

Original article

Comparison between two lunar situations on emission and larval transport of decapod larvae in the Mondego estuary (Portugal)

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Abstract

This study compares the rhythms of larval release of the most abundant decapod crustaceans between the New Moon and the First Quarter. Euryhaline field surveys were conducted at a small estuary (Mondego river) on the Atlantic coast of Portugal. All taxa showed tidal and lunar rhythm changes in abundance. The larval emission was very strong during nocturnal ebb neap tides at the First Quarter. Export of zoea did not occur to *Rhithropanopeus harrisi*. Despite the extensive literature on seasonal abundance, dispersal patterns, larval emission and recruitment of estuarine crabs, little is known about patterns of emission and larval transport in estuaries of Atlantic coast of Portugal, with crepuscular high tides around the quarter moons. The aim of the present study was to compare the larval emission of decapods in the Mondego river estuary, at different lunar situations and during nyctemeral cycles.

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1. Introduction

In temperate environments, most decapod crustaceans release their larvae to the water column during a determined period of the year, when the environmental conditions are favourable. Various studies suggest that the rhythm of release is synchronised with the light-dark cycle, the lunar and/or semi-lunar period, the tidal amplitude and the hour of the high tide (see Amend and Shanks, 1999; Ennis, 1975; Gonçalves, 1991; Paula, 1989; Salmon et al., 1986 and others). Larval release, and the consequent increase of zoeae I on water mass, occurs mainly between sunset and 24:00 h (local time), during high tide and with a semi-lunar period. This combination is different from region-to-region. For example, in the east coast of United States and Japan, that combination occurs during spring tides (highest amplitude) and the Portuguese coast, this combination occurs during neap tides (quarter moon).

Different taxa have been studied and revised, like *Uca* (Bergin, 1981; Christy, 1978, 1982; Christy and Stancyk, 1982; De Coursey, 1979, 1983; Dittel and Epifaniot, 1982; Lambert and Epifanio, 1982; Salmon et al., 1986; Wheeler,

1978), *Sesarma* (Saigusa, 1981; Saigusa and Hidaka, 1978), *Pinnixa* (Brookins and Epifanio, 1985; Christy and Stancyk, 1982; Salmon et al., 1986), *Callinectes sapidus* (Epifanio et al., 1984; Provenzano et al., 1983; Salmon et al., 1986), Xanthidae (Cronin and Forward Jr, 1982; Forward Jr. et al., 1982; Salmon et al., 1986), *Xanthodius sternberghii* and *Cataleptodius taboganus* (Christy, 1986), *Uca pugilator*, *Uca tangeri*, *Palaemon* spp., *Crangon crangon*, *Upogebia pusilla*, *Anapagurus* sp., *Panopeus africanus*, *Pachygrapsus marmoratus* and *Rhithropanopeus harrisi* (Gonçalves, 1991; Paula, 1989) *Carcinus maenas* (Queiroga et al., 1994, 1997). Thus, the rhythm of emission seems to be correlated with the hour of crepuscular high tide and not with the amplitude of tide (Paula, 1989).

Experiences carried out with *R. harrisi* (Forward Jr. and Lohmann, 1983; Forward Jr. et al., 1982) have shown that crabs coming from a non-regular tidal estuary release their eggs 2 h after sunset, thus suggesting a circadian rhythm. Crabs deriving from a semi-diurnal tidal estuary released their eggs in the beginning of high tide, showing a circatidal rhythm. According to the same authors, crabs can adapt their releasing rhythm to new environmental conditions that differ from the original site. The release occurs synchronised with several environmental conditions (e.g. light and temperature). The larval behaviour is fundamental to the dis-

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persal strategy, in new habitats colonisation and in the recruitment (Etherington and Eggleston, 2000).

Despite the extensive literature on seasonal abundance, dispersal patterns, larval emission and recruitment of estuarine crabs, little is known about patterns of emission and larval transport in estuaries of Atlantic coast of Portugal, with crepuscular high tides around the quarter moons. The aim of the present study was to compare the larval emission of decapods in the Mondego river estuary, at different lunar situations and during nyctemeral cycles.

2. Materials and methods

This study was conducted in a small estuary (Mondego river) on the Atlantic coast of Portugal (approximate coordinates 40°08'N 8°52'W) (Fig. 1). This estuary is composed of two arms with different flow regimes. The South Arm, where this study was done, is a shallow channel not connected with the North Arm at the upstream zone, and the flow regime is controlled by a sluice located at the Pranto river. Whenever the sluice is closed this channel works as a coastal lagoon.

