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Contribution of planktonic and benthic food sources to the diet of the reef-forming vermetid gastropod *Dendropoma petraeum* in the western Mediterranean

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ABSTRACT

In the Mediterranean Sea, the vermetid *Dendropoma petraeum* (Monterosato, 1884) forms highly biodiverse reefs that have received increasing attention in recent years although very little is known about the food habit of this species. The main goal of this study was to describe the trophic role of planktonic and benthic food sources for *D. petraeum*. Specimens from three morphological zones of the reef (inner edge, *cuvette* and outer edge) at two sites with different wave exposure along the north-western coast of Sicily (Italy; western Mediterranean) were compared for $\delta^{13}C$ and $\delta^{15}N$. Isotopic determinations were also carried out on potential food sources identified in epilithon, reef macroalgae and suspended particulate organic matter. $\delta^{13}C$ for *D. petraeum* showed significantly more depleted values in the more exposed conditions (i.e. the site with higher wave exposure and outer edge of the reef), while $\delta^{15}N$ did not differ appreciably. These results suggest greater exploitation of benthic sources in the sheltered than in the exposed site and reveal diet shift and trophic flexibility at a small spatial scale for the reef-former *D. petraeum*.

1. Introduction

Vermetids are sessile marine gastropods, mostly gregarious, which spend their adult life adhered to or embedded in solid substrata. They preferentially thrive in intertidal or shallow subtidal zones in temperate and tropical regions (Safriel, 1975) and some species form reefs in intertidal flats associated with coralline algae (Safriel, 1975; Calvo et al., 1998). Vermetid reefs are highly biodiverse biogenic constructions, in some cases structurally comparable to coralline reefs in tropical seas (Safriel and Ben-Eliahu, 1991; Consoli et al., 2008). Reefs play a pivotal role in modifying the shape and ecological characteristics of the transitional area between mesolittoral and infralittoral flats, creating more complex tridimensional structures and amplifying the space available for organisms (Safriel and Ben-Eliahu, 1991; Consoli et al., 2008).

In the Mediterranean Sea, two species of vermetid occur: *Dendropoma petraeum* (Monterosato, 1884) and *Vermetus triquetrus* (Bivona Ant., 1832), the former being the main structural species (Safriel, 1975). Moving from the shore towards the open sea, *D. petraeum* reefs can be divided into three morphological zones: the inner edge, the *cuvette* (Molinier and Picard, 1953) and the outer edge, which correspond respectively to the terrestrial boundary, the hollows of the central zone and the sea boundary of the bioconstruction platform (Chemello and Silenzi, 2011) (Fig. 1). These zones differ both in the level of exposure to waves and in their populations (Chemello et al., 1998). An important factor limiting the distribution and width of vermetid reefs is the superficial hydrodynamism: indeed *D. petraeum* platforms develop very little in width in sheltered shores, preferring exposed shores and more energetic hydrodynamic conditions (Chemello and Silenzi, 2011).

From the trophic point of view, *D. petraeum* has been described as essentially a ciliary filter-feeder (Barash and Zenziper, 1985): suspended particles are carried by the inhalant current into the mantle cavity, where they are trapped by the mucus covering the gill leaflets, then moved forwards in a ciliated tract and are finally led towards the mouth. In addition, *D. petraeum* is able to feed on suspended particles by occasionally producing a mucus net. This strategy is very common in another congeneric species, *Dendropoma maximum* (Kappner et al., 2000; Ribak et al., 2005), but is adopted by *D. petraeum* only under particular environmental conditions, such as complete immersion in the infralittoral zone (Schiaparelli et al., 2006). Moreover, grazing-like behaviour (i.e. animals extending their heads out of the shells and grazing the substratum) has been described for *D. petraeum*, which results in anti-fouling but potentially provides additional food (Calvo et al., 1998).

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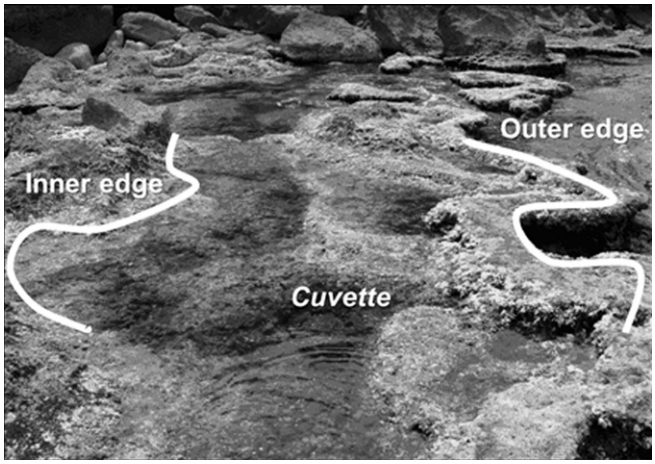

Fig. 1. Schematic drawing of the morphological reef zones along the shore to open-sea transect.

Due to its intertidal habitat and feeding strategies, potential food sources of *D. petraeum* consist of organic matter originating from living plankton, detrital particles of different origins (i.e. planktonic and benthic) and organic matter covering the rocky shore (i.e. epilithon and macroalgae) (Ward and Shumway, 2004; Grall et al., 2006). Food availability is affected by hydrodynamic conditions (Bode et al., 2006; Schaal et al., 2009). Hydrodynamism is thus expected to have a direct effect on open-sea input into the intertidal habitat, and resuspension and sedimentation processes, triggering benthic-pelagic coupling and allowing intertidal benthic consumers to gain access to a large variety of trophic resources.

