Note to Editor:
The extensive edits made, based on reviewer comments, are designated in red. Point-by-point responses to each reviewer comment follow the manuscript. The major edits include:

1. An improved Introduction with more background about the proxy used and a clearer statement about the paper's purpose (i.e. lines 124-139).
2. An improved explanation about the age-depth model for cores 32MC/GC, particularly acknowledging the assumptions that must be made when assigning chronology.
3. Lines 244-247 addresses a reviewer comment about ostracode density, so the supplement data now includes density of shells per gram of sediment.
4. A combined Results/Discussion section better streamlines the paper and reduces repetition and includes (expanded) interpretation.
5. A revised discussion (Section 4.6) documenting an abrupt range shift of a species not typically used as an indicator. This is new and important evidence for a species that may be used as an environmental proxy with additional future study.

Central Arctic Ocean paleoceanography from ~50 ka to present, on the basis of ostracode faunal assemblages from SWERUS 2014 expedition

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Abstract

Late Quaternary paleoceanographic changes at the Lomonosov Ridge, central Arctic Ocean, were reconstructed from multicore and gravity cores recovered during the 2014 SWERUS-C3 Expedition. Ostracode assemblages dated by accelerator mass spectrometry (AMS) indicate changing sea-ice conditions and warm Atlantic Water (AW) inflow to the Arctic Ocean from ~50 ka to present. Key taxa used as environmental indicators include *Acetabulastoma arcticum* (perennial sea ice), *Polycope* spp. (variable sea ice margins, high surface productivity), *Krithe hunti* (Arctic Ocean deep water), and *Rabilimis mirabilis* (nutrient, AW inflow). Results indicate periodic seasonally sea-ice free conditions during Marine Isotope

Stage (MIS) 3 (~57-29 ka), rapid deglacial changes in water mass conditions (15-11 ka), seasonally sea-ice free conditions during the early Holocene (~10-7 ka) and perennial sea ice during the late Holocene. Comparisons with faunal records from other cores from the Mendeleev and Lomonosov Ridges suggest generally similar patterns, although sea-ice cover during the last glacial maximum may have been less extensive at the new Lomonosov Ridge core site (~85.15°N, 152°E) than farther north and towards Greenland. The new data provide evidence for abrupt, large-scale shifts in ostracode species depth and geographical distributions during rapid climatic transitions.

1. Introduction

Environmental conditions are changing rapidly in the Arctic Ocean today, but a longer time perspective is necessary to assess and contextualize these changes and their contributing factors. These changing conditions include sea ice extent and thickness (Stroeve et al., 2012, 2014; Laxon et al., 2013), as well as ocean temperature, stratification, circulation, chemistry, and ecology (Polyakov et al, 2017; Moore et al, 2015; Chierici and Fransson 2009; Rabe et al., 2011; Grebmeier et al., 2006, 2012; Wassmann et al., 2011). Sea ice extent and thickness, in particular, are challenging parameters to reconstruct because most sea ice proxies lack temporal and geographical resolution (Stein et al., 2012). Sea ice extent and thickness, however, are very important variables because they influence albedo, near-surface salinity, light levels, surface-to-seafloor organic carbon flux, and other variables that are important to ecosystems. In fact, sea ice exerts a primary control on Arctic biological and geochemical cycles (Anderson et al, 2011), and sea ice changes are in part responsible for fast-feedback climate changes during the geologic past (Polyak et al., 2010).

Before the last few decades, instrumental oceanographic records were relatively sparse, and sediment proxy records provided insight into past sea-ice conditions and ocean circulation changes from all regions of the Arctic. These records are especially important for examining sea-ice history during past climate changes before the availability of instrumental records. The composition and abundance of marine microfossils preserved in many Arctic sediments provide an important constituent that helps address the growth and decay of ice sheets. For example, several excursions in records of oxygen and carbon isotopes of planktic foraminifers from Arctic sediment cores have been interpreted as releases of freshwater from collapsing continental ice sheets during glaciations and glacial terminations (Stein et al., 1994; Nørgaard-Pedersen et al., 1998)

This paper examines temporal changes in microfossil shells from ostracode indicator species that shed light on biological productivity and sea-ice extent during the last ~50 ka, including Marine Isotope Stages (MIS) 3, the Last Glacial Maximum (LGM, ~21 ka), the deglacial interval and the Holocene. Ostracoda are bivalved Crustacea that inhabit Arctic marine habitats and whose assemblages (Cronin et al., 1994, 1995, Poirier et al., 2012) and shell chemistry (Cronin et al., 2012) have been used extensively as proxies to reconstruct Arctic paleooceanography and sea-ice history (Cronin et al., 2010). Most ostracode species are benthic in habitat and their ecology reflects bottom water environmental conditions. Benthic ecosystems rely on biological productivity in the upper water column, and so benthic biomass production and community structure also reflect sea-ice cover and surface-to-bottom ecosystem links (Grebmeier and Barry, 1991; Grebmeier et al., 2006).

Two pelagic/epipelagic ostracode taxa are used in this paper to indicate water mass conditions. Sediment cores for this study were collected during the 2014 SWERUS-C3 (Swedish – Russian – US Arctic Ocean Investigation of Climate-Cryosphere-Carbon Interactions) Leg 2 expedition from previously unstudied regions of the Siberian margin and the Lomonosov Ridge. The radiocarbon-dated records presented here are from 85.15°N, 152°E on the Lomonosov Ridge in the central Arctic Ocean, a site located at ~800 m near the transition between Atlantic Water and Arctic Intermediate Water in the modern Arctic Ocean. During prior glacial-interglacial cycles, the region was influenced to various degrees by the strength and depth penetration of Atlantic Water. For example, during glacial intervals when thick ice shelves covered much of the Arctic Ocean (Jakobsson et al., 2016), Arctic Intermediate Water warmed (Cronin et al., 2012) and likely entrained to greater water depths (Poirier et al., 2012). Consequently, the new results, when compared to published faunal records from other regions of the Arctic Ocean (Fig. 1a, Table 1), show some regional differences but an overall remarkable consistency in central Arctic faunal abundance changes during the late Quaternary.

2. Arctic oceanography

The Arctic Ocean is strongly stratified, with distinct water masses separated by vertical changes in salinity and temperature (Figure 1b). The following summary of Arctic water masses and circulation is taken from Aagaard and Carmack (1989), Anderson et al. (1994), Jones (2001), Olsson and Anderson (1997), Rudels et al. (2012 and 2013). Arctic Ocean water masses include a fresh, cold Polar Surface Water layer ([PSW], T= ~0°C to -2°C, S= ~32 to 34), found between ~0 and 50 m. The PSW is characterized by perennial ice in most regions and seasonal sea ice in the margins of the Arctic Ocean. Beneath the sea-ice cover, a strong halocline separates the PSW from the underlying warmer, denser water mass of North Atlantic origin (Atlantic Water [AW], ~200 to 1000 m, T= >0°C, S= ~34.6 to 34.8). One branch of the AW flows into the Arctic Ocean from the Nordic seas along the eastern Fram Strait off the west coast of Spitsbergen and another branch flows through the Barents Sea. An intermediate-depth water mass below the AW in the Eurasian Basin at ~1000-1500 m is called the Arctic Intermediate water ([AIW], T= -0.5 to 0°C, S= ~34.6 to 34.8). Below 2000 m, the deep Arctic basins are filled with Arctic Ocean Deep Water ([AODW], T= -1.0°C to -0.6°C, S= 34.9, Somavilla et al., 2013). Bathymetry is a dominant factor governing circulation patterns for AW and AIW, and a sharp front over the Lomonosov Ridge near the SWERUS-C3 core site studied here partially isolates these waters in the Eurasian Basin from the Canadian Basin (Fig. 1b).