This investigation consisted of both spring and neap tide sampling periods. During each period of sampling, larvae were collected hourly in a horizontal haul at 1.0 m depth and near the bottom, in an Eurlian survey at a station near the mouth of estuary (Fig. 2). Larvae were collected with a conical plankton net (0.40 m aperture 1.60 m long and 0.335 mm mesh size) equipped with a Hydrobios flowmeter. The bottom samples were taken with the net previously described mounted on an epibenthic sled. All plankton samples were

fixed with 4% borate-buffered formalin (pH \approx 8.5). Salinity and temperature were measured in each sampling using a YSI 33 SCT conductivity meter. The current flow at 1.0 m below the surface and near the bottom was determined with a current meter model CM-1B (\pm 0.05 m/s). An average of 48.1 and 44.53 m³ of water was filtered at the surface and near the bottom, respectively. We have considered that the first zoal stage reflected the intensity of larval release by females.

3. Results

The velocity of the current during both cycles presents differences in intensity (Figs. 2 and 3). During the spring tides the velocity of the flow in the flood and ebb tide is remarkably higher than during the First Quarter. The maximum value registered was 1 m/s at 1.0 m depth and at the bottom, which was attained at 19:00 h in ebb tide. During the cycle that took place in First Quarter, the velocity of the flow was always equal or lower than the one registered at 1.0 m depth.

Salinity and temperature variations at 1.0 m below the surface and near the bottom show similar values in both lunar situations (Figs. 4 and 5). One has to point out only the stratification observed from the records taken from the 1.0 m and bottom sampling, during flood tide and the beginning of ebb tide.

For the two nyctemeral cycles accomplished near the mouth of the estuary during the New Moon and the First Quarter, larval emission was stronger during the First Quarter period, which is showed by the predominance of the zoeae I stage (Figs. 6–9).

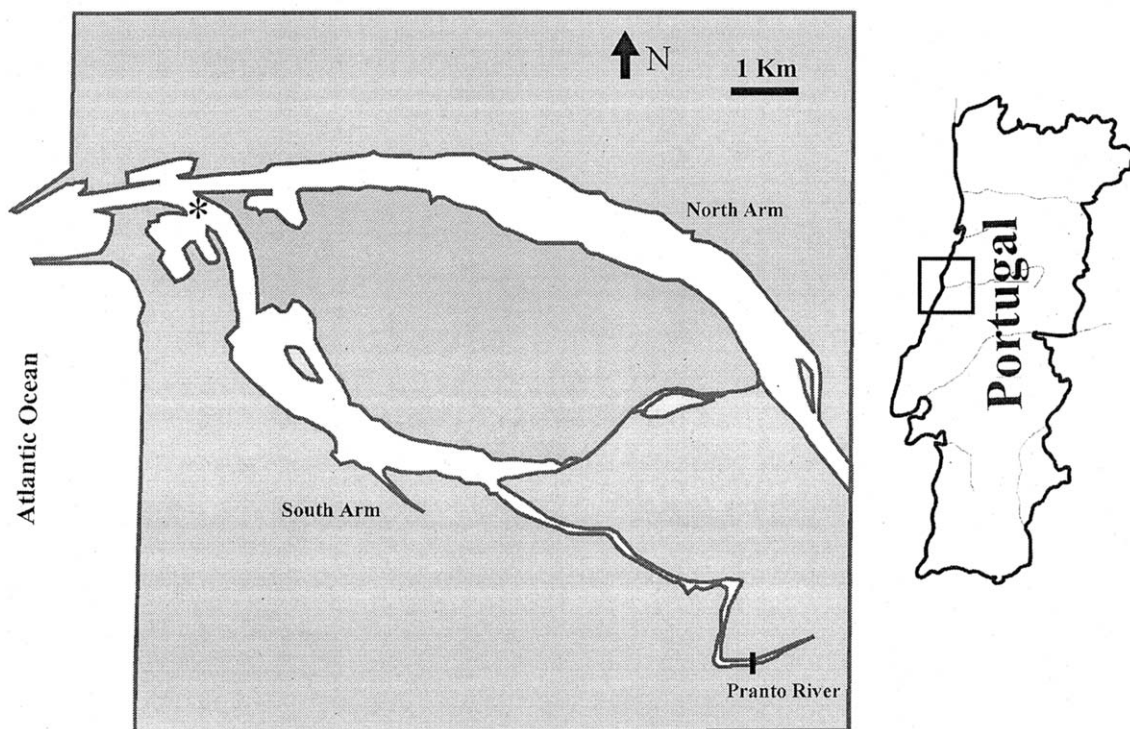


Fig. 1. Map of estuary with location of sampling station (*).

