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Relationship between modern deep-sea ostracods and water mass structure in East Antarctica

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Abstract

This study investigated the relationship between the distribution of modern ostracod biofacies and environmental factors in Lützow–Holm Bay, off Cape Darnley, and off Totten Glacier in East Antarctica. We collected study samples from water depths of 219 to 987 m by the 61st Japanese Antarctic Research Expedition. Nineteen species belonging to 13 genera and 47 species belonging to 31 genera of ostracods were found in three samples from Lützow–Holm Bay and ten samples from off Totten Glacier, respectively. We found no ostracods in the samples off Cape Darnley. Q-mode cluster analysis reveals four ostracod biofacies (A to D). *Antarctiloxoconcha frigida* (Neale, 1967) and *Australicythere polylyca* (Müller, 1908) were common under the influence of cold water in the upper bathyal zone (biofacies A to C). The genus

Krithe was the most abundant taxon in biofacies D with low dissolved oxygen and high-water temperature (0.38°C, 34.66, and 5.0 ml/L, respectively), indicating the presence of warm deep seawater, i.e., modified Circumpolar Deep Water. Thus, we have checked the relationships between the ostracod assemblages and the environmental parameters analyzed in Lützow–Holm Bay and off Totten Glacier, and so strengthened the previous ostracod and environmental data.

Keywards

Antarctic Ocean, East Antarctica, Lützow-Holm Bay, mCDW, Modern ostracod, off Totten Glacier

Introduction

The Antarctic Ice Sheet (AIS) is the largest freshwater reservoir, accounting for about 90% of the ice sheet volumes on the Earth (Vaughan *et al.*, 2013). Recently, the accelerated ice-mass loss of AIS has been reported through satellite and oceanographic observations (Jacobs *et al.*, 2011; Pritchard *et al.*, 2012; Williams *et al.*, 2014; Paolo *et al.*, 2015; Shepherd *et al.*, 2018; Rignot *et al.*, 2019). Regarding the melting of the ice-shelf base, the inflow of Circumpolar Deep Water (CDW), a relatively warm seawater, under the ice sheet terminus has a greater effect on melting the ice shelf than the previous thought (Favier *et al.*, 2014). Jacobs *et al*. (1996) obtained that CDW is > 2°C warmer than water masses at most other locations (e.g. Ross Ice Shelf, west of the Antarctic Peninsula) on the Antarctic shelf. Further, Whitworth *et al.* (1998) defined the modified CDW (mCDW) to lie between the two isopycnals that separate CDW from Antarctic Surface Water (AASW) above and from Antarctic Bottom Water (AABW) below, and for a given density to be colder and fresher than the regional CDW. Thus, several seawater masses are developed around Antarctica (e.g. Jacobs *et al*., 1996; Whitworth *et al.,* 1998), and benthic communities peculiar to each are inferred to exist.

Ostracods are small calcified bivalved crustacean that forms an important component of deep-sea meiobenthic communities along with nematodes and copepods (Brandt *et al*., 2007). They are essential for reconstructing the ecological history and paleoceanography of deep-sea due to their long preservation ability of valves as microfossils (Benson *et al*., 1984; Didié and Bauch, 2000; Yasuhara and Cronin, 2008; Yasuhara *et al*., 2009a). Thus, the distribution of modern Antarctic ostracods will provide key information for applications of fossil ostracod researches to Antarctic paleoenvironmental studies.

Research on benthic ostracods in the Antarctic region started with expeditions in the end of the 19th century. The earliest paper by Brady (1880) described ostracods collected on the *H. M. S. Challenger* expedition from the region around the South Ocean. Since then, many studies on recent and fossil Antarctic ostracods have significantly increased in West Antarctica (e.g. Whatley *et al*., 1988, 1996b, 1998b; Brandão, 2008a, b). Several studies on modern and fossil ostracods have been also conducted in East Antarctica (e.g. Hanai, 1961; Benson, 1964; Neale, 1967; Yasuhara *et al*., 2007; Sasaki *et al*., in press). However, no ostracod studies have been conducted in seas off Cape Darnley and Totten Glacier in the southeastern part of East Antarctica (Figure 1). A few studies have investigated the relationship between environmental factors, such as the bottom sediment, temperature, and water depth at the sampling sites, and the ostracod distribution in Antarctica (Ayress *et al*., 2004; Majewski and Olempska, 2005; Brandão *et al*., 2022). Brandão *et al*. (2022) showed that water depth is the highest correlation to influence the ostracod distribution around the Antarctic Peninsula of West Antarctic, followed by nitrate and phosphate. However, such a study is not fully conducted for reconstructing the paleoenvironment in the Antarctic area during the Holocene (Sasaki *et al*., in press).

Therefore, we examined the distribution of modern ostracod species in Lützow–Holm Bay, off Cape Darnley, and off Totten Glacier in East Antarctica, where there are few or no data on modern ostracods, collected by the 61st Japanese Antarctic Research Expedition (JARE 61) from 2019 to 2020 (Figure 1). Consequently, we identified environmental factors that control the modern ostracod distribution based on the analyses of water qualities, grain size, and CNS (carbon, nitrogen, and sulfur) elements.

Study area

Lützow–Holm Bay

Lützow–Holm Bay (LHB) is located on the coast of Dronning Maud Land, East Antarctica (68°S, 38°E, Figure 1b). A deep glacial trough with northwest–southeast direction is in LHB (Figure 1b), providing a connection from the shelf break to the Shirase Glacier Tongue ocean cavity (Hirano *et al*., 2020). Hirano *et al.* (2020) observed a simple two-layer structure consisting of winter water and mCDW on the northeast slope at the mouth of LHB. Compared with the mouth of the bay, mCDW at the ice front is cooler (*ca.*

0.14 °C), lower in salinity (*ca.* 34.58), and more oxygen-rich (*ca.* 5.0 ml/L), indicating the modification of CDW during its journey from shelf break to the ice front.

off Cape Darnley

The sea off Cape Darnley is located northwest of the Amery Ice Shelf, East Antarctica (67°S, 65–68°E, Figure 1c). Unlike the previously identified sources of AABW, which require the presence of an ice shelf or a large storage volume, bottom water production at Cape Darnley Polynya (Ohshima *et al.*, 2013) is thought to be primarily driven by the flux of salt released due to the sea-ice formation. They estimated that about 0.3 to 0.7 × 10^6 m^3/s of dense shelf water produced in the Cape Darnley Polynya are transformed into AABW. The transformation of this water mass, i.e., Cape Darnley Bottom Water, accounts for 6%–13% of the total circumpolar.

off Totten Glacier

The Totten Glacier, located on the coast of Wilkes Land, is one of the major draining glaciers in East Antarctica (66°S, 117–120°E, Figure 1d). Totten and Moscow University Ice shelves would raise sea level by ca. 5 m if they melted (Mohajerani *et al.*, 2018), and high melt rates were also revealed in the grounding zones (Rignot *et al.*, 2013). A potential pathway of warm water access has been discovered off Totten Glacier, whose ice discharge is accelerating (Greenbaum *et al.*, 2015; Hirano *et al.*, 2021). Greenbaum *et al.* (2015) estimated that at least 3.5 m of eustatic sea-level rise would be due to drains through Totten Glacier drains. Thus, coastal processes in this area could have global consequences. On the continental shelf off the eastern part of the Moscow University Ice Shelf, a dense concentration of grounded icebergs extending across the shelf is the Dalton Iceberg Tongue. The grounded icebergs contribute to forming persistent polynya on their western side, called Dalton Polynya (O'Brien *et al.,* 2020).

Samples and methods

We collected 17 surface sediment samples from the sea bottoms at water depths ranging from 219 to 987 m using a G.S. Kinoshita-type grab sampler (Itaki, 2018) from December 15, 2019, to March 5, 2020 (Figure 1, Table 1): four samples from the mouth of LHB, two samples from Cape Darnley Polynya, and 11 samples from off Totten Glacier (six samples around Totten Ice Shelve, three samples around Moscow University Ice Shelve, and two samples from Dalton Polynya). The uppermost 2 cm of these samples was collected after the description of sediments and divided into two sample sets. One sample set for ostracod analysis was immediately fixed with 99% of ethanol. The other sample set for grain-size and CNS elemental analyses was freeze-dried. Temperature, salinity, and dissolved oxygen (DO) were measured using a CTD (conductivity, temperature, and depth) probe (CTD 90M, Sun & Sea Marine Tech) through the water column and collected bottom water samples 7 m above the seafloor using a Niskin bottle attached with the grab sampler for each site. The temperature and DO sensors of the CTD have the measurement ranges of −2°C to 35°C with ± 0.005 °C error and 0% to 240% with ± 2% error, respectively. The salinity and DO values were calibrated based on manual measurements of the bottom water samples. The sampling time interval of the CTD was 0.2 s. We adopted downward profiles of the CTD (Ishiwa *et al*., 2021).

For grain-size analysis, about 0.03 g of dried samples were soaked in 6% hydrogen peroxide for several days to remove organic matter. After ultrasonic cleaning treatment for several seconds, we analyzed all samples using a laser diffraction particle-size analyzer (SALD-3000S) at the Department of Geoscience, Interdisciplinary Faculty of Science and Engineering, Shimane University (Sasaki *et al*., in press).

For CNS elemental analysis, about 3 g of dried samples was powdered using an agate mortar and pestle, and about 9 to 11 mg of each powdered sample was placed in a thin Ag film cup and weighed. Then, 1 M-HCL was added several times to remove the carbonate fraction until there was no reaction, followed by drying for 2 h. The dried samples were subsequently weighted and wrapped in a thin Sn film cup for combustion. The total organic carbon (TOC), total nitrogen (TN), and total sulfur (TS) contents were measured with a CHNS elemental analyzer at Estuary Research Center, Shimane University, using a FISON organic elemental analyzer.

For ostracod analysis, the samples were dried, weighed, and then wet-sieved using a 250-mesh (opening: 63 μm) sieve and dried in a 45°C oven. Under a binocular stereomicroscope, all ostracod specimens were picked up from the coarser sediment remaining after dry sieving using a 115-mesh (opening: 125 μm) sieve. Scanning electron micrographs of uncoated specimens of selected ostracod species were digitally imaged using the low-vacuum mode of the JEOL JCM-5000 Neoscope at the Department of Geoscience Interdisciplinary Faculty of Science and Engineering, Shimane University.