In addition to Arctic Ocean stratification, other factors influence sea-ice decay and growth over geologic time (i.e. Polyak et al., 2010). A recent study by Stein et al. (2017) notes the importance of large-scale atmospheric circulation patterns, such as the North Atlantic Oscillation (NAO) and Arctic Oscillation (AO), and radiative forcing (i.e. solar activity) on Holocene sea ice thickness, extent and duration. The NAO and AO influence changes of the relative position and strength of the two primary Arctic Ocean surface-current systems, the Beaufort Gyre in the Amerasian Basin and the Transpolar Drift in the Eurasian Basin (Fig. 1a; Rigor et al., 2002; Stroeve et al., 2014). Data resulting from the SWERUS expedition will help improve understanding of the spatial patterns of sea-ice and intermediate depth circulation, given the extreme variability in sea ice in this region recently evident from satellite records (Serreze and Stroeve, 2015; Stroeve et al., 2014), the importance of the Transpolar Drift in sea ice export through Fram Strait (Polyak et al., 2010; Smedsrud et al., 2017) and new evidence for the influence of inflowing Atlantic Water on sea ice and “atlantification” of the Eurasian Basin (Polyakov et al. 2017).

3. Materials and methods

3.1 Core material and sample processing

Cores for this study were obtained during the September 2014 SWERUS-C3 (Leg 2) expedition to the eastern Arctic Ocean aboard Swedish Icebreaker *Oden*. Figure 1 shows the location of multicore SWERUS-L2-32-MC4 (85.14°N, 151.57°E, 837 m) and nearby gravity core SWERUS-L2-32-GC2 (85.15°N, 151.66°E, 828 m) on the Lomonosov Ridge. These cores are hereafter referred to as 32-MC and 32-GC, respectively. Both cores were stored at 4°C and sampled at the Department of Geological Sciences, Stockholm University. Processing of the samples involved washing the sediment with water through a 63-μm mesh sieve. Core 32-MC was processed in Stockholm while 32-GC was processed at the U.S. Geological Survey (USGS) laboratory in Reston, Virginia. Sediment samples (1-cm thick, ~30 g prior to processing) were taken every centimeter in 32-MC along its 32 cm length. Section 1 (117 cm) of 32-GC was sampled every 2-3 cm (2-cm thick, ~45-60 g wet weight).

After processing and oven drying the samples, the residual >125 μm size fraction was sprinkled on a picking tray and ostracodes were removed to a slide. One exception for expediency is that specimens of the genus *Polycope* were counted and not removed from the sediment. A total of ~300 specimens were studied from each sample of 32-MC. More detailed counts of some samples in 32-MC were done periodically, where all specimens were picked and/or counted to ensure that 300 specimens provided a representative assemblage. In 32-GC, all specimens were picked and/or counted in each sample. Ostracodes were present throughout the entire studied intervals of both 32-MC and down to 62 cm in 32-GC. Planktic and benthic foraminifers were also present in abundance but not studied.

3.2 Chronology, reservoir corrections and sedimentation

Nine radiocarbon (^{14}C) ages were obtained from core 32-MC using accelerator mass spectrometry (AMS) (Fig. 2, Table 2). Most dates were obtained on mollusks (*Nuculidae* and *Arcidae* spp.), except a few samples where mollusks and benthic foraminifera were combined. Two ages from 32-GC were obtained using a combination of mollusks, foraminifera and ostracode shells. The final age models representing the two cores combined are based on all the calibrated ^{14}C ages listed in Table 2. Generally, ages >40 ka should be considered with caution because of large uncertainties in the radiocarbon calibration curve and high sensitivity to even extremely small levels of contamination. Calibration into calendar years was carried out using Oxcal4.2 (Bronk Ramsey, 2009) and the Marine13 calibration curve (Reimer et al., 2013), using a local marine reservoir correction, ΔR, of 300±100 years. Because ΔR values for the central Arctic Ocean were not constant during the last 50 ka, it is difficult to date pre-Holocene sediments independently (Pearce et al., 2017; Hanslik et al., 2012), and improved age models may be available in the future.

Patterns in ostracode assemblages in both cores were used to correlate cores 32-MC and 32-GC and produce a composite faunal record, which led to a 3-cm offset for core 32-GC. After adding the 3-cm offset to sample depths of 32-GC, the 32-MC core chronology was applied down to 31.5 cm core depth (dated at 39.6 ka). The average sedimentation rate at the core site was ~1.5 cm/ka, which is typical of central Arctic Ocean ridges (Backman et al., 2004; Polyak et al., 2009).

The lower section of 32-GC, from 31.5 cm to 61 cm, is beyond the limit of radiocarbon dating. However, the litho-stratigraphy of the gravity core can be readily correlated to other records from the central Lomonosov Ridge, where multiple dating techniques constrain the approximate positions of MIS 4 and 5 boundaries (Jakobsson et al., 2001; O'Regan, 2011). A correlation between SWERUS-C3 32-GC and AO96/12-1PC was previously presented in Jakobsson et al. (2016). The correlation is supported by the occurrences in 32-GC of the calcareous nannofossil *E. huxleyii* (Fig. 2). Based on this longer-term correlation, sediments between 31 and 61 cm are less than 50 ka. This age estimate is consistent with previous work on the Lomonosov Ridge, revealing a prominent transition from coarse-grained, microfossil-poor sediments (diamict) into bioturbated, finer-grained, microfossiliferous sediments that occurred during MIS 3 at approximately 50 ka (Spielhagen et al., 2004; Nørgaard-Pederson et al., 2007).

4. Results and Discussion

4.1 Ostracode taxonomy and ecology

The SWERUS 32 cores contained a total of 13,767 ostracode specimens in 32-MC and a total of 5,330 specimens in the uppermost 5-62 cm of 32-GC (the top few centimeters below the seafloor were not recovered in the gravity core). The bottom 54 cm of 32-GC (section 1 from 63-117 cm) was barren of calcareous material. Twenty-eight ostracode species were identified in 32-MC and 21 species were identified in 32-GC. Supplementary Tables S1 and S2 provide all species and genus census data for 32-MC and 32-GC, respectively. Data will also be accessible at NOAA's National Centers for Environmental Information (NCEI, https://www.ncdc.noaa.gov/paleo-search/). The primary sources of taxonomy and ecology were papers by Cronin et al. (1994, 1995, 2010), Gemery et al. (2015), Joy and Clark (1977), Stepanova (2006), Stepanova et al. (2003, 2007, 2010), Whatley et al. (1996, 1998), and Yasuhara et al. (2014).

