Tissue composition of sponges from the Weddell Sea, Antarctica: not much meat on the bones

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ABSTRACT: The tissue of 31 demosponge and 7 hexactinellid species was analyzed for its composition of organic and inorganic matter. With one exception (*Haliclona* cf. *gaussiana*) inorganic matter, i.e. mostly the siliceous skeleton, accounted for most of the dry weight, varying between about 60 and 95 % dry wt. There were no general trends in the ratio of organic to inorganic matter within sponge orders or genera, and within one species, the ratio could vary between stations. For one of the hexactinellids, *Bathydorus spinosus*, several size classes were analyzed and there was no systematic change in the organic:inorganic matter ratio with specimen size. For some species the results from the Weddell Sea sponges are in good agreement with earlier data from McMurdo Sound. The low organic matter content in Weddell Sea sponges implies that sponge biomasses are much lower than hitherto assumed on the basis of their high abundances and large sizes. In consequence, Antarctic sponges, despite their ubiquitousness, may only channel a minor fraction of the general bentho-pelagic flow of matter and energy, and their main role in the ecosystem is likely structural rather than dynamic.

KEY WORDS: Sponges · Antarctica · Tissue composition · Demosponges · Hexactinellids · Inorganic skeleton

INTRODUCTION

Sponges are dominant members of many Antarctic benthic communities (Beliaev & Ushakov 1957, Koltun 1969, 1970, Dayton et al. 1970, Voss 1988, Barthel et al. 1990). Most of the ca 300 different species known from the Antarctic are demosponges; only 28 species of hexactinellids are currently recognized (Barthel & Tendal 1994). Although only represented by comparatively few species, hexactinellids are important structural agents in this ecosystem. When living, they serve as a habitat for numerous other benthic organisms (Dearborn 1977, Gutt 1988, Wägele 1988, Barthel et al. 1991, Kunzmann 1992); the persistent skeletons of dead hexactinellids form the major part of the well-known Antarctic spicule mats, thereby modifying the substrate conditions for other benthic fauna (Barthel 1992a, b, Barthel & Gutt 1992). The demosponge species investigated by Kunzmann (1992) harbour a less rich fauna, and demosponge skeletons, composed of mostly small spicules, do not have the same structural properties as those of hexactinellids.

While we possess some information on the structural role of sponges in Antarctic benthic ecosystems, we have virtually no knowledge on their participation in the flow of matter and energy from the pelagic to the benthic realm. A noteworthy exception is the now classic study by Dayton et al. (1974), which gives data on tissue composition, growth rates, abundances of and predation on a number of sponges from the shallow part of McMurdo Sound.

In this contribution, data on the body composition of 37 dominant sponge species from the eastern Weddell Sea shelf are presented as a first step towards assessing their role in benthopelagic coupling.

MATERIAL AND METHODS

Sponge material was collected during leg 3 of the 'European Polarstern Study' (EPOS) cruise along the eastern Weddell Sea shelf. Particulars on sites and station lists are compiled in Arntz et al. (1990). The sponges were dredged with either Agassiz or large

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Table 1 Tissue composition of Antarctic demosponges (means ± SD). Depth values are depth at beginning and end of bottom time. A: Agassiz trawl; G: large bottom trawl; B: benthopelagic trawl