Data analysis

Many formulas for representing the grain size of sediments have been proposed (Trask, 1932; Krumbein, 1938; Otto, 1939; Inman, 1952; McCammon, 1962). The most widely used formulas are those proposed by Folk and Ward (1957) (Blott and Pye, 2001). Blott and Pye (2001) indicated that Folk and Ward measures, expressed in metric units, provide the most robust basis for routine comparisons of compositionally variable sediments. Thus, we calculated the grain-size indices, such as mean grain size (Mφ), median grain size (Mdφ), and sorting, according to the equations of Folk and Ward (1957).

Moreover, TOC, TN, and TS contents of sediments are essential proxies for reconstructing the depositional environment (Berner, 1982; Sampei *et al.*, 1997; Irizuki and Seto, 2004). TOC content depends mainly on the sedimentation rate and organic matter loads; however, TS content depends on salinity and sedimentation rate (Sampei *et al.*, 1997; Irizuki and Seto, 2004).

We conducted Q-mode cluster analysis using a raw data matrix to recognize ostracod biofacies. We used seven samples containing more than 30 ostracod specimens (valves) in the analysis, and all species were used. The similarity index used is Horn's overlap index (Horn, 1966), and the Paleontological Statistics (PAST) program (Hammer *et al.*, 2001) was used for calculations.

Results

Environment of the study stations

In LHB, the water temperature at Station (St.) LH1a-KG increased from the water depth of about 500–600 m to the bottom (Figure 2). The salinity of bottom water in four sites ranged from 34.24 to 34.62. The DO of bottom water showed a lower value (5.4 ml/L) at St. LH1a-KG and higher values ranging from 7.3 to 7.4 ml/L at the remaining three sites (Table 1).

In the sea off Cape Darnley, the water temperature, salinity, and DO of bottom water were −1.94°C, 34.80, and 7.72 ml/L at St. CD1-KG and −1.91°C, 34.61, and 7.50 ml/L at St. CD4-KG, respectively. The bottom water temperature was the lowest and DO of the bottom water was the highest in all the study sites (Table 1).

In the sea off Totten Glacier, the bottom water temperature showed positive values at two sites (stations 26-KG and 83-KG) and negative values at the remaining nine sites (Figure 2, Table 1). The salinity of bottom water in ten sites, except for St. X23-KG, where salinity was not measured, ranged from 34.24 to 34.67 (Table 1). The DO showed lower values ranging from 5.00 to 5.83 ml/L at three sites (stations 25-KG, 26-KG, and 83-KG) and higher values ranging from 6.12 to 7.49 ml/L at the remaining seven sites, except for St. X23-KG, where DO was not measured (Table 1). The water temperature at three sites (stations 25-KG, 26-KG, and 83-KG) increased from the water depth of about 500–600 m to the bottom (Figure 2).

Sediment

In LHB, three samples (stations LH2a-KG, LH3a-KG, and LH5a-KG) were composed of grayish-olive silty sand with some macrobenthos and ranged from 3.50 to 5.61 Mdφ (Table 1). The sorting index ranged from 1.65 to 2.66. However, the sample LH1a-KG was composed of gray-olive sandy silt with gravels and had the finest grain size in this area (6.61 Mdφ, Table 1).

In the sea off Cape Darnley, two samples (stations CD1-KG and CD4-KG) were composed of olive diatom ooze (Table 1). The median grain size and sorting index of St. CD1-KG were 4.28 Mdφ and 2.10, respectively. However, the median grain size and sorting index of St. CD4-KG were 5.83 Mdφ and 1.92, respectively (Table 1).

In the sea off Totten Glacier, samples collected from 11 sites were composed of grayish-olive mud with some living macrobenthos such as sea urchins and shrimps (Table 1). Two samples (stations X23-KG and 109-KG) were composed of coarser sediments showing 4.49 and 5.98 Mdφ, respectively. The eight samples (stations 12b-KG, 14b-KG, 15-KG, 17-KG, 18-KG, 26-KG, 83-KG, and 108-KG) were composed of finer sediments ranging from 7.30 to 8.10 Mdφ. The sorting index ranged from 1.51 to 2.63. The sample from St. 25-KG was composed of muddy gravel (6.9 Mdφ).

CNS elements

In LHB, the values of TOC, TN, and TS contents were very low, ranging from 0.10–0.30 wt%, 0.02–0.05 wt%, and 0.06–0.14 wt%, respectively (Table1). The TOC, TN, and TS contents in this area became higher with increased water depth.

In the sea off Cape Darnley, the TOC, TN, and TS contents in samples from stations CD1-KG and CD4-KG were 0.95, 0.11, and 0.19 wt%, 1.40, 0.17, and 0.51 wt%, respectively. These data showed higher values in this study (Table 1).

In the sea off Totten Glacier, the values of the TOC, TN, and TS contents in most samples were relatively low, ranging from 0.16–0.38 wt%, 0.03–0.09 wt%, and 0.08–0.22 wt%, respectively (Table 1). However, at St. 25-KG, relatively high values were observed for TOC, TN, and TS contents as 0.65, 0.09, and 0.19 wt%, respectively. The TOC, TN, and TS contents in this area were relatively higher in samples with high ostracod density.

Ostracod assemblages

Nineteen species belonging to 13 genera and 47 species belonging to 31 genera of ostracods were found in three samples from LHB and ten samples from off Totten Glacier, respectively (Figures 3–5, Table 2). Ostracod assemblages from the latter area were reported for the first time in this study. No ostracods were found from the sea off Cape Darnley. *Antarctiloxoconcha frigida* (Neale, 1967), *Australicythere polylyca* (Müller, 1908), and *Cytheropteron perlaria* Hao, 1988 in Ruan and Hao (1988), were relatively abundant (Figure 6, Table 2). *Krithe* sp. was abundant in the sample from St. 83-KG off Totten Glacier (Table 2).

The density (the valve number of ostracods per 1-g sediment sample) indicated very low values, ranging from 0.10 to 5.86, except for the sample at St. 17-KG off Totten Glacier, which indicated the highest density of 101.7 (Table 2).

Twenty-one species of living ostracods, i.e., ostracods with soft parts, were collected from eight sites (stations LH2a-KG, LH5a-KG, 14b-KG, 18-KG, X23 -KG, 83-KG, 108-KG, and 109-KG, Table 2). Their highest number (total of 23 carapaces and a valve with soft parts) was recorded at St. 108-KG off Totten Glacier (Table 2).

The living specimens pertaining to four species were found from different water depths (*Australicythere polylyca*; 219–523 m, *Austrotrachyleberis antarctica*; 309–431 m, *Bradleya mesembrina*; 219–309 m, and *Krithe* sp.; 309–842 m).

The result of the Q-mode cluster analysis showed four biofacies (A to D; Figure 7). Biofacies A consists of one sample collected from a water depth of 608 m near the Totten Glacier Ice Sheet (St. 17-KG). It was characterized by the most abundant ostracods and the mixture of epineritic ostracods, such as

Hemicytherura and *Paradoxstoma* (e.g. van Morkhoven, 1963), and deep-sea ostracods, such as *Poseidonamicus* (e.g. Benson, 1983) and *Krithe* (e.g. van Morkhoven, 1963). Biofacies B consists of three samples from the continental shelf of LHB (stations LH2a-KG and LH5a-KG; water depth: 310 and 219 m, respectively), and off Totten Glacier (St. 18-KG; water depth: 523 m). It was characterized by the dominance of *A. polylyca*. Biofacies C consists of two samples from the polynya off eastern part of Moscow University Ice Shelf (stations 108-KG and 109-KG; water depth: 309 and 431 m, respectively). It was characterized by the dominance of *A. frigida*. Biofacies D consists of one sample collected from a water depth of 842 m off Totten Glacier (St. 83-KG). It was characterized by the dominance of *Krithe* sp.

Discussion

Ostracod density

Ostracod density and diversity depend on several environmental factors (e.g. water temperature, salinity, substrates, DO, organic matters, and nutrients; Smith and Horne, 2002; Armstrong and Brasier, 2005). The water depth does not affect the ostracod distribution, but the environmental factors change with depth (Armstrong and Brasier, 2005). However, ostracod density is higher in marginal marine and shallow-shelf areas than offshore bathyal (Yasuhara *et al*., 2007). As the water depth of the study sites ranged from 219 to 987 m, corresponding to the upper and middle bathyal depth, ostracod densities were lower in most samples. For instance, no ostracods were found in samples off Cape Darnley (water depth: 544 and 644 m), where sediments were composed of olive sandy diatomaceous ooze. The TOC and TN contents were higher than any other samples (the TOC and TN contents were 0.95–1.4 wt% and 0.11–0.17 wt%, respectively, Table 1). Coastal polynyas are the regions of enhanced oceanic primary and secondary production (Arrigo and van Dijken, 2003). The growth and accumulation of phytoplankton biomass, including diatoms (Gradinger and Baumann, 1991; von Quillfeldt, 1997; Arrigo *et al*., 2000), dinoflagellates (Dennett *et al*., 2001), and prymnesiophytes (Kopczyńska *et al*., 1995; Arrigo *et al*., 2000; Rey *et al*., 2000; Becquevort and Smith, 2001; Dennett *et al*., 2001; Gowing *et al*., 2001), are much greater in polynyas than in adjacent waters. According to Ohshima *et al.* (2013), the high DO water masses along the bottom slope of the seafloor off Cape Darnley indicate that the surface cold water has not been submerged for a long time. We assumed that the sea off Cape Darnley represents a special environment, where the high DO water was submerged, and sediments had high TOC content due to abundant diatom frustules. In addition, calcareous foraminifers, which are usually found more abundantly than ostracods, were very few, poorly preserved, and partly dissolved in samples off Cape Darnley. Thus, there is a possibility that the water mass is unsaturated with carbonate for some reason, causing abundant diatoms and no ostracods in samples.

Ostracod biofacies and environmental factors

Only seven samples contained relatively abundant ostracod specimens (> 30 valves in sample) for Q-mode cluster analysis (Figure 1, Table 2). Consequently, four biofacies were recognized (Figure 7). Thus, we discuss the relationships between the four ostracod biofacies and environmental factors in LHB and the sea off Totten Glacier.

