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Findkelp, a GIS-based community participation project to assess Portuguese kelp conservation status

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ABSTRACT

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In almost any Atlantic coastal area of Europe where there is a suitable substratum and adequate water quality, one or more species of kelp may be found. Their high productivity and complex biological structure make kelps especially important members of their communities, particularly when present in dense stands known as "kelp forests". Currently, these species are subject to important novel constraints of physical and anthropogenic origins that can strongly modify their sustainability, their distribution and the biodiversity of associated species. Along the Portuguese coastline there is a perception by the local and scientific communities that some kelp species abundance is declining, particularly at the southern coast. Nevertheless, no large-scale spatial study of kelp abundance and diversity has been done. With the acronym Findkelp, this study aimed to assess from May to August 2008, the Portuguese kelp conservation status through community participation, field-based observations and large-scale Geographic Information System (GIS) technology. A communication strategy towards scuba divers and other coastal zone users was made to build and educate a team of informed volunteers that worked as independent observers, reporting georeferenced data in an electronic data-base available on the project's website. At randomly underwater chosen locations (n=56) from the volunteers reported sites (n=388), structural descriptors of kelp populations were groundtruthed, by means of non-destructive sampling techniques (3x50m belt-transects). By crossing the volunteer's reported data with the groundtruthed data, using error matrices and Kappa statistics with concordance agreement scales, a Portuguese coast line GIS map with perfect agreement (K=0.827) was made including the current distribution, diversity and conservation status of 6 kelp species.

ADDITIONAL INDEX WORDS: *Community participation, GIS, Marine conservation ,Laminaria, Kelp*

INTRODUCTION

The shallow subtidal rocky habitats of most temperate coastal areas are conspicuously dominated by large brown algae named kelp, strictly those belonging to the orders Laminariales and Tilopteridales (recently split from Laminariales, ADL et al. 2005), although large brown algae in other orders are sometimes also referred to as kelp. Their high productivity and complex biological structure make kelps especially important members of coastal communities (DAYTON, 1985), particularly when present in dense stands known as "kelp forests" (BODKIN, 1988). Almost any Atlantic coastal region of Europe follows this tendency. Where a suitable substratum and adequate water quality is present, one or more species of kelp may be found (BIRKETT et al., 1998). There are 13 confirmed species of kelp (incl. one introduced alien) in European waters (LUNING, 1990) of which, seven are present in Portuguese waters (DE MESQUITA RODRIGUES, 1963; ARDRÉ, 1970; ARAÚJO et al., 2003). Presently, these species are subject to important novel constraints of physical and anthropogenic origins that can strongly modify their sustainability, their distribution and the biodiversity of associated species (ARZEL, 2000; EDWARDS and ESTES, 2006). Along the coastal local communities of Portugal there is an empirical perception that some kelp species distribution is declining, particularly at the southern coast. Yet, no large-scale study of kelp diversity over space and time has been done.

Marine benthic habitat maps are an essential tool to identify and catalog species and habitat diversity and zonation (GRAYT, 1997; WARD et al., 1999; ROBERTS et al., 2003). With this type of data representation, planning managers and researchers are able to monitor spatial and temporal changes in species distribution at a landscape level. A large variety of methods are used to collect data to elaborate such maps. Currently, the most used are (1) direct sampling, (2) aerial remote sensing techniques and (3) sublittoral remote sensing techniques (DAVIES, 2001; TYRRELL, 2004). Additionally, (4) the use of community participation methods is rapidly growing (CRAIG et al., 2002). There is an increasing network of planning professionals interested in how Geographic Information System (GIS) can merge with community participation to map natural resources (AITKIN and Michel, 1995; CRAIG and ELWOOD, 1998; TALEN, 1999, 2000).

The present paper documents the approach used to, (1) obtain present-time valuable information about kelp species (i.e., Laminariales and Tilopteridales) distribution in Portugal and, (2) to identify and map the geographic and depth distribution limits of these species.

