Biodiversity and zoogeography of the Isopoda (Crustacea: Malacostraca) from the Victoria Land Coast, Ross Sea, Antarctica

Dissertation

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Summary

The aim of this thesis is to gain strong insights into the biodiversity of the isopod fauna and their zoogeography of the deeper shelf (100 - 500 m depth) off the Victoria-Land coast in the Ross Sea.

The study is based on benthic material obtained during the 19th *Italica* expedition along the Victoria-Land coast. This expedition took place in February 2004 and was the first campaign within the framework of the international and multidisciplinary *Victoria-Land Latitudinal Gradient Project*. It was also the first expedition using a Rauschert dredge, a gear with a small mesh size (500 μ m), in this area. The main sampling was performed at four study sites along a latitudinal (north to south) gradient off the Victoria land coast, i.e. at Cape Adare, Cape Hallett, Coulman Island and Cape Russell. Based on these macrobenthic data the taxa Isopoda was used as a model group to investigate and analyse diversity and zoogeographic patterns on different aspects and applying multiple methods.

This thesis comprises 6 chapters, starting with the investigation of higher taxonomic levels (i.e. isopod sub-orders and families) then shifting to species level to examine diversity and distribution patterns as well as taxonomic relatedness of species in the samples and finally describing new species from the material.

In **chapter 1** a first overview of the composition of isopod families, their abundances and distribution is given. In total, 19 isopod families were represented in the material, ten of which belonging to the sub-order Asellota. The most interesting results was that serolids were absent from the samples, though this family is known to be numerous on the Antarctic shelf. Desmosomatidae represented the most dominant family, yet their abundance differed strikingly between stations. While they were, for example, completely absent from Cape Adare, the northernmost study location, desmosomatids were highly abundant at Cape Russell, the southernmost site. Furthermore, the abundances of the five most common families (Paramunnidae, Munnopsidae, Munnidae, Janiridae and Desmosomatidae) were compared to their biomasses. Here, the Munnidae showed very low biomasses at all sites, compared to their abundance. Additionally, the faunal similarity of the composition of isopod families was investigated, which revealed that the similarity among the different stations reflected their geographical distance. **Chapter 2** focuses on the biodiversity, species richness and similarity in isopod species composition of the *Italica* samples. Different diversity and similarity measures and indices (e.g. Shannon H' and Rarefraction diversity methods, Bray-Curtis and Cosine similarity) were applied to the data set and the usefulness of each of the methods was discussed. The highest diversity was measured at Cape Hallett, lowest at Cape Russell; here both diversity measurements used (i.e. Shannon H' and Rarefraction) are in good agreement and showing the same result. The typical broad-scale factors like depth and latitude did not seem to be strong determinants of the isopod assemblages of the Victoria-Land coast., while sediment characteristics might have relatively strong influence on the diversity there. Using Bray-Curtis and Cosine similarity indices respectively, similarity analyses showed strong differences between both computed nMDS plots. Difference were most striking for stations yielding very low numbers of individuals. This might be due to the high emphasis the Bray-Curtis index assigns to the abundance data, whereas the cosine similarity does not put too much weight on this.

Based on the *Italica* material as well as data compiled from literature **chapter 3** provides an isopod species inventory for the Ross Sea and puts this data into a broader (Southern Ocean) context. One of the most striking findings, that examination of relatively few dredge samples nearly tripled the number of isopod species know for the Ross Sea, from previously 42 to 117 species. Of these 117 species nearly 50% were new to science and most of these currently undescribed species belong to the Paramunnidae. Moreover, the zoogeography and the depth distribution of these 117 species were examined. Therefore the SO was divided into 15 biogeographic regions. The analysis showed a high similarity between the Patagonian Shelf and the Falkland Islands while the area defined as High Antarctic region grouped more closely, meaning that these regions showing a similar faunal pattern. Interestingly, the analysis of the depth distribution showed that "typical" deep-sea families (i.e. desmosomatids and munnopsids) were both rich and abundant in relatively shallow waters (200-300 m). This might be explained by ice advance around Antarctica which might have facilitated faunal bathymetric shifts and thus led to a highly eurybathic fauna

In **chapter 4** a different approach has been applied to analyse the diversity of the isopod fauna in relation to their taxonomic distinctness. It summarizes the pattern of relatedness of taxa in a sample and considers presence and absence data only. Using taxonomic distinctness

enables to test whether the species of the four study sites and each station are representative of the biodiversity expressed in the species inventory list from chapter 3.

To test this a 95% probability average taxonomic distinctness (AvTD) funnel was simulated, in which ideally all stations/sites should fall. However, the results revealed that only three stations and the Cape Adare site were falling into the expected range of the average taxonomic distinctness; the other regions and stations fell significantly below the 95% probability funnel, which means that the species of the samples/study sites do not represent the biodiversity of the Ross Sea. The taxa which contributed to this pattern were the Sphaeromatoidea, being only represented at Cape Adare, but absent in all other sites. As most stations/study sites are outside of the expected (AvTD) funnel, it might also indicate a loss of biodiversity for the region. However the latter suggestion is most unlikely, as a second taxonomic distinctness measure, the variation of taxonomic distinctness shows that all stations and sites are within the expected variation.

As shown in chapters 2 and 3 the paramunnids were the most speciose family in the Ross Sea samples with a high proportion of species being new to science. In **chapter 5** a new genus (*Holodentata*) is described which comprises the description of two new species: *H. triangulata* from the Ross Sea shelf and *H. cacea* from the deep Weddell Sea. Finally in **chapter 6** another common paramunnid species *Coulmannia rossiae* is described from the Ross Sea.

General Introduction

The first substantial benthic sampling in the Southern Ocean (SO) was performed by the staff of the *HMS Challenger* (1872-1876). The main purpose of this cruise was to complete an inventory of the world's ocean fauna and through the strong emphasis on taxonomy a lot of new descriptions came up. Many other expeditions followed in order to enlarge the knowledge about the isolated continent and the surrounding waters. During the first half of the 20th century the discovery phase continued with establishing Antarctic stations ashore, and work there focusing on life history and behaviour of the benthic fauna in shallow waters.

To date, many parts of the Antarctic continental shelf have been reasonably well sampled, particularly in the Atlantic sector of the Southern Ocean,, however gaps remain in some particular areas (e.g. the Bellingshausen and Amundsen Sea). The benthos of the Ross Sea shelf and coastal areas was first studied in the late 1960s, mainly by New Zealand scientists (Dearborn 1967, Lowry 1975), whose investigations primarily focused on few groups (e.g. amphipods and polychaetes). Some extensive studies were conducted around McMurdo Sound and Terra Nova Bay concentrating on very shallow depth down to about 60 m (Arntz et al. 1994, Gambi et al. 1997, Cattaneo-Vietti et al. 1999, Cattaneo-Vietti et al. 2000). The few investigations on the isopod fauna in the Ross Sea are nearly a century old (Hodgson 1910, Vanhoeffen 1914). Yet, most of these studies were conducted either by scuba diving or using large mesh sizes. Therefore the small benthic epi- and macrofauna in this area is still highly under-sampled.

The Victoria Land Latitudinal Gradient Project, conducted within the framework of New Zealand, Italian and United States Antarctic programs, aims to assess the dynamics and coupling of marine and terrestrial ecosystem in relation to global climate variability along the Victoria-Land coast. In February 2004 the Italian research vessel *Italica* visited a number of locations along the Victoria-Land coast with the aim to characterise and quantify changes in benthic communities and water column processes. The current study investigates isopod material from this expedition. To the author's knowledge this expedition was the first one in this area using a gear with small mesh size (500µm), the Rauschert dredge, along a latitudinal transect and a depth gradient. Thus, these samples will give first insights into the composition and diversity of the isopods from the Ross Sea shelf.

The Southern Ocean and the Ross Sea

The break-up of Gondwana was initiated by the separation of the Indian subcontinent app. 155 million years (Ma) ago. New models of the Indian-Antarctic spreading system indicate the beginning of the break up about 130 Ma ago (Brown et al. 2006). Africa was the next continent that separated from Antarctica about 90 Ma ago (Lawver et al. 1992, Brown et al. 2006). At this time the first break-up between Australia and Antarctica started which initiated a deep-water current around East Antarctica and was almost completed about 55-35 Ma ago (Brown et al. 2006). The northward movement of Australia might also led to a successive cooling and glaciations of East Antarctica (Huber and Watkins 1992). The complete development of the circum-Antarctic current/Antarctic circumpolar current (ACC) was developed, after the separation of South America and the opening of the Scotia Sea approximately 32-24 Ma ago (Thomson 2004). The inception of the circum-Antarctic current could have resulted in further cooling of the SO (Clarke and Crame 1989, Lawver and Gahagan 1998, 2003). Nevertheless, DeConte and Pollard (2003) argued that the climatic decline and Cenozoic glaciations of Antarctica might also be a result of declining atmospheric CO₂ levels.

The Antarctic circumpolar current is a deep-water circulation, driven by west winds and represents the largest current system in the world contributing largely to the global heat distribution (Fahrbach 1995). The Polar Front, the ACCs strongest jet, thereby represents a strong thermal barrier for pelagic and benthic (shelf) organisms and defines the natural boundaries of the SO (Clarke 1990). It probably caused the development of a highly endemic fauna and might also be responsible (among other things) for the speciation and radiation of some SO taxa, such as notothenioid fish and peracarid crustaceans (Brandt 1999, Clarke and Johnston 1996, Eastman 2000).

Much of the SO overlies deep seafloor and relatively little of the sea-bed is continental shelf. Much of the shelf is quite deep as a result of scouring from ice shelves during last glacial maxima and depression by the enormous continental ice-sheets (Clarke 1996, Clarke and Johnston 2003). The average depth of the continental shelves around Antarctica is over 450 m deep and at some places they extend over 1000 m depth (Clarke et al. 2007). In some areas around Antarctica the shelves are quite narrow (Dronning Maud), however in others places the shelf can reach width of 125 km e.g. in the Ross- and Weddell Seas. Yet, both high Antarctic continental shelves are covered by floating ice shelves year-round.



Fig. 1: Map of Antarctica and the Southern Ocean, surrounded by the thin line; Map created with Ocean Data View.

The Ross Sea belongs to the Pacific sector of the SO and forms a triangular embayment in the Antarctic continent. It is a wide continental shelf which is located around 158°W and 170°E and is bounded by Cape Adare in the West and by Cape Colbek in the East. The southern boundary is the Ross Ice Shelf at around 78°S. The Ross Sea continental shelf is a unique region of the Antarctic. It is the largest continental shelf region in the Antarctic and remains relatively deep (mean depth is approximately 500 m). The shelf break occurs at about 800 m, with the slope extending to 3000 metres. The currents are characterized by a gyre like circulation, which also extend under the ice shelf (Smith et al. 2007) and are coherent throughout the entire water column. The deep canyons at the shelf break affect the deep circulation and facilitate intrusions of Circumpolar Deep Water onto the shelf (Smith et al. 2007). The Ross Sea's oceanography is mainly dominated by the Ross Sea polynya. In winter the polynya is formed by strong winds from the south, which advect ice to the north. Smaller polynyas also occur along the Victoria Land coast (Jacobs and Comiso 1989).

It is also an area of large phytoplankton blooms that begin in early summer in the polynya close to the Ross Sea Ice-Shelf and expand northwards. The Ross Sea continental shelf is characterized by a rather irregular morphology due to glacial erosion and deposition during the Cenozoic. The present-day sedimentation represents terrigenous inputs of glaciers and accumulation of biogenic material (Brambati et al. 2000). Towards the external margin of the Ross Sea Shelf, close to Cape Adare, the sediments are characterized by a high calcareous biogenic component. Throughout the sediment cores calcareous fragments were present.

Antarctic Isopoda

Isopod crustaceans represent an important component of Southern Ocean benthic macrofauna in terms of both, richness and abundance (Brandt 1999, De Broyer et al. 2003) contributing largely to the overall Antarctic biodiversity (Brandt 1999, Clarke and Johnston 2003). Isopoda in particular thrive in the SO (Holme 1962, Brandt et al. 2004) and display a broad variety of lifestyles, which range from swimming taxa to bottom dwellers (Hessler and Strömberg 1989). There are several common isopod families on the Antarctic shelf e.g. Serolidae, Antarcturidae, Idoteidae and Sphaeromatidae, while most genera of the superfamily Janiroidea (the marine Asellota) are very numerous in the Antarctic deeper waters (Wilson and Hessler 1987).

The origin of the Antarctic isopods is still unclear, as there are no fossil records found in the SO yet. Kussakin (1973) hypothesized that the Antarctic fauna is younger than the tropical isopod fauna; some isopod taxa can demonstrate this assumption, such as Sphaeromatidae, the munnoid Janiroidea and the Acanthaspididae (i.e. showing polar submergence see Brandt 1991). However, species derived from the families Munnopsidae, Desmosomatidae and Ischnomesidae most probably colonized the Antarctic continental shelf from the deeper waters (polar emergence, Wilson 1983); though the colonization of the deep sea remains unclear. Several authors (Brandt 1991, 2000, Thatje et al. 2005) proposed three ways of how the Antarctic shelf fauna might have survived during the last glacial period and had such a diverse development: (i) one possibility is that species migrated into the deep sea or further north and re-colonized the shelf from there during the interglacials; (ii) during the glacial periods, isolated shelters remained ice-free on the shelf (diachronous deglaciation), so that benthic animals migrated from one shelter to the next (Thatje et al. 2005); (iii) finally, species could have survived in refuges on the shelf (e.g. Thiel Trough, see Brandt 1991). The latter would explain high diversity of some taxa on the shelf i.e. retreat and expansion of ice sheets might have facilitated allopatric speciation in some species (e.g. fish) but maybe also explain cryptic speciation in e.g. isopods (Held 2003, Held and Wägele 2005).

The Antarctic isopods are relatively divers with a high number of species and a high degree of most certainly "endemic" species, especially in the deep waters of the Atlantic sector of the SO (Brandt et al. 2007). The extinction of many decapod crustaceans in the mid Miocene (about 15 Ma) may have allowed the Peracarida to occupy the left ecological niches and led to their evolutionary success in the Southern Ocean (e.g. Feldman et al. 1993, Brandt 1991, 2000). De Broyer and Jazdzewski (1996) and De Broyer et al. (2003) explained the high diversity of Antarctic benthic Peracarida by the following factors:

- Long evolutionary history of the isolated environment
- Habitat heterogeneity partly caused by iceberg drop stones
- Low dispersal potential due to the fact that Peracarida possess a brooding pouch and lack free spawning larvae
- The limited mobility of bottom dwelling peracarids
- Extinction of Decapoda, especially of brachyuran crabs, during the Tertiary cooling of the SO, which left ecological niches vacant for peracarid crustaceans

Aims and Questions

The aim of this thesis is to describe and interpret patterns of diversity and faunal composition in isopods obtained during the 19th *Italica* expedition to the northern Victoria Land Coast. On this particular background the scientific questions and aims are as follows:

- To document patterns in the current isopod composition of the northern Victoria Land coast. How many isopod families and species are there?
- To analyse the biodiversity and faunal similarity of the Ross Sea isopod species using different diversity measurements.
- To document and analyse the zoogeography of all currently known isopod species from the Ross Sea.

- To evaluate the taxonomic distinctness of the isopod species at the four study sites and all stations against the full species inventory of the Ross Sea.
- To describe a new paramunnid genus including two new species within this genus from differing high Antarctic regions, i.e. the Weddell and the Ross Sea; and a new species of the paramunnid genus Coulmannia.

Sampling

The 19th Italian expedition of RV *Italica*, carried out in February 2004, was the first large scale- attempt to collect samples along the northern Victoria-Land Coast systematically from Cape Adare (71°S) down to Terra Nova Bay (74°S) (Fig. 2). This expedition was the first campaign within the framework of the international and multidisciplinary Victoria-Land Latitudinal Gradient Project (Berkman et al. 2005).



Fig. 2: Victoria-Land coast, Ross Sea, Antarctica; study sites: Cape Adare, Cape Hallett, Coulman Island and Cape Russell

The study sites are composed of four different locations: Cape Adare (stations A1-A5), Cape Hallett (stations: outer transect H out 1, 2 & 4, inner transect H in 2, 3, 5), Coulman Island (stations C1-C2) and Cape Russell (stations SMN, R2, 3 & 4) (Table 1). In total 18 stations were sampled along the Victoria-Land Coast. The depth range of the stations extends from 84 m to 515 m.

Station	Pc	osition	Depth [m]	Haul length [m]
	Latitude [S] Longitude [E			
Cape Adare				
A1	71°15.5'	170°41.9'	515	358
A2	71°17.3'	170°39.2'	421	298
A3	71°18.7'	170°29.2'	305	257
A4	71°18.4'	170°28.9'	230	376
A5	71°18.7'	170°25.5'	119	59
Cape Hallet				
H out 1	72°15.7'	170°24.8'	458	375
H out 2	72°17.5'	170°29.4'	353	375
H out 4	72°18.5'	170°26.8'	235	194
H in 2	72°16.9'	170°12.2'	391	186
H in 3	72°17.0'	170°13.1'	316	194
H in 4	72°17.1'	170°14.0'	196	169
H in 5	72°17.2'	170°17.9'	84	113
Coulman Island				
C1	73°24.5'	170°23.2'	474	375
C2	73°22.7'	170°06.9'	410	153
Cape Russell				
SMN	74°43.2'	164°13.1'	366	192
R2	74°49.0'	164°18.1'	364	575
R3	74°49.3'	164°11.5'	330	565
R4	74°49.3'	164°11.5'	208	97

Table 1: Station list of Rauschert dredge samples from the expedition of RV *Italica*, H out = transect outside of Cape Hallet Bay, H in = transect inside Cape Hallet Bay, SMN = Santa Maria Novella (Terra Nova Bay)

During the 19th *Italica* expedition in the Ross Sea samples were obtained by means of a Rauschert dredge. The Rauschert dredge is a semi-quantitative sledge which was designed to collect relatively small epibenthic animals. The Rauschert dredge (Fig. 3) consists of a steel frame and a set of three nets: a small net with a wide (1.5 cm) mesh size, which holds back large stones or megafauna; the actual sampling net with a mesh size of 500 μ m and the third net with a mesh size of 1 cm, which protects the main net from damage (Stransky 2008). The Rauschert dredge was hauled over the ground at a mean velocity of 1 knot. Haul length varied from 59 m to 575 m (Rehm et al. 2006).



Fig. 3. Rauschert dredge, photograph from: Henri Robert, Royal Belgian Institute for Natural Sciences

On deck, all samples were immediately sieved through a 500 μ m screen. All samples were fixed in 90% pre-cooled ethanol and kept at -25° C for at least 48 hours before sorting to ensure proper fixation for DNA extraction. Isopod specimens were partly sorted on board or later in the Zoological Museum of the University of Hamburg.

Biodiversity and similarity analysis

In the present study two different methods are used to measure biodiversity:

- Hurlbert's (1971) modification of Sanders (1968) rarefaction method was used. This methodology was applied to benthic marine samples (Sanders 1968) and allows to compare samples of differing sizes as in the present study. It is a graphical method, where the number of species is applied against the number of individuals. The goal is to determine the "expected number of species" at a certain number of individuals.
- Diversity was measured using species richness (S), abundance (N), the Shannon–Wiener index (H') (log base) and eveness (J'). The Shannon-Wiener index describes the diversity of a location and it takes into account the degree of evenness in species abundances. The increase of the diversity might result either of an increase of the number of species or the increase of the evenness.

For similarity analysis a similarity matrix was constructed using the Bray-Curtis coefficient (Bray and Curtis 1957) as well as Cosine similarity (Pfeifer et al. 1998). For better comparison of the two indices the data was not transformed prior to the similarity analysis. The results were then displayed by non-metric multidimensional scaling (nMDS).

The univariate measurements of diversity are implemented in the PRIMER package, described in Clarke and Warwick (2001). Multivariate measurements, such as nMDS was also carried out with the software package PRIMER version 6 (Clarke and Gorley 2006); for the cosine index the similarity matrix was calculated with the software package PAST (Ryan et al. 1995).

Zoogeography

For the zoogeographic analysis of the Isopoda from the Ross Sea the monograph of Brandt (1991) was used as the starting point of this study. Extensive searches of literature after 1991 were undertaken to locate newly described species from the Southern Ocean and the Ross Sea. Also the material of the 19th *Italica* expedition served to investigate the zoogeography of the Ross Sea Isopoda. The biogeographic regions for the Ross Sea Ispoda are defined in chapter 3. For faunal similarity analysis between biogeographic regions the Bray-Curtis coefficient (Bray and Curtis 1957) was used. The results were displayed in a two dimensional cluster analysis and a nonmetric-multidimensional scaling (MDS). The measurements are implemented in the PRIMER package version 6 (Clarke and Gorley 2006), described in Clarke and Warwick (2001). Further details are described in chapter 3.

Taxonomic distinctness

The taxonomic distinctness is an average (AvTD) path length between two randomly chosen individuals, conditional on them being from different species. A master list of all known isopod species from the Ross Sea (aggregation file) was constructed after Choudhury and Brandt (in press 2009) using 5 taxonomic levels (order, sub-order, family, genus and species). Following Warwick and Clarke (1995) the simplest form of distances was adopted for the 5 taxonomic levels. The sample data of the 19th *Italica* expedition was reduced to presence/absence and a significance test on each sample and study site is carried out. The test is based on the theoretical mean and variance of the AvTD, values are randomly obtained for each sample from the species master list. The variance naturally increases with decreasing species, therefore the 96% confidence intervals take a form of a "funnel". The values of AvTD for any sample or study site can be related to this funnel; assuming that each sample or study site is random selection of the master list, and therefore should fall in the confidence

funnel. These measures are implemented in the PRIMER package, described by Clarke and Warwick (2001). For further details please see chapter 4.

Taxonomy

Isopod specimens were sorted and identified to species level. Since the material contained a relatively high number of new species, species were provisionally numbered and characterized, until complete and proper description.

The new paramunnid genus and species described in here, were identified using a Carl Zeiss (Axioskop 2) compound microscope equipped with a camera lucida. For SEM photographs were taken with a Leo 1525 microscope. The length of the head, the pereonites, free pleonite and pleotelson, and the total length of the body, were all estimated along the mid-dorsal line. The width of the head was measured between the tips of the eyestalks. The lengths of the articles of the appendages were taken according Hessler (1970). Further details are described in chapter 5.