Biofacies A: The sample from St. 17-KG, collected from a water depth of 608 m near the Totten Glacier Ice Sheet, produced the most abundant ostracods and a component of biofacies A (Figure 7). However, it does not contain living ostracods, i.e., it consists of only empty valves. Moreover, shallow phytal species, such as *Hemicytherura* and *Neonesidea*, and deep-sea species, such as *Krithe* and *Poseidonamicus*, were mixed in this sample (Table 2). Additionally, many ostracod fragments were recognized in this sample. This suggests that most ostracod valves were transported by glaciers and ocean current activities and accumulated in this deep-sea site.

Biofacies B: In LHB, three of the four samples produced ostracods. Two of these samples (stations LH2a-KG and LH5a-KG) had relatively abundant ostracods containing *A. polylyca* and *A. antarctica* (Table 2) and components of biofacies B. The sample from St. 18-KG, collected from the land shelf near the Totten Glacier Ice Sheet at a water depth of 523 m, was a component of biofacies B. This indicates that two sample sites in LHB (stations LH2a-KG and LH5a-KG) and one sample site in the sea off Totten Glacier (St.18-KG) are situated in a similar environment to each other: oxic cold-shallow sandy-silt to sandy-mud bottoms. The lower TOC, TN, and TS contents and higher DO values also support this conclusion. These samples were collected from the shallow-water shelf, ranging from 219 to 523 m in water depth, with a low bottom water temperature and high DO (Table 1). The TOC, TN, and TS content values were lower, supporting oxic conditions. *A. polylyca* and *A. antarctica* have been widely reported from sea bottoms shallower than 500 m in Antarctica (e.g. Hartmann, 1990; Yasuhara *et al.*, 2007; Brandão *et al.*, 2022).

Consequently, we identified that these species characterizing biofacies B are indicators of oxic cold-shallow sandy-silt to sandy-mud bottoms in Antarctica.

Biofacies C: Samples from stations 108-KG and 109-KG, collected from water depths of 309 and 431 m, respectively, of the Dalton Polynya off Moscow University Ice Shelf, are components of biofacies C (Figure 7). They contain living specimens of such as *A. frigida* and *A. antarctica* (Table 2), which have been widely reported from sea bottoms shallower than 500 m in Antarctica (e.g. Hartmann, 1990; Yasuhara *et al*., 2007). The TOC, TN, and TS contents in the Dalton Polynya were lower than those off Cape Darnley but higher than those in biofacies A and B. Arrigo and van Dijken (2003) reported that polynyas are also critical habitats for various higher trophic level organisms. Ambrose and Renaud (1995) reported that benthic organisms, such as sponges, echinoderms, crustaceans, and cnidarians, also rely on this concentrated phytoplankton-based food source for a large fraction of their nutrition in the Northeast Water Polynya on the northeast Greenland continental shelf. We supported their ideas due to the presence of relatively high-diversity ostracod biofacies in Dalton Polynya.

Biofacies D: The sample from St. 83-KG, the second deepest site (842 m) in this study, is a component of biofacies D (Figure 7). *Krithe* sp. was the most dominant species in biofacies D. *Krithe* is the worldwide deep-sea genus, called infauna (Didié and Bauch, 2002). This sample site showed warmer, saline, and low-oxygen waters (0.38°C in temperature, 34.66 in salinity, and 5.0 ml/L of DO; Figure 2, Table 1) than abundant ostracod assemblages in this study. The water mass structure at this site increased rapidly from negative values to positive values in water temperature at water depths of 500–600 m (Figure 2). The water mass below the thermocline can be correlated with mCDW based on previous studies (Jacobs *et al*., 1996; Hirano *et al*., 2020, 2021). Greenbaum *et al*. (2015) showed a new pass of warm water accessing Totten submarine valley based on the bathymetry of the seafloor in the region from gravity and magnetic data, as well as ice-thickness measurements. They identified entrances to the ice-shelf cavity below depths of 400–500 m that could allow warm water intrusions if the vertical structure of the inflow is similar to nearby observations. The mCDW was composed of warm, saline, low-oxygen waters (Park *et al*., 1998; Solomon *et al*., 2000; Tomczak and Godfrey 2003). It is associated with the glacier retreat in West Antarctica (Jenkins *et al*., 2010) and observed on the nearby continental shelf 400–500 m below the cold AASW in summer and winter (Williams *et al*., 2011). Thus, St. 83-KG was characterized by low DO, high bottom water temperature, and relatively high salinity, which may indicate the water mass structure characterizing the mCDW. Ayress *et al*. (2004) reported that *Krithe* cf. *dolichodeira* is an index species in the upper CDW by comparing ostracod assemblages and water mass structure. In this study, all specimens of *Krithe* were juveniles; thus, their species identifications could not be made. However, we thought the ostracod assemblage dominated by *Krithe* species indicated the presence of the mCDW. Therefore, deep-sea ostracods could be considered as useful indicators for reconstructing the paleoceanography and for anthropogenic climate changes in the Antarctic Ocean.

Taxonomic Notes

We briefly discuss the 14 species below, adding the following measurements. L: valve length (mm), H: valve height (mm). The specimens illustrated in this study are deposited in Shimane University Museum (SMU), Japan.

Class Ostracoda Latreille, 1802

Subclass Podocopa Sars, 1866

Order Podocopida Sars, 1866

Suborder Bairdiocopina Gründel, 1967

Superfamily Bairdioidea Sars, 1865

Family Bythocyprididae Maddocks, 1969

Genus ***Bythocypris*** Brady, 1880

***Bythocypris* sp.**

Figure 3.2a, b

Materials.—10 specimens

Measurements.— SMU-IC-F0014 (juvenile right valve, Figure 3.2), L=0.594 mm, H=0.384 mm.

Remarks.— The specimens in this study have the same central muscle scars as those of *Bythocypris*. This species is similar to *Bythocypris kyamos* (Whatley *et al*., 1998b) from the South Atlantic in general shape, but differs from the latter in having less elongate outline.

Occurrence.—off Totten Glacier (stations 17-KG, 108-KG) in this study.

Suborder Cypridocopina Jones, 1901

Superfamily Pontocypridoidea Müller, 1894

Family Pontocyprididae Müller, 1894

Genus ***Propontocypris*** Sylvester-Bradley, 1947

***Propontocypris* sp.**

Figure 3.5

Materials.—4 specimens

Measurements.— SMU-IC-F0017 (juvenile left valve, Figure 3.5), L=0.555 mm, H=0.313 mm.

Remarks.—This species is similar to *Propontocypris* sp. of Whatley *et al.* (1998b) from South Atlantic and *Propontocypris* sp. of Yasuhara *et al*. (2007) from Lützow-Holm Bay but differs from the latter two species in having acute dorsal margin.

Occurrence.—off Totten Glacier (St. 17-KG) in this study.

Suborder Cytherocopina Baird, 1850

Superfamily Cytheroidea Baird, 1850

Family Krithidae Mandelstam, 1958

Genus *Krithe* Brady, Crosskey and Robertson, 1874

***Krithe* sp.**

Figure 3.9

Materials.—24 specimens

Measurements.— SMU-IC-F0021 (juvenile right valve, Figure 3.9), L=0.262 mm, H=0.186 mm.

Remarks.—The specimens of this study were all juvenile valves. This species is similar to *Krithe* sp. 3 of Mazzini, 2005 from off south coast Tasmania in valve shape, but is stubbier than the latter species.

Occurrence.—off Totten Glacier (stations 17-KG, 18-KG, 83-KG, 108-KG) in this study.

Family Hemicytheridae Puri, 1953

Genus ***Australicythere*** Benson, 1964

Australicythere polylyca (Müller, 1908)

Figure 3.12

Cythereis polylyca Müller, 1908, p. 17, figs. 1, 5, 6.

Cythere davisi Chapmann, 1916, p. 72, pl. 6, figs. 46a–c.

Australicythere polylyca (Müller). Benson, 1964, p. 24, pl. 2, fig. 10; pl. 4, figs. 1–7, 9; text-figs. 15, 16, 17; Hartmann, 1987, p. 153, tafel. II, figs. 16–29; tafel. 3; fig. 30; Hartmann, 1989b, p. 279, tafel. VI, figs. 8, 9; tafel. VII, fig. 1; Hartmann, 1990, p. 239, tafel. I, figs. 8, 9; tafel. II, figs. 10–15; Whatley *et al*., 1998b, p. 125, pl. 3, figs. 24–28; Dingle, 2000, p. 489. Fig. 5A; Yasuhara *et al*., 2007, p. 481, pl. 1, figs. 3, 4.

Materials.—80 specimens

Measurements.—SMU-IC-F0024 (female left valve, Figure 3.12), L=1.123 mm, H=0.655 mm.

Remarks.—This species is similar to *Patagonacythere longiducta* (Skogsberg, 1928) and *Australicythere devexa* (Müller, 1908) in the general outline. However, the posteroventral portion of *A. polylyca* is not so protruded than that of the latter two species. *A. polylyca* is larger than *P. longiducta* and has different reticulation pattern. *A. devexa* has some short transverse ridges in anterior part.

Occurrences.—Halley Bay (Whatley *et al*., 1998b); McMurdo Sound (Chapmann, 1916); Ross Sea (Benson, 1964); Lützow-Holm Bay (Yasuhara *et al*., 2007 and stations LH2a-KG, LH5a-KG in this study); off Totten Glacier (stations 17-KG, 18-KG) in this study.

Family Thaerocytheridae Hazel, 1967

Genus ***Bradleya*** Hornibrook, 1952

Bradleya mesembrina Mazzini, 2005

Figure 3.14

Bradleya mesembrina Mazzini, 2005, p. 82, pl. 47, figs. a–k; Yasuhara *et al*., 2009a, p. 919, pl. 4, figs. 8, 9.

Materials.—18 specimens

Measurements.—SMU-IC-F0026 (adult left valve, Figure 3.14), L=0.779 mm, H=0.467 mm.

Remarks.—This species is closely similar to *Bradleya normani* (Brady, 1866), but the latter has straight, obliquely truncated anterior margin (see Yasuhara *et al*., 2009a for detail).

Occurrence.—ODP site 704 (Yasuhara *et al*., 2009a); Tasman Sea (Mazzini, 2005); Lützow-Holm Bay (St. LH5 a-KG) and off Totten Glacier (St. 108-KG) in this study.

