Ocean Acidification (OA): Country Report for Finland

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Background

This report is a working document of the project "Baltic Sea Acidification Mitigation" (BALSAM), supported by the Swedish Institute. The report is based on a presentation held at the project BALSAM workshop (Sven Lovén Centre of Marine Infrastructure, Kristineberg, Sweden, October 9-11, 2019). The aim of this report and other, corresponding reports (to be produced for the other countries participating in BALSAM) is to inform environmental NGOs on the status of OA in the Baltic Sea and the Black Sea, and give an insight into the actors working with OA. This is done as support for campaigning towards mitigation of greenhouse gases and protection of the seas, also bearing in mind the importance of being aware of sources for additional information. This document is not intended as a comprehensive literature review but does contain key publications and links to further in-depth reading. More information on OA effects in Finnish coastal waters can be found from the project BALSAM main report.

What is OA?

Ocean acidification comes in the wake of climate change as the result of increased atmospheric CO_2, which is taken up by the oceans. About 30-40% of the CO_2 that is emitted to the atmosphere because of human activity ends up in the waterbodies. Part of the CO_2 reacts with water, and forms carbonic acid. Some of the carbonic acid dissociates resulting in bicarbonate, and in hydrogen ions. This process leads to acidification (lower pH, i.e. higher concentration of hydrogen ions). Organisms in the oceans are adapted to the pH-conditions that have prevailed in the seas prior to this human driven acidification-process. Especially calcifying organisms are sensitive to acidification, but the physiology of many other organisms can be affected as well, as can the complex ecological interactions between organisms.

Research

A significant amount of research is focused on multiple stressors in the Baltic Sea, including considerations on the carbon cycle, pH, etc. Acidification *per se* is not necessarily the main focus in all of this research, but variables related to acidification are an important part of the work. Especially within larger research groups some studies have additionally been conducted focusing specifically on this problem. We have chosen to present below 1) the current work, which contains research specifically dedicated to OA, as well as more general approaches (that also have an important bearing for the understanding of OA), and 2) earlier (recent) work specifically on OA. The rationale is to bring forward the larger framework surrounding OA studies, as well as the specific results that have been (and likely will be) produced within this framework in the future.

Current work:

The Finnish Meteorological Institute currently conducts specific OA-research at the Utö Station. As stated on the home page of the station, diverse atmospheric and marine observations are carried out. The Utö station participates in several observing networks like ICOS, HELCOM and EMEP.
Many other actors work with multiple stressors in the Baltic Sea (with carbon chemistry and/or pH among the studied variables). At the University of Helsinki/Tvärminne Zoological Station, current research projects include, for example, biogeochemical cycling of essential elements in the sediments (e.g. CO_2 and methane dynamics). Work with multiple stressors is also carried out at Novia University of Applied Sciences/Bioeconomy Research Team in the Engström Team, with OA-work included (see "Earlier work" below), as well as at the Åbo Akademi University and the University of Turku (see e.g. https://seaandmaritime.fi/).
Projects Havsmanualen 2 & 3 address eutrophication and climate change. The research delivers high-resolution data from shallow coastal waters that include highly relevant variables also from an OA-perspective (e.g. data on carbon fractions, pH). Online data (time series) from various coastal habitats on e.g. pH are available at the Monicoast observatory.
Finally, the Finnish Environment Institute and its Marine Research Centre carries out a diversity of marine research, and coordinates the Finnish Marine Infrastructure FINMARI, the partners of which maintain observatories and other activities that produce data on pH and other relevant variables.

Earlier work:

The research on OA is - like most research work - dependent on funding schemes. Whereas rather few researchers currently work explicitly on OA, recent studies show that research has been active (and other studies are likely to occur among the groups and institutes mentioned above).
A major event for OA-research in Finland was the large mesocosm[1]-experiment carried out outside the Tvärminne Zoological Station in 2012. The experiment belonged to the KOSMOS concept, and it was led by Ulf Riebesell from the GEOMAR Helmholz Centre for Ocean Research in Kiel, Germany. Many Finnish researchers participated in the experiment. Scientific articles from this experiment were published in a special issue of the journal Biogeosciences.
Several (relatively) recent MSc- and PhD-thesis have also been published on OA-research in Finland (partly also utilizing results from the KOSMOS-experiment). These include:
Anu Vehmaa (PhD-thesis, Åbo Akademi University), 2012: "Climate driven changes in temperature, pH and food quality - Effects on copepod reproduction"
Anna Ahlnäs (MSc-thesis, Åbo Akademi University), 2015: "Natural diurnal and seasonal variations in pH in coastal habitats"
Anna Jansson (PhD-thesis, Åbo Akademi University), 2017: "Ocean acidification in the Baltic Sea : implications for the bivalve Macoma balthica"
Anna-Karin Almén (PhD-thesis, Åbo Akademi University), 2017: "Copepods in a changing sea: Ocean acidification, long-term changes and short-term variability"
Antti Takolander (PhD-thesis, University of Helsinki), 2018: "Assessing the effects of climate change on Baltic Sea macroalgae – implications for the foundation species Fucus vesiculosus L. "
Monitoring is performed by the Finnish Environment Institute, and data are made available via a number of services, including data for the HELCOM-stations that can be found via the ICES-map services.

