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Biogeosciences Discussions

Interactive comment on "Long-term record of pH in the Dutch coastal zone: a major role for eutrophication-induced changes" *by* P. Provoost et al.

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First of all we would like to thank the reviewer for his/her constructive comments. The referee expresses concern regarding the interpretation of the long-term patterns we observed. We acknowledge that the suggested link between eutrophication and pH changes is not well established. However, as we pointed out in our paper, pH is determined by a multitude of factors. We feel that an in-depth investigation into the driving factors of pH in the studied systems would require elaborate modelling and analysis of historical records of many different variables, which would be beyond the scope of this paper. Our main goal was to present this very interesting collection of historical data

and report the patterns we extracted from it. We agree that this should be reflected in the title and will change it to *Long-term record of pH in the Dutch coastal zone reveals large variability and major changes*.

Below we will try to address each of the received comments.

Methods: Well and clearly written but some questions arise from the wavelet analyses description which is maybe to concise. Was the analysis performed for each station or only for the "test" stations? Can you not perform a wavelet analysis on data from a group of stations? (group them by distance from coast for example). Results: How representative are the selected stations? For the North-Sea area especially, the covered area comprises very different zones (remote and close-to coast stations, influenced by river outlet or not,...) that must display strong variability.

The analysis was performed on all timeseries which were more or less continuous. As the long-term patterns did not differ significantly within each system, we decided to select and present only one station per system. There was an important difference in the seasonal amplitude of the North Sea stations however, and this is covered in Figure 6 where each point represents a single station or timeseries. We will add a figure showing long-term signals for 11 North Sea stations including both near-shore and off-shore stations, and the station we previously selected to represent this area (cf. attached figure).

In a companion paper by Van Engeland et al. (2010), we have analysed dissolved (organic) nitrogen patterns in terms of seasonality and long-term changes. This study revealed systematic differences between close-to-coast and open North Sea stations and high similarity within these domains. To make this point clear we will cite this paper.

North sea: seasonal amplitude vs distance from coast. What does figure 6 represents exactly, all stations? All years?

Each point represents one station. The value is an average of years where a seasonal

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amplitude could be calculated, i.e. where a value was available for both January and May. Stations with less than ten seasonal amplitudes were omitted.

Does seasonal amplitude vary over years (with productivity)? You show the spatial variability of seasonal amplitude, why not also represent the temporal variability of seasonal amplitude?

Yes, seasonal amplitudes appear to vary over the years, this can be seen in the medium-term signals in Figure 3.

Discussion: First paragraph is quite repetitive of what was presented in the introduction - not necessary to repeat. Maybe just concentrate of the pH changes that are not only linked to atmospheric CO_2 increase.

We feel that repeating the some of the results from other studies is desirable for the flow and readability of our manuscript. Also, the contrast between rates of change observed in oceanic systems, which are sited in this paragraph, and those seen our dataset is one of the major results of this study.

P4137 paragraph line 10 and down: what about year-to-year variations of productivity in these systems vs amplitude seasonal variation of pH? When you give productivity ranges, it is worth to give the years they apply on as the studied systems almost all underwent changes of productivity over the years.

There has indeed been substantial variation in primary production in the studied systems over the last 30 years. However, because the primary production rates found in literature have only very limited temporal coverage, we have not looked into year-by-year correlation between pH amplitude and primary production but merely made a cross-system comparison. In a revised manuscript we will include a more detailed account of the primary production rates found in literature (see below).

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area	location	time	reference	PP (gC m^{-2} yr^{-1})
North Sea	coastal	1986	Moll (1997)	>300*
North Sea	off-shore	1986	Moll (1997)	150*
North Sea	coastal	1988-1990	Peeters et al. (1991)	>350
North Sea	off-shore	1988-1990	Peeters et al. (1991)	>150
Wadden Sea	west	1975	Philippart et al. (2007)	100
Wadden Sea	west	1985-2005	Philippart et al. (2007)	100-300
Eastern Scheldt	west	1980-1984	Wetsteyn & Kromkamp (1994)	300-550
Eastern Scheldt	west	1987-1990	Wetsteyn & Kromkamp (1994)	250
Eastern Scheldt	central	1980-1984	Wetsteyn & Kromkamp (1994)	250-400
Eastern Scheldt	central	1987-1990	Wetsteyn & Kromkamp (1994)	250-300
Eastern Scheldt	east	1980-1984	Wetsteyn & Kromkamp (1994)	200-400
Eastern Scheldt	east	1987-1990	Wetsteyn & Kromkamp (1994)	250
Western Scheldt	east	1991	Kromkamp & Peene (1995)	100
Western Scheldt	west	1991	Kromkamp & Peene (1995)	300
Ems-Dollard	west	1976-1980	Colijn et al. (1987)	300
Ems-Dollard	central	1976-1980	Colijn et al. (1987)	100
Ems-Dollard	east	1976-1980	Colijn et al. (1987)	100

*simulation

P4138 line 10: do you mean CO_2 dissolution rather than uptake?