Family Trachyleberididae Sylvester-Bradley, 1948

Genus ***Austrotrachyleberis*** Hartmann, 1988

Austrotrachyleberis antarctica (Neale, 1967)

Figures 4.2, 4.3

Robertsonites antarcticus Neale 1967, p. 35, figs. a, b, pl. II, figs. l–l'

Abyssocythere antarctica (Neale). Whatley *et al.*, 1996b, p. 75, pl. 3, fig. 6; Whatley *et al.*, 1998a, p. 107, pl. 5, figs. 10, 11; Whatley *et al.*, 1998b, p. 127, pl. 4, figs. 19–21.

Austrotrachyleberis antarctica (Neale). Hartmann, 1988, p. 162, pl. I, figs. 1, 2; Hartmann, 1989b, p. 278, pl. V, figs. 7–12.

Materials.—18 specimens

Measurements.—SMU-IC-F0028 (adult right valve, Figure 4.2), L=0.883 mm, H=0.577 mm.

Remarks.—This species is similar to *Australicythere polylyca* (Müller, 1908) in the general outline, but the reticulation of *A. antarctica* does not develop like that of *A. polylyca*. The adults in this study have a thick valve with some radial obscure ridges between dorsal margin and subcentral tubercle.

Occurrence.—Halley Bay (Neale, 1967); Lützow-Holm Bay (stations LH1a, LH2a-KG, LH5a-KG) and off Totten Glacier (stations 108-KG, 109-KG) in this study.

Genus ***Pseudocythereis*** Skogsberg, 1928

Pseudocythereis spinifera Skogsberg, 1928

Figure 4.6

Cythereis (*Psedocythere*) *spinifera* Skogsberg, 1928, p. 131, pl. 2, fig. 8, pl. 5, fig. 5, text-fig. 22

Pseudocythereis spinifera Skogsberg. Hartmann, 1989b, p. 278, pl. V, figs. 1–6.

Materials.—7 specimens

Measurements.—SMU-IC-F0032 (juvenile left valve, Figure 4.6), L=0.628 mm, H=0.363 mm.

Remarks.—The specimens of this study were all juvenile valves. We identified them as *P. spinifera* in comparison with the juvenile forms of this species from Antarctic Peninsula by Hartmann (1989b). This species is different from *Pseudocythereis falcata* Skogsberg, 1928 in valve outline. The dorsal margin of *P. falcata* slopes rather steeply posteriorly (Skogsberg, 1928).

Occurrence.— Antarctic Peninsula (Hartmann, 1989b); South Georgia (Skogsberg, 1928); off Totten Glacier (St. 108-KG) in this study.

Subfamily Pseudocytherinae Schneider, 1960

Genus ***Pseudocythere*** Sar, 1866

Pseudocythere caudata Sars, 1866

Figure 4.9a, b

Pseudocythere caudata Sars, 1866, p. 88; Brady, 1880, p. 144, pl. 1, Figs. 6a–d; Whatley *et al*., 1998c, p. 18, pl. 1, figs. 8, 9; Didié and Bauch, 2000, p. 112, pl. 1, fig. 20; Yasuhara *et al*., 2009b, p. 889, pl. 4, figs. 7–12; Yasuhara *et al*., 2014a, p. 351, Figs. 1, 2; Yasuhara *et al*., 2014b, p. 417, pl. 6, figs. 1–12; Yasuhara and Okahashi, 2014, p. 30, fig. 5F, G.

Pseudocythere cf. *caudata* (Sars). Yasuhara *et al*., 2007, p. 489, pl. 5, fig. 13, p. 492, Appendix. 2.

Pseudocythere aff. *caudata* (Sars). Dingle, 2003, p. 130, pl. 1, fig. 11.

Pseudocythere sp. cf. *caudata* (Sars). Whatley *et al*., 1998b, p. 121, pl. 2, figs. 6, 7.

Materials.—8 specimens

Measurements.—SMU-IC-F0035 (adult left valve, Figure 4.9), L=0.761 mm, H=0.394 mm.

Remarks.—This species is similar to *Pseudocythere similis* (Müller, 1908) in general outline and surface ornamentation, but *P. similis* has a sharp spine on the posteroventral part. *Pseudocythere* cf. *caudata* of Yasuhara *et al*. (2007) and Whatley *et al*. (1998b) and *Pseudocythere* aff. *caudata* of Dingle (2003) are thought to be variations of *P. caudata* because they have the same valve morphology, especially the caudal process is similar to that of type specimen (Sars, 1866).

Occurrence.— Admiralty Bay (Majewski and Okempska, 2005); Greenland sea (Whatley *et al*., 1998c); Magellan Straits (Whatley *et al*., 1998b); ODP site 1055 (Yasuhara *et al*., 2009b); Lützow-Holm Bay (St. LH5a-KG) and off Totten Glacier (stations 17-KG, 108-KG) in this study.

***Pseudocythere* sp.**

Figure 4.10a, b

Materials.—2 specimens

Measurements.—SMU-IC-F0036 (adult left valve, Figure 4.10), L=0.535 mm, H=0.284 mm.

Description.—Valves ellipse in shape, thin calcified carapaces. Both valves same size. Anterior margin broadly rounded, posterior margin sinuate with distinct acute caudal process at posterodorsal corner.

Dorsal margin slightly convex and ventral margin slightly concave at anterior one-third of valve length. Surface smooth with distinct groove along dorsal margin and a compressed peripheral zone. The hinge of left valve, parallel to dorsal margin, seems to have terminal elements.

Remarks.—This species is similar to *P. similis* (Müller, 1908) and *P. caudata* (Sars, 1866) in general outline and smooth surface, but the shape and angle of caudal process differ from those of the latter two species. *P. similis* and *P. caudata* have a distinct spine and a sharp edge at the posteroventral portion, respectively. Thus, there is a possibility that this is a new species, but only two specimens were obtained in this study.

Occurrence.—off Totten Glacier (St. 26-KG) in this study.

Family Cytheruridae Müller, 1894

Genus ***Hemicytherura*** Elofson, 1941

Hemicytherura irregularis (Müller, 1908)

Figure 4.12

Cytheropteron irregulare Müller, 1908, p. 109, pl. 18, figs. 2, 3, 8.

Hemicytherura irregularis (Müller). Neale, 1967, p. 22, pl. 2, figs. d, e, g, j; Briggs, 1978, p. 28, figs. 2, 17; Whatley *et al.*, 1988, p. 193, pl. 1, figs. 5, 6; Hartmann, 1989b, p. 243, Abb. 19–24, p. 282, Tafel IX, figs. 6–9; Hartmann, 1990 p. 242, Tafel IV, figs. 38, 39; Hartmann, 1992, p. 418; Hartmann, 1993, p. 230; Whatley *et al.*, 1998b, p. 125, pl. 3, figs. 17, 18; Majewski and Olempska, 2005, p. 29, Figs. 8.6, 8.7; Sasaki *et al.*, in press, Figs. 4, 6, 7.

Materials.—19 specimens.

Measurements.—SMU-IC-F0038 (adult right valve; Figure 4.12), L=0.447 mm, H=0.276 mm.

Remarks.—This species is similar to *H. splendifera* (Whatley *et al.*, 1988) and *H. anomala* (Müller, 1908) in the general outline and valve size. However, it differs from them with having different ornamentation pattern on the valve surface. *H. irregularis* has weaker or more delicate ornamentation than *H. splendifera. H. anomala* is characterized by a straight ridge extending from anterior to posterior parts but *H. irregularis* has a sinuate ridge extending from anterior to posterior parts.

Occurrence.—Admiralty Bay (Majewski and Olempska, 2005); Antarctic Peninsula, Scotia Sea (Whatley *et al.*, 1998b); Lützow-Holm Bay (Yasuhara *et al.*, 2007 and St. LH2a-KG in this study), off Totten Glacier (stations 17-KG, 18-KG) in this study.

Genus ***Cytheropteron*** Sars, 1866

Cytheropteron perlaria Hao, 1988

Figures 5.3

Cytheropteron testudo Sars, Whatley and Coles 1987, p. 90, pl. 3, fig. 1; Whatley *et al.*, 1996a, p. 21, pl. 3, figs. 2, 3.

Cytheropteron perlaria Hao, 1988 pl. 8, figs. 1–8; Yasuhara *et al.*, 2009b, p. 895, pl. 7, figs. 12, 13; Yasuhara *et al.*, 2014b, p. 421, pl. 8, figs. 1–8; Jöst *et al.*, 2018, p. 768, pl. 3, figs. 20, 21.

Materials.—37 specimens

Measurements.—SMU-IC-F0041 (juvenile left valve, Figure 5.3), L=0.530 mm, H=0.298 mm.

Remarks.—This species is very similar to *Cytheropteron testudo* (Sar, 1869) in general outline, but the former has more elongate and triangular lateral outline (see Swanson and Ayress, 1999 for detail).

Occurrence.—North Atlantic Ocean around Iceland (Jöst *et al.*, 2018); ODP site 1055 (Yasuhara *et al.*, 2009b); Lützow-Holm Bay (St. LH2a-KG) and off Totten Glacier (stations 17-KG, 83-KG, 108-KG, 109-KG) in this study.

Family Loxoconchidae Sar, 1925

Genus ***Antarctiloxoconcha*** Hartmann, 1986

Antarctiloxoconcha frigida (Neale, 1967)

Figure 5.8

Loxocythere frigida Neale, 1967, p. 29, pl. II, a, b, text-figs. 9a–d.

? *Cytheropteron frigidum* (Neale). Whatley et al., 1988, p. 198, pl. 4, figs. 3–5.

Cytheropteron frigida (Neale). Whatley *et al.*, 1998b, p. 125, pl. 3, figs. 3, 4.

Antarctiloxoconcha rotundicaudata (Neale). Hartmann, 1986, p. 219, tafel. IV, figs. 2, 3.

Antarctiloxoconcha frigida (Neale). Hartmann, 1989b, p. 281, tafel. VIII, figs. 4–7, pl. 9, figs. 1–4; Hartmann, 1990, p. 242, tafel. IV, figs. 30–32; Szczechura and Blaszyk, 1996, p. 183, pl. 45, figs. 2–5; Yasuhara *et al.*, 2007, p. 481, pl. 1, fig. 5, p. 492, Appendix. 2.