Chapter 1

Composition and distribution of isopod families from the Ross Sea

Key words: Ross Sea, Victoria-Land Coast, Peracarida, Isopoda, distribution, composition

Abstract

The benthic fauna off the Victoria-Land-Coast, Ross Sea (Antarctica) was investigated during the 19th *Italica* expedition in February 2004. Samples were taken along a latitudinal transect from Cape Adare down to Terra Nova Bay at water depths ranging from 84 m to 515 m. A Rauschert dredge was used at 18 stations to collect epi- and infaunal macrobenthos. 9494 specimens of Isopoda were collected, representing 19 families. Desmosomatidae were the most abundant family (35297 ind/1000 m²), followed by Paramunnidae (23973 ind/1000 m²). Paramunnidae was the most frequent taxon and was collected at all stations, in contrast to the Desmosomatidae, which did not occur at any station off Cape Adare.

Introduction

The order Isopoda (Crustacea, Malacostraca) is highly abundant and speciose in costal waters of the Southern Ocean (Kussakin 1967, Brandt 1991). Yet knowledge of the isopod fauna along the Victoria-Land Coast is limited and sampling was mainly performed in the McMurdo Sound (Waterhouse 2001). The first studies on benthic communities of the Ross Sea were done by Zaneveld (1966a, 1966b), who worked on marine algae of the Ross Sea. A first systematic classification of benthic communities was provided by Bullivant (1967a, 1967b) and Dearborn (1967), whose investigations focused on amphipods and polychaetes. Further investigations were carried out by several authors (Dayton et al. 1970, 1972, Gambi et al. 1997, Knox and Cameron 1998, Cattaneo-Vietti et al. 1999, Cattaneo-Vietti et al. 2000) but always around McMurdo Sound or Terra Nova Bay and their work was focussed on other taxa, such as molluscs, polychaetes and sponges.

The 19th Italian expedition of RV *Italica*, carried out in February 2004, was the first large scale- attempt to collect samples along the northern Victoria-Land Coast systematically from Cape Adare (71°S) down to Terra Nova Bay (74°S). This expedition was the first campaign within the framework of the international and multidisciplinary Victoria-Land Latitudinal Gradient Project (Berkman et al. 2005). To our knowledge this expedition was the first one in this area using a gear with small mesh size (500 μ m), the Rauschert dredge, along a latitudinal transect and a depth gradient. During this cruise, 47871 specimens of Peracarida were collected (Rehm et al. 2006). Out of these 9494 belonged to the order Isopoda.

The objectives of this paper are to analyse the abundance, presence and absence of families of isopods collected off the northern Victoria-Land Coast, to describe their depth distribution between 84 - 515 m depth and to compare the different study sites with the lifestyles of the isopods.

Material and Methods

The present investigation is based on material collected with a Rauschert dredge in February 2004 in the Ross Sea aboard RV "*Italica*" during the 19th Italian expedition (Table 1). The samples were taken along a latitudinal transect between Cape Adare and Cape Russell and along a depth gradient between 84 m-515 m. The study sites are composed of four different locations: Cape Adare (stations A1-A5), Cape Hallett (stations: outer transect H out 1, 2 & 4, inner transect H in 2, 3, 5), Coulman Island (stations C1-C2) and Cape Russell (stations SMN, R2, 3 & 4) (Fig. 1). The Rauschert dredge has an opening of 0.5 m and a sampling net with a mesh size of 500 μ m (Lörz et al. 1999). It was hauled over the ground at a mean velocity of 1 knot (1.852 m/h). As the haul distances varied (Table 1), densities were calculated for a standardized 1000 m haul.

On deck, the complete samples were immediately sieved through a 500 µm screen and transferred into pre-cooled 90% ethanol and kept at least for 48 hours at -25°C for later DNA extraction. Biomass is given as ash free dry mass (AFDM) calculated from the wet mass (WM) using conversion factors according by Brey (2001).

For similarity analysis a similarity matrix was constructed using the Bray-Curtis coefficient (Bray and Curtis, 1957). The results were then displayed by nonmetric multidimensional scaling (MDS). The univariate measurements are implemented in the PRIMER package version 6 (Clarke and Gorley 2006) and described in Clarke and Warwick (2001).

Results

Among all peracarid crustaceans of the Rauschert dredge samples, the isopods were the second largest group comprising 23% (Fig. 4 after Rehm et al. 2006).



Fig. 4: Relative abundance of Peracarida from the Rauschert dredge in percent (after Rehm et al. 2006)

The number of isopod specimens collected was 9494, belonging to 19 families. The number of individuals was standardized to 1000 m² trawled distance for comparison of the stations. The isopod abundances ranged between hauls ranging from 95 to over 22,320 ind/1000m² (Table 2). The highest abundance was found at Cape Russell (R2) with a total number of 22320 ind/1000m². But also at shallow stations at Cape Hallett (H in 4, H in 5) the abundances were extremely high (H in 4: 17,147 ind/1000 m² and H in 5, 16226.4 ind/1000 m²), the lowest abundance was reported from station A1 at Cape Adare. Most families were rare and occurred only with few specimens. The Asellota were clearly dominating the samples. Desmosomatidae was the most abundant family (35297 ind/1000 m²) followed by Paramunnidae (23973 ind/1000 m²), Munnidae (14857 ind/1000 m²) and Janiridae (10484 ind/1000 m²). Paramunnidae was the only family being collected at all stations and depths. Munnidae, Janiridae and Gnathiidae were also frequently sampled but not at every station (Table 2).

Area		C	APE ADA	RE				CA	PE HAL	LET			COU ISI	LMAN AND	C	CAPE RU	JSSELL	r	TOTAL
Station	A1	A2	A3	A4	A5	H out	H out	H out	H in 2	H in 3	H in 4	H in 5	C1	C2	SMN	R2	R3	R4	
						1	2	4											
Depth [m]	515	421	305	230	119	458	353	235	391	316	196	84	474	410	366	364	330	208	
Taxa																			
Acanthaspidiidae	-	47.0	7′	37.2	-	-	167	371.1	-	41.2	11.8	230.1	-	13.1	-	-	-	-	979.5
Antarcturidae	44.7	-	-	-	67.7	-	37.3	72.2	-	41.2	-	477.9	26.7	248.4	156.3	34.8	10.6	-	1217.8
Bopyridae	-	53.7	62.3	53.2	-	101.3	-	195.9	-	82.5	355	123.9	-	91.5	135.4	-	-	-	1254.7
Chaetiliidae	-	-	-	-	-	-	-	-	-	-	-	17.7	-	-	-	-	-	-	17.7
Cirolanidae	5.6	80.5	7.8	-	271.2	-	-	-	-	-	-	-	-	-	31.3	20.9	-	-	417.3
Desmosomatidae	-	-	-	-	-	170.8	5.3	-	1070.1	804.1	863.9	141.6	80	3916	4885.4	21600	1430.1	329.9	35297.2
Exparanthuridae	-	-	194.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	194.6
Gnathiidae	-	134.2	264.6	319.2	339	85.3	165.3	618.6	107.5	463.9	615.4	2070.8	42.7	2952.2	260.4	97.4	49.6	61.9	8648.0
Haploniscidae	-	13.4	-	-	-	-	5.3	-	-	-	-	-	-	-	-	-	-	-	18.7
Idoteidae	-	-	-	-	-	-	-	20.6	-	144.3	-	70.8	-	78.4	-	-	-	-	314.1
Janiridae	11.2	255.0	653.7	1728.7	372.9	69.3	202.8	1195.9	107.5	597.9	1301.8	3646	21.3	209.2	41.7	69.6	3.5	-	10484.5
Janirellidae	-	6.7	-	-	-	10.8	192	1680.4	10.8	-	11.8	370.1	-	-	-	-	-	-	2282.6
Joeropsidae	-	26.9	241.3	574.5	-	10.8	32	154.6	-	61.9	307.7	743.4	-	-	-	-	-	-	2153.1
Microparasellidae	-	-	-	-	-	5.3	-	-	-	-	-	-	-	-	-	-	-	-	5.3
Munnidae	22.4	147.7	124.5	154.3	135.6	208	197.3	2536.1	107.5	619.6	4544.4	4761.1	-	352.9	531.3	139.1	28.3	247.4	14857.5
Munnopsidae	-	40.3	-	47.0	101.7	842.8	362.8	1329.9	86	432.9	473.4	814.2	16	522.9	4187.5	219.1	244.2	-	9720.8
Paramunnidae	11.2	295.3	2871.6	2558.5	711.9	138.8	224	2752.6	172	1309.2	8662.7	2389.4	5.3	444.4	1020.8	139.1	60.2	206.2	23973.2
Paranthuridae	-	26.9	-	26.7	-	-	-	61.9	10.8	30.9	-	370.1	-	104.6	-	-	-	-	631.9
Santiidae	-	26.9	241.3	-	339	-	26.8	51.5	-	-	-	-	-	-	-	-	-	-	1024.3
Sphaeromatidae	-	-	-	-	-	-	-	-	-	20.6	-	-	-	-	-	-	-	-	20.6
Sum	94.9	1154.3	4669.3	5500	2338.9	1642.8	1626.8	11041.2	1772.2	4649.5	17147.9	16226.4	192	8836.6	11250	22320	1826.5	845.4	

Table 2: Abundance of isopod families per station, standardized to 1000 m² hauls

The Janiridae, Munnidae and Paramunnidae were mainly sampled at depths between 84 m - 300 m. Desmosomatidae, however, occurred predominantly at deeper stations (200 m- 474 m). Higher abundances of Munnopsidae were also found at stations around 350 m (SMN, H out 2). The Munnidae occurred mainly at shallower stations (84 - 235 m) and deeper stations between 421 m to 515 m, while are rare at intermediate depth, between 300 m to 400 m (Fig. 5).



🗖 Desmosomatidae 🖾 Munnidae 🖾 Janiridae 🗖 Paramunnidae 🗖 Munnopsidae

Fig. 5: Relative abundance of five isopod families, stations ordered according to depth

Figure 6a shows the relative abundance of the five most frequent families at the four different study areas (Gnathiidae were not included, as these are ectoparasites and most individuals sampled were larvae). The Desmosomatidae were completely absent at any station of Cape Adare, but showed the highest abundance at Cape Russell, representing almost 100% of the isopod assemblage. On the contrary, the Paramunnidae showed a very low abundance at Cape Russell and a relatively high abundance at Cape Adare. The Munnidae and Munnopsidae showed a north to south tendency with regard to abundances. The highest abundance of Janiridae was found at Cape Adare (Fig. 6a). In terms of biomass the Desmosomatidae, Janiridae, and Paramunnidae showed a relatively similar pattern compared to their relative abundance at the four different study sites (Fig. 6a), but the biomass for Munnopsidae increased from Cape Adare to Cape Russell, where the highest values are reported. The biomasses of Munnidae were extremely low at all four sites (Fig. 6b).





Fig. 6: Abundance (a) and Biomass (AFDM) (b) of the five major isopod families from the four study sites

The faunistic similarity analysis showed a high similarity in family composition within the stations of Cape Hallett, between four stations of Cape Adare and between two stations of Coulman Island and Cape Russell (Fig. 7). The outlier stations A1 and C1 are not grouping to any geographical area; this might be due to an sampling artefact, as technical problems occurred while collecting the samples (P. Rehm pers. comm.).



Fig. 7: MDS of all stations of the 19th Italica expedition, using Bray-Curtis similarity and fourth-root transformation

Discussion

The analysis of the isopod families revealed great differences in composition and abundance between the study areas. The investigated isopods from the Rauschert dredge samples, as anticipated, are clearly dominated by Asellota (Table 2). From total 19 isopod families 10 belong to the order of the Asellota, as Wägele (1992) stated that Antarctic Asellota represent about 60% of the Isopoda of the Antarctic region. Contrary to the high abundance of Asellota, other orders are only represented with 3 species (Valvifera), 2 (Anthuroidea, Flabellifera) or only 1 species (Epicaridea, Gnathiidea). Some families like the Chaetiliidae and Sphaeromatidae, only occurred at one station with a single specimen. These results are corresponding to Brandt (1991), who showed that these taxa are relatively abundant in the Weddell Sea, but less abundant in the Ross Sea. Another very abundant and frequently sampled, but non-asellote taxon were the Gnathiidae. The larval stages of these ectoparasites (pranziae)

use specialized mouthparts to suck blood from the fishes (Wägele 1988). In our samples, there were many pranizae and their appearance may indicate the presence of large fish stocks along the Victoria Land Coast.

Interestingly, not a single serolid isopod was sampled with the Rauschert dredge in the Ross sea at these 18 stations, whereas in the Weddell Sea the Serolidae occur in relatively high numbers on the shelf (Brandt 1991, Brandt et al. 2004). This could be due to a sampling artefact, even though the Rauschert dredge is known to be very effective in catching smaller macrozoobenthic animals (Rehm et al. 2006, Lörz et al. 1999), and specimens of Serolidae were previously sampled with the Rauschert dredge in the Weddell Sea (Rauschert, pers. comm.).

In station H in 5 (at the inner transect from Cape Hallett), the most divers station, 15 from total 19 isopod families occurred. The sediment in this area mainly consists of mud, and Bullivant (1967b) described the fauna of this area as "deep shelf mud bottom assemblages", but only briefly described major taxa (Polycheata, Crustacea and Mollusca). The diversity of the isopod fauna in this area implies sufficient food availability and favourable substrate which allows isopod taxa with very different morphologies and feeding modes to coexist: competition among the isopods for habitat and food seems to be low at station H in 5. Passive filter feeders, like the Antarcturidae, which are probably depended on phytoplankton and micro-zooplankton (Wägele 1987), share the habitat together with smaller isopods, which feed on the sediment, like Paramunnidae (Hessler and Strömberg 1989).

The biomasses of the five most abundant isopods families display differences to their abundance. Especially the Munnidae show very low biomasses at all sites, compared to their abundance. This family is known to be relatively abundant on the high Antarctic shelf (Gambi 1994), but they are usually small animals (Teodorczyk and Wägele 1994) and in our Rauschert dredge samples many juveniles were found. Therefore, the low biomass of Munnidae is not surprising. The biomass of Janiridae is much higher at Cape Adare and Cape Hallett than their abundance. However, comparisons of abundance and biomass data can be difficult because often varying depth ranges, numbers of samples and sediment characteristics are compared and thus results may differ depending on the investigated families and their lifestyles (Gambi et al. 1994).

The MDS in figure 7 shows that the similarity among the different stations is roughly arranged according to the geographical order. The differences outlined above are probably

related to the varying number of samples and the depth ranges. At Cape Hallett samples were obtained from an inner and outer transect of Cape Hallett Bay, in total 7 samples were taken in this area, whereas at Coulman Island only 2 samples could be taken. Also some Antarctic benthic families have species, e.g. the Desmosomatidae, which are highly eurybathic (Brix pers. comm.) and are found at all depths (Brey et al 1996). The high abundance of the Desmosomatidae at station R2 at Cape Russell (Table 2, Fig. 6a, b) may be due to sampling at deeper sites between 208 – 366 m depth.

The Desmosomatidae and the Munnopsidae are typical deep-sea families, which are very abundant and speciose in the Southern Ocean deep sea (Malyutina and Kussakin 1996, Brandt et al. 2004, 2005), but less so on the Antarctic shelf (Brandt 1991). These families are eyeless and have natatory legs, which allow them to swim (Hessler and Strömberg 1989). As a result of their ability to swim Desmosomatidae and Munnopsidae have a greater dispersal potential and may actively select an area with more favourable substrate and food supply. Until now little is known of the feeding habits of the small isopods from deeper waters, but investigations on three species of the Munnopsidae from the North Atlantic indicate that foraminiferivory may be widespread (Gudmundsson et al. 2000). Interestingly, a great abundance of agglutinated foraminifers is recorded from the Terra Nova Bay (Violanti 1999), where species of the Munnopsidae thrive.

The absence of several isopod families and the extremely low abundances at stations in Cape Russell, especially at station R2, may be due to the sediment structure. It mainly consists of sand of coarse grain sizes, large stones and rocks (Rehm et al. 2006). Another reason for the absence or the dominance of Desmosomatidae could be the iceberg disturbances in this area, which has been recorded by Thrush et al. (2006). As most species of the Desmosomatidae have a swimming ability, they may recolonize the disturbed area faster than isopods which only have walking legs.

The identification to species level is still in process and thus this paper gives a preliminary and descriptive review of the composition and abundance of the isopod fauna from the northern Victoria Land coast.

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Chapter 2

Biodiversity of Isopoda:

new data from the Victoria Land coast

Keywords: Isopoda, species distribution, diversity, Ross Sea

Abstract

During the 19th *Italica* expedition in February 2004 samples were taken along the Victoria Land Coast with a Rauschert dredge. A total of 9494 specimens of Isopoda were collected at 18 stations. These individuals comprised 20 families, 39 genera and 67 species. Species richness is highest in the Paramunnidae with 12 genera and 18 species, followed by the Desmosomatidae with 15 species, and the Antarcturidae with 9 species. Interestingly, species of the desmosomatids did not occur at the northern most study site at Cape Adare, but were sampled frequently at Cape Russell, the most southern study site. Two different diversity (Shannon index and the rarefaction method) and similarity (Bray-Curtis and Cosine) measures are applied to the data. Both measures for diversity display consistent results and are in good agreement. Highest diversity and species richness was measured at Cape Hallett, lowest was found at Cape Russell.

Introduction

The Antarctic shelf has been subject to many studies in the past (e. g. Dayton et al. 1970, Arntz et al. 1994) and is known for its peculiar fauna with high rates of endemism due to the long isolation of the continent and the conditions of a polar environment, such as seasonality and high spatial heterogeneity (Arntz et al. 1997). The crustacean fauna of the Antarctic shelf is characterised by the enormous diversity of Peracarida which are thought to occupy niches left vacant by the almost complete absence of benthic Decapoda (DeBroyer and Jazdzewski 1996).

The Amphipoda and the Isopoda in particular thrive in the Southern Ocean (Holme 1962, Brandt et al. 2004), displaying a broad variety of lifestyles. Within the Isopoda some taxa of the Scutocoxifera, namely the Valvifera and the Serolidae, are important elements of the shallow Antarctic fauna. The Serolidae are thought to have undergone an extensive radiation in the southern hemisphere, most probably in the Antarctic (Held 2000). Besides these typical shallow water groups, many taxa of the Asellota, both with shallow or deep-sea origin are known to occur on the continental shelf. The missing thermocline and the deep shelf probably facilitate emergence of deep-sea taxa onto the shelf (Hessler and Thistle 1975, Wägele 1992, Brandt et al. 2004).

While shelf areas of the Weddell Sea and around the Antarctic Peninsula have been partly well studied (Clarke and Johnston 2003), knowledge on the fauna of the Ross Sea is scarce. The

benthos of the Ross Sea shelf and coastal areas was first studied in the late 1960s, mainly by New Zealand scientists (Dearborn 1967, Lowry 1975), whose investigations primarily focused on few groups (e.g. amphipods and polychaetes). Some extensive studies were conducted around McMurdo Sound and Terra Nova Bay concentrating on very shallow depth down to about 60 m (Arntz et al. 1994, Gambi et al. 1997, Cattaneo-Vietti et al. 1999, Cattaneo-Vietti et al. 2000). The few investigations on the isopod fauna in the Ross Sea are nearly a century old (Hodgson 1910, Vanhoeffen 1914). Besides, most of these studies were conducted either by scuba diving or using large mesh sizes. Therefore the small benthic macrofauna was greatly under-sampled.

The present investigation is based on material of the 19^{th} *Italica* expedition, which to our knowledge included the first extensive sampling with a small mesh size gear (500 µm) and was part of the Latitudinal Gradient project (Williams et al. 2006).

First results from this expedition concerning the isopod composition were published by Choudhury and Brandt (2007).

The present study aims to investigate the diversity of the isopods from the 19th *Italica* expedition. On this background different methods for measuring diversity and similarity between stations is applied and compared.

Material and Methods

Sampling and sample processesing

The present investigation is based on material collected during the 19th *Italica* expedition in February 2004 along the Victoria Land Coast. Samples were taken along a latitudinal transect between Cape Adare and Cape Russell and along a depth gradient between 84 m and 515 m. The study includes four different sites: Cape Adare (stations A1-A5), Cape Hallett (stations: outer transect H out 1, 2 & 4, inner transect H in 2, 3, 5), Coulman Island (stations C1-C2) and Cape Russell (stations SMN, R2, 3 & 4) (Fig. 1). Eighteen Rauschert dredge samples were collected and analysed (Tab. 1). The Rauschert dredge has an opening of 0.5 m and a sampling net with a mesh size of 500µm (Lörz et al. 1999). It was hauled over the ground at a mean velocity of 1 knot (1.852 m/h). The Rauschert dredge was used in the Ross Sea for the first time and provided new insights into the epibenthic fauna (Rehm et al. 2007).

On deck, the complete samples were immediately sieved through a 500µm screen, transferred into pre-cooled 90% ethanol and kept at least 48 hours at -25°C before sorting. The isopods were sorted into families and then to species level.

Data analysis

The data was not standardised with the exception of Fig. 2, where the number of specimens per 100 m trawling distance was calculated, since haul length generally varied and mostly increased with depth. Diversity was measured per station, for each site and for depth intervals of 100 m pooling all sites. Depth intervals were defined as follows: 100 - 200 m (stations: A5, H in 4, including H in 5 with 84 m and 97 m), 200 - 300 m (stations: A4 and H out 4), 300 - 400 m (stations: A3, H out 2, H in 2, H in 3, SMN, R2 and R3) and 400 - 500 m (stations: A2, H out 1, C1, C2 and including A1).

Univariate measurements of diversity were applied, the Shannon–Wiener index (H') (log base) and eveness (J') as well as Hurlbert's (1971) modification of Sanders (1968) rarefaction method. The latter methodology is particularly suited to compare samples of differing sizes as in the present study (Sanders 1968).

For similarity analysis a similarity matrix was constructed using the Bray-Curtis coefficient (Bray and Curtis 1957) as well as Cosine similarity (Pfeifer et al. 1998). For better comparison of the two indices the data was not transformed prior to the similarity analysis.

The results were then displayed by non-metric multidimensional scaling (nMDS). The univariate measurements of diversity are implemented in the PRIMER package, described in Clarke and Warwick (2001). Multivariate measurements, such as nMDS was also carried out with the software package PRIMER version 6 (Clarke and Gorley 2006); for the cosine index the similarity matrix was calculated with the software package PAST (Ryan et al. 1995)

Results

A total number of 9494 specimens of Isopoda were sorted from 18 samples (Table 1 and Fig 1). The Gnathiidae (176 specimens) and the Bopyridae (213 specimens) are excluded from this investigation because these are mostly represented by larval stages, discrimination of which is nearly impossible. Excluding those families, the samples comprise 18 families, 51 genera and

88 species (Table 3). The most speciose family is the Paramunnidae with 18 species followed by the Desmosomatidae (15 species) and the Antarcturidae with 9 species (Table 3). Fifty-two of all species (57%) are new to science, 23 (25%) were previously reported from the Southern Ocean and only 17 (18%) were known from the Ross Sea.