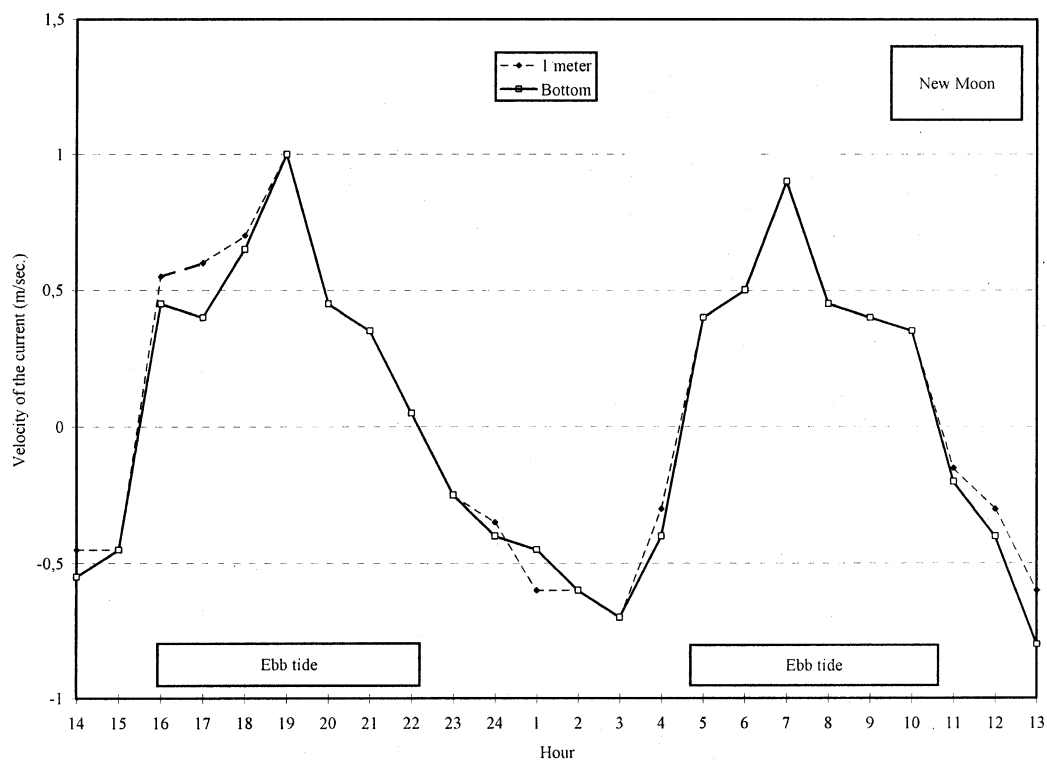


Fig. 2. Temporal variation of velocity of the current at 1 m and near the bottom in the sampling station at estuary of Mondego, during a nyctemeral cycle at new moon.