Materials.—27 specimens

Measurements.—SMU-IC-F0046 (juvenile right valve, Figure 5.8), L=0.32 mm, H=0.219 mm.

Remarks.—The specimens in this study were all juvenile valves but have the same outline as that of the type specimen (Neale, 1967). Whatley *et al*. (1998b) tentatively referred this species within *Cytheropteron* because it lacks the typical sub-rectangular shape. On the other hand, Hartmann (1986) proposed newly *Antarctiloxoconcha* belonging to the subfamily Loxoconchinae to this species. It is characterized by strongly bulbous contour, a distinct caudal process, and a weakly merodont hingement. In this study, we used *Antarctiloxoconcha frigida* according to Brandão and Karanovic (2021).

Occurrence.—Halley Bay (Neale, 1967; Whatley *et al*., 1998b); Lützow-Holm Bay (stations LH2a-KG, LH5a-KG) and off Totten Glacier (stations 18-KG, 108-KG, 109-KG) in this study.

Genus ***Kuiperiana*** Bassiouni, 1962

Kuiperiana meridionalis (Müller, 1908)

Figure 5.9

Loxoconcha meridionalis Müller, 1908, p. 133, pl. 23, figs. 1, 9.

Myrena meridionalis (Müller). Neale, 1967, p. 19, pls. I, h; p. 20, fig. 7

Kuiperiana meridionalis (Müller). Whatley *et al*., 1996b, p. 72, pl. 2, fig. 17; Whatley *et al*., 1998b, p. 127, pl. 4, fig. 8; Yasuhara *et al*., 2007, p. 487, pl. 4, fig. 12.

Materials.—4 specimens

Measurements.—SMU-IC-F0047 (juvenile right valve, Figure 5.9), L=0.428 mm, H=0.265 mm.

Remarks.—This species is similar to the species of genus *Loxoconcha* in the general outline, but possesses the modified gongylodont hinge typical to the genus *Kuiperiana*.

Occurrences.—Magellan Strait (Whatley *et al*., 1996b), Scotia Sea (Whatley *et al*., 1998b); Lützow-Holm Bay (Yasuhara *et al*., 2007 and St. LH5a-KG in this study); off Totten Glacier (stations 17-KG, 109-KG) in this study.

Genus ***Nodoconcha*** Hartmann, 1989a

Nodoconcha minuta Hartmann, 1989a

Figure 5.14a, b

Nodoconcha minuta Hartmann, 1989a, p. 226, abb. 42–49; Hartmann, 1988, p. 162, tafel. I, fig. 8; Hartmann, 1990, p. 245, tafel. VII, figs. 63–65; Dingle, 2000, p. 489, fig. 5F; Melis and Salvi, 2020, p. 24, fig. 3.

Materials.—1 specimen

Measurements.—SMU-IC-F0052 (juvenile right valve, Figure 5.14), L=0.196 mm, H=0.139 mm.

Remarks.—This species is similar to the species belonging to *Loxoconcha* in valve shape, but has distinct five tubercles with the second reticulation.

Occurrence.—Antarctic Peninsula, Scotia Sea (Hartmann, 1989a); Cape Adare (Melis and Salvi, 2020); Hope Bay (Hartmann, 1990); off Totten Glacier (St. 14b-KG) in this study.

Conclusions

1. Nineteen species belonging to 13 genera and 47 species belonging to 31 genera of ostracods were found in three samples from Lützow–Holm Bay and ten samples from off Totten Glacier, respectively. We found no ostracods in the samples off Cape Darnley.
2. Q-mode cluster analysis reveals four ostracod biofacies (A to D). *Antarctiloxoconcha frigida* (Neale, 1967) and *Australicythere polylyca* (Müller, 1908) were found common under the influence of cold water in the upper bathyal zone (biofacies A to C).
3. The genus *Krithe* was the most abundant taxon in biofacies D with low DO values and high-water temperature (5.0 ml/L and 0.38°C), indicating the presence of the warm deep seawater, i.e., mCDW.
4. This study clarified the ostracod assemblages that characterize the deep-sea condition off Totten and Lützow–Holm Bay, thus confirming the previous data and supplying further information about ostracods from East Antarctica to understand anthropogenic climate changes.

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Captions of figures and tables

Figure 1. Maps showing the study area (made by Generic Mapping Tools, Wessel *et al.*, 2013).

a, Index map of the study area. **b, c,** and **d,** Sample sites of the study area. Each bathymetric contour interval is 500 m (made by ETOPO1, Amante and Eakins, 2009). Solid circles, open circles, and cross marks show the site containing >10 ostracod valves, <10 ostracod valves and no ostracods, respectively. Dotted lines in Figure1c, 1d show the areas of Cape Darnley Polynya and Dalton Polynya based on Ohshima *et al*. (2013) and O'Brien *et al*. (2020), respectively.

Figure 2. Vertical profiles of water temperature, salinity, dissolved oxygen in the study areas measured during December 2019 to March 2020 (JARE 61th), respectively.

a, Lützow-Holm Bay, **b,** off Cape Darnley, **c, d,** and **e,** off Totten Glacier.

Figure 3. SEM photographs of the selected ostracod species (part 1).

1, *Polycope* sp. 1, juvenile right valve, SMU-IC-F0013, sample from St. 17-KG; **2,** *Bythocypris* sp., juvenile left valve, SMU-IC-F0014, sample from St. 17-KG; a, left lateral view; b, internal view; **3,** *Neonesidea* sp., juvenile right valve, SMU-IC-F0015, sample from St. 17-KG; a, right lateral view; b, internal view; **4,** *Macrocypris* sp., juvenile left valve, SMU-IC-F0016, sample from St. 18-KG; **5,** *Propontocypris* sp., juvenile left valve, SMU-IC-F0017, sample from St. 17-KG; **6,** *Argilloecia* sp. 1, adult left valve, SMU-IC-F0018, sample from St. 17-KG; a, left lateral view; b, internal view; **7,** *Argilloecia* sp. 2, juvenile left valve, SMU-IC-F0019, sample from St. 17-KG; **8,** *Argilloecia* sp. 3, adult right valve, SMU-IC-F0020, sample from St. 109-KG; **9,** *Krithe* sp., juvenile left valve, SMU-IC-F0021, sample from St. 83-KG; **10,** *Austrocythere reticulotuberculata* Hartmann, 1989, juvenile right valve, SMU-IC-F0022, sample from St. 108-KG; **11,** *Rotundracythere austromarscotiensis* Whatley *et al.*, 1998c, juvenile left valve, SMU-IC-F0023, sample from St. 109-KG; **12,** *Australicythere polylyca* (Müller, 1908), female left valve, SMU-IC-F0024, sample from St. 18-KG; **13,** *Muellerina* sp., juvenile right valve, SMU-IC-F0025, sample from St. 18-KG; **14,** *Bradleya mesembrina* Mazzini, 2005, adult left valve, SMU-IC-F0026, sample from St. LH5a-KG.

Figure 4. SEM photographs of the selected ostracod species. (part 2).

1, *Poseidonamicus* sp., juvenile right valve, SMU-IC-F0027, sample from St. 17-KG; a, right lateral view; b, internal view; **2, 3,** *Austrotrachyleberis antarctica* (Neale, 1967), 2, female right valve, SMU-IC-F0028, sample from St. LH2a-KG; 3, juvenile left valve, SMU-IC-F0029, sample 108-KG; **4,** *Cythereis* sp., juvenile left valve, SMU-IC-F0030, sample from St. 108-KG; **5,** *Echinocythereis*? sp. 1, juvenile left valve, SMU-IC-F0031, sample from St. 17-KG; **6,** *Pseudocythereis spinifera* Skogsberg, 1928, juvenile left valve, SMU-IC-F0032, sample from St. LH2a-KG; **7,** *Retibythere* (*Bathybythere*) *scaberrima* (Brady, 1886), juvenile left valve, SMU-IC-F0033, sample from St. 17-KG; a, left lateral view; b, internal view; **8,** *Antarcticythere laevior* (Müller, 1908), adult right valve, SMU-IC-F0034, sample from St. 17-KG; a, right lateral view; b, internal view; **9,** *Pseudocythere caudata* Sars 1866, adult left valve, SMU-IC-F0035, sample from St. 17-KG; a, left lateral view; b internal view; **10,** *Pseudocythere* sp. adult left valve, SMU-IC-F0036, sample from St. 26-KG; a, left lateral view; b, internal view; **11,** *Sclerochilus* sp., juvenile right valve, SMU-IC-F0037, sample from St. 17-KG; **12,** *Hemicytherura irregularis* (Müller, 1908), adult right valve, SMU-IC-F0038, sample from St. 17-KG.

Figure 5. SEM photographs of the selected ostracod species. (part 3).

1, *Cytheropteron demenoali* Yasuhara *et al*., 2009, juvenile right valve, SMU-IC-F0039; sample from St. LH2a-KG; **2,** *Cytheropteron gaussi* Müller, 1908, adult right valve, SMU-IC-F0040, sample from St. 17-KG; **3,** *Cytheropteron perlaria* Hao, in Ruan and Hao (1988), juvenile right valve, SMU-IC-F0041, sample from St. 108-KG; **4,** *Cytheropteron* sp. 1, juvenile left valve, SMU-IC-F0042, sample from St. 17-KG; **5,** *Cytheropteron* sp. 2, juvenile left valve, SMU-IC-F0043, sample from St. 17-KG; **6,** *Pedicythere* sp., juvenile left valve, SMU-IC-F0044, sample from St. 17-KG; **7,** *Paracytheridea* sp., adult right valve, SMU-IC-F0045, sample from St. 17-KG; **8,** *Antarctiloxoconcha frigida* (Neale, 1967), juvenile right valve, SMU-IC-F0046, sample from St. 108-KG; **9,** *Kuiperiana meridionalis* (Müller, 1908), adult right valve, SMU-IC-F0047, sample from St. LH5a-KG; **10,** *Xestoleberis* sp., juvenile left valve, SMU-IC-F0048, sample from St. LH2a-KG; **11,** *Microcythere* sp., juvenile right valve, SMU-IC-F0049, sample from St. 17-KG; **12,** *Paradoxostoma gracilis* (Chapmann, 1915), adult left valve, SMU-IC-F0050, sample from St. 17-KG; a, left lateral view; b, internal view; **13,** *Paradoxostoma* sp. 1, juvenile left valve, SMU-IC-F0051, sample from St. 17-KG; **14,** *Nodoconcha minuta* Hartmann, 1989, juvenile right valve, SMU-IC-F0052, sample from St. 14-KG; a, right lateral view; b, internal view.