Podocopid ostracodes were identified at the species level except the genera *Cytheropteron* and myodocopid *Polycope.* Table 3 provides a list of species included in the genus-level groups, which was sufficient to reconstruct paleoenvironmental changes. There are several species of *Cytheropteron* in the deep Arctic Ocean but they are not ideal indicator species given their widespread modern distributions. There are at least eight species of *Polycope* in the Arctic Ocean, but juvenile molts of *Polycope* species are difficult to distinguish from one another. Most specimens in 32-MC and 32-GC belonged to *P. inornata* Joy & Clark, 1977 and *P. bireticulata* Joy & Clark, 1977. Nonetheless, most *Polycope* species co-occur with one another, are opportunistic in their ecological strategy, and dominate assemblages associated with high surface productivity and organic matter flux to the bottom (Table 4; Karanovic and Brandão, 2012, 2016).

The relative frequency (percent abundance) of individual dominant taxa is plotted in Figure 3 and listed in Supplementary Table S3. Abundances were computed by dividing the number of individual species found in each sample by the total number of specimens found. For 32-MC, using the algorithm for a binomial probability distribution provided by Raup (1991), ranges of uncertainty ("error bars") were calculated at the 95% fractile for the relative frequency in each sample to the relative frequency of each species and the total specimen count of each sample at a given core depth (Supplementary Table S4). Faunal densities were high enough to allow comparisons from sample to sample, and Supplementary Table S4 lists the density of ostracode specimens per gram of dry sediment, which averaged >125 shells per gram sediment. For this study of the SWERUS-C3 32 cores, the focus was on an epipelagic species (*Acetabulastoma arcticum),* a pelagic genera (*Polycope* spp.), three benthic species *(Krithe hunti, Pseudocythere caudata, Rabilimis mirabilis)* and a benthic genus *(Cytheropteron* spp.). Table 4 provides an overview of pertinent aspects of these species' ecology that have paleoceanographic application.

4.2 Temporal patterns in ostracode indicator species from SWERUS-C3 32-MC/GC

The faunal patterns in cores from the SWERUS-C3 32-MC/GC sites confirm faunal patterns occurring over much of the central Arctic Ocean during the last 50 ka, including MIS 3-2 (~50 to 15 ka), the last deglacial interval (~15 to 11 ka), and the Holocene (~11 ka to present). Similar patterns are seen in both the multicore and gravity core. Relative frequencies of indicator taxa in cores 32-MC and 32-GC (Fig. 3) show four distinct assemblages, which are referred to as informal faunal zones following prior workers (Cronin et al., 1995; Poirier et al., 2012). These zones are as follows: (1) *Krithe* zone (primary abundance up to 80% during ~45-42 ka and a secondary abundance of 5-10% during ~42-35 ka); (2) *Polycope* zone (with abundance of 50 to 75% during ~40-12 ka, also containing a double peak in abundance of *P. caudata*); (3) *Cytheropteron-Krithe* zone (12-7 ka); and (4) *Acetabulastoma arcticum* zone (~7 ka-present). This paper briefly discusses the paleoceanographic significance of each period in the following sections 4.3 - 4.5 based on the comparison cores presented in Figs 4 and 5. Figures 4 and 5 compare the new SWERUS-C3 results from 32-MC with published data from box and multicores from the Lomonosov and Mendeleev Ridges, respectively, covering a range of water depths from 700 m to 1990 m. Most records extend back to at least 45 ka, and the age model for each core site is based on calibrated radiocarbon ages from that site (i.e. Cronin et al., 2010, 2013; Poirier et al., 2012). In addition, section 4.6 discusses a potential new indicator species, *R. mirabilis*, which exhibits distinct faunal migrations that coincide with *Krithe* zones in 32-MC/GC. *R. mirabilis* lives on today's continental shelf but is found in limited intervals in sediment cores that are far outside its usual depth and geographic range. *R. mirabilis* migrations are documented not only in 32-MC/GC but in cores 96-12-1PC, HLY0503-06JPC, P1-94-AR-PC10, P1-92-AR-PC40, LOMROG07-04 and P1-92-AR-PC30.

4.3 MIS 3-2 (~50-15 ka)

A strong peak in the abundance of *Krithe hunti* (Fig. 3) is seen in 32-GC sediments estimated to be ~45-42 ka in age. A similar peak of lower but still significant abundance also occurs in sediments dated between 42 and 35 ka, and this peak is consistent with other cores on the Mendeleev Ridge and particularly on the Lomonosov Ridge (Figs 4, 5). Prior studies of Arctic ostracodes have shown that *Krithe* typically signifies cold well-ventilated deep water and perhaps low food supply (Poirier et al., 2012 and references therein). *Krithe* is also a dominant component (>30%) of assemblages in North Atlantic Deep Water (NADW) in the subpolar North Atlantic Ocean. Its abundance varies during glacial-interglacial cycles, reaching maxima during interglacial and interstadial periods (Alvarez Zarikian et al., 2009). Peaks in the abundance of *Krithe* in the Arctic Ocean probably signify faunal exchange between the North Atlantic Ocean and the Greenland-Norwegian Seas through the Denmark Strait and Iceland Faroes Ridge and the central Arctic through the Fram Strait. In other Arctic Ocean cores, the ostracode genus *Henryhowella* is often associated with *Krithe* sp. in sediments dated between ~50 to 29 ka (MIS 3), and its absence in the 32-MC/GC cores may reflect the relatively shallow depth at the coring site. While *Henryhowella* was absent in records from this site, *R. mirabilis* abruptly appears and spikes to an abundance of 60 percent at 40 ka, which coincides with the *Krithe* zone.

A. arcticum is present in low abundance (~5%) in sediment dated at ~42 to 32 ka in 32-MC/GC (Fig. 3), signifying intermittent perennial sea ice. A second increase in abundance of *A. arcticum* corresponds to a (modeled, mean, 2-sigma) radiocarbon date of 21.6 ka. This suggests the location of this core may not have been covered by thick ice during the LGM as long as other areas.

A *Krithe* to *Polycope* shift occurred at ~35-30 ka. This "K-P shift" is a well-documented, Arctic-wide transition (Cronin et al., 2014) that has paleoceanographic significance as well as biostratigraphic utility. *Polycope* is clearly the dominant genus group from sediment dated ~40-12 ka in 32-MC/GC and all sites on the Lomonosov and Mendeleev Ridges (Figs. 4, 5), signifying high productivity likely due to an intermittent, rapidly oscillating sea-ice edge at the surface. *P. caudata* has varying percentages (3-14%) in sediment dated ~40-12 ka, depending on the site. *P. caudata* is an indicator of AI water and Cronin et al. (2014) report that it appears to be ecologically linked to the surface conditions. *Cytheropteron* spp. is present in moderate abundance (20-30%) in sediment dated ~35-15 ka.

Overall, the faunal characteristics from this time period imply relatively restricted and/or poorly ventilated intermediate waters near the 32-MC/GC site. The major exception to this corresponds with the pronounced peaks in *Krithe* and *R. mirabilis*. This significant shift in faunal composition implies changes in ice margins, AW inflow, deep ocean ventilation and/or enhanced deep-water transfer between the Central Arctic Ocean and the North Atlantic.

