In order to identify the attributes that contributed most to the similarities within areas and the dissimilarities between areas the similarities percentage routine (SIMPER) was used (Bray-Curtis similarities, 90% cut-off for low contributions). This procedure ranks the attributes according to their average contribution to the similarity and dissimilarity within and between areas.

Assessment of seamount functioning hypotheses

The final aim of this study was to investigate whether the information gathered during the data mining process supported the existing hypotheses regarding seamount

ecosystem functioning. This was done by summarizing data regarding the attributes *Taylor column present*, *Primary production increased*, *Zooplankton production increased* and *Topographic blockage*. In addition, information concerning endemism and increased biomass of seamount fauna was investigated. Information was extracted from the SEEF database, and thus organised per individual seamount and reference. The data was additionally sorted according to the knowledge score, in order to visualize the *quality* in addition to the *quantity* of information.

Results

General patterns of knowledge

By June 2011, 95 seamounts in the North Atlantic Ocean and the Mediterranean Sea have been evaluated through the Seamount Ecosystem Evaluation Framework (SEEF) (Table 10, Appendix 2). All these features have been sampled or mapped bathymetrically (i.e. at least one attribute is scored as *known* or *well known*). 74 seamounts are situated in the Atlantic Ocean and 21 in the Mediterranean Sea. A large geographical range is covered, spanning nearly 60 latitudinal degrees from the Cape Verde region in the South (the João Valente Bank: 15°38'N - 23°06'W) to the Arctic in the North (the Vesterisbanken Seamount: 73°31'N - 9°07'W), and around 65 longitudinal degrees from the Eastern Mediterranean Levantine Basin (Eratosthenes Seamount: 33°40'N - 32°40'E) to the New England Seamount Chain (Bear Seamount: 39°55'N - 67°25'W).

Thirty-three of the total 36 SEEF attributes (Table 7, Appendix 1) have been employed to this stage. The most frequently used are *Depth of the peak*, *Height of the peak* and *Proximity to neighbour seamounts* (scored for all seamounts). *Demersal invertebrates*, *Corals* and *Demersal fish* are the most commonly applied ecological attributes, with 57, 46 and 40 seamounts scored for these attributes, respectively (Fig. 1). On average, the percentage of attributes scored per individual seamount is 27%, but the variation is large (Fig. 2), ranging from 8 to 67% per seamount. The averages for geological and ecological attributes separately are 39 and 21%, respectively.

A total of 1387 entries have been collected in the Atlantic/Mediterranean SEEF database (information regarding one attribute for an individual seamount, from a single reference). In addition, 1667 records of fish species and 724 entries of demersal invertebrate taxa (in both cases per seamount and individual references) make SEEF the largest collection of interdisciplinary information about Atlantic and Mediterranean seamounts to our knowledge.

Regarding the *quality* of the information from North Atlantic and Mediterranean seamounts, 28% of the entries were scored as *inferred*, 57% as *known* and 16% as *well known*. The patterns of knowledge vary between the North Atlantic and Mediterranean seamounts (Fig. 3). The majority of the entries for the North Atlantic Ocean belong to the ecological attributes, and a large proportion of these (74%) are scored as *known*. The geological information for the North Atlantic is to a larger extent scored as *inferred*. The opposite situation is observed for the Mediterranean Sea, where the geological attributes are dominating, and of which a majority are scored as *known* or *well known*. The non-parametric Mann-Whitney test was employed to test if seamount knowledge, in terms of proportion of geological or ecological attributes scored per seamount, differed significantly between the two areas (Table 1). The proportion of geological attributes

scored per seamount was significantly higher in the Mediterranean Sea ($U = 1163.50$, $p < 0.001$), while the opposite was found for ecological attributes ($U = 563.00$, $p < 0.05$). No significant difference was detected considering the total proportion of attributes scored ($U = 859.00$, $p: 0.23$).

The Spearman rank correlation analysis was conducted in order to investigate possible associations between the degree of knowledge (i.e. proportion of attributes scored per seamount) and the physical factors *Depth of the peak* and *Height of the seamount*. First the correlation between the two physical factors was assessed, as they were thought to be interlinked. No significant association was detected ($r_s = 0.124$, $p: 0.116$), and both factors were therefore included in the analysis.

Depth of the peak was significantly negatively correlated with the proportion of attributes scored ($r_s = -0.527$, $p < 0.001$); i.e. the deeper the seamount the lower is the knowledge. Running the test for the proportion of geological and ecological attributes scored separately gave similar results ($r_s = -0.280$, $p < 0.005$ and $r_s = -0.486$, $p < 0.001$). *Height of the seamount* was neither significantly correlated with the global proportion of attributes scored nor with ecological attributes separately ($r_s = 0.121$, $p: 0.122$ and $r_s = 0.042$, $p: 0.341$). However, when tested against the proportion of geological attributes scored a significant correlation was detected ($r_s: 0.174$, $p < 0.05$). This was due to three well-mapped seamounts with large heights (Vesterisbanken, Palinuro and Marsili). When these features were removed from the analysis the association was non-significant ($r_s = 0.106$, $p: 0.158$).

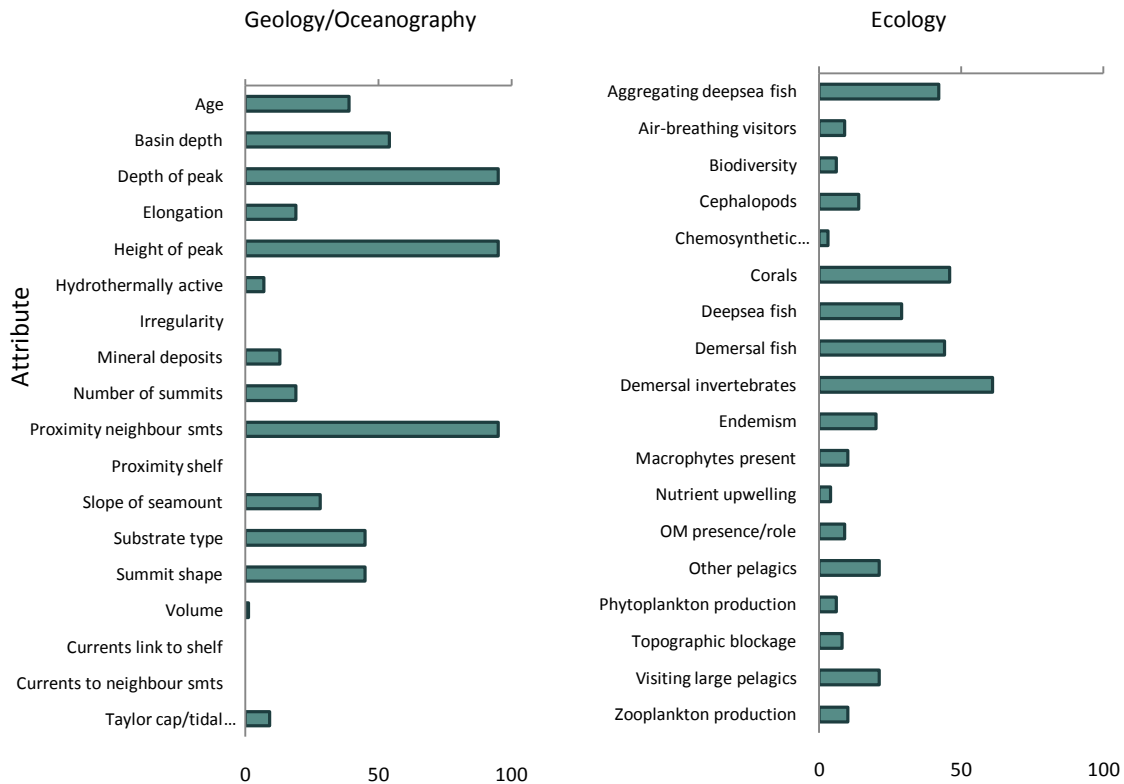


Figure 1: Number of seamounts scored for each of the 36 SEEF attributes.