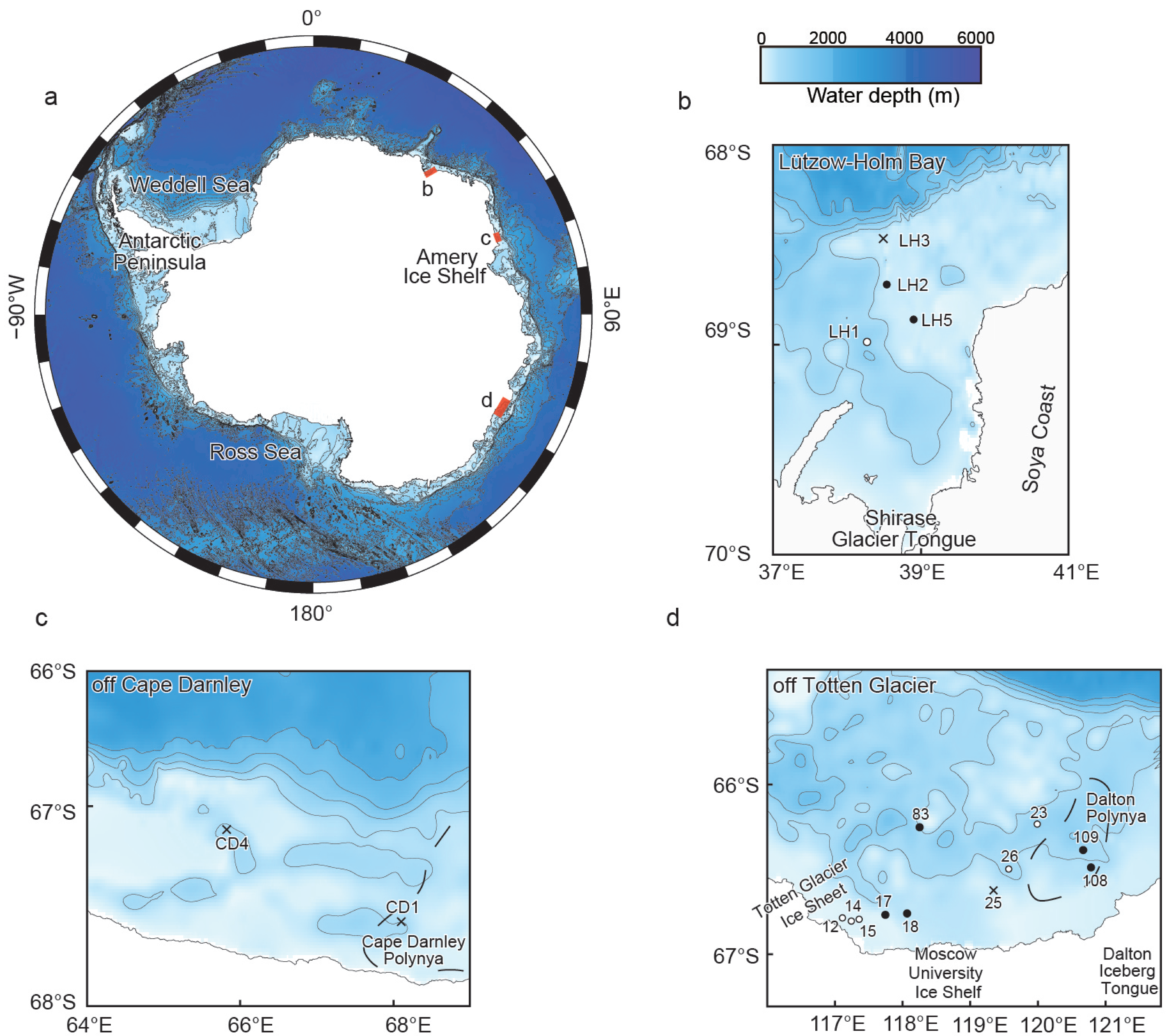
Figure 6. Water depth ranges of the selected ostracod species in this study.

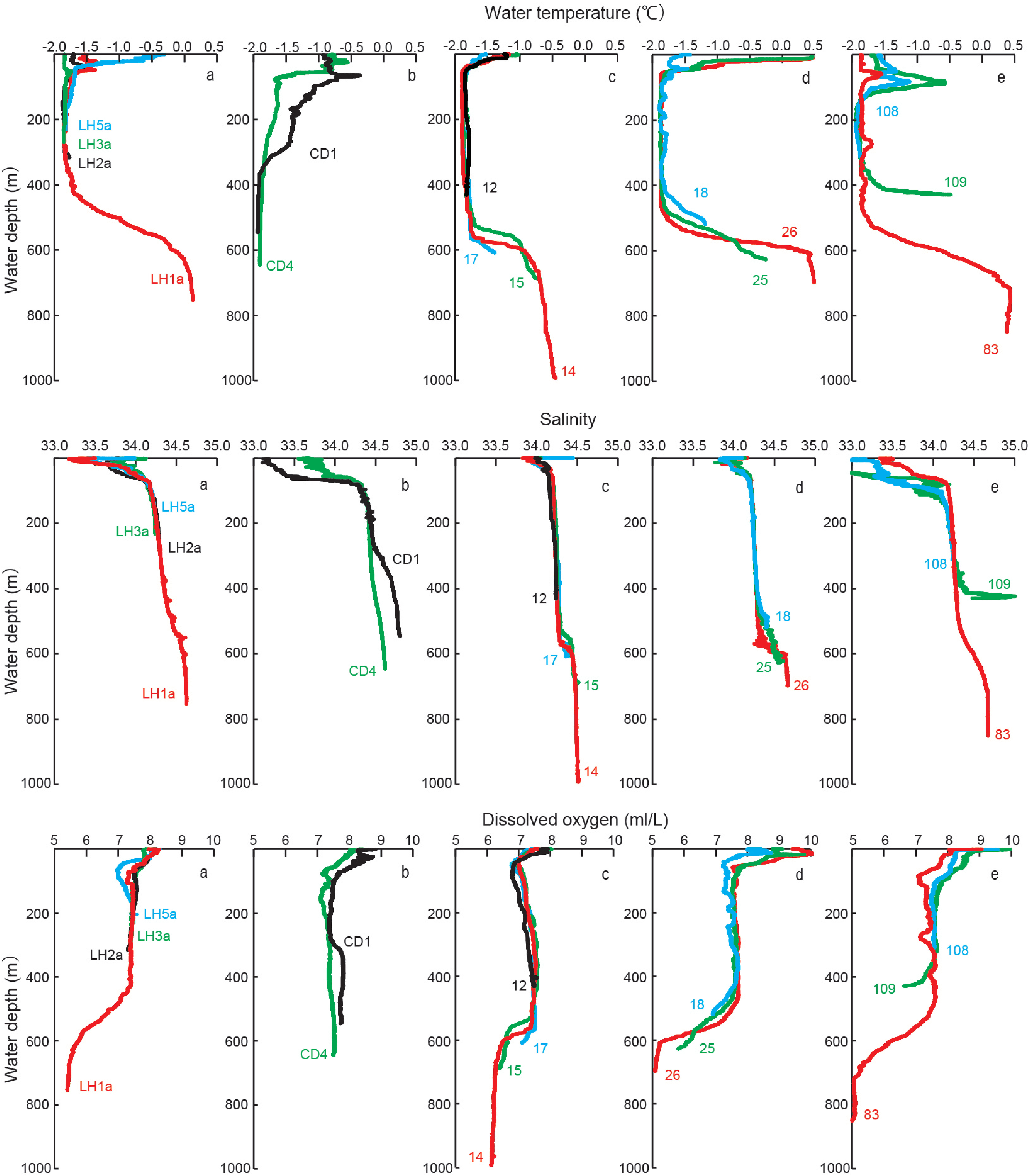
Solid and open circles show the living specimens and empty valves off Totten Glacier, respectively. Solids and open triangles show the living specimens and empty valves in Lützow-Holm Bay, respectively.

Figure 7. Dendrogram showing the results of ostracods Q-mode cluster analysis.

Table 1. List showing the environmental information of the sample sites and the results of grain and CNS elemental analyses.

Table 2. Occurrence list of ostracods from the surface sediment samples collected from Lützow-Holm Bay and off Totten Glacier, East Antarctica. Numerals in parentheses show the number of living specimens.

