Seasonal variation in food intake of *Holothuria* (*Roweothuria*) *poli* (Holothuroidea: Echinodermata) of Stidia in Mostaganem, Algeria

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Abstract

A study of the diet of *Holothuria poli* from the southwestern Mediterranean Sea (Stidia, Mostaganem) was carried out at a depth of 3 m during four seasons in order to gain an idea of the variation of the different trophic sources used and appreciated by this sea cucumber species. *H. poli* feeds on plants and animals, although diatoms constitute its most consumed food source. *H. poli* consumes large amounts of cyanophyceae in summer and algae in spring. The dead or living leaves of the seagrass *Posidonia* are also part of the diet of *H. poli*, but only in small proportions. In terms of animals consumed, foraminifera constitute the most important resource. A relatively large amount of sponge fragments, however, was observed in the digestive tract of *H. poli*. In addition, crustaceans are widely consumed in spring while nematodes and bivalve mollusc fragments are less consumed.

Key words: *Holothuria* (*R.*) *poli,* selective feeding, diet, seasonal variation, *Posidonia* meadow, Algeria

Introduction

Sea cucumbers play an important role in the recycling of organic matter within the food web of the *Posidonia oceanica* ecosystem (Zupo and Fresi 1984; Uthicke and Karez 1999; MacTavish et al. 2012). During feeding, these deposit-feeder organisms collect sediments with their tentacles to extract organic matter. The collection is done selectively with respect to the richness of organic matter particles (Mezali and Soualili 2013; Belbachir et al. 2014), which could be a strategy for ecological niche partitioning between different sea cucumber species. *Holothuria poli* (Delle Chiaje, 1824) is the most abundant holothurian in Algerian coastal waters (Mezali 2008; Belbachir 2018). The sediment ingested by this species consists mainly of inorganic matter (coral detritus, skeletons of marine organisms and benthos inorganic remains), detrital organic matter (marine plants, algae, decaying or dead animals) or microorganisms (bacteria, diatoms, protozoa and cyanophyceae) (Massin 1982; Moriarity 1982; Gao et al. 2014). Physical selectivity (size of sedimentary particles) and chemical selectivity (organic matter) of *H. poli* have been discussed for Algerian coastal areas (Mezali et al. 2003; Mezali and Soualili 2013; Belbachir et al. 2014) but data on the seasonal variations of its diet are lacking (Mezali et al. 2003). The aim of the present paper is to present a study of the diet of *H. poli* over the four seasons.

Methods

Ten individuals (20-cm long on average, contracted length) of *H. poli* and the uppermost millimeters of the sediment were collected during each of the four seasons (summer and autumn 2016, winter and spring 2017) at Stidia (35°49'N / 0°01'W) on the southwestern Algerian coast (Fig. 1). This site is located between two great commercial harbours (Mostaganem and Arzew), which are considered to be two potential pollution sources (Belbachir 2012). The seabed at Stidia is mainly composed of a succession of rocky and sandy substrata. The seagrass meadow (*Posidonia oceanica*) in the area is considered to be of type II (dense meadow, 400–700 plants/m^2), according to the classification by Giraud (1977). The fauna at the sampling site is mainly represented by echinoderms (*Ophioderma* sp. and *Paracentrotus lividus*), sponges, crustaceans (*Chthamalus* sp. and *Pachygrapsus* sp.), molluscs (*Littorina* spp. and *Patella* spp.) and fishes (*Coris* sp., *Diplodus* spp., *Serranus* spp. and *Sarpa* sp.) (Belbachir 2012). Flora is mainly represented by red algae (*Corallina* spp.), green algae (*Ulva* spp., *Caulerpa* spp.) and brown algae (*Padina* sp. and *Cystoseira* spp.) (Belbachir 2012). The invasive alga *Caulerpa racemosa* has also been present at Stidia since 2009 (Bachir Bouiadjra et al. 2010). This species has a hard body covered with a thin layer of sand (Mezali 2008), and inhabits detrital bottoms and *Posidonia* seagrass (Francour 1984; Mezali 2004).

