Usefulness of semi-automatic image analysis for the assessment of zooplankton community structure in a highly dynamic area of the Alboran Sea (SW Mediterranean).

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Introduction

The Alboran Sea is the westernmost basin in the Mediterranean Sea, which is connected to the Atlantic Ocean by the Strait of Gibraltar. The entrance of the Atlantic Jet through the Strait results in a system of two quasi-permanent anticyclonic gyres dominating the entire basin. This circulation pattern coupled with westerly winds also produces an intermittent upwelling of nutrient-rich Deep Mediterranean Water in the northern coast (Figure 1). Previous studies have shown the strong influence of the hydrodynamics on the planktonic communities, dividing the Mediterranean basin in areas with marked different productivities. In the coastal area, the enrichment in inorganic nutrients produced by the upwelling makes the Alboran Sea one of the most productive areas of the Mediterranean Sea (Mercado et al., 2007; Yebra et al., 2017) whereas the western central basin is dominated by an oligotrophic anticyclonic gyre (WAG). Besides, the frontal area between the Atlantic Jet and the edge of the WAG enhances plankton productivity in open waters (Yebra et al., 2018). In this work we tested the usefulness of semiautomatic image analysis to assess the variability in taxonomic composition and normalized biovolume size spectra (NBSS) of the zooplankton communities associated to those different mesoscale hydrological structures.

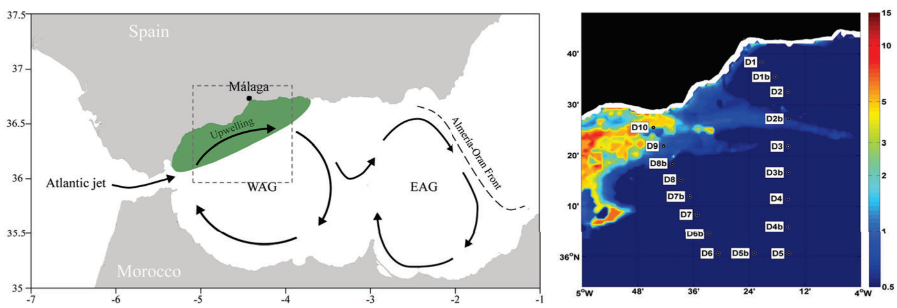

Figure 1: Study area (dashed box), Left: Alboran Sea surface circulation, WAG: western anticyclonic gyre, EAG: eastern anticyclonic gyre, green area: upwelling influence zone; Right: stations location (b stations were only sampled with CTD) and Chl a composite 9–19 July 2014 (mg Chl · m^{-3}).

Methods

Ten stations were sampled in summer 2014 by day and night, on board R/V García del Cid, following a transect perpendicular from the Spanish coast towards the WAG (Figure 1). Zooplankton samples were obtained with double WP2 net (200 μm mesh size) in vertical tows (maximum depth 100m). The samples were fixed with buffered formalin (f.c. 4%) and scanned in aliquots with an Epson Perfection v850 scanner, in glass trays at 2400dpi. The images were processed with Zooprocess software developed for Zooscan (https://sites.google.com/view/piqv). Resulting vignettes and associated data were imported to Ecotaxa (Picheral et al., 2017). We used an initial selection of 4,069 vignettes to create our initial training set for the identification of images in the study area. We classified all the vignettes resulting from the image processing, including zooplankton and some large phytoplankton taxa, detritus and artifacts (scratches, shadows and borders of the scanning tray). Several cycles of prediction and validation over the whole set of samples were carried out until achieving an adequate precision in relation to the abundance of each group.

