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Comparative study of isotopic trends in two coastal ecosystems of North Biscay: A multitrophic spatial gradient approach

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A B S T R A C T

In coastal estuarine embayments, retention of water masses due to coastal topography may result in an increased contribution of continental organic matter in food webs. However, in megatidal embayments, the effect of topography can be counterbalanced by the process of tidal mixing. Large amounts of continental organic matter are exported each year by rivers to the oceans. The fate of terrestrial organic matter in food webs of coastal areas and on neighboring coastal benthic communities was therefore evaluated, at multi-trophic levels, from primary producers to primary consumers and predators. Two coastal areas of the French Atlantic coast, differing in the contributions from their watershed, tidal range and aperture degree, were compared using carbon and nitrogen stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) during two contrasted periods. The Bay of Vilaine receives large inputs of freshwater from the Vilaine River, displaying ^{15}N enriched and ^{13}C depleted benthic communities, emphasizing the important role played by allochtonous inputs and anthropogenic impact on terrestrial organic matter in the food web. In contrast, the Bay of Brest which is largely affected by tidal mixing, showed a lack of agreement between isotopic gradients displayed by suspended particulate organic matter (SPOM) and suspension-feeders. Discrepancy between SPOM and suspension-feeders is not surprising due to differences in isotopes integration times. We suggest further that such a discrepancy may result from water replenishment due to coastal inputs, nutrient depletion by phytoplankton production, as well as efficient selection of highly nutritive phytoplanktonic particles by primary consumers.

1. Introduction

Coastal ecosystems are places of intense biogeochemical activity, where both continental (through freshwater runoff) and oceanic inputs (through upwellings and tidal mixing) contribute to their high biological productivity and their important role in the global cycle of carbon, nitrogen and phosphorus (Gattuso et al., 1998). For instance, Cole et al. (2007) estimated worldwide that over 0.9 Pg C is annually exported by the rivers to the oceans. This carbon can either be buried in coastal sediments, exported to the open ocean, or enter coastal food webs. Studying the fate of terrestrial organic matter in these environments is therefore of considerable importance. In coastal estuarine embayments, the retention of water masses due to coastline topography should result in an increased contribution of continental organic matter to the associated communities, compared to open coastline areas. However, the effect of topography can be counterbalanced in megatidal areas by the process of tidal mixing. The relative importance of these different factors on the fate of terrestrial matter in coastal and neighboring communities is a significant step toward the understanding of the role played by coastal habitats as an interface between continental and marine ecosystems.

The influence of terrestrial organic matter from large rivers (e.g. Rhône river, Danube river) proved to be significant on coastal communities down to deeper waters (to 100 m, Darnaude et al., 2004). However, the few studies investigating the effects of small rivers showed a very limited bathymetric effect on the stable isotope ratios of coastal biota (Connolly et al., 2009). Nevertheless, all these studies agreed in showing that the effects of terrestrial inputs were maximal on deposit feeders, which ingest sedimented particles on the seafloor.

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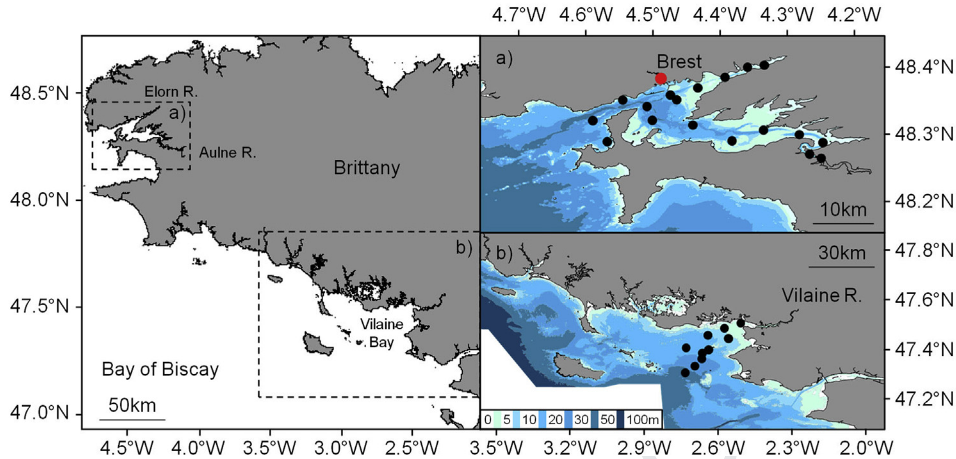