4.4 The Last Deglacial Interval (~15 to 11 ka)

The major shift from *Polycope*-dominated to *Cytheropteron*-*Krithe*-dominated assemblages occurs in sediment dated 12 ka in 32-MC/GC and ~15-12 ka in other Lomonosov and Mendeleev Ridge cores. In 32-MC/GC, *Krithe* reappears in low (10%) but significant abundance after 11 ka after being absent during MIS 2. Both *Cytheropteron* and *Krithe* are typical faunas in NADW. Although low sedimentation rates prevent precise dating of this shift, it almost certainly began ~14.5 ka at the Bølling-Allerød warming transition. Because the Bering Strait had not opened yet (Jakobsson et al., 2017), this faunal shift must have been related to one or several of the following changes: (1) atmospheric warming; (2) strong Atlantic Water inflow through the Barents Sea; and (3) strong Atlantic Water inflow through the eastern Fram Strait. *A. arcticum* is absent or rare (<2% of the assemblage) in sediment dated ~15-12 ka, suggesting minimal perennial sea ice cover and probably summer sea-ice free conditions during late deglacial warming.

4.5 The Holocene (~11 to Present)

Krithe and *Cytheropteron* remain abundant in sediment dated ~10-7 ka (early Holocene) across most of the central Arctic Basin, signifying continued influence of water derived from the North Atlantic Ocean (Figs. 4, 5). Also during this time, *R. mirabilis* reappears and spikes to an abundance of 55 percent at ~8 ka. *A. arcticum* (which represents the *A. arcticum* zone) increases to >6-8% abundance beginning in sediment dated ~7 ka, and increases to >10% abundance in sediment dated ~3 ka. This increase in abundance is correlated with an increase in perennial-sea ice, and is more prominent in cores from the Lomonosov Ridge than in cores from the Mendeleev Ridge (most likely due to more persistent perennial sea ice cover over the Lomonosov Ridge sites). The inferred middle to late Holocene development of perennial sea ice is consistent with interpretations from other sea-ice proxies (Xiao et al., 2015) and with the transition from an early-middle Holocene “thermal maximum” (Kaufman et al., 2004, 2016) to cooler conditions during the last few thousand years.

4.6 *Rabilimis mirabilis:* New faunal events signifying rapid oceanographic change

In addition to the standard ostracode zones discussed above, the cores from the SWERUS 2014 expedition provide evidence of uncharacteristic and brief, yet significant events of faunal dominance of a taxon. Such events are indicative of rapid environmental change. For example, prior studies have documented range shifts in Arctic benthic foraminifera during the last deglacial and Holocene intervals from the eastern Arctic Ocean (Wollenburg et al., 2001), the Laptev Sea (Taldenkova et al., 2008, 2012), the Beaufort Sea and Amundsen Gulf (Scott et al., 2009) and in older sediments (Polyak et al., 1986, 2004; Ishman et al., 1996; Cronin et al., 2014). The SWERUS-32 data reveal two *Rabilimis mirabilis* “events” -- intervals containing high proportions of this shallow water ostracode species dated at ~45-36 ka and 9-8 ka. The modern circum-Arctic distribution of *R. mirabilis* is confined to shallow (<200 m) water depths (Fig. 6a, b, and c; Hazel, 1970; Neale and Howe, 1975; Taldenkova et al., 2005; Stepanova, 2006; Gemery et al., 2015). *R. mirabilis* can also tolerate a range of salinities, explaining its presence in regions near river mouths with reduced salinity (Fig. 6a). *R. mirabilis* also occurs in 2014 SWERUS-C3 multicore top samples on the Eastern Siberian Sea slope (Supplementary Table S5; cores 23-MC4 (4%, 522 m); 18-MC4 (18%, 349 m); 16-MC4 (11%, 1023 m); 15-MC4 (41%, 501 m) and 14-MC4 (70%, 837 m). These locations correspond to the summer sea-ice edge that has receded during recent decades over the Lomonosov Ridge.

Figures 7a and 7b show the stratigraphic distribution of *R. mirabilis* at the new SWERUS site and other sites on the Lomonosov Ridge (96-12-1PC), the Mendeleev Ridge (P1-94-AR-PC10) and Northwind Ridge (P1-92-AR-PC40) and in longer cores on the Lomonosov and Northwind Ridge. These patterns suggest a depth range extension of *R. mirabilis* into deeper water (700 to 1673 m) during interstadial periods (MIS 5c, 5a, 3). The abundance of *R. mirabilis'* reaches 40-50% of the total assemblage at Lomonosov Ridge site 96-12-1PC at a water depth of 1003 m. Such anomalously high percentages of well-preserved adult and juvenile specimens of *R. mirabilis* indicate that they were not brought to the site through sediment transport from the shelf. Instead, the *R. mirabilis* events represent in-situ populations. Although these *R. mirabilis* events are not synchronous, most occur in sediment dated ~96-71 ka (late MIS 5) and at SWERUS-C3 sites of 32-MC and 32-GC in sediment dated 45-36 ka and ~9-8 ka (early Holocene). Thus the *R. mirabilis* events correlate with interglacial/interstadial periods that experienced summer sea-ice free and/or sea-ice edge environments where there may have been enhanced flux of surface-to-bottom organic matter. However, additional study of cores from Arctic margins will be required to confirm the paleoceanographic significance of *R. mirabilis* migration events.

5. Conclusions

Changes in ostracode assemblages in new cores from the central Arctic Ocean signify major paleoceanographic shifts at orbital and suborbital scales during the last 50 ka. Peaks in dominant ostracode taxa include: (1) *Krithe* zone (~45-35 ka); (2) *Polycope* zone (~40-12 ka); (3) *Cytheropteron-Krithe* zone (~12-7 ka); and (4) *Acetabulastoma arcticum* zone (~7 ka-present). Brief yet significant depth migrations of *R. mirabilis* corresponding with the *Krithe* zone and *Cytheropteron-Krithe* zone imply rapid paleoceanographic changes associated with influx of Atlantic Water and/or deep ocean convection during suborbital events in MIS 3 and the late deglacial to early Holocene. When ostracode assemblage patterns in 32-MC/GC cores are compared to similar records from the Northwind, central Lomonosov, Mendeleev and Gakkel Ridges (Cronin et al., 1995, 2010, Poirier et al., 2012), these changes demonstrate pan-Arctic, nearly synchronous changes in benthic ecosystems in association with rapid sea ice, surface productivity, and oceanographic changes in the Atlantic Water and Arctic Intermediate Water during MIS 3-1 (the last 50 ka). These results confirm the sensitivity of Arctic benthic fauna to large, sometimes abrupt, climate transitions.

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Fig 1. a.) International Bathymetric Chart of the Arctic Ocean showing the location of this study's primary sediment cores on the Lomonosov Ridge (red star: 32-GC2 and 32-MC4), and other core sites discussed in this paper (black circles, white circles). (See Table 1 for supplemental core data.) White circles designate cores that contain *Rabilimis mirabilis* events. Red arrows show generalized circulation patterns of warm Atlantic water in the Arctic Ocean. White arrows indicate the surface flow of the Transpolar Drift, which moves sea ice from the Siberian coast of Russia across the Arctic basin, exiting into the North Atlantic off the east coast of Greenland. Transect line through the map from "1" in the Chukchi Sea to "2" in the Barents Sea shows direction of temperature profile in Fig1b.
b.) Cross section of modern Arctic Ocean temperature profile from showing major water masses. PSW: polar surface water, AL: Atlantic layer, AIW: Arctic intermediate Water, AODW: Arctic Ocean Deep water. Ocean Data View Source: Schlitzer, 2012. Ocean Data View: http//odv.awi.de

Fig. 2 Chronology and stratigraphy of SWERUS-32-GC and 32-MC. Bulk density and magnetic susceptibility profiles for 32GC were previously correlated to the well-dated 96-12-1PC core by Jakobsson et al. (2016). Bulk density primarily reflects changes in grain size, with coarser material having a higher density than finer grained material. The overall position of MIS 5 is supported by the occurrence of *E. huxleyi*. The chronology for the upper 30-35 cm is based on radiocarbon dating in both 32-MC and 32-GC. Beyond the range of radiocarbon dating, an extrapolation to the inferred position of MIS 3/4 boundary (57 ka at 105 cm) is applied.

