

The ability of holothurians to select sediment particles and organic matter

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Abstract

Particle selectivity by deposit feeders is an important concept in the ecology of benthic species. The holothurians, as deposit feeders, utilise the organic matter that coats sediment and detrital particles as food. Thus, particle size has been proposed as one resource axis along which niche separation can occur in optimal foraging strategy. Interspecific differences in particle size preference are thought to reduce the interspecific competition among benthic deposit-feeder species.

The analyses of the digestive contents of the holothurian species that were sampled in two localities of Algerian shallow water areas are presented. The results illustrate the specificity of each species: holothurians ingesting the coarse and fine sediment [*Holothuria (Holothuria) tubulosa*, *H. (Roweothuria) poli* and *H. (H.) stellati*], and holothurians selecting fine and very fine sediment [*H. (Panningothuria) forskali* and *H. (Platyperona) sanctori*]. Concerning the selectivity of organic matter, *H. (P.) forskali* is the most selective species followed by *H. (Platyperona) sanctori*, *H. (H.) tubulosa*, *H. (H.) stellati* and *H. (R.) poli*. This feeding behaviour is discussed between species and sites.

Keywords: Aspidochirotid Holothurians, Algerian basin, organic matter, *Posidonia oceanica* meadows, optimal foraging.

Introduction

Deposit-feeding holothurians belonging to the Aspidochirotid group ingest non-living sediment and detritus material (Coulon et al. 1991; Coulon and Jangoux 1993) for the nutritive particles it contains and for micro-organisms, such as bacteria (Yingst 1976; Moriarty 1982; Birkeland 1989; Plotieau et al. in press), cyanobacteria (Sournia 1976), meiofauna (Berthon 1987), microalgae and fragments of marine phanerogams (Massin and Jangoux 1976; Traer 1980; Verlaque 1981). This behaviour includes processes such as food selection, handling, ingestion, digestion and assimilation (Massin 1982b).

By their feeding activity, holothurians influence microbiological processes at the water-sediment interface (Amon and Herndel 1991a, 1991b) and the bio-accumulation of chemical and organic particles (Lappanen 1995). In addition, rejection of fecal pellets enriches the marine sediment with organic matter; this makes the substratum more attractive for

other deposit-feeders (Amon and Herndel 1991a, 1991b). By their selective activity, deposit-feeding holothurians can affect the physicochemical properties of the sediment (Taghon 1982). In fact, they alter the sediment actively and deteriorate the stability of the bottom (Massin 1982a, 1982b). This process, called "turn over" has an effect on the incorporation of organic matter into sediment in finely divided form (Roberts and Bryce 1982; Francour 1989), which is available for the meiobenthos and the microbenthos (Mann 1978).

This study focused on the granulometry of the particles ingested by sea cucumbers and also on the organic matter found throughout their digestive tract. We analysed and compared the contents and the rates of organic matter assimilation of the digestive tract with those of the ambient sediment. Particle selection during foraging was studied by comparing the grain size distribution of the ambient sediment with that of the gut sediment of five holothurian species inhabiting the *Posidonia oceanica* meadows of two contiguous Algerian areas.

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Materials and methods

Sampling sites

Investigations were carried out at two sites, the first situated in Algiers Bay (Tamentefoust) and the second in Bou-Ismaïl Bay (Sidi Fredj), at a depth of 1–9 m (Fig. 1). The site of Tamentefoust, located in the eastern part of Algiers Bay, is in a half closed creek, an area well protected from the dominant winds and influenced by the Oued El-Hamiz. Holothurians inhabit the rocky bottom, with photophile algae dominated throughout the year by *Colpomena sinuosa*, sparse *Posidonia oceanica* beds (Semroud 1993) and scattered benthic fauna: seasonally by *Fosliella* sp. and *Ulva rigida*. It is a polluted area with harbour activities and the discharge of domestic waste water.

