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OCEANOGRAPHY

Ocean acidification research in Estonia: challenges and opportunities

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Abstract. Anthropogenic carbon dioxide (CO_2) emissions to the atmosphere are causing a decrease in the average surface global ocean pH, also known as ocean acidification. Our understanding of the global impacts of ocean acidification on marine ecosystems is growing rapidly. In the Baltic Sea area, however, the vast majority of studies have so far focused on the effects of eutrophication on marine ecosystems. Less is known about the changing carbon chemistry due to increasing CO_2 concentrations in seawater, which could influence Baltic Sea marine ecosystems. The present study focuses on Estonian waters, located in the northeastern part of the Baltic Sea. The aim of this article is to summarize the existing knowledge on ocean acidification research in Estonia as well as to highlight the opportunities and challenges for future research. One key challenge is that the present national marine monitoring of carbonate chemistry in Estonia is not following best practices. The lack of proper seawater carbonate chemistry data in the study area is strongly limiting the ability to design relevant biological experiments and forecast future changes. So far, the effect of ocean acidification on marine biota in the Estonian coastal waters is mostly unexplored. However, several sensors for measurements of carbonate chemistry variables as well as laboratory facilities for conducting ocean acidification experiments are now available.

Key words: ocean acidification, carbon dioxide, carbonate chemistry, acidification experiments, Estonian waters, Baltic Sea, brackish water.

INTRODUCTION

Intensive fossil-fuel burning and deforestation over the last two centuries have increased atmospheric carbon dioxide emissions to 50% above the preindustrial values. The global ocean currently absorbs one third of the released anthropogenic carbon dioxide, fundamentally altering ocean carbonate chemistry including a decrease in the pH or ocean acidification (Raven et al., 2005). Current projections suggest that the average surface ocean pH will decrease by up to 0.4 pH units by the end of this century, a change 100 times faster than anything seen in the past hundreds of millennia (Caldeira and Wickett, 2003). The Intergovernmental Panel on Climate Change published its report on the impacts of climate change (IPCC, 2014) and concluded that it is ‘virtually certain’ that human influence through carbon dioxide emissions has led to significant changes in ocean chemistry resulting in an increased seawater acidity known as ocean acidification. Moreover, a large body of evidence combining palaeo-record investigations, modelling studies, and natural and manipulated field experiments demonstrates that ocean acidification has the potential to significantly impact marine ecosystems (e.g. IPCC, 2014),

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including species extinction (Dupont et al., 2008). Our understanding of the global impacts of ocean acidification on marine ecosystems is growing rapidly. However, despite their critical importance for the development and implementation of adaptation strategies, little is known about the consequences at the local scale. For example, an unexpected diversity of biological responses was observed. Some closely related species respond differently to the same levels of pH, some being negatively impacted while others were not impacted or even responded positively (Wittmann and Pörtner, 2013). The Intergovernmental Panel on Climate Change (IPCC) concludes that 'a pattern of positive and negative impacts emerges (high confidence) but key uncertainties remain in our understanding of the impacts on organisms' (IPCC, 2014). This species-specificity in response to ocean acidification is strongly limiting our ability to forecast future changes (e.g. Vargas et al., 2017).

The Baltic Sea is one of the largest brackish-water areas in the world and it is under a strong influence of human activities. The complexity of environmental factors, characterized by wide regional and seasonal fluctuations, makes this water body a very unique and fragile environment (Feistel et al., 2008). The biogeochemical fluxes and transformations are rather complex in the Baltic Sea due to its numerous sub-basins, layers, and interfaces. The current study focuses on Estonian waters, which are located in the northeastern part of the Baltic Sea (Fig. 1). Estonia is surrounded by the sub-basins of the Baltic: the Gulf of Finland, the Baltic Proper, and the Gulf of Riga. These all differ considerably in their characteristics.

The Gulf of Finland has a complex coastline with an abundant freshwater inflow and nutrient discharge from the east, while its west end is heavily affected by the influx of saltwater from the Baltic Proper. This interplay in combination with the complex topography of the gulf determines a strong east–west salinity gradient (mean surface salinity ranges between 0 and 7) (Soomere et al., 2008). The salinity gradient has a strong impact on the benthic biodiversity: in the eastern part the biological diversity is low and species of freshwater origin dominate. The western part with a higher salinity hosts a unique complex of freshwater, brackish-water, and marine species and its species richness is higher (Peterson and Herkül, 2017).