Fig 3. Relative frequencies (percent abundance) of dominant taxa in SWERUS-C3 32-MC and 32-GC. The y-axis shows the modeled, mean age during a 2-sigma range of uncertainty.

Fig 4. Relative frequencies (percent abundance) of dominant taxa in SWERUS 32-MC (dotted line) compared to other Lomonosov Ridge cores 2185, 2179 and AOS94 28 (Poirier et al., 2012). The chronology for core PS 2185-4 MC (1051 m) is described in Jakobsson et al., 2000, Nørgaard-Pederson et al., 2003, Spielhagen et al., 2004; core PS 2179-3 MC (1228 m) in Nørgaard-Pederson et al., 2003 and Poirier et al., 2012; and core AOS94 28 (PI-94-AR-BC28, 1990 m) in Darby et al., 1997.

Fig 5. Relative frequencies (percent abundance) of dominant taxa in SWERUS 32-MC (dotted line) compared to other Mendeleev Ridge cores AOS94 8 (Poirier et al., 2012), AOS94 12, and HLY6. The chronology for core HLY6 (HLY0503-06JPC, 800 m) is described in Cronin et al., 2013; core AOS94 8 (PI-94-AR-BC8, 1031 m) in Cronin et al., 2010 and Poirier et al., 2012; and core AOS94 12A (PI-94-AR-BC12A, 1683 m) in Cronin et al., 2010.

Fig 6. a.) Occurrence map of *Rabilimis mirabilis* in the Arctic Ocean and surrounding seas based on 1340 modern surface samples in the Arctic Ostracode Database (AOD; Gemery et al., 2015).
b.) Modern depth and c.) latitudinal distribution of *R. mirabilis* based on 1340-modern surface samples in the AOD (Gemery et al., 2015).

Fig 7. a.) Relative frequency (percent abundance) of *R. mirabilis* in SWERUS-32 cores and in central Arctic Ocean cores, 160 ka to present. b.) *R. mirabilis* in core LOMROG07-04 from 260 ka to present and in core P1-92-AR-PC30 from 340 ka to present.

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---REVIEWER COMMENTS

Interactive comment on “Central Arctic Ocean paleoceanography from ~ 50 ka to present, on the basis of ostracode faunal assemblages from SWERUS 2014 expedition” by Laura Gemery et al. Anonymous Referee #3 Received and published: 22 June 2017

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2017-22, 2017.

The paper by Gemery and colleagues represents an interesting study that illustrates how the analysis of ostracod fauna can shed new light on the paleoceanographic changes occurred in the central Arctic Ocean during the Late Quaternary (ca. the last 50 ka). This study can be particularly welcomed by teams involved in the reconstruction of recent past sea-ice conditions and relative strength of Atlantic Water influx to the Arctic Ocean during periods of climate variations. The Authors also put into question the possibility to use peaks in ostracod species (i.e. Rabilimis mirabilis) commonly recorded at shallow water-depths (<200m) as proxy for abrupt changes in paleoceanographic conditions. In my opinion, the most interesting elements of the paper are (i) the potential paleoceanographic significance of R. mirabilis migration events, (ii) the comparison among relatively high-resolution ostracod data from several cores and (iii) the effort to reconstruct a robust chronological framework for the 2 studied cores (32- GC and 32-MC). However, there are some aspects, concerning the interpretation of ostracod data and text organization, that could be improved:

1. I have the impression that the paper, in its present state, doesn’t fully emphasize all the new results derived by the analysis of ostracode fauna (cores 32-GC and 32- MC). In particular, the discussion section (section 5.) only focuses on the distribution of R.

mirabilis, while it should also include the reconstruction of paleoceanographic conditions from ca. 50 ka to present (according to the scope and title of the paper), emphasizing the novelty in respect to previous studies undertaken in the same area (e.g.,higher sampling resolution). On the other hand, results concerning R. mirabilis distribution patterns are poorly described in section 4. Moreover, I suggest to describe in more detail the stratigraphic/temporal patterns of ostracod indicator species from the 2 new cores (section 4.2) and more clearly distinguish data interpretation from the discussion and conclusions, based on the comparision among several cores.

Authors' reply:

We thank the reviewer for this thoughtful and helpful review. Yes, we agree that a restructuring was in order. We find it is more streamlined to present the results of the faunal patterns along with a discussion of their significance so we combined the Results/Discussion section into one and also added a new section (4.6 New faunal events) that presents R. mirabilis migration events and our interpretation.

2. The ostracod zones could be a little bit refined, highlighting the occurrence of a “transitional” ostracod fauna zone, between ca. 42-35 ka, dominated by Polycope spp., but also characterized by remarkable percentages of A. arcticum and Krithe spp.. I think that the ostracod data (Fig. 3) show interesting faunal turnover that could be investigated in depth using a statistical approach. Did the Authors perform multivariate analysis (e.g., DCA) to improve the identification of the main faunal turnover through the core succession/time and the comprehension of the main controlling parameters? Moreover, it could be useful a more detailed explanation of the main turnover in terms of paleoenvironmental conditions: what do the two peaks in P. caudata (between ca. 35-30 ka and 20-12 ka) mean? I also wonder why the percentages of A. arcticum are higher during the mid-late Holocene in respect to the LGM.

Authors' reply:

We followed Poirier et al., 2012 faunal zonation, as these zones are well established throughout the Arctic Ocean and in the SWERUS 32 cores. Yes, statistical analyses have already been done to establish the ecological relationships of the indicator species with environmental conditions (Gemery et al., 2013; Cronin et al., 1994, 1995).

We do not interpret P. caudata, but record its frequency. Cronin et al 2014 report that based on P. caudata's co-occurrence with A. arcticum in modern and downcore samples, the benthic species appears to be ecologically linked to the surface conditions (also Cronin et al 2014, Fig 6).

Percentages of A. arcticum are higher in the mid-late Holocene than the LGM because sea ice during the glacial at this location may have been too thick to allow light penetration under the ice.

3. The Authors state that the R. mirabilis peaks are composed by in-situ populations because of the presence of well-preserved adult and juvanile valves. I agree with the Authors that this is a good autochthonity indicator, however I wonder if there are other data that can support this interpretation and/or other analyses can be performed to exclude the possibility of resedimentation events.

Authors' reply:

We feel confident stating that R.mirabilis events represent in-situ populations because of the number and excellent preservation of the specimens. While there is the possibility of resedimentation, we do not see any signs of the shells being reworked.

4. In Mendeleev Ridge area, the visual inspection of ostracod data seems to show a low degree of correlation among cores. Maybe, it could be useful to compare cores ostracod data (Figs. 4, 5) using statistical methods. How much the ostracod patterns are really similar as stated by the Authors (e.g., in the abstract "Comparisons with faunal records from other cores from the Mendeleev and Lomonosov Ridges suggest generally similar patterns, . . .")?