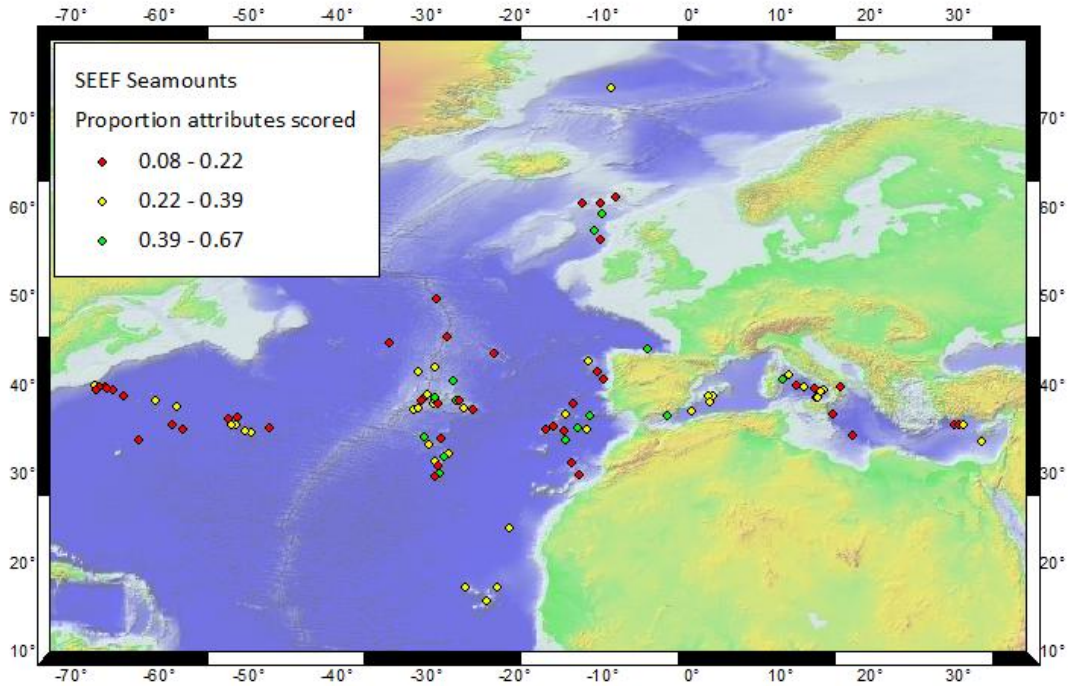


Figure 2: Proportion of attributes scored for all seamounts. The colour of the symbol reflects the proportion of the total 36 attributes that have been scored for the individual seamount (for list of seamounts, see Appendix 2).

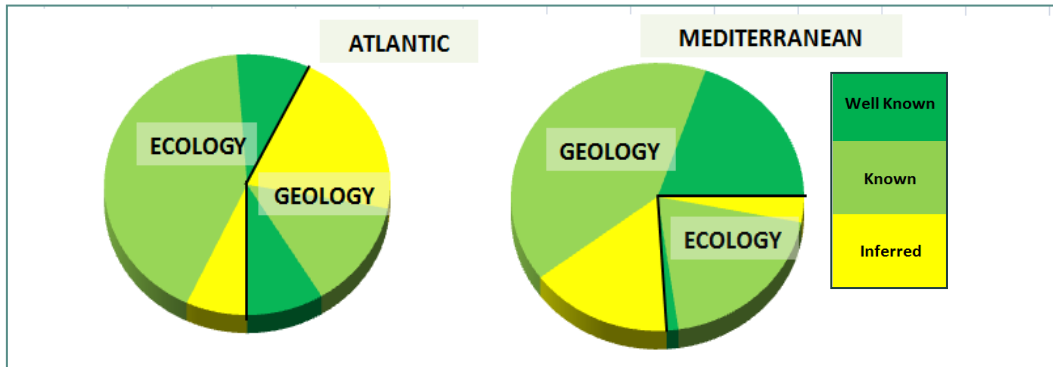


Figure 3: Proportion of entries in different score categories. The coloured slices of the charts reflect the proportion of the total entries in the SEEF database belonging to the different score categories, for the North Atlantic Ocean (left) and the Mediterranean Sea (right). Note that *unknown* is excluded, since only the quality of the information we have is considered.

Table 1: Test of the knowledge values from the North Atlantic and Mediterranean seamounts. The second column shows median values of prop. attributes scored per seamount for the two areas, considering all attributes in total; only geological attributes; and only ecological attributes. The third column shows the U and p-values from the Mann-Whitney test regarding the equality of the ranked values.

	Median values (proportion of attributes scored)		Mann-Whitney test	
	Atlantic (n=74)	Mediterranean (n=21)	U	p
Total	0.25	0.28	859.00	0.2327
Geology	0.33	0.53	1163.50	0.0003
Ecology	0.17	0.11	563.00	0.0281

Structural patterns of knowledge

Distribution of individual seamounts

Figure 4 shows the two-dimensional ordination of the distances between individual seamounts, calculated from the matrix of maximum knowledge scores for 28 attributes. 8 attributes that never contributed >6% to the summed knowledge score for any seamount were excluded prior to the analysis. The stress value of 0.15 is on the limit of what can be considered a useful representation of the structure of the data (Clarke & Gorley, 2006). This means that the seamounts relative positions on a fine scale should not be given much weight. However, by overlaying groupings that were found to be statistically significant (SIMPROF test, 1000 permutations, $p < 5\%$), and consulting with the original data matrix, some patterns emerge.

Seamounts placed to the right on the horizontal axis of the nMDS plot have in general high knowledge scores for the attributes *Corals*, *Deepsea fish*, *Demersal fish* and *Demersal invertebrates*. Moving leftwards along the horizontal, the scores of these attributes decrease. The separation of seamounts along the vertical axis seems to be related to the scores for geological attributes; e.g. seamounts for which substrate composition has been analyzed are placed at the lower end of the axis. Thus, the seamounts in the lower left cluster are geologically well-studied features with relatively poor knowledge in terms of ecology. The central left cluster contains a large number of seamounts for which only a few attributes are scored, i.e. features that have been mapped but not sampled, or only briefly sampled. The majority of the Mediterranean seamounts fall within this group, as well as some Northwest Atlantic seamounts for which only a few studies on corals are currently available. Bathymetrical data from this area will soon be published (Timothy Shank, personal communication).

The upper central cluster is characterized by relatively high scores for the ecological attributes, in particular concerning the *Aggregating deepsea fish*, but with varying degree of bathymetric or geological studies. Many Azorean seamounts fall within this group. Some individual features are distinguished in the plot: seamount 531, 533 and 542 are the Seine, Sedlo and Great Meteor seamounts, for which the knowledge scores are overall high, and information for attributes such as *phytoplankton* and *zooplankton production* is available. Seamount 589, the João de Castro bank, is also a relatively well studied seamount, mainly because of its unique shallow-water hydrothermal activity.

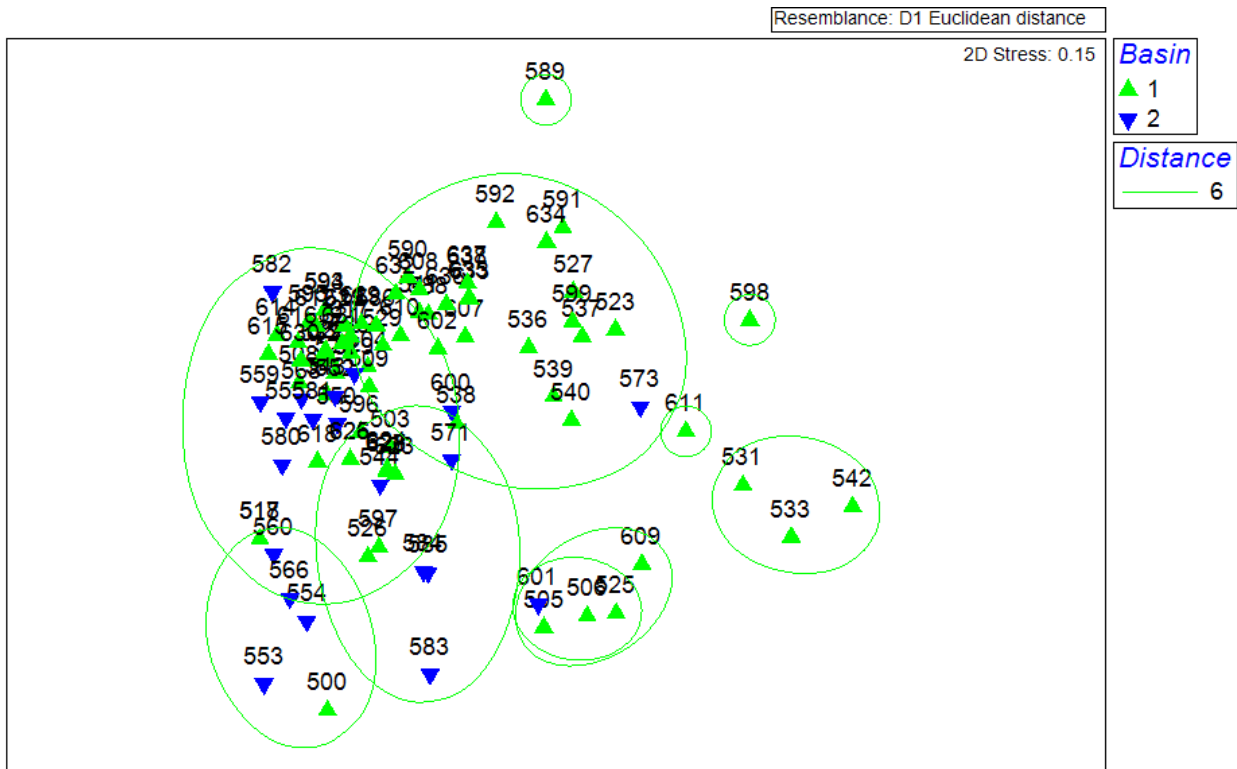


Figure 4: nMDS ordination of seamounts from the Atlantic Ocean (group 1, green triangles) and the Mediterranean Sea (group 2, blue triangles). The ordination was based on Euclidean distances calculated from maximum knowledge score for 28 attributes. See Table 10 (Appendix 2) for seamount names and geographical positions.

