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Diversity and abundance of isopod fauna associated with holdfasts of the brown alga *Himantothallus grandifolius* in Admiralty Bay, Antarctic

Karol ZEMKO, Krzysztof PABIS, Jacek SICIŃSKI
and Magdalena BŁAŻEWICZ-PASZKOWYCZ*

Zakład Biologii Polarnej i Oceanobiologii , Uniwersytet Łódzki,
ul. Banacha 12/16, 90-237 Łódź, Poland

** corresponding author <magdab@biol.uni.lodz.pl>*

Abstract: Fifteen species of isopods, representing 10 families, were recorded on holdfasts of the brown alga *Himantothallus grandifolius*. Material was collected in the 15–75 m depth range during the austral summer of 1979/80. The isopod community was dominated by *Caecognathia antarctica* (mean density 12.4 ± 13.1 ind./100 ml) followed by *Cymodocella tubicauda* (mean density 0.7 ± 2.1 ind./100 ml). Mean total density of isopods reached the value of 16.1 ± 14.0 ind./100 ml. The comparison with the other studies showed that holdfasts are inhabited by a distinctive isopod community that differs from the isopod fauna associated with soft bottom of Admiralty Bay.

Key words: Antarctic, Admiralty Bay, Isopoda, macroalgae, habitat complexity.

Introduction

Isopoda are amongst the major groups of Southern Ocean benthic fauna. There are 441 species of isopods recorded in this region (De Broyer *et al.* 2011), but many, especially from the deep sea, are still waiting for formal description (Brandt *et al*. 2007). These benthic brooders are characterized by high functional diversity, including surface deposit feeders, suspension feeders, predators and scavengers (Poore and Bruce 2012). They are an important element of the Antarctic benthic communities, both on the shelf and in the deep sea (Brandt *et al*. 2004). However, most of the previous studies of the Antarctic isopod fauna were dedicated to taxonomy, and to large scale patterns of species richness and zoogeography (*e.g.* Brandt 1990, 1992; Teodorczyk and Wagele 1994; Castello 2004; Brandt *et al*. 2005; Kaiser *et al*. 2007, 2009; Choudhury and Brandt 2009; Kaiser 2014, and references therein). There are few studies analyzing diversity and patterns of distribution at smaller scales, especially at the microhabitat level. Moreover, those studies are focused mostly on soft bottom fauna (*e.g.* Richardson and Hedgpeth 1977; Siciński *et al*. 2012).

Knowledge on the Southern Ocean benthic fauna associated with macroalgae is poor. Most of the earlier studies focused on the subantarctic (*e.g.* Arnaud 1974; Smirnov 1982; Smith and Simpson 1998, 2002) or southern tip of South America (Ojeda and Santelices 1984; Adami and Gordillo 1999; Rios *et al*. 2007). Only a few studies were dedicated to the Antarctic invertebrate fauna associated with this habitat. Until now only diversity of amphipods (Huang 2007; Martin *et al.* in press), polychaetes (Pabis and Siciński 2010), gastropods (Amsler *et al*. 2015; Martin *et al.* in press) and bivalves (Martin *et al.* in press) has been assessed.

Kelp holdfasts are considered islands on the ocean floor and provide shelter for various macro-invertebrate organisms (Thiel and Vasquez 2000; Pabis and Siciński 2010). Moreover, kelp forests have been highlighted as the most important biodiversity hotspots in the Southern Ocean (Gray 2001; Huang 2007). Detached thalli and holdfasts are also vectors for passive dispersal of benthic organisms in the Antarctic (Smith 2002; Nikula *et al*. 2010). Therefore, studies of various groups of benthic fauna, associated with different species of macroalgae, at different research sites are important not only for further understanding of the Southern Ocean benthic diversity, but also to contribute to knowledge of species distributions in the Antarctic.

Admiralty Bay, a medium sized, semi-closed glacial fjord, characterized by the presence of a large phytal zone, that covers about 30% of the bottom surface (Zieliński 1981, 1990; Furmańczyk and Zieliński 1982; Oliveira *et al.* 2009), is a model system for studies of benthic macrofauna associated with complex habitat provided by kelp. This basin was also selected as one of the best monitoring sites for the future assessment of the climate related changes in the region of the West Antarctic Peninsula (Siciński *et al.* 2011).

Our study aims to describe the isopod community associated with holdfasts of *Himantothallus grandifolius* in Admiralty Bay.