Species	Stn and trawl type	Depth (m)	DW (% WW)	AFDW (% DW)	Ash (% DW)	Ash (% WW)	n
Choristida							
Monosyringa longispina	284 G	402–412	22.31 ± 3.03	25.49 ± 3.46	74.52 ± 3.46	16.66 ± 2.64	6
Spirophorida							
Tetilla leptoderma	293 G	771–793	24.74 ± 5.88	25.34 ± 1.86	74.66 ± 1.86	18.53 ± 4.65	21
	249 G	499–515	26.46	16.69	83.31	22.09	3
	274 A	196–212	20.81 ± 4.78	23.95 ± 6.02	76.05 ± 6.02	16.01 ± 4.77	11
	211 G	207–213	50.86 ± 18.27	14.89 ± 0.63	85.11 ± 0.63	43.23 ± 15.37	5
	235 G	405–407	33.04 ± 2.79	34.16 ± 4.19	65.84 ± 4.19	21.83 ± 3.03	8
Tetillid sp.	241 G	451–453	17.56	23.21	76.79	13.50	3
Cinachyra antarctica	274 A	196–212	29.64 ± 5.12	39.67 ± 2.63	60.33 ± 2.63	17.92 ± 3.41	13
Cinachyra barbata	274 A	196–212	30.43 ± 7.56	16.85 ± 4.39	83.15 ± 4.39	25.45 ± 7.19	12
	224 G	186–187	35.02	29.87	70.13	24.31	2
Hadromerida							
Polymastia invaginata	235 G	405–407	35.55 ± 2.41	16.01 ± 4.54	83.99 ± 4.54	29.91 ± 3.15	10
Polymastia isidis	275 A	301–330	39.37	10.27	89.73	35.37	2
Tentorium papillatum	241 G	451–453	32.80 ± 4.11	38.14 ± 4.00	61.86 ± 4.00	20.44 ± 3.73	5
	235 A	399–404	37.25	32.48	67.52	25.24	3
Suberites sp.	241 G	451–453	24.58	19.22	80.78	19.84	2
Pseudosuberites nudus	248 G	599–602	52.73 ± 3.71	6.06 ± 2.76	93.94 ± 2.76	49.56 ± 4.17	5
Latrunculia apicalis (red)	261 B	798–799	22.59 ± 3.82	27.08 ± 5.16	72.92 ± 5.16	16.62 ± 3.88	5
Poecilosclerida							
Mycale acerata	272 A	406–409	24.29	16.80	83.20	20.20	2
Isodictya erinacea	284 G	402–412	47.12	15.12	84.88	40.10	2
	241 G	451–453	39.76 ± 4.49	18.25 ± 2.85	81.75 ± 2.85	32.58 ± 4.44	16
Isodictya cavicornuta	258 B	484–509	17.84 ± 3.30	22.93 ± 4.13	77.07 ± 4.13	13.70 ± 2.32	18
Isodictya toxophila	284 G	402–412	41.01	14.30	85.70	35.23	2
	235 G	405–407	45.30 ± 7.30	8.63 ± 3.15	91.37 ± 3.15	41.31 ± 6.28	9
	245 A	483–484	39.18 ± 3.24	12.87 ± 1.01	87.13 ± 1.01	34.69 ± 2.96	11
	291 G	499–515	41.66	14.04	85.97	35.81	2
	248 G	599–602	29.90 ± 4.13	9.13 ± 0.70	90.87 ± 0.70	27.19 ± 3.92	5
	249 G	701–702	33.43 ± 1.53	8.03 ± 0.36	91.97 ± 0.36	30.75 ± 1.50	4
Desmacidon ramosa	275 A	301–330	23.20	18.44	81.56	18.93	1
Myxodoryx hanitschi	272 A	406–409	24.62	14.78	85.22	21.06	3
Tedania tantula	271 A	352–399	23.96 ± 6.56	17.70 ± 1.94	82.30 ± 1.94	19.75 ± 5.54	11
	235 G	405–407	27.02 ± 5.98	14.74 ± 2.52	85.26 ± 2.52	23.16 ± 5.74	6
Tedania oxeata	229 A	500–509	27.97 ± 5.69	10.54 ± 2.65	89.46 ± 2.65	25.15 ± 5.85	9
	235 G	405–407	32.82 ± 8.19	7.36 ± 2.58	92.64 ± 2.58	30.59 ± 8.50	5
	275 A	301–330	32.22	11.74	88.26	20.68	3
	235 A	399–404	40.90 ± 4.19	6.25 ± 1.31	93.75 ± 1.31	38.37 ± 4.35	7
	256 B	382–399	15.72	14.79	85.21	13.45	3
Tedania vanhoeffeni	256 B	382–399	10.89 ± 1.51	33.92 ± 3.41	66.08 ± 3.41	7.19 ± 1.06	6
Tedania triraphis	241 A	457–462	15.54 ± 1.10	28.63 ± 2.77	71.37 ± 2.77	10.70 ± 1.03	4
	271 A	352–399	17.30 ± 7.51	32.34 ± 14.34	67.66 ± 14.34	9.46 ± 2.23	5
Artemisina plumosa	248 G	599–602	44.22 ± 6.04	13.81 ± 2.68	86.19 ± 2.68	38.17 ± 5.68	13
	241 G	451–453	24.39 ± 2.11	23.79 ± 0.94	76.21 ± 0.94	18.58 ± 1.58	4
Artemisina apolloni	235 A	399–404	35.74	7.14	92.86	33.19	1
Ectyodoryx ramilobosa	249 G	701–702	22.57 ± 5.56	15.24 ± 2.83	84.76 ± 2.83	19.03 ± 4.17	5
	235 G	405–407	44.52 ± 2.32	14.55 ± 1.91	85.45 ± 1.91	37.87 ± 1.15	3
Iophon spatulatus	241 G	451–453	24.58	19.22	80.78	19.84	1
	271 A	352–399	11.63	18.61	81.39	9.46	1
Phorbas glaberrima	261 B	798–799	30.35 ± 10.26	16.59 ± 5.32	83.41 ± 5.32	25.81 ± 9.52	6
Haplosclerida							
Haliclona cf. *gaussiana*	235 A	399–404	22.02	52.24	47.76	10.52	1
(*Hemi*)*Gellius rudis*	235 G	405–407	29.27 ± 6.07	14.00 ± 1.76	86.00 ± 1.76	25.19 ± 5.31	9
	241 A	457–462	19.05 ± 5.72	10.17 ± 1.84	89.83 ± 1.84	17.09 ± 5.15	11
Hemigellius flagellifer	229 A	500–509	45.26 ± 10.04	9.99 ± 0.83	91.01 ± 0.83	41.24 ± 9.48	4
Xestospongia cf. *coralloides*	249 G	701–702	19.21	14.48	85.52	16.43	1

