



# Vertical and temporal distribution of pelagic decapod crustaceans over the shelf-break and middle slope in two contrasting zones around Mallorca (western Mediterranean Sea)



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## ABSTRACT

The pelagic decapod crustacean fauna of two different zones (Sóller and Cabrera) with different hydrographic dynamics and oligotrophy levels was studied around Mallorca (western Mediterranean), the latter with a higher degree of oligotrophy than the former. Samples were taken with a Pelagic Trawl and an IKMT in the upper 600 m of the water column, targeting larger and middle-sized nektonic species, respectively. Fourteen species were collected: five dendrobranchiate shrimps, eight caridean shrimps and one scyllarid lobster. Some species were restricted to the shelf-break: *Chlorotocus crassicornis* and *Plesionika heterocarpus*. Others were exclusive of the middle slope: *Pasiphaea multidentata*, and *Sergia robusta*. *Pasiphaea sivado* and *Gennadas elegans* occurred in all pelagic strata. Multivariate analyses showed several distinct assemblages related to bathymetry and sampling depth. No significant differences were found concerning zone or sampled seasons. Bathymetrically, Deep Scattering Layers showed the highest diversity. No decapod crustaceans occurred in epipelagic daytime samples. The pelagic decapod community sampled was structured by both the geomorphology (and associated hydrographic characteristics over the shelf-break) and the influence of light in the water column. Size analysis showed species-specific patterns concerning size/age movements into the water column throughout the day–night cycle.

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## 1. Introduction

Pelagic decapod shrimps have a widespread geographic and bathymetric distribution from high latitudes in both hemispheres to intertropical waters (Burghart et al., 2007; Casanova and Judkins, 1977; Clarke and Holmes, 1987; Fasham and Foxton, 1979). Provided of high locomotion abilities, some species are able to maintain themselves at particular water masses as well as to migrate to other layers (Kaartvedt et al., 1988; Karuppusamy et al., 2006; Omori, 1974). This displacement is usually cyclic and associated to the photoperiod as shown in some pasiphaeid and sergestid shrimps (Aguzzi et al., 2007; Cartes et al., 1993; Frogliola and Giannini, 1982). The vertical daily migration ability present in the behavior of these crustaceans (Macquart-Moulin and Patriti, 1993; Naylor, 2010) provides them with an important role in the transference of matter and energy from the upper primary productive layers of the ocean, where these species tend to feed at night, down to the middle

slope epibenthic community, where many of them dwell during day-time hours (Cartes, 1993a; Herring and Roe, 1988; Naylor, 2010). Some of these pelagic shrimps have a relevant ecological importance as well as an exploitation potential as commercial target species (Nanjo and Ohtomi, 2009). Relevant studies on faunistics, biology and ecology of pelagic shrimps have however been conducted in a few regions, such as the Mediterranean Sea (Casanova and Judkins, 1977; Company et al., 2001, 2003; Orsi-Relini and Relini, 1990; Ramirez-Llodra et al., 2007), the Japan Sea (Nanjo, 2007; Nanjo and Ohtomi, 2009), or the Northeast and Southeast Atlantic Ocean (Gibbons et al., 1994; Kensley and Schotte, 2006; Matthews and Pinnoi, 1973).

From the energetics point of view, in oligotrophic areas such as most of the Mediterranean Sea (Estrada, 1996; Estrada et al., 1985), the secondary production of deep-sea species depends in a practically exclusive way on the role of the vertical migrators throughout the water column (Klages et al., 2001). Pelagic shrimps constitute a fundamental food item to fish, other crustaceans and cephalopods with epibenthic habits on the continental slope and deep sea (Dalpadado et al., 1998; Fanelli and Cartes, 2008; Garrison and Link, 2000). Some of them can be considered as benthopelagic since they spend most of the daytime in close contact with the bottom (Aguzzi et al., 2007; Cartes, 1993a, 2001), and accordingly play, as stated above, a relevant

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role in the energetics dynamics of the continental slope and bathyal ecosystems.

The present work aims at studying the pelagic decapod crustacean assemblages inhabiting two hydrographically differentiated areas around the island of Mallorca in the western Mediterranean. Faunistic and size composition, differential distribution in relation to oceanographic water masses, geomorphology (shelf break versus deep continental slope), time of the day and temporality between the two seasons sampled were particularly the specific targets of this study. We have contributed to this topic by providing evidences of the vertical movements, localization of the species in the water column and in relation to bathymetry/geomorphology, as well as on inter-seasonal stability of species assemblages.

## 2. Material and methods

### 2.1. Study area and hydrographic setting

Mallorca is the main island of the Balearic archipelago, in the western Mediterranean. It is located east of the Iberian Peninsula and is separated from the continent by a wide hydro-geographical basin with maximum depths of 2200 m (Massutí et al., 2008). This archipelago is located in an area showing high hydrographical variability, both in space and time, which is mainly conditioned by the circulation of water masses through their channels (López-Jurado et al., 2008). Surface waters are usually formed by lower salinity Atlantic Water entering from the south through the channels between the islands, and between them and the continent. Deeper than 100 m more saline Mediterranean water masses predominate. The Western Mediterranean Intermediate Waters (WIW) usually occupy the 100–300 m depth stratum, the Levantine Intermediate Waters (LIW) are placed between 200 and 700 m and finally the Western Mediterranean Deep Water (DW) is found on the bottom (Pinot et al., 2002).