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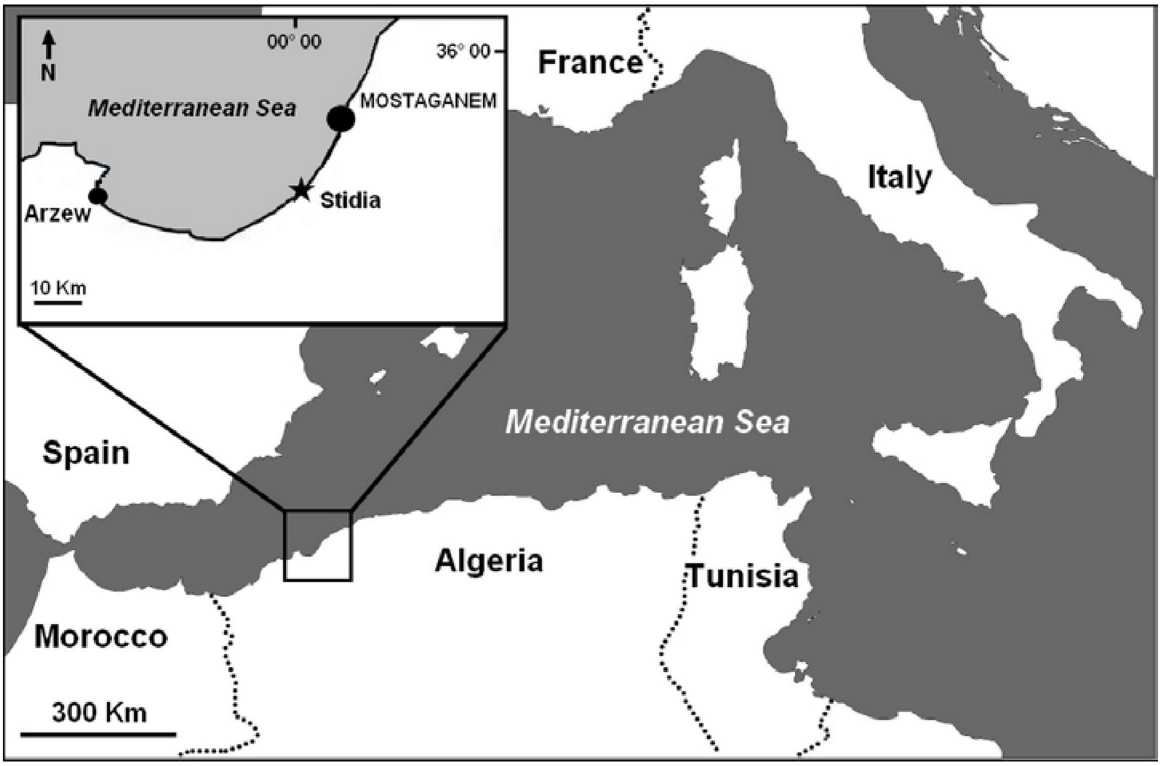

Figure 1. Geographical location of Stidia (star) where samples of *Holothuria poli* were collected.

Each specimen of *H. poli* and each sediment sample originating from the biotope collected were isolated in a plastic bag containing seawater for further processing. In the laboratory, each individual was dissected and the digestive tract content carefully collected for microscopic observations. The method developed by Jones (1968) and later modified by Nedelec (1982), was used for the digestive content analysis (see Belbachir and Mezali 2018). This method was also used for the sediment (holothurian biotope) analysis. Holothurian selectivity in food choice was studied by calculating the Ivlev electivity index $E' = (ri - pi) / (ri + pi)$, where ri is the ratio of a food item in the digestive content, and pi is the ratio of the same food item in the sediment (Ivlev 1961; Belbachir and Mezali 2018). Permutational multivariate analysis of variance (PERMANOVA) (Anderson 2001) was carried out using R v3.4.1 software (R Core Team 2017) to test the dissimilarity of the diet of *H. poli* during the different seasons.