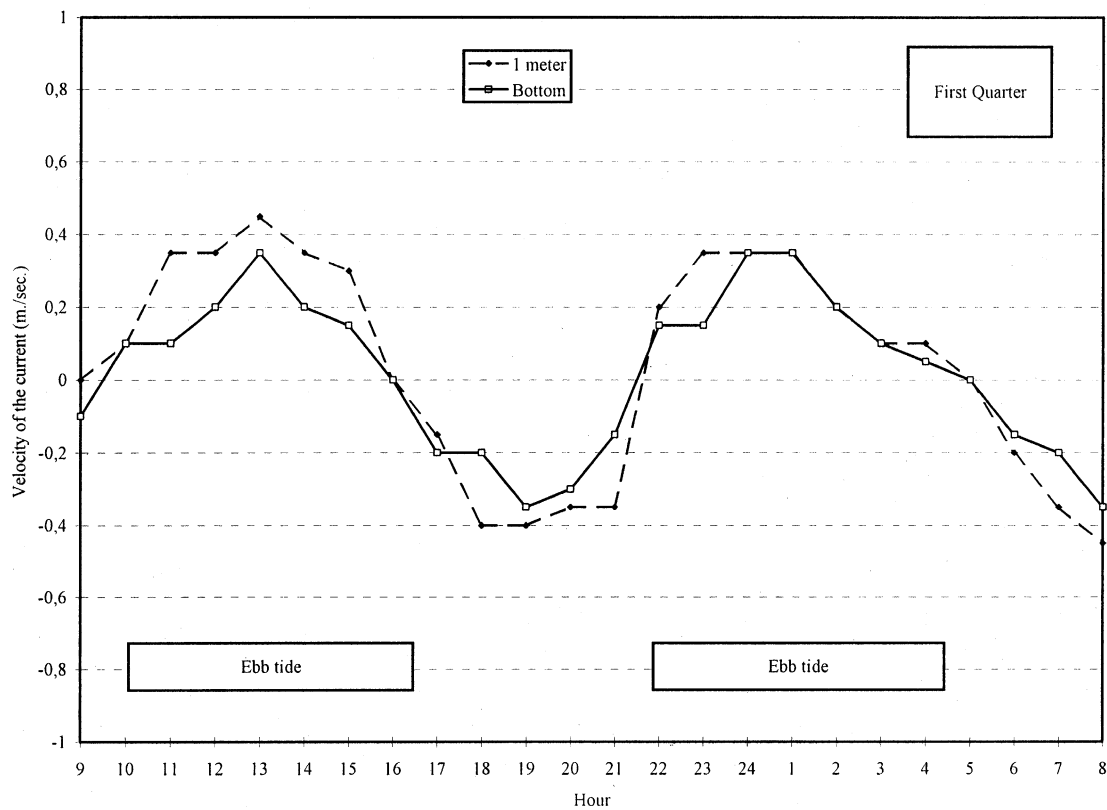


Fig. 3. Temporal variation of velocity of the current at 1 m and near the bottom in the sampling station at estuary of Mondego, during a nyctemeral cycle at first quarter.

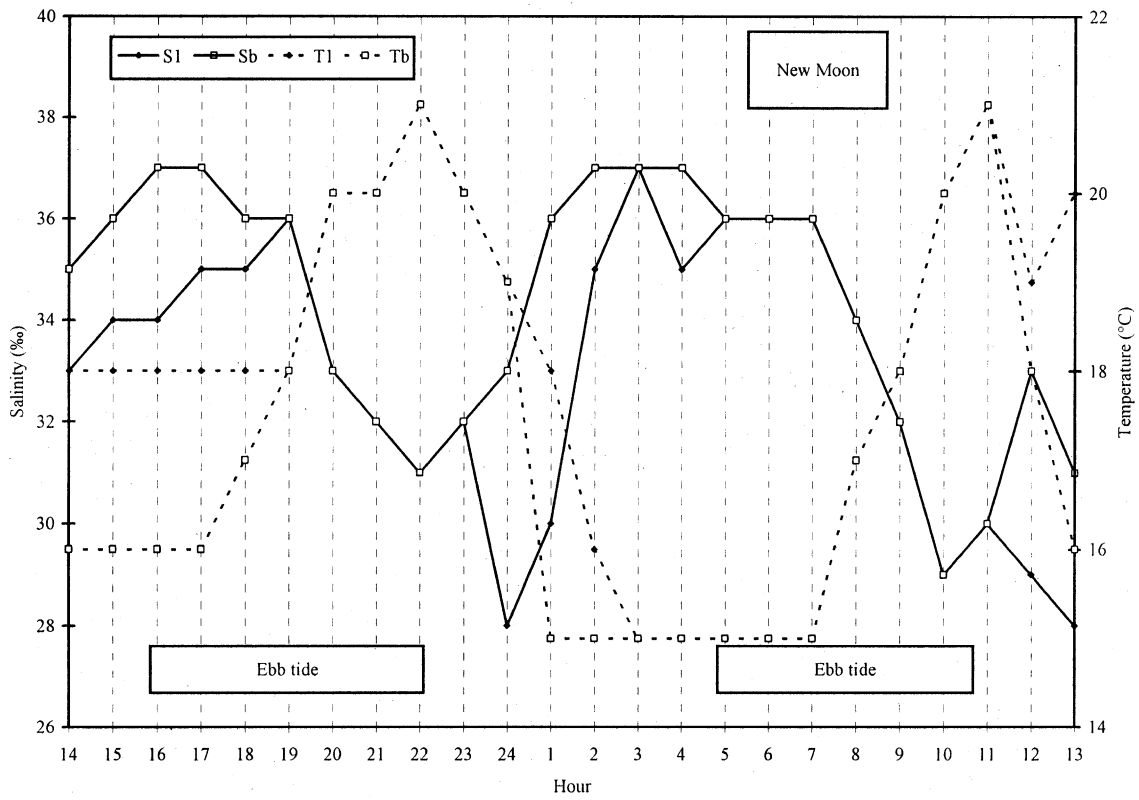


Fig. 4. New moon. Nyctemeral variation of salinity at 1 m (S1) and near the bottom (Sb) and nyctemeral variation of temperature at 1 m (T1) and near the bottom (Tb) in the sampling station at estuary of Mondego.