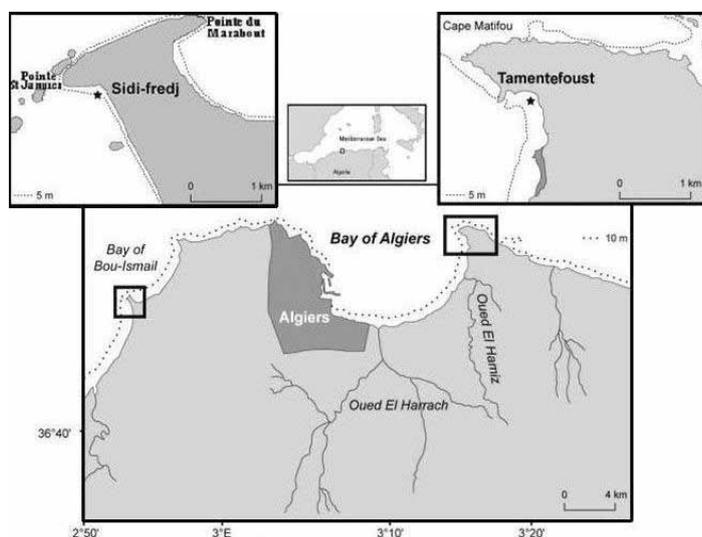


Figure 1. Location of the two sampling sites: Tamentefoust and Sidi Fredj.

Table 1. Mean densities [standard deviation] of the studied holothurian species in the two sites, evaluated for 240 m² (Mezali 1998, 2008).

Species	Sidi Fredj	Tamentefoust
<i>Holothuria (Holothuria) tubulosa</i>	0.942 [0.113]	0.396 [0.045]
<i>Holothuria (Roweothuria) poli</i>	0.400 [0.068]	0.096 [0.022]
<i>Holothuria (Holothuria) stellati</i>	0.050 [0.017]	0.038 [0.014]
<i>Holothuria (Panningothuria) forskali</i>	0.225 [0.036]	0.054 [0.024]
<i>Holothuria (Platyperona) sanctori</i>	0.250 [0.051]	0.050 [0.026]

The sampling site of Sidi Fredj is further from the much industrialised area of Algiers and is located in Bou-Ismaïl Bay, an area much less exposed to domestic waste water than Tamentefoust, and considered less polluted (Soualili et al. 2008) but more

exposed to the dominant winds (Guettaf et al. 2000). The site is in a semi-protected area (enclosing a marine medical centre) on a rock ledge interrupted by sandy and heterogeneous block bands where marine phanerogams are dominant. *Posidonia oceanica* meadow is in better health here than in Tamentefoust. A *Cymodocea nodosa* meadow is also present.

Collection and preparation of samples

In the Mediterranean *Posidonia* meadows, three deposit-feeding holothurian species [*Holothuria (Holothuria) tubulosa*, *H. (Roweothuria) poli* and *H. (Panningothuria) forskali*] are common. Within the Algerian *Posidonia* meadow, these three species are indexed with two others species [*H. (Platyperona) sanctori* and *H. (Holothuria) stellati*]. The mean densities of these species are shown in Table 1 for Sidi Fredj and Tamentefoust sites (Mezali 1998, 2008).

The holothurians were collected by scuba diving at a depth of 1–9 m during spring. Batches of samples, each batch composed of ten individuals of each species (larger than 150 mm contracted length), were collected from each site, measured and isolated individually into small plastic bags, together with some sediment taken from the study area. A Plexiglas box closed in one of its ends was used to sample the first millimetres of the bottom sediment. In the laboratory, each animal was dissected longitudinally and its digestive tract carefully collected. To calculate the percentage of organic matter, the sediment collected from the gut of the ten individuals of each species was pooled. We used the following relation: % OM = (1-AW/DW) × 100, where DW = Dry Weight; AW = Ash Weight and OM = Organic Matter (Massin 1980). The same protocol was used for the bottom sediment. The percentage of organic matter in the gut sediment was compared with that of the ambient sediment in each site.

