

Interactive comment on “Spring phytoplankton communities of the Labrador Sea (2005–2014): pigment signatures, photophysiology and elemental ratios” by Glauca M. Fragoso et al.

Glauca M. Fragoso et al.

glauca.fragoso@noc.soton.ac.uk

Received and published: 10 October 2016

We thank the reviewer for his comments and suggestions, which we feel have greatly improved the manuscript. Below we respond to each comment in detail. RC refers to “Reviewer’s Comments” and AC to “Author’s comments”. We have enumerated the reviewer’s comments to organise better our responses.

Reviewer #2, Simon Wright:

RC2.1 - GENERAL COMMENTS:

This paper provides a decadal assessment of phytoplankton communities of the Labrador Sea using pigment markers and CHEMTAX analysis, as well as environ-

C1

mental parameters (T, S, nutrients, MLD, etc) and photosynthetic parameters. A single transect was sampled during each late spring – early summer for 10 years with high geographic resolution. The comprehensive suite of measurements makes this a valuable data set that should provide a useful reference for future cruises. I believe it is appropriate for Biogeosciences.

The analyses appear to have been competently performed and I have no worries about the data. Although the text itself is generally well written, at the broader level the manuscript itself unfortunately has two serious problems. First, it is not well structured – in particular, it lacks a clear Aim.

AC2.1 - The aim of the work has now been reinforced in the last paragraph of the Introduction. Please see the new version of the introduction attached as a pdf.

RC2.2 - Secondly, and perhaps as a consequence, the authors have attempted to cover too much data in a single publication. They describe the entire data set rather than derive a clear story from it. As a result, key parts of the story are insufficiently described despite a huge volume of complex text, and the overall story is confusing. Three subplots are introduced (Accessory pigment:Chl_a ratios, POC:PON ratios, and photosynthetic parameters) that add little to (what I consider to be) the main story but add considerable verbiage and unnecessary confusion. There is possibly sufficient data here for a thesis, in which each of these subplots would warrant a separate chapter. Here they would be better relegated to separate publications, possibly followed by a review paper that integrates this study with previous work in the region. Due to lack of a coherent focus, the data and discussion are not well integrated.

AC2.2 - We have now reaffirmed the aim of the paper which is to compare the biogeochemical and photophysiological properties of phytoplankton communities from contrasting biogeographical regions in the Labrador Sea and to create a baseline of these trends which could be compared with in the future. Although we agree with the reviewer that this manuscript covers a lot of information, we feel that the results from

C2

sections 3.4 and 3.5 are directly linked to the information on phytoplankton groups and that writing a different paper about POC:PON ratios and photochemical aspects on its own becomes largely irrelevant. We hope the reviewer can appreciate our focus and restated aim and view our responses in light of these.

RC2.3 -Despite these problems, this is a very useful study that should be published, but the manuscript requires substantial revision.

STRUCTURAL COMMENTS: Introduction: This paper desperately needs a clear Aim to provide a basis for a narrative, to dictate what is included in (or excluded from) the paper, to provide a focus for the Results, Discussion and Conclusions, and by which to judge the success of the project.

AC2.3 - A clear aim has now been added in the last paragraph of the introduction and the Results, Discussion and Conclusions all follow this aim.

RC2.4 -There is an implicit aim in the sampling regime – “What are the major determinants of phytoplankton composition and abundance in the Labrador Sea?” My comments hereafter will address this aim, and I leave the authors to judge how appropriate they are to the revised paper.

AC2.4 - The major determinants of phytoplankton composition and abundance has already been investigated in Fragoso et al 2016. The uniqueness of this manuscript is that it takes the subject matter a step further to focus on additional algal groups, including those that potentially were not included in Fragoso et al 2016. Moreover, we investigate the biogeochemical (C:N) and photophysiological signatures of these communities that are shown to vary across the biogeochemical regions of the Labrador Sea. Therefore, the current manuscript details a much larger dataset (10 years) and more stations from the AR7W line in order to provide a baseline of the determination of phytoplankton communities and their specific biogeochemical and photophysiological signatures from spring to summer in the Labrador Sea. Following this reasoning, we have decided not to follow the direct suggestions of the reviewer to focus only on

C3

hydrography, but rather we examine other aspects (biogeochemistry and physiology) of the phytoplankton communities. This provides a more holistic understanding of phytoplankton dynamics in the Labrador Sea.