Study area

Admiralty Bay is a glacial fjord of King George Island (South Shetlands). The bay consists of a central basin and three inner fjords (Ezcurra Inlet, Martel Inlet and MacKellar Inlet). Maximum depth of the fjord reaches 550 m. Waters of Admiralty Bay are affected by high inflow of mineral suspension of glacial origin. The daily value of mineral suspension inflow during the austral summer was estimated at about 2 000 tons. The highest values (over 100 mg/dm^3) were observed during the austral summer, in the vicinity of glaciers. The lowest values, reaching 2.8 mg/dm^3, were observed during winter in the central basin (Pęcherzewski 1980).

Forty two species of macroalgae have been recorded in the Admiralty Bay. *Himantothallus grandifolius* (A. Gepp & E.S. Gepp) Zinova, 1959 and *Desmarestia anceps* Montagne, 1842 are the most common and widely distributed species (Zieliński 1981, 1990; Furmańczyk and Zieliński 1982; Oliveira *et al*. 2009). The largest phytal zone occurs in the central basin. It covers about one-third of the bottom surface in this part of the Admiralty Bay. The phytal zone extends down to about 90 m depth (Zieliński 1990).

Material and methods

Sixteen *H. grandifolius* holdfasts collected at depth range of 10–75 m were used in the analysis. Material was gathered in the summer season of 1979/1980 in the central basin of Admiralty Bay, close to *Henryk Arctowski* Station. Holdfasts were collected using various sampling gears such as bottom nets, fish pots or dredges (net mesh size from 0.1 to 0.5 cm). In the laboratory, the holdfasts were washed over a 0.5 mm sieve. On board of the ship, each holdfast was placed into a separate container. Only the holdfasts that were still partially filled with sediment and still attached to the dropstones were used for the further analysis. Therefore, possible underestimations, which may result from washing out of some individuals, were minimized. The volume of each holdfast was measured by placing it in a beaker and measuring the volume of displaced water.

Species richness (number of species per holdfast) and total density of isopods [ind./100 ml] were measured for each sample. Mean values with standard deviation were also calculated. The frequency of occurrence (F – percentage of samples where a species was found in a total number of samples), dominance (D – percentage of the individuals of a particular species in a total number of individuals) and density [ind./100 ml] was also calculated for each species. Regression analysis was used to examine the relationship between volume of holdfast and number of individuals.

Results

Fifteen species of isopods, representing 10 families (856 individuals) were found in the collected material (Table 1). The most speciose families were Munnidae (four species) and Janiridae (three species). All other families were represented only by a single species. The isopod community associated with holdfasts of *H. grandifolius* was dominated by *Caecognathia antarctica* (Fig. 1A) (F = 100%, mean density 12.4 ± 13.1 ind./100 ml) followed by *Cymodocella tubicauda* (Fig. 1B) (F = 37.5%, mean density 0.7 ± 2.1 ind./100 ml). *Munna longipoda* had relatively high density value (0.9 ind./100ml; max. density 7 ind./100ml) although its frequency of occurrence was low (18.7%). Three other species *Iathrippa sarsi*,

Table 1

Dominance (D), frequency of occurrence (F), density and total number of individuals of isopods recorded on *Himantothallus grandifolius* holdfasts in Admiralty Bay (the highest values are marked with bold).

