

Author's response to Dr. G. Cortese

We are grateful to your comments and useful suggestions that improved our manuscript greatly. As described below, we have revised our manuscript. Please note that the expression in **blue colored letters** are the ones provided by you whereas those in black are our replies.

Specific comments:

Page 16647, line 12-15

This means it was not dominant only during the full sea ice season. Probably this is also the reason why the environmental conditions you associate this species with are very confusing/not clear...

“*Amphimelissa setosa* was dominant during the open water and the beginning and the end of ice cover seasons with well-grown ice algae, ice fauna and with alternation of stable water masses and deep vertical mixing.”

**was changed to**

“*Amphimelissa setosa* was dominant during the season with open water as well as at the beginning and at the end of the seasons with sea ice cover. Ice algae and fauna have good ecological conditions with a rapid growth during these periods due to alternation of the stable water masses which also causes deep vertical mixing.”

Page 16647, line 17-19

It is not clear at all how this relates to productivity/species diversity in radiolarians...

We revised the text as follows:

“greater, which might be associated with the seasonal increase of solar radiation that induce the growth of algae on the ice and the other phytoplankton species under the sea-ice.”

**was changed to**

“greater. This might be associated with the seasonal increase of solar radiation stimulating the growth of algae on the ice and other phytoplankton species under the sea-ice, upon which the radiolarians can feed on.”

Page 16647, line 19-21

This is a very general statement, as it does not explain in detail how sea-ice impacts radiolarians (if you think that the discussion on *A. setosa* vs. *Actinommidae* is that explanation, well, you do not need last period then)... and in a way one would expect it

to be so, as the presence and extent of sea ice have a very strong impact on various environmental variables and processes that will, eventually, have an impact on any plankton group.

“These indicated that the dynamics of sea-ice was a major factor affecting the productivity, distribution, and composition of radiolarian fauna.”

**was changed to**

“This evidence suggests that the dynamics of sea-ice are a major factor affecting the general biological productivity, distribution, and composition as demonstrated in the radiolarian fauna.”

Page 16648, line 2

Specify which water mass or, at the very least, replace this with "North Pacific".

We accepted your suggestion and replaced “pacific” with “North Pacific”.

Page 16648, line 6-7

Why? How?

Possibilities: enhance (with melting injecting nutrients in the surface ocean, thus promoting blooms/export) and reduce (as the lack of ice cover favours outgassing)

And: whatever Nishino's argument is on the circulation itself (see next comment)...

It would probably be better to split this part in a few sentences, otherwise it becomes too long and complex.

Thanks for your comment.

We explained in the next comment.

Page 16648, line 13-14

You however do not explain why....

Is this exclusively by the fact that the circulation pattern generates downwelling of surface waters within the gyre?

We revised the text as follows:

“The efficiency of the biological pump is reduced within the Beaufort Gyre, and conversely, it is enhanced outside the Beaufort Gyre (Nishino et al., 2011).”

**was changed to**

“Melting of sea ice reduce the efficiency of the biological pump within the Beaufort Gyre because of deepening of the nutricline caused by freshwater accumulation within the gyre (Nishino et al., 2011). Conversely, the efficiency of the biological pump is enhanced outside the gyre because of nutrient supply from shelves and improved light

penetration (Nishino et al., 2011).”

Page 16649, line 2

What do you mean by this word?

We replaced “regime” with “conditions”

Page 16649, line 28-29

mentioned already, remove.

Replace with: "...Ocean, and discuss..."

According to your comment.

We replaced “Ocean based on plankton tow samples and sediment trap material, respectively. We discuss.” with “Ocean, and discuss”.

Page 16650, line 10

I am not quite sure "psu" is used anymore, I think salinity is now dimensionless, but please check with a physical oceanographer

Thanks for your comment. We removed “psu” throughout the text.

Page 16650, line 26

We replaced “Atlantic Water (AW), Canada Basin Deep Water (CBDW)” with “Atlantic Water (AW) and Canada Basin Deep Water (CBDW)”.