Results

Seasonal variation of trophic resources

Summer

During summer, diatoms and cyanophycea are the most consumed vegetal components (30.7% and 14.7% of the diet, respectively) (Fig. 2). Macrophytes algae (mainly coralline) comprise 5.3% of the diet; dead and live leaves of *Posidonia* comprise 4.7% and 0. 7%, respectively (Fig. 2). The animal portion of the diet is mainly composed of foraminifera and sponge fragments (16.7% and 12.0%, respectively) (Fig. 2). Crustaceans, nematodes and bivalve mollusc fragments represent 5.3%, 5.3% and 2.0% of the diet, respectively (Fig. 2).

Autumn

During autumn, the vegetal component of the diet of *H. poli* is composed of diatoms (26.7%) and algae (10.0%), followed by cyanophycea (2.0%). The leaves of *Posidonia* (live or dead) are absent (Fig. 2). For the animal component of the diet, foraminifera is dominant (20.0%), whereas sponge fragments, crustaceans, nematodes and bivalve mollusc fragments are only present in small proportions (6.7%, 6.0%, 6.0% and 5.3%, respectively) (Fig. 2).

Winter

In winter, diatoms, cyanophycea and algae are the dominant vegetal sources at 31.1% 10.0% and 9.3%, respectively (Fig. 2). The dead and live leaves of *Posidonia* are present in low proportions (2.7% for the two items) (Fig. 2). Sponge fragments are highly represented in the gut during this coldest season of the year (17.9%) (Fig. 2). Animal sources, such as foraminifera, bivalve mollusc fragments, crustaceans and nematodes make up a small portion of the diet (6.6%; 4.1%, 4.0% and 1.3%, respectively) (Fig. 2).

Spring

In spring, diatoms are clearly dominant in the diet (38.0%), followed by algae (14.7%) (Fig. 2). Cyanophycea, live and dead *Posidonia* leaves represent 6.0%, 2.0% and 1.3% of the diet, respectively (Fig. 2). The animal component of the diet is mainly composed of foraminifera (14.0%) and crustaceans (13.3%) (Fig. 2). Sponges and nematodes represent only 2.0% and 1.3% of the diet, respectively, while bivalve mollusc fragments are not consumed during this time of year (Fig. 2).