Group	Precision	Recall
Bacillariophyceae	72.3 (*)	81.5
Dinoflagellata	-	-
Ceratium	85.4	100
Noctilucales	99.4	92.1
Pyrocystales	96.6	65.1
Appendicularia	66	82.4
Copepoda	-	-
Calanoida	73.9	78.8
Oncaeidae	62.6	64.7
Oithonidae	27.4 (*)	65.5
Harpacticoida	100 (*)	2.7
Corycaeidae	0 (*)	0
Poecilostomatoida	0 (*)	0
Copepoda (undet.)	0 (*)	0
Copepoda nauplii	100	2.8
Cladocera	-	-
Evadne	61.4	90.2
Penilia	86.1	76.7
Podon	1.9 (*)	3.2
Cladocera (undet.)	7.1 (*)	3.2
Doliolida	90.6	91.7
Chaetognatha	30.5	81.2
Cirripedia	0 (*)	0
Cnidaria	18.1	28.3
Decapoda	0 (*)	0
Echinodermata	0 (*)	0
Egg (others)	16.7	2.4
Euphausiacea	3.3 (*)	17.4
Fish	-	-
Fish larvae	18.5 (*)	21.7
Fish egg	46.4 (*)	46.4
Foraminifera	30.9	79.2
Mollusca	-	-
Bivalvia	16.8 (*)	24.1
Limacinidae	63	11.9
Ostracoda	100	5.3
Polychaeta	0 (*)	0
Bryozoa	0 (*)	0
Radiolaria	16.5 (*)	47.1
Siphonophorae	2.8 (*)	2.1
Tintinnida	0 (*)	0
Others (undet.)	0 (*)	0
Detritus	96.7	68.3
Artefact	99.2	86.5
Multiple	77.8	93.3

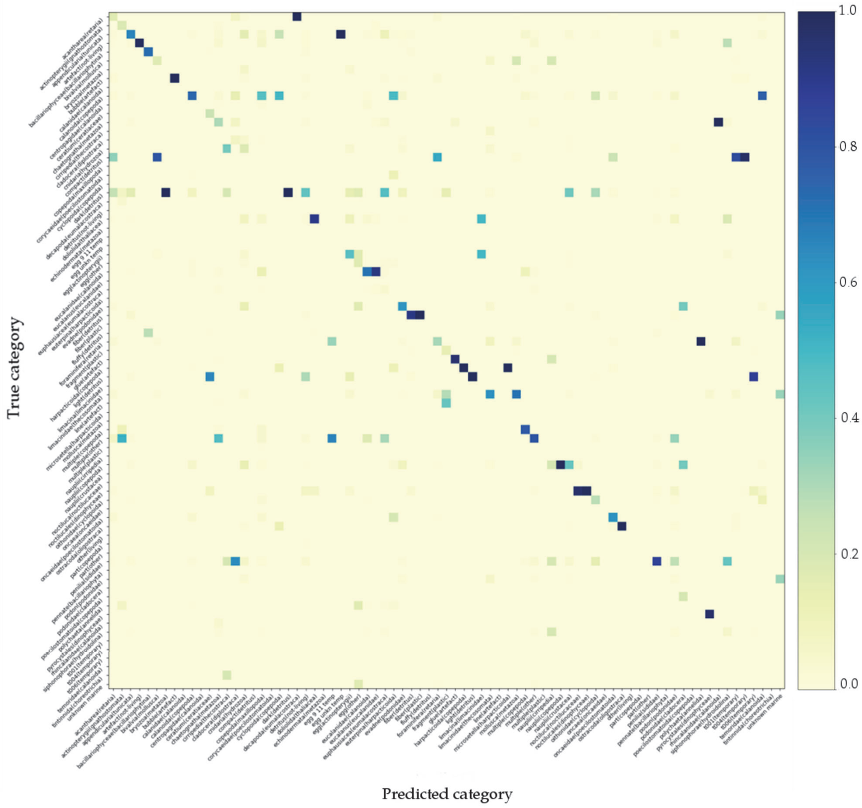

Figure 2: Accuracy parameters of the Alboran Sea training set. Left: Percentages of precision and recall for each group. Groups marked with (*) had all their vignettes validated. Right: Confusion matrix, the diagonal contains the precision rate. Blank rows represent groups from previous versions of the training set, final groups in the set are listed in the table.