Page 16651, line 1

either "which are" (if this refers to the surface waters), or "and is" if it refers to the deeper water mass.

We here refer to the deeper water and as you suggested, we replaced “which is” with “and is”.

Page 16651, line 14

You are already saying "simultaneously", so what you mean is obvious.

According to your suggestion, we replaced “from a CTD observation with the plankton sampling” with “from a CTD cast”

Page 16654, line 17

We replaced “ $H = -P_i \log_2 P_i$ ” with “ $H = -\sum P_i \log_2 P_i$ ”.

Page 16654, line 18

What do you mean by this?

We meant the contribution of species as relative abundance in total radiolarian.

Page 16654, line 18

Add a sentence explaining why the traps were lowered, example:

"This was done in order to..."

The traps were lowered for some reason unintentionally.

We revised the text as follows:

“Moored trap depth for the upper trap was lowered by about 80 m during the second year (about 260 m depth) than during the first year (about 180 m depth). Especially, during July-August in 2012, the moored trap depth was lowered to about 300 m (Fig. S1).”

**was changed to**

“Moored trap depth for the upper trap was lowered by about 80 m during the second year (about 260 m depth) than during the first year (about 180 m depth), caused by entanglement of the mooring ropes. During July-August in 2012, the moored trap depth was lowered to about 300 m, because of intensified water currents (Fig. S1).”

Page 16655, line 1

This is a bit too detailed, and could go to the legend of some of your tables.

I suspect the renaming suggestion does not have a taxonomic value, as you do not re-describe it anyway here.

We disagree in this judgement as this species is repeatedly being referred to as a species with a sagittal ring belonging to the family Spyridae. There is no sagittal ring and therefore this is not a Spyridae. The problem is in which nassellarian family to put this species? We have concluded to assign this species to the family Plagiacanthidae, and that it should be referred to as *Tripodiscium gephyristes*. As the species is not redescribed and therefore does not have a taxonomic value is correct, but never the less it do show that it is no Spyridae. We do not claim any authorship for this renaming, just making the point that it is no Spyridae.

We consider this taxonomic note important and it should be exposed in our text, not hidden as a subtitle in table legend.

Page 16655, line 8

We added the following text to the end of the text on line 8:

“until a proper taxonomic analysis has been undertaken”.

Page 16655, line 14

either "Radiolaria" or "radiolarians"

We use “radiolarians”.

Page 16656, line

We replaced “are juvenile forms of” with “are mostly two-shelled juvenile forms of”.

Page 16656, line 14

We replaced “Adult” with “adult”.

Page 16656, line 25

I am not quite sure you can call that common.... maybe use "present"/"rare".

I did not fix it earlier on in this page because your statements were about several species, and some of them had abundances around 6%, so while that is not really common, it sort of makes sense.

Thank you for your comment.

We replaced “Station 32 (0.4%) but common at Station 56 (1.4%)” with “Station 32 (0.4%) but with a slight increase at Station 56 (1.4%)”.

Page 16659, line 3

As this paper is about a lot of things: when? Or are you citing a general issue/observation (in which case you may want to rephrase to something like: "While it is generally assumed that...") ?

On a separate note: this is all good, but (due to their generally higher abundances/fluxes) it applies a lot more to diatoms than radiolarians.

Thanks for your comment.

We revised the text as follows:

“Biogenic particle flux into the deep sea in the Canada Basin was low”

**was changed to**

“Biogenic particle flux into the deep sea in the Canada Basin was generally assumed to be low”

Page 16659, line 9-13

As mentioned above, it would be good to actually say how does the diatom flux

compared to radiolarians, just to get an idea of their relative importance in this environment.

“The biogenic opal collected in this study mainly consisted of radiolarians and diatoms, therefore siliceous skeletons of radiolarians and diatoms might play important role to export biogenic silica to the deep Arctic. Relatively high flux of radiolarians in arctic microplankton might contribute to substantial part of the POC flux.”