Table 3: Station list of Rauschert dredge samples from the expedition of RV *Italica*, H out = transect outside of Cape Hallett Bay, H in = transect inside Cape Hallett Bay, SMN = Santa Maria Novella (Terra Nova Bay); S = species richness, N = number of individuals, H' diversity and J'= evenness;

Station	Depth [m]	Haul length [m]	S	Ν	H'	J'
Cape Adare			Σ98	1622	2.6	0.67
1			ø 19.6			
A1	515	358	11	14	2.305	0.9611
A2	421	298	29	218	2.55	0.7572
A3	305	257	18	485	2.157	0.7461
A4	230	376	24	868	2.209	0.695
A5	119	59	16	37	2.464	0.8887
Cape Hallet			Σ202			
			$\tilde{\emptyset}_{28.8}$	3400	3.27	0.76
H out 1	458	375	17	62	2,485	0.8769
H out 2	353	375	27	161	2,834	0.86
H out 4	235	194	37	906	3,022	0.8368
H in 2	391	186	26	60	3,088	0.9479
H in 3	316	194	31	332	2,934	0.8545
H in 4	196	169	32	1223	2,486	0.7173
H in 5	84	113	32	656	2,523	0.7281
			Σ38			
Coulman Island			ø 19	367	2.7	0.78
C1	474	375	8	15	1.934	0.8952
C2	410	153	30	352	2.685	0.8931
Cape Russell			Σ74			
1			ø 18.5	1973	2.38	0.66
SMN	366	192	34	899	2.598	0.7367
R2	364	575	19	629	1.821	0.6185
R3	330	565	14	418	1.434	0.5433
R4	208	97	7	27	1.674	0.8604

Asellota are the dominating suborder with high numbers of specimens and 68 (77%) species found, while Cymothoidea, Valvifera and Sphaeromatidea together are represented by 20 species 22%) only. Species of these suborders occurred with low numbers (less than 30 individuals/station) and frequencies (1-5 stations). Twenty species occurred at one station only (6 species with only one individual each), 17 species at two stations. The most frequent species (14 stations) is *Munna* spec. 1, followed by *Neojaera antarctica* (13 stations), *Coulmannia* spec. 1 (12 stations) and *Munna* spec. 2 (12 stations). By far the most individuals (714) were found of

Austronanus glacialis, a species occurring at 11 stations, being absent from Coulman Island and the outer transect of Cape Hallett.

Families	Genera	Species
Asellota	39	68
Acanthaspidiidae	1	3
Desmosomatidae	7	15
Haploniscidae	2	2
Janiridae	6	6
Janirellidae	1	1
Joeropsidae	1	1
Munnidae	1	11
Munnopsidae	8	8
Paramunnidae	12	18
Santiidae	1	3
Cymothoida	5	8
Aegidae	1	2
Anthuridea	2	4
Cirolanidae	1	1
Expananthuridae	1	1
Valvifera	5	11
Antarcturidae	3	9
Chaetiliidae	1	1
Idoteidae	1	1
Sphaeromatidea	1	1
Sphaeromatidae	1	1

Table 4: Taxon richness of the 19th Italica expedition

The number of specimens varies markedly between the stations and their depth (Fig. 8). At six stations less than 100 specimens were found. Station H in 4 at Cape Hallett yielded the highest number of specimens, due to high occurrences of paramunnid and munnid specimens).

A slight trend towards decreasing numbers of individuals and species can be observed (Fig. 8). While there is considerable variation in medium depth, stations below 400 m show a more distinct decline of number of specimens and species.



Fig. 8: samples from the 19th Italica expedition; S = number of species, N = Number of individuals

Species richness is high at Cape Hallett (H out 4, H in 4 and H in 5) and at station SMN (Table 3). Low species richness corresponds to low abundances at stations A1, C1 and R4. Highest diversity was observed at station H in 2, where evenness was high, too. Evenness was slightly higher at station A1; however, this station has the lowest abundance with only 14 individuals and relatively low diversity. Cape Russell has lowest values of diversity (R3) and species richness (R4).

These findings are comparable to the results of the rarefaction analysis. Cape Hallett station H in 2 has the steepest curve, indicating highest evenness and diversity, while these are lowest at stations R2 and R3 (Fig. 9).



Fig. 9: Rarefaction curve of all samples from the 19th Italica expedition;

Comparison of the four study sites (stations pooled) (Fig. 10) illustrate that diversity is highest at Cape Hallett, too, and lowest at Cape Russell. Corresponding results are obtained by the Shannon-Wiener analysis of pooled station data, where diversity is highest at Cape Hallett and lowest at Cape Russell (Table 2).



Fig. 10: Rarefaction curves of the four study sites of the 19th Italica expedition.

Rarefaction analysis and Shannon-Wiener index of depth intervals with stations of different study sites pooled shows that the depth interval between 400 and 500 m is most diverse. However, species richness is higher for the depth interval between 300 and 400 m. The shallower stations (100-200 m and 200-300 m) are represented by low rarefaction curves, corresponding to the values of the Shannon-Wiener analysis (Fig. 11, Table 5).



Fig. 11: Rarefaction curves of the four depth intervals of the 19th Italica expedition

Table 5: S = species richness, N = number of individuals, H' diversity and J'= evenness of the four depth intervals

depth interval	S	Ν	H'	J'
100m-200m	53	1916	2.1	0.71
200m-300m	53	1774	3.1	0.77
300m-400m	71	2948	3.16	0.74
400m-500m	64	661	3.41	0.82

Some differences between the results of Bray-Curtis similarity and Cosine similarity show in the MDS plots. In general the grouping of stations according to their location is slightly more evident in the cosine plot. However, in both plots a clear separation between the different regions is missing. A slight separation in two groups of station appears in the Cosine plot (Fig. 12): The stations of Coulman Island and Cape Russell are forming one group, the stations of Cape Hallett and Cape Adare another, with station R4 (of Cape Russell) nearly in between. This grouping hardly shows in the Bray-Curtis plot (Fig. 13). Here the two stations of Coulman Island are widely separated from each other as is R4 from the remaining Cape-Russell stations. Also the grouping of the Cape-Hallett stations is somewhat stronger in the Cosine MDS. The position of station A 5 varies strongly between the two plots, while station A1 is located far from the remaining Cape Adare stations in both plots. The stress of the Bray-Curtis MDS is slightly lower (0.13) than of the Cosine MDS (0.15).



Fig. 12: MDS plot, untransformed abundance data using cosine similarity index; the thin line shows a clear separation of the stations.



Fig. 13: MDS plot, untransformed abundance data using Bray-Curtis index from the 19th Italica expedition.

Discussion

Investigations on isopod diversity in Antarctic Waters mainly focused on the continental shelf or the deep-sea of the Weddell Sea or the Antarctic Peninsula (Clarke and Johnston 2003, Brandt et al. 2005). Some authors also refer the Ross Sea benthos as well investigated (Gambi 1997); however this only relates to shallower waters around McMurdo Sound and Terra Nova Bay. This study is the first investigation of isopod diversity on the deeper shelf along the northern Victoria-Land coast.

Previous studies in Antarctic waters established that, while Asellota are usually the dominant isopod group, isopod communities also include a significant amount of taxa other than Asellota, namely Valvifera and Serolidae (Wägele 1992; Brandt 1999). About 77 % of the species in our material belong to the suborder Asellota, while only about 13 % are Valvifera and the family Serolidae was completely absent from the samples. Yet, at least three species of

Serolidae have been reported to occur in the Ross Sea (Brandt 1991). The peculiar absence of the family from our samples cannot be attributed to the sampling gear, since the Rauschert dredge has been reported to sample Serolidae before (Rauschert, pers. comm.).

Although a depth gradient between about 100 m and 500 m was sampled, no distinct decrease in number of specimens and species could be observed above 400 m. However, samples deeper than 400 m generally contained fewer specimens, probably due to reduced food availability, a common phenomenon (Hessler 1974, Gage and Tyler 1991). Species richness in this depth was also lower, but this may be correlated to the decreasing numbers of specimens. Across the study area, species richness was not related to latitude (ranging from 71° to 74°S) or longitude (171° to 164°E). But the scale of this study is rather small.

The typical broad-scale factors like depth and latitude do not seem to be strong determinants of the isopod fauna of the Victoria-land coast. Also sediment characteristics have been suggested to be influential on diversity (Etter and Grassle, 1992). For this dataset the sedimentary environment seems to have influence on the diversity. A relatively high number of species and individuals were found at Cape Adare as the northern most location of this study. Interestingly, this result does not match to the findings of Rehm et al. (2007) who reported that this location shows the lowest diversity for Cumacea. A possible reason for this might be the sediment structure at the stations near Cape Adare, which is predominantly composed of gravel and coarse sand. Cumacea, which are mostly endobenthic, prefer finer substrates (Zimmer 1941).

The highest number of individuals and species was found at both transects near Cape Hallett. The high diversity implies favourable conditions for the isopods. The stations of the inner transect of Cape Hallett were mostly fine sand and mud with some gravel; the stations of the outer transect contained higher amounts of gravel with less fine sand or mud. The most common and frequent isopods in this location are the Paramunnidae (esp. *Austronanus glacialis*) and the Munnidae (esp. *Munna* spec. 2). Most probably these species favour the substrate on which they might erode detritus, however, until now little is known of the feeding habits of the small isopods from deeper waters. The Paramunnidae and the Munnidae, while containing several deep-sea species, originated on the shelf, which is indicated by the occurrence of species with eyes in these families (Brandt 1999). Therefore it is not surprising that species of these families are common on the Antarctic shelf. Cummings et al. (2006) found a very strong correlation of phaeophytin concentrations and numbers of individuals and taxa

from different macrofaunal groups (e.g. amphipods, cumaceans, isopods, bivalves, echinoderms and polycheates) at Cape Hallett and Cape Adare. This suggests that the distribution of the benthos in these locations might reflect their response to seafloor productivity to certain depths. Zaneveld (1968) reported viable macroalgal material from depth greater than 600 m and suggested that these could be a direct contributor to benthic food webs; however this observation is most probably decaying, as Cummings et al. (2006) measured low values of chlorophyll at greater depth.

At Coulman Island the isopod diversity was lowest. Although the sediment is heterogeneous with fine, coarse sand and mud, the number of individuals and corresponding to this the number of species is low. Most probably the low number of species at station C1 was due to technical problems during sampling (Rehm pers. comm.). Here Cummings et al. (2006) also found the lowest values of the microphytobenthos (chlorophyll a and phaeophytin) compared to the other study sites. This result is not surprisingly as the stations at Coulman Island are relatively deep (410 - 474 m), however Cummings et al. (2006) found quite high numbers of chlorophyll in depth between 200 - 300 m at Cape Russell. Here again our result is different to what Rehm et al. (2007) reported for the Cumacea, as this area showed the highest diversity for the Cumacea.

Cape Russell, the southern most location of this study had the lowest isopod diversity and evenness. Multibeam imagery has shown that the seafloor around Cape Russell is strongly impacted by iceberg scouring (Thrush et al. 2006). Iceberg scouring is amongst the five most significant disturbances on ecosystems on earth (Gutt and Starmans 2001). Gerdes et al. (2003) studied the impact of this disturbance of macrofauna in the Weddell Sea. They documented that macrofaunal biomass and species richness decreased from undisturbed areas to old scours to young ones. Also Gerdes et al. (2003) found that there was greater variety of taxonomic groups in undisturbed areas. A high degree of iceberg scouring is likely to favour few opportunistic species in the region of Cape Russell, which are able to colonise the disturbed areas of seafloor rapidly, resulting in low eveness values (Brown and Lomolino 1998). An increasing frequency of iceberg scouring is assumed for the northern Victoria-Land coast, but has not been further investigated until now (Thrush et al. 2006). Also hydrographical data indicate a strong northward current, which is likely to entrain icebergs (Van Woert et al. 2003).

In the present study two diversity measurements (Shannon index and rarefaction) were applied to our data. The Shannon index assumes that individuals are randomly sampled from a large community and that all species are represented in the sample. It also takes into account the distribution of individuals over the species. The Shannon index is problematic when the sample does not include all species in the community (Magurran 2004), which is usually the case, and when applied to different sample sizes. Therefore conclusions based only on the Shannon index have to be treated with care, as the data will never be completely unbiased (Magurran 2004). In contrary the rarefaction method estimates the richness of the smaller samples. In the present study stations A1 and C1 in particular only have a small number of specimens; samples with higher numbers of individuals are "rarefied" down to the sample with the lowest number of specimens. Rarefaction usually assumes that species are randomly dispersed, however as the patchy distribution is common for isopods, species richness will be overestimated.

For our data both methods showed consistency and confirmed that Cape Hallett is the most diverse study site and Cape Russell the least. Sanders (1968) and Magurran (2004) also confirmed a good agreement between the rarefaction method and the Shannon-Wiener index. The differences between Bray-Curtis and Cosine similarity index are found in the resulting MDS plots. Strong differences between plots can be observed for stations with very low numbers of individuals (A1, A5, C1, R4), due to the high emphasis the Bray-Curtis index assigns to the abundance data. Apart from this, the two analyses differ in the grouping of stations. The Cosine MDS results in a slight distinction between stations of Coulman Island and Cape Russell on the one hand and Cape Hallett and Cape Adare on the other hand. This result reflects the distribution of desmosomatid species, which were completely absent at Cape Adare and were rare at Cape Hallett (only 7 of total 15 species), but frequent at Coulman Island and most abundant at Cape Russell. Since the family has evolved in the deep sea with subsequent emergence of species onto the especially deep shelf in Polar Regions, its increased occurrence at the deeper stations of Coulman Island and Cape Russell is not surprising. In contrast, species of the Munnidae and especially the Paramunnidae (Choudhury and Brandt 2007) occurred rather more frequently at Cape Adare and Cape Hallett than at the other two locations.

Although the Bray-Curtis similarity is widely used in ecological studies and is recommended because it complies with the criterion of joint absences (Pfeifer et al. 1998), the major weakness is its high emphasis on abundances, meaning that species occurring with low numbers have little or no influence in the analysis. We did not transform the abundance matrix, as our goal was to compare both indices.

The cosine similarity, though rarely used in ecological studies (Pfeifer et al. 1998), while including abundance data, does not assign as much weight to this as the Bray-Curtis Index. Therefore this approach suites our data, as some species occur with relatively low abundances and the pronounced occurrence of some taxa, such as the Desmosomatidae, the Paramunnidae and the Munnidae, was very characteristic.

The stress (<0.2) is relatively high with both approaches, however even though the data are weak, they still allow cautious interpretation of the results (Clarke and Warwick 2001).

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Chapter 3

Isopod species checklist from the Ross Sea

and their zoogeography

in the Southern Ocean

Keywords: Species checklist, Isopoda, Ross Sea, Southern Ocean, Antarctica, zoogeography

Abstract

Within this study isopod species of the Ross Sea were investigated. Literature until March 2008 was checked to provide an overview of all known and described species in the Ross Sea. This species checklist was then enlarged through material of the 19^{th} *Italica* expedition in 2004. During this expedition for the first time a small mesh net (500μ) was used. 9481 isopod species in the Ross Sea increased from 42 to 117 species, which belong to 20 families and 49 genera. 56 % of the isopods species collected during the *Italica* expedition are new to science. The zoogeography of the 117 species was investigated. A non-transformed binary presence-absence data matrix was constructed using the Bray–Curtis coefficient. The results were displayed in a cluster analysis and by nonmetric multidimensional scaling (MDS). This paper gives a first insight about the occurrence and distribution of the isopod species of the Ross Sea.

Introduction

Shelf areas of the Weddell Sea, West Antarctic Peninsula and Ross Sea, have been sampled to comparable levels (Clarke and Johnston 2003). Yet, the deeper shelf of the Ross Sea region remains understudied. The few investigations on the isopod fauna in the Ross Sea are nearly a century old (Hodgson 1910; Vanhoeffen 1914). In the Ross Sea, benthic sampling is very unevenly distributed and limited to the shallow waters around McMurdo Sound and Terra Nova Bay which are easily accessible from the shore or by scuba diving (Clark and Rowden 2004). Biological research mainly focused on other invertebrate taxa, such as amphipods, polychaetes, molluscs and sponges (Dearborn 1967; Dayton et al. 1970; Dayton 1972; Gambi et al. 1997; Cattaneo-Vietti et al. 1999).

During the 19th *Italica* expedition in February 2004, benthic samples of the deeper shelf of the Ross Sea were taken for the first time. This expedition was part of the Italian national project PNRA (Progetto Nazionale per al Ricerca in Antartide) organized by R. Cattaneo-Vietti. To our knowledge, this expedition was the first one in this region, using a gear (Rauschert dredge) with a small mesh size of $500\mu m$ (Rehm et al. 2006, Choudhury and Brandt 2007). This gear is designed to catch small-sized epibenthic animals (Rehm et al. 2007). First insights into

distribution and family composition of isopod crustaceans of the Ross Sea was presented by Choudhury and Brandt (2007).

Knowledge of the isopod fauna in the Ross Sea is relatively poor in comparison to the Weddell Sea. This is reflected by the lower number of recorded isopod species in the Ross Sea (42 species) compared to 68 species known from the Weddell Sea (see Brandt 1991). Since Brandt's monograph (1991) some new species of the Southern Ocean isopods were described or redescribed. However most of these new species were described from the Atlantic sector of the Southern Ocean and especially from the Weddell Sea. Here, extensive sampling of the shelf, slope and deep sea (e.g. by the EPOS (European Polarstern studies), EASIZ (Ecology on the Antarctic Sea Ice Zone) (Clarke and Arntz 2006) and ANDEEP (ANtarctic benthic DEEP-sea biodiversity, colonisation history and recent community patterns) I-III expeditions) (Brandt and Hilbig 2004; Brandt and Ebbe 2007) increased the number of isopod species in the entire Southern Ocean from 365 (Brandt 1999) to nearly 1000 species. Most of these species (86%) were new to the region or even new to science (Brandt et al. 2007b), however are not described so far.

A number of 48 isopod species by name were reported from the Ross Sea (Bruce and Brandt 2006), in an unpublished list from the NIWA (National Institute for Water and Atmospheric Sciences, New Zealand), we counted a number of 42 described species from published literature until March 2008. Through the samples of the *Italica* expedition the authors increased the number of isopod species; some of the species are new records of this area. However, most of the species are new to science.

The aim of this paper is to give a current state of composition of isopod species from the Ross Sea and their general distribution in the Southern Ocean. It updates and adds on the species list from Brandt (1991) and the World list of Marine Isopoda (Schotte et al. 1995 onwards).

Material and Methods

Species checklist

The monograph of Brandt (1991) is used as the starting point of this study. Extensive searches of literature after 1991 were undertaken to locate newly described species from the Southern Ocean and the Ross Sea. The Zoological Record served as a basis for the literature check, but also the World list of Isopoda (Kensley and Schotte, 1995 onwards) was used for this study. The literature has been checked until May 2008.

Besides the literature based research, material from the 19th *Italica* expedition was used to enlarge the species list. This expedition took place in February 2004 and was the first campaign within the framework of the international and multidisciplinary Victoria-Land Latitudinal Gradient Project (Berkman et al. 2005) and the Bio Ross project (Clark and Rowden, 2004). Samples were taken with a Rauschert dredge at four study sites at Cape Adare, Cape Hallett, Coulman Island and Cape Russell at depths between 84 - 500 m (Rehm et al. 2006, Table 1). The samples were fixed in pre-cooled 96% ethanol for later DNA extractions. The analysis was based on the morphospecies concept and no molecular investigations were done at this stage. Most species will have to be compared with museums material for confirmation and new species have to be described.

The authors decided to exclude the parasitic families, Gnathiidae and Bopyridae from the *Italica* material from the further investigation, as these families were represented mainly by juveniles which are very difficult to determine morphologically. However the previous records of these families found in the Ross Sea are included in Table 6 and 7.

Biogeographic areas

To describe the distribution of the isopod species from the Ross Sea we divided the Southern ocean into specific regions, based on the biogeography of Hedgepeth (1969), Knox and Lowry (1977), Linse et al. 2006 and Clarke et al. 2007. Linse et al. (2006) divided the Southern Ocean into three major areas, i.e. the sub-Antarctic islands, the Magellan region and the New Zealand islands. Moreover they defined 12 sub-regions of Southern Ocean (Linse et al. 2006).

The biogeographic areas for the isopods are separated into four major Antarctic regions and 15 sub-regions according to Brandt (1991) however our results will reflect a different composition. The following abbreviations will be used in the further paper:

<u>Sub-Antarctic region</u>: This region extends from the 48°S to 60°S latitude. It includes the following islands: Bouvet Island, Prince Edward and Marion Islands, Crozet Islands (CI), and the Heard and McDonald Islands, Macquaire (MI) and Campbell Islands (CA) and Kerguelen Islands (KI). Clarke et al. (2007) excluded the Kerguelen and Crozet Islands from their analysis, as they only included areas north of the Polar Front.

<u>Scotia region</u>: Knox and Lowry (1977) excluded this region from the SA region on the basis of amphipod distribution. For the biogeographic analysis on the Southern Ocean molluscs, Linse et al. (2006) separated South Shetland and South Orkney islands and excluded them from the "Scotia region". In the current paper, this region comprises the South Shetland (SS) and South Orkney (SO) Islands as well as South Georgia (SG). Brandt (1991) showed that the composition of isopods is more similar between the South Shetland Island, South Orkney Islands and South Georgia and should therefore be treated separately from the Sub-Antarctic region.

<u>Magellan region:</u> This region covers the waters around the southern tip of South America, the Patagonian shelf (PS) and the Falkland Islands (FI).

<u>High Antarctic region</u>: This region includes the coast and shelf areas around the whole Antarctic continent; the Bellingshausen Sea (BS), Antarctic Peninsula, the Weddell (WS) and Ross Sea (RS). East Antarctic region also belongs to the High Antarctic region; however this area will be further separated to the Dronning Maud Land (DM), the Enderby Land (EL) and Wilkes Land (WL).