Elliptical biovolume (EBv, mm^3), was calculated from major and minor axis computed by Zooprocess as follows:

$$EBv = \frac{4}{3} \cdot \pi \cdot \left(\frac{Major}{2}\right) \cdot \left(\frac{Minor}{2}\right)^2 \quad (1)$$

To calculate the NBSS, particle abundances were arranged on the x-axis in $\log_2$ size classes (mm^3). The y-values were the sum of the individual EBv for each interval normalized to the length of the size class ($mm^3 \cdot m^{-3} \cdot mm^{-3}$). Finally, the NBSS was calculated from the linear regression between the biomass of each size and the size classes expressed on a logarithmic scale (Blanco et al., 1994).

Results and Discussion

Due to the high productivity of the Alboran Sea, all our samples presented high percentages of detritus (40 to 60% of vignettes in the WAG and coast, respectively), making difficult to achieve high precision in the prediction of some groups (Figure 2). In addition, some shallow samples (D1 and N1) could not be processed, because the amount of detritus and mucus prevented a correct subsampling. Nevertheless, the identification accuracy of the main taxonomic groups ranged from 66.0% (*Appendicularia*) to 90.6% (*Doliolida*). Regarding the total abundance, we identified 95% of the total vignettes and 90% of the zooplankton images with a mean precision of 81.7% ± 15.1 SD (Figure 2). The application of the semi-automated image analysis allowed us to detect differences in the taxonomic composition (data not shown) and variations in the slope of the NBSS among the coast, the gyre and the Atlantic Jet. We observed steeper slopes in the stations belonging to areas of high productivity compared to the WAG (Figure 3). This is in agreement with the differences expected between eutrophic and oligotrophic areas.

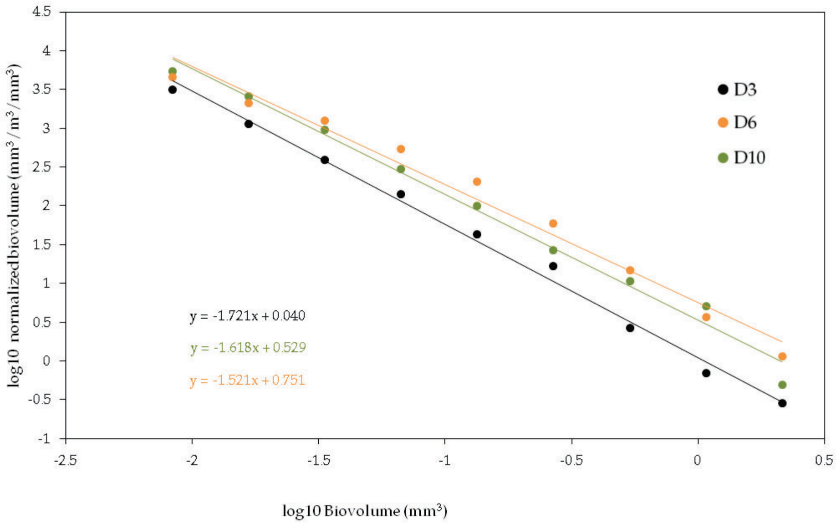

Figure 3: Slopes of the normalized biovolume size spectra at three stations from different productivity areas: coast (D10), WAG (D6) and Atlantic Jet (D3).

Our analyses demonstrate that semi-automated image analysis of plankton is an especially interesting tool for research studies with large spatial and temporal scales, because it allows to obtain results faster than the traditional methods. Despite presenting lower taxonomic resolution compared to microscopy, it is a useful tool to be implemented in ongoing long-term monitoring programs in our study area, which are necessary for the implementation of international initiatives such as MEDPOL and the EU Marine Strategy Framework Directive.

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