Authors' reply:

Central Arctic Ocean ostracode faunal patterns documented in publications during the last 20 years (i.e. Cronin et al., 1995) show Cytheropteron spp., Henryhowella asperrima, and Krithe spp. dominate assemblages during the Holocene interglacial period (MIS 1) and interstadial events, while Polycope spp. dominates the glacial period (MIS 2) and stadial events. There are different proportions of these dominant species due to influence of deeper water masses, location, depth of the particular core examined. For example H. asperrima is not found in 32MC/GC but is found in other Lomonsov Ridge cores at deeper depths.

5. The construction of the age-depth model for the 2 new cores deserves a more detailed explaination and discussion. In particular, I'd like to see how ostacod data help to depth align the 2 cores.

Authors' reply:

To correlate cores 32-MC and 32-GC and produce a composite faunal record, we used patterns in ostracode assemblage in both cores, which led to a 3-cm offset for core 32-GC. It was obvious when comparing the initial depth-abundance plots of 32-MC and 32-GC that the faunal patterns would align if we added 3cm to the GC. After adding the 3-cm offset to sample depths of 32-GC, we applied the 32-MC core chronology down to 31.5 cm core depth (dated at 39.6 ka).

Minor comments:

a) Cytheropteron spp. should be added in the abstract along with the other ostracod indicator species.

Authors' reply:

The Cytheropteron genus includes several deep-water species that are difficult to interpret so we are only including this group in a general way.

Generally, the dominance of Krithe and Cytheropteron may signify seasonally open ocean conditions, possibly with deep-water convection as is found in parts of the modern Norwegian-Greenland Seas (Cronin et al., 2013).

b) In the introduction, I suggest to more clearly state the aims of the paper and highlight the novelty of this study in respect to previous works dealing with ostracod fauna from nearby cores.

Authors' reply:

We added a few sentences in to the introduction referring to previous foundational work.

c) An entire sub-section (5.1.) focused on foraminiferal fauna events is a little bit too much for a paper dealing with ostracode fauna.
Authors' reply:
We agree, we removed this section.

d) Paleoenvironmental changes documented by ostacodfauna should be reported in conclusions.
Authors' reply:
We restated the Conclusion section to summarize the general faunal patterns

e) Figure 3: please replace Krithe sp. with Krithe spp.
Authors' reply:
We only found Krithe hunti in the 32MC and GC cores, but in other cores from the central Arctic, Krithe minima was also found. So for this paper, Krithe sp. refers to Krithe hunti.

Interactive comment on "Central Arctic Ocean paleoceanography from _50 ka to present, on the basis of ostracode faunal assemblages from SWERUS 2014 expedition"
by Laura Gemery et al.
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Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2017-22, 2017.

The manuscript by Gemery et al. addresses an important topic, that of the ocean and climate change in the Arctic during the Quaternary. The new data from the SWERUS core 32 add useful information on the stratigraphy of ostracods over the last 40,000 years in the Arctic Ocean. The study core is one of the rare relatively well-dated sequence from the central Arctic Ocean, at least for the last 35 kyr and relatively high sedimentation rates (~1 cm/kyr on average) permit to report the stratigraphical distribution of microfossils with millennial time resolution. The new results from core 32 are very interesting. They are used together with the data from many other cores (most being already published) to present an Arctic Ocean wide synthesis for the last ~40 kyr. This offers a very valuable contribution as announced in the title and summarized in the abstract. In the manuscript, however, other data encompassing longer time scales, ranging up to the 160 kyr or even 340 kyrs, are discussed with reference to occurrence peaks of Rabimilis mirabilis in the ostracode assemblages. Hence, the scope of the paper is not clear. There is a hiatus between the abstract summarizing the new data from the SWERUS core 32 data and the discussion dealing with the longer time scales. In my opinion, the new data unquestionably deserve publication after a few points is clarified. The comparison with other records encompassing the last 40 kyr is very interesting and could be much useful especially if the basin-scale results are discussed in a more comprehensive manner. The synthesis part on the longer time scales, however, seems to be another story, which would require a better presentation/demonstration of the chronostratigraphy (including uncertainties) before to offer a robust scientific contribution.

My recommendation is therefore to revise the manuscript by focusing on the new data and their implication in term of large-scale paleoceanography at the scale of the last 40 kyrs. The manuscript will then offer an original, robust and useful contribution providing that some clarification/modification are made with regard to (a) the chronology and (b) the absolute abundance of ostracodes.

Authors' reply:

We thank the reviewer for these suggestions, and to refocus the scope of the paper to the last ~40ka. The revised copy does this and focuses more on large-scale paleoceanography of the central Arctic Ocean. We reorganized the Results section so that all environmental interpretations are in the Discussion section. Also, in the chronology section we acknowledge that revised age models may be needed in the future.

(a) The age-depth relationship in cores 32MC and 32G was derived from linear interpolation between 14C dates as shown in figure 2. However, other solutions with highly variable sedimentation rates are very likely in the Arctic Ocean context. In particular, no accumulation or extremely low sedimentation rates during the last glacial maximum are recorded at many sites of the central Arctic Ocean (e.g., Norgaard-Pedersen et al. 2003; Polyak 2004; Not & Hillaire-Marcel 2010; Hanslik et al. 2010). Hence, the age of ca. 20 ka in core 32MC can simply result from mixing. The use of a Bayesian approach (e.g., with the Bacon software for depth/age modelling; Blaauw & Christen, 2011) would be appropriate and could help constraining the uncertainties. Another concern comes for the old 14C ages (> 40 ka) that must be considered with caution because of potential biases due to even extremely small contamination (e.g., Hughen 2007), notably through diagenetic processes and carbonate recrystallisation (Sivan et al., 2002; Douka et al., 2010). Thus, the chronology of the lower part of the sequence, older than about 35 kyr, is equivocal because the absolute age as well as the linear interpolation can be questioned. A critical presentation of the age-depth relationships in the other cores from the Lomonosov and Mendeleev ridges (Figures 4 and 5) would be useful to give an information on the time window represented by the samples analyses, to strengthen the regional zonation proposed and to clearly demonstrate the synchroneity or time lags in the records.

Authors' reply:

We agree the dates >40ka need to be approached with caution, and we amended the chronology section to note this concern. We agree that a presentation of the age-depth relationships of the other cores from the Lomonosov and Mendeleev ridges (Figures 4 and 5) would be ideal, and we acknowledge in the amended figure caption that the chronology of these cores may NOT have been derived from a standardized method or with the assumptions used to generate 32MC/GC chronology. Our goal of showing these comparison plots of indicator species' abundance was to emphasize the broadly similar faunal changes that occur from core to core in the central Arctic Ocean.

Also we specified that the reservoir age was not likely constant through time. Chronology beyond 50ka and use of E. huxleyi is presented is based on correlation of sediment properties and dates from other nearby cores. Chronology beyond 50 ka is not relevant to this paper, albeit we still present it as supplementary information for the reader.

(b) The results are presented in term of number of ostracod counted and percentages of main taxa. The concentration or density of ostracode valves per unit of weight (g) or unit of volume (cc) would be very useful to describe the real abundance of ostracod in sediment and to get a picture of the actual fluxes of the key species. Moreover, Rabimilis mirabilis is discussed as an important species, but its downcore distribution is not shown in figures 3-5. It should be added (% and concentration) in the diagrams of these figures.