Fig. 14: Biogeographic areas: BS – Bellingshausen Sea, CA – Cambell Islands, CI – Crozet Islands, DM – Dronning Maud Land, EL – Enderby Land, FI – Falkland Islands, KI – Kerguelen Islands, MI – Macquaire Islands, PS – Patagonian Shelf, RS – Ross Sea, SG – South Georgia, SO – South Orkney Island, SS – South Shetland Islands, WS – Weddell Sea, WL – Wilkes Land; Map created with Ocean data view (Schnitzler, 2006)

Data analysis

For faunal similarity analysis between biogeographic regions a non-transformed binary presence-absence data matrix was constructed using the Bray–Curtis coefficient (Bray and Curtis 1957). A group-averaged cluster analysis was applied to the data to display the faunal similarities species level in two-dimensions. The results were also displayed by nonmetric- multidimensional scaling (MDS). The measurements are implemented in the PRIMER package version 6 (Clarke and Gorley 2006) and are described in Clarke and Warwick (2001).

Results

The investigations of the literature up to March 2008 showed only 42 species of Isopoda have been known from the Ross Sea. Through the material from the 19th *Italica* expedition the numbers of isopod species increased to 117; belonging to 20 families and 49 genera (Table 6). The suborder Asellota is the most abundant and frequent taxon represented in the Ross Sea with 10 families and 33 genera, followed by the Scutocoxifera with 8 families and 16 genera (Table 6). The Desmosomatidae, the Haploniscidae, the Janirellidae and the Paranthuridae were recorded for the first time in the Ross Sea. In total, fifty-two species (56 %) were new to science, of which 41 species belonged to the Asellota. The Paramunnidae represented the most diverse family comprising 14 genera and 23 species of which 10 were new to science. Likewise, the Desmosomatidae show a high number of new species, i.e. of the 16 identified species 13 were new to science (Table 6).

Families	Genera	Total number of species from the Ross Sea	Number of species new to science	Number of new species records for the Ross Sea	Number of species formerly known from Ross Sea
Acanthaspidiidae	Ianthopsis	4	-	3	1
Aegidae	Aega	2	-	-	2
Antarcturidae	Antarcturus	6	2	1	3
	Chaetarcturus	2	-	-	2
	Dolichiscus	5	1	-	4
	Fissarcturus	5	4	-	1
	Litarcturus	1	-	-	1
Chaetaliidae	Glyptonotos	1	-	-	1
Cirolanidae	Cirolana	1	-	-	1
	Natatolana	3	-	-	3
Desmosomatidae	Austroniscus	2	1	1	-
	Desmosoma	3	3	-	-
	Eugerdella	2	1	1	-
	Mirabilicoxa	2	2	-	-
	Nannoniscus	4	3	1	-
	Pseugerdella	1	1	-	-
	Regabellator	1	1	-	-
Exparanthuridae	Eisothistos	1	-	-	1
Gnathiidae	Caecognathia	2	-	-	2
	Euneognathia	1	-	-	1
Haploniscidae	Haploniscus	1	1	-	-
	Mastigoniscus	1	1	-	-
Idoteidae	Edotia	1	-	-	1
Janiridae	Austrofilius	3	2	-	1
	Ectias	2	1	-	1
	Janira	1	1	-	-
	Neojaera	1	-	1	-
	Notasellus	1	-	1	-
Janirellidae	Janirella	1	1	-	-

Table 6: Total number of species from the Ross Sea, separated to new species, new records and previous records from the Ross Sea

Joeropsidae	Joeropsis	1	-	1	-
Munnidae	Munna	12	5	6	1
Munnopsidae	Disconectes	1	1	-	-
	Coperonus	1	1	-	-
	Eurycope	1	1	-	-
	Ilyarachna	1	-	1	-
	Lionectes	1	1	-	-
	Munneurycope	1	1	-	-
	Notopais	3	1	1	1
Paramunnidae	Austronanus	1	1	-	-
	Austrimunna	2	-	1	1
	Austrosignum	2	1	-	1
	Coulmannia	3	1	-	2
	Harrietonana	1	1	-	-
	Kiklonana	1	-	-	1
	Kussakinella	1	-		
	Munnogonium	1	1	-	-
	Notoxenus	2	2	-	-
	Omanana	2	2	-	-
	Pagonana	2			2
	Cryosignum	1	-	-	2
	Palanana	1	-	-	1
	Pleurogonium	1	1	-	-
	Pleurosignum	2	-	2	-
	Holodenata	1	1	-	-
Paranthuridae	Accalanthura	2	2	-	-
	Paranthura	2	2	-	-
Santiidae	Santia	3	1	1	1
Serolidae	Acutiserolis	1	-	-	1
	Ceratoserolis	1	-	-	1
	Frontoserolis	1	-	-	1
Sphareomatidae	Cymodocella	1	-	1	-
Sum		117	52	23	42

The complete species composition of the Isopoda of the Ross Sea is shown in table 7. All 42 known species are marked with a °, the new records with a * and the new species are bold (Table 7). For the Magellan region only 11 species were also found in the RS. 22 of the 117 species occur in the Sub-Antarctic region, 14 species around the KI, six species around the CI and only *Cymodocella tubicauda* and *Munna maculata* were found around the MI and CI. In the Scotia Region a number of 33 species are also present in the RS; most of these were also found off the SS and SG. Only seven species were recorded from the SO. The High Antarctic regions share a high species number with the RS (i.e. 42 species). Twenty-two species were found in the east Antarctic region as well as the Weddell Sea (Table 7). The most widely distributed species in the Southern Ocean were *Austofilius furcatus* and *Notasellus sarsi*. These two species occur in every Antarctic region. Five additional species were also widely distributed (*Antarcturus furcatus, Ceratoserolis trilobitoides, Cymodocella tubicauda, Ianthopsis nasicornis* and *Munna antarctica*), however these were absent in the Magellan region (Table 7).

The bathymetric distribution (Table 7) of the isopod species from the Ross Sea ranged from 0 down to 7000 m (*Ilyarachna antarctica*). Though, there are seven species which only occur at depth between 0-100 m (*Austrimunna antarctica, Austofilius furcatus, Austrosignum grande, Dolichiscus* spec.1, *Ectias turqueti, Pagonana hodgsoni* and *Santia mawsoni*). Most of the isopod species occur between 0-500 m. At this depth, there is a shift from a `typical` shelf (i.e. species of Paramunnidae) to a `typical` deep-sea fauna (Desmosomatidae).

Tab. 7: Species of the Ross Sea (ordered alphabetically, their bathymetry and distribution in the Southern Ocean. PS – Patagonian Shelf, FI – Falkland Island, CA – Campell Islands, MI – Macquaire Islands, KI – Kerguelen Islands, CI – Crozet Islands, SS – South Shetland Islands, SO – South Orkney Islands, SG – South Georgia, BS – Bellinghausen Sea, WS – Weddell Sea, RS – Ross Sea, DM – Dronning Maud Land, EL – Enderby Land, WL – Wilkes Land; Species which were previously known are marked with the circle $^{\circ}$; new records market with a -* and new species are bold.

	Bathymetric	Magella	n Region	Si	ub-Antarci	tic Regior	1	Scot	ia Region	ı	High Antarctic Region						
Species from the Ross Sea	distribution	PS	FI	CA	MI	ĸĭ	CI	SS	SO	SG	BS	WS	RS	DM	EL	WL	
Accalathura spec. 1	230 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Accalathura spec. 2	235-421 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Acutiserolis spinosa,° Kussakin, 1967	500-900 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Aega antarctica,° Hodgson, 1910	40-710 m	-	-	-	-	-	-	+	-	-	+	+	+	+	+	+	
Aega glacialis,° Tattersall, 1920	15-700 m	-	-	-	-	-	-	+	-	-	-	+	+	+	+	+	
Antarcturus furcatus,° Studer, 1882	4-3065 m	-	-	-	-	+	+	+	+	+	+	-	+	-	+	+	
Antarcturus horridus horridus,° Tattersall, 1921	5-560 m	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	
Antarcturus polaris,° Studer, 1882	10-600 m	-	-	-	-	-	-	+	-	-	+	-	+	+	+	+	
Antarcturus spec. 1	366 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Antarcturus spec. 2	366 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Antarcturus spinacoronatus,* Schultz, 1978	191-481 m	-	-	-	-	-	-	+	-	-	-	+	+	+	-	+	
Austrimunna antarctica,° Richardson, 1906	12-15 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Austrofilius furcatus,° Hodgson, 1910	0-40 m	+	+	-	-	+	-	+	+	+	-	+	+	+	+	+	
Austrofilius spec. 1	84-316 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Austrofilius spec. 2	84-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Austronanus cf. glacialis,° Hodgson, 1910	unknown	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	
Austroniscus ovalis, * Vanhoeffen, 1914	70-358 m	-	-	-	-	-	-	-	-	+	-	+	+	+	-	+	
Austroniscus spec. 1	366-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Austrosignum glaciale, ° Hodgson, 1910	12-385 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	
Austrosignum spec. nov.	84-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Caecognathia hodgsoni,° Vanhoeffen, 1914	unknown	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	
Caecognathia polaris,° Hodgson, 1902	unkown	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	
Ceratoserolis trilobitoides,° Eights, 1833	unkown	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	
Chaetarcturus franklini,° Hodgson, 1902	50-500 m	+	+	-	-	-	+	+	-	-	-	-	+	-	+	+	
Chaetarcturus adareanus,° Hodgson, 1902	45-650 m	-	+	-	-	-	-	+	-	+	+	-	+	-	-	+	
Cirolana mclaughlinae,° Bruce & Brandt, 2006	451 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Coperonus spec. 1	84-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Coulmannia australis,° Hodgson, 1910	183-400 m	-	-	-	-	-	-	+	-	+	-	-	+	-	-	-	

	Bathymetric Magellan Region		S	1b-Antarc	tic Region	Scotia Region				High Antarctic Region						
Species from the Ross Sea	distribution	PS	FI	CA	MI	KI	CI	SS	SO	SG	BS	WS	RS	DM	EL	WL
Coulmannia frigida,° Hodgson, 1910	91-385 m	-	-	-	-	+	-	-	-	-	-	+	+	+	-	+
Coulmannia spec. 1	84-385	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Cryosignum lunatum,° Hale, 1937	unkown	+	-	-	-	-	-	+	-	+	-	-	+	-	-	+
Cymodocella tubicauda, °Peffer, 1887	0-245 m	-	-	+	-	-	-	+	+	+	+	+	+	+	+	+
Desmosoma spec. 1	208-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Desmosoma spec. 2	208-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Desmosoma spec. 3	364-366 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Disconectes spec. 1	235-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Dolichiscus acanthaspidus,° Schultz, 1982	55-481 m	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Dolichiscus hiemalis,° Hodgson, 1910	24-159 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Dolichiscus meridionalis,° Hodgson, 1910	24-2000 m	-	-	-	-	-	-	+	-	-	-	+	+	+	+	+
Dolichiscus profundus,° Schultz, 1982	unkown	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Dolichiscus spec. 1	84 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Ectias spec. 1	421 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Ectias turqueti,° Richardson, 1906	12-15 m	-	-	-	-	-	+	-	-	-	-	+	+	-	+	-
Edotia tangaroa,° Brandt & Bruce, 2006	130 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Eisothistos antarcticus°, Vanhoeffen, 1914	46-385 m	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+
Eugerdella serrata, * Brix, 2006	1121 m	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Eugerdella spec. 1	316-474 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Euneognathia gigas,° Beddard, 1886	180-284 m	-	-	-	-	+	-	-	-	-	-	+	+	+	+	+
Eurycope spec. 1	196-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fissarcturus rossi,° Brandt, 2007	205-220 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fissarcturus spec. 1	84-353 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fissarcturus spec. 2	366-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fissarcturus spec. 3	316-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Fissarcturus spec. 4	474 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Frontoserolis acuminata,° Sheppard, 1957	unkown	-	-	-	-	-	-	-	-	-	-	+	+	-	+	+
Glyptonotos antarcticus,° Eights, 1852	0-580 m	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
Haploniscus spec. 1	458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Harrietonana spec. 1	391 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Ianthopsis bovalli,° Studer, 1884	12-457 m	+	+	-	-	-	-	+	-	+	-	-	+	-	-	+
Ianthopsis multispinosa,* Vanhoeffen, 1914	385 m	+	-	-	-	-	-	+	-	-	-	+	+	-	-	+
Ianthopsis nasicornis, * Vanhoeffen, 1914	75-385 m	-	-	-	-	-	-	+	+	+	+	+	+	-	+	+

	Bathymetric	Magellan Region		Sub-Antarctic Region			Scot	ia Regior	'n	High Antarctic Region						
Species from the Ross Sea	distribution	PS FI		CA	CA MI KI			SS	SO	SG	BS	WS	RS	DM	EL	WL
Ianthopsis ruseri, * Vanhoeffen, 1914	385 m	-	-	-	-	-	-	+	-	-	-	+	+	-	+	+
Ilyarachna antarctica,* Vanhoeffen, 1914	252-7000 m	-	-	-	-	+	-	-	-	+	-	-	+	-	-	+
Jaeropsis antarctica*, Menzies & Schutz, 1968	210-1408 m	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Janira spec. 1	84-421 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Janirella spec. 1	84-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Kikolana arnaudi,* Amar & Roman, 1974	13-20 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Kussakinella spinosa,° (Kussakin, 1982)	17 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Lionectes spec.1	364-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Litarcturus lillei,° Tattersall, 1921	67-560 m	-	-	-	-	+	-	+	-	-	-	-	+	+	+	+
Mastigoniscus spec. 1	421 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Mirabilicoxa spec. 1	208-474 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Mirabilicoxa spec. 2	84-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna amphicauda,* Teodorczyk & Waegele, 19	994483-561 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna antarctica, ° Pfeffer, 1887	2-310 m	-	-	-	-	+	+	+	+	+	-	+	+	+	+	+
Munna globicauda,* Vanhoeffen, 1914	350-385 m	-	-	-	-	-	-	+	-	-	-	+	+	+	-	+
Munna maculata, * Beddard, 1886	22-141 m	-	-	-	+	+	-	+	-	+	-	-	+	-	-	+
Munna neglecta,* Monod, 1931	22-600 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spec. 1	196-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spec. 2	196-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spec. 3	196-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spec. 4	196-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spec. 5	208-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munna spicata,* Teodorczyk & Waegele, 1994	240-522 m	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Munna studeri,* Hilgendorf, 1893	0-210 m	-	-	-	-	+	-	-	-	+	-	-	+	-	-	+
Munneurycope spec. 1	316-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Munnogonium spec. 1	353-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Nannoniscus bidens,* Vanhoeffen, 1914	385 m	-	+	-	-	+	-	+	+	+	+	+	+	-	+	+
Nannoniscus spec. 1	196 - 366 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Nannoniscus spec. 2	364 - 366 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Nannoniscus spec. 3	410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Natatolana albinota, °Vanhoeffen, 1914	35- 670 m	-	-	-	-	+	-	+	-	-	-	+	+	+	-	+
Natatolana intermedia,° Vanhoeffen 1914	385 m	-	-	-	-	-	-	+	-	-	-	+	+	۔ ب	-	+
Natatolana merdionalis,° Hodgson 1910	385 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-

	Bathymetric	Magella	n Region	Si	ub-Antarc	tic Regior	1	Scot	ia Regior	1	High Antarctic Region						
Species from the Ross Sea	distribution	PS	FI	CA	MI	KI	CI	SS	sõ	SG	BS	WS	RS	DM	EL	WL	
Neojaera antarctica,* Pfeffer, 1887	1-700 m	+	-	-	-	+	-	-	-	+	-	+	+	-	-	+	
Notasellus sarsi,*Peffer, 1887	4-230 m	+	+	-	-	+	-	+	-	+	+	-	+	+	+	+	
Notopais spec.1	196-230 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Notopais magnifica,° Vanhoeffen, 1914	380-385 m	-	-	-	-	-	-	-	-	-	-	-	+	-	+	+	
Notopais spinosa,* Hodgson, 1910	unkown	-	-	-	-	-	+	+	-	-	-	+	+	-	-	-	
Notoxenus spec. 1	235-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Notoxenus spec. 2	196-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Omanana spec. 1	235 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Omanana spec. 2	230-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Pagonana hodgsoni*, Just & Wilson, 2004	0-45 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Pagonana rostrata°, Hodgson, 1910	0-569 m	-	-	-	-	+	-	+	-	+	+	-	+	+	+	+	
Paramunnidae spec nov	84-353 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Palanana serrata°, Richardson, 1908	7-40 m	-	+	-	-	-	-	+	-	-	+	-	+	-	+	+	
Paranthura spec. 1	235-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Paranthura spec. 2	391 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Pleurogonium spec. 1	84-410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Pleurosignum elongatum,* Vanhoeffen, 1914	84-515 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	
Pleurosignum magnum,* Vanhoeffen, 1914	235-458 m	-	+	-	-	-	-	-	-	-	-	-	+	-	-	+	
Pseugerdella spec. 1	364 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Regabellator spec. 1	410 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	
Santia mawsoni,* Hale, 1937	0-40 m	-	-	-	-	-	-	+	-	-	-	-	+	-	-	+	
Santia charcoti,° Richardson, 1906	-	-	-	-	-	-	-	+	+	-	+	+	+	+	+	+	
Santia spec. 1	119-458 m	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	

The analysis of the 15 selected areas at the species level revealed no clear pattern; however three biogeographic regions can be distinguished. These are the Magellan region, the High Antarctic region, including the South Shetland Islands and the Sub-Antarctic/Scotia region, including the Bellingshausen Sea. This pattern emerged both in the cluster analysis and the MDS (Fig. 15 and 16). In both interpretations there are two outliers: the South Shetland Islands which are clustering with the Wilkes Land and the Bellingshausen Sea, which clusters with the South Orkney Islands (both areas are poorly sampled). The Magellan and the Sub-Antarctic region split at ~45% similarity level, whereas the High Antarctic region splits at ~65% similarity (Fig. 16).



Fig. 15: Presence-absence transformed MDS plot of the biogeographic areas of the Ross Sea isopods. BS – Bellingshausen Sea, CA – Cambell Islands, CI – Crozet Islands, DM – Dronning Maud Land, EL – Enderby Land, FI – Falkland Islands, KI – Kerguelen Islands, MI – Macquaire Islands, PS – Patagonian Shelf, RS – Ross Sea, SG – South Georgia, SO – South Orkney Island, SS – South Shetland Islands, WS – Weddell Sea, WL – Wilkes Land


Fig. 16: Cluster analysis of the biogeographic areas of the Ross Sea isopods. BS – Bellingshausen Sea, CA – Cambell Islands, CI – Crozet Islands, DM – Dronning Maud Land, EL – Enderby Land, FI – Falkland Islands, KI – Kerguelen Islands, MI – Macquaire Islands, PS – Patagonian Shelf, RS – Ross Sea, SG – South Georgia, SO – South Orkney Island, SS – South Shetland Islands, WS – Weddell Sea, WL – Wilkes Land

Discussion

Through the material of the 19th *Italica* expedition a first insight into the isopod community of the deeper shelf of the Ross Sea is possible. The family composition was documented by Choudhury and Brandt (2007). One potential reason for the high number of the collected specimens of this expedition was the use of the Rauschert dredge. This gear has a net mesh size of 500 μ m is very effective in catching smaller animals. A first attempt to describe the benthic community structure was done by Rehm et al. (2006). By means of these samples the number of Isopoda for the Ross Sea increased from 42 known species to 117 species. 52 of these species were new to science and need descriptions. The high number of new species and new records for this region is due to the first time that sampling occurred in the deeper waters and the use of gear with a wider mesh size.

The patchy nature and intensity of sampling is a critical factor for biogeographical analysis. Although some parts of the Southern Ocean have been relatively well sampled (several Sub-Antarctic Islands, Magellan Region, Weddell Sea and Ross Sea), there are areas which remain under sampled, as those are difficult to access e.g. East Antarctica (Wilkes Land) the Bellingshausen and Amundsen seas (Linse et al. 2006, Clarke et al. 2007).

The cluster analysis and the MDS plot documented that the Patagonian Shelf and the Falkland Islands grouped together more closely as usual in zoogeographic accounts (Linse et al. 2006). Also the area here defined as High Antarctic region grouped more closely. A potential reason for this might be the more similar sampling areas. Interestingly, the Bellingshausen Sea and the South Orkney Islands grouped more closely on the basis of six shared species. Also the South Shetland Islands and the Wilkes Land of the East Antarctic grouped together probably because they share twenty-seven species. These results should be treated with care, as this might be due to the patchy nature of the isopod distribution and the sampling artefacts in those areas.

As the regulation of species diversity differ at local, regional and global scales and with time, it is difficult to compare results from different areas or years (Levine et al. 2001; Snelgrove and Smith 2002; Witman et al. 2004). Kaiser et al. (2007) therefore propose to investigate communities and abundances at local scales, rather then comparing different regions. However, the available data for the Ross Sea presents a first insight of the composition and distribution of the Ross Sea Isopods.

Table 6 shows that the Desmosomatidae, the Haploniscidae and some genera of the Munnopsidae have been recorded for the first time in the Ross Sea. These families are known to be highly abundant and speciose in the Atlantic sector of the Southern Ocean deep sea (Brandt et al. 2004, 2007a); although in the Ross Sea they were found in relatively shallow waters. The typical depth of most of the continental shelves in other oceans is 60-200 m (Walsh 1988, Gerlach 1994). This definition is not applicable for the Southern Ocean. The Antarctic shelf is extraordinarily deep, as it was formed by depression due to the weight of the ice shield and the scour of the extensions of the ice sheet. Clarke and Johnston (2003) defined the Antarctic continental shelf to a depth down to 1000 m. With regard to this definition the Isopod fauna of Ross Sea should actually represent a typical shelf fauna and it is known that on the Weddell Sea shelf the taxa of the Scutocoxifera e.g. the Serolidae and the

Antarcturidae are most speciose and highly abundant (Brandt 1999). In the Ross Sea these families are represented, although Table 1 clearly shows that the asellotes were the most dominant and speciose taxa. This pattern has also been shown in the other parts of the world's ocean, especially in the deep sea (Hessler et al. 1979, Hessler and Wilson 1983, Wilson 1987, Brandt 1991).

Some of the Ross Sea isopods show trends towards eurybathy, such as the Antarcturidae, the Paramunnidae and the Munnidae. These families are well represented on the Ross Sea shelf, however also have wide bathymetric ranges down to 600 m. While it is generally agreed that the deep-sea species of these families submerged from the Antarctic shelf (Kussakin 1973, Brandt 1991, Brandt et al. 2004,), the relatively wide bathymetric range of some of the species (e.g. *Dolichiscus meridionalis, Ianthopsis bovalli, Joeropsis antarctica*) (Table 7) is supporting the theory of enhanced eurybathy of Southern Ocean taxa (Brey et al. 1996). Another explanation of the wide bathymetric distribution of marine invertebrates might be the sea-ice extension in the Ross Sea, which stabilizes the water column and limits the primary production and enhances the habitat similarities between the costal environments and the deeper waters. Moreover, the deep Antarctic shelf might also facilitate faunal bathymetric shifts and lead to eurybathy (Berkman et al. 2004, Brey et al. 1996).

