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Bioavailable organic matter in seston modulating differential absorption rates by mussels

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ABSTRACT

This study aims to analyze the seasonal variations in seston biochemical compounds (biopolymeric organic carbon (C-BPC), i.e. the sum of proteins, carbohydrates and lipids) in order to infer the bioavailable organic fraction controlling food absorption by mussels cultured in a Galician Ria. Different proxies for high-quality food (including C-BPC) vs. energy absorbed by mussels were explored to elucidate the validity of each proxy in an embayment of intensive mussel cultivation.

Our results showed a strong correlation between C-BPC and both the organic fraction (*f*) and the carbon equivalent of Chloropyll-*a* (C-Chl-*a*) in the seston. This fact points to variations in C-BPC (predominantly composed of proteins) are strongly linked with the phytoplankton fluctuations, which in turn are modulated by the seasonal upwelling regime. Maximum total energy absorbed by mussels (about 97%) occurred during the spring phytoplankton bloom, when high-quality organic carbon (high C-BPC) dominated the seston. Minimum energy absorbed (56%) occurred during winter, when continental runoff and local resuspension of surface sediments reintroduce into the water column more refractory organic compounds not favourable to the mussel diet. These results allowed us to establish that parameters such as *f*, C-Chl-*a*, and C-BPC have close correlations with physiological responses in mussels and could be used as proxies for food quality. Nonetheless, the use of these high-quality food estimations should be considered according to particularities of each ecosystem.

1. Introduction

Upwelling areas with high pelagic primary productivity can support many marine communities feeding on suspended particles (Isla et al., 2010). Among these regions, the Galician Rías are suitable sites for culturing the mussel *Mytilus galloprovincialis* on hanging ropes. High-quality plankton biomass is produced in the Rías due to fertilisation by coastal upwelling. Additionally, the topography of the Rías protects the mussel rafts from intense northerly winds and storms during the upwelling and downwelling seasons, respectively (Figueiras et al., 2002; Álvarez-Salgado et al., 2008).

In these highly productive systems, suspension-feeders are exposed to a rapidly changing, often unpredictable food supply. Changes may occur not only in the numbers of suspended particles, but also in their size and nutritional value, which may be particularly important in the absorption of energy consumed by filter feeders (Figueiras et al., 2002; Froján et al., 2014). Historically, the nutritional value of seston has been evaluated by measuring total organic matter, organic carbon and nitrogen contents (Copin-Montegut and Copin-Montegut, 1983). Later on, some studies assessing seston quality have shown that its biochemical composition comprise an useful set of chemical variables to determine the available organic matter (OM) for filter feeders (Dell'Anno et al., 2000; Grémare et al., 1997). This labile portion of OM mainly consists of simple and/or combined compounds (i.e. biopolymers), and includes rapidly mineralized proteins, carbohydrates, lipids and nucleic acids, whilst the refractory OM, composed by complex substances like humic and fulvic acids, is slowly broken-down (Henrichs, 1992).

The Galician Rías are low-seston environments where total particulate matter is usually less than 3 mg L^{-1} and Chlorophyll-*a* (Chl-*a*) concentration less than 5 μg L^{-1} (Figueiras et al., 2002). In these environments the bivalves feeding process, in particular selective ingestion mechanism, is expected to be less complex because the available seston is mostly organic and below the threshold for pseudofaeces production (Bayne et al., 1988, 1993). Detailed laboratory studies simulating the environmental conditions of the Rías showed that the *M. galloprovincialis* clearance rate (CR) is stable under a wide range of food conditions (Filgueira et al., 2009, 2010), exhibiting a more complex behaviour when the organic content of the seston has a low digestibility (Duarte et al., 2010, 2012). Zúñiga et al. (2013) carried out an in situ