RC2.5 -The Introduction must provide sufficient information to provide the context for the Aim and to allow the reader to understand the significance of the results as they are presented. It must introduce all of the major topics covered in the paper, but nothing else. Thus, the first two paragraphs (lines 42-65) are unnecessary; as is the paragraph on CHEMTAX starting line 86 (which should be replaced by a brief outline on the approach taken to address the Aim).

AC2.5 - A holistic understanding of phytoplankton dynamics requires suitable introduction of phytoplankton photophysiology and biogeochemistry. Therefore, we retain the first two paragraphs as paragraph one refers to the impact of hydrography on community structure and paragraph two refers to the impact of phytoplankton community structure on C:N ratios. However, we do agree with the reviewer that the introduction needs to better guide the reader and provide enough information for the stated aim of the paper. Thus, we have now radically shortened the whole introduction and reorganised it in attempt to make it clearer for the reader.

RC2.6 -The description of the study region is currently split between the Introduction (lines 66- 84), Methods (lines 114-132), and Discussion (lines 409 – 413). Given that the notional paper is now about the Labrador Sea, I suggest that all of this information should be amalgamated in the Intro, as should most of the description of the NAO (lines 425-430), and Figure 1.

AC2.6 - Paragraph three in the introduction gives a brief overview of why it is important to research the Labrador Sea. We consider this information to be crucial for the wider relevance of our study where phytoplankton biogeography is influenced by contrasting hydrography. Phytoplankton biogeography in the Labrador Sea, in turn, influences the contrasting biogeochemical and photophysiological traits observed in distinct wa-

C4

ter masses. The study area section in the methods focuses mostly on the complex hydrography of the area and provides further details that are crucial for the reader to understand the biogeography of the community. Line 409-413 has now been moved to the study area section (see new version of introduction) as suggested by the reviewer as it is important information about the region. Although the reviewer suggests it would be better to amalgamate the information from the introduction and the study area, we believe that the information is more clearly organised as is. Thus, the introduction provides a brief explanation of why is important to study the Labrador Sea, while the study area section in the methods gives a more in depth description of the complex hydrography of the region. The possible effects of the NAO are not investigated in depth in this manuscript, therefore, it is not relevant to describe it in the Introduction.

RC2.7 -I would specifically identify the main factors that may control phytoplankton – temp, salinity, mixed layer depth, light, nutrients, ice, meltwater. I also think that the Introduction should mention that the cruises occurred at different times of the Spring/Summer, introducing the notion of a temporal sequence, as this was the basis for one of the Conclusions (which surprised me on the first read!). Also that there were some cruises that deviated from the normal transect. I note that there was another publication by the same authors in the same region this year. I am surprised that there was not a specific reference to how this study relates to the previous one.

AC2.7 - We agree with the reviewer that the notion of the temporal sequence of the phytoplankton communities is important to guide the reader. Therefore, we have now added information about the seasonality of late spring/early phytoplankton communities in the introduction (see paragraph three of the new version). However, we left the detailed information about cruises occurring at different times in the Methods section, and have made it clear to the reader that there is temporal variability in the sampling times. See the sentences rewritten below.

Line 137 – “Stations were sampled during late spring and/or early summer, varying mostly within a 6 week window (see sampling dates in Table 1) over a 10 year period

C5

(2005-2014) by scientists from the Canadian Department of Fisheries and Oceans. Fixed stations (total of 28), as well as some additional non-standard stations, were sampled across shelves and in the deep central basin on the AR7W section or slightly north or south of this transect (Fig. 1).”

RC2.8 -Method

The inclusion of results in section 2.4 surprised me at first, but I think that this section is peripheral to the main story and is appropriate here.

AC2.8 - We agree with the reviewer.

RC2.9 -Results: I was frustrated by the fact that CHEMTAX results were presented only at the community level as defined through cluster analysis – but what was happening with the individual taxa that comprised these communities? Later I discovered that these results were (sort of) presented in the Discussion. I suggest that the distributions of individual taxa should be presented (with figures) before the distributions of communities.