Table 2. Tissue composition of Antarctic hexactinellids (means ± SD). Depth values are depth at beginning and end of bottom time. A: Agassiz trawl; G: large bottom trawl; B: benthopelagic trawl

Species	Stn and trawl type	Depth (m)	DW (% WW)	AFDW (% DW)	Ash (% DW)	Ash (% WW)	n
Rossella racovitzae	248 G	599–602	41.24	4.84	95.16	38.35	1
	253 A	1996–2012	36.74	19.32	80.68	29.64	1
	256 B	382–399	31.69 ± 2.44	23.06 ± 7.14	76.94 ± 7.14	24.53 ± 4.17	5
Rossella villosa	230 A	270–280	30.63 ± 6.03	14.64 ± 1.80	85.36 ± 1.80	26.20 ± 5.46	5
Rossella fibulata	230 A	270–280	34.81 ± 5.39	19.04 ± 4.86	80.96 ± 4.86	28.43 ± 6.15	4
	281 A	389–450	22.98 ± 1.83	26.71 ± 1.47	73.29 ± 1.47	16.87 ± 1.63	6
Rossella nuda	226 G	569–574	40.03 ± 15.75	8.41 ± 1.44	91.59 ± 1.44	36.83 ± 14.99	4
	230 A	270–280	30.54 ± 6.46	18.65 ± 4.00	81.35 ± 4.00	24.96 ± 6.16	16
	281 A	389–450	25.54	25.94	74.06	18.92	1
Rossella vanhoeffeni	274 A	196–212	24.26	30.38	69.62	16.88	2
Bathydorus spinosus	258 B	484–509					
0–2 cm			25.62 ± 4.21	19.39 ± 2.19	80.61 ± 2.19	20.65 ± 3.44	11
2–4 cm			23.67 ± 4.14	23.05 ± 15.40	76.95 ± 15.40	18.33 ± 4.93	17
4–6 cm			25.49 ± 7.47	21.68 ± 3.15	78.32 ± 3.15	19.94 ± 5.91	14
8–10 cm			32.72	31.52	68.48	22.40	1
10–12 cm			25.72	24.46	75.54	19.43	1
Scolymastra joubini	281 A	389–423	20.04 ± 0.53	27.68 ± 1.39	72.32 ± 1.39	14.50 ± 0.51	4