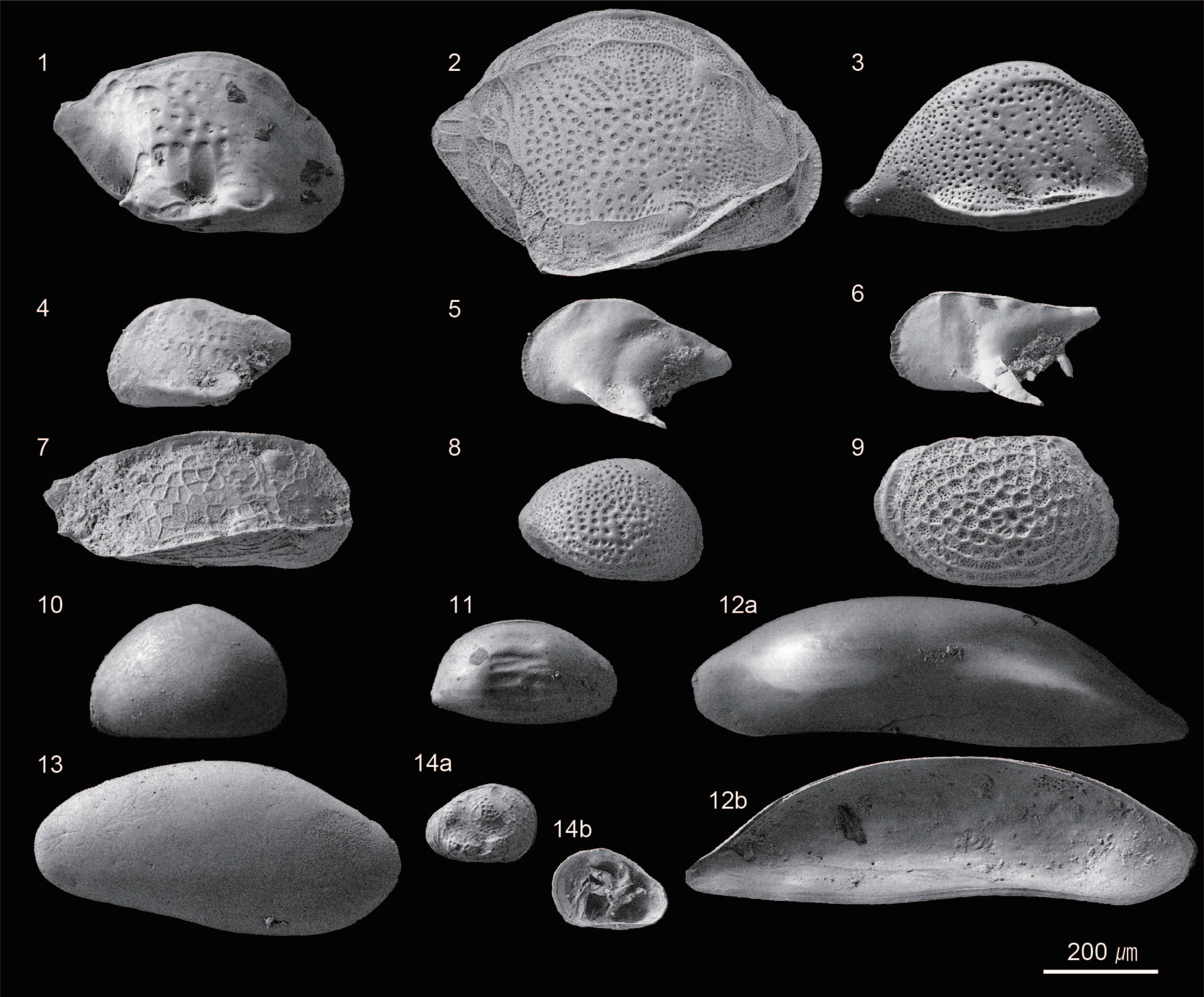

a
0°
90°E
180°
−90°W
Weddell Sea
Antarctic Peninsula
Amery Ice Shelf
Ross Sea
b
c
d
0
2000
4000
6000
Water depth (m)
Lützow-Holm Bay
LH3
LH2
LH5
LH1
Soya Coast
Shirase Glacier Tongue
68°S
69°S
70°S
37°E
39°E
41°E
off Cape Darnley
CD4
CD1
Cape Darnley Polynya
66°S
67°S
68°S
64°E
66°E
68°E
off Totten Glacier
Dalton Polynya
83
23
109
26
108
25
17
18
14
12
15
Totten Glacier Ice Sheet
Moscow University Ice Shelf
Dalton Iceberg Tongue
66°S
67°S
117°E
118°E
119°E
120°E
121°E

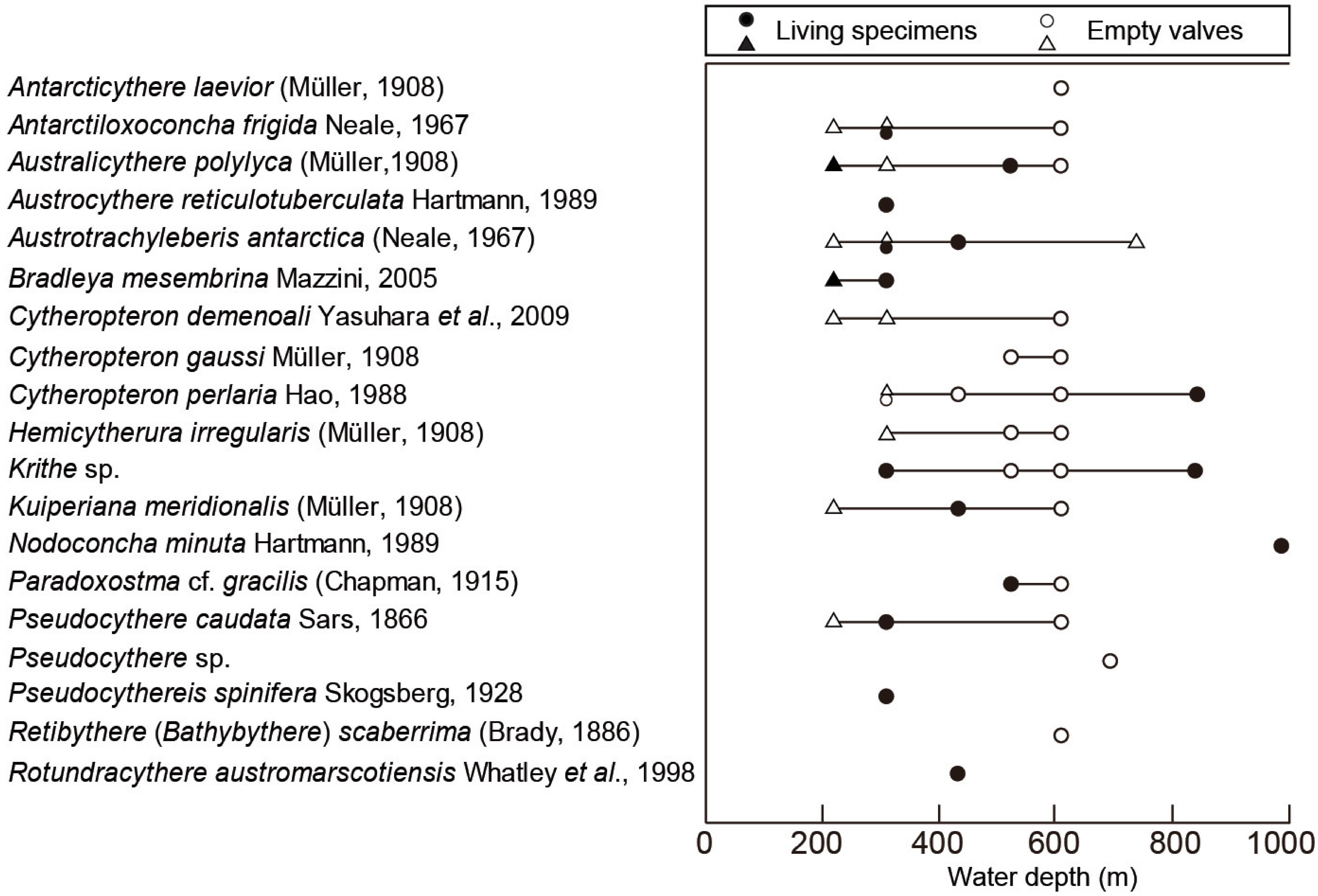


Water temperature (℃)
Salinity
Dissolved oxygen (ml/L)
Water depth (m)
a
b
c
d
e
LH5a
LH3a
LH2a
LH1a
CD1
CD4
12
14
15
17
18
25
26
83
108
109