The granulometric technique used is indicated in Figure 2. For each species, the sediment from the gut of the ten individuals of that species was pooled in order to provide samples of a size suitable for granulometric analysis (≥ 150 g) (Roberts 1979). The obtained sediment was oven dried (for 24 hours at 105°C), then weighed (initial weight = 150 g). A fine fraction was obtained by sifting under running water using a 40 μm mesh sieve (Fig. 2). The rest of the sediment was dried, weighed (final weight), then sieved mechanically using a series of AFNOR sieves. What

remained in each sieve was weighed and expressed as a percentage of the initial weight. Percentages of the various fractions, coarse (600–2000 μm), average (200–600 μm), fine (60–200 μm) and very fine (40–60 μm) were thus determined (Berthois 1975). A multiple comparison of average rates was carried out using a non-parametric statistical test [Kruskal-Wallis one-way analysis of variance by ranks ($P < 0.05$) (Statistica 6.0)]. Prior to this analysis, an arcsin transformation was used for the percentages ($x' = \arcsin\sqrt{x}$).

Results

Size selection of sediment particles

The percentages of the size classes of the surrounding sediment in both sites differed from those found in the guts of holothurians. The bottom sediments were characterised by high rates of fine fraction (59.87% and 55.13% respectively in Sidi Fredj and Tamentefoust sites, Table 2). This phenomenon was observed at Sidi Fredj site for all holothurians species that have a tendency to select in preferential way the fine fraction (42.76–57%, with an average of $49\% \pm 5.7$, Table 2). At that site, *Holothuria (R.) poli* was the most significantly selective for this fraction ($P < 0.01$).

Holothuria (R.) poli at Tamentefoust site also selected the fine fraction (31.92%, Table 2). At Sidi Fredj site *H. (P.) forskali* and *H. (P.) sanctori* had a tendency to select the very fine fraction (22.09–31.32%, Table 2), this was also observed at Tamentefoust site for *H. (H.) tubulosa* and *H. (R.) poli*, which showed the highest

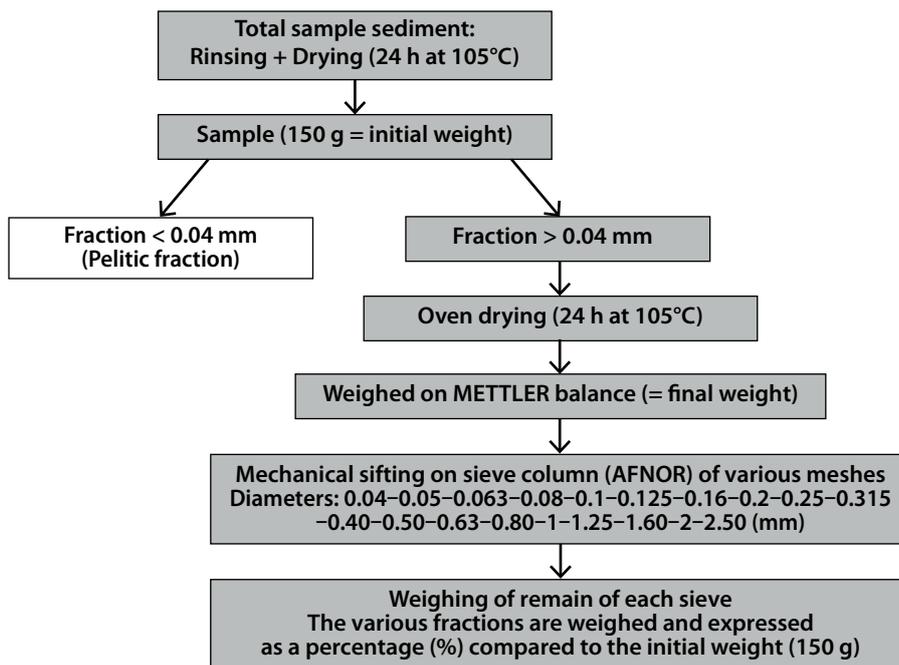


Figure 2. Grain size analysis of the holothurians guts and bottom sediments.