AC2.9 - Information about individual taxa has now been inserted as a subsection “4.2 Chemtax interpretation and groups distributions” in the results section as suggested by the reviewer. See the attached pdf with the new figure and the new subsection.

RC2.10 - I would like to see a more detailed analysis of the factors controlling phytoplankton in each water mass. Even though there was considerable data on photosynthetic properties, I didn't get a clear message on the role of light in controlling biomass.

AC2.10 - MLD and stratification are included as indirect indicators of light availability. Unfortunately PAR was not measured at all stations during the 10 years of sampling. One paragraph (photosynthetic parameters) in the discussion (see paragraph rewritten in the response to the reviewer #3, AC3.60), now covers the effect of light on taxonomic segregation. Further analysis of nutrient and light variability across the Labrador Sea and its impact on phytoplankton composition is discussed in Fragoso et al. (2016).

C6

RC2.11 -The Results should include a specific section on the temporal sequence, possibly exploring the sequence of events in each region. I note in Fig 3 that the data for 2012 and 2014, which were sampled late in the season, differ from other years, particularly Chl and nutrients in the central region.

AC2.11 - Unfortunately, there is not enough information to provide a true temporal sequence of data. Although there is some temporal variability in when the section was sampled, as discussed in the paper, the main variability is spatial as Figure 3 clearly shows. A figure has now been added showing the sampling day on the Z axis in figure 3. See the new version of figure 3 in the pdf file attached.

RC2.12 -Discussion: Much of the discussion about individual taxa in section 4.1 should be first described in the Results section.

AC2.12 - Information about individual taxa have been now added to the Results section. See new figure 4 and text in the pdf.

RC2.13 -Most of sections 4.2 and 4.3 should be saved for another paper.

AC2.13 - The reasons why we have kept the biogeochemical and photophysiological data in the revised manuscript are that they directly pertain to the aim and focus of our paper (see previous comments).

RC2.14 -The Discussion should focus specifically on the results of this paper in relation to the Aim, only referring to other studies to provide context, generally in the style of "Our results match those of Smith and Jones. . .". Only then should the wider implications of the work be discussed, and there should be clear signals when the narrative extends beyond the current work. Much of this Discussion reads like a review. It was often difficult to determine whether the results being discussed were from this paper or from others.

AC2.14 - We agree with the reviewer and have now considerably revised the discussion to focus on our results and improve the interpretation of our data in comparison to other

C7

studies.

RC2.15 -Conclusions: Most of the final paragraph seems more appropriate to the Introduction. The authors may also consider any further research questions that arise from this study.

AC2.15 - This last paragraph was removed from the conclusions.

RC2.16 -Abstract: I think the first sentence is redundant and that the second sentence should be extended to include the Aim. The abstract will require revision in line with the changes to the rest of the manuscript.

AC2.16 - We have now changed the beginning of the abstract to reinforce the aim and the importance of the study. See the beginning of the abstract rewritten below.

Line 12 - "Abstract. The Labrador Sea is an ideal region to study the biogeographical, physiological and biogeochemical implications of phytoplankton communities due to sharp transitions between distinct water masses across its shelves and central basin. The aim of this study is to provide a baseline description of the distributions and biogeochemical traits of phytoplankton communities from distinct biogeographical regions of the Labrador Sea. We have investigated the multi-year (2005-2014) distributions of late spring and early summer (May to June) phytoplankton communities in the various hydrographic settings of the Labrador Sea. Our analysis is based on pigment markers (using CHEMTAX analysis), and photophysiological and biogeochemical characteristics associated with the communities present in the different water masses of the Labrador Sea."

RC2.17 -SPECIFIC COMMENTS: Line 186 and Table 3: Lutein not used for chlorophytes? (Does the BIO method separate ZEA & LUT?) If not, Table 3 ZEA must be ZEA+LUT

AC2.17 - The BIO method does not separate lutein and zeaxanthin so we renamed it to Zea + Lut

C8

RC2.18 -Lines 192-200 and Figure 2: I note that two of the categories include Hex but no Chlc3 – I assume this is a simplification of the text and diagram as this combination does not exist to my knowledge. Figure 2 is unnecessary and should be replaced with a table including all pigments.