The relatively high number of new species records (23 species) for the Ross Sea and their wide geographic distribution, has to be treated with care, as the taxonomic discrimination relies on subtle morphological characters. While discriminating some species (e.g. *Eugerdella serrata* and *Munna amphicauda*) slight but consistent differences were found in comparison to the original descriptions, therefore further new species might be identified when type material is compared. It is possible that some species currently diversify, as Brökeland (2004) described for the Haploniscidae. As the isopods are brooders and do not have free-living larvae the gene flow is reduced, which increases the speciation events (Raupach and Wägele 2006). However, Held (2003) demonstrated that the isopod species *Ceratoserolis trilobitoides* comprises cryptic species, which were previously described as variations (Wägele 1986). Also studies on *Acanthaspidia drygalskii*revealed cryptic species (Raupach and Wägele 2006).

A first approach to investigate a species complex of deep-sea isopods by morphological and molecular methods was recently published by Brökeland and Raupach (2008). The combination of morphological and molecular work will be helpful for future identification and biogeography of isopods in the Ross Sea and other biogeographic areas.

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Chapter 4

Assessing diversity of benthic Isopoda on the Ross Sea shelves (Southern Ocean) using taxonomic distinctness

Keywords: taxonomic distinctness, diversity, Isopoda, macrobenthos, Ross Sea

Abstract

A relatively new and rarely used diversity measure, the taxonomic distinctness is applied to a data set of Isopoda from the 19th *Italica* expedition. This measure differs from more conventional diversity indices by incorporating the taxonomic relatedness of species. Based on a species master list a 95% probability funnel of the average (AvTD) and variation (VarTD) in taxonomic distinctness is simulated and the 19th *Italica* samples and study sites are drawn against this funnel. Interestingly only three stations and Cape Adare are falling into the AvTD range and most samples and three of four study sites are departing the AvTD funnel. Cape Adare is within the expected range, as all five sub-orders of Isopoda were represented in this area; the low values of the AvTD might indicate disturbed areas and a temporal loss of the isopod biodiversity. However, the variation of taxonomic distinctness does not show any significant departures from the 95 % probability funnel, which indicates only minor unevenness of species pairs in the samples. The joint ellipse plots (AvTD and VarTD), is a bivariate approach, and however shows the same results: only Cape Adare falls into the expected region.

Introduction

The "common" measures to analyse the biological diversity (biodiversity), such as species richness (S), Shannon Wiener index (H') and evenness (J') have some major drawbacks. In probably most marine contexts it is nearly impossible to collect all species from one region; also species accumulation curves often illustrate how the number of species increases as the samples are accumulated and the observed number of species is still rising. This shows that the "common" diversity measures are highly sensitive to sampling (Magurran 2004). Comparing of richness, Shannon and evenness values across studies of differing sample sizes is quite difficult.

Two relatively new measures which address some of the problems outlined above were defined by Warwick and Clarke (1995). These measures are based only on the presence and absence of species and on the taxonomic distances between every pair of species.

Assemblages with the same species diversity may comprise species which are closely related to each other, or are taxonomically more distinct, as they belong to different phyla. Warwick and Clarke (1995) introduced the concept of taxonomic distinctness into marine

ecology as a measure of the average degree to which individuals in an assemblage are related to each other. They showed that the mean value of this average taxonomic distinctness (AvTD) is independent of the sample size and sampling effort (Clarke and Warwick 1998). The AvTD is simply a sum of the path length trough a taxonomic tree and dividing this by the number of paths.

In February 2004 the "Victoria Land Transect" project was carried on board of RV *Italica*. The voyage visited a number of locations along the Victoria Land coast and multidisciplinary investigations were conducted at each location. The long-term objective of this programme is to provide fundamental information on structural (biological communities and habitats) and functional (ecological processes and trophic relationships) diversity (Cummings et al. 2006) and how the different components are linked together. This will enable us to make predictions about how the ecosystem will respond to environmental change. The ongoing research in the Ross Sea was focused on shallow coastal benthic ecosystems; however the 19^{th} *Italica* expedition provides insight to the benthic life at the deeper shelf (100 - 500 m).

In the present investigation samples and the study sites of the 19th *Italica* expedition are checked against a 95% probability funnel, which is based on the species master list, to detect any differences in taxonomic distinctness. Choudhury and Brandt (2008) presented an up to date species inventory of the entire Ross Sea, which is the starting point of this investigation. The hypothesis is that the taxonomic distinctness (TD) of the Ross Sea is not different to the TD of the samples or study sites. The aim of this paper is to test whether the species of the four study sites and each station are representative of the biodiversity expressed in the species inventory (Choudhury and Brandt 2008) and to identify any specific pattern in the taxonomic distinctness.

Material and Methods

Study sites and sampling

The present investigation is based on material collected during the 19th *Italica* expedition along the Victoria Land Coast in February 2004. Samples were taken along a latitudinal transect between Cape Adare and Cape Russell and along a depth gradient between 84 m and 515 m. The study includes four different sites (Table 1): Cape Adare (stations A1-A5), Cape

Hallett (stations: outer transect H out 1, 2 & 4, inner transect H in 2, 3, 5), Coulman Island (stations C1-C2) and Cape Russell (stations SMN, R2, 3 & 4) (Fig. 1). In total, 18 Rauschert dredge samples were collected and analysed. On deck, the complete samples were immediately sieved through a 500µm screen, transferred into pre-cooled 90% ethanol and kept at least 48 hours at -25°C before sorting. The isopods were sorted into families and then to species level.

Data analysis

For the present paper we used the currently accepted hierarchical Linnean classifications, as detailed and fully resolved cladograms for most of the isopod groups are not available. We compiled composite taxonomy based on Raupach et al. (2008), Brandt and Poore (2003) and Wilson (1987) (Fig 17). A master list of all known isopod species from the Ross Sea (aggregation file) was constructed after Choudhury and Brandt (2008) using five taxonomic levels (order, sub-order, family, genus and species). Following Warwick and Clarke (1995) the simplest form of distances was adopted for the five taxonomic levels (Table 8); $\omega = 0$ means individuals of the same species, $\omega = 1$ same genus but different species, $\omega = 2$ different genera, $\omega = 3$ different families, $\omega = 4$ different sub-orders and $\omega = 5$ order.

Tab.8: The five levels of classification used for the Isopoda from the Ross Sea.

k	Level	ω_k
1	Species	20
2	Genus	40
3	Family	60
4	Sub-order	80
5	Order	100

We reduced our abundance sample data simply to a presence/absence matrix and carried out a significance test. It tests the distinctness measures of any sample with *m* species, from the Ross Sea species master list. Assuming that each sample or study site is a random selection from the species master list, therefore all values should fall into the confidence funnel. The average taxonomic distinctness and the variation measures are implemented in the PRIMER version 6 packages, described in Clarke and Warwick (2001) and Clarke and Gorley (2006).



Fig. 17: The isopod taxonomy compiled for this analysis, to show the first three levels of the classification

Results

The total number of species known from the Ross Sea is 117, belonging to 61 genera, 19 families and four sub-orders. The most common isopod sub-order is the asellotes, with 48 genera and 78 species, followed by the Valvifera with 7 genera and 21 species (Table 9).

Sub-Order	Number of families	Number of genera	Number of species
Asellota	9	42	78
Cymothooida	5	8	14
Sphaeromatoidea	2	4	4
Valvifera	3	7	21
Sum	19	61	117

Tab.9: The four sub-orders and the numbers of the families, genera and species

Fig. 18 displays the 95% funnel for the simulated distribution of the AvTD for a random subset of all 18 samples taken during the 19th *Italica* expedition. Interestingly, only three samples (A2, A5 and C1) fell into the confidence funnel; although most samples had significantly lower values of AvTD than the theoretical mean.



Fig. 18: The 95% probability funnel for the AvTD from 1000 independent simulations for each station drawn randomly fro the species master list. The thick line denotes the theoretical mean for such a random selection.

For the same data sets, Fig. 19 similarly displays the values for the variation in taxonomic distinctness (VarTD). Here most stations are within the variation funnel, only station A1 clearly departs above and stations H in 2, H in 4, H out 1 and A4 are below the variance funnel. The VarTD is defined as the variance of the taxonomic distances between each pair of species. The simulated mean (thick line within the funnel) is independent of the sublist size.



Fig. 19: The 95% probability funnel for the VarTD from 1000 independent simulations for each sample taken during the 19^{th} *Italica* expedition drawn randomly fro the species master list. The thick line denotes the theoretical mean for such a random selection

The AvTD funnel of the four study sites shows that only Cape Adare fell within the 95% confidence funnel; the three other sites (Cape Hallett, Cape Russell and Coulman Island) are below the funnel (Fig. 20). However all study sites are within the VarTD funnel (Fig. 21); Cape Russell and Cape Adare fall slightly above the mean VarTD line, whereas Cape Hallett and Coulman Island are slightly below the mean.



Fig. 20: The 95% probability funnel for the AvTD from 1000 independent simulations for each study site drawn randomly fro the species master list. The thick line denotes the theoretical mean for such a random selection



Fig. 21: The 95% probability funnel for the VarTD from 1000 independent simulations for each study site drawn randomly fro the species master list. The thick line denotes the theoretical mean for such a random selection

For the interpretation of the regional differences in the taxonomic distinctness table 10 helps to identify, which isopod taxa have contributed to this pattern. It shows the number of species belonging to each of the 5 sub-orders. The most obvious finding is that at Cape Adare all four

sub-orders are represented, whereas the other three regions only include each four of the five sub-orders.

Sub-Order	Cape Adare	Cape Hallett	Coulman Island	Cape Russell
Asellota	14	27	13	14
Cymothooida	5	3	1	2
Sphaeromathoida	1	0	0	0
Valvifera	5	10	4	5
Sum	25	40	18	21

Tab. 10: The number of species of each sub-order found at each study site

The funnel plots are univariate analysis, concentrating only on one index at a time. Fig 22 shows an ellipse plot, which is a bivariate measure. In this analysis the values of AvTD and VarTD are considered jointly, both in respect of the outcome of the real data sets and their expected values from the species master list. The contours of the ellipse plot define the expected region as a result of a large number of random selections from the species master list. Superimposed in the same plot are the observed pairs (AvTD and VarTD) for the four study sites. All four sites are within the expected region.



Fig. 22: Fitted 95% probability contours of the joint AvTD and VarTD distributions, from 1000 simulations for a range of values of m number of species.

Discussion

The taxonomic distinctness measure summarizes the pattern of relatedness in a sample. It only considers presence and absence data and ignores abundances; Warwick and Clarke (1998) show that these measures are largely independent of any sampling effort.

This measure is applied for the first time for isopods from the Ross Sea. Choudhury et al (in prep.) documented diversity patterns for Isopoda from the northern Victoria Land coast, from four study sites: Cape Adare, Cape Hallett, Coulman Island and Cape Russell and found that Cape Hallett is the most divers study site with the hightest species richness.

These results are showing that only Cape Adare, the northern most location is within the expected range of AvTD. There is no clear pattern that the taxonomic distinctness is positively correlated with the latitudinal range. It also does not appear to be strongly dependent on habitat type (Warwick and Clarke 1998): stations of Cape Russell and Coulman Island have different numbers of species and different sediment types (Choudhury et al. in prep., Cummings et al. 2006), but are rather placed centrally in the AvTD funnel.

The AvTD of the other regions are clearly seen to be reduced and therefore those are placed below the confidence funnel. Cape Adare falls into the expected range of AvTD, as this region comprises all four sub-orders, whereas all other regions are missing the Sphaeromatidae. Coulman Island has the lowest value of AvTD. This result corresponds to the findings of Choudhury et al. (in prep.) who reported the lowest isopod species richness of this region.

For the current investigation however the most possible reason for the low values of Coulman Island are the absence of species of the Sphaeromatidae and the relatively low number of species of the Cymothoidea and the Valvifera in comparison to Cape Hallett and Cape Russell. Also, at stations around Coulman Island desmosomatids are better represented than paramunnids, which are quite abundant at Cape Adare and Cape Hallett. The Paramunnidae are represented with 16 genera and 23 species in the species master list of the Ross Sea, whilst the Desmosomatidae are only represented with 7 genera and 15 species.

The region around Cape Russell is known to be strongly impacted by iceberg scouring (Thrush et al. 2006). Generally low values of AvTD might display regions with high impacts

of disturbance (Rogers et al. 1999). The implication is that disturbance is associated with a loss of biodiversity of higher taxa. These higher taxa are typically those which are only represented by relatively few species compared to the more specious taxa. As already seen for Coulman Island, the desmosomatids again seem to be responsible for this pattern, as these occur with a minor number of species, and relatively low number of genera in the samples. This is in contrast to the Paramunnidae, which comprise relatively more genera and species. Station A1 of Cape Adare in the VarTD funnel is indicating a higher than expected variation in distinctness of species pairs (Fig. 19). A possible implication is that there is a widespread representation of higher taxa at this station.

Warwick and Clarke (1993) described a scenario as a consequence of the event of perturbations caused either by pollution or changing environmental conditions, which shows that the relative number of species in the four major marine macrobenthos taxa are following the sequence: polychaetes > molluscs > crustaceans > echinoderms, with the latter being first to be reduced during disturbances, whereas polychaetes appear to be the most resilient. There is usually an increase in opportunistic groups with close taxonomic affinities with an increasing disturbance frequency, which may even be sibling species or species complexes. Gerdes et al. (2003), for example, found a greater variety of taxonomic groups in undisturbed areas. Disturbed benthic environments are kept in early successional stage with usually low species diversity, and often consist of related species, while undisturbed benthic communites in a late successional stage often comprise a wider range of taxonomically distinct species (Warwick and Clarke 1995). Thus it is not clear whether all communities with a small number of species have a more limited taxonomic range than those with many species.

Another reason for the relatively low values of AvTD of our data set is a result of the absence of the Serolidae. Interestingly, the latter family did not occur in our *Italica* samples, though the family is known to be very numerous and species rich on the Antarctic shelf (Held 2000). The Serolidae are thought to have undergone an extensive radiation in the southern hemisphere, most probably in the Antarctic (Held 2000). Species of the Gnathidae were present in our samples, however we excluded those from our analysis, as most individuals are juveniles and their determination is very difficult. Nevertheless, these two families are represented in the Ross Sea and the isopod master list.

The ellipse plot is a different approach to fit both measures (AvTD and VarTD) into one 2-dimensional plot. However the conclusions are largely unchanged, meaning that only Cape Adare falls into the expected region. To conclude: most of the samples taken at the four study sites during the 19th *Italica* expedition, have a lower than expected average taxonomic spread, but the variation in of species pairs in the taxonomic tree are within the expected range.

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Holodentata gen. nov. (Isopoda:Asellota: Paramunnidae) with description of two new species: *H. caeca* and *H. triangulata*

Keywords: Isopoda, *Holodentata*, Ross Sea, Powell Basin, Southern Ocean, taxonomy, new genus, new species.

Abstract

A new genus of Paramunnidae, *Holodentata* (type species: *Paramunna gaussi* Vanhoeffen, 1914) is erected. The new genus comprises two new species: *H. caeca*, from the deep Weddell Sea and *H. triangulata*, from the Ross Sea. The new genus is distinguished by the following characters: article 3 of the antenna short and with strong denticles, mandible palp absent, article 2 of maxilliped palp longest, coxal plates visible in dorsal view in all pereonites, pleotelson broad and laterally denticulated. A key for identifying the three species included in *Holodentata* is presented.

Introduction

The family Paramunnidae Vanhoeffen, 1914 (Isopoda: Asellota) includes more than 100 species which are characterized by their small size (approximately 0.6–3 mm). The species belonging to this family are distributed all over the world from the poles to the tropics, but their major diversity lies in the temperate/cold water of the southern hemisphere (Wilson 1980). This family shows high abundance and species richness in shallow waters. However, it also shows a wide bathymetric range with some abyssal species. Several paramunnids have been described from the Antarctic waters, mainly from the Antarctic Peninsula, McMurdo Sound, Davis Sea, Adélie and Queen Mary Coasts (Richardson 1906, 1908, 1913; Hodgson 1910, Vanhoeffen 1914, Hale 1937, among others). Recently, a worldwide revision of this family was published by Just and Wilson (2004, 2006, 2007), who erected several new genera and re-diagnosed many others. As a result of these studies the Paramunnidae has proved to be a more highly diverse family than previously thought.

The Southern Ocean shows a high percentage of endemic isopods species, a fact that is probably a consequence of an intense speciation processes in geographic isolation (Brandt 1992). However, this fauna is far from being well known. With regard to this, it is worth noting that the ANDEEP (<u>AN</u>tarctic benthic <u>DEEP</u>-sea biodiversity, colonisation history and recent community patterns) surveys recently carried out in the deep Weddell Sea on board RV *Polarstern* revealed high levels of unrecorded biodiversity. In particular, of the 674 isopod species collected 585 were new to science (Brandt et al. 2007a).

The species description are based on material from two recent Antarctic expeditions; the ANDEEP III expedition, with RV *Polarstern*, which took place in 2005 in the deep Weddell Sea and the 19th *Italica* expedition on board of RV *Italica*, carried out in February 2004 in the Ross Sea. The latter one was the first large-scale attempt to collect samples along the northern Victoria-Land Coast systematically from Cape Adare (71°S) down to Terra Nova Bay (74°S). Choudhury and Brandt (2007) reported the Paramunnidae is the most abundant and most frequently collected isopod family in the *Italica* material. In the ANDEEP III material the paramunnids were less abundant and the family was sampled to 4069 m depth (Brandt et al. 2007b). An overview of all known 21 paramunnid species from the Southern Ocean and their bathymetric range are given in Table 11.

Species	Depth (m)
Austrimunna antarctica Richardson, 1906	12 - 60
Austronanus glacialis Hodgson, 1910	36.5 - 45
Austronanus dubius (Hale, 1937)	46 - 55
Austrosignum glaciale Hodgson, 1910	18 – 36
Austrosignum escandellae Castelló, 2004	45
Coulmannia australis Hodgson, 1910	183 - 400
Coulmannia frigida Hodgson, 1910	91-385
Coulmannia ramosae Castelló, 2004	124
Cryosignum incisum Richardson,1908	?
Cryosignum lunatum (Hale, 1937)	3.5 – 7
Harrietonana subtriangulata (Richardson, 1908)	0 – 12
Kiklonana arnaudi (Amar & Roman, 1974)	13-20
Kussakinella spinosa (Kussakin, 1982)	17
Notoxenus spinifer Hodgson, 1910	50
Pagonana hodgsoni Just & Wilson, 2004	< 45
Pagonana rostrata (Hodgson, 1910)	< 45
Palanana serrata (Richardson, 1908)	0.5 - 20
Palanana gaini (Richardson, 1913)	6
Paramunna gaussi Vanhoeffen, 1914	385
Pleurosignum elongatum Vanhoeffen, 1914	25 - 30
Pleurosignum magnum Vanhoeffen, 1914	22 - 150

Table 11: Species of Paramunnidae recorded from the Southern Ocean.

Material and Methods

Specimens of *Holodentata caeca* sp. nov. were collected in the Powell Basin (sub-Antarctic) during the ANDEEP III (ANT XXII/3) expedition in 2005 on board of the RV *Polarstern* in the Southern Ocean. The material was obtained by means of an epibenthic sledge (Brenke 2005).

Specimens of *Holodentata triangulata* sp. nov. were collected during the 19th *Italica* expedition, in February 2004 in the Ross Sea. Samples were taken along a latitudinal transect between Cape Adare and Terra Nova Bay with a modified Rauschert dredge (Lörz et al. 1999).

The material from both expeditions was sieved using a 500 μ m mesh and fixed in precooled 96% ethanol for later DNA analysis.

Some specimens of both species were stained with Chlorazole Black $E^{\text{(B)}}$, and the appendages were dissected and temporarily mounted in glycerin. Illustrations of the whole animal and dissected appendages were prepared using a Carl Zeiss (Axioskop 2) compound microscope equipped with a camera lucida. For SEM photographs, the specimens were cleaned with nonionic detergent Triton^(B) X100 and ultrasound. After that, they were dehydrated through a graded series of ethanol ending in 100%, critical point dried, gold-palladium sputter coated, and examined under a Leo 1525 microscope.

The length of the head, the pereonites, free pleonite and pleotelson, and the total length of the body, were all estimated along the mid-dorsal line. The width of the head was measured between the tips of the eyestalks. The lengths of the articles of the appendages were taken according to Hessler (1970). The draws of the habitus in lateral view (Figs. 1B, 6B) are presented in order to show the proportions of the segments; the denticles on the margins of head, pereonites, pleotelson and coxal plates were not drawn.

Taxonomy

Paramunnidae Vanhoeffen 1914 Holodentata gen. nov. Type species. Paramunna gaussi Vanhoeffen 1914 Species included. Holodentata gaussi (Vanhoeffen 1914), comb. nov.; H. caeca sp. nov.; and H. triangulata sp. nov. *Diagnosis*. Head with eyestalks, with or without ommatida. Lateral margins of eyestalks, pereonites, pleotelson and coxal plates surrounded with denticles. Article 3 of the antenna short and with strong denticles. Mandibular palp absent. Article 2 of maxilliped palp longest. Coxal plates visible in dorsal view in all the pereonites. Pereopod 1 carpus oval with two robust setae on ventral margin. Pereopods 2–7 without supplementary claw. Uropod biramous without protopod.

Etymology. The genus name is combined from Latin *holo* meaning entirely and *dentis* alluding to the denticles of the lateral margins of the pereonites, pleotelson and coxal plates. *Remarks.* The most striking character for *Holodentata* is the fact that the second article of the maxillipedal palp is the longest article. This feature was never reported before for any other genera of the family Paramunnidae. Four other genera show coxal plates process-like, viz., *Antennulosignum* Nordenstam, 1933; *Austrogonium* Menzies & George, 1972; *Bathygonium* Kussakin & Vasina, 1984 and *Pleurosignum* Vanhoeffen, 1914. However, *Holodentata* can easily be distinguished from those genera, as all the coxal plates possess denticles.

Geographic distribution. Species of the genus *Holodentata* have only been found in the Southern Ocean; *H. gaussi* was originally described from Wilkes Land (385 m), *H. caeca* sp. nov. was collected in the Powell Basin (1584 m), Weddell Sea and *H. triangulata* sp. nov. was found at different stations around Cape Hallett (84–353 m), Ross Sea.