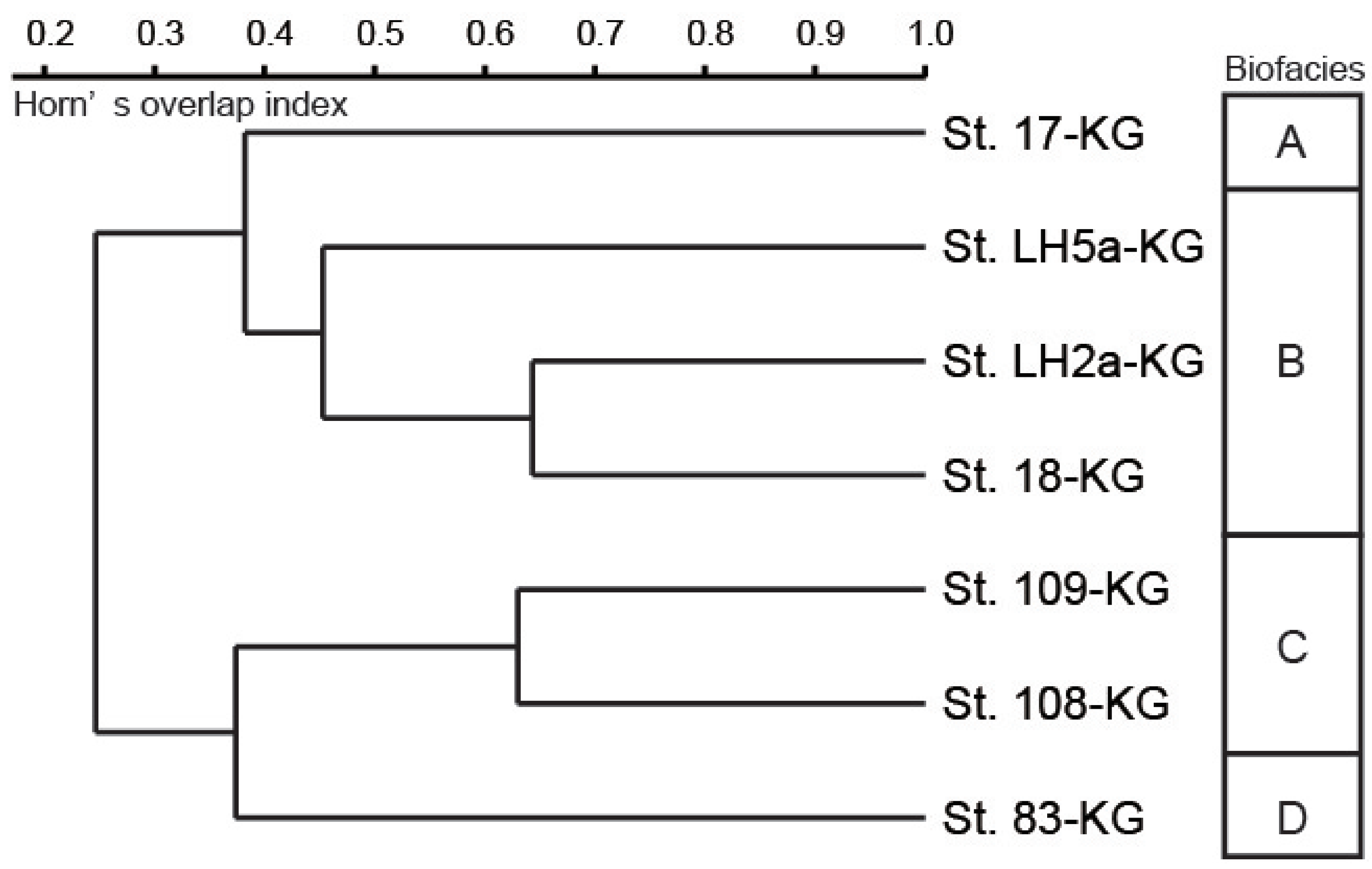

1
2a
2b
3a
3b
4
5
6a
7
8
6b
9
10
11
12
13
14
200 μm

1a
1b
2
3
4
5
6
7a
7b
8a
8b
9a
9b
10a
10b
11
12
200 μm


1
2
3
4
5
6
7
8
9
10
11
12a
12b
13
14a
14b
200 ㎛



Living specimens
Empty valves
Antarcticythere laevior (Müller, 1908)
Antarctiloxoconcha frigida Neale, 1967
Australicythere polylyca (Müller,1908)
Austrocythere reticulotuberculata Hartmann, 1989
Austrotrachyleberis antarctica (Neale, 1967)
Bradleya mesembrina Mazzini, 2005
Cytheropteron demenoali Yasuhara *et al*., 2009
Cytheropteron gaussi Müller, 1908
Cytheropteron perlaria Hao, 1988
Hemicytherura irregularis (Müller, 1908)
Krithe sp.
Kuiperiana meridionalis (Müller, 1908)
Nodoconcha minuta Hartmann, 1989
Paradoxostma cf. *gracilis* (Chapman, 1915)
Pseudocythere caudata Sars, 1866
Pseudocythere sp.
Pseudocythereis spinifera Skogsberg, 1928
Retibythere (*Bathybythere*) *scaberrima* (Brady, 1886)
Rotundracythere austromarscotiensis Whatley *et al*., 1998
0
200
400
600
800
1000
Water depth (m)



0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
Horn' s overlap index
Biofacies
St. 17-KG
St. LH5a-KG
St. LH2a-KG
St. 18-KG
St. 109-KG
St. 108-KG
St. 83-KG
A
B
C
D

Area	Lützow-Holm Bay				off Cape Darnley		off Totten Glacier										
Local station	St. LH1a-KG	St. LH2a-KG	St. LH3a-KG	St. LH5a-KG	St. CD1-KG	St. CD4-KG	St. 12b-KG	St. 14b-KG	St. 15-KG	St. 17-KG	St. 18-KG	St. X23-KG	St. 25-KG	St. 26-KG	St. 83-KG	St. 108-KG	St. 109-KG
Latitude	68°59.11'S	68°42.17'S	68°28.33'S	68°51.95'S	67°35.02'S	67°06.70'S	66°46.79'S	66°47.90'S	66°47.52'S	66°45.73'S	66°45.51'S	66°13.72'S	66°37.44'S	66°29.73'S	66°14.79'S	66°29.38'S	66°22.88'S
Longitude	38°14.95'E	38°30.97'E	38°29.02'E	38°53.43'E	68°06.19'E	65°48.88'E	117°06.44'E	117°13.95'E	117°21.33'E	117°44.47'E	118°03.64'E	119°59.28'E	119°20.43'E	119°33.68'E	118°15.07'E	120°47.07'E	120°40.12'E
Water depth (m)	737	310	264	219	544	644	419	987	691	608	523	487	627	693	842	309	431
Bottom temperature (°C)	0.13	-1.78	-1.86	-1.83	-1.94	-1.91	-1.82	-0.45	-0.69	-1.38	-1.18	-1.09	-0.25	0.49	0.38	-1.88	-0.49
Calib_DO [ml/l]	5.40	7.31	7.43	7.47	7.72	7.50	7.49	6.12	6.38	7.11	6.91	-	5.83	5.09	5.00	7.54	6.62
Calib Salinty	34.62	34.32	34.29	34.24	34.80	34.61	34.24	34.51	34.49	34.35	34.40	-	34.54	34.66	34.67	34.24	34.48
Median (φ)	6.61	5.61	3.50	4.18	4.28	5.83	8.03	8.10	7.83	7.92	7.38	4.49	6.94	7.30	7.85	7.40	5.98
Mean (φ)	6.74	6.36	3.79	4.82	4.69	6.14	7.99	8.10	7.70	7.86	7.31	4.92	7.04	7.28	7.81	7.14	6.57
Sorting	2.40	2.66	1.65	2.17	2.10	1.92	1.51	1.86	1.90	1.75	1.71	2.18	2.43	1.93	1.77	2.06	2.63
TOC	0.30	0.20	0.10	0.10	0.95	1.40	0.32	0.22	0.19	0.28	0.36	0.30	0.65	0.16	0.38	0.37	0.35
TN	0.05	0.04	0.02	0.03	0.11	0.17	0.04	0.05	0.04	0.05	0.07	0.07	0.09	0.03	0.07	0.07	0.09
TS	0.14	0.06	0.06	0.09	0.19	0.51	0.22	0.08	0.11	0.10	0.14	0.12	0.19	0.09	0.17	0.18	0.19
Sample	Grayish olive sandy silt with pebble (20 cm)	Grayish olive silty sand with cobble and many bryozoa (16 cm)	Grayish olive silty sand with bryozoa (14 cm)	Grayish olive silty sand with many bryozoa (13 cm)	Olive sandy diatomaceous ooze (19 cm)	Olive diatomaceous ooze (18 cm)	Yellowih brown silty clay (23 cm)	Grayish olive silty clay (23 cm)	Grayish olive silty clay (23 cm)	Grayish olive sandy clay with many bryozoa (23 cm)	A few grayish olive sandy mud with bryozoa	Grayish olive pebbly mud (19 cm)	40 cm subangular boulder with a few olive gray sandy mud	Grayish olive silty clay (23 cm)	Olive yellow clay (24 cm)	Grayish olive silty sand (20 cm)	Grayish olive sandy silt (22 cm)

Sample	St. LH1a-KG	St. LH2a-KG		St. LH5a-KG		St. 12b-KG	St. 14b-KG	St. 15-KG	St. 17-KG	St. 18-KG		St. X23-KG	St. 26-KG	St. 83-KG		St. 108-KG		St. 109-KG	
V: valve, C: carapace	V	V	C	V	C	V	V	V	V	V	C	C	V	V	C	V	C	V	C
Antarcticythere laevior (Müller, 1908)									2										
Antarctiloxoconcha frigida Neale, 1967		4		1						3						7	2 (2)	8	
Argilloecia sp. 1									10										
Argilloecia sp. 2									9									1	
Argilloecia sp. 3			1 (1)														3 (3)	1	1 (1)
Australicythere polylyca (Müller,1908)		28		5	1 (1)				15	16	7 (7)								
Austrocythere reticulotuberculata Hartmann, 1989																4(1)	4 (4)		
Austrotrachyleberis antarctica (Neale, 1967)	1	4		3												2	2 (2)	2	1 (1)
Bradleya mesembrina Mazzini, 2005				8	3 (3)											2	1 (1)		
Bythocypris sp.									8								1 (1)		
Cythereis ? sp.																1			
Cytheropteron demenoali Yasuhara *et al*., 2009		2		1					7										
Cytheropteron gaussi Müller, 1908									35	2									
Cytheropteron perlaria Hao, 1988		1							9					13	1 (1)	9		3	
Cytheropteron sp. 1		3																	
Cytheropteron sp. 2									3										
Echinocythereis ? sp. 1									7										
Echinocythereis ? sp. 2		2		2					1									1	
Hemicytherura irregularis (Müller, 1908)		1							17	1									
Hemicytherura sp. 1																	1 (1)		
Hemicytherura sp. 2		3																	
Hemicytherura sp. 3				1					1							1			
Krithe sp.									6	1				3(1)	6 (6)		1 (1)		
Kuiperiana meridionalis (Müller, 1908)				1					1										1 (1)
Macrocypris sp.										1									
Microcythere sp.															1 (1)		1 (1)		1 (1)
Muellerina sp.										1									
Neonesidea sp.									10	1									
Nodoconcha minuta Hartmann, 1989							1(1)												
Paracytheridea sp.									5										
Paradoxostma cf. *gracilis* (Chapman, 1915)									11		1 (1)								
Paradoxostma sp. 1									4										
Paradoxostma sp. 2		3						1	9	1							1 (1)		3 (3)
Paradoxostma sp. 3																			1 (1)
Pedicythere sp.									1										
Polycope spp.		1(1)	3 (3)	1	1 (1)				1			1 (1)		1	2 (2)		3 (3)	4	
Poseidonamicus sp.									1					1					
Propontocypris sp.									4										
Pseudocythere caudata Sars, 1866				1					5								1 (1)		
Pseudocythere sp.													2						
Pseudocythereis spinifera Skogsberg, 1928																3	2 (2)		
Retibythere (*Bathybythere*) *scaberrima* (Brady, 1886)									1										
Rotundracythere austromarscotiensis Whatley *et al*., 1998																			1 (1)
Sclerochilus sp.									5										
Xestoleberis sp.		9							4										
Gen. et sp. indet. 1															1 (1)				
Gen. et sp. indet. 2																		1	
Gen. et sp. indet. 3				1															
Gen. et sp. indet. 4		2																	
Gen. et sp. indet. 5						2													
Gen. et sp. indet. 6									3										
Total number of specimens	1	63 (1)	4(4)	25	5 (5)	2	1(1)	1	195	27	8 (8)	1 (1)	2	18 (1)	11 (11)	29 (1)	23 (23)	21	9 (9)
Total number of valves	1	71		35		2	1	1	195	43		2	2	40		75		39	
Total number of species	1	14		11		1	1	1	29	10		1	1	6		16		13	
Sample dry weight (g)	6.03	41.54		35.55		19.73	3.39	3.50	1.92	7.34		5.34	3.94	25.05		33.76		42.50	
Individual number of valves / 1-g sediment sample	0.17	1.71		0.98		0.10	0.30	0.29	101.7	5.86		0.37	0.51	1.60		2.22		0.92	