**was changed to**

“The biogenic opal collected in this study mainly consisted of radiolarians and diatoms in microscopic observation. Other siliceous skeletons (silicoflagellate skeletons, siliceous endoskeleton of dinoflagellate genus *Actiniscus*, chrysophyte cysts, ebridian flagellate, and palmales) are minor in the same trap samples (Onodera et al., 2014), therefore siliceous skeletons of radiolarians and diatoms might play an important role to export biogenic silica to the deep Arctic. Onodera et al. (2014) also estimated the diatom contribution to POC flux at station NAP, but more than half of the contribution to total POC has not been explained yet. Relatively high flux of radiolarians in arctic microplankton might contribute to a substantial part of the POC flux.”

We added the following reference:

“Onodera, J., Watanabe, E., Harada, N., and Honda, M. C.: Diatom flux reflects water-mass conditions on the southern Northwind Abyssal Plain, Arctic Ocean, Biogeosciences Discuss., 11, 15215-15250, doi:10.5194/bgd-11-15215-2014, 2014.”

Page 16659, line 16-18

If you put it this way, one always thinks about the question: "When?".

How about: "The radiolarian fauna observed in this study of the western Arctic Ocean was found to have a close affinity..."

According to your suggestion, we replaced as follows:

“Radiolarian fauna in the western Arctic Ocean had”

**was changed to**

“The radiolarian fauna observed in this study of the western Arctic Ocean was found to have”

Page 16660, line 8

Or: "... suggested the possibility of endemism for..."

We accepted your suggestion, and revised lines 7-13 as follows:

“Kruglikova et al. (2009) described two new species *Actinomma georgii*

and *A. turidae*, and suggested the possibility of endemism for these two species.---They also indicated a fifth group *Actinomma* indet. (their fig. 5, p. 32) which consists of several species.---Their argument was that the endemism arose as radiolarians had been rapidly evolving under the stressful conditions in the Arctic Ocean, and that speciation within the family Actinommidae might be ongoing in the central Arctic Basin. Our results support this hypothesis, and suggest that local speciation took place not only in the central Arctic basin, but also in the western Arctic Ocean.”

Page 16660, line 13

I am not quite sure this is proof of that, given the paucity of recent work in the Arctic Ocean. It essentially is a measure of Bjorklund's and Kruglikova's taxonomic interest... and it refers to VERY few new species.

We replaced “This is demonstrated by the occurrence” with “In addition we have an occurrence”.

Page 16660, line 14

We replaced “Actinomma” with “*Actinomma*”.

Page 16661, line 6-7

A mention of the Bjorklund et al., 1998 MarMicro paper would also be good for your argument, as *A. setosa* was found with similar percentages (in surface sediments) on the Voering Plateau (NE of Iceland, within Arctic surface water).

We added the following text to the end of the text on line 7:

“Bjørklund et al. (1998) reported its distribution in the western part of the GIN Seas, being dominant (up to 76%) at the Iceland Plateau and common (>20%) just north of the Iceland–Faeroe Ridge. In the eastern part of the Barents Sea, west of Novaja Zemlya, Bjørklund and Kruglikova (2003) reported *Amphimelissa setosa* as the dominant (77%) species.”

Page 16661, line 18

That's a very thin logical link. In the absence of information specifically on these species (or at the very least the genus), I would delete this as too hypothetical.

We think this text can be as it is, but it is correct as you say, we do not have any evidence to say this, but it is a possibility.

Page 16661, line 24

You cannot use "also" if you just said that it is a surface dweller...

Thank you for your comment.

We deleted "also".

Page 16663, line 1-3

That's very slim evidence... that would translate to ca. 0.5 degree over last century or so. Do you really think that half a degree affects the distribution of a species that much? I would tend to rather believe that the studies from the 50s/60s simply did not pick it up, so there is more a sampling bias than a "warming trend" observation.

Thanks for your comment.

