Ocean Sci. Discuss., 11, C775–C779, 2014
www.ocean-sci-discuss.net/11/C775/2014/

Ocean Science
Discussions

Interactive comment on "Consequences of artificial deepwater ventilation in the Bornholm Basin for oxygen conditions, cod reproduction and benthic biomass – a model study" *by* A. Stigebrandt et al.

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Received and published: 1 September 2014

The manuscript develops a model to estimate the effect of pumping lower salinity water above the halocline deeper into the water column and to examine the effects on oxygen concentrations in deeper waters. The mixing will reduce the salinity stratification in the water column, enhancing mixing and cause increased numbers of salt water inflows into the Bornholm Basin and subsequently into the Baltic Proper. The paper goes on to describe the positive effects of adding oxygen on the ecosystem and calculates the increase in benthic biomass and reproductive volume for cod populations. The paper

concludes that bottom sediments will no longer be anoxic and the sediments will act as a phosphorus sink.

While the model describes the effect on mixing on oxygen concentrations in the Bornholm Basin there are a number of important repercussions that greatly affect the Baltic Sea ecosystem both in terms of the circulation and the biological response that are not addressed in this manuscript. Some important considerations not addressed in the manuscript include:

- The halocline in the Bornholm Basin has varied between 55-60 m and between 65-80 m in the Baltic Proper over the last 100 years (Carstensen et al. 2014, PNAS). When the vertical salinity stratification (Pg. 1808, line 13) in the Baltic Proper is reduced by lowering the salinity gradient across the halocline, what are the chances that a large winter mixing event will break through the weakened permanent halocline? If so, what are the repercussions on circulation? How far down will mixing occur? Will the halocline be reestablished at the same depth? Or on what timescales will restratification occur? How will destratification in the Bornholm Basin effect the Baltic Proper?

- Probably strong Major Baltic Inflows may enter the deep Baltic proper without being significantly altered by the pumping, while less strong inflows are significantly reduced in salinity. Is there a possibility that a gap in the inflow distribution could increase the risk of long stagnation periods in the deepwater of the Baltic proper?

- Our current understanding regarding the area of hypoxia in the Baltic Sea is that variations in the total amount of salt water brought into the Baltic has a significant effect on hypoxic area. During the 1980s when salinity decreased, the area of hypoxia was reduced due to less vertical stability in the water column. When more salt water entered the Baltic Sea in the 1990s the halocline depth shoaled with reduced vertical mixing and more hypoxia was observed (Conley et al. 2002; Carstensen et al. 2014).

Both experimental (Byfjorden) results and the model presented here states that pumping leads to increased number of inflow events. What is the effect on the increased salt

water inflows on oxygen concentrations in the Baltic Proper? What is the effect on the long-term salinity structure and the salinity content of the Baltic Proper?

Although the model might describe conditions in Bornholm Basin, what is of critical importance is what are the effects on the Baltic Proper?

- If the physical circulation is modified with reduced vertical stratification, e.g. more deep water mixing, changes in the depth of the halocline, or changes in inflows, what will the effects be on biological populations? If the permanent halocline changes its depth, what will the effect be on phytoplankton, zooplankton and larvae?

- The section of the manuscript on increases in benthic biomass is essentially the same calculations that have been made in a previous paper (Karlsson et al. 2010), e.g. if oxygen returned than X amount of benthic biomass would happen (Pg. 1809, lines 3-11). There is nothing new here.

However, there is a calculation of the effect if Marenzelleria, an invasive species, was able to penetrate into the deep waters of the Bornholm Basin at the same magnitude that they have colonized the shallow waters. There is no evidence to suggest that the shallow, coastal Marenzelleria species will colonize the deeper waters of the Baltic once oxygen returns. In addition, the following discussion of increases in bioturbation with the possibility of increases in Marenzelleria (Section 4.7) is irrelevant unless there is evidence that Marenzelleria could colonize the deeper waters.

- Currently, a large proportion of denitrification in the Baltic Sea occurs in the oxycline (Dalsgaard et al. 2014), as in oceanic oxygen minimum zones. Will total denitrification be reduced in the Baltic Sea when there is not a strong oxycline? The Baltic Sea is currently limited by the availability of nitrogen. What happens to the system when the amount of nitrate increases?

Or what happens when high nutrient concentration in the water below the halocline are mixed upwards into the surface layer?

- Will the sediments actually become oxic? We have built up large stores of organic matter in sediments with the organic carbon concentrations 3-5 times higher today than in the 1950s (Emis et al. 2000). Will oxygen in the water column be able to oxidize the sediment in the face of this large respiratory burden? Will the sediments be sufficiently oxygenated to overcome the respiratory burden to increase P burial and or increase the importance of the sediments in denitrification?

Overall, I believe the manuscript is an inadequate description of the consequences of artificial deep water ventilation. The authors do not address many of the potentially important changes in circulation, the ecological effects, or the changes in the biogeochemical cycles of P and N.

Additional comments

Pg. 1784, Line 2. The Bornholm Basin is not an isolated basin.

Pg. 1806, Line 14. “It would be easy to . . .” - it depends upon what your definition of easy is.

Pg. 1807-1808, Lines 27-2. It is not clear from the text the origin of the diverging opinions of Gustafsson et al. (2008) and this manuscript and why contrasting results were obtained with pumping.

Pg. 1813, Lines 5-10. All of the problems with cod in this manuscript are attributed to changes in the reproductive volume. While I agree that is a very important parameter, there is no recognition of the effects of overfishing on fish populations. What are the expected effects with the large reductions in fishing pressure with passage of the Common Fisheries Policy (CFP) in Europe? At what level will cod populations recover and how do these compare to changes in reproductive volume? In addition, trophic interactions between cod, herring and sprat believed to be important factors affecting cod reproduction (Cassini et al. 2009, PNAS). What is the relative effect of trophic interactions as compared to reproductive volume?

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Interactive comment on Ocean Sci. Discuss., 11, 1783, 2014.