Regional Studies in Marine Science 3 (2016) 33–41

Contents lists available at ScienceDirect

Regional Studies in Marine Science

journal homepage: www.elsevier.com/locate/rsma

Fish and cephalopod assemblage structure of green alga *Caulerpa prolifera* (Chlorophyta) meadow in the eastern Mediterranean Sea (Elounda Bay, Crete Island)

Panayota Koulouri [a,*], Stefanos Kalogirou [b], Maria Maidanou [a,c], Drosos Koutsoubas [c], Costas Dounas [a]

[a] *Hellenic Centre for Marine Research, Institute of Marine Biology, Biotechnology and Aquaculture, Gournes Pediados, P.O. Box 2214, 71003, Heraklion, Crete, Greece*

[b] *Hellenic Centre for Marine Research, Institute of Marine Biological Resources and Inland Waters, Hydrobiological Station of Rhodes, 85100, Rhodes, Greece*

[c] *University of the Aegean, Department of Marine Sciences, Faculty of Environment, 81100, Mytilene, Lesvos Island, Greece*

HIGHLIGHTS

- Fish and cephalopod assemblages in a shallow semi-enclosed marine ecosystem.
- Fish assemblages associated with a green alga *Caulerpa prolifera* meadow.
- Species/density peaks in summer due to extremely high numbers of juveniles.
- An important juvenile habitat for many fish and cephalopod species.

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form
2 December 2015
Accepted 8 December 2015
Available online 18 December 2015

Keywords:
Macroalgal habitat
Semi-enclosed coastal ecosystems
Fish assemblages
Juvenile habitat
Functional guilds

ABSTRACT

The present study investigated for the first time in the eastern Mediterranean Sea species composition, density, wet biomass and body size of fish and cephalopod species associated with a *Caulerpa prolifera* meadow in a shallow semi-enclosed coastal marine ecosystem (Elounda Bay, Crete Island). Quantitative sampling with a local boat seine, revealed 34 fish species belonging to 22 families and three cephalopod taxa. The number and density of species peaked during the summer sampling period due to high numbers of juveniles, while the highest wet biomass was observed during the autumn sampling period. The fish species *Boops boops*, *Spicara smaris*, *Mullus barbatus* and the non-indigenous *Siganus luridus* were dominant, making up a high proportion of the total fish fauna of the studied area. The cephalopod *Sepia officinalis* was the most important species, in terms of wet biomass. The results of the study indicated that the semi-enclosed coastal marine ecosystem of Elounda Bay, characterized by a dense monospecific *C. prolifera* bed as well as specific abiotic and biotic features could be regarded as an important habitat for the development of fish and cephalopod species, thus contributing to the conservation and maintenance of marine biological resources of the area.

1. Introduction

The presence of vegetation in near-shore ecosystems has often been reported as supporting more diverse fish assemblages and higher numbers of fish species as well as their juveniles, than non-vegetated substrates (Paterson and Whitfield, 2000; Guidetti, 2000). Such patterns are typically explained, by taking into account the high structural complexity and productivity of vegetated systems, especially seagrass meadows, which thus provide food and shelter from predators to a great number of littoral fish species (Guidetti, 2000; Short et al., 2007). However, it is not a specific type of habitat but its structure *per se* that seems to be the most important factor in the nursery role carried out in vegetated substrates; when seagrass meadows are compared to other structured habitats such as macroalgal beds, there appears to be very few differences in abundance, growth or survival of juveniles (Heck et al., 2003).

* Corresponding author.
E-mail address: yol72@hcmr.gr (P. Koulouri).

http://dx.doi.org/10.1016/j.rsma.2015.12.002
2352-4855/

In the Mediterranean Sea, most researchers have focused on the fish fauna associated with the most widespread endemic seagrass *Posidonia oceanica* (e.g. Francour, 1997; Deudero et al., 2008 and Kalogirou et al., 2010). The structure and dynamics of fish communities associated with other less common seagrass species, such as *Cymodocea nodosa* and *Zostera noltii*, as well as infralittoral rocky bottoms and sandy non-vegetated habitats have also been investigated (e.g. Guidetti, 2000; Guidetti and Bussotti, 2002 and Kalogirou et al., 2012). Nevertheless, soft-bottom macroalgae-dominated ecosystems have so far received little attention (Verdiell-Cubedo et al., 2007a,b; Franco et al., 2012; Cheminée et al., 2013).

Caulerpa prolifera (Forsskål) J.V. Lamouroux 1809 is a subtropical green alga which forms dense permanent meadows, usually occurring on muddy sand bottoms in sheltered areas at depths ranging from 1 to 20 m (Davies et al., 2004). Even though *C. prolifera* beds have been observed in various areas of the Mediterranean Sea, only a few studies have been concerned with its structure, distribution pattern and dynamics as well as its associated macrofauna (e.g. Sánchez-Moyano et al., 2001 and Pérez-Ruzafa et al., 2012). In particular, fish communities associated with *C. prolifera* beds were only examined in the Mar Menor coastal lagoon in the south-east of Iberian Peninsula (Verdiell-Cubedo et al., 2007a,b; Franco et al., 2012).