Family/species	D [%]	F [%]	Mean density [ind./100ml] with SD	Max. density [ind./100ml] on single holdfast	Total number of individuals
Janiridae					
Austrofilius furcatus Hodgson, 1910	0.3	6.2	0.05 ± 0.2	0.8	4
Ectias turqueti Richardson, 1906	0.3	12.5	0.05 ± 0.1	0.7	8
Iathrippa sarsi (Pfeffer, 1887)	**2.4**	37.5	0.4 ± 0.8	3.1	16
Gnathiidae					
Caecognathia antarctica (Studer, 1884)	**77.1**	100	12.4 ± 13.1	47.8	697
Sphaeromatidae					
Cymodocella tubicauda Pfeffer, 1887	**4.4**	37.5	0.7 ± 2.1	8.4	29
Chaetiliidae					
Glyptonotus cf *antarcticus* Eights, 1852	0.5	6.2	0.08 ± 0.3	1.3	3
Acanthaspidiidae					
Ianthopsis nasicornis Vanhöffen, 1914	0.5	12.5	0.08 ± 0.25	1	3
Joeropsididae					
Joeropsis intermedius Nordenstam, 1933	0.5	12.5	0.09 ± 0.3	1.2	7
Limnoriidae					
Limnoria antarctica Pfeffer, 1887	**2.4**	31.2	0.3 ± 0.9	3.4	25
Munnidae					
Munna antarctica (Pfeffer, 1887)	**1.9**	37.5	0.3 ± 0.6	2.5	13
Munna jazdzewskii Teodorczyk *et* Wägele, 1994	0.3	12.5	0.05 ± 0.1	0.6	3
Munna longipoda Teodorczyk *et* Wägele, 1994	**5.8**	18.7	0.9 ± 2.2	7	24
Munna neglecta Monod, 1931	0.2	18.7	0.04 ± 0.1	0.2	3
Paramunnidae					
Pagonana rostrata (Hodgson, 1910)	0.2	6.2	0.03 ± 0.1	0.5	1
Plakarthriidae					
Plakarthrium punctatissimum (Pfeffer, 1887)	**2.6**	25.0	0.4 ± 0.9	2.6	20

Limnoria antarctica and *Munna antarctica* had relatively high frequency of occurrence (31.2–37.5%), while the same parameter for nine other species was very low and did not exceed 20%, as was also found for mean density (< 0.1 ind./100 ml).

The total number of species per holdfast was low and varied from 1 to 8. Mean species richness per holdfast was as high as 3.7 ± 1.9. Mean density of isopods reached the value of 16.1 ± 14.0 ind./100 ml, while maximal value was 48.1 ind./100 ml. Total number of individuals per holdfast varied from 1 to 308. Most of the species were represented by very low number of individuals (1 to 8 specimens) in the whole material. Moreover, five of the species (*Ectias turqueti*, *Glyptonotus* cf. *antarcticus*, *Joeropsis intermedius*, *Munna jazdzewskii* and *Pagonana rostrata*) were found only in one or two samples.

No correlation between the number of individuals and holdfast volume was indicated (Fig. 2).

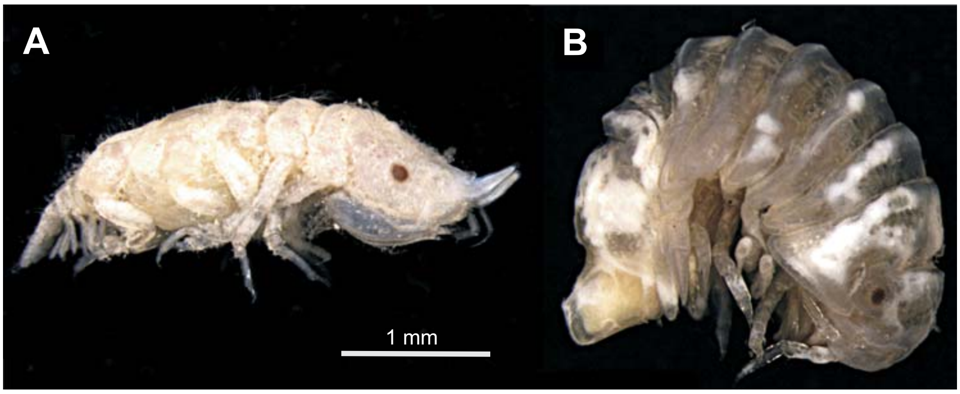

Fig. 1. *Caecognathia antarctica* (**A**) and *Cymodocella tubicauda* (**B**) in lateral view.