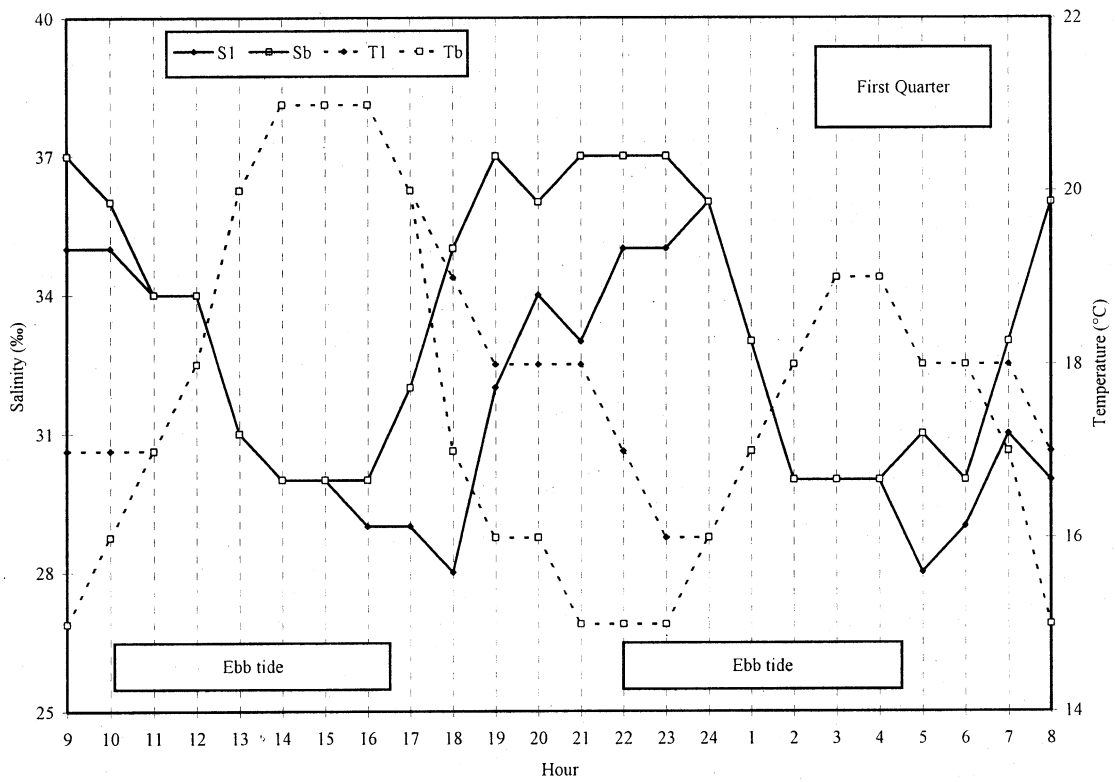


Fig. 5. First quarter. Nyctemeral variation of salinity at 1 m (S1) and near the bottom (Sb) and nyctemeral variation of temperature at 1 m (T1) and near the bottom (Tb) in the sampling station at estuary of Mondego.