Fig. 1. Study area on the northern Bay of Biscay (France). Framed areas highlight the different sampling sites located on (a) the Bay of Brest and (b) the Bay of Vilaine. The blue shades indicate the average depth from 0 to 100 m. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Stable isotope analyses have proven in the past thirty years to be a powerful tool to investigate the assimilation of terrestrial organic matter into coastal food webs. In temperate areas, catchments are generally dominated by C_3 plants, that typically display ^{13}C depleted signatures (around −28‰, Peterson and Fry, 1987). Detritus from C_3 plants may constitute therefore the largest part of organic matter brought to the coastal environment by estuaries. This organic matter can easily be distinguished from marine primary producers, which display ^{13}C enriched signatures (Peterson and Fry, 1987). In addition, particulate organic matter and nutrients brought to the coastal ocean by rivers are generally ^{15}N enriched, compared to coastal primary producers, due to anthropogenic activities (McClelland et al., 1997; Riera et al., 2000), hence allowing efficient characterization of riverine inputs into coastal food webs. Consequently, the use of stable isotopes is currently the most popular one to address the origin of organic matter in coastal ecosystems (e.g. Darnaude et al., 2004; Banaru et al., 2007; Connolly et al., 2009; Marchais et al., 2013).

Previous studies trying to characterize the assimilation of terrestrial material into coastal food webs in Western Europe using stable isotopes have shown the importance of freshwater discharge for the food web associated to juvenile flatfish in the Bay of Vilaine (Kostecki et al., 2010; Kopp et al., 2013), as well as marked isotopic gradients reflected in oysters along an estuarine gradient in the Bay of Brest (Marchais et al., 2013). At a larger scale, depth gradients affecting both carbon and nitrogen isotopic ratios suggested that the influence of small rivers might propagate down to the entire continental shelf scale (Nerot et al., 2012). These studies provide consistent evidence that even small rivers can significantly affect their neighboring coastal communities. However, comparison among dissimilar environmental systems would provide additional information on ecological mechanisms affecting the spatial and temporal extent of organic matter exchanges between rivers, estuaries and coastal ecosystems.

Our aim was therefore to assess the fate of terrestrial material on adjacent coastal communities at multi-trophic levels, from primary producers to primary consumers and predators. Two estuarine bays of the French Atlantic coast, differing in their freshwater runoff, tidal amplitude and aperture degree, were compared. Two sampling dates, corresponding to different freshwater runoff conditions, were also compared, and factors affecting the incorporation of terrestrial material into coastal communities were expected to be identified.

2. Material and methods

2.1. Study area

This study was conducted on the northern coast of the Bay of Biscay, in the Bay of Brest and the Bay of Vilaine (Fig. 1). The Bay of Brest is a semi-enclosed ecosystem of more than 100 km^2, connected to the Iroise Sea by a 2 km wide and 40 m deep channel. Most of freshwater inputs to the bay originate from the Elorn and the Aulne rivers, which drain a total catchment of 2135 km^2. Maximal tidal amplitude reaches 8 m and the daily water inflow from the ocean into the bay ($13 \cdot 10^8$ m^3) reach the annual freshwater volume discharge by the two rivers ($11 \cdot 10^8$ m^3 yr^{-1}, Table 1). Such a water inflow combined with the bay surface, leads to strong tidal currents favoring vertical exchange and estuary/ocean water mixing. The Bay of Vilaine, however, receives large freshwater inputs from the Vilaine River ($29 \cdot 10^8$ m^3 yr^{-1}), which drains a 10,500 km^2 catchment (Table 1). The maximal tidal amplitude reaches 5.5 m and the oscillating volume ($14.5 \cdot 10^8$ m^3) is similar to that of the Bay of Brest. However, the larger surface of the bay coupled to both lower mean depth and larger aperture degree to the open ocean, lead to low water mixing in the estuary. The low currents recorded (0.5 m s^{-1} maximum) lead to active deposition of fine sediment.

2.2. Sample collection and preparation

Sampling was carried out in March and May 2008 for the Bay of Vilaine and the Bay of Brest, respectively, as well as in

Table 1
Bays and upland basins characteristics from Aulne, Elorn and Vilaine rivers.

	Iroise front		Vilaine estuary
Surface (km^2)	102.8		227.5
Mean depth (m)	16		7
Volume (low tide – m^3)	$16.5 \cdot 10^8$		$16.1 \cdot 10^8$
Volume (high tide – m^3)	$29.4 \cdot 10^8$		$30.6 \cdot 10^8$
River	Aulne	Elorn	Vilaine
Catchment area (km^2)	1875	260	10,500
Length (km)	140	57	218
Mean flow (m^3 s^{-1})			
2008	28	6	92
Max.	58	12	230
Min.	5	2	13
Population	70,000	285,000	10^6
Density (km^{-2})	37	1100	100

Sources: DREAL Bretagne/HYDRO – MEDD/DE – (De Nadaillac and Breton, 1986; Hily, 1991).