We will rewrite this sentence to make it more clear.

P4138 last paragraph - For the Western Scheldt the pH increases only (but strongly) between 1985 and 1990 while the ammonium reduction was continuous since 1975 (Soetaert et al 2006)...

Inorganic nitrogen has indeed decreased since 1975. This decrease in ammonium loadings was accompanied by other changes (organic loadings) and shifts in along axis distribution of processes, i.e. nitrification is now occurring more upstream than in the past. For instance, changes in organic matter degradation may have influenced the long-term pH signal.

The interpretation of increased pH is somewhat confusing - you link it to NH_4^+ reduction and so less nitrification, but also to nutrient reduction and increased turbity - but this should both limit primary production and so decrease pH?

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Modelling studies have shown that nitrification and degradation processes are more important than primary production in the Western Scheldt (Hofmann et al., 2009). So while nutrient reduction has the potential to limit primary production, we do not expect this to be of any importance here. We have indeed linked the attenuation of the seasonal signal in the Ems-Dollard to increased turbidity and we do not think this excludes the possibility of an increased pH on the longer time-scale due to changes in nitrification rates. As stated before, unravelling the overall effect on pH of these different processes will require extensive modelling. Because of this we will be even more careful in our wording when making any attempts towards interpretation.

P4139 last sentence: During periods of enhanced nutrient loadings pH increased, while pH decrease during periods of lower nutrient loads: This view is to simplistic and does not apply, straightforward, on all the studied systems.

We agree that this is too simplistic and will be omitted.

You do not show a direct and evident link between long term nutrient load variations to the studied systems and long term pH changes. You should be more cautious and show (or cite from literature) more precise nutrient load variation data for the studied areas. It would be helpful to have a kind of summary table with, for each studied area: the period - the nutrient load variations - the PP variation (when available) - the pH variation.

Nutrient reduction has many interacting effects on pH, making it impossible to establish a straight-forward link between nutrients and pH. At least for the North Sea, the resemblance between the modelling results of Borges & Gypens (2010) and our data suggests that nutrients are indeed the driving factor for the changes we observed. Without further evidence we cannot generalize and therefore have modified the title to *Long-term record of pH in the Dutch coastal zone reveals large variability and major changes*.

Fig 1. Symbols in the legend do not correspond with the ones in the figures for Wadden

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Sea, Western- and Eastern Scheldt.

Thank you, we will correct this.

Fig 8. Not necessary - same info as in Figure 3.

We agree, and this figure will therefore be omitted from the revised manuscript.

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Interactive comment on Biogeosciences Discuss., 7, 4127, 2010.

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Interactive Comment

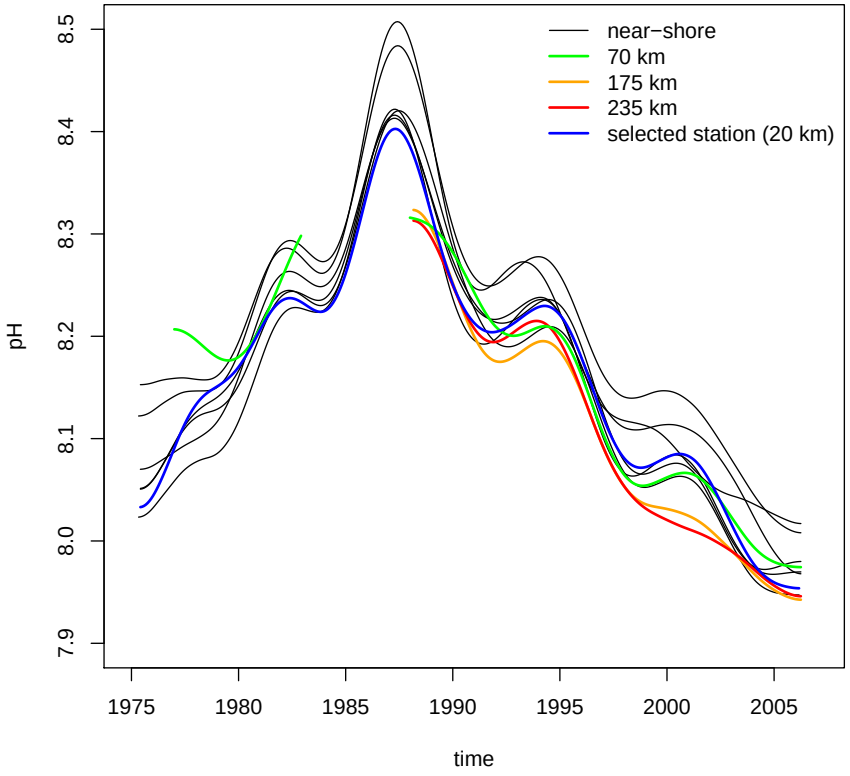

Fig. 1.

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