bottom trawls, cleaned and frozen either whole or in part, depending on size. In species possessing long anchoring spicule tufts, care was taken to include these tufts. However, the specimens were torn from the bottom by the trawl and thus the whole spicule tuft may not always have been included. Visibly incomplete specimens were not included in the analysis. In the laboratory, wet weight (WW) was determined. Then, the sponges were freeze-dried and thereafter completely dried in a drying oven for 24 h at 100°C and the dry weight (DW) was measured. Ash-free dry weight (AFDW) and ash content were determined after burning the material in a muffle furnace (500°C, 24 h).

RESULTS

Tables 1 & 2 give the tissue composition of demosponges and hexactinellids respectively. The organic matter content, i.e. cellular material and organic skeleton, was low, ranging from 4.84 % in the hexactinellid *Rossella racovitzae* to 52.24 % in the demosponge *Haliclona* cf. *gaussiana*. There was no homogeneity of tissue composition within orders or even genera. A good example is the genus *Tedania*, represented by 4 species. *T. tantula* and *T. oxeata* have a hard, almost brittle consistency. Between 82.30 and 93.75 % of their dry weight consisted of inorganic skeletal material. The 2 other congeners, *T. vanhoeffeni* and *T. triraphis*, are large, soft-bodied species which exude copious quantities of slime when disturbed (Barthel & Gutt 1992). In these species the content of inorganic material varied between 66.08 and 71.37 % DW, i.e. was considerably

lower. Within any one species, tissue composition could vary between stations. Usually the variation was small and could not be related to the only known factor, depth, as can be seen from the data on the poecilosclerid *Isodictya toxophila* and the spirophorid *Tetilla leptoderma*, sampled from 6 and 5 different depths, respectively.

In most cases there was not enough material to investigate the influence of specimen size on tissue composition. This was only possible in the case of the hexactinellid *Bathydorus spinosus*, which occurred in large quantities at Stn. 258, and for this species, no systematic change of body composition with size could be found (Table 1).

The hexactinellids included in this study all had a low organic matter content, between 4.84 and 31.52 % DW. It is noteworthy that one of the highest values, 30.38 % DW, occurred in the softest of the hexactinellids, *Rossella vanhoeffeni*, a species we hardly ever found as complete specimens — only fragments — and which possesses only a negligible anchoring spicule tuft.

DISCUSSION

The data on the body composition of Antarctic sponges show that the organic matter content is, on average, rather low (below 40 %), compared with the few available data on sponges from temperate and tropical waters. The only exception is *Haliclona* cf. *gaussiana*, where the organic matter constitutes 52.24 % DW. Arndt (1930), who compiled data on 6 demosponge species from shallow temperate waters,

Table 3. Ash content of Antarctic demosponges and hexactinellids. Comparison of data from shallow water in McMurdo Sound (Dayton et al. 1974, McClintock 1987) and deeper water in the Weddell Sea. Given are means (or ranges in cases where specimens from more than 1 station were analyzed). Numbers in parentheses are number of specimens investigated

Species	Ash (% DW)		
	McMurdo Sound (Dayton et al. 1974)	McMurdo Sound (McClintock 1987)	Weddell Sea (this study)
Tetilla leptoderma	76.72 (5)	52.2 (3)	65.84 – 85.11 (48)
Cinachyra antarctica	70.26 (3)	73.0 (3)	60.33 (13)
Mycale acerata	82.88 (4)	68.2 (3)	83.20 (2)
Polymastia invaginata	85.21 (3)	–	83.99 (10)
Latrunculia apicalis	–	49.8 (3)	72.92 (5)
Isodictya erinacea	79.86 (2)	68.4 (3)	81.75 – 84.88 (18)
Rossella racovitzae	86.25 (9)	77.1 (3)	76.94 – 95.16 (7)
Rossella nuda	–	74.6 (3)	81.35 (16)