METHODS

In order to achieve a valuable marine benthic habitat map with kelp species distribution, a volunteers' community participation (coastal zone users) project was developed and combined with fieldbased observations. These were completed using non-destructive sampling techniques, and spatial statistical evaluations of concordance agreement based on error matrices. The volunteers' team worked independently as field observers, reporting kelp species observations (Table 1) and photos in an electronic data-base over the Internet. The first step to build this team was to give the project a national context. Promotion was made in the Internet through a dedicated website, alongside with magazines and newspapers articles. In order to better achieve this promotion, a set of didactic and awareness materials including leaflets, posters, underwater species identification slates and t-shirts were prepared and distributed. Simultaneously, to increase the extent of field data records from the volunteers and to make them more reliable, lectures and workshops on how to identify kelp species were given nationally. As the project proceeded, the volunteers' data was recorded and represented spatially at the project's webpage (using on-line GIS technologies) to keep them informed about the project results. Moreover, each time a volunteer reported a field observation through the project's webpage, a rank point was automatically attributed. A ranked table of honour was available at the webpage showing the more participative volunteers. In addition, an electronic bulletin was automatically delivered twice a month to the signed-in volunteers with the latest news, the projects table of honour and with queries concerning specific problems of species identification. These approaches were used to motivate volunteers to participate more.

Table 1. Volunteer kelp report data.

Reported data	Value
Site	Name of site
Coordinates	Coordinates of site
Date	Date of observation
Depth	Depth (m) of observation
Confidence level	From 1 (positive) to 3 (not sure)
Species report	*Phyllariopsis brevipes* *Phyllariopsis brevipes var. purpurascens* *Phyllariopsis purpurascens* *Saccorhiza polyschides* *Saccharina latissima* *Laminaria hyperborea* *Laminaria ochroleuca* *Undaria pinnatifida* No species recorded Not identified

In order to make use of the volunteers' kelp distribution data, a large-scale field validation process (i.e. groundtruth) was made using non-destructive sampling techniques. Fifty six sites were randomly chosen from the volunteers reported sites to assess the structural descriptors of kelp populations. At each site, the accurate GPS (Geographic Positioning System) position was recorded and three replicated 50 m long belt transects were made at randomly chosen underwater sampling locations. Transect depth was also recorded. At chosen shallow subtidal sites, inaccessible by boat, visual transect evaluations were made by means of free diving (snorkelling) when in clear water conditions. At deep water or low visibility subtidal sites, visual evaluations were made by means of scuba diving. Along transects, kelp species were recorded on waterproof paper. From a landscape ecology perspective, the spatial structure of the habitats were also recorded at 6 different levels: (1) Rocky reefs; (2) Stable boulders; (3) Cobbles; (4) Pebbles; (5) Gravel; (6) Sand; (7) Mud; (8) Artificial reefs. By comparing the volunteer's data with the groundtruthed data, accuracy estimates were made using error matrices, also known as confusion matrices (SMITS et al., 1999). These were used to compare sets of data from matching sites and to estimate the Kappa statistic. Developed by COHEN (1960) the Kappa coefficient, calculated from an error matrix, measures the proportion of agreement after chance agreements. In order to better apprehend the evaluation of accuracies, the concordance agreement scale for the Kappa coefficient, proposed by LANDIS and KOCH (1977), was applied. The concordance agreement achieved by measuring the 56 chosen sites, was assumed to be representative of the maps accuracy elsewhere along the Findkelp study area (e.g. CONGALTON, 1991).

Finally, in order to perform a GIS-based kelp species distribution habitat map, the statistically validated volunteers' reported data and the groundtruthed data were integrated in a GIS in the form of electronic shape files. GIS query point analyses were made to evaluate (1) the number of reported kelp species sites, (2) the reports depth, (3) the reports average depth, (4) the overall confidence level average, (5) the kelp species depth range, (6) the kelp species average depth and (7) the geographic limits of kelp species distribution.