Signs and effects of OA

[1] Experimental enclosures where experimental manipulations and observations can be performed in near-natural conditions

pH has already decreased in the Baltic Sea. For instance, the PhD-thesis by Anna-Karin Almén (2017) indicated a decrease of winter time pH of 0.14 and 0.30 in the surface and deep layers of the Western Gulf of Finland, respectively (1979-2015). Unlike in the open oceans, pH in the Baltic Sea (and especially in its coastal areas) is affected to a large degree by biogeochemical processes, such as the mineralization of organic material. As the load of organic matter and primary production (due to eutrophication) can be high in coastal areas, these processes can have a great impact on pH. This notion underlines the importance of multiple stressors in the Baltic Sea. Further reading on projected effects of multiple stressors (including atmospheric CO2) can be found in e.g. a review by Reusch et al. (2018).

The effects of OA in the Baltic Sea have mostly been studied at the species level. However, studies on community responses have started to accumulate in recent years. The direction and scale of the effect of OA on the Baltic biota is also largely dependent on other stressors, such as warming, salinity

changes, light and eutrophication. For example, Antti Takolander (2018) found in his PhD-thesis that OA may have some positive effects on the carbon storage of the bladderwrack (*Fucus vesiculosus*), but the effect is small in comparison to other environmental effects. Hence in combination, declining salinity, increasing temperature, intensifying coastal eutrophication and ocean acidification are favoring filamentous algae over the perennial foundation species, the bladderwrack, which endangers the ecosystem services that it provides.

Experimental work supports the conclusion that organisms occurring in Finnish waters could also be adversely affected by OA. For instance, Anna Jansson (2017) showed negative effects on the lifecycle and physiology of the bivalve *Limecola* (previously *Macoma*) *balthica* in her PhD-thesis. Several other studies have investigated effects on e.g. microalgae[2] and zooplankton[3]. More information of the OA effects on the Baltic Sea ecosystem can be found from the project BALSAM main report[4].

2 Brutemark et al. 2015; Spilling et al. 2016; Kremp et al. 2012

3 Vehmaa 2012, PhD-thesis; Engström-Öst et al. 2014

4 Vehmaa & Reinikainen 2021

Literature

Ahlnäs, A. (2015) Kusthabitats naturliga dygns- och säsongsvariationer i pH (Natural diurnal and seasonal variations in pH in coastal habitats). MSc-thesis, Åbo Akademi University, Turku, Finland.

Almén, A.-K. (2017) Copepods in a changing sea: Ocean acidification, long-term changes and short-term variability. PhD-thesis, Åbo Akademi University, Turku, Finland. http://urn.fi/URN:ISBN:978-952-12-3529-0

Brutemark, A., Engström-Öst, J., Vehmaa, A., Gorokhova, E. (2015) Growth, toxicity and oxidative stress of a cultured cyanobacterium (Dolichospermum sp.) under different CO_2/pH and temperature conditions. *Phycological Research* 63. 56-63. https://doi.org/10.1111/pre.12075

Engström-Öst, J., Holmborn, T., Brutemark, A., Hogfors, H., Vehmaa, A., Gorokhova, E. (2014) The effects of short-term pH decrease on the reproductive output of the copepod *Acartia bifilosa* – a laboratory study. Marine and Freshwater Behaviour and Physiology 47, 173-183. https://doi.org/10.1080/10236244.2014.919096

Kremp, A., Godhe, A., Egardt, J., Dupont, S., Suikkanen, S., Casabianca, S. and Penna, A. (2012) Intraspecific variability in the response of bloom-forming marine microalgae to changed climate conditions. Ecology and Evolution 2, 1195-1207. https://doi.org/10.1002/ece3.245

Jansson, A. (2017) Ocean acidification in the Baltic Sea : implications for the bivalve Macoma balthica. PhD-thesis, Åbo Akademi University, Turku, Finland. http://urn.fi/URN:ISBN:978-952-12-3514-6

Spilling, K., Paul, A. J., Virkkala, N., Hastings, T., Lischka, S., Stuhr, A., Bermúdez, R., Czerny, J., Boxhammer, T., Schulz, K. G., Ludwig, A., Riebesell, U. (2016) Ocean acidification decreases plankton respiration: evidence from a mesocosm experiment. Biogeosciences 13, 4707–4719. https://doi.org/10.5194/bg-13-4707-2016

Takolander, A. (2018) Assessing the effects of climate change on Baltic Sea macroalgae – implications for the foundation species Fucus vesiculosus L. PhD-thesis, University of Helsinki, Helsinki, Finland. http://urn.fi/URN:ISBN:978-951-51-4426-3

Reusch, T.B.H., Dierking, J., Andersson, H.C., Bonsdorff, E., Carstensen, J., Casini, M., Czajkowski, M., Hasler, B., Hinsby, K., Hyytiäinen, K., Johannesson, K., Jomaa, S., Jormalainen, V., Kuosa, H., Kurland, S., Laikre, L., MacKenzie, B.R., Margonski, P., Melzner, F., Oesterwind, D., Ojaveer, H., Refsgaard, J.C., Sandström, A., Schwarz, G., Tonderski, K., Winder, M., Zandersen, M. (2018) The Baltic Sea as a time machine for the future coastal ocean. Science Advances 4(5), eaar8195. doi: 10.1126/sciadv.aar8195

Vehmaa, A. (2012) Climate driven changes in temperature, pH and food quality - Effects on copepod reproduction. PhD-thesis, Åbo Akademi University, Turku, Finland. http://urn.fi/URN:NBN:fi-fe201311117335

Vehmaa, A., Reinikainen, M. (2021) Ocean acidification in the Baltic Sea. The project BALSAM main report. The Air Pollution and Climate Secretariat (AirClim), Gothenburg, Sweden. **LINK**