AC2.18 - Figure 2 shows the percentage contribution of each pigment to each cluster. In this study, *Phaeocystis pouchetii* did not contain 19-hex and was identified using Chl C3. This has previously been observed in the Labrador Sea (Stuart et al., 2000) and is stated in line 589 – 594.

RC2.19 -Section 3.2: Did the authors try further subdivision of group C3b? This group is by far the biggest, it is widest spread across the S-T diagram (Fig 5a), and its composition is “mixed”, yet Fig 4a shows major divisions within the group. Would these subdivisions distinguish communities that were more coherent in composition and habitat?

AC2.19 - Cluster C3b had the highest level of similarity in terms of sample composition, although it was the most “mixed” in terms of community structure and the most widespread group in the Labrador Sea. Hence, we decided to leave it as is because a further division would bring information that we consider unnecessary, since they are, according to the Bray-Curtis similarity values (73 %), the most equal when compared to the other clusters.

RC2.20 -Line 316: change “*Phaeocystis* (cluster B)” to “A community dominated by diatoms and *Phaeocystis* (cluster B)”. This is an important consideration throughout the document – e.g. lines 328, 329 – there is not a careful distinction between the cluster groups (communities) and the taxa comprising them. I would invent an acronym or abbreviation for each community to avoid this confusion.

AC2.20 - Changes updated. We agree with the reviewer that it is important to elucidate that we are referring to multiple taxa in the community in the text. Therefore, we have now rewritten these sentences for clarification.

C9

RC2.21 -Line 527: The possibility that “diatom species from both Arctic and Atlantic waters varied intrinsically in pigment composition” can be supported by consulting Table 3 of this paper, where we see that they do.

AC2.21 - This is true but our argument is that diatom composition (polar versus Atlantic species) might be influencing these discrepancy. See our response to the reviewer #1 (AC1.4).

RC2.22 -Line 551: “chlorophytes were present in high concentrations on the Labrador Shelf, which may explain the discrepancy between these results.” Some more details are required to constitute an explanation.

AC2.22 - This sentence has been completely rewritten for clarification. See the response to the reviewer #3 where we include the new version of this paragraph (AC3.60)

RC2.23 -Table 5: This table should be augmented by information on the region in which each cluster is found, and the major taxonomic components.

AC2.23 - We believe that this might confuse the reader. The taxonomic components are already provided in Figure 4 and should be examined in parallel with Table 5.

RC2.24 - Also expressing the values like Temperature with standard errors is inappropriate. The values are not based on repeat measurements of a single parameter –e.g. Cluster 3b is listed as 3.4+/-0.2 C, but the actual range is from about -1.3 to +8, the widest of any group. I would be surprised if the standard error given is correct. Even if is, it is meaningless. This table should list the range for each cluster instead.

AC2.24 - We now included standard deviations rather than standard errors in Table 5. A table of data ranges for the parameters discussed for each cluster would be strongly influenced by outliers, hence we have chosen to retain the averages. However, we have added a table with the parameter ranges in the Supplementary material.

RC2.25 -Also: I didn't see any reference to the data for DT:(DT+DD) in text (nor was there any reference to how long the filters were held between sample collection and

C10

freezing. This should be < 5-10 min for this parameter to be valid).

AC2.25 - We have now included information on the filtering time. See our response to reviewer #1 (AC 1.16).

RC2.26 -Results: I did not notice any indication that the raw pigment data were to be included in Supplementary Material or an online databank. I would hope that this will be the case to increase the value of this data set.

AC2.26 Some of these data (from Bedford Institute of Oceanography) are publicly available online (<http://www.dfo-mpo.gc.ca/science/data-donnees/biochem/index-eng.html>). We are discussing with the co-authors the possibility of submitting additional data to PANGEA.

RC2.27 -TECHNICAL COMMENTS: Line 67 and throughout: References should be cited in order of date – oldest to newest

AC2.27 - For Biogeosciences, in case of co-authors papers, citation should be first alphabetically according to the second author's last name, and then chronologically within each set of co-authors.