We replaced Page 16662, line 21-22 as follows:

"This species has not been observed in the Canada Basin during the 1950s and 1960s (Hülseman 1963, Tibbs 1967)."

**was changed to**

"This species has not been observed in the Canada Basin during the 1950s and 1960s (Hülseman 1963, Tibbs 1967), but this can probably also be interpreted as a result of their sample quality and they therefore did not observe this species, compared with our modern samples of good quality."

We added the following text to the end of the text on line 3 in page 16663:

"It is not so much the effect of the temperature itself that is causing the expanding distribution of *C. hystricosus*, but the general temperature increase indicates that larger volumes of warmer AW is entering the Arctic Ocean. The increasing volumes of inflowing AW will therefore increase the chances for more exotic radiolarians to reach the western parts of the Arctic Ocean."

Page 16663, line 5-6

This is the other aspect that plays a big role in these findings: mesoscale dynamics (i.e., warm-core eddies). If a certain water mass/sediment trap study is "lucky" to happen to sample waters at exactly a location/time affected by the passage of a few of them, then suddenly a lot of these warm water species are picked up and reported.

While it is a viable mechanism (and probably a right interpretation in terms of a warming Arctic... in terms of higher frequency of warm-core eddies being shedded northwards and making it into the Arctic), it still contains a big sampling bias.

In this case surface sediments would help a lot to assess the long-term trends (and the significance and relative abundance of such faunas), as even the topmost cm or so



would integrate decades/centuries.

If anything, they may risk to integrate too long a time period, sort of "diluting" the recent signal/trends (if any).

Any place in the Arctic with a sediment drift allowing sub-centennial resolution in the topmost few centimeters? Probably such a sedimentary archive does not exist...

The pulsating inflow of warm water is important, and as you mentioned above, these events also happened in the past is difficult to prove as there is no sediment cores that can pick up these signals that only have a very limited distribution in time. Areas with such high sedimentation rate probably do not exist!

We regard this as a discussion between you and us and should not be commented on in our text.

Page 16664, line 10

distribution? abundances?

Thanks for your comment.

We added "distribution".

Page 16664, line 11

Is the Iceland Sea a marginal sea?!?!?!?

The Iceland Sea is according to my understanding partly covered with winter ice and the East Greenland Current (water from the Arctic Ocean) is passing on its western side. We regard this sea as a marginal sea to the Arctic Ocean. We still want to say YES, it is a marginal sea.

Page 16666, line 2

Do you really mean "under" here or "lower"?

Thanks for your comment. We really mean "lower".

Page 16667, line 1

You do not elaborate much at all about the biological pump, so why mention it at different places in the text?!?!?!?

I can see how it belongs in the next section, when you start talking about Watanabe's mesoscale-resolving ocean modelling, but till this point in the text, its association to radiolarians is very vague...

Thanks for your comment. We mention the biological pump in the next chapter.

We replaced “biological pump system” with “ecological conditions”.

Page 16667, line 18

disturbance? passage?

Thanks for your comment.

We added “passage” to the text.

Page 16668, line 10

availability of?

This is a rather vague statement, without other data/discussion to back it up.

Thanks for your comment.

We replace “reflect the food supply” with “reflect the availability of food supply”.

Page 16668, line 10-11

You just mentioned this exact group of species as spread between "wide vertical distribution" and "intermediate to deep", and all of a sudden they become "deep"

We revised the text as follows:

“Flux of deep water dwellers (*Pseudodictyophimus g. gracilipes*, *P. plathycephalus*, Plagiacanthidae gen. et sp. indet., *Cycladophora davisiana*)”

**was changed to**

“The flux of *Pseudodictyophimus g. gracilipes*, *P. plathycephalus*, Plagiacanthidae gen. et sp. in det. and *Cycladophora davisiana*”

Page 16668, line 13-15

I will mention this here, but similar examples occur at other spots in the text (essentially ALL your conclusions/hypotheses trying to link radiolarian abundances/flux and feeding habits):

I do realise that you use mitigating words as "maybe", "probably", "suggest", etc, but these hypotheses are not based on anything factual, not a shred of data, and remain highly controversial.