Key to species of Holodentata

1 Lateral margins of all pereonites rounded ... H. gaussi (Vanhoeffen, 1914)

- Lateral margin rounded only in pereronite 4, other prereonites variable ... 2
- 2 Head anterior lobe triangular, eyestalks with ommatidia ... H. triangulata sp. nov.

- Head anterior lobe rounded, eyestalks without ommatidia ... H. caeca sp. nov.

Holodentata caeca sp. nov. (Figs. 23 - 27)

Material examined: Holotype: 1 ovigerous \bigcirc (1.6 mm), ZMH–41970, Weddell Sea; Station 133–2, (62°46.73'S, 53°02.57'W), depth 1584 m, 16 March 2005, RV *Polarstern*. Paratypes: same locality as holotype: 25 brooding $\bigcirc \bigcirc$ (1.2–1.5 mm), 87 preparatory $\bigcirc \bigcirc$ (1.2–1.4 mm), 81 adult $\bigcirc \bigcirc$ (0.9–1.4 mm) and 5 juveniles (0.8–0.9 mm) (ZMH–41971). *Diagnosis*: Head anterior lobe rounded and curving upward in lateral view. Eyestalk long axis pointing laterally, without ommatidia. Lateral margin of pereonites 1–3 expanded into a subquadrate projection, 4 rounded and 5–7 produced into a single processes. Coxal plates produced into processes.

Description: Ovigerous female (body description based on the holotype ZMH–41970, description of appendages on the paratype ZMH–41971). Length: 1.6 mm (Fig. 23A, B). Body width 0.6 length, widest at pereonite 3. Head width 2.2 length; anterior lobe rounded and curving upward in lateral view, margin with small denticles (broken off in the specimen illustrated, Fig. 23C). Eyestalks apex denticulated, long axis pointing laterally, without ommatidia. Lateral margin of pereonites 1–3 expanded into a subquadrate projection, 4 rounded and 5–7 produced into single processes. Pereonite 1 about as long as pereonite 2, pereonite 2 < 3 > 4 > 5< 6 = 7 = free pleonite. Pereonite 5 shortest and pereonite 3 longest. Coxal plates produced into processes and denticulated, visible in dorsal view in all pereonites. Pleotelson width 1.2 length, marginally with 21–23 denticles on each side, apex pointed.

Antennula (Fig. 24B), article 1 largest, with 1 simple seta and 5 robust denticles on one side; article 2 0.7 length of article 1, with 4 broom and 3 simple setae; article 3 shorter than article 2, with 1 simple seta, article 4 shortest with 1 broom seta, article 5 slightly longer than article 6 without setation; article 6 with 4 simple setae and 1 aesthetasc.

Antenna (Fig. 24A), article 1 without setation, article 2 with 1 simple seta, article 3 with 5 robust denticles on each side and 3 denticles on distal margin, and 4 simple setae; article 4 shortest with 2 simple setae; article 5 subequal in length to article 6 with 1 broom and 2 simple setae; article 6 with 3 broom and 2 simple setae; flagellum with 8 articles, each article with numerous setae.

Right mandible (Fig. 24C), incisor process with 5 blunt cusps (proximal one quadrate); spine row with 5 serrate setae; molar process with 1 row of teeth and 1 seta on distal edge.

Left mandible (Fig. 24D) as right except for: incisor process with a 3-cusped lacinia mobilis and spine row with 4 serrate setae; molar process without setation.

Maxillula (Fig. 24E), lateral lobe with 1 simple seta close to distal margin, 11 cuspidate setae distally (2 of these setulated) and 5 simple setae on lateral margin; mesial lobe with 4 large setulated setae distally and 4 slender simple setae on lateral margin.

Maxilla (Fig. 24F), lateral and middle lobe protruding distomedially, with 1 pectinated and 3 simple setae distally; mesial lobe with 2 pectinated, 1 setulated and 5 simple (with pore-

bearing tip) setae on distal margin, 1 setulated seta and numerous simple slender setae on mesial margin.

Maxilliped (Fig. 25A), endite with 2 coupling hooks, distal margin with 3 simple and 2 setulated setae, ventral surface with 2 fan setae, dorsal with 3 setulated setae (see detail drawing). Epipod ovate, width 0.5 of length.

Pereopod 1 (Fig. 25B), basis longest article with 3 simple setae. Ischium 0.6 basis length, with 3 simple setae. Merus cup-shaped, with 6 simple setae and 2 cuticular combs. Carpus oval, 0.7 ischium length; dorsal margin with 2 simple setae distally; ventral margin with 2 robust and 5 simple setae and anterior surface with 1 cuticular comb. Propodus 0.9 ischium length, dorsal margin with 3 simple setae, ventral margin with 7 simple setae, anterior surface with 5 cuticular combs and 1 simple seta. Dactylus with 2 simple setae near distal end and 2 simple setae between unguis and supplementary claw, unguis slightly shorter than dactylus, supplementary claw 0.7 unguis length.

Pereopods 2–7 (Figs. 25C, D; 26). Bases with 2–4 simple setae. Ischia with 3–4 simple setae. Meri with 3–5 simple setae. Carpi with 2 simple setae at half length of article, and 3–5 simple setae and 1 broom simple setae on distal end, carpus of pereopod 7 with 6 cuticular combs. Propodi with 2–3 simple setae at half length of article, and 3–4 simple setae and 1 broom seta on distal end. Dactyli with 4–6 simple setae, unguis slightly longer than dactylus, supplementary claw absent.

Operculum (Fig. 27A) ovoid and pointed distomedially, width 0.9 length; lateral margins with several simple setae (many of these broken).

Pleopod 3 (Fig. 27B), endopod width 0.6 length, with 3 plumose setae distally. Exopod with 2 articles, distal one with 1 distal simple seta, which extends beyond the tips of the endopod setae.

Pleopod 4 (Fig. 27C), exopod reaching half length of endopod (endopod folded in the specimen illustrated).

Pleopod 5 (Fig. 27D) width 0.5 length.

Uropod (Fig. 27E) exopod 0.2 endopod length, with 2 simple seta distally; endopod with 3 simple setae subapically and 5 broom setae distally.

Description of adult male (paratype ZMH-41971)

Pleopod 1 (Fig. 27F) maximum width 0.6 length; lateral lobes at 0.7 of its length from proximal end, each one with 6 simple setae; ventral surface with 4 simple setae (2 of these close to lateral margin).

Pleopod 2 (Fig. 27G), protopod width 0.4 length, with 18 simple setae on lateral margin. Endopod slightly surpassing protopod. Exopod bilobed.

Remarks. H. caeca sp. nov. is most similar to *H. triangulata* sp. nov.; the main differences between these two species are discussed in the remarks section of the latter one.

Distribution. Only known from type locality.

Etymology. The species name is Latin *caeca* meaning blind and refers to the absence of ommatidia.



Fig. 23: *Holodentata caeca* sp. nov., holotype \mathcal{Q} , ZMH–41970, A, dorsal view. B, lateral view. Scale bar = 1 mm. C, head in ventral view. D, pleotelson in ventral view. Scale bar = 0.5 mm.



Fig. 24: *Holodentata caeca* sp. nov., paratype \bigcirc , ZMH–41971, A, antenna. Scale bar = 0.1 mm. B, antennula. C, right mandible. D, left mandible. E, maxillula. F, maxilla. Scale bars = 0.05 mm.



Fig. 25: *Holodentata caeca* sp. nov., paratype \bigcirc , ZMH–41971, A, maxilliped. B, pereopod 1. C, pereopod 2. D, pereopod 3. Scale bars = 0.1 mm.



Fig 26: *Holodentata caeca* sp. nov. paratype $\stackrel{\bigcirc}{_{_{_{_{_{}}}}}}$, ZMH–41971, A, pereopod 4. B, pereopod 5. C, pereopod 6. D, pereopod 7. Scale bars = 0.1 mm.



Fig. 27: *Holodentata caeca* sp. nov., paratype \bigcirc , ZMH–41971, A, operculum. B, pleopod 3. C, pleopod 4. D, pleopod 5. Scale bars = 0.2 mm. E, uropod. Scale bar = 0.05 mm. Paratype \eth , ZMH–41971. F, pleopod 1. G, pleopod 2. Scale bars = 0.2 mm.

Holodentata triangulata sp. nov. (Figs. 28-31)

Material examined: Ross Sea, RV *Italica*. Holotype: 1 adult \bigcirc (ZMH–41972); station H out 4, 72°18.5'S, 170°26.8'E, 235 m depth, 12 Feb 2004. Paratypes: same locality as holotype: 25 brooding $\bigcirc \bigcirc \bigcirc (1.4-1.8 \text{ mm})$, 26 preparatory $\bigcirc \bigcirc (1-1.7 \text{ mm})$, 12 adult $\bigcirc \bigcirc (1.1-1.5 \text{ mm})$ and 7 juveniles (0.9–1 mm); (ZMH–41973). Station H out 2, 72°17.5'S, 170°29.4'E, 353 m depth, 11 Feb 2004: 7 brooding $\bigcirc \bigcirc (1.5-1.7 \text{ mm})$, 5 preparatory $\bigcirc \bigcirc (1.1-1.5 \text{ mm})$, 3 juvenile $\bigcirc \bigcirc (0.9-1 \text{ mm})$ and 3 adult $\bigcirc \bigcirc (1.1-1.2 \text{ mm})$. Station H in 3, 72°17.0'S, 170°13.1'E, 316 m depth, 16 Feb 2004: 3 preparatory $\bigcirc \bigcirc (1-1.4 \text{ mm})$ and 2 adult $\bigcirc \bigcirc (1.4-1.5 \text{ mm})$. Station H in 4, 72°17.1'S, 170°14.0'E, 196 m depth, 16 Feb 2004: 5 brooding $\bigcirc \bigcirc (1.3-1.7 \text{ mm})$, 9 preparatory $\bigcirc \bigcirc (1.2-1.3 \text{ mm})$ and 7 juveniles (0.8–1 mm).
Station H in 5, 72°17.2'S, 170°17.9'E, 84 m depth, 16 Feb 2004: 4 preparatory 99 (1.3–1.4 mm), 1 juvenile 9 (0.9 mm) and 2 adult 33 (0.9–1.1 mm). Station H out 1, 72°14.8' S, 170°15.2'E, 542 m depth, 9 Feb 2009: 4 preparatory 99 (1.2–1.6

mm) and 1 juvenile $\bigcirc \bigcirc$ (1 mm).

Diagnosis: Head anterior lobe triangular with blunt apex, and curving upward in lateral view. Eyestalk long axis pointing laterally, with 4 ommatidia. Lateral margin of pereonites 1–3 expanded into a subquadrate projection, 4 rounded and 5–7 produced into single processes. Coxal plates produced into processes. Pereopod 7, carpus with 1 robust seta distoventrally.

Description: Brooding female (Body description based on the holotype (ZMH–41972), description of appendages on the paratype ZMH–41973). Length: 1.9 mm (Fig. 29A, B). Body width 0.6 length, widest at pereonite 3. Head width 2.4 length; anterior lobe triangular with blunt apex, curving upward in lateral view, marginally denticulated (Fig. 28C, 10B). Eyestalks long axis pointing laterally, with 4 ommatidia. Lateral margin of pereonites 1–3 expanded into a subquadrate projection, 4 rounded and 5–7 produced into single processes. Total length of all pereonites and free pleonite combined subequal to pleotelson length. Coxal plates produced into processes and denticulated, visible in dorsal view in all pereonites. Pleotelson width 1.2 length, marginally with 20–25 denticles on each side, apex truncate.

Antennula (Fig. 29A), article 1 largest, with 1 broom seta, and 3 and 1 robust denticles on each side; article 2 0.6 length of article 1, with 2 broom and 3 simple setae; article 3 0.7 length of article 2 and subequal in length to article 5 (and 6); article 4 shortest, with 1 simple seta; article 6 with 3 simple setae and 1 aesthetasc.

Antenna (Fig. 29B) articles 1 and 2 glabrous; article 3 short distally broadened, with 2 simple setae and several robust denticles; article 4 with 1 simple seta; article 5 subequal in length to article 6, with 1 simple seta; article 6 with 3 broom and 3 simple setae; flagellum with 9 articles, each article with numerous setae.

Right mandible (Fig. 29C), incisor process with 4 blunt cusps (proximal one quadrate); spine row with 5 serrate setae; molar process with 1 row of teeth and 1 serrate seta on distal edge. *Left mandible* as right except for: incisor process with a 4-cusped lacinia mobilis (1 of these cusps minute) and spine row with 4 serrate setae; molar process without setation.

Maxillula (Fig. 29D), lateral lobe with 1 simple seta close to distal margin and 12 cuspidate setae distally (2 of these setulated), mesial lobe with 5 setulated setae distally and 4 slender simple setae.

Maxilla (Fig. 29E), lateral and middle lobe protruding distomedially, with 1 pectinated and 3 simple setae distally; mesial lobe with 2 pectinated, 1 setulated and 6 simple (with porebearing tip) setae on distal margin, 1 setulated seta and numerous slender simple setae on mesial margin.

Maxilliped (Fig. 29F), endite with 2 coupling hooks, distal margin with 4 setulated setae, ventral surface with 2 fan setae and 1 setulated seta, dorsal surface with 3 setulated setae (see detail). Epipod ovate, width 0.6 of length.

Pereopod 1 (Fig. 30A, B), basis longest article with 3 simple setae. Ischium 0.5 basis length, with 2 simple setae and 1 cuticular comb. Merus cup-shaped, with 5 simple setae and 2 cuticular combs. Carpus oval, 0.8 ischium length; dorsal margin with 1 simple seta distally; ventral margin with 2 robust and 6 simple setae, anterior surface with 1 cuticular comb. Propodus 0.8 ischium length, dorsal margin with 4 simple setae (1 at half length article and 3 distal), ventral margin with 7 simple setae, anterior surface with 1 simple seta and 4 cuticular combs. Dactylus with 3 simple setae near distal end and 2 simple setae between unguis and supplementary claw, unguis slightly shorter than dactylus, supplementary claw 0.8 unguis length.

Pereopods 2–7 (Figs. 30C–E, 31A–C). Bases with 2–3 simple setae. Ischia with 2–4 simple setae. Meri with 3–5 simple setae. Carpi with 2 simple setae at half length article, and 3–6 simple setae and 1 broom seta on distal end; carpus of pereopod 7 with 1 robust seta distoventrally and some cuticular combs. Propodi with 2–3 simple setae at half length of article, 2–4 simple setae and 1 broom seta on distal end; propodus of pereopod 7 with some cuticular combs. Dactyli with 4–5 simple setae, unguis slightly longer than dactylus, supplementary claw absent.

Operculum (Fig. 31D) ovoid and acuminating distomedially, width 0.9 length; lateral margins with several simple setae (many of these broken).

Pleopod 3 (Fig. 31E), endopod width 0.6 length, with 3 plumose setae distally. Exopod with 2 articles; distal one with 3 minute setae and 1 distal simple seta, which extends towards the tips of the endopod setae.

Pleopod 4 (Fig. 31F), endopod width 0.5 length, exopod reaching half length of endopod. *Pleopod 5* (Fig. 31G) width 0.5 length.

Uropod (Fig. 31H) exopod 0.3 endopod length, with 2 simple setae distally; endopod with 3 simple setae subapically and 5 broom setae distally.

Description of adult male (paratype ZMH-41973)

Pleopod 1 (Fig. 31I) maximum width 0.6 length; lateral lobes at 0.7 of its length from proximal end, each one with 6–7 simple setae; distal projection with 2 simple setae; ventral surface with 4 simple setae (2 of these close to lateral margins).

Pleopod 2 (Fig. 31J), protopod width 0.4 length, with 17 simple setae on lateral margin. Endopod slightly surpassing protopod. Exopod bilobed.

Remarks. H. triangulata is most similar to *H. caeca*, but it can be easily distinguished from the latter by having (features dealing with *H. caeca* are in parentheses): Head anterior lobe triangular (anterior lobe rounded), eyestalks with ommatidia (blind), antenna article 3 with denticles on one side (article 3 with denticles on both margins), carpus pereopod 7 with one distal robust seta on ventral margin (robust seta absent).

Distribution. Only known from type locality.

Etymology. The epithet is derived from Latin *triangulus* meaning triangular alluding to the triangular shape of the head.



Fig. 28: *Holodentata triangulata* sp. nov., holotype \bigcirc , ZMH–41972, A, dorsal view. B, lateral view. Scale bar = 1 mm. C, head in ventral view. Scale bar = 0.5 mm. D, Pleotelson in ventral view. Scale bar = 0.5 mm.



Fig. 29: *Holodentata triangulata* n. sp, paratype \mathcal{Q} , ZMH–41973, A, antennula. Scale bar = 0.05 mm. B, antenna. Scale bar = 0.1 mm. C, mandible. D, maxillula. E, maxilla. Scale bars = 0.05 mm. F, maxilliped. Scale bar = 0.1 mm.



Fig. 30: *Holodentata triangulata* sp. nov., paratype \mathcal{Q} , ZMH–41973, A, pereopod 1. B, dactylus of pereopod 1. C, pereopod 2. D, pereopod 3. E, pereopod 4. Scale bars = 0.1 mm.



Fig. 31: *Holodentata triangulata* sp. nov., paratype \bigcirc , ZMH–41973, A, pereopod 5. B, pereopod 6. C, pereopod 7. Scale bar = 0.1 mm. D, operculum. E, pleopod 3. F, pleopod 4. G, pleopod 5. Scale bars = 0.2 mm. H, uropod. Scale bar = 0.05 mm. Paratype \bigcirc , ZMH–41973. I, pleopod 1. J, pleopod 2. Scale bars = 0.2 mm.



Fig. 32: SEM photographs. *Holodentata triangulata* sp. nov., paratype \Im , ZMH–41973. A, dorsal view. Scale bar = 100 µm. B, ommatidia in dorsal view. C, antenna. Scale bars = 20 µm. D dorsal view of lateral margins of the pereonites. Sclae bars = 20 µm. *H. caeca* sp. nov., paratype \Im , ZMH–41971. E, dorsal view. Scale bar = 100 µm. F antenna. Scale bars = 20 µm.

Discussion

At present, *Holodentata* gen. nov. includes three species, all of them from the Southern Ocean: *H. gaussi* (Vanhoeffen 1914) from the Gauss Station, Wilkes Land; *H. triangulata* sp. nov. from the Ross Sea; and *H. caeca* sp. nov. from the Powell Basin, Weddell Sea. *Holodentata gaussi* (Vanhoeffen 1914), the type species of the new genus described herein, was originally placed in the genus *Paramunna*.

Just and Wilson (2004) revised the genus *Paramunna* and redefined its diagnostic characters. These authors also transferred several species which were formally placed in the genus *Paramunna*; *P. gaussi* was removed from this genus but was not assigned to any other genera until now. It is worth noting that two other species also excluded from the genus *Paramunna* (*P. quadratifrons* Iverson and Wilson 1981 and *P. pellucida* Kensley 2003) still remain *incertis sedis*. Most probably these two species require the erection of new genera, however to confirm this assumption an examination of their type specimens is needed.

Just and Wilson (2004) reported that several genera of the *Paramunna* complex have a wide geographical distribution, while the species usually show a very narrow range of distribution. Our data support this geographical pattern, *Holodentata* being a circumpolar Antarctic genus, with three species each one distributed in a restricted area. Also *Holodentata* shows a wide bathymetric range, as *H. triangulata* was collected in relatively shallow waters (84–542 m), whereas *H. caeca* was collected in bathyal depth (1584 m).

Just and Wilson (2004) described a sexual dimorphism in several species of the *Paramunna* complex, however it was not observed in any of the two new described species.

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Chapter 6

Coulmannia rossiae sp. nov.

(Asellota: Paramunnidae) from the Ross Sea

Keywords: Isopoda, Ross Sea, Southern Ocean, new species, taxonomy

Abstract

A new species of *Coulmannia*, *C. rossiae*, is described from the Southern Ocean. It is most similar to *C. ramosae* Castelló, 2004, but can easily be distinguished from this species by the paired tuberculated elevations of pereonites 2-6. The female of the new species differs from the male in having only single tuberculated elevations being very broad on pereonites 1 and 2 and decreasing in width in pereonites 3-4.

Introduction

The family Paramunnidae was erected by Vanhoeffen (1914) and includes 28 genera to date. *Coulmannia* Hodgson, 1910 originally included two Southern Ocean species, *C. australis* from Coulman Island, 183-400 m and *C. frigida* from McMurdo Sound, 229 m. Later, Vanhoeffen (1914) reported *C. frigida* for the Gauss Station, Wilkes Land at 385 m depth. Castelló (2004) described the third species of this genus *Coulmannia ramosae* from the South Shetland Islands at 124 m depth. This genus has only been reported from the Southern Ocean. In the present paper we describe the fourth species of this genus: *Coulmannia rossiae* sp. nov., obtained during the 19th *Italica* expedition, in February 2004 in the Ross Sea.

Material and Methods

Specimens of *Coulmannia rossiae* sp. nov. were collected during the 19th *Italica* expedition, in February 2004 in the Ross Sea. Samples were taken along a latitudinal transect between Cape Adare and Terra Nova Bay with a modified Rauschert dredge (Lörz et al. 1999).

The material was sieved using a 500 μm mesh and fixed in pre-cooled 96% ethanol for later DNA analysis.

Some specimens of this species were stained with Chlorazole Black $E^{\text{(B)}}$, and the appendages were dissected and temporarily mounted in glycerin. Illustrations of the whole animal and dissected appendages were prepared using a Carl Zeiss (Axioskop 2) compound microscope equipped with a camera lucida.

The length of the head, the pereonites, free pleonite and pleotelson, and the total length of the body, were estimated along the mid-dorsal line. The width of the head was measured between the tips of the eyestalks. The lengths of the articles of the appendages were taken according to Hessler (1970).

Taxonomy

Janiroidea Sars, 1897

Paramunnidae Vanhoeffen, 1914

Genus Coulmannia Hodgson, 1910

Composition: C. australis Hodgson, 1910, C. frigida Hodgson, 1910 and C. ramosae Castelló, 2004.