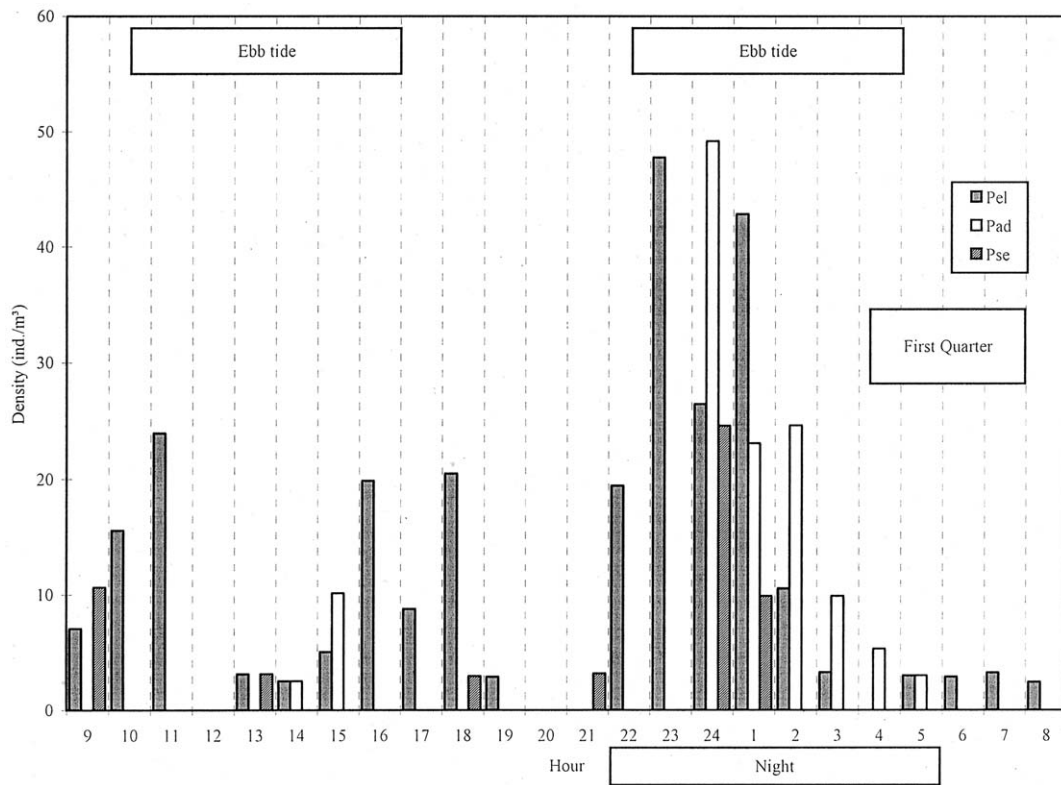


Fig. 6. First quarter. Nyctemeral densities of first larval stage of *P. elegans* (Pel), *P. adspersus* (Pad) and *P. serratus* (Pse) in the sampling station at estuary of Mondego.

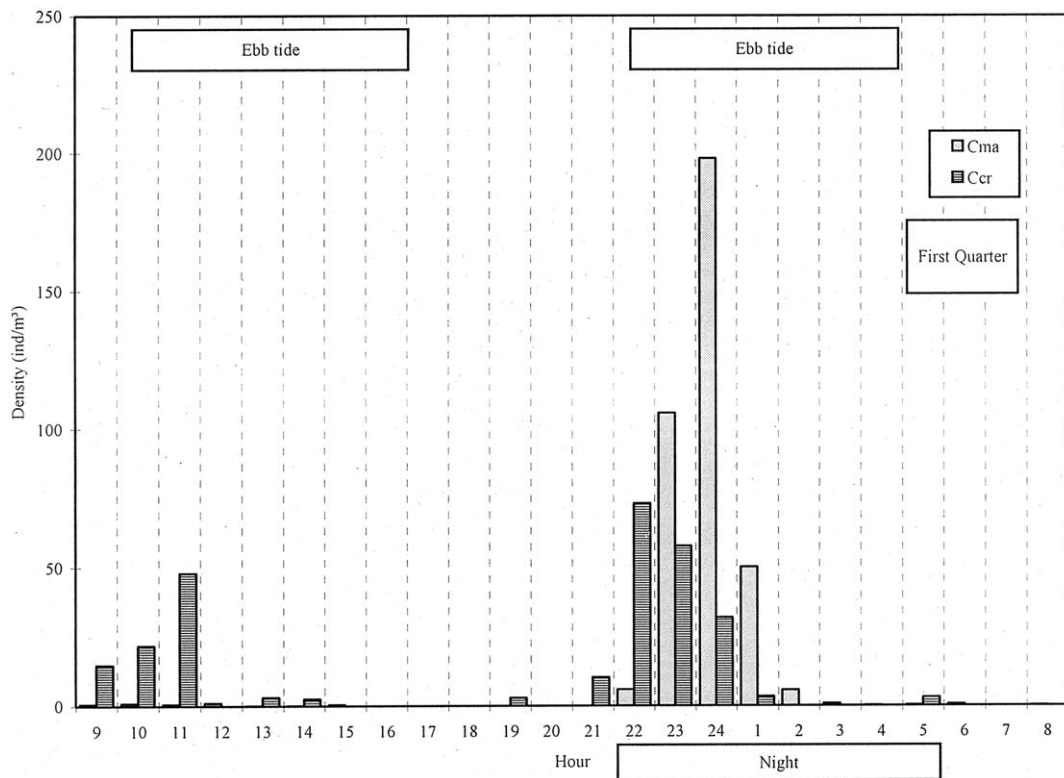


Fig. 7. First quarter. Nyctemeral densities of first larval stage of *C. maenas* (Cma), *C. crangon* (Ccr) in the sampling station at estuary of Mondego.

