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ORIGINAL RESEARCH ARTICLE

Composition and diel vertical distribution of euphausiid larvae (calyptopis stage) in the deep southern Adriatic

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Summary Diel changes in the vertical distribution and abundance of calyptopes were studied in the deepest area of the southern Adriatic over four seasons (July 2003, February 2004, October 2004, April 2009). Temperature variations were limited to the upper 100 m and salinity variations were small. Of previously known adult euphausiid species — 12 for the Adriatic (Gangai et al., 2012) and 13 for the Mediterranean (Mavidis et al., 2005) — calyptopes of 11 species of euphausiids were recorded. Abundance of calyptopes of all species was the highest in spring. Species were characterized according to their mean depth: surface (0—50 m), sub-surface (50—200 m), mesopelagic (200—800 m), or bathypelagic (800—1200 m) and vertical dispersion (scattered or non-scattered). Four diel patterns emerged: (i) nocturnal ascent to upper layers (*Euphausia brevis*, *E. hemigibba*, *E. krohnii*, *Nematoscelis megalops*, *N. couchii*), (ii) migration to upper layers at middle of the day and at night, and descent during the morning and evening (*Stylocheiron maximum* — only winter), (iii) weakly-migrating or non-migrating (*S. longicorne*), (iv) irregular migration independent of the day/night cycle (*S. abbreviatum*, *S. maximum* — during spring, summer and autumn, *T. aequalis*).

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1. Introduction

The Adriatic Sea consists of two contrasting ecosystems: the Northern Adriatic, eutrophic shelf area where nutrients are supplied by lateral terrestrial inputs; and the Southern Adriatic, semicircular oligotrophic basin with depths to about 1200 m, influenced by water masses from the Ionian Sea. The most prominent bathymetry feature in the Adriatic is the South Adriatic Pit (SAP), which is preserving cyclonic circulation around its perimeter (Gačić et al., 2002). The SAP interacts with the Eastern Mediterranean through the Strait of Otranto (~800 m depth). Advection of saline Levantine Intermediate Water (LIW) alternates with low-salinity Modified Atlantic Water (MAW) that originates in the Western Mediterranean (Gačić et al., 2010; Vilibić et al., 2012) on a roughly 10-year cycle termed the Adriatic-Ionian Bimodal Oscillation or BiOS (Gačić et al., 2010). The low primary production, low chlorophyll *a*, and high temperatures in many oligotrophic environments favor heterotrophic plankton communities (Duarte et al., 2013). One such region, the phosphate-limited Eastern Mediterranean Sea (Krom et al., 2010; Siokou-Frangou et al., 2010), is the predominant influence on the open waters of the South Adriatic (Malanotte-Rizzoli et al., 1997). Being a temperate area, the Adriatic Sea is characterized by a strong seasonal variability of the phytoplankton biomass reaching a maximum in spring (Antoine et al., 1995) followed by zooplankton annual peak in this period (Benović et al., 2005; Hure et al., 1980; Kršinić, 1998). Picophytoplankton dominates the South Adriatic and appears to be its main primary producers (Najdek et al., 2014). Microphytoplankton production is restricted to lower-salinity, nutrient-rich coastal waters, the deep chlorophyll maximum, and periods during or following winter convection (Batistić et al., 2012; Cerino et al., 2012; Gačić et al., 2002). The microzooplankton is dominated by tintinnids (Fonda Umani and Monti, 1993). Herbivorous copepods are dominant in mesozooplankton community throughout the year, while carnivorous species are also better represented (Fonda Umani, 1996). The community of this area shows high diversity and greater stability.

Euphausiids play an important role in pelagic food webs. This is expressed by their substantial contribution to ocean biomass (Casanova, 2003; Mauchline and Fisher, 1969) and their diel vertical migrations that rapidly transport organic matter from the productive epipelagic zone to deeper layers (Harvey et al., 2009; Longhurst and Harrison, 1989; Longhurst et al., 1989). These migrations are modulated principally by light and temperature. It is not unusual that distribution varies during larval development because different stages require different nutritional and predator-avoidance needs (Spiridonov and Casanova, 2010).

Investigating only larvae instead of adults is sensible as these occur in high numbers and can be sampled reliably with planktonic nets. Also, data on Mediterranean euphausiids is largely restricted to older papers (Casanova, 1970, 1974; Casanova-Soulier, 1963; Franqueville, 1971; Mauchline and Fisher, 1969; Mavidis et al., 2005; Ruud, 1936; Trégouboff and Rose, 1957; Wiebe and D'Abramo, 1972) and relatively little attention has been paid to their developmental stages (Andersen et al., 1998; Brancato et al., 2001; Casanova, 1970, 1974; Gangai et al., 2012; McGehee et al., 2004). This data fills a knowledge gap in the Mediterranean Sea of larval euphausiid.

Investigations of the Adriatic Sea euphausiids thus far have been restricted to the deep South Adriatic Pit (~1200 m) and a limited area of the Jabuka Pit in the mid-Adriatic (~275 m). The first records of Adriatic euphausiids were by Ruud (1936) who identified 12 species in the southern section. Hure (1955, 1961) and Šipoš (1977a) later confirmed these findings. Guglielmo (1979) provided records from the deep Southern Adriatic using an Isaacs-Kidds mid-water trawl. The first data for euphausiid developmental stages are those of Gangai et al. (2012) who noted their importance in the secondary production of the oligotrophic Southern Adriatic and related furciliae and calyptopes migrations to extrapolated mean-depth light intensity. Diel differences in calyptopes numbers within designated depth layers were interpreted as an indication of the extent of diel vertical migration. Gangai et al. (2012) found larvae of 11 euphausiid species with first record of *Thysanoessa gregaria* previously reported only from the western and central Mediterranean (Brinton et al., 2000; Casanova, 1974; Mauchline and Fisher, 1969; Mavidis et al., 2005).

With euphausiids and their developmental stages among the least known elements of the Mediterranean and Adriatic holoplankton, the objectives of this study were to: (1) determine the composition and abundance of Adriatic calyptopes; (2) compare these with data from earlier investigations; (3) describe and explain any changes in the composition of Adriatic calyptopes; (4) identify the pattern of calyptopes diel and seasonal distribution over the four seasons. A key assumption is that seasonal samples collected at short intervals and at different times of day provide data with sufficient resolution to accomplish all stated research objectives. Depending on temperature and feeding, each calyptopis stage lasts a few days before molting. Another assumption is that all species whose calyptopes have been found in our samples spawn in deep Adriatic and their distribution is limited by depth.

2. Material and methods

2.1. Study area

Zooplankton was sampled at a single station (41°44′N 17°52′E, ~1200 m depth, Fig. 1) in the southern Adriatic Sea during four seasons (10 and 11 February 2004; 24 April 2009; 22, 23, 24, 25, 27 and 28 July 2003; 18 October 2004). This is the deepest part of the Adriatic and therefore the most representative place to study distribution of euphausiid larvae. Thirty-five sample series were collected (Table 1) with a Nansen opening-closing net (200 μm mesh, 113 cm diameter) at the following depth intervals: 0—15 (above the summer thermocline), 15—50, 50—100, 100—200, 200—400, 400—600, 600—800, and 800—1200 m. Some tows overlapped sunrise or sunset with day or night periods (Table 1). Average hauling speed of all tows was 0.5 m s^{-1}. Samples were preserved in a 4% formalin-seawater solution buffered with $CaCO_3$. Species were identified with an Olympus SZX-9 stereomicroscope.

2.2. Data analysis

Euphausiids pass through six developmental stages: egg, nauplius, metanauplius, calyptopis, furcilia, and postlarvae.