RESULTS

The strategy applied motivated 194 volunteers (scuba divers and spear fisherman) to participate. From the 15th of May to the 31th of August, 388 georeferenced sites were reported at the project's webpage. Data reported by volunteers was obtained at depths between 2 and 55 m (average of 10.3 m ± 8.5 m) with an average confidence level of 1.12 ± 0.32. Three hundred thirty eight of the reported sites (n=338) had kelp species records, while 50 had no species records. The volunteers were able to identify 283 of the 338 kelp species records (84%). The dominant identified kelp species were *Saccorhiza polyschides* and *Phyllariopsis brevipes* (n=185 and n=54 sites, respectively). *Saccharina latissima* and *Phyllariopsis brevipes var. purpurascen*s were the less reported kelp species (n=1 and n=2 reported sites, respectively). *Undaria pinnatifida* was not reported or identified by the volunteers. The overall reported kelp species depth range was between 3 and 23m. *Phyllariopsis brevipes*, *Saccorhiza polyschides*, *Laminaria ochroleuca* and *Laminaria hyperborea* had a similar reported depth range distribution (from 2 m depth to 23 m). The upper-limit of the depth range of *Phyllariopsis purpurascens* and *Phyllariopsis brevipes var. purpurascens* were reported as deeper (5 m and 7 m respectively) than the other species. Furthermore, *Phyllariopsis purpurascens* was reported to have the deeper average depth (16.2 m ± 3.3 m). *Saccharina latissima* depth range could not be determined due to lack of reported sites.

The groundtruth process was conducted by means of underwater scuba diving and free diving transects at 56 randomly chosen locations, from haphazardly chosen sites from the volunteer reported sites. Kelp species records were made between 3 and 30 m of depth (average of 7.3 m ± 8.4 m). The recorded kelp species along the Portuguese coast were: *Phyllariopsis brevipes*, *Phyllariopsis purpurascens*, *Saccorhiza polyschides*, *Laminaria* *ochroleuca*, *Laminaria hyperborea* and *Saccharina latissima*. *Saccorhiza polyschides* and *Phyllariopsis brevipes* were the dominant species found at the overall validation process (28 and 13 sites, out of 56, respectively), while *Laminaria hyperborea* and *Saccharina latissima* were the less dominant (1 site, out of 56). *Undaria pinnatifida* species was not sighted in the validation process. All species preferrably used the habitat of rocky reefs (exception to *Saccorhiza polyschides* and *Saccharina latissima*). *S. polyschides* was also found at stable boulders and artificial reefs, while *S. latissima* was only found at stable boulders). No species were found at cobbles, pebbles, gravel, or sand. The muddy habitat type was not investigated.

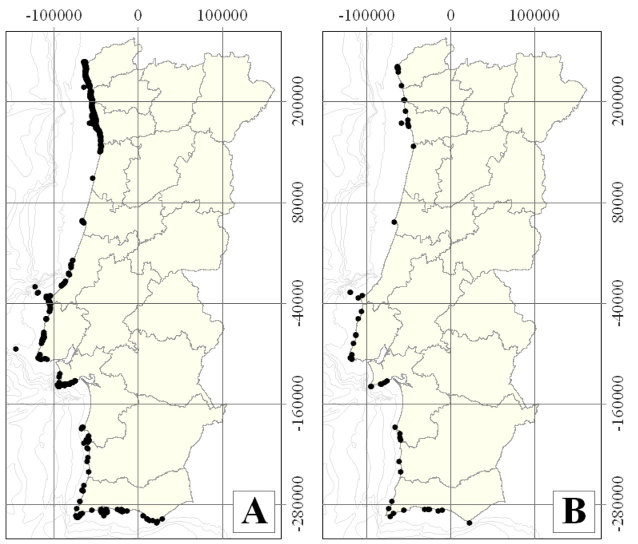

Figure 1. GIS recorded data. A – Volunteers reported sites (n=387); B – Groundtruth validation field sites (n=56).

The overall accuracy value measured by the error matrix (Table 2) between the volunteers reported data and the groundtruthed validated data was 0.871. At some sites, the volunteers confused *Phyllariopsis brevipes* with *Saccorhiza polyschides* (2 out of 18 P.b. occurrences), *Phyllariopsis purpurascens* with *Phyllariopsis brevipes* (1 out of 3 P.p. occurrences) and *Laminaria ochroleuca* with *Saccorhiza polyschides* (2 out of 14 L.o. occurrences). Also, at some sites, the volunteers did not recognize the presence of *Phyllariopsis brevipes* (1 out of 18 P.b. occurrences) and *Saccorhiza polyschides* (1 out of 26 S.p. occurrences). At sites were the validation process recognized the presence of *Laminaria hyperborea*, *Saccharina latissima* and the absence of kelps species, no identification errors were made by the volunteers.

The calculated Kappa coefficient value was 0.827. This is a perfect agreement value, using the concordance agreement scale proposed by LANDIS and KOCH (1977) – for values in the range 0.81-1.00.