RC2.28 -Line 84: change “while” to “but”

AC2.28 - Changed.

RC2.29 -Line 118: inset “wide” after “km” (twice)

AC2.29 - Changed.

RC2.30 -Line 123: change “fresh” to “low salinity”. Rest of same paragraph: three water masses are described as “warm and salty” or “cold, low salinity” but other water masses lack these descriptions (parallel form required– see below). Also, is the warm arrow parallel to the Labrador Current in Fig 1 considered to be part of that current?

AC2.30 - This whole paragraph has changed, however, we have described the waters

C11

masses in an orderly manner as suggested by the reviewer. See the response to the reviewer #3 (AC3.24). The red arrow in Figure 1 (lighter in colour) represents a modified (cooled and freshened) branch of the IC through lateral and vertical mixing following the Labrador slope. We will include the modified figure in the new version of the manuscript for clarification.

RC2.31 -Line 177: The correct reference for the method ascribed to “Coupel et al. (2015)” is Higgins et al (2011).

AC2.31 - We have actually updated this reference to Wright et al., (2009). See response to reviewer #1 (AC 1.27) where we include the new version of this paragraph.

RC2.32 -Line 316: Add “respectively” after “(IC)”?

AC2.32 - Changed.

RC2.33 -Line 325: Replace “respond strongly to” with “are associated with” and “spatial aspects of the data” with “environmental parameters”

AC2.33 - Changed.

RC2.34 -Line 331: The description of Fig 5b could hardly be more obscure: “In Atlantic waters, temporal aspects of the data were also observed (upper and lower right quadrants (Fig. 5b)).” There is nothing in that figure that implies a temporal sequence. It was only when the Conclusions mentioned clear temporal differences that I searched the document for “temporal” to find what I had missed and came back to this figure. After some cross-referencing I realised that the description should have read, “In Atlantic waters (upper and lower right quadrants (Fig. 5b)), the phytoplankton community was composed of mixed taxa during May (orange circles), but became dominated by diatoms and dinoflagellates during the bloom in June (red circles), showing a clear temporal succession in these waters”. More generally, the authors must not rely on the reader to discern what is in a figure. The reader is not familiar with the data and may not see what the author sees, or they may see something different. Whatever story

C12

exists in the figure, it must be stated clearly in text as part of the narrative. The figure supports the narrative, it does not replace it.

AC2.34 - We have now clarified the temporal succession of the spring bloom in the Labrador Sea in the text (see response AC2.7). Lastly, we have changed this sentence, now following the suggestion of the reviewer.

RC2.35 -Line 368: Replace “lower accessory pigments to TChla ratio” with “lower ratio of accessory pigments to Tchla”

AC2.35 - Changed.

RC2.36 -Line 369: Replace “(Fig. 7b). Furthermore, communities from warmer waters (Irminger Current from Atlantic origin), particularly those co-dominated by diatoms and dinoflagellates had “ with “(Fig. 7b) than communities from warmer waters (Irminger Current from Atlantic origin), particularly those co-dominated by diatoms and dinoflagellates which had”

AC2.36 - Changed.

RC2.37 - Line 376: Replace “ $\mu\text{g C } \mu\text{g Chla h}^{-1}\text{W m}^{-2}$ ” with “ $\mu\text{g C } \mu\text{g Chla h}^{-1}\text{ W}^{-1}\text{ m}^2$ ” or “(Wm⁻²)-1 “ Also line 378

AC2.37 – All changed.

RC2.38 -Lines 375 to 386. Sentences should be rearranged to “parallel form” i.e. talk about the same things in the same order for each case cited

AC2.38 – We have rewritten this whole paragraph. See the response to the reviewer #3 (AC3.60) where we show how this paragraph would be in the new manuscript version.

RC2.39 -Line 392: Insert “Atlantic,” before “Labrador”

AC2.39 - Changed.

RC2.40 -Lines 437 – 450: Reads like a review. Note also that the paragraph starts with

C13

“Phaeo- cystis and diatoms. . . (Fragoso et al 2016)” but by line 441 it’s “PRESUMABLY of Phaeocystis and diatoms (Fragoso et al 2016)”. Also is “eastern central Labrador Sea” (line 437) equivalent to “West Greenland Current” (line 440)?