Coulmannia rossiae sp. nov. (Figs. 33–37)

Material examined: Ross Sea, RV *Italica*. Holotype: 1 adult 3° (ZMH-00000); station H out 2, 72°17.5'S, 170°29.4'E, 353 m depth, 11 Feb 2004. Paratypes: same locality as holotype: 5 $3^{\circ}3^{\circ}$ (1.3-1.4 mm), 4 brooding $9^{\circ}9^{\circ}$ (1.6-1.7 mm), 2 preparatory $9^{\circ}9^{\circ}$ (1.2-1.3 mm) and 2 juveniles (0.9-1 mm); (ZMH-00000). Station H in 3, 72°17.0'S, 170°13.1'E, 316 m depth, 16 Feb 2004: 5 $3^{\circ}3^{\circ}$, 2 brooding $9^{\circ}9^{\circ}$, 1 preparatory 9° and 2 juveniles. Station H in 4, 72°17.1'S, 170°14.0'E, 196 m depth, 16 Feb 2004: 7 $3^{\circ}3^{\circ}$, 3 preparatory ff# and 2 juveniles. Station H in 2, 72°16.9'S, 170°12.2'E, 391 m depth, 10 Feb 2004: 4 $3^{\circ}3^{\circ}$ and 1 preparatory 9° . Station SMN, 74°43,2', 164°13,1', 366, date 20 Feb 2004: 2 $3^{\circ}3^{\circ}$ and 2 juveniles. Station H out 1, 72°15,7', 170°24,8', 458, 9 Feb 2004: 2 $3^{\circ}3^{\circ}$, 1 preparatory 9° and 2 juveniles. Station H out 4, 72°18.5'S, 170°26.8'E, 235 m depth, 12 Feb 2004: 4 $3^{\circ}3^{\circ}$ and 2 preparatory $9^{\circ}9^{\circ}$. Station A 4, 71°18.4'S, 170°28.9'E, 230 m depth, 14 Feb 2004: 1 preparatory 9° . Station C1, 73°24.5'S, 170°23.2'E, 474 m depth, 18 Feb 2004: 1 brooding $9^{\circ}9^{\circ}$, 6 preparatory $9^{\circ}9^{\circ}$ and 3 juveniles.

Diagnosis: Dorsal sculpture formed by pairs of distinct tuberclated bumps on pereonites 1–6, pereonite 7 and free pleonite with a single one. Coxal plates rounded, only on pereonites 5-7 visible dorsally. Uropodal endopod minute, about 0.5 length of exopod. Apex of pleotelson with setose margins and dorsal surface.

Description of the male (body description based on the holotype, description of appendages on the paratype ZMH–0000) (Fig.33): Cephalon with lateral eyes on robust stalks, placed at the end of cephalon, with 5 ommatidia. Length of eyestalks 0.18 of width of cephalon. Dorsal sculpture (Fig. 33) formed by two transverse tuberculated bumps on pereonites 1–6, pereonite 7 and free pleonite with a single tuberculated bump. Lateral margins of pereonites 1 and 5-7 rounded, those of pereonites 2-4 produced into a single process. Coxa rounded, those of pereonites 5–7 visible in dorsal view. Pleotelson with free pleonite 1.6 times as long as the last 3 pereonites combined. Pleotelson (Fig.1) oval, with convex lateral margins and distally pointed. Uropods inserted at two thirds of pleotelson length in posterolateral indentations of pleotelson, directed backwards.

Antennula (Fig. 34a): peduncular articles 1-3 longer than wide; first article with 4 simple and 1 broom setae; second article largest, with 5 simple and 4 broom setae on one side; article 3 shorter than article 2, with one simple seta; article 4 shortest, with 1 broom seta, article 5 slightly longer than article 6, without setation; article 6 with 5 simple setae, 1 broom seta and 1 aesthetasc.

Antenna (Fig. 34b): article 1 broken off during dissection, without setation; article 2 with 1 simple seta; article 3 with proximolateral bulge and 5 simple setae; article 4 shortest, with 2 simple setae; article 5 with 3 simple setae; article 6 longest, with 5 broom setae and 5 simple setae; flagellum with 7 articles, each article with numerous setae.

Left mandible (Fig. 34c) stout, without palp: incisor process with 5 blunt cusps (proximal one nearly quadrate); spine row with 2 simple and 1 serrate setae, with a 4-cusped lacina mobilis; molar process with row of teeth.

Right mandible (Fig. 34d): as left except for spine row with 4 serrated setae and without lacinia mobilis, replaced by an additional seta. Pars molaris cylindrical, transversely truncated, with lower margin of apex toothed.

Maxillula (Fig. 34f): lateral lobe with apex bearing 10 stout cuspidate and acute setae, medial lobe with 4 setae, 2 of these distally serrated.

Maxilla (Fig. 34e): lateral and medial lobes with 4 long setae respectively, two of these being serrated. Inner lobe with 9 apical and distomedial setae, 4 simple slender setae on inner margin.

Maxilliped (Fig. 35a): endite reaching the half of third article of palp, with 2 coupling hooks, distal margin with 4 setulated setae (detail drawing), ventral surface with 2 fan setae, dorsal with 3 setulated setae; epipode ovate, width 0.5 of length, reaching dorsal margin of

second palp article. All articles of palp bearing smooth setae on inner margin; article 3 shows 1 seta on outer margin. Relative lengths of articles 1 : 1.4 : 1.4 : 1.7 : 1.

Pereopod 1 (Fig. 35b): stoutest. Basis longest article, with 4 simple setae. Ischium with 4 simple setae. Merus with 1 sensory and 1 simple setae distodorsally, and 4 simple setae on ventral margin. Carpus with 1 apical sensory seta and two further more proximal sensory setae, and 3 simple setae on ventral margin as well as 2 small cuticular ridges equipped with cuticular combs. Propodus oval, broadest medially, with 3 distodorsal simple setae and 1 further more proximal one, 1 mediolateral seta and 4 simple ventral setae. Dactylus with apical unguis about equal in length to article, ventral unguis shorter, 2 apical seta, one of these as long as apical unguis; and 3 distomedial setae.

Pereopod 2-7 (Figs. 35c, d, e; 36a, b, c): of subequal shapes and lengths. Meri with a distodorsal sensory seta, meri of pereopods VI and VII also with a distoventral sensory seta. Carpi and propodi with a distodorsal broom seta each; and 4 sensory setae and 3 sensory setae on ventral margin, respectively. Dactylus bearing 2 unguis (ventral one seta-like); apical unguis longer than dactylus, slender and slightly curved.

Pleopod 1 (Fig. 36d): lateral lobes at level of 2/3 of its length, each lobe with 8 setae on their tips; 4 ventral setae and 4 setae at caudal margin from lateral lobes.

Pleopod 2 (Fig. 36e): with sympod bearing outer margin rounded and setose in little more than distal half; inner margin concave. Apex without setae. Endopod stylet-like, curved to the apex of the sympod. Relative lengths endopod : sympod, 1 : 1.3. Exopod without setae.

Pleopod 3 (Fig. 36f): endopod width 0.6 length, with 3 plumose setae distally. Exopod with 2 articles, distal one with 1 distal simple seta, which extends beyond the tips of the endopod setae.

Pleopod 4 (Fig. 36g): exopod reaching half length of endopod.

Pleopod 5 (Fig. 36h): width 0.5 length.

Uropod (Fig. 36i): biramous; exopod 0.4 endopod length, distally with 2 simple, broken setae; endopod with 5 broom and 3 simple setae.

Differences of adult female (paratype ZMH–00000) (Fig. 37): The female differs in dorsal view from the male in bearing only a single tuberculated bump on pereonites 1–6. First tubercular bump being broadest, but shallowest, following bumps slightly narrowing from pereonites 2–4.

Discussion

Because of the dorsal ornamentation and the lateral margins of the pereonites *Coulmannia rossiae* sp. nov. is most similar to *C. ramosae* Castelló, 2004; the main difference between them is that the male of the new species bears a paired of tubercular bumps on pereonites 1–6, whereas males of *C. ramosae* bears only paired ones on pereonites 1-2. Moreover, the pleotelson of the new species is shorter and broader than that of *C. ramosae*.

Dorsal margin of bases of pereopods 2-5 in *C. ramosae* with sensory setae and with only simple setae in *C. rossiae*. Propodi of pereopods 2-4 with 4 sensory setae in *C. ramosae* and only 3 in *C. rossiae*.

Distribution: only known from type locality.

Etymology: The species name refers to the Ross Sea where it has been sampled in the Southern Ocean.



Fig. 33: *Coulmannia rossiae* sp. nov., holotype 3° , ZMH–00000. A, dorsal view. B, lateral view. Scale bars = 1 mm. C, head in ventral view. D, pleotelson in ventral view. Scale bars = 0.2 mm.



Fig. 34: *Coulmannia rossiae* sp. nov., paratype 3, ZMH–00000. A, antennula. B, antenna. C, left mandible with detail of the incisor and molar processes. D, right mandible. E, maxilla. F, maxillula. Scale bars = 0.5 mm.



Fig. 35: *Coulmannia rossiae* sp. nov., paratype 3° , ZMH–00000. A, maxilliped with detail of the distal end of endite (fan setae were not drawn in the detail). B, pereopod 1. C, pereopod 2. D, pereopod 3. E, pereopod 4. Scale bars = 0.1 mm.



Fig. 36: *Coulmannia rossiae* sp. nov., paratype 3, ZMH–00000. A, pereopod 5. B, pereopod 6. C, pereopod 7. D, pleopod 1. E, pleopod 2. F, pleopod 3. G, pleopod 4. H, pleopod 5. Scale bars = 0.1 mm. I, uropod. Scale bar = 0.05 mm.



Fig. 37: *Coulmannia rossiae* sp. nov., paratype \bigcirc , ZMH–00000. A, dorsal view. B, lateral view. Scale bar = 1 mm. C, operculum. Scale bar = 0.2 mm.

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General Remarks

Several aspects of the isopod composition, their abundance, diversity and zoogeography off the Victoria Land coast have been analysed and discussed within the various chapters of this thesis. Nevertheless, this chapter concludes the major findings and critically evaluates the methods applied in this thesis:

The results presented here revealed high species richness of the Ross Sea Isopoda. This corresponds with samples from the Weddell Sea, which also proved to be highly specious (Brandt et al. 2004, 2007). An important factor for the high diversity is the age of the environment (Brandt 2000) that is the evolutionary time in which the species were able to radiate and develop. Age, for example, is one of the major differences between Arctic and Antarctic waters. In a comparative bipolar study, Brandt (2001) reported that densities of Peracarida were higher in Arctic waters; however species richness was found to be higher in the Southern Ocean (SO). However, the Antarctic continental shelf had been covered several times during last glacial maxima. Thus, benthic life there was either not possible or reduced to few ice-free areas under ice-shelves or beneath grounding ice sheets (Brandt 1991, Thatje et al. 2005). Following previous glaciations, at least some, if not all, taxa had to recolonize the shelf e.g. from the slope, the deep sea or Subantarctic islands (Brandt 1991), and it appears as if the Antarctic benthic shelf fauna is still under recolonisation (e.g. Gutt 2006).

A latitudinal decline of diversity from the tropics to the poles have been documented for terrestrial habitats and (in the sea) for the Northern hemisphere (Rosenzweig 1995, Clarke & Lidgard 2000, Rex et al. 1993 etc.). At high Southern latitudes there is little evidence for latitudinal diversity gradients in the (shallow) marine realm, though some have been reported for certain taxa, e.g. bivalves and gastropod molluscs (Stehli 1967). In isopods, Rex et al. (1993) found a strong cline in diversity from the equatorial deep sea to the North Atlantic and Arctic, while there was so significant trend in the Southern hemisphere. Yet Brey et al. (1996) showed that these result were due to a sampling bias, as most of the samples Rex et al. (1993) analysed came from the North Atlantic at depth between 500 - 4000 m and no samples were analysed south of 40° S. Examining samples from the Ross Sea did not show any effect of latitude (or rather factors changing with latitude, such as ice cover) on isopod diversity, which might be due to the small size of the sampling area spanning only $74 - 78^{\circ}$ of latitude (**chapter 1 and 2**). Yet, striking differences were found in abundance and diversity patterns across sites and taxonomic groups driven by various environmental and historical processes.

Geographic and bathymetric distribution in Ross Sea Isopoda

Interestingly at the northernmost location (Cape Adare) the Paramunnidae were very abundant and specious and the Desmosomatidae were completely absent. This is most probably related to the habitat, which consists of gravel and coarse sand, a substrate which is favoured by paramunnids and munnids which might erode detritus. At the southernmost location (Cape Russell) paramunnids were nearly absent, and the desmosomatids were the most abundant taxa. For this area frequent iceberg disturbance was documented and the sediment was found to consist of large rocks and stones. One possible explanation for the dominant occurrence of the desmosomatids might be their swimming ability, which may enable them to recolonize disturbed areas faster (**chapter 1 and 2**).

Relatively strong faunal links can be documented at the deeper shelf off the Victoria Land coast (chapter 3). Polar submergence has been postulated for some isopod families (e.g. the Acanthaspidiidae, the Antarcturidae, the Munnidae and the Paramunnidae), for others emergence processes over time have been suggested (e.g. the Desmosomatidae, the Ischnomesidae and the Munnopsidae) (Kussakin 1973, Brandt 1999, Raupach et al. 2004). Wide bathymetric ranges (i.e. eurybathy) have been proposed for some SO taxa (Brey et al. 1996) as being an adaptation to glacial-interglacial migration processes, e.g. species escaped adverse conditions on the shelf by down slope migration. In the Italica samples I also found a relatively high number of desmosomatid and munnopsid species in relatively shallow waters (between 200-300 m) and contrary paramunnids and munnids (i.e. shallow water groups) occurred in deeper waters (>400 m). The recently described genus (Holodentata, see chapter 5) also indicates eurybathy in this genus, as H. caeca was found at 1584 m depth. Based on molecular genetic analysis Raupach et al. (2004) suggested that the SO deep-sea has been colonized several times, which would generally support the theory of enhanced SO eurybathy. Furthermore, the Ross Sea shelf is quite deep (see introduction) and has been (at least partly) overrun by ice sheets during the last glacial maximum and therefore may have facilitated the occurrence of a combined shelf, slope and deep-sea fauna. Yet, thorough molecular genetic studies will probably uncover cryptic species in many SO taxa (Held 2003, Brökeland and Raupach 2008) and thus will alter levels of eurybathy likewise for shelf and deep-sea species.

The zoogeographic analysis (**chapter 3**) demonstrated that most species represented in the Ross Sea had wide geographic ranges and also occurred in the Weddell and Scotia Sea regions. Even though circum-Antarctic distribution has been hypothesized for several macrobenthic taxa (Hedgepeth, 1969, Brandt 1991, Wägele 1992 Held 2000) the apparent wide distribution of some isopod species (e.g. *Eugerdella serrata*) is probably due to sibling species (Brix pers. comm.) which show a restricted distribution (Brökeland and Raupach 2008).

The Paramunnidae is the most frequently sampled and abundant family. In **chapter 5 and 6** new species of this family are described from the Ross Sea (*Holodentata triangulata* and *Coulmannia rossiae*) and the Weddell Sea (*Holodentata caeca*). Further descriptions are planned in future, as this group seems to be an important component of the SO Ross Sea isopod fauna.

Rauschert dredge

The sampling effort has a significant impact on biodiversity measures and the comparability of the data, even though taken during one expedition. A major source of errors is the consistency of the deployment of the Rauschert dredge which, depends on several factors. For example, the velocity of the ship might change during the deployment; as it is unrealistic that the ship moves constantly with the same velocity. Also, as table 1 shows, the haul lengths can vary, that is that the trawled distance on the ground is different from one station to another. Once the gear is deployed it might drift at the bottom due to the topography, sediment and bottom currents. The latter might have strong influence on the amount of material collected; a frontal current increases the sample size, whereas a lateral current might result in a decreased sample size. All these factors affect the accuracy of the quantitative analysis and therefore should be always treated with the awareness of this inaccuracy. Nevertheless, the Rauschert dredge is a very successful gear to sample small epibenthic fauna (Lörz et al. 1999, Lörz 2000, Stransky 2008) and to assess the diversity of an area.

Assessing diversity and faunal similarity

Due to the issues outlined above different measures for assessing diversity and faunal similarity patterns of the assemblages were applied to the *Italica* samples (**chapter 1, 2 and 4**). Different diversity indices emphasize the species richness or evenness components to different degrees. The most commonly used diversity measure for marine benthic studies is, besides species richness, the Shannon diversity index.

This index assumes that individuals are randomly sampled from a large community and that all species are represented in a sample. As true species richness of an assemblage is usually unknown, the Shannon index is problematic and therefore an unbiased estimator does not exist. The other diversity measure applied to this data set is the rarefaction method (Sanders 1968, Hurlbert 1971). The major advantage of rarefaction is that this method enables the comparison of samples of different sizes, as it is the case in this study. Samples with higher numbers of individuals are "rarefied" down to the sample with the lowest number of specimens. Another advantage is the presentation of the rarefaction results, in which one can easily deduce, which station is the most or least diverse one. However in the current study results from both indices were in good agreement.

For the examination faunal similarity two different indices were applied to the data. The Bray-Curtis similarity index (Bray and Curtis 1957) is widely used and plays a dominant role in ecological studies. Clarke and Warwick (2001) described this coefficient as a very satisfactory measure, as the value of the index is not changed by an inclusion or exclusion of a species and an inclusion of a third sample makes no difference in the similarity of the initial pair of samples. It also reflects differences in total abundances. Due to the influence of abundance of the most dominant species to the Bray-Curtis index, Clarke and Warwick (2001) suggest to transform the raw data. The latter reason (the high emphasis on abundances) is also the major weakness of the Bray-Curtis index, as rare species (low number of individuals) have little influence on the analysis. However, in this study no transformation was performed for better comparison with the Cosine similarity index.

Pfeifer et al. (1998) introduced the Cosine similarity into ecological studies, however it is rarely used in the literature (but see George 1999). This index also includes abundances, however, is not assigning too much weight to it. Therefore, in contrast to the Bray-Curtis

index, species which do not occur or only occur in low abundances at some stations are not neglected. Consequently, the Cosine similarity suites the data of the 19th *Italica* expedition better, as some species occur with relatively low abundances and the pronounced abundant occurrence of some taxa, such as the Desmosomatidae, the Paramunnidae and the Munnidae, was very characteristic.

Taxonomic distinctness

The response of benthic marine assemblages to disturbance is thought to be easily detected at higher taxonomic levels Warwick and Clarke (1993). It is generally known that disturbed benthic environments are in an early successional stage with a low species diversity and species which are closely related, while undisturbed benthic communities are in a late successional stage with taxonomically distinct species (Warwick and Clarke 1995). Yet the "common" diversity measures mainly use the relative abundance of species and do not describe the degree of the relatedness of those species. The taxonomic distinctness measure is an approach to translate taxonomic diversity into ecological diversity. This measure is a qualitative diversity assessment based on a simple presence/absence matrix, which is applied against a species master list for a defined region. The average taxonomic distinctness (AvTD) simply describes the average distance between two randomly chosen organisms in an assemblage. It is a pure measure of taxonomic relatedness of species in a sample (Magurran 2004). Variation in taxonomic distinctness (VarTD) measures the evenness with which the taxa are distributed in the taxonomic tree (Magurran 2004). A randomisation test is possible to detect differences in TD for any subset of species, from the expected AvTD from the species master list. The randomisation test leads to a "95% confidence funnel" against which distinctness values for any specific area can be checked. The hypothesis is whether a locality has a "lower than expected" AvTD spread (Clarke and Warwick 1999).

The advantages of these measure were highlighted in a study of Warwick and Clarke (1998). Their investigation on nematodes from the UK demonstrated that lower values of AvTD was found at localities which where polluted and therefore were falling out of the 95% probability funnel. They also realized that AvTD was closely associated with trophic diversity; meaning AvTD was lower in localities with fewer trophic groups (Warwick and Clarke 1998). Magurran (2004) pointed out that taxonomic distinctness is "extremely" robust in terms of variation in sampling effort and "only" requires incidence data. This is in sharp

contrast with those diversity measures which are strongly influenced by the number of observed species.

The taxonomic distinctness measure has been applied to isopod data for the first time (**chapter 4**). This was possible as a complete species master list for the Ross Sea was constructed during this thesis (see chapter 3). As this measure is quite new, there are only a few investigations published so far (e.g. Hall and Greenstreet 1998, Rogers et al. 1999, Clarke and Warwick 1999, 2001). The stations of the 19th *Italica* expeditions are calculated against the simulated 95% probability average taxonomic distinctness (AvTD) and interestingly most of the stations are below the funnel and therefore depart significantly from expectation with low values of the AvTD. The main reason for these results is due to be absence of some families (e.g. the Serolidae and the Gnathiidae) and genera, which are known for the Ross sea, but were however not represented in the samples. Two conclusions can be made: (i) the samples taken in the four study sites are not representative for the biodiversity of the Ross Sea and indicate a loss in biodiversity. The latter is unlikely, as most stations fall into the variation of taxonomic distinctness funnel. Moreover a more frequent monitoring would be necessary to support the second possible conclusion.

The pristine nature of the Ross Sea offers unique opportunities to study this polar ecosystem as yet untouched by humans. To date, studies conducted in the Ross Sea benthos have tended to focus on shallower shelf regions, often less than 30 m depth. At present our knowledge about the structure and function of the Ross Sea ecosystem is poor.

The Victoria Latitudinal Gradient Project is the first step to provide more valuable information about macro-ecological patterns in the Ross Sea. The current thesis contributes to this and enlarges our knowledge about the epi- and macrofaunal community composition of the northern Victoria Land coast, as Isopoda are a major group of the Antarctic Southern Ocean.

Nonetheless major gaps remain, as many areas have not been biologically sampled, and consequently basic information such as habitat type and species composition are missing. To fill into these gaps more surveys have to be implemented at more locations along the latitudinal gradient of the Ross Sea and meta analysis should be used to investigate the relative importance of the relationships between benthic diversity, local processes and broad-scale variables (e.g. latitude).

With respect to the isopod fauna it will be crucial to describe the most frequently sampled new species, mainly those of the families Paramunnidae and Desmosomatidae in near future. In this thesis I already began with two new species descriptions, however more work would be necessary, as the new species of these families were represented with a high number of individuals. Also, the implementation of the new measure of biodiversity, the taxonomic distinctness with a species master list of the whole SO would provide valuable insights with respect to the relatedness of the SO isopod assemblage. For introducing such a master list, a species inventory and a cross check of existing species list from different expeditions will be required.

This will allow us to understand changes and shifts in benthic isopod community, which might occur due to changing environments, particularly climate change/variation or anthropogenic threats (tourism, extraction of resources).