Regional patterns

A significant difference in the structure of knowledge scores was detected between the North Atlantic Ocean and the Mediterranean Sea (ANOSIM, $R: 0.145$, $p < 0.05$). The Mediterranean seamount group is more homogenous than the Atlantic, with an average similarity of 52.60 % versus 44.32 %, respectively. The results from the SIMPER analysis show (Table 2), similarly to the univariate analysis, differences due to higher scores for geological attributes in the Mediterranean (*Summit shape*, *Basin depth* and *Elongation*), while attributes such as *Demersal fish*, *Demersal invertebrates* and *Aggregating deepsea fish* are scored higher for the Atlantic Ocean seamounts. However, no appropriate 'indicator attribute' emerged; instead 20 attributes collectively contributed 90 % to the dissimilarities between the two groups (Table 2).

To investigate whether the structure of seamount knowledge differed on a smaller geographical scale the analysis of variance was conducted for 7 subregions (based on the same resemblance matrix as for the preceding analysis). The overall difference between the regions was significant ($R: 0.245$ $p: 0.01$). The pairwise analysis (Table 3) indicated 10 paired groups which differed on a 0.5 % significance level. Simultaneously, the average similarity levels within each group were in general low (Table 4), signifying a lack of conformity. Nevertheless, it was possible to distinguish differences between groups of seamounts in terms of which attributes contribute most to within-group similarities (the uppermost attributes listed for each group in Table 4).

Table 2: Results of the SIMPER analysis of dissimilarities between the knowledge of North Atlantic and Mediterranean seamounts. Attributes are listed in order of contribution to the similarity within seamount group.

Attribute	Atlantic		Mediterranean		Contrib%	Cum.%
	Av.Score	Av.Score	Av.Diss	Diss/SD		
Summit shape	0.81	1.81	4.28	1.19	7.27	7.27
Basin depth	0.97	1.67	3.9	1.22	6.63	13.91
Elongation	0.26	1.29	3.43	0.97	5.84	19.74
Demersal fish	1.19	0.81	3.28	1.03	5.57	25.32
Substrate type	0.8	1.33	3.26	1.1	5.55	30.86
Demersal invertebrates	1.46	1.05	3.22	0.94	5.47	36.34
Aggregating deepsea fish	1.2	0.14	3.16	0.95	5.38	41.72
Age	0.91	0.71	3.11	0.89	5.29	47.01
Depth of peak	1.58	2.38	2.92	1.42	4.96	51.96
Corals	1.01	0.67	2.83	0.94	4.8	56.77
Slope of seamount	0.47	0.81	2.68	0.78	4.56	61.33
Height of peak	1.46	2.05	2.65	1.19	4.5	65.83
Number of summits	0.36	0.86	2.62	0.76	4.45	70.28
Deepsea fish	0.91	0.24	2.34	0.76	3.98	74.26
Mineral deposits	0.19	0.57	1.77	0.65	3	77.26
Proximity neighbour smts	1.31	1.67	1.7	0.98	2.89	80.15
Macrophytes present	0.09	0.57	1.58	0.62	2.69	82.84
Visiting large pelagics	0.53	0.1	1.53	0.58	2.6	85.44
Other pelagics	0.54	0.24	1.47	0.63	2.51	87.95
Endemism	0.49	0	1.35	0.52	2.29	90.23

Table 3: Results of the pairwise analyse of variance (ANOSIM) between seamount subregions, based on the Euclidean resemblance matrix of maximum knowledge scores per attribute. Pairs found to be different at a 0.05 significance level are shaded.

Groups	R Statistic	p	Groups	R Statistic	p
Rockall* Central	-0.087	0.775	Azores* Med. East	0.202	0.072
Rockall* Azores	0.225	0.071	Azores* Med. West	0.463	0.001
Rockall* Med. East	0.039	0.287	Azores* Cape Verde	0.072	0.31
Rockall* Med. West	0.088	0.204	Azores* Northwest	0.326	0.001
Rockall* Cape Verde	0.077	0.21	Med. East* Med. West	0.015	0.399
Rockall* Northwest	0.282	0.034	Med. East* Cape Verde	0.403	0.024
Central* Azores	0.197	0.014	Med. East* Northwest	0.306	0.005
Central* Med. East	-0.084	0.771	Med. West* Cape Verde	0.083	0.226
Central* Med. West	0.143	0.011	Med. West* Northwest	0.499	0.001
Central* Cape Verde	-0.175	0.894	Cape Verde* Northwest	0.59	0.003
Central* Northwest	0.236	0.001			

Table 4: Results of the SIMPER analysis of similarities within subregions. Attributes are listed in order of contribution to the similarity within seamount group. Number of seamounts in each group and average proportion of attributes scores is indicated

Rockall Trough (n=6, avg. prop. attributes scored = 0.29)						Eastern Mediterranean (n=7, avg. prop. attributes scored = 0.20)						Cape Verde (n=4, avg. prop. attributes scored = 0.29)					
Average similarity: 35.23						Average similarity: 28.76						Average similarity: 42.15					
Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%	Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%	Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%
Basin depth	1.83	11.26	2.05	31.95	31.95	Basin depth	1.14	11.34	0.8	39.43	39.43	Demersal fish	2	9.68	0.89	22.96	22.96
Corals	1.33	7.08	0.92	20.09	52.04	Summit shape	1.29	6.46	0.59	22.48	61.91	Basin depth	1.5	7.88	13.56	18.69	41.65
Dem. invertebrates	1	3.93	0.4	11.15	63.19	Dem.invertebrates	1.14	5.68	0.6	19.74	81.65	Substrate type	1.5	7.52	0.91	17.83	59.48
Summit shape	1.5	3.74	0.74	10.62	73.81	Substrate type	0.86	2.9	0.39	10.08	91.72	Dem.invertebrates	1.5	7.52	0.91	17.83	77.31
Age	1.5	3.22	0.47	9.15	82.96							Visiting large pelagic	1.25	5.5	0.83	13.06	90.37
Demersal fish	1	1.88	0.47	5.35	88.31												
Substrate type	0.83	1.26	0.48	3.59	91.89												
Central East Atlantic (n=15, avg. prop. attributes scored = 0.29)						Western Mediterranean (n=14, avg. prop. attributes scored = 0.28)						Northwest Atlantic (n=19, avg. prop. attributes scored = 0.21)					
Average similarity: 29.54						Average similarity: 43.91						Average similarity: 49.22					
Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%	Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%	Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%
Dem.invertebrates	1.73	5.68	0.74	19.25	19.25	Summit shape	2.07	8.88	1.44	20.21	20.21	Corals	1.74	14.72	1.29	29.92	29.92
Basin depth	1.27	5.07	0.79	17.16	36.41	Elongation	1.79	6.73	0.87	15.33	35.54	Endemism	1.47	10.64	0.94	21.61	51.53
Age	1.33	4.57	0.52	15.47	51.88	Substrate type	1.57	6.66	1.31	15.18	50.72	Dem.invertebrates	1.53	10.14	0.97	20.61	72.14
Agg. deepsea fish	1.4	3.19	0.53	10.81	62.69	Basin depth	1.93	6.45	1.05	14.68	65.4	Age	1.26	3.69	0.43	7.5	79.64
Summit shape	1	2.43	0.49	8.23	70.92	Demersal fish	1.14	2.58	0.63	5.88	71.28	Substrate type	0.79	3.45	0.45	7.02	86.66
Corals	1.07	2	0.58	6.77	77.69	Dem.invertebrates	1	2.21	0.54	5.03	76.31	Basin depth	0.89	2.39	0.43	4.85	91.51
Demersal fish	1.2	1.58	0.4	5.34	83.03	Number of summits	1.14	2.16	0.42	4.92	81.22						
Substrate type	0.93	1.36	0.47	4.59	87.62	Age	0.93	2.03	0.48	4.62	85.84						
Deepsea fish	1	1.09	0.32	3.7	91.32	Corals	0.86	1.63	0.44	3.72	89.56						
						Mineral deposits	0.71	1.4	0.34	3.18	92.74						
Açores/Meteor Seamounts (n=29, avg. prop. attributes scored = 0.34)																	
Average similarity: 37.67																	
Attribute	Av.score	Av.Sim	Sim/SD	Contrib%	Cum.%												
Agg. deepsea fish	1.83	8.43	0.94	22.38	22.38												
Demersal fish	1.83	7.9	0.99	20.96	43.34												
Dem.invertebrates	1.34	5.18	0.72	13.76	57.1												
Deepsea fish	1.41	4.24	0.66	11.26	68.35												
Visiting large pelagics	1.03	3.68	0.48	9.76	78.11												
Slope of seamount	0.66	2.54	0.51	6.75	84.86												
Other pelagics	0.93	1.89	0.46	5.02	89.88												
Cephalopods	0.69	0.98	0.34	2.59	92.47												