gives the following ranges for various tissue composition parameters: DW (% WW) 14.5 to 25.4; AFDW (% DW), 33.8 to 70.2; ash (% DW), 29.2 to 66.2; ash (% WW), 4.4 to 14.5. In other words, the water content is comparatively high in these species, because the content of mineral skeleton is much lower than in the Antarctic sponges investigated in the present study. It seems as if most Antarctic species are characterized by an extremely well-developed mineral skeleton and only a little living tissue. Comparison with data gathered by Dayton et al. (1974) and McClintock (1987) from McMurdo Sound, on the other side of the continent, indicates that this also holds true for other areas of the Antarctic (Table 3). While the data of the present study and those of Dayton et al. are in very good agreement, the values reported by McClintock for spicule (i.e. inorganic) content in the dry matter of sponges from virtually the same site as Dayton's are on average considerably lower. This discrepancy has not as yet been explained. In temperate areas, the tissue composition of sponges varies considerably with season and reproductive cycle (e.g. Barthel 1988), but within the slow-growing Antarctic sponges (Dayton 1979), which probably do not reproduce in a yearly rhythm, we may assume that there is no pronounced seasonal cycle such as that observable in temperate species; organic matter content in Antarctic sponges may be constantly low. Another factor to consider is the proportion of organic skeletal material (spongin, collagen) in the tissue of different sponge species. Hexactinellids contain hardly any skeletal protein (Mackie & Singla 1983). In contrast, organic skeleton can account for a large portion of the total organic sub-

stance in demosponges (for a discussion see Barthel 1993). This further reduces the amount of metabolically active tissue in the demosponge species.

The low content of metabolically active tissue in Antarctic sponges results in a low real biomass, even in habitats dominated by sponges. This implies that despite their ubiquitousness, high abundance and large volume, they may channel only a very minor fraction of the flow of matter from the pelagic to the benthic ecosystem. Recent calculations (A. Jarre-Teichmann pers. comm.) support this assumption, but we still lack biomass determinations and metabolic activity measurements to prove it.

Dayton et al. (1974) showed for the shallow water of McMurdo Sound that sponges were an important food source for a number of asteroid species and for the nudibranch Austrodoris mcmurdensis, which occurs in high abundances in the habitat. In the Weddell Sea the situation seems to be different in that large potential sponge predators are rare (Table 4). Two of the 5 asteroid species found to feed on sponges in McMurdo Sound do not occur in the eastern Weddell Sea shelf; the other 3 species are much less abundant. Equally rare are browsing and feeding marks on sponges (own obs.). The only sponge predators encountered more regularly are micropredators such as small gastropods and amphipods (Kunzmann 1992). The likely consequence is that most of the energy stored in the form of sponge tissue will ultimately enter the detrital food chain. Thus, the major influence Antarctic sponges have on their habitat is not as mediators of matter or energy flow, but as structuring agents. They add a 3-dimensional structure to an essentially flat environment, serve as habitat for a multitude of small organisms and change substratum conditions by creating a secondary hard substratum with their deposited skeletons (Barthel 1992b).

Table 4. Comparison of densities of known asteroid sponge predators in McMurdo Sound (Dayton et al. 1974) and the eastern Weddell Sea shelf (Voss 1988, own obs.)

Species	Abundance (no. per 1000 m^2)	
	McMurdo Sound	Weddell Sea shelf
Odontaster meridionalis	128 ± 19	0 – 5
Acodontaster conspicuus	56 ± 17	0 – 5
A. hodgsoni	3 ± 5	0 – 5
Perknaster fuscus antarcticus (adult)	10	Not found in area
P. fuscus antarcticus (juvenile)	~10	Not found in area

Evolutionarily, the high content of mineral skeleton and low amount of living tissue in Antarctic sponges may be a special adaptation to living in cold environments. If this is so, we have to expect similar proportionalities in sponges of Arctic waters and the deep sea.

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