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Biogeosciences Discussions

Interactive comment on "Gradients in intact polar diacylglycerolipids across the Mediterranean Sea are related to phosphate availability" *by* K. J. Popendorf et al.

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The authors thank both reviewers for their helpful comments and positive assessment. We have incorporated most of their suggestions into revisions and additions in the text as well additional panels in figure 4. We feel that these additions strengthen the existing discussion, and hope that the reviewers find these revisions to be satisfactory. Below is a detailed response to the individual comments from reviewers.

The first reviewer suggested the abundance of phospholipids be presented as a fraction of organic phosphate, and we have incorporated this suggestion as an additional panel in Figure 4, as well as text in the results and discussion. We feel that this is a valu-

able calculation which is relevant for consideration of the role of phospholipids in the phosphorus cycle and microbial dynamics in the surface ocean. We found that phospholipids were 7.1% (+/- 2.5%) of particulate organic phosphorus, which is within error of published data from the South Pacific (Van Mooy and Fredricks GCA 2010) where phospholipids were found to be 4 +/- 1% of particulate phosphorus. Phospholipids were sampled using a 0.2 μm poresize membrane filter, whereas in the Mediterranean Sea particulate phosphate was sampled using combusted GF/F filters (Pujo-Pay et al. BG 2011), with a nominal poresize less than 0.7 μm after combustion (Nayar and Chou, Est. Coast. and Shelf Sci., 2003). More material might be expected to be retained in the lipid sampling than particulate phosphorus sampling, thus the 7% calculated in the Mediterranean is likely a maximum estimate. In the South Pacific, sampling for particulate phosphorus used sequential filters of 0.2 μm, 0.6 μm, and 2 μm poresize (Duhamel et al. BG 2007), nonetheless the results in these two locations are within error of each other. We also calculated N-containing lipids (PE, PC, DGTA, DGTS, and DGCC; see manuscript for full names) as a percent of particulate nitrogen and found this to be 0.4% (+/- 0.2%), which has also been included in the text of the results.

In response to suggestions from the second reviewer: "Page 7924, Line 20, Page 7939, Line 15 etc. The authors sometimes describe the system they are studying, and the Sargasso sea, as 'Phosphorous-limited'. Although phosphorous is clearly severely depleted in both the Sargasso and the (Eastern) Mediterranean, the authors describe their system as 'not phosphate limited' on the basis of their own experiments see Line 17 Page 7938 (described more fully by Tanaka et al. 2011 who suggest the system is N or NP co-limited). I am not aware of any direct evidence that the Sargasso is any more 'limited'? Although this may seem pedantic, I personally would prefer a description of both the Sargasso and Mediterranean as phosphorous depleted."

As the reviewer points out, we should perhaps reassess our terminology of nutrient limitation versus nutrient depletion with respect to the Mediterranean Sea in this manuscript. Certainly the Mediterranean Sea has one of the highest N:P ratios in the world's oceans, and there is evidence from previous studies that primary production in the Mediterranean is limited by phosphate availability (Diaz et al. 2001; Krom et al. 1991; Moutin and Raimbault 2002), and also that bacterial production in some cases is phosphate limited (Van Wambeke et al. 2002). However, as the reviewer points out, the microcosm incubation conducted during the BOUM cruise found most measures of system productivity (primary production, heterotrophic bacterial production, chlorophyll concentration presented in Tanaka et al. BG 2011, as well as total IP-DAGs as a measure of biomass as presented in this paper) to indicate N-P colimitation in most locations across the Mediterranean. This corroborates a large-scale nutrient addition experiment that also found primary production to be N-P colimited in the eastern Mediterranean (Thingstad et al. Science 2005). In light of the results from our microcosm incubation, we agree that in the context of this paper it would be most correct to describe the Mediterranean Sea (and the Sargasso Sea) as phosphorus depleted rather than phosphorus limited as the reviewer suggests and we have made this modification throughout the text. The modification of terminology implies that phosphorus limitation refers to the limitation of biological activity, while phosphorus depletion refers to the abundance and ratio of nutrients present.

"Page 7930, line 19. Presumably the range of IP-DAGs per cell will reflect in some way that there is a big range in cell sizes, this could be mentioned briefly."

This is a relevant point that we agree should be noted, and have added a sentence to the discussion accordingly.

"Page 7936, Line 1. Could this be presented? E.g. a plot of the ratio of phospholipids/total IP-DAGs against phosphate? Or an additional panel in Fig. 2?"

We have added a plot of phospholipids as a percent of total lipids to Figure 4, presented as a cross-section across the Mediterranean in the same way as the ratios of other lipids in that figure. We agree that a plot of this data in some form is helpful for the discussion, and felt that this format is the most straightforward way to convey the

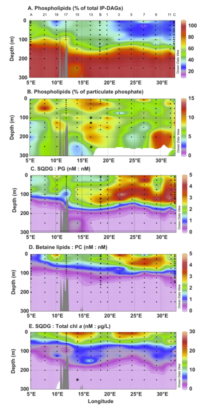
significant features, notably the decrease from west to east in the upper 100 m across the Mediterranean. A scatter plot of phospholipids/total IP-DAGs versus phosphate also conveys the relationship between phosphate concentration and phospholipids as a percent of total lipids, but this format accentuates the shallow vs. deep trend (with low phosphate and low % phospholipids in the surface, and higher phosphate and high % phospholipids at depth), which, while interesting, is less relevant to the discussion which focuses on gradients across the Mediterranean.

"Figure 6. Would it be possible to include an additional set of panels showing the overall community response to nutrient manipulation? E.g. chlorophyll? I realise this data is in Tanaka et al. 2011, but it might help a reader to orientate."

We appreciate the suggestion, and, while we recognize that we are asking the reader to consider a collection of results not presented in our manuscript, we feel that the depth of data provided in Tanaka et al. BG 2011 is the best resource for a full comparison of our results of changes in IP-DAGs to shifts in community structure and productivity. After consideration we decided against republishing figures from the Tanaka paper in our manuscript. We trust that the discussion presented gives enough of a summary of results from the Tanaka paper that our analysis of the shifts in membrane lipids can stand alone, and we hope that the interested reader can readily compare the Tanaka results to our own for a more in-depth consideration of the broader microcosm results.

Interactive comment on Biogeosciences Discuss., 8, 7921, 2011.

Figure 4



Distribution of the ratios of lipids each shown in the upper 300 m from west to east across the Mediterranean Sea. Total phospholipids (the sum of the concentrations of PG, PE and PC) are shown as a percent of total IP-DAGs (A), and as a percent of total particulate phosphate (B). The ratio of non-phosphorus lipids to phospholipids are shown as the ratio of the sulfolipid SQDG to the phospholipid PG (C), and the ratio of the sum of the betaine lipids to the phospholipid PC (D). Also shown is the ratio of SQDG to total chlorophyll a (E). Numbers across the top panel indicate station labels; black dots indicate individual samples, colored contours indicate interpolated gradients; * indicates outlier values not plotted.

Fig. 1. Revised figure 4 with additional panels