Public interface of SEEF

One of the broader aims of the SEEF project is to make knowledge on seamount ecosystem available to the public through an online interface. As a part of this process, interactive GoogleEarth® maps (version 6, 2010) were generated (fig. 5). The maps show the position of the seamounts in the database, and the level of information available for individual seamounts is indicated by the colour of the symbol (overall proportion of attributes scored). When the pointer is placed above the seamount the name of the feature is visible. Through a click on the symbol a window shows information about depth and height of the seamount, along with 4 boxes indicating the level of knowledge for each of the fields *Geology*, *Oceanography*, *Ecology* and *Threats*. (Note that the *Threats* field has not yet been implemented and is therefore always scored as unknown,) The most updated GoogleEarth® files can be downloaded at <http://www.horta.uac.pt/projectos/seamounts/GoogleEarth/>. Through these maps the degree of knowledge for individual seamounts can be explored.

Table 2 shows how the degree of knowledge for individual seamounts in terms of the 36 SEEF attributes altogether can be displayed. This format facilitates comparison between features and regions.

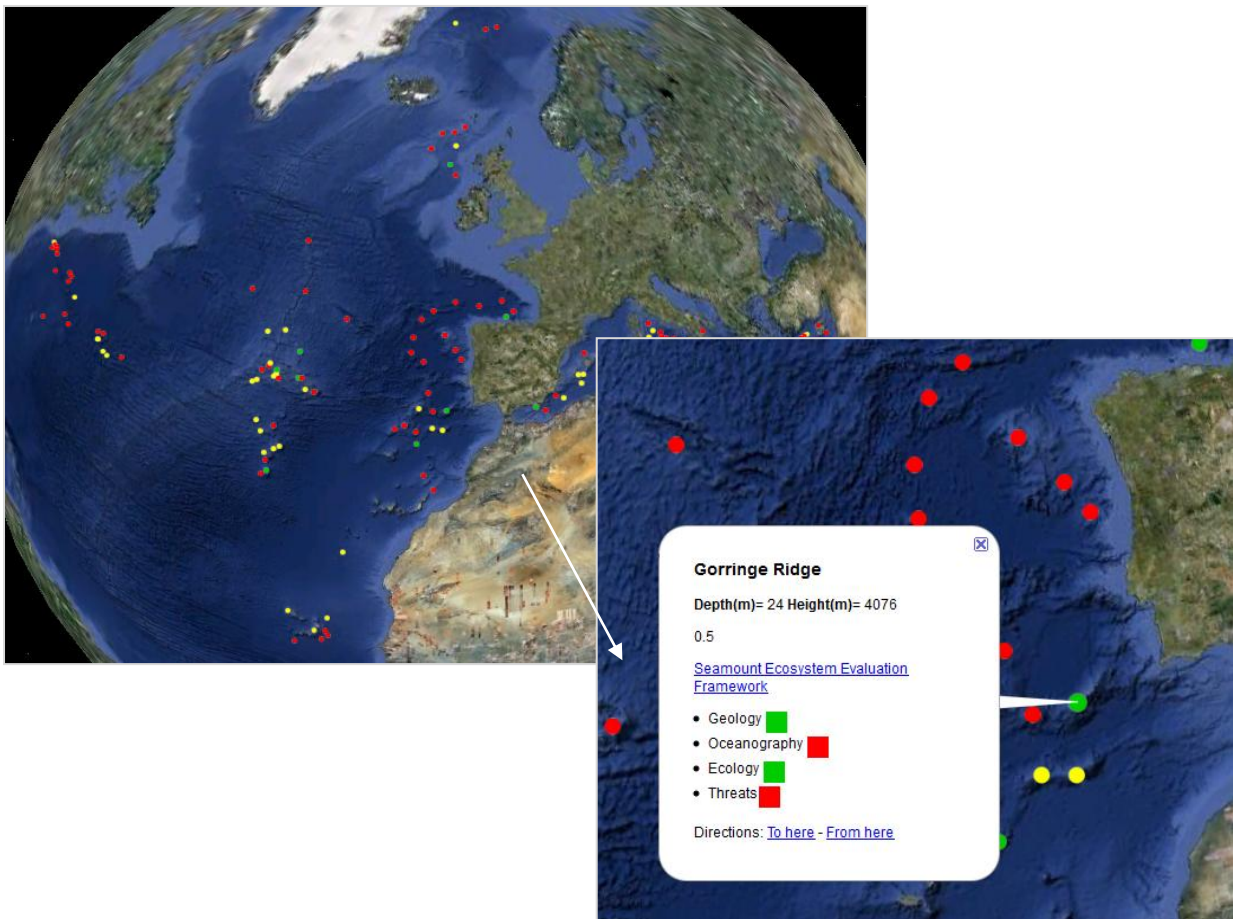


Figure 5: Example of GoogleEarth® maps. These maps show the distribution of the seamounts in the SEEF database (left) and an example of the information available for individual seamounts (right). The colours of the symbol represent the proportion of attributes scored: Red: <20%, yellow: 20-40%, green: >40%.

Table 5: SEEF score table. This table shows the degree of knowledge in terms of maximum knowledge score for each attribute for 19 of the 95 seamounts in the SEEF database. See Appendix 1 for details on the individual attributes and Appendix 4 for position of the seamounts.

Attributes	Northeast Atlantic					Azores				Mediterranean				Cape Verde		New England		Corner Rise	
	Rosemary	Anton Dohrn	Vigo	Ashton	Seine	João Castro	Cruiser	Great Meteor	Sedlo	Eratosthenes	Anaximenes	Palinuro	Baronie	Senghor	João Valente	Bear	Nashville	Corner West	Yakutat
Age	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Basin depth	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Depth of peak	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Elongation	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Height of peak	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Hydrothermally active	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Irregularity	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Mineral deposits	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Prox. to seamounts	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Slope of seamount	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Substrate type	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Summit shape	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Volume	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Currents link to shelf	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Currents to seamounts	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Taylor cap/ tidal rect.	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Aggr. deepsea fish	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Air-breathing visitors	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Biodiversity	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Cephalopods	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Chemosynth. comm.	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Corals	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Deepsea fish	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Demersal fish	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Demersal invertebrates	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Endemism	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Macrophytes present	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Nutrient upwelling	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
OM presence/role	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Other pelagics	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Phytoplankton prod.	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Topographic blockage	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Visiting large pelagics	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known
Zooplankton prod.	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known	known

Knowledge status
 unknown ■ inferred ■ known ■ well known ■

Seamount ecosystem functioning

Table 6 summarizes the literature gathered through SEEF that support or oppose selected 'seamount hypotheses'. The data are organized based on individual seamounts (3 digits number, Table 10, Appendix 2) and reference (number in brackets, Table 11, Appendix 3). Information not regarding specific seamounts is not included in SEEF, and thus not listed here. Supportive evidence is sorted based on the entries' knowledge score, thus reflecting the extensiveness of the study (Table 8, Appendix 1). The first 3 attributes listed regard mechanisms that can affect seamount productivity (Genin 2004; White et al. 2007, and references therein). Following, increased zooplankton production and increased abundance of demersal or pelagic organisms compared to adjacent comparable habitats would be expected if seamounts were highly productive areas (in concordance with the 'oasis hypothesis', (Samadi et al. 2006). The last attribute, *increased endemism*, concerns the hypothesis that seamounts function as isolated submarine islands with unique fauna (Forges et al. 2000; Hubbs 1958).