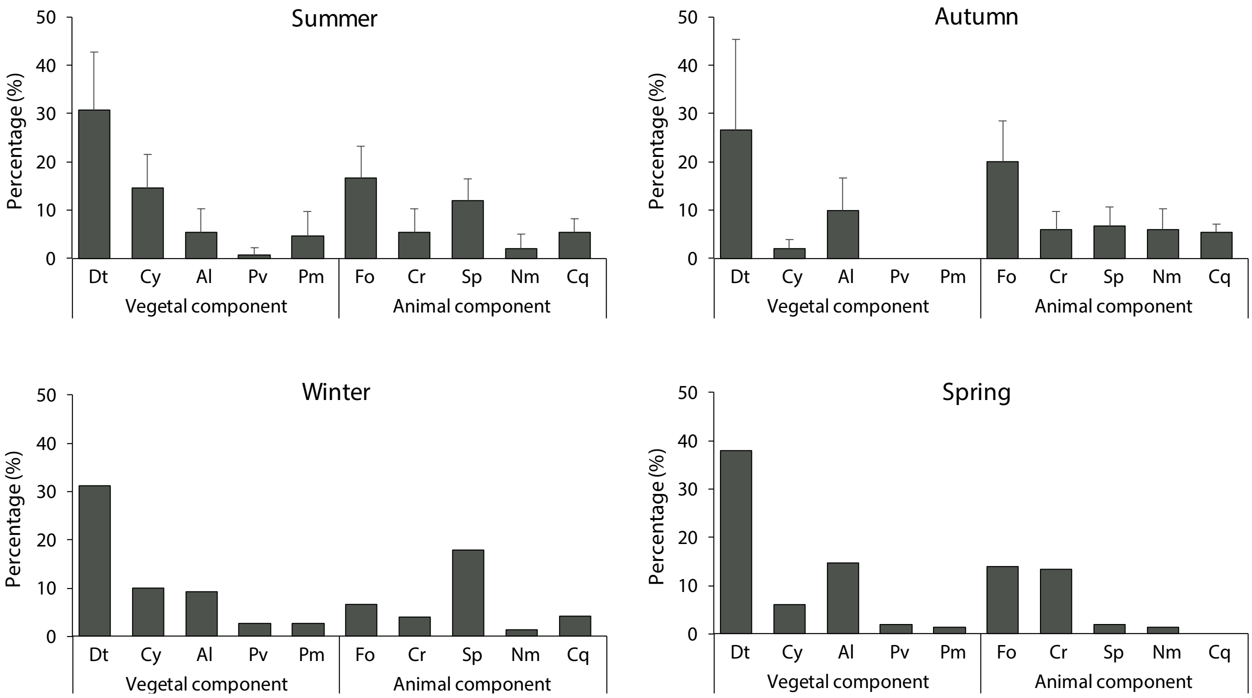

Figure 2. Seasonal variation (in percentage of diet components) of the different trophic sources of the diet of *Holothuria poli*. Dt: diatoms; Cy: cyanophyceae; Al: macrophytes algae; Pv: live Posidonia leaves; Pm: dead Posidonia leaves; Fo: foraminifera; Cr: crustaceans; Sp: sponge fragments; Nm: nematodes; Cq: bivalve mollusc fragments.

Selective behaviour towards food sources

PERMANOVA reveals a difference in diet between the four seasons (P<0.001). Although diatoms are dominant throughout the year, this food source is hardly selected in winter and spring (*E'* = 0.1) by *H. poli* and is avoided in summer and autumn (*E'*<0) (Fig. 3). The dead leaves of *Posidonia* are consumed during most seasons, and is sometimes the most preferred (*E'* = 0.6 in summer) (Fig. 3). Live *Posidonia* leaves are also consumed throughout the year, with the highest electivity index for this trophic source in spring (*E'* = 0.4) (Fig. 3). Algae and cyanophycea were also consumed, and the maximum electivity index for algae (*E'* = 0.3) was obtained in summer, while th maximum index for cyanophycea (*E'* = 0.5) was obtained in the spring (Fig. 3). Sponge fragments are a slightly preferred component of the diet, and the electivity index reaches its maximum values in summer (*E'* = 0.2, Fig. 3). Foraminifera show a negative electivity index throughout winter and spring (*E'* = -0.3 and -0.4, respectively), with the highest value obtained in summer and autumn (*E'* = 0.1, Fig. 3). Except during summer, *H. poli* preferentially consume crustaceans; the most important electivity index is obtained in autumn and spring (*E'* = 0.3 for both seasons) (Fig. 3). *H. poli* also preferentially consumes nematodes in autumn (*E'* = 0.3) and winter (*E'* = 0.2) (Fig. 3), although this food source is poorly represented in the gut contents.

Discussion

Food sources for *H. poli* are very diverse and their respective roles vary with seasons. The Ivlev electivity index reveals that diatoms are avoided in summer and autumn, although paradoxically, they still constitute the highest portion of the food content in the digestive tract of *H. poli,* which is probably due to their high availability in the environment during certain periods. In fact, nutrients originating from fertilisers used in agricultural areas adjacent to Stidia could be the reason for the high availability of diatoms. In spring, *H. poli* prefers photosynthetic organisms such as algae, diatoms and live *Posidonia oceanica* leaves. The high rates of diatoms and algae found in the digestive contents of holothurians was also reported by Sonnenholzner (2003) for *Holothuria theeli* from the Gulf of Guayaquil (Ecuador). The consumption of dead *Posidonia* leaves by detritus-feeders has been reported in the literature (e.g. Buia et al. 2000; Walker et al. 2001); this could have a significant impact on the primary production transfer from *Posidonia* plant. In fact, the litter biota mainly composed of dead leaves of *Posidonia* is an important source of organic matter for communities living in seagrass beds (Walker et al. 2001); it is even the main pathway for the organic matter transfer from *Posidonia oceanica* meadow (Cebrian et al. 1997). The consumption of live *Posidonia* leaves by *H. poli* is interesting as few marine animals consume them. In autumn, *H. poli* concentrates more on the animal component of its food sources, particularly on foraminifera and to a lesser degree on crustaceans, bivalve mollusc's fragments, and sponge fragments. Holothurians tend to change their food preferences according to seasons, and this is probably due to the availability of food items and their nutritional qualities. From our results, we think that *H. poli* exhibits a feeding plasticity in response to food items and their availability, which suggests that this sea cucumber is a generalist species.

