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Seasonal pathways of organic matter within the Avilés submarine canyon: Food web implications

Sonia Romero-Romero [a,*], Axayacatl Molina-Ramírez [a], Juan Höfer [a,1], Gerard Duineveld [b], Aitor Rumín-Caparrós [c], Anna Sanchez-Vidal [c], Miquel Canals [c], José Luis Acuña [a]

[a] Área de Ecología, Dpto. de Biología de Organismos y Sistemas, Universidad de Oviedo, Catedrático Rodrigo Uría s/n, 33071 Oviedo, Asturias, Spain
[b] NIOZ Royal Netherlands Institute for Sea Research, Department of Ocean Systems Sciences, and Utrecht University, PO Box 59, 1790 AB Den Burg, Texel, The Netherlands
[c] GRC Geociències Marines, Departament de Ciències de la Terra i de l'Oceà, Universitat de Barcelona, E-08028 Barcelona, Spain

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ABSTRACT

The transport and fate of organic matter (OM) sources within the Avilés submarine canyon (Cantabrian Sea, Southern Bay of Biscay) were studied using carbon and nitrogen stable isotope ratios. The isotopic composition of settling particles and deep bottom sediments closely resembled that of surface particulate OM, and there were no marked differences in the isotopic composition of settling particles inside and outside of the AC. This indicates that the Avilés Canyon (AC) receives inputs of sinking OM mostly from the upper water column and less through advective near-bottom down-canyon transport. Sinking OM fluxes are of marine and terrestrial origin in proportions which vary seasonally. Analysis of $\delta^{13}C$ in the canyon fauna indicates a dependence on OM mainly produced by marine phytoplankton. A tight coupling of isotopic signatures between pelagic organisms and benthic suspension feeders reflects an active biological vertical transport of OM from the surface to the deep-sea. The food web presented seasonal variations in the trophic niche width and the amplitude of the primary carbon sources, reflecting seasonality in the availability of fresh particulate OM. Those seasonal changes are larger for benthic organisms of lower trophic levels.

1. Introduction

Organic matter (OM) availability is a key constraint for life in deep-sea ecosystems that depend on allochthonous food sources (Gooday, 2002; Lampitt et al., 2001). These systems are typically under bottom-up, donor control (Bailey et al., 2006). The OM available to deep-sea benthos comes mainly from phytoplankton dwelling in the illuminated upper water column, which sinks as phytodetritus to the seafloor often in episodic pulses (Billett et al., 1983), depending on surface production rate (Deuser, 1986; Gooday, 2002). Therefore seasonal variations are a key factor controlling deep-sea food webs (Gooday, 2002). Thus, deep-sea fauna tends to adapt to the fluctuating food availability through rapid feeding responses (Graf, 1989; Hunter et al., 2013; Jeffreys et al., 2010). These fluctuations are more accentuated in regions with a strong seasonal cycle like temperate seas where primary production peaks during the spring and, to a lesser extent, during the autumn phytoplankton bloom (Longhurst, 2007).

Submarine canyons, which are found worldwide along continental margins (Harris and Whiteway, 2011), channel sediments and organic matter from the shelf to the deep ocean (Canals et al., 2006). Submarine canyons that are indented close to the shoreline and are connected to river outflows may also enhance the transport of terrigenous material to the deep-sea (Sanchez-Vidal et al., 2009). Hence, in this case the canyon fauna would receive OM from vertical transport and also laterally transported across the continental margin. Most ecological studies conducted in submarine canyons have focused on the higher abundance and biomass of fauna compared to adjacent environments (e.g. Cunha et al., 2011; Duineveld et al., 2001; Gunton et al., 2015; Vetter et al., 2010), which is often attributed to the enrichment with detrital and sedimentary organic matter funneled along the canyon. Also, the steep topography of submarine canyons can enhance upwelling events which increase local productivity (Allen and Durrieu de Madron, 2009; Allen et al., 2001; Hickey, 1995). Indeed, in several canyons, the sediment has been found to contain higher levels of bioavailable OM than sediments on the adjacent slope (De Leo et al., 2014; García and Thomsen, 2008; Lopez-Fernandez et al.,

* Corresponding author.
E-mail address: romeroromerosonia@gmail.com (S. Romero-Romero).
[1] Present address: Instituto de Ciencias Marinas y Limnológicas, Universidad Austral de Chile, Casilla 567, Valdivia, Chile.

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2013; Pusceddu et al., 2010). However, studies on the pathways of organic matter and its incorporation into the food web within a submarine canyon are relatively scarce (Bosley et al., 2004; Van Oevelen et al., 2011).

The relative importance of marine and terrigenous organic matter as food source within a food web can be quantified by the isotopic signature of its organisms. Carbon and nitrogen stable isotopes, $\delta^{13}C$ and $\delta^{15}N$, can be used as tracers of organic matter and its transfer through food webs (Middelburg, 2014). $\delta^{13}C$ changes little with trophic level (~1‰), while it differs markedly depending on the photosynthetic pathway used by the primary producers (France et al., 1998). The $\delta^{13}C$ in marine phytoplankton is between −19 and −22‰, while it ranges between −25 and −28‰ for terrestrial organic matter produced by C3 plants (Hedges et al., 1997). $\delta^{15}N$ also reflects the isotopic composition of the nutrient source, the $\delta^{15}N$ of nitrogen fixers is around 0‰ and 4.8‰ for primary producers assimilating dissolved nitrogen (Sigman et al., 2000). In addition, nitrogen provides a measure of trophic position, because the $\delta^{15}N$ of a consumer is enriched by 3.4‰ relative to its diet on average (Minagawa and Wada, 1984).