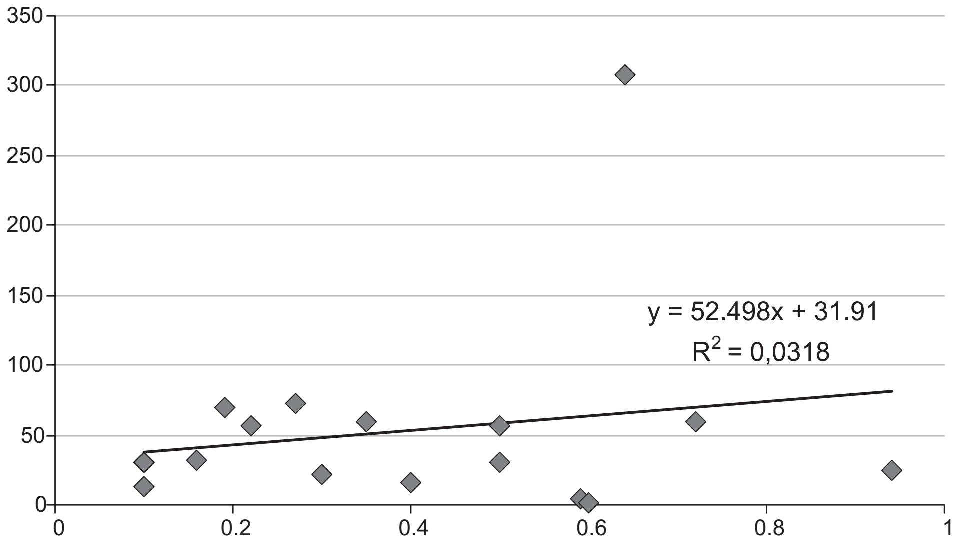

Fig. 2. Relationship between holdfast volume and number of individuals.

Discussion

The complex holdfast habitat of *H. grandifolius* (Fig. 3) of Admiralty Bay is inhabited by a unique fauna that seems to be distinctive for this habitat. Four of 15 species (*Ectias turqueti*, *Joeropsis intermedius*, *Limnoria* cf. *antarctica* and *Pagonana rostrata*) recorded in the studied material were found in this bay for the first time. Two species (*Cymodocella tubicauda* and *Plakarthrium punctatissimum*), previously known from the basin (Siciński *et al.* 2011), were recorded only on holdfasts of *H. grandifolius* and were absent on the soft bottom (Zemko, unpublished results, based on the analysis of 150 soft-bottom samples). Moreover

Caecognathia antarctica, the dominant species on holdfasts, was found in only one sample from soft bottom material that was mentioned above. Similar results were obtained in analysis of polychaete fauna associated with *H. grandifolius* holdfasts in Admiralty Bay. Species which dominated within holdfasts were almost completely absent on the surrounding soft bottom (Pabis and Siciński 2010).

Some of the isopod species recorded on *H. grandifolius* holdfasts in Admiralty Bay are probably primary associates of this habitat. This conclusion is supported by other studies. For example, an Australian species of *Plakarthrium* Chilton, 1883 was recorded on *Amphibolis* C. Agardh and *Eclonia* Kjellman holdfasts (Poore and Brandt 2001). Isopods of the genus *Limnoria* are known as typical kelp-boring species associated with holdfasts and haptera of large macroalgae (Haye *et al*. 2012). Some of the species recorded in our study were found also on holdfasts of macroalgae from other Southern Ocean sites (Table 2), including the isopods that were most frequent and/or abundant. For example *Caecognathia antarctica* was found on *H. grandifolius* holdfasts off Adelie Land and on *Macrocystis pyrifera* (Linnaeus) C. Agardh holdfasts on Kerguelen Islands (Arnaud 1974). *Limnoria antarctica* was found on *Durvillea antarctica* (Chamisso) Hariot holdfasts at Macquarie Island (Keny and Haysom (1962), while *Cymodocella tubicauda* was recorded on *H. grandifolius* holdfasts at Adelie Land (Arnaud 1974).

Table 2

Comparison of isopod species richness and composition between holdfasts of *Himantothallus grandifolius* in Admiralty Bay and thalli or/and holdfasts of *Durvillea antarctica*, *Himantothallus grandifolius* and *Macrocystis pyrifera* from various Southern Ocean sites.

Site	Species of macroalgae	Number of isopod species	Isopod species common to Admiralty Bay holdfast fauna	References
Kerguelen Islands	thalli of *M. pyrifera*	10	*Munna antarctica* *Caecognathia antarctica* *Austrofilius furcatus*	Arnaud (1974)
Kerguelen Islands	holdfasts of *D. antarctica*	Isopoda indet.	Isopoda indet.	Arnaud (1974)
Adelie Land	holdfasts of *H. grandifolius*	16	*Iathrippa sarsi* *Austrofilius furcatus* *Cymodocella tubicauda* *Caecognathia antarctica*	Arnaud (1974)
Maquarie Island	holdfasts of *D. antarctica*	8	*Limnoria antarctica*	Kenny and Haysom (1962)
Patagonian shelf	floating holdfasts of *M. pyrifera*	22	–	Smirnov (1982)
Puerto Toro (Chile)	holdfasts of *M. pyrifera*	4	–	Ojeda and Santelices (1984)
Kerguelen Islands	floating holdfasts of *M. pyrifera*	3	*Iathrippa sarsi* *Limnoria antarctica*	Edgar (1987)
Beagle Channel	thalli and holdfasts of *M. pyrifera*	4	–	Adami and Gordillo (1999)
Strait of Magellan	holdfasts of *M. pyrifera*	8	–	Rios *et al.* (2007)

Fig. 3. Holdfast of *Himantothallus grandifolius* attached to dropstone.