The majority of the information regarding the presence of a Taylor column and the level of phytoplankton or zooplankton production is scored as *inferred*. These data come largely from indirect studies or models. Explicit evidence to confirm the presence of these phenomena for individual seamounts is scarce for North Atlantic and Mediterranean Sea. There is some information that supports the presence of a topographic blockage mechanism trapping vertically migrating organisms, mainly from the Great Meteor Guyot. However, most studies are based on samples from few stations or a limited time interval (scored as *known*), and contradictory results are found for the same seamounts.

Information regarding increased biomass of seamount biota, or increased abundances of visiting organisms around seamounts, is also scarce. In most cases the published literature lack appropriate quantitative comparisons (e.g. with the surrounding deep sea and the adjacent continental slope). This type of qualitative information is registered in the SEEF database only as *presence* (e.g. *presence of corals*), and is thus not valuable to evaluate the 'seamount oasis hypothesis'.

Lastly, solid data that support the notion that seamounts host increased levels of endemism is particularly rare for the investigated areas. First, the abovementioned lack of appropriate comparisons is also the case for most studies that suggest this seamount effect. In addition, the majority of the surveys on seamounts have only considered specific taxa, which means that when high levels of endemism have been reported this is only known for a limited group of organisms (e.g. benthic copepods or demosponges (George & Schminke 2002; Xavier & van Soest 2007)). A considerable number of studies have on the contrary to the 'seamount island hypothesis' found a low degree of endemism on seamounts when analyzed against comparable areas. Further details on some of these findings will be developed in the discussion.

Table 6: Evidence gathered during the SEEF data mining process regarding seamount hypotheses. The data is organized by seamount (3 digit ID number, Table 10, Appendix 2) and reference (in parentheses, Table 11, Appendix 3) Note that this cannot be considered a complete list, as literature might have been overlooked or unavailable during the time of study.

Hypothesis/attribute	Inferred	Known	Well Known	Opposing
Taylor column present	505(7)	506(221)	533(15)	582(109)
	506(5;197)	609(217)	542(39)	
	531(16)			
	539(74)			
	542(38;74;178) 602(179)			
Topographic blockage	573(118)	523(51)		531(18;25)
	588(131)	531(23)		533(18)
		537(62)		
		542(41;42;58;61;62; 63;178)		
Primary production increased	525(33)	531;533(22)		531;533(17)
	533(26)			
	539(74)			
	542(74) 608(182)			542(40;74;78)
Zooplankton production increased	542(78)			527; 531;533(20)
	588(126)			542(41)
	601(111)			553;559(96)
				582(109) 589(137)
Increased abundance of:				
Demersal fish			531;533(23)	
Aggregating deep-sea fish		506(221)	533(23)	537; 540(144)
Demersal invertebrates				542(87) 542(88)
	544(92)			589(138)
Air-breathing visitors		591;592;595(143)		
Visiting large pelagics		589;590;591;592; 593;594(143)		
Increased level of endemism		525(124)		505;506(231)
		542(82)		525(57)
				542(59)
				542(87)
				542(158)
				589(138)
				611;612;613;614;615;617;618;619;621;623;624627;628;629(188)

Discussion

General patterns of knowledge

The latest estimates of the total number of seamounts in the North Atlantic are in the order of 3000 large (>1000 meters) and 15 000 smaller features (500-1000 meters), while a number of around 6% of this is found the Mediterranean Sea (Yesson et al. 2011). We have attempted to summarize our current degree of knowledge regarding these features, both quantitatively and qualitatively. Ninety-five seamounts have been evaluated through SEEF, 74 in the North Atlantic and 21 in the Mediterranean Sea. All of these features have been identified from available literature; they have thus been subject to some degree of bathymetrical mapping or sampling. If we compare this number with the estimates from Yesson et al. (2011), approximately 2.5% of the *large* seamounts in the North Atlantic, or only 0.005% of *all* seamounts over 500 meters, have been studied. The 'coverage' in the Mediterranean Sea is around 12%. These numbers are of course highly speculative, both because some information might have been overlooked, and because of the uncertainty regarding the total number of seamounts (Etnoyer et al. 2010)

Nevertheless, it is obvious that Atlantic and Mediterranean seamounts are largely unexplored. For the investigated seamounts, information was on average found for less than 1/3 of the relatively general SEEF attributes. Furthermore, a considerable proportion of the information available was scored as inferred (Fig. 3).

It is already somewhat a tradition in seamount literature to state the global lack of ecological knowledge and cite that 'less than 300 features have been thoroughly sampled' (Schlacher et al. 2010). Research suffers due to the inaccessible nature of both the seamounts per se and much of the information regarding them. Rogers (1994) listed various reasons impeding in-depth research, in both senses, on seamount ecology, such as the long travelling time to the areas; the roughness of the open ocean; and the difficulties in sampling the often steep and rocky seamount surface. We detected a negative correlation between the depth of the seamount peak and the degree of knowledge, which reflects the challenges met in deep sea research. It is also important to consider that most of the seafloor has never been mapped (Becker et al. 2009). Thus, even the positions of the vast majority of seamounts are unknown.

In addition to the genuine obstacles to sample seamounts, much of the data from past studies are hardly accessible. A substantial amount of research on Atlantic Ocean seamount has been done by Russians, and the publications are generally not translated. Also, information might be 'hidden' in unpublished data or reports not found through literature search engines. This last factor is important to keep in mind when the level of seamount knowledge is discussed, as it inevitably depends on how thorough the data search is.

Spatial patterns of knowledge

Our results have highlighted differences in the patterns of seamount knowledge between the Mediterranean Sea and the North Atlantic Ocean. In the Mediterranean Sea, seamount research has traditionally been focused on geology. In particular the seamounts in the Tyrrhenian Sea are relatively well-studied in terms of volcanology, mineralogy and hydrothermalism (e.g. Dekov & Savelli 2004; Trua et al. 2002). Many Western Mediterranean seamounts are also well-mapped bathymetrically, reflected in the high scores for attributes such as *Summit shape* and *Elongation* (Table 4).

Ecological research has on the other hand been sparse: only a few publications are available from the last century (e.g. Galil & Zibrowius 1998; Perrone 1982; Strusi et al. 1985). However, recent studies regarding seamount ecology seem to indicate a growing interest for this field in the Mediterranean (e.g. Ettoumi et al. 2010; Sevastou et al. 2011; Bo et al. 2011). Also conservation organizations have engaged in seamount research, which has augmented considerably the knowledge of some features in terms of habitat and species diversity (OCEANA 2008; 2010). These findings have additionally encouraged the recent protection of the seamounts in the Channel of Mallorca, constituting the first seamount MPA in the Mediterranean Sea (Madina 2011).

The multivariate analysis showed significant differences between subregions in terms of knowledge of individual attributes, but also low conformity within groups (Table 3 and 4). The North-western seamounts were the only which differed significantly from all the other groups. Research campaigns have recently visited several New England and Corner Rise seamounts in order to investigate levels of invertebrate connectivity (Cho & Shank 2010; Thoma et al. 2009). These multi-seamount studies have lead to a greater similarity within this group in terms of knowledge.

The Azorean/Meteor seamounts differ from features closer to the European continent (the Central East group), mainly due to higher focus on fisheries research in the former region. The similarity within the Central East assemblage is the lowest of all the groups. Some of these seamounts, such as the Josephine Bank, have a long history of biological investigations, dating back to the German *Meteor* cruises (e.g. Hesthagen, 1970). Other features have been bathymetrically mapped but to our knowledge received no ecological research (e.g. the Vigo and Porto seamounts, Mougnot et al. 1984). The recent OASIS project (Christiansen & Wolff 2009) has shed light on both oceanographic and ecological aspects of two Northeast Atlantic seamounts; Seine and Sedlo; and demonstrated the importance such comparative studies.

In the Cape Verde and the Eastern Mediterranean regions only a few features have been studied and the range of knowledge is low. Additionally research is clearly needed in these areas.

Seamount ecosystem functioning

In a classical paper Hubbs (1958) challenged future seamount ecologists through a set of questions such as *to what degree are seamount communities isolated; what is the abundance of the organisms found; and what are the physical processes that control these patterns*. In a review 36 years later Rogers (1994) stated that due to the scarcity and randomness of seamount research most of these questions remain unanswered.

Fifty-three years after Hubbs' publication we have attempted to synthesise available knowledge about seamount ecosystems from the North Atlantic Ocean and the Mediterranean Sea. Information from individual seamounts in terms of a set of interdisciplinary attributes (Table 7, Appendix 1) was collected, and data directly regarding existing 'seamount hypotheses' were summarized (Table 6).