The Avilés submarine canyon (AC) is part of a complex network of canyons and valleys off the Central Cantabrian margin in Northern Iberian Peninsula (Gómez-Ballesteros et al., 2014). The system is supplied with terrestrial sediments and organic matter by the Nalón River, and an active downcanyon transport has been recently reported by Rumín-Caparrós et al. (2016). The canyon supports rich populations of commercial species like monkfish and hake, top predators such as cetaceans and giant squid (*Architeuthis dux*) and rich communities of cold water corals (Louzao et al., 2010). Some recent studies have dealt with aspects of its geomorphology (Gómez-Ballesteros et al., 2014) and biology (Lourido et al., 2014; Louzao et al., 2010; Romero-Romero et al., 2016; Sánchez et al., 2014), but studies about the sources and pathways of OM within the food web are still missing.

This paper aims to trace the origin and fate of OM within the Avilés submarine canyon and its incorporation by the food web using stable C and N isotopes on a seasonal basis. We specifically addressed the following questions: Are terrestrial inputs of OM arriving to the canyon sediments? Is along-canyon transport important in sustaining the benthic community of the Avilés Canyon? To which degree is the food web dependent on seasonal changes of OM inputs?

2. Materials and methods

The AC exhibits a depth range from 128 m at its head, located 12 km off the coast, down to 4766 m depth when it reaches the abyssal plain of the Bay of Biscay around 40 km far from shore (Gómez-Ballesteros et al., 2014; Fig. 1). It is composed of a main canyon axis and several other tributary channels that flow into the former. Our sampling area was extended from 44°23′ to 43°56′ N and from 6°31′ to 5°47′ W (Fig. 1).

2.1. Sampling methods

Samples were collected during three oceanographic cruises which took place between 3 and 13 March 2012 (BIOCANT 1); between 27 September and 6 October 2012 (BIOCANT 2) and between 24 April and 4 May 2013 (BIOCANT 3) onboard the research vessel B/O Sarmiento de Gamboa at six different stations distributed along the main axis of the AC at 1200, 2100, 3000 and 4700 m depth (stations C3, C5, C6 and C8, respectively), and on the adjacent slope at 1200 and 1500 m depth (stations P3 and TP, respectively; Fig. 1). At each station profiles of temperature, salinity and fluorescence were obtained by means of a Seabird 911-plus CTD probe, which was supplemented by a rosette of Niskin bottles. Water samples for particulate organic matter (POM) were collected at depths of 5, 25, 50, 75, 100, 200, 300, 500 m and then every 500 m down to the seafloor at each station. At each station we also sampled nekton by double oblique hauls with a 10 mm pore size Isaacs-Kidd Midwater Trawl net (IKMT), and mesozooplankton by oblique tows of a Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) equipped with 8 nets of 200 μm mesh size. Mesozooplankton and nekton samples were taken from 0 to 1200 m in stations C3, P3 and TP and from 0 to 2000 m in C5, C6 and C8 (Fig. 1). The benthic community was sampled with a 5 m wide Agassiz dredge hauled at the bottom floor during 1 h or by means of a rock dredge also hauled during 1 h when the bottom substrate was rocky. In addition, muscle tissue samples of cetaceans: common dolphin (*Delphinus delphis*), striped dolphin *(Stenella coeruleoalba)* and sperm whale (*Physeter*

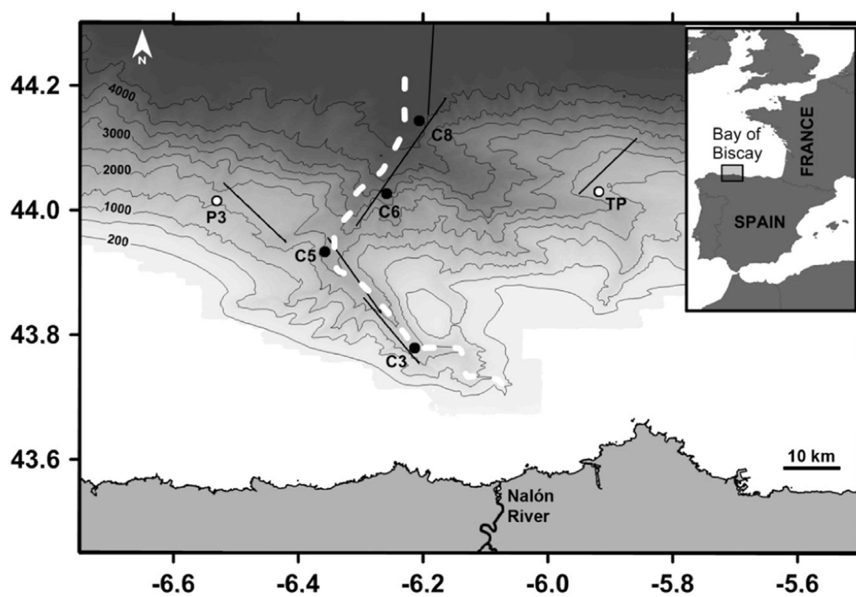

Fig. 1. Map of the study area, the Avilés Canyon System. Dashed white line marks the main axis of the AC. Dots indicate locations of stations and lines refer to the trawling of nets and dredges. Black dots point the stations situated along the main axis of the AC and white dots point those on the adjacent slope.