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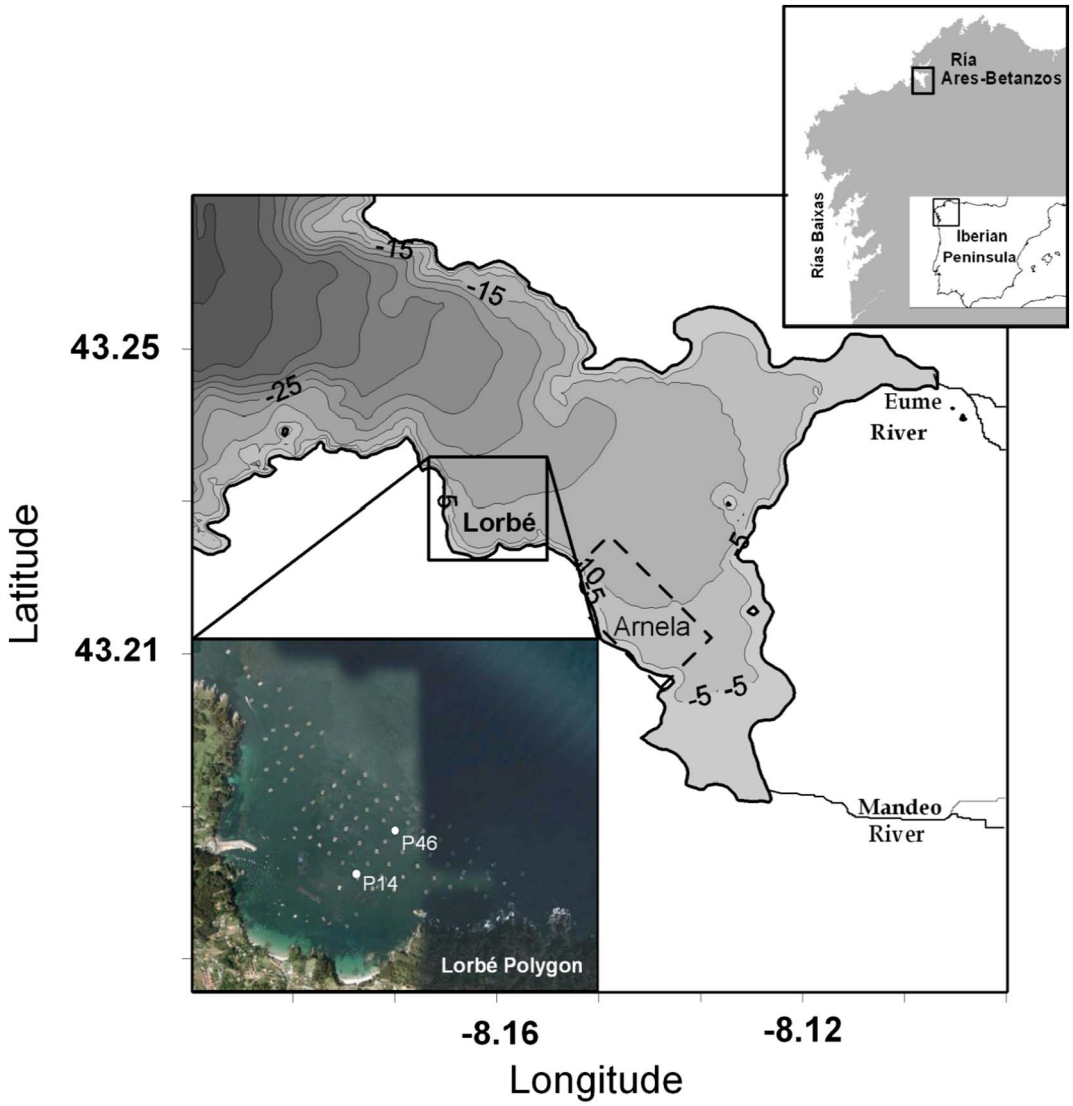

Fig. 1. Map indicating the location of the Lorbé raft cultivation polygon in the Ría Ares-Betanzos (Galicia, NW Spain). Positions of the raft (P-46 and P-14) sampling sites inside the polygon are shown.

study in the Ría de Vigo revealing that organic ingestion rate and absorption efficiency were strongly correlated with microbial plankton carbon ultimately representing high-quality food for mussels. However, none of these studies have considered biochemical compounds analysis in order to infer the labile organic fraction controlling food absorption by mussels.

This work aims to examine seasonal variations in seston characteristics in an embayment of intensive mussel cultivation (Galician Ria, NW Spain) considering the energetic value of its different organic matter biochemical compounds. The relationships between different proxies for high-quality food and differential assimilatory balance by mussels were analyzed in order to elucidate the validity of each proxy in an embayment of intensive mussel cultivation.

2. Material a methods

2.1. Study site

Field studies were carried out in the Lorbé raft polygon in the Ría Ares-Betanzos, NW Spain (Fig. 1; latitude 43°23′ 24.74″ N; longitude 8°17′ 48.30″ W). This polygon is the main area of mussel *M. galloprovincialis* culture with 107 rafts and a total annual production of approximately 7000 metric tons (Labarta, 2004). In this area, the current direction varies predominantly with the tide (Piedracoba et al., 2014). Average residual current speeds were 3.70 and 3.64 cm s^{-1} at P-14 and P-46 raft sites, respectively. During the sampling period, maximum total current speeds ranged from 5.1 to 13.1 cm s^{-1} at the P-14 raft location, and from 5.3 to11.5 cm s^{-1} at the P-46 raft sampling site. The seabed in Lorbé is dominated by medium to fine sand with an organic carbon content of less than 2.8%, indicative of highly hydrodynamic conditions (Sánchez-Mata et al., 1999).

2.2. Sampling strategy

This study was based on: 1) a dataset including environmental characteristics and composition of seston and 2) a set of physiological measurements on *M. galloprovincialis* cultured on 12 m long ropes (stocking density of 700–1000 mussels m^{-1}). The datasets were obtained at P-14 (43° 23.3328′ N; 8° 17.2878′ W) and P-46 (43° 23.4876′ N; 8° 17.109′ W) commercial rafts, located at the inner and outer parts of the Lorbé polygon, respectively (Fig. 1). Water column sampling and mussel experiments were carried out over two consecutive days during each seasonal campaign following the most representative oceanographic scenarios of the Galicia Rías: i) summer upwelling (July 2010), ii) autumn bloom (October 2010), iii) winter mixing (February 2011), and iv) spring bloom (May 2011) (Irisarri et al., 2013, 2014). Three