Just because a few deep-living radiolarian species increase in abundance, it does not necessarily mean that organic matter export to depth increases (and so on, and so on). It's just a conjecture, maybe not even an hypothesis.

If you had measurements of organic matter at various levels in the water column, and through time, and you would see some correlation to species abundance, you might have been able to formulate such an hypothesis.

Even then, as you surely know, correlation is not causality, and such a coincidence between organic matter and species data would not prove the hypothesis.

Thanks for your comments.

We revised the text as follows:

“This probably indicates that decomposing material from the primary production during the sea-ice free season was transported to great depths, giving nutrition to the deep water radiolarian fauna.”

**was changed to**

“This probably indicates that decomposing material from the primary production during the sea-ice free season was transported to great depths and might also act as a substrate for bacterial growth, providing the deep water radiolarians with sufficient food elements. We have no data to support this but in the Chukchi Sea, moderately high rates of bacterial production at the end of the growing season (July-August) have been found (Cota et al., 1996, Wheeler et al., 1996, Rich et al., 1997).”

and added three references as follows:

Cota, G. F., Pomeroy, L. R., Harrison, W. G., Jones, E. P., Peters, F., Sheldon Jr, W. M., and Weingartner, T. R.: Nutrients, primary production and microbial heterotrophy in the southeastern Chukchi Sea: Arctic summer nutrient depletion and heterotrophy, Mar. Ecol. Prog. Ser., 135, 247-258, 1996.

Rich, J., Gosselin, M., Sherr, E., Sherr, B., & Kirchman, D. L.: High bacterial production, uptake and concentrations of dissolved organic matter in the Central Arctic Ocean, Deep-Sea Res. Pt. II, 44, 1645-1663, 1997.

Wheeler, P. A., Gosselin, M., Sherr, E., Thibault, D., Kirchman, D. L., Benner, R., Whitledge T. E.: Active cycling of organic carbon in the central Arctic Ocean, Nature, 380, 697-699, 1996.

Page 16668, line 18-19

[I don't understand what you mean here](#)

We revised the text as follows:

“In addition, the flux peak during March in 2011 was made up of more than 80% of *A. setosa*, which were surface water species although the peaks around the same period were not found in the upper trap. Therefore, the flux peaks during March in 2011 would be derived from some lateral advection at a depth lower than 180 m or a re-suspension

of shelf bottom materials into the upper water column.”

**was changed to**

“In addition, in the lower trap the flux peak during March in 2011 was made up of more than 80% of *A. setosa*, a definite surface water species. However, during this period a similar peak was not found in the upper trap. Therefore, the flux peaks during March 2011 could be derived from some lateral advection at a depth lower than 180m or a re-suspension of shelf sediments.”

Page 16669, line 3

We inserted the text below.

We similarly thankful to G. Cortese for his detailed comments and correcting our English, this greatly improved our manuscript.

Page 16691, Figure 8

Maybe include references (and location) for each of the other studies?

Example: AB (xxxx Sea, Xxxx et al., 2012), SA (xxxx Sea, Xxxx et al., 2013), etc

We revised the text as follows:

“Fig. 8. Box plot of total radiolarian fluxes at Station NAP and previous studied areas in the North Pacific Ocean.”

**was changed to**

“Fig. 8. Box plot of total radiolarian fluxes at Station NAP and previous studied areas in the North Pacific Ocean (Okazaki et al., 2003, 2005; Ikenoue et al., 2010, 2012a). Summary information of previous sediment trap studies in the North Pacific Ocean is shown in table S5.”

Page 16681, Table 3

We replaced “*Tripodiscium gephyristes*, Hülsemann (1963)” with “*Tripodiscium (Tholospyrus) gephyristes*, Hülsemann (1963)”. It will be of great help for the reader.

Technical corrections:

Thanks for your suggestions.

We accepted all technical corrections from you.