

***Interactive comment on* “The significance of nitrogen fixation to new production during early summer in the Baltic Sea” by U. Ohlendieck et al.**

U. Ohlendieck et al.

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We greatly appreciate the comments made by L. Stal.

Answers to his comments:

3) excerpt:

“The data confirm earlier reports on N₂ fixation except that these authors reach considerable higher estimates of new N over the period that they have measured than previous estimates by others. However, this does not necessarily mean that the older reports have underestimated N₂ fixation. There is still very little knowledge about the year-to-year variation of N₂ fixation and the authors may have picked years with exceptional high rates of N₂ fixation.”

ANSWER – N₂ fixation from the early stage of a bloom must not be neglected. Our

study of the early stage of a cyanobacteria bloom shows that up to 26% of N_2 fixation can be added to calculations of new N established in previous studies (where only the later stages of a bloom was considered). Our study clearly shows the wide discrepancy in the integrated rates of both primary production and N_2 fixation during the early summers of 1998 and 1999. Specifically, we found that the station-to-station variability in calculated rates of N_2 fixation ranged by a factor of 8 (1998) and 9 (1999). Due to the wide discrepancy in rates of N_2 fixation found in this study, it is also possible that earlier (and lower) estimates may be a function of regional under-sampling. Therefore, earlier studies may have based their calculations on a limited number of stations and wrongly assumed regional homogeneity in their measured rates of N_2 fixation in the Baltic Sea. Due to this possible artefact, we deliberately did not make any close comparisons with previous estimates from early summer in the Baltic Sea. Based on our basin-wide sampling approach towards a median estimate, we believe the inter-annual variability in N_2 fixation found in this study (median factor of 2) is more accurate than estimates from earlier studies.

3) excerpt:

“The authors could not confirm the claim of Wasmund et al. (2001) that non-heterocystous, putative picocyanobacteria fix N_2 .”

ANSWER – Wasmund et al. (2001) did not specifically talk about pico-cyanobacteria, but used the term “cocoid non-heterocystous” for diazotrophs other than filamentous cyanobacteria. We were able to show that cells $<20 \mu\text{m}$ were able to fix N in daytime incubations (Table 2 shows 1–10% of the total rate of N_2 fixation). This estimate may be higher if we assume (as Wasmund et al. 2001 showed) that non-heterocystous, non-filamentous rates of N_2 fixation are higher at night. We also found that enrichment of ^{15}N in cells $<5 \mu\text{m}$ appeared only when filamentous cyanobacteria were present. This accumulation appeared as a function of the measured rate of total N_2 fixation (Figure 5) and may suggest a tight coupling between filamentous diazotrophy and re-generated incorporation of dissolved organic N by cells $<5 \mu\text{m}$. Since single cells of

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pico-cyanobacteria are smaller than 5 μm and we did not detect any N_2 fixation in cells $<5 \mu\text{m}$, we concluded that these cells were not contributing significantly towards new production in the Baltic Sea in early summer. In our study however, we found that cells $<20 \mu\text{m}$ collected on 5 μm screens and without the presence of filamentous cyanobacteria, showed detectable rates of N_2 fixation (Table 2). This size fraction of diazotrophs (5–20 μm) may include nano-sized single cell cyanobacteria, as well as *Pseudoanabaena* sp. and aggregations of pico-cyanobacteria.

6) Reference to Meyerhöfer 1994

ANSWER – All necessary information about the HPLC method is already included in the text. The reference to Meyerhöfer 1994 is redundant and was left in the text by accident. Please delete the reference in the text (page 1286 line 23) and in the reference list. Additionally please add “during the two cruises” to the last sentence of this chapter (page 1286 line 23) for more clarity. Thank you for pointing this out.

14) Use of the Redfield et al. (1963) reference:

ANSWER – Please insert this reference at the end of sentence on lines 5–7 (page 1291)

14) Page 1292 and the Konopka et al. (1985) reference:

ANSWER – Please change this reference to Konopka et al. (1987) as it is used in the reference list.

Minor editorial points

ABSTRACT – line 16:

Exchange ‘suggest’ to ‘suppose’

ANSWER – Suggested change is altering what we intend to say and we do not agree with the reformulation of this particular sentence.

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RESULTS – lines 18–20:

‘...unclear to me what was done here...’

ANSWER – Starting on line 15 (page 1288) the paragraph should read (changes in bold face):

Total Chl *a* as a function of depth did not show any pronounced inter-annual differences (Fig. 4A). Integrated rates of total N₂ fixation were a fraction of 0.71 lower at night than in daytime at the drift station (Tab. 1). The daytime rates of N₂ fixation (**NF_{DAY}**) measured on all transect stations in both years, were factor corrected for the night-time activity (**NF_{DAY}+NF_{DAY}*0.71**) to yield daily rates (Fig. 4B).

RESULTS – line 22 (page 1288):

Change to: ‘...very low rates or no N₂ fixation...’

ANSWER – We agree

RESULTS – line 24 (page 1288):

What do you mean by integrated median rates?

ANSWER – The ‘integrated median rate’ is essentially the geometric average calculated using all the transect stations during each of the cruises (as stipulated in Figure 4 legends). This has been reformulated to improve clarity and, beginning on line 24, the last part of this paragraph should read as follows:

The median average of the depth-integrated rates of total N₂ fixation (0–14 m) from each transect were 0.5 mmol N m⁻²d⁻¹ in 1998 (range 0.1–0.8) and 1.0 mmol N m⁻²d⁻¹ in 1999 (range 0.3–2.7). The median average of the depth-integrated rates of total primary production from each transect were 32.3 mmol C m⁻²d⁻¹ in 1998 (range 20.4–40.9) and 57.9 mmol C m⁻²d⁻¹ in 1999 (range 25.9–85.2).

RESULTS – line 8 (page 1289):

What do you mean by '...of the total rate...?'

ANSWER – We are alluding to the total rate of N₂ fixation. Sentence starting on line 8 has been rewritten to avoid confusion in this matter:

The fraction of diazotrophy in cells >20 μm ranged between 0.92–0.88 of the total rate of N₂ fixation in surface waters in 1998, and was 0.48 of the total at 14 m depth (Tab. 3).

DISCUSSION – lines 10–15 (page 1294):

'...consider aggregations of cyanobacteria...'

ANSWER – We agree that aggregations of pico-sized single cell cyanobacteria cannot be ruled at this stage. Sentence on line 13 has been rewritten to reflect this issue:

Since we did not detect any significant rates of N₂ fixation in cells <5 μm in our daylight incubations, we conclude that cells between 5–20 μm (or aggregations of smaller sized single cell cyanobacteria) in the Baltic Sea in early summer may at times use N₂ fixation to support their nutrient requirements.

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