Authors' reply:

We added the density of ostracodes per gram of sediment to the Appendix, which also lists raw ostracode counts in each sample. The number of ostracode specimens in all 32MC samples exceeded 300, and specimen counts in 32GC ranged from 52 to more than 1000. R. mirabilis' abundance is not plotted in Fig 3 because it is instead presented in Fig.7 along with other cores in which it is found. R. mirabilis' abundance is not plotted in Figs 4 and 5 because it was not present in any of the cores on the Lomonosov Ridge and only in one core on the Mendeleev Ridge (HLY6 in the top 12cm of the core).

Beyond clarification in the presentation of results, some discussion about the actual significance of the ostracodes in the sediment would be helpful, as briefly suggested below.

1. In the interpretative schemes of the result section, the ostracode assemblages are associated with water masses, some of Atlantic origin. Are the ostracodes indicative of actual conditions in bottom waters or to transport with water masses ?

Authors' reply:

Unlike planktic foraminifers that live in the uppermost water column and are free-floating within water masses, most ostracode species are benthic in habitat and their ecology reflects bottom water environmental conditions. We added a sentence in the introduction to clarify this.

2. Acetabulostoma arcticum is associated with multi-year sea-ice cover, which makes it a very important bio-indicator, actually the only one that can be used to assess "positively" on the occurrence of perennial sea ice as far as I know. The fact that it characterizes the postglacial on the Lomonosov Ridge is important, but its low occurrence during the glacial interval is equivocal. Can it relate to low general productivity due to too thick perennial ice? Its low occurrence on the Mendeleev Ridge for most the study interval is also intriguing.

Authors' reply:

A. arcticum characterizes perennial sea ice conditions where light can penetrate through the sea ice and surface-ocean productivity is possible. A. arcticum is not benthic dwelling; it lives parasitically in an amphipod that lives under sea ice.

We clarified this in Table 4: The stratigraphic distribution of *A. arcticum* is used as an indicator of periods when the Arctic Ocean experienced thicker sea-ice conditions but not fully glacial conditions when productivity would have halted. This pelagic ostracode is a parasite on *Gammarus* amphipods that live under sea ice in modern, perennially sea-ice-covered regions in the Arctic (Schornikov, 1970).

3. Rabimilis mirabilis is mentioned as a shallow water taxon. Could it be transported from the shelf (with sea ice for ex.) ? The fact that both adult and juvenial specimens are recovered (lines 361-364) is not a very convincing argument.

Authors' reply:

The preservation quality of the valves and abundance of valves leads to the hypothesis that spikes in R mirabilis signify abrupt environmental changes. The R. mirabilis valves we found in narrow sediment slices were extremely well preserved. It is highly unlikely that a R. mirabilis population would be transported in such numbers and with excellent preservation as the valves that we found in not just one core but multiple cores on the Lomonosov and Mendeleev Ridges. Transported shells are typically partially dissolved, corroded and/or chalky.

4. The zonation from the Lomonosov Ridge seems relatively robust, but Krithe spp. and Pseudocythere caudata show somewhat different records in the study cores. How can the difference be interpreted ? Does the deeper location of core AOS94-28 matter ? Similar, the assemblages from the Mendeleev Ridge show differences notably with regard to Krithe spp. Pseudocythere caudata. Are the differences indicative of a regionalism?

Authors' reply:

Usually we find Polycope is inversely correlated with that of Krithe.Yes, P. caudata's signal could be indicative of regionalism. We include P. caudata because of its fairly robust signal during MIS 3-2 in 32MC/GC. P. caudata appears to be ecologically linked to the surface conditions and generally with A. arcticum and perennial sea ice conditions (per Cronin et al 2014, Fig 6b). The significance of P. caudata could benefit from a DCA or CCA that involves multiple Lomonosov and Mendeleev Ridge cores.

5. High abundance/dominance of Polycope spp. characterizes the pre-Holocene sediment of almost all cores (Figures 3-5). This is interesting as it might indicate uniform water masses from Atlantic origin in intermediate layers of the Arctic Ocean during glacial time.

Authors' reply:

Yes, Polycope spp. demonstrates a strong signal in most of the cores; it's abundance is inversely correlated with that of Krithe; Polycope becomes dominant ~ 30-35 ka during late MIS 3 (Cronin et al., 2014, Fig 8). We followed Poirier et al., 2012 faunal zonation, as these zones are well established throughout the Arctic Ocean and in the SWERUS 32 cores. Broad deglacial-Holocene faunal changes are discussed as interpreted in Poirier et al. (2012) and further in our paper.

Other minor comments:

- The supplementary tables are not easy to read and there are parts missing. Probably there was a problem when saving them as pdf.

Authors' reply:

Yes this will be corrected in final production. The spreadsheets were created in excel and exceed the length of a page when converted to a pdf for the review process.

- The nomenclature of cores in figures 4 and 5 is not exactly the same than in the map of figure 1, which is a little confusing.

Authors' reply: We clarified this in the caption.

- In figure 5, the spacing of data points from core HLY6 is so large that comparison with other cores is not very useful ; Linking the data points between _12 ka and _27 ka for core AOS94 8, and between _ 13 ka and 40 ka for core AOS94 12 is inappropriate.

Authors' reply:

The sampling interval of HLY6 was not as highly resolved compared to the other cores, but is presented because the data are still important in helping to understand the environmental conditions at a millennial scale. We agree about linking data points during a hiatus period or time when a species abundance was zero, so we have removed the long lines linking the data points from 12 to 27ka and 13 to 40ka.

Interactive comment on
“Central Arctic Ocean paleoceanography from ~50 ka to present, on the basis of ostracode faunal assemblages from SWERUS 2014 expedition” by Laura Gemery et al.
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Interactive comment on Clim. Past Discuss., doi:10.5194/cp-2017-22, 2017.

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In the context of global warming and recent Arctic sea ice waning, it is important to understand the natural forcing of past sea ice changes. Here, Gemery and co-authors present a low resolution reconstruction of Central Arctic sea ice changes over the past 50,000 years using ostracode faunal assemblages in two twin cores retrieved in 2014. Although such records are highly necessary, the manuscript suffers from several limitations and flaws that prevent acceptation in its present form. First, the manuscript does not go further than the previous study published by the same group (Cronin et al., 2010) in which conclusions were exactly the same. Central Arctic sea ice was re-constructed in several cores from the Lomonosov Ridge, over the same time period. It was evidenced that “Results suggest intermittently high levels of perennial sea ice in the central Arctic Ocean during Marine Isotope Stage (MIS) 3 (25-45 ka), minimal sea ice during the last deglacial (16-11 ka) and early Holocene thermal maximum (11-5 ka) and increasing sea ice during the mid-to-late Holocene (5-0 ka)”. Similar interpretations are here presented by Gemery and co-atuhors. The only addition to Cronin et al. (2010) is that “sea-ice cover during the last glacial maximum may have been less extensive at the southern Lomonosov Ridge at our core site (~85.15◦N, 152◦E) than farther north and towards Greenland”, which is pretty weak.