Table 2. Error matrix of species records (columns) vs correct identification (lines), based on 56 sites. *Phyllariopsis brevipes* (P.b.), *Phyllariopsis purpurascens* (P.p.), *Saccorhiza polyschides* (S.p.), *Laminaria ochroleuca* (L.o.), *Laminaria hyperborea* (L.h.), *Saccharina latissima* (S.l.) and no species (N.s.)

	P.b.	*P.p.*	*S.p.*	*L.o.*	*L.h.*	*S l.*	N.s.
P.b.	15	0	2	0	0	0	1
P.p.	1	2	0	0	0	0	0
S.p.	2	0	23	0	0	0	1
L.o.	0	0	2	12	0	0	0
L.h.	0	0	0	0	1	0	0
S.l.	0	0	0	0	0	1	0
N.s.	0	0	0	0	0	0	8

Saccorhiza polyschides is the most conspicuous Portuguese kelp species (Table 3). With 185 reported sites, its distribution covers the West coast from Rio Minho to Carrapateira, with most reported sites at the northern regions (Viana do Castelo and Porto). *Phyllariopsis brevipes* is the second most distributed species (54 reported sites). It is present from São Martinho do Porto to Ilha do Farol, with a single northern site at Perafita and more reported sites at the southeast exposed coast of Sesimbra and Sagres. *Laminaria ochroleuca* is the third most reported species (26 reported sites). Its distribution is mainly at the northern part of the Portuguese coast, from Rio Minho to Espinho. Also, this species was reported in Peniche, Ericeira, Estoril and Espichel, and at two off-shore sites (Montanhas de Camões and Gorringe Bank). *Laminaria hyperborea* was reported at 10 sites, from Rio Minho to Esposende. *Phyllariopsis purpurascens* was reported for 5 sites from Farilhões to Alvor. *Phyllariopsis brevipes var. purpurascens* was only reported for 2 sites (Farilhões and Ingrina) and *Saccharina latissima* was only reported for Praia Amorosa (Viana do Castelo region).

Table 3. Depth range distribution (D.R.), average depths distribution (A.D.), number of sites (N.S.) and North (N.L.) and South kelp species distribution limits, per species.

Species	D.R.	A.D.	N.S.	N.L.	S.L.
P. brevipes	3-21	13.7 ± 4.9	54	Perafita, Porto	Ilha do Farol, Algarve
P. brevipes var *purpurascens*	7-10	8.5 ± 2.1	2	Farilhões, Peniche	Ingrina, Algarve
P. purpurascens	5-22	16.2 ± 3.3	5	Farilhões, Peniche	Alvor, Algarve
S. polyschides	2-19	6.2 ± 5.5	185	Rio Minho, Viana do Castelo	Carrapateira, Algarve
L. ochroleuca	3-23*	10.4 ± 8.8	26	Rio Minho, Viana do Castelo	Espichel, Sesimbra
L. hyperborea	3-20	9.6 ± 7.6	10	Rio Minho, Viana do Castelo	Vila do Conde, Porto
S. latissima	3	3	1	Praia Amorosa, Viana do Castelo	Not determined
U. pinnatifida	-	-	0	-	-
No species recorded	2-55		50		

