



Moon phase effects and timing of emerging macrobenthic assemblages in a sheltered soft-bottom sublittoral habitat



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ABSTRACT

Several species of benthic macro and meio-invertebrates actively emerge from the seabed to the water column during the night. Such diel vertical migrations have important consequences for benthic–pelagic coupling, dispersal, connectivity and recovery after disturbance of benthic assemblages. However, this process has never been studied in the coast of the Humboldt Current ecosystem. Herein we examined the relationship between the emerging assemblage and moon phases (and co-variables) and the timing of emergence during the day/night cycle, in a sublittoral soft-bottom habitat. Sampling using emergence traps was conducted at 7 m depth in the zone of Bolsico, a sheltered cove with low bottom hydrodynamics in northern Chile. Multivariable analysis showed that changes in the dissimilarity of the emerging assemblage were related to each moon phase. The percentage of moon illumination, bottom illumination and tide amplitude explained most of the variation of the emerging assemblage. Species showed differential responses to each moon phase; some were abundant at intermediate phases (e.g., harpacticoids), or peaked at full moon (e.g. ostracods) and others such as mysids emerged in equal abundances at all moon phases. The timing of assemblage emergence followed a consecutive sequence through the night/day period. Most of the studies dealing with the emergence processes have described species-specific responses. Our research shows that the examination at assemblage level may reveal new and distinct patterns of emergence in sublittoral soft-bottom habitats.

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1. Introduction

Soft-bottom benthic invertebrates regularly enter in the water column using two main mechanisms: (1) passive dispersal in which bottom currents resuspend organisms and (2) active dispersal by swimming up into water column regardless (or in combination) of the seabed hydrodynamics (Armonies, 1994; Pacheco et al., 2013a; Palmer, 1988). Some meio- and macro-invertebrates perform diel vertical migrations into the water column *i.e.*, they emerge from a position in/on the sediment during the night and return to the seabed during the day or night (Mees and Jones, 1997). These organisms, also known as emerging benthos, are mainly composed of peracarid crustaceans, copepods, mysids and polychaetes (Aldredge and King, 1980, 1985), typically inhabiting vegetated and unvegetated soft-bottoms (Cahoon and Tronzo, 1992; Thistle, 2003; Walters, 1991; Walters and Bell, 1994), coral reefs and rocky substratum (Melo et al., 2010), kelp forest (Jørgensen and Christie, 2003) and even the deep sea (Thistle et al., 2007). In terms of benthic–pelagic coupling, emerging assemblages represent an important trophic link *i.e.*, some organisms feed on the water column and return to the seabed bringing water column resources to the benthos (e.g. Vallet and Dauvin, 2001), and benthic organisms are consumed by pelagic predators moving benthic resources into the water column (e.g., Pitt

et al., 2008). In addition, emergence from and re-entry of the benthos are important dispersal mechanisms for colonization of disturbed sediments and contribute to the rearrangement of species' spatial distributions at small-spatial scales (Pacheco et al., 2012a, 2013a).

The patterns of emergence have been related to environmental conditions mainly the day/night, moon and tidal cycles (Jacoby and Greenwood, 1989; Saigusa, 2001; Saigusa and Oishi, 2000; Saigusa et al., 2003) and concurrent changes in water temperature, oxygen content, illumination and primary productivity (Armonies, 1988). However, patterns and rhythms of emergence vary substantially among habitats. For example, while in intertidal habitats, emergence patterns are well correlated with moon and tidal cycles; these signals may be attenuated in sublittoral habitats (Saigusa, 2001), thus emergence is related to other factors such as oxygen fluctuations, bottom hydrodynamics, predation and/or food supply (Aldredge and King, 1980, 1985; Dinning and Metaxas, 2013; Vopel and Thistle, 2011). In fact, emerging harpacticoids copepods have been recorded at the deep sea (at 3087 m) where there are no tidal changes (nor day/night cycles), thus different mechanisms are involved compared to those in the shallow realm (Thistle et al., 2007). Therefore, a better understanding of the emergence processes requires better knowledge of the mechanisms involved in a vast range of habitats and ecosystems.

An important aspect of emergence is the timing of the pelagic incursion through the day/night cycle. The processes seem to be asynchronous with pulses of emerging invertebrates in the water column

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occurring shortly after sunset, in the middle of the night and shortly before dawn (e.g., Teasdale et al., 2004; Vopel and Thistle, 2011; Walters, 1991; Walters and Bell, 1994). However, most of the studies of the timing of emergence have focused mainly on harpacticoid copepods and only few examples, coming from controlled field experiments, have assessed the whole assemblage (e.g., Alldredge and King, 1980). Thus, it is important to conduct experiment testing whether the aforementioned pulses of emergence occur at the whole assemblage level or if different species-specific patterns occur.

The occurrence of emerging invertebrates in sublittoral soft-bottom habitat off northern Chile (Humboldt Current Ecosystem) was ignored until recently (Pacheco et al., 2013b). This is surprising taking into account the considerable research effort invested in understanding the dynamics of benthic–pelagic coupling in this highly productive ecosystem (González et al., 2004; Vargas et al., 2007, 2010). Experimental studies focused on colonization, succession and dispersal of post-larval macrobenthos at locations with different bottom hydrodynamics (i.e. exposed and sheltered) suggested that active emergence constitutes an important mechanism of dispersal of macro invertebrates post-larvae (Pacheco et al., 2010, 2012a, 2013a). Nevertheless, the dynamics and factors associated with the variability of the emergence processes in this region remain unknown. Therefore, the objectives of this study were: (i) to examine the influence of the moon cycle on the structure of the emerging assemblage and (ii) to evaluate the timing of emergence in a sheltered sublittoral site in northern Chile. Specifically we predict that: (i) the emerging assemblage will show specific structure related to the moon phase and (ii) the timing of the emergence will proceed through consecutive changes in the structure of the emerging assemblage through the night/day cycle.