(of Introduction, Material and Methods and Concluding remarks)

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Tab. 12: Isopod species-abundance matrix from the 19th Italica expedition

Species	A 1	A2	A3	A 4	A5	H out 1	H out 2	H out 4	H in 2	H in 3	H in 4	H in 5	C1	C2	SMN	R2	R3	R 4
Accalathura spec. 1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Accalathura spec. 2	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Aega antarctica	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0
Aega glacialis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Chaetarcturus adareanus	1	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Antarcturus furcatus	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Antarcturus spec. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Antarcturus spec. 2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	13	0	0	0
Antarcturus spinacorunatus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0
Austrofilius spec. 1	0	18	0	3	1	0	0	29	1	5	13	1	0	0	0	0	0	0
Austrofilius spec. 2	0	0	0	0	0	1	7	9	0	0	0	1	0	0	2	2	1	0
Austronanus cf. glacialis	0	10	32	154	2	0	0	0	0	48	347	26	0	0	70	2	16	7
Austroniscus ovalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Austroniscus spec. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0
Austrosignum glaciale	0	0	0	9	1	0	0	20	1	9	13	0		0	0	0	0	0
Austrosignum spec. nov.	0	0	7	10	2	0	1	0	4	0	23	22	0	4	2	0	0	0
Cirolana mclaughlinae	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coperonus spec. 1	0	1	0	6	0	0	0	80	3	25	19	40	0	11	34	6	6	0
Coulmannia frigida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Coulmannia spec. 1	0	4	0	1	0	1	14	8	5	10	11	2	1	13	4	0	0	0
Cymodocella tubicauda	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmosoma spec. 1	0	0	0	0	0	1	0	0	1	0	0	0	0	4	143	205	78	6
Desmosoma spec. 2	0	0	0	0	0	0	0	0	2	0	0	0	4	54	39	192	245	1
Desmososma spec. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59	83	0	0
Disconectes spec. 1	0	0	0	0	0	0	0	21	0	2	1	0	0	3	16	1	12	0
Dolichiscus spec. 1	0	0	0	0	1	0	0	0	0	0	0	7	0	0	0	0	0	0
Echinozone spinosa	0	3	0	2	0	0	0	7	3	0	0	0	0	1	19	0	14	0
Ectias spec. 1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Edotia tangaroa	0	0	0	0	0	0	0	2	0	13	0	3	0	6	0	0	0	0
Eisothistos antarcticus	0	0	25	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Eugerdella serrata	0	0	0	0	0	8	0	0	2	15	0	0	1	20	0	0	0	0
Eugerdella spec. 1	0	0	0	0	0	0	0	0	2	0	0	0	0	49	0	0	0	0
Eurycope spec. 1	0	0	0	0	0	0	0	1	0	0	1	0	0	7	165	30	18	0
Fissarcturus rossi	0	0	0	0	0	0	1	4	0	0	0	3	1	2	0	0	0	0
Fissarcturus spec. 1	0	0	0	0	0	0	2	0	0	0	0	8	0	0	0	0	0	0
Fissarcturus spec. 2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	7	0	1	0
Fissarcturus spec. 3	0	0	0	0	1	0	0	0	0	3	0	0	0	0	1	0	0	0
Fissarcturus spec. 4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Glypotonotos antarcticus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Haploniscus spec. 1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Harrietonana spec. 1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
Ianthopsis multispinosa	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ianthopsis nasicornis	0	0	1	6	0	0	2	0	1	4	1	13	0	1	0	0	0	0
Ianthopsis ruseri	0	0	0	0	0	0	28	38	0	0	0	0	0	0	0	0	0	0
Ilyarachna antarctica	0	0	0	0	0	0	0	8	0	9	2	4	3	8	81	27	19	0
Jaeropsis antarctica	0	82	30	0	0	1	0	13	0	6	23	38	0	0	0	0	0	0
Janira spec. 1	0	1	28	0	1	0	6	6	1	2	5	3	0	0	0	0	0	0
Janirella spec. 1	0	1	2	0	0	2	3	123	1	0	1	2	0	0	0	0	0	0
Kikolana arnaudi	0	10	193	186	1	0	0	0	3	5	20	6	0	0	0	0	0	0
Lionectes spec.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Mastigoniscus spec. 1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mirabilicoxa spec. 1	0	0	0	0	0	0	0	0	0	0	0	0	2	81	134	35	0	2
Mirabilicoxa spec. 2	0	0	0	0	0	4	0	0	1	2	55	3	0	0	27	27	0	0
Munna amphicauda	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0
Munna globicauda	0	0	2	7	0	0	0	0	1	5	0	22	0	1	4	0	0	0
Munna maculata	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0
Munna neglecta	0	0	0	0	0	0	0	1	0	7	0	11	0	0	0	0	0	0
Munna spec. 1	1	7	7	3	0	7	5	83	2	29	98	150	0	1	6	0	2	0

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Species	A 1	A2	A3	A4	A5	H OUT 1	H out 2	H out 4	H IN 2	H IN 3	H IN 4	H IN 5	C1	02	SMN	R2	R3	R4
Munna spec. 2	3	0	0	12	0	14	10	38	5	0	204	121	0	13	21	0	3	2
Munna spec. 3	2	4	0	3	0	0	10	33	1	0	22	0	0	0	14	3	0	0
Munna spec. 4	1	0	0	0	0	2	0	0	0	0	17	0	0	0	0	0	0	0
Munna spec. 5	1	0	0	0	0	5	1	50	0	1	0	10	0	0	2	0	0	8
Munna spicata	0	0	0	0	2	0	0	8	0	0	0	0	0	0	0	0	0	0
Munneurycope spec. 1	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0
Munnogonium spec. 1	0	0	0	0	0	0	1	0	0	0	0	0	0	10	2	0	0	0
Nannoniscus bidens	0	0	0	0	0	0	0	1	1	23	3	3	0	7	0	0	1	0
Nannoniscus spec. 1	0	0	0	0	0	1	0	0	0	0	2	0	0	0	3	0	2	0
Nannoniscus spec. 2	0	0	0	0	0	2	0	0	0	0	1	0	0	0	3	1	0	0
Nannoniscus spec. 3	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Neojaera antarctica	0	4	23	224	5	5	10	39	5	40	41	108	2	14	0	0	0	0
Notasellus sarsi	0	0	28	88	0	0	0	0	0	0	3	3	0	0	0	0	0	0
Notopais spec.1	0	0	0	7	0	0	0	0	0	0	12	0	0	0	0	0	0	0
Notoxenus spec. 2	1	0	0	0	0	0	5	20	2	10	0	0	0	0	0	1	0	1
Omanana spec. 1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Omanana spec. 2	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pagonana hodgsoni	0	1	31	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0
Pagonana rostrata	1	16	36	39	1	0	3	0	4	5	115	13	0	0	0	0	0	0
Holodentata triangulata	0	5	0	0	0	0	23	89	0	6	26	7	0	0	0	0	0	0
Pagonana hodgsoni	0	0	0	13	1	0	0	0	0	0	121	1	0	0	1	0	0	0
Paranthura spec. 1	0	0	0	0	0	0	5	4	0	3	0	0	0	8	0	0	0	0
Paranthura spec. 2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Pleurogonium spec. 1	0	9	0	22	0	3	9	35	2	32	15	9	0	10	0	0	0	0
Pleurosignum elongatum	0	7	0	0	0	4	3	45	0	1	0	0	0	0	12	0	0	0
Pleurosignum magnum	1	5	1		0	1	3	40	0	6	7	14	0	0	2	1	0	0
Pseugerdella spec. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Regabellator spec. 1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0
Santia mawsoni	0	4	7	51	5	0	0	2	0	0	0	0	0	0	0	0	0	0
Santia charcoti	0	4	31	15	4	0	0	2	0	0	0	0	0	0	0	0	0	0
Santia spec. 1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

Species	Genus	Familiy	Sub-Order	Order
Ianthopsis bovalli	Ianthopsis	Acanthaspidiidae	Asellota	Isopoda
Ianthopsis multispinosa	Ianthopsis	Acanthaspidiidae	Asellota	Isopoda
Ianthopsis nasicornis	Ianthopsis	Acanthaspidiidae	Asellota	Isopoda
Ianthopsis ruseri	Ianthopsis	Acanthaspidiidae	Asellota	Isopoda
Austroniscus ovalis	Austroniscus	Desmosomatidae	Asellota	Isopoda
Austroniscus spec. 1	Austroniscus	Desmosomatidae	Asellota	Isopoda
Desmosoma spec. 1	Desmosoma	Desmosomatidae	Asellota	Isopoda
Desmosoma spec. 2	Desmosoma	Desmosomatidae	Asellota	Isopoda
Desmosoma spec. 3	Desmosoma	Desmosomatidae	Asellota	Isopoda
Eugerdella serrata	Eugerdella	Desmosomatidae	Asellota	Isopoda
Eugerdella spec. 1	Eugerdella	Desmosomatidae	Asellota	Isopoda
Mirabilicoxa spec. 1	Mirabilicoxa	Desmosomatidae	Asellota	Isopoda
Mirabilicoxa spec. 2	Mirabilicoxa	Desmosomatidae	Asellota	Isopoda
Nannoniscus bidens	Nannoniscus	Desmosomatidae	Asellota	Isopoda
Nannoniscus spec. 1	Nannoniscus	Desmosomatidae	Asellota	Isopoda
Nannoniscus spec. 2	Nannoniscus	Desmosomatidae	Asellota	Isopoda
Nannoniscus spec. 3	Nannoniscus	Desmosomatidae	Asellota	Isopoda
Pseuderdella spec. 1	Pseugerdella	Desmosomatidae	Asellota	Isopoda
Regabellator spec. 1	Regabellator	Desmosomatidae	Asellota	Isopoda
Haploniscus spec. 1	Haploniscus	Haploniscidae	Asellota	Isopoda
Mastigoniscus spec. 1	Mastigoniscus	Haploniscidae	Asellota	Isopoda
Austrofilius furcatus	Austrofilius	Janiridae	Asellota	Isopoda
Austrofilius spec. 1	Austrofilius	Janiridae	Asellota	Isopoda
Austrofilius spec. 2	Austrofilius	Janiridae	Asellota	Isopoda
Ectias spec. 1	Ectias	Janiridae	Asellota	Isopoda
Ectias turqueti	Ectias	Janiridae	Asellota	Isopoda
Janira spec. 1	Janira	Janiridae	Asellota	Isopoda
Neojaera antarctica	Neojaera	Janiridae	Asellota	Isopoda
Notasellus sarsi	Notasellus	Janiridae	Asellota	Isopoda
Janirella spec. 1	Janirella	Janirellidae	Asellota	Isopoda
Jaeropsis antarctica	Joeropsis	Joeropsidae	Asellota	Isopoda
Munna amphicauda	Munna	Munnidae	Asellota	Isopoda
Munna antarctica	Munna	Munnidae	Asellota	Isopoda
Munna globicauda	Munna	Munnidae	Asellota	Isopoda
Munna maculata	Munna	Munnidae	Asellota	Isopoda
Munna neglecta	Munna	Munnidae	Asellota	Isopoda
Munna spec. 1	Munna	Munnidae	Asellota	Isopoda
Munna spec. 2	Munna	Munnidae	Asellota	Isopoda
Munna spec. 3	Munna	Munnidae	Asellota	Isopoda
Munna spec. 4	Munna	Munnidae	Asellota	Isopoda
Munna spec. 5	Munna	Munnidae	Asellota	Isopoda
Munna spicata	Munna	Munnidae	Asellota	Isopoda
Munna studeri	Munna	Munnidae	Asellota	Isopoda
Disconectes spec. 1	Disconectes	Munnopsidae	Asellota	Isopoda
Coperonus spec. 1	Coperonus	Munnopsidae	Asellota	Isopoda
Echinozone magnifica	Echinozone	Munnopsidae	Asellota	Isopoda
Echinozone spinosa	Echinozone	Munnopsidae	Asellota	Isopoda
Eurycope spec. 1	Eurycope	Munnopsidae	Asellota	Isopoda
Ilyarachna antarctica	Ilyarachna	Munnopsidae	Asellota	Isopoda
Lionectes spec.1	Lionectes	Munnopsidae	Asellota	Isopoda

Tab. 13: Isopod species master list and aggregation file for the AvTD and VarTD measures.

Species	Genus	Familiy	Sub-Order	Order
Munneurycope spec. 1	Munneurycope	Munnopsidae	Asellota	Isopoda
Notopais spec.1	Notopais	Munnopsidae	Asellota	Isopoda
Austronanus cf. glacialis	Austronanus	Paramunnidae	Asellota	Isopoda
Austrimunna antarctica	Austrimunna	Paramunnidae	Asellota	Isopoda
Palanana serrata	Palanana	Paramunnidae	Asellota	Isopoda
Austrosignum glaciale	Austrosignum	Paramunnidae	Asellota	Isopoda
Austrosignum spec. nov.	Austrosignum	Paramunnidae	Asellota	Isopoda
Coulmannia australis	Coulmannia	Paramunnidae	Asellota	Isopoda
Coulmannia frigida	Coulmannia	Paramunnidae	Asellota	Isopoda
Coulmannia spec. 1	Coulmannia	Paramunnidae	Asellota	Isopoda
Harrietonana spec. 1	Harrietonana	Paramunnidae	Asellota	Isopoda
Kikolana arnaudi	Kiklonana	Paramunnidae	Asellota	Isopoda
Kussakinella spinosa	Kussakinella	Paramunnidae	Asellota	Isopoda
Munnogonium spec. 1	Munnogonium	Paramunnidae	Asellota	Isopoda
Notoxenus spec. 1	Notoxenus	Paramunnidae	Asellota	Isopoda
Notoxenus spec. 2	Notoxenus	Paramunnidae	Asellota	Isopoda
Omanana spec. 1	Omanana	Paramunnidae	Asellota	Isopoda
Omanana spec. 2	Omanana	Paramunnidae	Asellota	Isopoda
Pagonana hodgsoni	Pagonana	Paramunnidae	Asellota	Isopoda
Pagonana rostrata	Pagonana	Paramunnidae	Asellota	Isopoda
Crvosignum lunatum	Crvosignum	Paramunnidae	Asellota	Isopoda
Pleurogonium spec. 1	Pleurogonium	Paramunnidae	Asellota	Isopoda
Pleurosignum elongatum	Pleurosignum	Paramunnidae	Asellota	Isopoda
Pleurosignum magnum	Pleurosignum	Paramunnidae	Asellota	Isopoda
Holodentata triangulata	Holodentata	Paramunnidae	Asellota	Isopoda
Santia mawsoni	Santia	Santiidae	Asellota	Isopoda
Santia charcoti	Santia	Santiidae	Asellota	Isopoda
Santia spec. 1	Santia	Santiidae	Asellota	Isopoda
Antarcturus furcatus	Antarcturus	Antarcturidae	Valvifera	Isopoda
Antarcturus horridus horridus	Antarcturus	Antarcturidae	Valvifera	Isopoda
Antarcturus polaris	Antarcturus	Antarcturidae	Valvifera	Isopoda
Antarcturus spec. 1	Antarcturus	Antarcturidae	Valvifera	Isopoda
Antarcturus spec. 2	Antarcturus	Antarcturidae	Valvifera	Isopoda
Antarcturus spinacoronatus	Antarcturus	Antarcturidae	Valvifera	Isopoda
Chaetarcturus franklini	Chaetarcturus	Antarcturidae	Valvifera	Isopoda
Chaetarcturus adareanus	Chaetarcturus	Antarcturidae	Valvifera	Isopoda
Dolichiscus acanthaspidus	Dolichiscus	Antarcturidae	Valvifera	Isopoda
Dolichiscus hiemalis	Dolichiscus	Antarcturidae	Valvifera	Isopoda
Dolichiscus meridionalis	Dolichiscus	Antarcturidae	Valvifera	Isopoda
Dolichiscus profundus	Dolichiscus	Antarcturidae	Valvifera	Isopoda
Dolichiscus spec. 1	Dolichiscus	Antarcturidae	Valvifera	Isopoda
Fissarcturus rossi	Fissarcturus	Antarcturidae	Valvifera	Isopoda
Fissarcturus spec. 1	Fissarcturus	Antarcturidae	Valvifera	Isopoda
Fissarcturus spec. 2	Fissarcturus	Antarcturidae	Valvifera	Isopoda
Fissarcturus spec. 3	Fissarcturus	Antarcturidae	Valvifera	Isopoda
Fissarcturus spec. 4	Fissarcturus	Antarcturidae	Valvifera	Isopoda
Litarcturus lillei	Litarcturus	Antarcturidae	Valvifera	Isopoda
Glyptonotos antarcticus	Glyptonotos	Chaetaliidae	Valvifera	Isopoda
Edotia tangaroa	Edotia	Idoteidae	Valvifera	Isopoda
Aega glacialis	Aega	Aegidae	Cymothoida	Isopoda
Aega antarctica	Aega	Aegidae	Cymothoida	Isopoda

Species	Genus	Familiy	Sub-Order	Order
Accalathura spec. 1	Accalanthura	Paranthuridae	Cymothoida	Isopoda
Accalathura spec. 2	Accalanthura	Paranthuridae	Cymothoida	Isopoda
Paranthura spec. 1	Paranthura	Paranthuridae	Cymothoida	Isopoda
Paranthura spec. 2	Paranthura	Paranthuridae	Cymothoida	Isopoda
Cirolana mclaughlinae	Cirolana	Cirolanidae	Cymothoida	Isopoda
Natatolana albinota	Natatolana	Cirolanidae	Cymothoida	Isopoda
Natatolana intermedia	Natatolana	Cirolanidae	Cymothoida	Isopoda
Natatolana merdionalis	Natatolana	Cirolanidae	Cymothoida	Isopoda
Eisothistos antarcticus	Eisothistos	Exparanthuridae	Cymothoida	Isopoda
Caecognathia hodgsoni	Caecognathia	Gnathiidae	Cymothoida	Isopoda
Caecognathia polaris	Caecognathia	Gnathiidae	Cymothoida	Isopoda
Euneognathia gigas	Euneognathia	Gnathiidae	Cymothoida	Isopoda
Acutiserolis spinosa	Acutiserolis	Serolidae	Sphaeromatoidea	Isopoda
Ceratoserolis trilobitoides	Ceratoserolis	Serolidae	Sphaeromatoidea	Isopoda
Frontoserolis acuminata	Frontoserolis	Serolidae	Sphaeromatoidea	Isopoda
Cymodocella tubicauda	Cymodocella	Sphareomatidae	Sphaeromatoidea	Isopoda

Species	Cape Adare	Cape Hallett	Coulman Island	Cape Russell
Accalathura spec. 1	5	0	0	0
Accalathura spec. 2	4	2	0	0
Aega antarctica	1	0	0	10
Aega glacialis	0	0	0	1
Chaetarcturus adareanus	3	2	0	0
Antarcturus furcatus	1	1	0	0
Antarcturus spec. 1	0	0	0	3
Antarcturus spec. 2	0	1	0	13
Antarcturus spinacoronatus	0	1	1	2
Austrofilius spec. 1	22	49	0	0
Austrofilius spec. 2	0	18	0	5
Austronanus cf. glacialis	198	421	0	95
Austroniscus ovalis	0	0	0	1
Austroniscus spec. 1	0	0	2	3
Austrosignum glaciale	10	43	0	0
Austrosignum spec. nov.	19	50	4	2
Cirolana mclaughlinae	10	0	0	0
Coperonus spec. 1	7	167	11	46
Coulmannia frigida	0	0	0	2
Coulmannia spec. 1	5	51	14	4
Cymodocella tubicauda	9	0	0	0
Desmosoma spec. 1	0	2	4	432
Desmosoma spec. 2	0	2	58	477
Desmosoma spec. 3	0	0	0	142
Disconectes spec. 1	0	24	3	29
Dolichiscus spec. 1	1	7	0	0
Echinozone spinosa	5	10	1	33
Ectias spec. 1	3	0	0	0
Edotia tangaroa	0	18	6	0
Eisothistos antarcticus	25	2	0	0
Eugerdella serrata	0	25	21	0
Eugerdella spec. 1	0	2	49	0
Eurycope spec. 1	0	2	7	113
Fissarcturus rossi	0	8	3	0
Fissarcturus spec. 1	0	10	0	0
Fissarcturus spec. 2	2	0	0	8
Fissarcturus spec. 3	1	3	0	1
Fissarcturus spec. 4	0	0	1	0
Glyptonotos antarcticus	0	1	0	0
Haploniscus spec. 1	0	1	0	0
Harrietonana spec. 1	0	4	0	0
Ianthopsis multispinosa	0	2	0	0
Ianthopsis nasicornis	7	21	1	0
Ianthopsis ruseri	0	66	0	0
Ilyarachna antarctica	0	23	11	
Jaeropsis antarctica	112	81	0	0
Janira spec. 1	30	23	0	0
Janirella spec. 1	3	132	0	0
Kikolana arnaudi	390	34	0	0
Lionectes spec.1	0	0	0	4

Tab. 14: Isopod species from the 19th Italica expedition and their abundances at the four study sites.

Species	Cape Adare	Cape Hallett	Coulman Island	Cape Russell
Mastigoniscus spec. 1	1	0	0	0
Mirabilicoxa spec. 1	0	0	83	171
Mirabilicoxa spec. 2	0	65	0	54
Munna amphicauda	0	17	0	0
Munna globicauda	9	28	1	4
Munna maculata	0	3	3	0
Munna neglecta	0	19	0	0
Munna spec. 1	18	374	1	8
Munna spec. 2	15	392	13	26
Munna spec. 3	9	66	0	17
Munna spec. 4	1	19	0	0
Munna spec. 5	1	67	0	10
Munna spicata	2	8	0	0
Munneurycope spec. 1	0	3	3	0
Munnogonium spec. 1	0	1	10	2
Nannoniscus bidens	0	31	7	1
Nannoniscus spec. 1	0	3	0	5
Nannoniscus spec. 2	0	3	0	4
Nannoniscus spec. 3	0	0	6	0
Neojaera antarctica	256	248	16	0
Notasellus sarsi	116	6	0	0
Notopais spec.1	7	12	0	0
Notoxenus spec. 2	1	37	0	2
Omanana spec. 1	0	3	0	0
Omanana spec. 2	3	0	0	0
Pagonana hodgsoni	32	23	0	0
Pagonana rostrata	93	140	0	0
Holodentata triangulata	5	151	0	0
Pagonana hodgsoni	14	122	0	1
Paranthura spec. 1	0	12	8	0
Paranthura spec. 2	0	2	0	0
Pleurogonium spec. 1	31	105	10	0
Pleurosignum elongatum	7	53	0	12
Pleurosignum magnum	7	71	0	3
Pseugerdella spec. 1	0	0	2	0
Regabellator spec. 1	0	0	7	0
Santia mawsoni	67	2	0	0
Santia charcoti	54	2	0	0
Santia spec. 1	1	1	0	0