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# Seasonal variability of emerging invertebrate assemblages in a sheltered soft-bottom sublittoral habitat

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ABSTRACT

In the Humboldt Current upwelling ecosystem of northern Chile, seasonal variation in the assemblage structure of pelagic invertebrates is strongly coupled with seasonal oscillations in upwelling intensity, however, benthic assemblages apparently show no clear responses to seasonal changes in the environment. Herein, we assess seasonal variability in the structure of the emerging assemblage (i.e., invertebrates that migrate nocturnally from the seabed to the water column, returning to the seabed during the day). This assemblage uses both the pelagic and benthic habitats daily, and thus offers an interesting group to study in order to assess their response to seasonal variability. We carried out replicated sampling during the austral autumn, winter, and spring of 2012 and the summer of 2013 in the subtidal zone of Bolsico (northern of Chile), using traps specifically designed to capture emerging benthic invertebrates, at 7 m depth in a sheltered soft-bottom habitat. We observed clear seasonal effects, with total abundance increasing during spring and a cyclical pattern in assemblage structure of the emerging benthos. Three main patterns characterized seasonal changes in species abundance; peaks of abundances during autumn (e.g. amphipods *Eudevenopus gracilipes* and *Liljeborgia* sp.), summer (e.g. amphipods *Aora typica* and *Microphoxus* sp.) and spring (e.g. copepods *Tigriopus* sp. and *Corycaeus* sp.). Strong seasonal patterns in emerging invertebrates closely resembled the pattern observed in the pelagic fauna.



## 1. Introduction

Seasonal variation in solar radiation modifies oceanographic and atmospheric cycles (Gili and Petraitis, 2009), resulting in seasonal cues that could trigger different biological responses (e.g. pulses of primary and secondary production, reproduction, recruitment, migration, etc.). These responses may potentially then translate into population, community (de Juan and Hewitt, 2014), and ecosystem level dynamics (Gili and Petraitis, 2009). Although many studies have documented seasonality in biological processes, response may depend on latitude, regional environment and intrinsic biological characteristics. At high and middle latitudes strong seasonal changes are often more predictable than those at lower latitudes, where seasonality can be weak (Gray and Elliott, 2009). Hence, understanding seasonal variation requires examination of biological dynamics in a given area and their relationship with environmental variation.

Wind-driven upwelling characterizes the coastal region of the Humboldt Current ecosystem, transporting cold, nutrient-rich waters from moderate depths (100–400 m) to the euphotic zone, supporting very high levels of primary productivity (Arntz et al., 2006; Halpin et al., 2004). Along the central-south coast of Peru and northern Chile, permanent upwelling changes only incrementally in magnitude during the austral spring and summer (Echevin et al., 2008; Thiel et al., 2007). This pattern contrasts with the strong seasonal upwelling changes in other coastal regions located at the northern (~3°S) and southern (~36°S) extremes of this ecosystem (Chavez et al., 2008; Thiel et al., 2007), and with other coastal systems at similar latitude (Carstensen et al., 2010; Uribe et al., 2012). Seasonal variability in the structure of invertebrate assemblages in this ecosystem appears habitat specific. For example, time series studies reveal significant increases in species richness, biomass, and abundance of dominant pelagic (defined broadly here to include all water column environments) copepods coupled with the seasonal intensification of upwelling during the transition from spring–summer to autumn–winter months (Escribano et al., 2012; Hidalgo et al., 2010). In contrast to the pelagic realm, time-series analyses and experimental studies of soft-bottom macrobenthic invertebrate assemblages suggest that fluctuations in diversity, biomass, and structure are not necessarily in phase with the seasonal variation and/or upwelling intensity (Carrasco, 1997; Carrasco and Moreno, 2006; Laudien et al., 2007; Moreno et al., 2008; Pacheco et al., 2010). In fact, inter-annual fluctuations drive the strongest temporal variation in benthos, notably El Niño-Southern Oscillation and inter-decadal oscillations (Gutiérrez et al., 2008; Pacheco et al., 2012a).

The cause of this apparent dichotomy remains unclear, given that different life history stages and behaviors link benthic and planktonic habitats. Many benthic invertebrate taxa display pelagic larval dispersal (Levin, 2006; Metaxas, 2001) and many pelagic organisms may show

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demersal and/or benthic habitat association during diel vertical migrations (Berasategui et al., 2013; Mees and Jones, 1997; Vallet and Dauvin, 2001). In this context, the emerging benthos represents an interesting study case to assess seasonal variability, given that emerging benthos utilize both benthic and water column habitats on a daily basis. In this study, we focus on emerging assemblages composed by invertebrates that migrate vertically into the water column on a diel basis (i.e., they emerge from the seabed and return to the bottom during the day or night hours, Mees and Jones, 1997). This assemblage is therefore neither entirely pelagic nor totally benthic, thus representing a challenging and less known biotic component in understanding seasonal effects.