Elounda Bay is a semi-enclosed embayment which is covered by a dense monospecific *C. prolifera* meadow, located in the north-eastern part of Crete Island (S. Aegean Sea, E. Mediterranean). This shallow area sheltered from wave energy is considered by the local fishermen as an important habitat for the conservation and maintenance of its marine biological resources. The objectives of the present study were: (a) to describe the qualitative and quantitative structure of the fish and cephalopod assemblages associated to *C. prolifera* meadow in Elounda Bay (Crete Island) throughout a single year; (b) to characterize the fish and cephalopod fauna in the study area by using ecological guilds; (c) to determine the role and importance of this particular habitat for the development of fish and cephalopod species; (d) to compare results with those available from other areas in the Mediterranean Sea.

2. Materials and methods

2.1. Study area

Elounda Bay has a surface area of 6.5 km^2, while its inner part, sheltered from waves and currents, occupies an area of 4.7 km^2 covered by a dense *C. prolifera* meadow (Fig. 1). The shallow part of the Bay (2–9 m depth) is traditionally considered to be an important habitat for the conservation and maintenance of marine biological resources of commercial value for the fisheries of the wider area. The outer coastal Mirabello Bay connects to Elounda Bay through three straits (Fig. 1). The northernmost strait is located between the north coast of Mirabello Bay and Spinalonga Island with a total width of 750 m, while another northern strait is located between the Islands of Spinalonga and Kolokitha with a total width of 150 m and depth of 1.5 m. The south strait was artificially created in 1897 with a total width of 3 m and depth of 1 m.

The environmental variables in the water column and the surface sediments of the study area were measured within the framework of a project financed by the local authorities and described in the project's Final Report (Dounas, 2006, unpublished). The seawater temperature showed strong seasonality, varying between 13.30 °C (±0.12) during winter and 24.95 °C (±0.25) during summer. Salinity remained relatively stable throughout the water column with values ranging between 37.95 (±0.11) and 40.02 (±0.25) in late autumn and summer, respectively. Concentrations of the chloroplastic pigments (chlorophyll *a* and phaeopigments) and the particulate organic carbon (POC) in the water column were relatively low (maximum values of chl *a* : 0.57 μg/l, phaeopigments: 0.12 μg/l, POC: 0.90 mg/l), while fifteen macrozooplanktonic groups (e.g. copepods, appendicularians, cnidarians) were found in the study area (10–1463 ind m^{-3}). Surface sediments (0–0.01 m depth) were mostly classified as mud with the fraction <63 μm making up more than 40%–70% of the sediment. The coarse-grained constituents (20%–30%) were mainly shell fragments and debris of bivalves. Sedimentary chloroplastic pigments and especially chlorophyll *a* reached a peak in autumn (24.70 μg/g), while concentrations over the remaining study periods were also relatively high, ranging from 8.56 μg/g in summer to 15.48 μg/g in spring. The concentrations of POC in the surface sediment were also high, with maximum values in autumn (28.18 mg/g) and the lowest in spring (19.93 mg/g). Twenty-five different macrofaunal benthic groups (e.g. crustaceans, molluscs, polychaetes) were found in the study area (72–447 ind m^{-2}).

2.2. Sampling

Daylight sampling was carried out at Site A (Fig. 1) every two months on six occasions: May 2006, July 2006, September 2006, November 2006, February 2007 and April 2007. Selection of the sampling site representative of the *C. prolifera* meadow density variability in the study area was made based on visual observations by the Hellenic Centre for Marine Science (HCMR) scientific diving team. This site (8 m depth) is the only boat seine fishing ground in the Bay. Boat seine fishing is a very effective sampling technique in coastal waters, though it has impacts on living resources as small meshes in the cod-end may result in the capture of undersized fish and non-target species. Therefore, its use was prohibited in Greek waters from 1 April to 31 September until 2010; ever since then, in accordance with European regulations (EC Regulation 1967/2006) it has been completely banned throughout the year. The boat seine net used (cod-end mesh size: 8 mm bar length) by a local fishing boat to sample fishes and cephalopods (especially *Sepia officinalis*) swept an area of approximately 6×10^3 m^2. The design of the boat seine fishing method is described in Kalogirou et al. (2010). All fish captured were identified to species level, counted and weighed. Sample materials were then fixed in 10% formalin on board, before transportation to the laboratory, where they were individually measured to the nearest mm (total length; *TL* for fish and mantle length; *ML* for cephalopods) and weighed to the nearest 0.01 g. The fish assemblage structure was analysed in terms of the number of species, density (number of individuals) and total wet biomass (kg).

2.3. Data analysis

Non-metric multidimensional scaling (MDS) ordination analysis (Field et al., 1982), based on fish and cephalopod density and biomass matrices of the six seasonal sampling periods, was performed using the Bray–Curtis similarity coefficient (Bray and Curtis, 1957). Dispersion weighting was carried out to reduce the contribution of schooling species in separating samples (Clarke et al., 2006). The ANOSIM (analysis of similarity) test was used in order to detect statistically significant differences between the two-month surveys (six surveys-hauls in total) throughout the study period. Species contribution to the similarity and/or dissimilarity of the six hauls was investigated by applying the SIMPER (similarity percentage) procedure. The similarity and/or dissimilarity of the hauls was estimated (%) and the species contribution to the similarity and/or dissimilarity of the hauls was also estimated (%). The PRIMER v6 statistical software package was used for the above data analyses.