Authors’ reply:

This paper addresses the distribution of key species of benthic Ostracoda and uses them as paleoenvironmental proxies to shed light on benthic community responses to changing ice and ocean conditions during the past 50ka. The core location is in a region of the Arctic unstudied for glacial, deglacial and interglacial paleoceanography and as such, fills an important geographic gap in a region that today is undergoing rapid sea ice decay. Many of the results do corroborate the conclusions of prior studies conducted on other Arctic submarine ridges (Cronin et al., 2010, which focused on a sea ice-dwelling species and Poirier et al. 2012). The new SWERUS core provides evidence for large-scale shifts in ostracode species bathymetric and geographical distributions during rapid climatic transitions. Some evidence suggests that the location of this core may not have been covered by thick ice during the lst glacial period as long as other sites, but we are cautious to state this, as additional studies, especially radiocarbon dating, would be ideal to support or reject this.

Second, the manuscript is only descriptive and does not present any forcing mechanisms to explain the observed changes in sea ice cover over the past 50,000 years. Why the MIS 3 did not experience perennial sea ice cover when temperatures where globally lower than during the Late Holocene? What is the link between intermittent perennial and seasonally ice-free conditions during MIS3 and HE/DO? What is the impact of lower sea-level during MIS3 on ocean circulation (less to no North Pacific waters), on sea ice formation (mainly on marginal seas if I am right) and sea ice transport off the Arctic Ocean? The new data should be presented and explained in the context of large scale ocean and atmosphere changes over the past 50,000 years. There are plenty of publications from the GIN Seas and Fram Strait to document NADW inflow (marked here by Krithe spp. and Cytheropteron spp.) and AW outflow (marked here by Polycope spp. and P. caudata). There is also a wealth of publications from continental peri-Arctic to document atmospheric patterns and their impact on central Arctic sea ice. As such, the very attractive title is misleading.

Authors' reply:

The reviewer poses excellent questions about what atmospheric and oceanic forcings and feedbacks are at play causing sea ice changes. We have added some explanations about the large-scale forcings affecting/controlling/linking oceanographic changes from published literature but a more thorough discussion is beyond the scope of this paper. The regional variability of changes in the sea-ice regime, especially during rapid climatic events, is not yet well understood due to the low sedimentation rates in the central Arctic (1-2 mm/ka). Our study focused on A. arcticum as an indicator for the expansion/contraction of sea ice; other proxies might also be applied to this region (ie, dinoflagellates, IP25).

Third, results are discussed in "climatic phases" that are not congruent with the ostracode faunal changes. It is more sensible to discuss changes in the four "ostracode zones". I however do not fully agree on the four zones. Based on faunal changes more periods can be discussed: The K zone, a first increase in A. arcticum between 42-35 kyrs BPP, a P. caudata peak between 35-27 kyrs BP, a second increase of A. arcticum between 25-20 kyrs BP, a second P. caudata peak between 20-12 kyrs BP, the C zone and the A zone.

Line 266-271: The shift between Polycope spp. and the Krithe-Cytheropteron group is at 12 kyrs BP not 14.5 kyrs BP. And the Krithe gp is less than 10%. Is this small increase significant? Over the deglaciation I see the following sequence: P. caudata (20-12 kyrs BP); Cytheropteron (12-9 kyrs BP); Krithe (10-7 kyrs BP). This is not really discussed.

Line 280: Krithe spp. are less than 10%. This is not what I call abundant.

Authors' reply:

We followed Poirier et al., 2012 faunal zonation, as these zones are well established throughout the Arctic Ocean and in the SWERUS 32 cores. Broad deglacial-Holocene faunal changes are discussed an interpreted in Poirier et al. (2012) and further in our paper.

There is no information on why there are so much difference in ostracode abundances and species numbers between the twin cores.

Authors' reply:

The dominant species' faunal trends in 32MC and 32GC are very similar. The difference in ostracode numbers between the two cores is due to getting the larger sediment sample sizes for the multicore and sampling it every centimeter. For the gravity core, we sampled every 2 or 3 cm but within that interval we sampled usually a smaller amount from half the width from the already halved archive half.

This difference is commonplace when splicing together records from two types of cores from the same location. It is preferred as piston and gravity coring often does not recover the uppermost sediments, which in the Arctic can pose a huge problem due to low sed. rates. Hence, one augments the gravity core with a multicore. The sampling strategy is described in the Methods section.

Fourth, the “Results” part present description of results mingled with some environmental interpretations. And the “Discussion” part does not present any environmental interpretations nor forcing mechanisms. The structure should be modified accordingly. Lines 307-325: Useless in the paper. Authors should stick to paleoceanographic re-constructions and interpretations.

Authors’ reply:

We thank the reviewer for pointing this out and we modified the Results section by instead putting all environmental interpretations in the Discussion section.

We agree, lines 307-325 are tangential, but are relevant to discussion of microfaunal species indicators of ecosystem regime change.

Fifth, the paper oscillates between presenting new sea ice reconstructions (but no explanation of such changes) and validation of R. mirabilis to infer past sea ice changes. I would say that these are two different topics and should perhaps be presented in two different papers.

Authors’ reply:

R. mirabilis’ stratigraphic appearance in intermediate depth cores is an important finding; they are distinct microfaunal migrational events in which a species that lives on today’s continental shelf is found in intervals in sediment cores that is far outside its usual depth and geographic range. For example, R. mirabilis migrations are found not only in 32MC/GC but in other cores (Fig. 7) presented in this paper. In addition to their paleoceanographic and ecological significance, rapid faunal migrations and limited stratigraphic ranges make these potentially useful stratigraphic markers for correlating cores from across the Arctic Ocean.

Additionally, records of R. mirabilis should be described in the “Results” part. They here appear out of the blue at the very end of paper. Lines 328-330: Ostracode species mentioned here are not presented in the results. There is no way to compare and assess what is written. Although it is difficult to assess here because the records are presented in different plots, it seems to me that R. mirabilis record in the twin cores are similar to the Krithe spp. record with peaks centered at 42-44 kyrs BP and 10-5 ka BP. This contradicts lines 328-333 where authors state that R. mirabilis modern distribution mimics B aculeata’s one. This should be expanded. Why these two species share a similar modern distribution (linked to perennial sea ice) while presenting different down-core records whereby B. aculeata is still linked to perennial sea ice while R. mirabilis goes together with species tracking less sea ice and NADW influx into central Arctic?

Authors’ reply:

The reviewer makes excellent points and we have reorganized the Results section and removed comparisons with foraminifera such as B. aculeata.

Sixth, the “Chronology” part is not totally clear to me. Data used to estimate the mentioned 3cm offset between the MC and GC cores are not presented. The tuning below 31.5 cm is not presented. It seems that there is only one point with E. huxleyi to infer the MIS5. I strongly doubt that the mean reservoir age was constant through time. It should be acknowledges even though this may not have a big impact on the results/interpretations here due to low temporal resolution.

Authors' reply:

We have clarified these points in the text and specified that the reservoir age was not likely constant through time. We used the dominant ostracode patterns to align the MC and GC and thereby determine the 3cm offset. Chronology beyond 50ka and use of E. huxleyi is presented is based on correlation of sediment properties and dates from other nearby cores. Chronology beyond 50 ka is not relevant to this paper, albeit we still present it as supplementary information for the reader.

Seventh, the "Introduction" is very weak. The scientific issue is not very well presented (only in first and last paragraph). There is not state-of-the art. I suggest to much better highlight the difference to Cronin et al. (2010).

Authors' reply:

We thank the reviewer for the suggestion to fortify the Introduction. We have added and revised this section accordingly.