According to the 'seamount oasis hypothesis' (formulated by Samadi et al. 2006) seamounts are areas of increased productivity and local biomass. Different physical mechanisms that might lead to this effect have been proposed (Genin 2004; White et al. 2007 and references therein). Most of the data regarding seamount productivity come from indirect studies (e.g. registered upwelling but no records of increased primary production), and there is subsequently no convincing evidence for increased primary or secondary (zooplankton) production over seamounts from the North Atlantic or Mediterranean. The recent studies conducted during the OASIS project did not find any

clear evidence neither of increased local production nor topographic blockage, and suggested that higher trophic levels were rather sustained by enhanced horizontal fluxes above the summit (Arístegui et al. 2009; Hirsch et al. 2009; Hirsch & Christiansen 2010). However, seasonal variation and unambiguous results were reported. Since the importance of these mechanisms is determined by both the physical structure of the seamount and temporarily varying oceanographic factors (Lavelle & Mohn 2005) contradictory results from the same feature are perhaps not unexpected. In order to firmly determine the dominating regime on individual seamounts long-term studies should be conducted. Unfortunately, considering the time and cost constraints related to deep sea research, this is not feasible in most cases.

Increased biomass of seamount fauna has been observed in the Pacific Ocean, e.g. for corals compared to adjacent continental slopes of the same depth (Rowden et al. 2010). Seamounts can offer suitable hard substrate and increased horizontal currents (Genin et al. 1986), and these 'coral gardens' can in turn act as structuring organisms providing habitat for other species (Roberts et al. 2006). Hardly any studies in the North Atlantic or Mediterranean have quantitatively compared abundances of seamount biota with other habitats of similar depths. From the literature scanned it is thus not possible to confirm a general 'seamount oasis effect' on demersal communities. On the other hand, there is some evidence of an aggregating effect on visiting pelagic species, such as tuna, seabirds and dolphins (Fonteneau 1991; Monteiro et al. 1996; Morato et al. 2008, seamounts not specified for the two former). It is hypothesised that seamounts are used by oceanic species for feeding, spawning or as guidelines for migration (Kaschner 2007; Morato et al. 2008; Santos et al. 2007). However, if observing pelagic organisms is difficult, it is even more challenging to determine why or to what degree seamounts are frequented. Modern tagging technology can hopefully shed some light on these questions in the future.

Information regarding the level of endemism on seamounts was not originally included in SEEF, as the framework focuses on trophic functioning of seamount ecosystems. However, in order to assess the validity of the 'seamount island hypothesis' it was decided to keep track of these data when the level of endemism was explicitly discussed in the literature. These data should be considered with some caution, as they were not the prime purpose of the literature search and some studies might have been overlooked.

Theoretically, in order to know the true level of endemism for a habitat all species from that area and all surrounding areas (and ideally globally!) need to be known. Needless to say, this is never the case for deep sea habitats. As treated in various reviews, apparent high endemism of seamounts might thus be due to the lack of knowledge of deep sea fauna (e.g. Rogers 1994; Rowden et al. 2010). An example from our dataset is a study of benthic copepods of the order Harpacticoida from the Great Meteor (George & Schminke 2002). The authors report a high number of new species, taken as a sign of 'pronounced endemism'. However, it is also stated that this was the first study of Harpacticoida going to species-level on a seamount. Thus, it seems reasonable to believe that if more seamounts were studied the level of new species would decrease.

Regardless of the facility to overestimate the number of unique species, recent studies have reported low or no levels of endemism on seamounts. A recent study from the Rockall Trough failed to detect any distinct seamount community when compared with an adjacent bank, neither in terms of biodiversity nor endemism (Howell et al. 2010). Another study on corals from Northeast Atlantic seamounts as a whole found

level of endemism to be less than 3% (Hall-Spencer et al. 2007), in striking contrast to levels of 29-34 % reported from Pacific seamounts (Forges et al. 2000). Overall, the 'seamount island hypothesis' is not supported from the available data for the North Atlantic and Mediterranean seamounts.

Future usage of the SEEF

The original idea behind the SEEF was to categorically quantify information about seamounts in order to allow detection of potential 'seamount effects' on local biomass or production. This first trial of the framework in the North Atlantic and Mediterranean Sea shows that we lack quantitative data with appropriate comparisons to detect patterns on a general scale. We have also gathered a large quantity of taxonomic information, but comparing seamounts in terms of community structure is impeded by factors such as varying depths and sampling effort.

However, we have demonstrated how seamounts can be mapped in terms of knowledge. With larger sets of quantitative data, patterns of functioning or seamount effects can be compared with patterns of knowledge in order to detect correlations. Artifacts due to different degree of research can thus be revealed.

The SEEF project will continue to compile information in order to create a global overview of seamount knowledge. By constructing an online database researchers who possess information regarding individual features will hopefully be encouraged to add this data. An online information system is valuable both for scientists and managers who wish to assess available knowledge; or to encourage research in areas where information is scarce.

SEEF originally encompassed a third part regarding conservational issues or threats posed to seamounts. Due to time constraints this was not yet implemented, but we envisage a future SEEF which also considers this aspect. Fisheries pose today the most obvious threat to seamounts (Clark 2009; Clark & Koslow 2007), both for the target fish species and for the benthic community on seamounts (Clark 2009; Morato, et al. 2004). Around 350 seamounts are under some sort of protection, but since most seamounts are situated in high-sea areas management is extremely challenging (Alder & Wood 2004, current number not certain). The conservational part of SEEF will evaluate both the severity of threats posed to individual seamount ecosystems and the protection status. In combination with the current framework this would create a global evaluation system that considers seamount productivity, the presence of vulnerable fauna, the intensity of fishing or other human activities and the degree of management or protection of the seamount. However, as demonstrated by this study, most seamounts are poorly known and SEEF will in most cases serve to show what we *do not know* rather than what we know.

Conclusions

The objectives of this work were to produce an overview the knowledge of Atlantic and Mediterranean seamounts today and to assess patterns of seamount ecosystems. Knowledge of seamounts in the North Atlantic and Mediterranean Sea is overall scarce. Seamount scientists experience the difficulties common to all deep sea research related to the remoteness of these habitats. Most studies are qualitative, and are not appropriate to validate seamount effects such as increased biomass of demersal or pelagic organisms. The 'seamount island hypothesis' is not supported by available

data.

Patterns of seamount knowledge vary between regions, with a greater focus on geology in the Mediterranean Sea, and ecology in the North Atlantic. Also at smaller geographical scales differences exist, and some regions are clearly under-explored. Simultaneously, there has been an increase in seamount ecology research the last few years. In the North Atlantic, the OASIS project shed some light on the dominant productivity mechanisms for the Seine and Sedlo seamounts, showing the importance of such comparative studies. In the Mediterranean Sea, research is being conducted, and the efforts of conservation organizations have led to protection of some seamount ecosystems. However, as the knowledge regarding seamounts is for most features very low it is not possible to confirm that they generally act as 'marine oases'. However, the reports of 'seamount effects' from some areas should in combination with the low level of knowledge encourage future research, and application of the precautionary principle when exploiting these marine ecosystems.

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Appendices

Appendix 1: SEEF attribute information

Table 7: Original and revised version of the SEEF with comments for the individual attributes.