2. Materials and methods

2.1. Study site

A series of field studies were conducted from early April to late August 2012 in Bolsico (23°28' S; 70°36' W) a small cove at the southern part of Península Mejillones, northern of Chile. This region is characterized by strong upwelling, where cold waters with high nutrient and low oxygen contents rise to the surface (González et al., 2004; Pacheco et al., 2011). In Bolsico, the soft-bottom habitat at 7.5 m

depth is composed of poorly sorted sand and bottom current velocity is rather low year round (~2.7 cm/s). The tidal regime is semi-diurnal. Details of the abiotic characteristics of the site are available in Pacheco et al. (2012a). This site was chosen since it is a sheltered, low bottom current location which allowed us to separate actively emerging invertebrates from those that may be resuspended by strong hydrodynamics in a more exposed site (Palmer, 1988). To collect emerging invertebrates we used emergence traps. The trap consisted of a white plastic cylinder (40 cm high and 20 cm diameter) with an inverted funnel installed in the bottom part (Fig. 1A). The upper part was covered with a plastic lip made of 0.5 mm. The inner aperture of the inverted funnel was 3 cm of diameter and when installed the distance between the lower and the upper aperture was 15 cm. Thus, any emerging invertebrate would have to swim at least 15 cm to be caught. The trap was fixed on the seabed by inserting two metal bars attached at each trap side (Fig. 1A).

2.2. Pilot study

There are no unique methods for effectively sampling emerging invertebrates when moving from the seabed to the water column and/or vice versa. Thus, sampling artifacts must be tested *a priori* in order to evaluate their potential caveats and their effectiveness. The trap used in this study was based on previous designs published in the literature reporting collection of such invertebrates successfully (e.g., Junkins et al., 2006; Pacheco et al., 2013a; Thistle, 2003; Valanko et al., 2010; Walters and Bell, 1994). Nevertheless, we conducted a pilot study aiming to: (i) describe the taxonomical composition of the emerging benthic assemblage in the study area, (ii) to evaluate the effectiveness of the trap for collecting such invertebrates, and (iii) to get the necessary *a priori* praxis for deploying the experimental set-up. To study the emerging assemblage composition, invertebrates were captured using the trap with two different designs (Fig. 1B). The first design, “bottom traps”, consisted of traps placed onto the sediment surface so that the outer rim of the inverted funnel (i.e., the base of the trap) was in contact with the sediment surface (Fig. 1B). In addition, since it has been suggested that emerging organisms may use bottom current cues to trigger migrations into the water column (Armonies, 1994; Palmer, 1988), the second design consisted of traps, “leg traps”, were installed three centimeters above the seabed, thus allowing bottom current to flow (Fig. 1B).

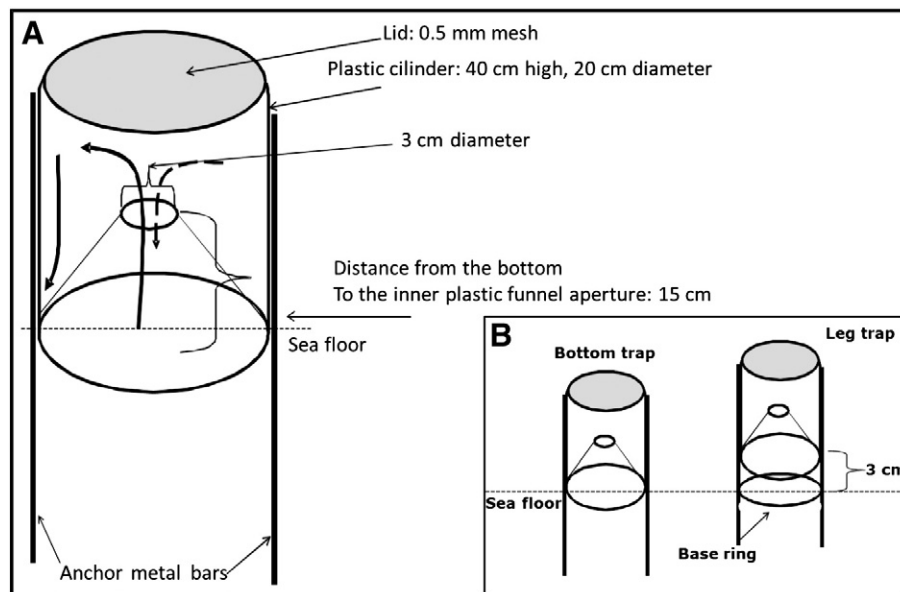


Fig. 1. (A) A diagrammatic representation of the emergence traps showing its parts. (B) Representation of both trap designs used during the pilot study. The base ring show in the leg trap design consisted in a 0.5 cm width plastic ring of the same diameter of the trap base. This ring was installed in order to keep a fix 3 cm distance from the seabed to the lower part of the trap.

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