Table 2. Grain size distribution in percentages of dry weight per size class of sediment taken from the holothurians guts and the surrounding sediment. *: classification according to Berthois (1975). T = Tamentefoust; SF = Sidi Fredj. The first line in size classes refers to the mean, the second line to the standard deviation.

	Substratum	<i>Holothuria (Holothuria) tubulosa</i>	<i>Holothuria (Roweothuria) poli</i>	<i>Holothuria (Holothuria) stellati</i>	<i>Holothuria (Panningothuria) forskali</i>	<i>Holothuria (Platyperona) sanctori</i>
Fraction* (μm)	T/SF	T/SF	T/SF	---/SF	---/SF	---/SF
< 40	3.50/4.59 [1.20/2.40]	4.81/6.05 [1.00/2.30]	2.89/4.32 [2.30/2.70]	6.86 [2.00]	5.06 [2.30]	6.16 [2.70]
40–60	3.70/18.80 [2.40/2.50]	1.75/9.81 [3.30/2.50]	9.10/10.20 [1.70/2.10]	8.96 [2.50]	22.09 [2.50]	31.32 [2.10]
60–200	55.13/59.87 [3.50/2.30]	17.32/42.76 [4.00/3.50]	31.92/57.09 [2.10/3.40]	47.21 [2.30]	52.56 [2.50]	45.64 [1.40]
200–600	35.12/4.54 [2.10/2.34]	60.26/13.35 [5.50/2.80]	40.36/11.34 [3.10/2.20]	9.57 [2.34]	11.00 [2.80]	10.68 [2.20]
600–2000	2.55/12.20 [2.20/2.30]	15.86/28.03 [2.70/2.30]	15.73/17.05 [1.20/2.70]	27.40 [2.10]	9.29 [3.40]	6.20 [2.20]

percentage of this fraction (200–600 μm) with respective percentages of 60.26 and 40.36% compared with 35.12% in the ambient sediment (Table 2). At Tamentefoust site, *H. (H.) tubulosa* and *H. (R.) poli* had significant selectivity for the average fraction (40.36–60.26%, Table 2) with, however, *H. (H.) tubulosa* the more selective compared to *H. (R.) poli* ($P < 0.01$). This selectivity for the average fraction was not observed for these species at Sidi Fredj site. We noted, by comparing the sediment fractions in the holothurians guts and the surrounding sediment of the two sites, that *H. (R.) poli* presented an adaptation to its environment. At Sidi Fredj site the highest fraction was between 60 and 200 μm and at Tamentefoust site it was between 200 and 600 μm (Table 2).

Organic matter assimilation

The high rate of organic matter in the gut sediment of *Holothuria (R.) poli* and *Holothuria (H.) tubulosa* at the Tamentefoust site [6.67 and 8.70% respectively for each species (Kruskal-Wallis, $P < 0.01$), Table 3] shows that both species have a tendency to select organic matter from the bottom sediment (3.18%, Table 3). This result was true for *Holothuria (P.) forskali* and *H. (P.) sanctori* at Sidi Fredj site (8.58 and 7.72% respectively, Table 3) ($P < 0.01$), but not observed for *H. (R.) poli*, *H. (H.) tubulosa* and for *H. (H.) stellati* (2.49, 4.31 and 3.55% respectively, Table 3). *Holothuria (H.) tubulosa* at Sidi Fredj site presented a percentage in organic matter (4.31%) closer to that of the substratum (4.77%) (Table 3). However, the percentage of organic matter of *H. (P.) forskali* at Sidi Fredj site did not differ significantly from that of *H. (H.) tubulosa* at Tamentefoust site ($P > 0.01$). *Holothuria (H.) tubulosa* at Tamentefoust site was able to concentrate approximately three times the organic matter compared to that of the bottom sediment. *Holothuria (P.) forskali* at Sidi Fredj site was able to concentrate approximately two times the amount of organic matter that the bottom sediment could (Table 3).