Past studies correlate significant changes in abundance during emergence with seasonal changes. In particular, invertebrates emerge in higher abundances during spring and summer months (Cahoon et al., 1992; Jacoby and Greenwood, 1989; Shimode and Shirayama, 2006). Seasonal changes in primary productivity and strong pulses of reproduction (e.g. increased mating activity, Thistle, 2003) represent some described mechanisms to explain seasonal differences in abundance of emerging invertebrates. However, the existence of seasonal changes must be demonstrated before searching for explanations for those differences in a given ecosystem. This is particularly true in our study region, where emerging invertebrates have only recently been described (Pacheco et al., 2013a,b) and patterns of variability in emergence have been related only to moon cycle changes (Pacheco et al., 2014). In this study, we evaluate seasonal changes in total abundance, species abundances and assemblage structure of emerging benthic invertebrates. We predict that seasonal changes, if present would result in strong affinity between the emerging assemblage and the pelagic assemblage, but a stronger benthic affinity if little seasonal variation occurs.

## 2. Materials and methods

### 2.1. Study site

We conducted our study in the sublittoral area of Bolsico (23°28′ S; 70°36′ W), a sheltered cove located at the southern part of Peninsula Mejillones on the northern coast of Chile (Fig. 1). Bolsico is located within a region characterized by permanent upwelling, where cold waters with high nutrient and low oxygen contents rise to the surface (González et al., 2004; Pacheco et al., 2011). Poorly sorted fine sand with low organic matter content (<0.5%) characterized the sediment at the 7.5-m deep study site. Further details of the study site are reported in Pacheco et al. (2012b, 2013a,b,c). The sheltered location, weak bottom currents (~2.7 cm/s) and weak semi-diurnal tide (~0.3–1.3 m tidal range) allowed us to separate active emerging invertebrates from those resuspended by seabed hydrodynamics at more exposed sites (e.g., Pacheco et al., 2013a; Palmer, 1988).

### 2.2. Seasonal sampling strategy

To sample emerging invertebrates we built traps based on previous designs that reported successful collections (e.g. Junkins et al., 2006; Pacheco et al., 2013a; Thistle, 2003; Valanko et al., 2010; Walters and Bell, 1994). The trap consisted in a plastic cylinder with an inverted funnel inside placed onto the sediment surface (see Fig. 2). We tested the trap at our site prior to this study, and confirmed that it captured the assemblage of emerging invertebrates (see Pacheco et al., 2013b). The similarity in composition of the emerging assemblage obtained in our pilot sampling (Pacheco et al., 2013b) and main study reported here indicates that a fairly constant emerging assemblage over time in the study area.

Our study aimed to evaluate seasonal variation in community structure of the emerging assemblage. To achieve this, we installed ten emergence traps at 7.5 m depth at the study site from 1800 h to 0900 h the following day, thus collecting species that emerged during night hours. No sampling was conducted between 0900 and 1800 h because less emergence occurs during daylight hours (e.g. Alldredge and King, 1980). Replicated sampling was conducted on two dates in each season; autumn (14–15 and 28–29 May 2012), winter (24–25 July and 9–10 August 2012), spring (21–22 October and 8–9 November 2012) and summer (19–20 January and 16–17 February 2013). We sampled on intermediate moon phase nights (i.e., first and/or last quarters) in order to avoid the effects of extreme moon phases (i.e. full and new moon, see Alldredge and King, 1980; Pacheco et al., 2014) that could confound effects of seasonal variation. Before installation on the bottom, we filled traps with filtered sea water (taken from the surface), closed them with rubber plugs and placed individual plastic bags inside, in order to prevent the collection of water column invertebrates. During retrieval, traps were closed with rubber plugs, inserted in the inner part of the

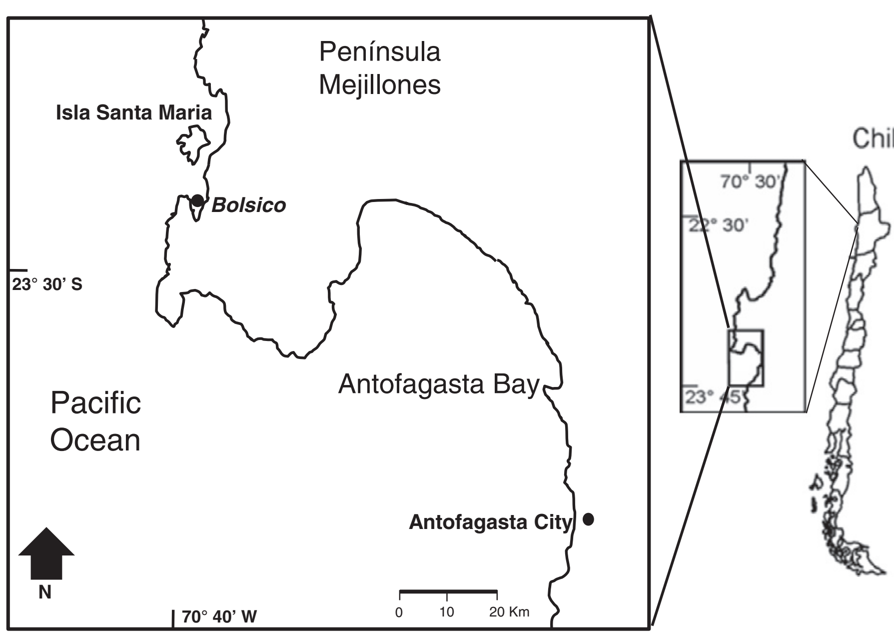


**Fig. 1.** Location of the study site at the southern area of Peninsula Mejillones in northern Chile.