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Application of landscape mosaics for the assessment of subtidal macroalgae communities using the CFR index

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ABSTRACT

The assessment of anthropogenic impacts and ecological status of coastal waters is an important task to accomplish under the European Water Framework Directive (WFD 2000/60/EEC). Macroalgae are one of the biological quality elements that must be considered, but their assessment has been generally limited to intertidal areas due to the difficulties and costs associated with working in subtidal areas. In this work, the suitability of using landscape mosaicing techniques is analyzed for the application of the “Quality of Rocky Bottoms” index (CFR by its Spanish acronym) in subtidal areas. For this purpose, the sensitivity and accuracy of both the indicators that compose the CFR index (characteristic macroalgae coverage, fraction of opportunistics and characteristic macroalgae richness) and the index itself were tested against different sampling surfaces and validated through direct applications of the CFR carried out in situ by scuba divers. The study was carried out at three sites, located on the coast of Cantabria (N. Spain), covering a variety of environmental conditions (depth ranges and anthropogenic pressures). Underwater video transects of 5–20 m length were recorded by scuba divers and processed with specialized software to build continuous image mosaics of the assessment sites. Each mosaic was inserted into a Geographical Information System where all distinguishable macroalgal species were identified and their coverages were estimated. Replicated subsamples of different areas (0.25 m^2, 0.5 m^2, 1 m^2 and 2.5 m^2) were tested from each mosaic for the estimation of both the single indicators and the CFR index itself. Main results showed that larger subsample areas produced higher and more accurate CFR values, mainly related to higher srichness values and to smaller variability within the replicates. Accordingly, the minimum sample size required to carry out this type of studies was estimated to be of 2.5 m^2, showing no significant differences with the total mosaics. At this spatial scale, the assessments of the CFR index using mosaics showed a significant correlation and an excellent agreement with the results obtained in situ. In summary, underwater video mosaicing techniques proved to be a useful tool for the application of the CFR index and could also be of great interest for the study of subtidal environments by allowing visualization of extensive seafloor areas.

1. Introduction

During the last decade, the requirements established by the European Water Framework Directive (WFD 2000/60/EEC) have motivated the development of several biotic indices for the assessment of different biological quality elements (phytoplankton, macroalgae, angiosperms, benthic invertebrates and fishes). Regarding macroalgae communities, most European countries have limited their assessments to the intertidal fringe due to costs and difficulties associated with working in subtidal areas. In this sense, most of the developed indices have been focused on their application to intertidal areas (e.g., Ballesteros et al., 2007; Bermejo et al., 2012; Díez et al., 2012a; Neto et al., 2012; Orfanidis et al., 2003; Pinedo et al., 2007; Wells et al., 2007) but only a few of them are appropriate for subtidal areas (Derrien and Legal, 2010; Carpentier et al., 2011) or for both intertidal and subtidal areas (Juanes et al., 2008). Most of these indices require precise species identifications, which makes their application in subtidal areas difficult. However, the “Quality of Rocky Bottoms” index (CFR by its Spanish acronym) (Juanes et al., 2008; Guinda et al., 2014) uses an easy to apply methodology that does not require very precise taxonomical identifications because it is based on the assessment of general coverages

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of large characteristic macroalgae and opportunistic species. This simplification of the assessment procedure makes fast application of the index possible (e.g. Guinda et al., 2008), which is very practical for extensive monitoring works or for its application to subtidal areas.

Most of the studies carried out at subtidal rocky bottoms require in situ sampling works that are usually performed by scuba divers. These studies are very time-consuming because they require visual assessments at various sampling units or quantitative sample collection works. In the case of visual assessments, divers must be skilled in taxonomic identification and assessment procedures and quantitative sample collections are extremely time-consuming and limited to small sampling areas. These inconveniences reduce the number of sampling units and the total areas that can be covered at each dive. To facilitate these surveys, other sampling techniques, such as underwater photography and video, have been used as an alternative. Photo-transect techniques have been successfully used for the study of several aspects regarding benthic communities, such as their structure and dynamics (Garrabou et al., 2002), long-term temporal changes (Kollmann and Stachowitsch, 2001), continuous changes along depth gradients (Smale, 2008), coral reef recovery after hurricane impacts (Coles and Brown, 2007), algal bed ecological monitoring (Ducrotoy and Simpson, 2001) and general monitoring works (Van Rein et al., 2011). Video techniques have been applied by Norris et al. (1997) for the assessment of subtidal seagrasses or, combined with hydroacoustic techniques, for the seafloor substrate classification (Rooper and Zimmermann, 2007). Combinations of underwater imagery and hydroacoustic techniques, together with modeling and automated classification techniques, have been useful for the development of predictive habitat distribution maps (Ierodiaconou et al., 2011; Holmes et al., 2008), which are very valuable for the extensive management of subtidal areas.