In contrast with other marine rocky reefs, the trophic structure of these unique bioconstructions has received no attention until now. Little is known about the origin of the *D. petraeum* diet or which components of ingested organic matter are actually assimilated and gaining a full understanding of the diet using direct observations of feeding behaviour and stomach content analysis is challenging. The information derived from these techniques, when applicable, is limited to the food items ingested, while food assimilated over a longer period cannot be determined. In contrast, the analysis of stable carbon and nitrogen isotopes ($\delta^{13}C$ and $\delta^{15}N$) has been shown to be a powerful tool in describing organic matter flow and resolving trophic relationships in coastal ecosystems (Bode et al., 2006; Yokoyama and Ishihi, 2007). The technique is based on the predictable isotopic fractionation from one trophic level to the next. Indeed the $\delta^{13}C$ and $\delta^{15}N$ of consumers reflect the composition of assimilated food plus a slight enrichment for $\delta^{13}C$ and a higher one, for $\delta^{15}N$ (Post, 2002).

In this paper, we have used stable carbon and nitrogen isotopes to analyse the feeding habits of the reef former *D. petraeum*, an ecologically important and also threatened species, protected by European legislation (the Habitats Directive 92/43/EEC) and included in the Threatened Species List of the Mediterranean. Since hydrodynamism is supposed to be a principal feature affecting the availability of planktonic and benthic sources to the intertidal reef former, we expect *D. petraeum* to exhibit diet shifts related to wave exposure. In more detail, we hypothesise that the contribution of reef local sources (epilithon and reef macroalgae) will be greater in sheltered conditions, while in exposed ones open-sea input will shift the diet towards planktonic resources. To test this hypothesis we compared i) two adjacent sites with different wave exposure and ii) the three reef zones (inner edge, cuvette, outer edge) along the shore to open-sea transect.

2. Materials and methods

2.1. Study area and sampling sites

The study was carried out along the north-western coast of Sicily (Italy) in the Marine Protected Area (MPA) "Capo Gallo-Isola delle Femmine". The MPA is divided into three different zones of protection: zone A (integral reserve), zone B (general reserve) and zone C (partial reserve). The intertidal rocky shore and the infralittoral seabed host a number of species and communities worthy of protection for their high ecological value and good level of conservation, such as *Posidonia oceanica* meadows, sciaphilous communities characterised by the soft red seaweed *Corallina elongata* and *C. officinalis*, and one of the most extensive vermetid reefs in the Mediterranean (Badalamenti et al., 1992).

Two sites with different geographical and wave action exposure were selected in zone B of the MPA: a site (38 12.754 N, 13 17.455 E) facing north-west (hereafter Exposed site), where the most common winds originate from in the area (see data reported by the Sicilian Agrometeorological Information Service, http://www.sias.regione.sicilia.it/) and characterised by higher exposure to wave action, and a site (38 13.360 N, 13 19.165 E), facing north-east (Sheltered site) with weaker wave action.

Wave exposure was estimated using erosion rates of plaster of Paris clod cards under calm conditions (Jokiel and Morrissey, 1993). Ten pre-weighed clod cards were deployed in each site in April 2006 for 72 h. After collection these were air-dried for 1 week and re-weighed after drying at 60 °C for 24 h. Weight loss was then directly related to water motion (see Jokiel and Morrissey, 1993; Santin and Willis, 2007). One and three of the 10 cards deployed in each site were lost in the Sheltered and Exposed site respectively. Average clod card weight loss per day at the Exposed site was approximately double (32.0 ± 0.9 g d^{-1}; 19% of initial weight) that at the Sheltered one (18.1 ± 1.1 g d^{-1}; 9% of initial weight) and between-site differences were significant (*t*-test: t-value $= 28.6$, df $= 14$, $P \leq 0.001$).

2.2. Sample collection and analyses

2.2.1. Stable carbon and nitrogen isotope ratios

D. petraeum and its potential food sources (epilithon-EPI, reef macroalgae-MA and suspended particulate organic matter-SPOM) were sampled in May 2006. To obtain a temporal-integrated measure of the isotopic composition of SPOM, sea water was also collected in April 2006. Samples of surface sea water were collected in triplicate at both Exposed and Sheltered sites, at a distance of about 20 m from the reef (mean depth ~5 m). SPOM for isotopic analysis was obtained by filtering 2 l of pre-filtered (200 μm) sea water onto pre-combusted (450 °C, 4 h) Whatman GF/F filters within 2 h of collection. Epilithon and the most abundant and frequent reef macroalgae (i.e. *Ceramium* sp., *Cystoseira* spp. and *Laurencia* spp.; Mannino, 1992) were collected in triplicate, by scraping the reef surface and by hand respectively, at low tide at three random stations of both Exposed and Sheltered sites. Epilithon, which was mainly composed of benthic diatoms and filamentous microalgae, was analysed whole because separating its single components did not produce sufficient material for isotopic analysis.

Samples of *D. petraeum* were collected in triplicate in each zone of the reef (inner edge, *cuvette*, outer edge) at three random stations at both the Exposed and Sheltered sites. *D. petraeum* were removed from the reef using a small chisel; particular care was taken to avoid serious damage to the bioconstruction.

Epilithon, reef macroalgae and SPOM samples were analysed separately for $\delta^{15}N$ and $\delta^{13}C$. Samples to be analysed for $\delta^{13}C$ were