Original attributes (Pitcher et al. 2010)	Revised attributes (new attributes*)	Comments
Geology		
Depth of peak	Depth of peak	Shallowest depth of seamount summit (meters)
Depth of surrounding ocean	Basin depth	Average depth of surrounding basin (meters)
Height of peak	Height of peak	Height from seamount base to shallowest depth of the summit (meters)
Slope of seamount	Slope of seamount	Average slope of seamount flanks in degrees
Summit shape	Summit shape	3D shape of the summit (appendix 3)
Percentage mapped		Attribute not in use
Age	Age	Estimated age of the seamount in million years
Proximity to shelf	Proximity to shelf	Km distance to shelf
Proximity to neighbour seamounts	Proximity to neighbour seamounts	Km distance to closest seamount
Hydrothermally active	Hydrothermally active	Present hydrothermal activity on the seamount
	Elongation*	Adopted from SBN (http://earthref.org/SBN/)
	Irregularity*	Adopted from SBN (http://earthref.org/SBN/)
	Mineral deposits*	Presence of mineral deposits on the seamount
	Number of summits*	Number of individual summits when > 1
Substrate type summit	} Substrate type	If specific information for summit/flanks is available this is kept track of in separate column (1:total, 2:summit, 3:flanks)
Substrate type flanks		
	Volume*	Volume of seamount in km ³
Oceanography		
Ocean currents link to shelf	Ocean currents link to shelf	Not implemented at this stage
Ocean currents to neighbour seamounts	Ocean currents to neighbour seamounts	Not implemented at this stage
Taylor cap or other retention mechanism	Taylor cap or tidal rectification	Physical retention mechanisms known to occur on some seamounts (White et al. 2007)
Ecology		
Chemosynthetic community	Chemosynthetic community	Presence of community or organisms dependent on chemosynthetic-based production
Macrophytes present	Macrophytes	Includes the orders Antipatharia, Scleractinia, Zoanthidea Helioporacea, Alcyonacea and Pennatulacea (Octocorallia) within the Anthozoa, and the family Stylasteridae within the Hydrozoa (Rogers et al. 2007) The taxonomic information (order level) is kept track of in a separate table.
Hard-corals present	} Corals	
Soft-corals present		
Epiphytes present	} Demersal invertebrates	All demersal invertebrates excluding corals are kept in a single attribute, but taxonomic information (following Stocks 2001) is kept in a separate table. Since the ecological function of many marine invertebrates is uncertain or variable within groups, information on functional role (e.g. filter feeder, infauna or detritivore) is only kept when stated in the reference.
Sponges present		
Other benthic filter feeders		
Demersal invertebrates		
Infauna		
Detritivores present		
Nutrient upwelling occurs	Nutrient upwelling	Nutrient upwelling caused by the seamount
Phytoplankton enhancement	Phytoplankton production	Level of primary production above the seamount

Table 7 (continuation)

Original attributes (Pitcher et al. 2010)	Revised attributes (new attributes*)	Comments
Zooplankton engagement Detritus build-up	Zooplankton production Organic matter role	Level of zooplankton production above the seamount Importance of organic matter in the seamount foodweb
Deep Scattering layer organisms entrapped Zooplankton migrates in feeding range	Topographic blockage	Process of trapping of vertically migrating organisms, described in Genin (2004).
Demersal fish	Demersal fish	Fish categorized as Demersal, Benthopelagic or Bathydemersal in FishBase. Taxonomic information kept (species level) in separate table.
Cephalopods Aggregating deep-sea fish	Cephalopods Aggregating deep-sea fish	Class Cephalopoda Fish species listed as seamount-aggregating in Morato & Clark (2007.) Taxonomic information kept (species level) in separate table.
Visiting large pelagic fish predators Visiting elasmobranchs Visiting marine turtles Visiting mammal predators Visiting seabird predators	Visiting large pelagics Air-breathing visitors	Tunas, billfish and large pelagic sharks (pelagic-oceanic species in FishBase). Taxonomic information kept (species level) in separate table. Includes marine turtles, marine mammals and seabirds. The taxonomic information (species level) is kept track of in a separate table.
	Deep-sea fish*	Fish categorized as Bathypelagic in FishBase. Taxonomic information kept (species level) in separate table.
	Other pelagic fish*	Fish categorized as pelagic in FishBase, excluding tunas, billfish and large pelagic sharks. Taxonomic information kept (species level) in separate table.
	Biodiversity*	Level of biodiversity described for seamount fauna
	Endemism*	Level of endemism described for seamount fauna

Table 8: Scoring standards for SEEF knowledge categories

Geology	Well Known (3)	Known (2)	Inferred (1)
Depth of peak	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Depth of surrounding ocean	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Height of peak	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Slope of seamount	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Summit shape	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Age	<i>Radiometric analysis</i>	<i>Derived from some datasets (e.g. forameniferans, paleomagnetism)</i>	<i>Inferred/proposed by indirect estimations (e.g. age of the seafloor; implied age progression; isostatic implications; size-age relationship)</i>
Proximity to shelf	<i>Seamount position obtained from bathymetric soundings</i>		<i>Seamount position obtained from satellite data</i>
Proximity to neighbour smts	<i>Proximity calculation based on extensive and detailed regional bathymetric maps</i>	<i>Proximity calculation based on seamounts with position confirmed by SEEF</i>	<i>Proximity calculation based on seamounts with position not confirmed by SEEF</i>
Hydrothermally active	<i>Visual observation covering the whole seamount</i>	<i>Partial underwater observation</i>	<i>Inferred from ocean chemistry anomalies, sediment staining or fresh mineral precipitates</i>
Elongation	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Irregularity	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Mineral deposits	<i>Quantitative description of mineral deposits</i>	<i>Observation of mineral deposits but no quantitative information available</i>	<i>Presence of mineral deposits inferred from geological models</i>
Number of summits	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>
Substrate type	<i>Samples and/or video records throughout the seamount (summit and flanks)</i>	<i>Samples and/or video records from a limited portion of the seamount</i>	<i>Inferred from sonar measurements or from datasets without a clear reference</i>
Volume	<i>High multi-beam coverage</i>	<i>Low multi-beam coverage / single beam measurement</i>	<i>Satellite altimetry</i>

Table 8: Scoring standards for SEEF knowledge categories (continuation)

Oceanography	Well Known (3)	Known (2)	Inferred (1)
Ocean currents link to shelf	<i>Data from long term moorings etc</i>	<i>Data collected from field sampling</i>	<i>Models or inferred from biological data</i>
Ocean currents to seamounts	<i>Data from long term moorings etc</i>	<i>Data collected from field sampling</i>	<i>Models or inferred from biological data</i>
Taylor cap or tidal rectification forms	<i>Data from long term moorings etc</i>	<i>Data collected from field sampling</i>	<i>Models or inferred from biological data</i>
Ecology	Well Known (3)	Known (2)	Inferred (1)
Air-breathing visitors	<i>Evidence of seamount's importance to air-breathing visitors for feeding, reproductive and/or migratory purposes</i>	<i>Visiting air-breathing species on seamounts reported in single or few studies</i>	<i>Presence of air-breathing visitors inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount, undisclosed data from different seamounts or single observation</i>
Aggregating deep sea fish	<i>Aggregating deep-sea fish abundance known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few species</i>	<i>Aggregating deep-sea fish presence inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Biodiversity	<i>Measurement of biodiversity based on a quantitative description of the biota of the seamount, compared with other habitats in the region (e.g.continental slope, seafloor) and considering equal sampling effort</i>	<i>Measurement of the biodiversity of the seamount, based on single faunal assemblage of the seamount, compared with other habitats in the region (e.g.continental slope, seafloor)</i>	<i>Biodiversity described, but without explicit comparison with other habitats in the region (e.g.continental slope, seafloor)</i>
Cephalopods	<i>Cephalopods abundance known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few species</i>	<i>Cephalopods presence inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Corals	<i>Coral abundance reported in several and/or detailed local studies based on quantitative data</i>	<i>Data reporting coral presence from a limited number of studies or from a small proportion of the seamount</i>	<i>Coral presence inferred from models, anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Chemosynthetic community	<i>Description of the chemosynthetic community, based on detailed studies</i>	<i>Description of chemosynthetic organisms from the seamount</i>	<i>Description of hydrothermal activity</i>
Deep-sea fish	<i>Deep-sea fish assemblages known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few specific taxa (e.g., commercially valuable species)</i>	<i>Presence of species of deep-sea fish inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>

Table 8: Scoring standards for SEEF knowledge categories (continuation)

Demersal fish	<i>Demersal fish assemblages known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few specific taxa (e.g., commercially valuable species)</i>	<i>Presence of species of demersal fish inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Demersal invertebrates	<i>Demersal invertebrate assemblages known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few specific taxa (e.g., commercially valuable species)</i>	<i>Presence of species of demersal invertebrates inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Endemism	<i>Detailed description of the biota of the seamount, comparable habitats in the region (e.g. continental slope, other seamounts) and surrounding areas (e.g. seafloor)</i>	<i>Description of the endemic fauna on the seamount, but limited knowledge of the regional faunal assemblages</i>	<i>Endemic species described, but no information given about the regional faunal assemblages</i>
Macrophytes present	<i>Macrophytes reported in several and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or from a small proportion of the seamount</i>	<i>Macrophyte presence inferred from models, anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Nutrient upwelling occurs	<i>Comparative studies and detailed local studies based on quantitative data, ideally from long term data series</i>	<i>Single study of nutrient upwelling above the seamount</i>	<i>Indication of nutrient upwelling from few indirect samples and/or satellite data</i>
Organic matter role	<i>Detailed description of the origin and abundance of the POM pool and of the role it plays in the local trophic web</i>	<i>Single study of detritus pool, but no information of the importance it has for the local trophic web</i>	<i>Detritus levels inferred from indirect measurements, such as detritivores abundance, stomach content, etc.</i>
Other visiting pelagics	<i>Pelagic fish assemblages known from comparative studies and/or detailed local studies based on quantitative data</i>	<i>Data from a limited number of studies or only concerning few specific taxa (e.g., commercially valuable species)</i>	<i>Presence of species of pelagic fish inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount or undisclosed data from different seamounts</i>
Phytoplankton production	<i>Comparative studies and detailed local studies based on quantitative data, ideally from long term data series</i>	<i>Single study of phytoplankton production above the seamount</i>	<i>Indication of phytoplankton levels from few indirect samples and/or satellite data</i>
Topographic blockage	<i>Detailed local studies based on quantitative data, ideally from long term data series</i>	<i>Single study based on sampling and/or sonar data</i>	<i>DSL blockage inferred from indirect samples (e.g., stomach content)</i>
Visiting large pelagics	<i>Evidence of seamount's importance for large pelagic visitors for feeding, reproductive and/or migratory purposes</i>	<i>Visiting large pelagic species on seamounts reported in few studies</i>	<i>Large pelagic visitors presence inferred from anonymous entries in datasets, bycatch data from the proximity of the seamount, undisclosed data from different seamounts or single observation</i>
Zooplankton Production	<i>Comparative studies and extensive local studies based on quantitative data, ideally from long term data series</i>	<i>Single study of zooplankton production above the seamount</i>	<i>Indication of zooplankton levels from few indirect samples</i>