The geomorphology of the Balearic Basin, coupled to the climatological variability of the region, confers to this Sea a very dynamic hydrographical scenario, which is conditioned mainly by the amount of WIW occupying the submarine channels. During mild winters the Northern current (NC) from the Gulf of Lions flows southward along the continental slope, reaching the Ibiza Channel and bifurcates creating the north-eastern Balearic current (BC) when reaching surface low salinity Atlantic Water, while part of the main current flows southwest along the continental margin. However during severe winters the high amount of WIW occupying the channels block partially the NC current reinforcing the BC, thus recirculating the waters in the NW basin without a significant transport of Mediterranean waters through the channels into the Algerian Basin (Monserat et al., 2008).

The hydrographical characteristics actually observed during the sampling cruises in the study area (Olivar et al., 2012; Torres et al., same Special Issue) showed that surface waters were of recent Atlantic origin. During the December cruise, both temperature and salinity were homogeneous within the first 60–80 m of the water column and a highest gradient was located from there to 120 m depth. In the summer the mixing layer was restricted to the first 10 m and from there a gradient zone was placed until 100 m depth. Below the thermocline layer down to 400 m temperature was approximately constant at around 13 °C, while salinity gradually increased up to 38.5 until reaching 300–400 m depth.

### 2.2. Sampling

In December 2009 (late autumn) and July 2010 (early summer) two cruises were conducted around the island of Mallorca on board the R/V “Sarmiento de Gamboa” (Olivar et al., 2012). Two geographic regions were selected according to previous knowledge on water productivity characteristics: one off Cabrera island (in the SE of Mallorca, Algerian sub-basin) and the other off the town of Sóller, along the western coasts

of Mallorca (Balearic sub-basin) (Fig. 1). Within each area samples were taken over (1) the continental shelf-break and (2) the middle slope. Hydrographical data were obtained by means of CTD casts from the surface to the bottom with a CTD SBE911 in two regular grids of stations covering from 100 to 1200 m isobaths.

Aggregations of pelagic organisms were detected by acoustic backscatter using a Simrad EK60 echosounder and then the sampling was performed with midwater trawls at different depths of the water column inside the acoustic layers that presented the strongest and widest echo-reverberation, i.e. the Deep Scattering Layers (DSL) in mid waters (ca. 400 m) and the Benthic Boundary Layer (BBL), ca. 50 m above the bottom.

Nekton and micronekton were sampled by two different pelagic gears which given their different codend mesh size and mouth characteristics are aimed at different size range target species: a Pelagic Trawl net (PT) and an Isaaks-Kidd Midwater Trawl (IKMT). Trawl gear geometry and depth were controlled using Scanmar sensors. The Pelagic Trawl net used was a double-warp, modified commercial mid-water trawl, with standard pelagic otter board doors and a codend mesh size of 10 mm; the effective duration of the trawls was of 1 h at a speed of 4 knots (nautical miles h<sup>-1</sup>). PT densities were calculated as number of individuals per hour standardized to 100 m<sup>2</sup> of net mouth surface. The IKMT net had a length of 3 m, 3 m<sup>2</sup> of mouth opening and 3 mm codend mesh size, and the trawls had duration of 30 min at a speed of 3 knots. IKMT densities were calculated as number of individuals per 10<sup>4</sup> filtered m<sup>3</sup>. More detailed sampling information is available in Olivar et al. (2012). Tables 1 and 2 show the number of samples taken within each Sampling Cell (SC), i.e. combination of season (December/July), area (Cabrera/Sóller), shelf/slope and daylight strata by sampling gear (PT and IKMT). A total of 36 valid PT samples were obtained, 12 in Cabrera and 24 in Sóller. In the December cruise all the PT hauls were performed at night time; while in July the shelf of Cabrera could not be sampled with PT. A total of 65 valid IKMT samples were obtained, 37 in Cabrera and 28 in Sóller. Additionally, each sample was assigned to one of the three defined positions in the water column, i.e. Epipelagic (samples taken in near surface waters well above the DSL), DSL (which was usually located around 400 m depth in both study periods) or BBL (samples taken at around 50 m above the bottom).

Pelagic decapod crustaceans were sorted out and identified to species level (Zariquiey Álvarez, 1968; Judkins and Kensley, 2008). Nomenclature followed the World Register of Marine Species (<http://www.marinespecies.org>). Total fresh weight and number of specimens per species and haul were obtained from PT hauls. All individuals, or a representative subsample of a minimum of 50 individuals, were sexed and measured (carapace length (CL), in mm) with a 0.01 mm precision using a digital caliper. The samples from IKMT were fixed in buffered 5% formalin. After sorting out and species identification and quantification, each specimen was sexed and CL measured using a ‘Leica MZ12’ magnifier provided with ocular micrometer.

Size frequency distributions (SFD) (carapace length, CL, in mm) were generated by pelagic layers (Epipelagic, Deep Scattering Layers – DSL, and Benthic Boundary Layers – BBL) for the most abundant species for both Pelagic Trawl and IKMT samples. Additionally, samples obtained from the epibenthic/demersal survey taking place in parallel with the pelagic survey (Massutí et al., 2014–in this volume) were also used to generate the corresponding SFD for the population fraction of each species sampled in the epibenthic environment during day time. The gears used to collect demersal fauna were a demersal bottom trawl with a 16 m horizontal width, opening height of 2.7–3.2 m and 20 mm codend mesh size (Moranta et al., 2008), and an epibenthic beam trawl (horizontal and vertical openings: 3.5 m and 0.6 m respectively; codend mesh size: 10 mm). Both epibenthic and demersal bottom trawl samples were taken on board the F/V “Punta des Vent”, who worked in parallel with the research vessel (Ramon et al., same Special Issue).

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