DISCUSSION

Kelp forests are one of the most ecologically dynamic and biologically diverse habitats on the planet. They probably received more scientific attention than any other group, and the habitats dominated by them have also been fairly well studied (BIRKETT et al., 1998). The Findkelp project was the first Portuguese attempt to cover the current knowledge gaps concerning the diversity, distribution and abundance of kelps species. From May to August 2008, a communication strategy was carefully underlined to captivate coastal zone users to become active contributors to the field work process. The volunteers' reported sites contained essential information to accomplish all the project goals. EVANS (2003) states that in order to keep the community participations and support, there is a continuous need to educate and update the issues at hand. With this aim, to motivate the Findkelp volunteers, so that they could keep contributing with report data, electronic bulletins were delivered with relevant information, a ranked table of honour was generated and the volunteers' data were spatially represented at the project's webpage. Remarkably, a few days after each bulletin delivery, volunteers accessed the webpage to make reports and to look at the multimedia section or to the spatially represented data. Moreover, the fact that each time a volunteer reported a field observation gained a point, and that this information was present at the webpage, might account for the disparity in number of observation of five most participant volunteers, as these seemed to be competing for the first place in the rank. These approaches seemed to be very useful in keeping the volunteers motivated. Reported data was sent to the projects' webpage in a pre-designed format so it could be easily integrated in the GIS database. Most volunteers (63.4%) sent reported data with the correct site coordinates. When this information was missing, volunteers were asked to detail at most the site location, or to point it out through accessible mapping tools (e.g. Google earth), such that all reported sites were geographically referenced at a landscape level. From the reported sites, 338 had kelp species records, while 50 had no species records. Where kelps were present, the volunteers were able to identify 84% of the species with a confidence level near 1. This generally high confidence level in species identification can be explained by the previous workshops they attended and by the delivered underwater species identification slates, as these seemed to have a positive effect over the volunteers' level of understanding of species identification (pers. obs.). Moreover, the volunteers had the ability to send photos through the website's private area. This tool allowed the post-hoc identification of specimens and the calibration of the volunteer's identification skills.

When using data driven by non-scientific personnel, such as the Findkelp volunteers, to spatially represent natural features, it is important to remember that it is not a perfect representation of reality. There are errors in the reported data and before we can evaluate its utility or map a particular feature, we need to have an idea of how accurate it really is and how accurate it should be to sufficiently meet the requirements for the intended application (BROWN, 2008). In order to check the accuracy of the volunteer's raw data, a fieldbased accuracy assessment was made, recurring to non-destructive techniques and statistical analyses – Kappa statistics (MONSERUD and LEEMANS 1992; MONSERUD et al., 1993). Since the morphology of kelps makes them relatively easy to identify and individual plants are large and easy to count, the transect visual census proved to be a precise and accurate method. Also, important data about habitat use was recorded. The analysis of the agreement between the volunteers' data and the accuracy assessment was considered, following LANDIS and KOCH (1977), to be a perfect agreement. Since the validation process was made at randomly chosen locations, the concordance agreement value was assumed to be representative of the maps accuracy along the Portuguese coast (e.g. CONGALTON, 1991). Thus, when using the volunteers' data to analyze the distribution of kelp species, we should be aware that it contains errors, but also that the overall mapped features are represented with perfect accuracy.

By using the proposed methodology, the Findkelp project provided very important information such as the habitat use, the present time geographic limits and the depth ranges of 6 species and 1 subspecies along the Portuguese coast. Beyond the near shore nature of the project, 2 offshore sites were reported: Gorringe Bank and Montanhas de Camões at 36m and 45m, respectively. Presently, *Saccorhiza polyschides* has a West coast distribution, while *Laminaria ochroleuca* and *Laminaria hyperborea* are more restricted to northern latitudes. Nevertheless, *Laminaria ochroleuca* is also found at the West coast and offshore sites. *Phyllariopsis brevipes*, *Phyllariopsis brevipes var. purpurascens* and *Phyllariopsis purpurascens* have a more southern distribution. Apparently, *Saccharina latissima* is only represented at the Viana do Castelo region. Generally, with the exception of *Saccharina latissima*, the majority of species occurred preferntially in rocky reefs habitats. However, we should be aware that some studies indicate that given adequate water movement in the form of tidal currents rather than wave action, large kelps may frequently be found attached to other substrata besides rocky reefs (BIRKETT et al., 1998).

CONCLUSIONS

The need for community participation in ecosystem management and conservation has long been accepted at all levels of national and international governments (WILLIAMS, 2002). This issue was stressed at The Rio Declaration on Environment and Development (UNEP, 1992) when it was stated that the "environmental issues are best handled with the participation of all concerned citizens, at the relevant level". The Findkelp project was a testimony of this statement. The opportunity given to the community to participate in the project, led to the success of the inventory of Portuguese sites of occurrence of kelp species. The final product was the actual kelp distribution on the Portuguese coast, geographically and in depth. Furthermore, the spatial visualization capacities inherent to the GIS and web-based technologies were a unique opportunity to enhance the community enthusiasm and involvement. In addition to the documented information, the project gave an opportunity for more than 200 participants to become aware of the importance of kelp forests conservation. Possibly, these coastal zone users will be more conscious to notice and report future changes in coastal marine environments.

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