Table 9: Categories for SEEF information storage

ATTRIBUTE	VALUE		
Summit shape	1: Conical 2: Guyot 3: Caldeira 4: Irregular 5: Other (.5: with pinnacles)		
Major substrate type	1: Solid 1.25: Mostly solid 1.5: Mixed 1.75: Mostly soft 2: Soft	If specified (add in separate column) 1: Seamount 2: Summit 3: Flanks	
Global endemism	2=Low=<20%; 3=Medium=[20-40%]; 4=High=>40%; 1=No global value of endemism, but single or few taxa described as endemic/increased, decreased, no difference		
Hydrothermally active Mineral deposits Chemosynthetic community Topographic blockage	}	YES/NO	
Aggregating deep sea fish Air-breathing visitors Cephalopods Corals Deep-sea fish Demersal fish Demersal invertebrates Macrophytes Other pelagics Visiting large pelagics		}	Increased Decreased No significant difference Presence Absence
Biodiversity Nutrient upwelling Organic matter role Phytoplankton production Zooplankton production			Increased Decreased No significant difference

*Table 7-9 were developed in company with Gerald H. Taranto and is therefore also presented in his thesis work.

Appendix 2

Table 10: List of the 95 seamounts in the Atlantic & Mediterranean SEEF database, with geographical region and position (decimal degrees)

Atlantic Ocean

ID	Name	Region	Latitude	Longitude
500	Vesteris	Arctic	73.52	-9.13
503	Bill Bailey Bank	Rockall Trough	60.58	-10.33
504	Lousy Bank	Rockall Trough	60.49	-12.37
505	Rosemary Bank	Rockall Trough	59.25	-10.15
506	Anton Dohrn	Rockall Trough	57.45	-11.10
508	Hebrides Terrace	Rockall Trough	56.45	-10.32
509	Faeroe Bank	Rockall Trough	61.12	-8.57
517	Porto Hill	Western Iberian margin	40.72	-10.05
518	Vigo	Western Iberian margin	41.50	-10.64
522	Ashton	Western Iberian margin	37.98	-13.37
523	Josephine	Madeira	36.67	-14.25
525	Gorringe Ridge	Madeira	36.54	-11.56
526	Coral Patch	Madeira	34.93	-11.95
527	Ampere	Madeira	35.08	-12.92
528	Unicorn	Madeira	34.75	-14.45
529	Lion	Madeira	35.25	-15.58
530	Dragon	Madeira	34.92	-16.50
531	Seine	Madeira	33.76	-14.38
532	Dacia	Canary	31.15	-13.66
533	Sedlo	Açores	40.40	-26.92
535	Tyro	Meteor Seamounts	33.91	-28.38
536	Plato	Meteor Seamounts	33.23	-29.63
537	Atlantis	Meteor Seamounts	34.08	-30.25
538	Cruiser	Meteor Seamounts	32.28	-27.50
539	Irving	Meteor Seamounts	31.97	-28.05
540	Hyeris	Meteor Seamounts	31.48	-28.97
541	Plateau	Meteor Seamounts	30.88	-28.73
542	Great Meteor Guyot	Meteor Seamounts	30.00	-28.50
543	Small Meteor	Meteor Seamounts	29.62	-28.99
586	Antialtair	Mid-Atlantic Ridge	43.58	-22.42
587	Olympus Knoll	Mid-Atlantic Ridge	45.40	-27.68
588	Faraday	Mid-Atlantic Ridge	49.65	-28.88
589	João de Castro	Açores	38.22	-26.61
590	Formigas-Dollabarát	Açores	37.26	-24.76
591	Princess Alice Bank	Açores	37.99	-29.24
592	Açores	Açores	38.20	-28.99
593	Alcatraz	Açores	38.25	-26.23
594	Pico Leste of Princess Alice	Açores	37.89	-28.69
595	Agulhas do Sul do Gigante	Açores	38.73	-29.99
596	Conception Bank	Canary	29.92	-12.75
597	Tropic	Saharan	23.88	-20.71
598	Le Danois Bank	Bay of Biscay	44.08	-5.10
599	Galicia Bank	Bay of Biscay	42.71	-11.75
602	Senghor	Cape Verde	17.19	-21.95
607	Nola	Cape Verde	17.23	-25.53
608	João Valente	Cape Verde	15.64	-23.12
609	Condor de Terra	Açores	38.55	-29.04

610	Altair	Mid-Atlantic Ridge	44.72	-34.08
611	Bear	New England	39.92	-67.42
612	Retriever	New England	39.84	-66.25
613	Kelvin	New England	38.80	-64.06
614	Manning	New England	38.26	-60.55
615	Nashville	New England	35.00	-57.40
616	Physalia	New England	39.86	-66.92
617	Balanus	New England	39.39	-65.39
618	Rehoboth	New England	37.50	-58.17
619	Muir	NW Atlantic	33.72	-62.49
621	Picket	New England	39.65	-65.95
623	Caloosahatchee East	Corner Rise	34.68	-49.77
624	Caloosahatchee West	Corner Rise	34.82	-50.51
625	Rockaway	Corner Rise	36.17	-52.25
626	Castle Rock	Corner Rise	36.28	-51.35
627	Corner East	Corner Rise	35.46	-51.37
628	Corner West	Corner Rise	35.54	-51.91
629	Yakutat	Corner Rise	35.19	-47.67
630	Hodgson	New England	35.54	-58.64
631	Mytilus	New England	39.37	-67.15
632	Cavala	Açores	38.30	-30.64
633	Gigante IIa	Açores	38.99	-29.89
634	Mar da Prata	Açores	37.36	-25.72
635	Monte Alto	Açores	37.18	-31.43
636	Voador	Açores	37.40	-30.97
637	Hard Rock Café	Açores	41.53	-30.94
638	Banco DMA	Açores	41.93	-28.99

Mediterranean Sea

ID	Name	Region	Latitude	Longitude
544	Eratosthenes	Levantine Basin	33.67	32.67
550	Arichmedes	Ionian Sea	34.32	17.99
552	Alfeo	Ionian Sea	36.74	15.86
553	Palinuro	Tyrrhenian Sea	39.48	14.85
554	Marsili	Tyrrhenian Sea	39.25	14.39
555	Poseidone	Tyrrhenian Sea	39.67	13.83
559	Enareta	Tyrrhenian Sea	38.64	14.01
560	Eolo	Tyrrhenian Sea	38.60	14.12
566	Vavilov	Tyrrhenian Sea	39.87	12.60
568	Magnaghi	Tyrrhenian Sea	39.88	11.78
571	Vercelli	Tyrrhenian Sea	41.12	10.90
573	Baronie Mountains	Tyrrhenian Sea	40.66	10.25
579	Amendolara Bank	Ionian Sea	39.87	16.74
580	Anaximander	Levantine Basin	35.50	29.50
581	Anaxagora	Levantine Basin	35.50	30.00
582	Anaximenes	Levantine Basin	35.50	30.50
583	Emile Baudot	Balearic	38.70	2.33
584	Ausias March	Balearic	38.73	1.80
585	Ses Olives	Balearic	38.01	2.00
600	Seco de Palos	Balearic	37.01	0.00
601	Seco de los Olivos	Alboran Sea	36.52	-2.85

Appendix 3

Table 11: References for seamount hypotheses assessment

Number	Reference
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