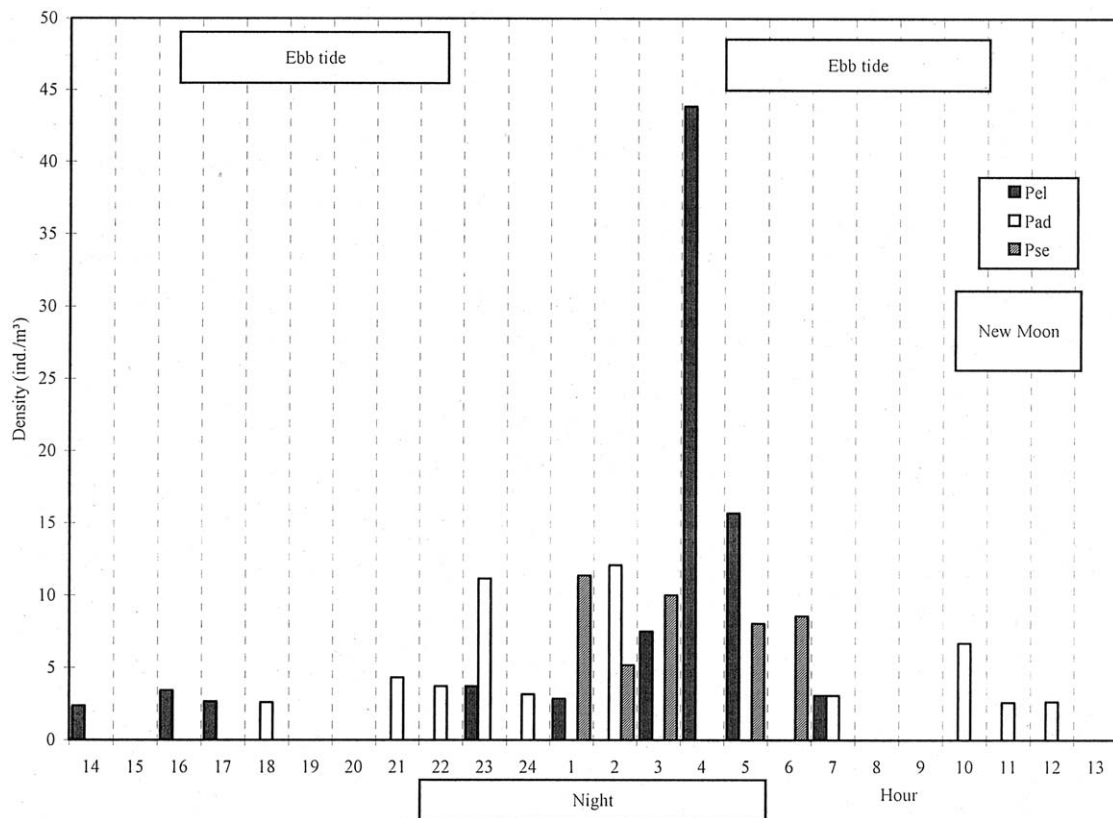


Fig. 8. New moon. Nyctemeral densities of first larval stage of *P. elegans* (Pel), *P. adspersus* (Pad) and *P. serratus* (Pse) in the sampling station at estuary of Mondego.

During the cycle carried out in the First Quarter, the maximum values obtained at night varied according to the hour (Figs. 6 and 7). Thus, *Palaemon adspersus*, *Palaemon serratus* and *C. maenas* reached the maximum around 00:30 h (local time); *Palaemon elegans* around 23:30 h and *C. crangon* at 22:30 h. In the First Quarter, *C. crangon* also presents its peak of abundance at the beginning of nocturnal ebb tide. Whereas *C. maenas*, *P. adspersus* and *P. serratus* show it 2 h later and *P. elegans* 1 h later. During the cycle carried out in the New Moon, the pattern obtained is not as consistent, since densities are much more lower (e.g. *P. adspersus* and *P. serratus*, maximum being 12 individuals per m³) (Figs. 8 and 9). Nevertheless, the highest peak of abundance of the *C. maenas* and of *C. crangon* was reached around 05:30 h, while for *P. elegans* was reached around 04:30 h. For the former two species the abundance reaches the maximum value at the beginning of the ebb tide, at dawn. *C. crangon* presents high levels of abundance in the beginning of ebb tide in the afternoon (16:30 h), and 2 h later. However, it is during the night, 3 h before the start of ebb tide, that the first larvae begin to appear in the water column, which may be related with the area of emission of this species.

4. Discussion

All species of decapods in Mondego estuary show a stronger larval emission during nocturnal ebb tide in First Quarter.

At this latitude, this type of tide coincides with the beginning of the night. However, at different hours in this cycle, first larval stages of some species were caught, although in very low densities. This could be connected with both the larval emission area of the different species and the hydrology of the system. As for *P. serratus*, larval stages have been captured during the whole nyctemeral cycle, even though this species has been using the platform or the terminal part of the estuary for emission of larvae. The beginning of ebb tide (22:30 h, in this particular case) and the area of emission have played an important role conditioning the peaks.