AC2.40 - We have now changed the beginning of this paragraph. See below.

Line 437 - In this study, Phaeocystis and diatoms were observed blooming together in waters of the WGC, in the eastern central part of the Labrador Sea. The occurrence of Phaeocystis in these waters has been observed before by several authors (Fragoso et al., 2016; Frajka-Williams and Rhines, 2010; Harrison et al., 2013; Head et al., 2000; Stuart et al., 2000; Wolfe et al., 2000). The eastern part of the Labrador Sea is a region with high eddy kinetic energy during spring (Chanut et al., 2008; Frajka-Williams et al., 2009; Lacour et al., 2015), which causes the accumulation of low-salinity surface waters from the West Greenland Current. This buoyant freshwater layer contains elevated levels of biomass of both Phaeocystis and diatoms (this study, Fragoso et al., 2016).

RC2.41 -Line 598: Add reference e.g Gieskes and Kraay (1983) Mar. Biol. 75, 179-185.

AC 2.41 - Suggested reference added.

RC2.42 -Line 886: remove “et al” ; page numbers = 78 – 80

AC 2.42 - Changed.

RC2.43 -Figure 2 is unnecessary and should be replaced with a table including all pigments.

AC 2.43 - We believe that Figure 2 is key to the CHEMTAX analysis, although we have now included it in the supplemental material rather than the main text.

RC2.44 -Figure 4b. The colours of the sectors would be much more easily interpreted if they made sense to a phycologist! Surely cyanobacteria = Cyan, chlorophytes = Dk

C14

Green, Prasinophytes = Lt Green, Phaeocystis = Brown, etc. (Leave diatoms white)

AC 2.44 - Although we appreciate the colour selection of the reviewer, we have retained the original pastel colours in 4b as the colours suggested are already used elsewhere in Figure 4 (4a, 4c), which could confuse the reader.

RC2.45 -Figure 4c. The single circle as a scale is ambiguous. Does the biomass relate to the diameter or the area of the circle? In any case it's difficult to judge. There should be a range of circles representing a biomass scale (if circles are to be used). Also I estimate that about 20% of the data points are hidden in this diagram as they underlie another circle. This could be solved by increasing the breadth of the figure or using vertical bars instead of circles. Could the fronts be marked for each year by dotted lines?

AC 2.45 - A scale for the bubbles used in this figure has now been added, as well as the width of the figure (see attached pdf). Physical fronts are already discernible through sharp changes in phytoplankton community composition, as mentioned in line 305, whereas dotted lines would become confusing between adjacent years.

RC2.46 -Figure 5: It would be good to see individual taxa plotted in such diagrams.

AC 2.46 -We could add the "arrows" of individual taxa in the figure 5b, however, we decided to leave it as is because adding information on taxa would be confusing to interpret the message of the figure. That is because, diatoms, for example, are the dominant taxa in all communities (except cluster C3b), so the "diatom arrow" in just one direction could bias the interpretation. We are focused in the community, rather than individual taxa in this paper.

RC2.47 -Table 2 is unnecessary. The individual pigments are not part of the story – simply quote the references.

AC 2.47 - We believe that individual pigment information is important for the CHEMTAX analysis, though we have now moved this table to the supplementary material.

C15

RC2.48 -Table 3: The legend doesn't make it clear that the references cited provided the starting ratios from which these data were calculated. Cyanobacteria is misspelt.

AC 2.48 - We have now clarified in the legend that the references provided inform the starting ratios from which the data were calculated. See the pdf attached in the response letter for reviewer #1, where we have added a new version of this table. "Cyanobacteria" has now been spelt correctly.

RC2.49 -Table 4: The formatting is strange. It looks as if it should be split into A & B, horizontally.

AC 2.49 - Table 4 has now been split horizontally into a) and b) for better clarification. See the new version of the table and the response to the reviewer #3 (AC3.46).

Please also note the supplement to this comment:

<http://www.biogeosciences-discuss.net/bg-2016-295/bg-2016-295-AC2-supplement.pdf>

Interactive comment on Biogeosciences Discuss., doi:10.5194/bg-2016-295, 2016.

C16