Those findings might suggest that floating thalli and holdfasts drifting with the Antarctic Circumpolar Current are also an important vector for isopod dispersion, as has been demonstrated for other invertebrates, such as the case of long distance (2000 km) dispersal of the bivalve *Gaimardia trapesina* (Helmuth *et al*. 1994). Kelp-boring isopods of the genus *Limnoria* are known from their abilities for passive migration (Miranda and Thiel 2008; Nikula *et al*. 2010). Moreover, other isopods were also found on drifting *Macrocystis pyrifera* holdfasts around Kerguelen Islands and two of them, *L. antarctica* and *Iathrippa sarsi* (Edgar 1987), were also recorded in our study. Kelp rafts were also possible vector of dispersion for serolid isopods in the Southern Ocean (Leese *et al.* 2010).

Macrocystis pyrifera is known as a major kelp vector for fauna transportation in the Southern Ocean (Smith 2002), although other macroalgae might be also important in passive dispersal (Nikula *et al*. 2010). Floating thalli and holdfasts of *H. grandifolius* were observed (Siciński personal observations), but there is no data about the fauna associated with its drifting holdfasts. It is worth mentioning that some isopods, *e.g. Caecognathia antarctica,* might be associated not only with macroalgae but, in general, with the other complex biogenic habitats, like colonies of sponges (Hadfield, unpublished results).

The number of species found on *H. grandifolius* holdfasts in Admiralty Bay was relatively high if compared with results of the other studies done in the Southern Ocean (Table 2). However, this result differs significantly from the analysis of polychaete diversity that was based on the same set of samples (Pabis and Siciński 2010). Almost 80 species of polychaetes were found on 19 holdfasts. This constitutes one half of the polychaete species recorded in Admiralty Bay. With 99 species recorded (Siciński *et al*. 2011; Zemko personal communication) isopods are the third most speciose group of macroinvertebrates in this basin, following amphipods (172 species) and polychaetes (162 species). This disproportion between the number of isopod species recorded on holdfast and total number of isopod species found in Admiralty Bay is somewhat unexpected, especially taking into account general opinion that complex biogenic structure can provide a shelter from predation and disturbance events, resulting in high diversity of associated fauna (Almany 2004; Hereu et al. 2005). Patterns showing a positive correlation between the number of species and degree of branching were also found for fauna associated with macroalgae (Chemello and Milazzo 2002).

It is possible that the disproportion is caused by chemical defenses provided by Antarctic macroalgae, including *H. grandifolius*, through the production of lipophilic and hydrophilic extracts that are designed to deter herbivores, especially amphipods and fishes (Amsler *et al*. 2008). Chemical defenses have been found to influence abundance and species richness of amphipods associated with different macroalgae in the Antarctic Peninsula region (Huang *et al*. 2007). On the other hand, chemical defenses against omnivorous fishes may provide a suitable refuge from predation for various kelp-associated invertebrates (Huang *et al*. 2007; Amsler *et al*. 2014).

We did not detect a correlation between a holdfast volume and isopod abundance as has been demonstrated in previous studies, where a positive correlation between the holdfast volume and number of individuals was observed (Ojeda and Santelices 1984; Thiel and Vasquez 2000). A similar pattern was also demonstrated for the polychaete fauna associated with *H. grandifolius* holdfasts in Admiralty Bay (Pabis and Sicinski 2010), although Anderson *et al.* (2005) showed that it may differ depending on the taxonomic group studied. On the other hand our results might be to some point associated with low sampling effort and collecting method which could have caused some underestimation of abundance. However, it is impossible to collect large size *H. grandifolius* associated with the deeper part of the Antarctic sublittoral by deploying quantitative sampling methods that are used for studies of other macroalgae (Amsler 2014).

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