Our data has indicated that larval emission does not occur with the same intensity during the whole night or during all ebb tide. Several studies have demonstrated that larval emission takes place preferably during the night (Bergin, 1981; Christy, 1982, 1986; Morgan and Christy, 1995; Paula, 1989; Queiroga et al., 1994; Salmon et al., 1986). Accordingly, a great number of females release their larvae in the early evening in a synchronised way. This behaviour increases larval aggregation and minimises visual predation, hence reducing vulnerability to predators (Morgan and Christy, 1994, 1995). Salmon et al. (1986) concluded that any ebb tide presents enough condition to export larval stages into the ocean. However, for the Mondego estuary the former type of tide has presented the inconvenience of having a small amplitude and the sluice in the Pranto zone closed during the night, hence retaining the larval stages in the upper parts of the

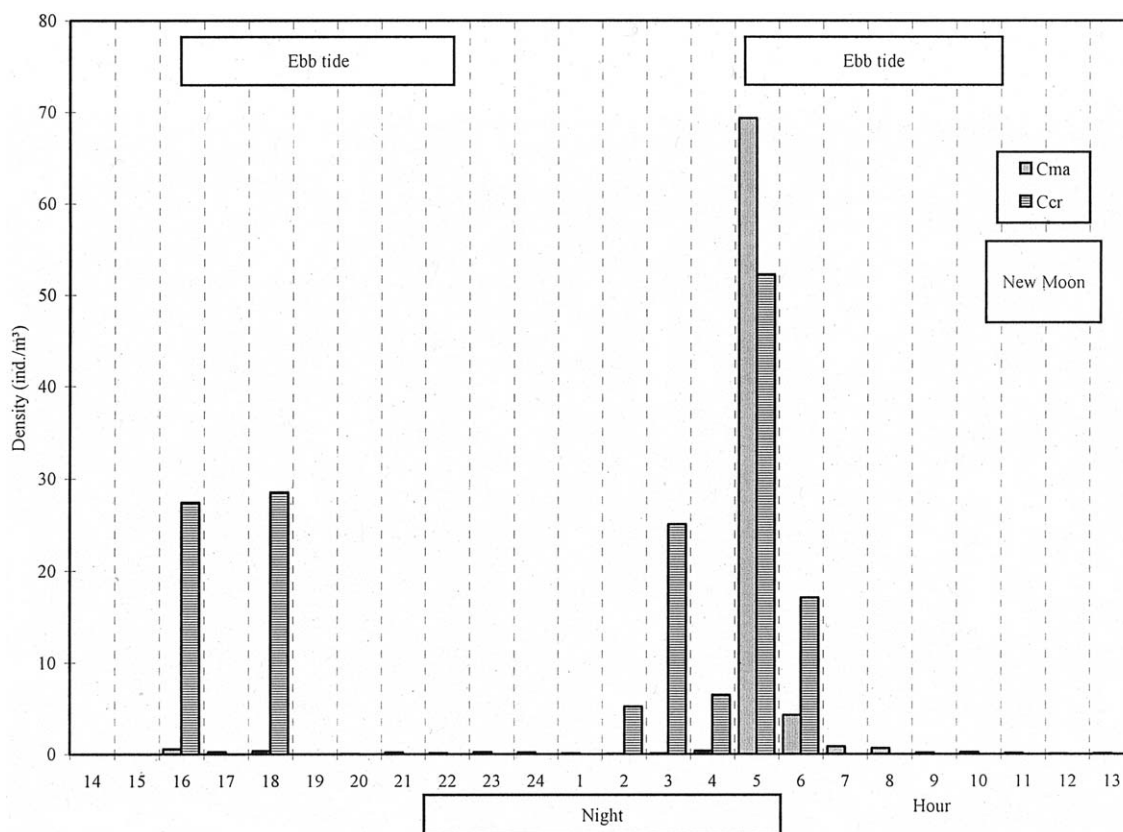


Fig. 9. New moon. Nyctemeral densities of first larval stage of *C. maenas* (Cma), *C. crangon* (Ccr) in the sampling station at estuary of Mondego.

estuary, where lethal combinations of salinity and temperature can affect larval survival.

During New Moon, the larval emission apparently occurred more intensively during the night and the peaks were registered in the beginning of diurnal ebb tide. The best examples are the densities of *C. maenas*, *P. elegans* and *C. crangon*. However, during other hours of the cycle the abundance of larvae is lower. This might be connected with the (a) horizontal movements, during flood tide conditions, (b) without synchronised larval emission and/or horizontal movements, during ebb tide conditions, and (c) with the period of residence of the water mass in the South Arm zone of the estuary.

Our results had shown a larval emission centred in the night, during the beginning of ebb tides, around First Quarter. Previous studies have demonstrated that rhythms of larval release have a cycle with a semi-lunar period (see [Morgan and Christy, 1994; Paula, 1989]). This behaviour increases larval survival and maximises the recruitment.

5. Conclusion

Our study, carried during two different lunar situations, confirms the results of Gonçalves (1991), Paula (1989) and Queiroga (1997) regarding the abundance of the first larval stage of crustaceans decapods for the Portuguese Atlantic coast. Furthermore, the occurrence of crepuscular ebbing

tides during both First and Last Quarter Moon is coincident with the higher abundance of the first stage of crustacean decapods, in the estuary of Mondego.

Acknowledgements

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