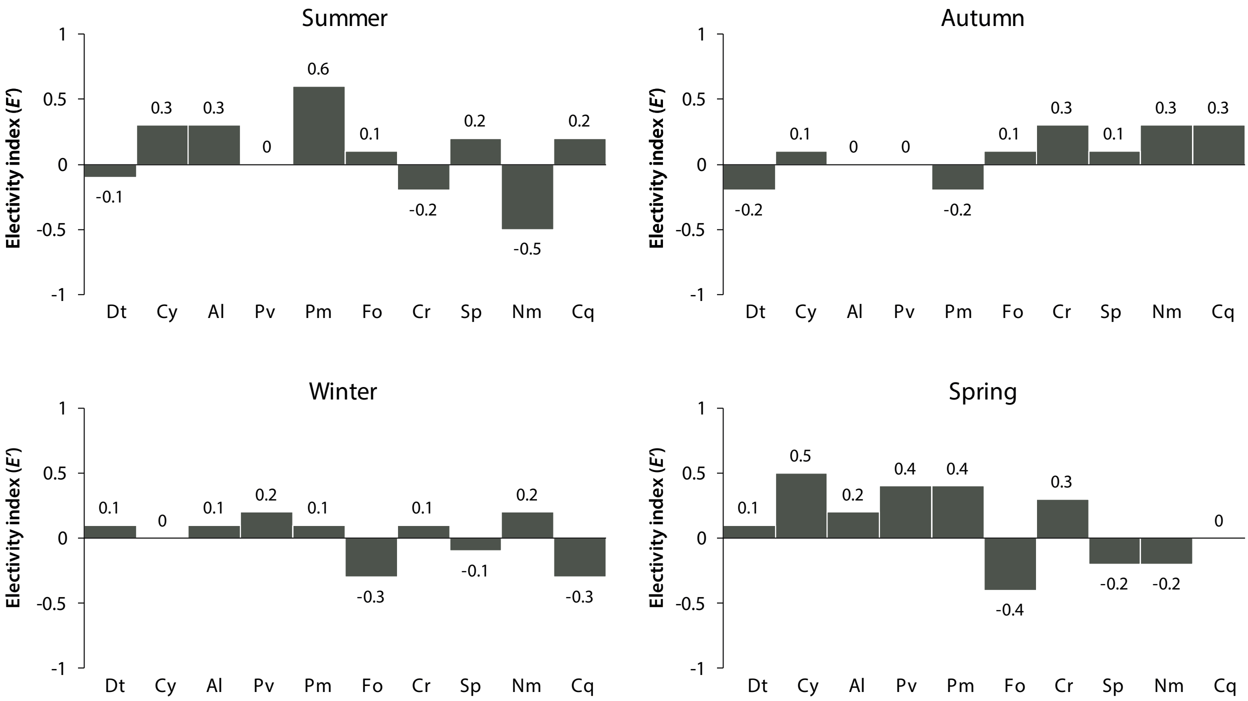

Figure 3. Ivlev electivity index indicating the preference or avoidance of a food source by H. (R.) poli. Dt: diatoms; Cy: cyanophyceae; Al: macrophytes algae; Pv: live Posidonia leaves; Pm: dead Posidonia leaves; Fo: foraminifera; Cr: crustaceans; Sp: sponge fragments; Nm: nematodes; Cq: bivalve mollusc fragments.

The components of the sediment are not all assimilated in the same way by the different sea cucumber species that inhabit the same place (Belbachir and Mezali 2018). In addition, sea cucumber species are distributed heterogeneously in various biotopes present at the same site (Mezali 2004). Consequently, even if all species ingest sediment, they can live in the same place as they are not really in competition with each other for food.

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