In addition to the reduced scientific expertise needed for divers and the reduced diving times needed for video recordings or photographs, these techniques provide the added benefit of permanent visual records, which can be later analyzed in the laboratory, looking for additional information in the images. However, one of the main weaknesses of the photography and video surveys is their low resolution; species must be identified from a photograph or from individual video frames, which can be difficult in case of small-sized organisms. This limitation is partially compensated by the possibility of having information from large surveyed areas, which are especially attractive for extensive assessments or monitoring studies. A step forward in this sense has been achieved with the development of video and photomosaicing techniques (e.g. Gracias and Santos-Victor, 1998; Marks et al., 1995; Rzhanov et al., 2000; Rzhanov et al., 2007) that allow the creation of large images of the seafloor by mosaicing several photographs or video frames, thus providing a wide vision of the structure and composition of benthic assemblages in the surveyed area. In this aspect, Parravicini et al. (2009) and Kaiser (2003) considered that sampling unit size, rather than sampling method, is the crucial factor to take into account in sampling design. Consequently, it is necessary to define, according to the pursued objectives, the minimum sampling area required for each type of study. Most studies of subtidal environments use small sampling quadrats that generally range between 0.025 and 1 m^2 (e.g. Carpentier et al., 2011; Álvaro et al., 2008; Garrabou et al., 2002; Parravicini et al., 2010). In contrast, video mosaic analyses are based on records of wide areas that can range between 10 and 600 m^2 (e.g. Lirman et al., 2007; Lirman et al., 2010; Ludvigsen et al., 2007) and subsampling of different quadrats with areas between 0.25 and 1 m^2 (Lirman et al., 2007, 2010). Video-mosaicing techniques have been used in different types of underwater studies, such as the assessment of coral reef status (Lirman et al., 2007), recovery of reefs after injuries suffered by vessel groundings (Lirman et al., 2010) and by hurricane impacts (Gleason et al., 2007). Besides biological applications, these techniques have been also used in deep-sea archeological surveys (Søreide and Jasinski, 2005; Ludvigsen et al., 2007). Geographic Information Systems (GIS) provide a very useful tool for these applications, as they allow carrying out spatial analyses (e.g. estimation of coverage percentages of different biological species) over large geo-referenced videomosaics (Jerosch et al., 2006).

The use of Remotely Operated Vehicles (ROVs) and underwater towed cameras has provided an additional tool to survey deep subtidal areas (e.g Guinan et al., 2009; Lorance and Trenkel, 2006; Norcross and Mueter, 1999; Rzhanov et al., 2007). These systems reduce the inherent limitations of scuba divers because they can reach deeper depths and provide longer underwater time, thereby increasing the possibility of carrying out more extensive surveys at greater depth ranges. In shallow areas, the use of ROVs can be also very useful as they allow surveying a great number of sampling stations in the same day, which is not possible by scuba diving, thus reducing the temporal variability and costs of the surveys. This advantage can be even more interesting in highly hydrodynamic coastal regions, such as the Cantabrian Sea (Castanedo et al., 2006; Valencia et al., 2004), where the number of subtidal surveying available days can be very limited.

Finally, the use of non-destructive sampling methods, included in the recommendations of the International Council for the Exploration of the Sea (ICES, 2001), assumes less environmental damage and absence of laboratory work, thereby simplifying data processing and notably reducing the total monitoring costs (Ballesteros et al., 2007; DEFRA, 2004; García-Castrillo et al., 2000). Non-destructive sampling methods in underwater surveys require fast visual assessments that usually cannot allow for detailed taxonomical identifications (e.g. Guinda et al., 2012). In this sense, the level of taxonomic detail required in the studies should be taken into account based on the pursued objectives. Since Ellis (1985) introduced the concept of taxonomic sufficiency, many studies have demonstrated that, in some cases, identification of organisms to higher taxonomic levels, such as family or order, is sufficient to achieve the desired objectives (Díez et al., 2010; Ferraro and Cole, 1990; Puente and Juanes, 2008; Somerfield and Clarke, 1995; Warwick, 1988a, 1988b).

The assessment of the CFR index is based on an ecological approach that does not require a precise taxonomical identification of macroalgal species and which application should be carried out over extensive survey areas. Hence, considering all the above mentioned aspects, the use of underwater videomosaics as large subtidal sampling units, combined with the use of GIS applications for the identification and quantification of main macroalgal species, and the application of the CFR index (Juanes et al., 2008), might be a low-cost and effective strategy for the rapid assessment of subtidal macroalgae assemblages in order to carry out extensive management or monitoring works. In that sense, one of the main aspects that should be solved is the minimum sampling area required for accurate and reliable results.

According to these guidelines, the aim of this work is to assess the suitability of using seafloor video mosaics for the application of the CFR index in subtidal areas. For this purpose, two specific objectives are established: (i) to analyze the sensitivity and accuracy of the estimation of both the indicators that compose the CFR index (characteristic macroalgae coverage, fraction of opportunistics and characteristic macroalgae richness) and the index itself using different sampling surfaces and (ii) to validate the obtained results through direct applications of the CFR index in the field.

2. Material and methods

2.1. Study area

The study was carried out during the summer of 2011 in the coast of Cantabria (N. Spain) (Fig. 1). This coastal region is