Discussion

The high rate of fine fraction found in the bottom sediment is related on the one hand to the exposition of the sampling area (quiet mode of both sites) and on the other hand to the organic matter concentration. In fact, according to Berthois et al. (1968), the rate of organic matter increases with the importance of the fine fraction of the sediment. This is observed for *H. (R.) poli* at Tamentefoust site, which has a tendency to select this fraction (31.92%). Indeed, Plotieau et al. (unpublished results) suggested that the nutritional value of the fine sediments would be higher than that of the coarse sediments because of their higher number of nutritive microorganisms. It is also noticed that *H. (H.) tubulosa* and *H. (R.) poli* have a significant preference for the average fraction (200–600 μm).

The results obtained corroborate the observations of Massin and Jangoux (1976) on *H. (H.) tubulosa*, which can accumulate approximately three times more organic matter than the bottom sediment can. The difference in organic matter noted in the gut sediment of holothurian species could be related to their micro-distribution in *Posidonia oceanica* meadow (preferred biota and its organic matter richness). *H. (H.) tubulosa* was observed between *Posidonia* leaves (30% of individuals, Mezali 2004). In fact, Blanc (1958) demonstrates that the length of *Posidonia* leaves is responsible for the decantation and accumulation of a great quantity of biodetritical and terrigenous material. *H. (H.) tubulosa* was also observed between the blocs mixture (33% of individuals, Mezali 2004) where food is stocked. *H. (R.) poli* prefers the sandy bottom (40% of individuals, Mezali 2004) influenced by hydrodynamism that disperses food.

The difference in organic matter noted in the gut sediment is also due to the difference in the texture of the tentacles. Indeed, according to Massin and Jangoux (1976), *H. (H.) tubulosa* is able to recognise particles covered by organic matter.

Table 3. Percentages (%) of organic matter (OM) in the gut sediment of holothurians and the surrounding sediment at both sites.

T = Tamentefoust; SF = Sidi Fredj; SD = standard deviation.

	Substratum	<i>Holothuria (Holothuria) tubulosa</i>	<i>Holothuria (Roweothuria) poli</i>	<i>Holothuria (Holothuria) stellati</i>	<i>Holothuria (Panningothuria) forskali</i>	<i>Holothuria (Platyperona) sanctori</i>
OM	T/SF	T/SF	T/SF	---/SF	---/SF	---/SF
Means	3.18/4.77	8.70/4.31	6.67/2.49	3.55	8.58	7.72
SD	---/---	4.83/2.92	2.34/1.67	2.82	6.05	4.46

We can conclude that these aspidochirotid holothurians species are deposit feeders, feeding on materials present at the water-sediment interface. They feed selectively and are able to discriminate between the rich and poor particles in nutritive elements, and select the rich ones. This recognition is undoubtedly due to the gustatory receivers located on their tentacles. The food preferences are related to the size of individuals (Paine 1976). This last point has great implications for the distribution and abundance of nutritive matter.

The aspidochirotid holothurians' capacity to select food was studied by comparing the composition of their digestive tract sediment and the bottom sediment. This comparison gives a valid indication, since the studied sites are relatively homogeneous (Khripounoff and Sibuet 1982). The detritus (i.e. degrading or dead organic matter) represents the essential nutritive source for these benthic animals: *Holothuria (R.) poli* at Tamentefoust site is the more selective for the organic matter.

The granulometric analysis of the digestive contents illustrates the feeding specificity of *H. (H.) tubulosa* and *H. (R.) poli*. Both species ingest the average and fine sediment fraction. The granulometric analysis of guts contents allowed us to classify the holothurians in two groups: (1) holothurians that ingest the coarse and the fine fractions of sediment (600–2000 μm and 200–60 μm): *H. (H.) tubulosa*, *H. (R.) poli* and *H. (H.) stellati*; (2) holothurians that have a tendency to select the fine and very fine fractions of the sediment (40–200 μm and < 40 μm): *H. (P.) forskali* and *H. (P.) sanctori*. The two groups react in a different way in polluted and less polluted areas and their physiological answers may be interpreted in the light of optimal foraging theory.

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