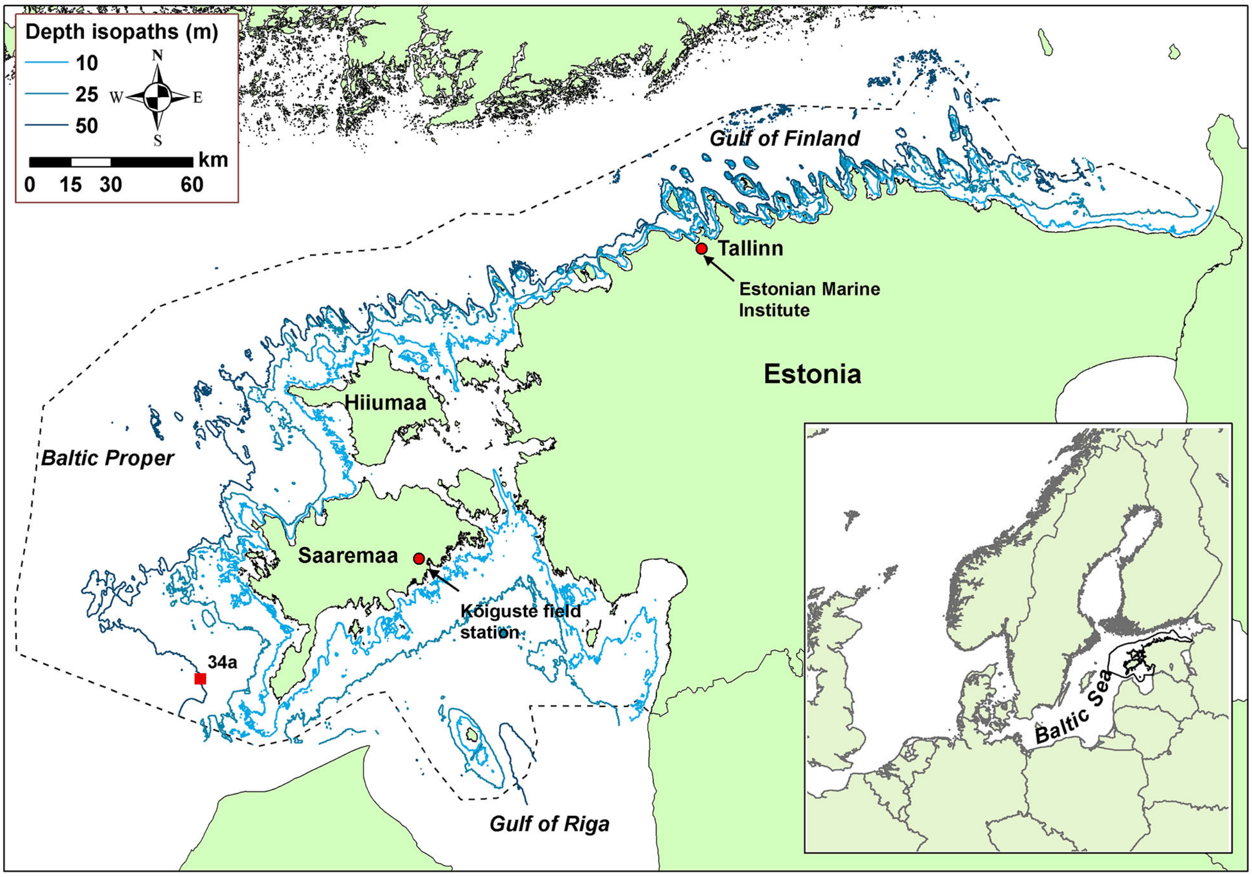

Fig. 1. Location of the Estonian marine waters (the dashed line indicates Estonian exclusive economic zone).

In the Baltic Proper, on the other hand, the salinity ranges around 7 (Lindberg, 2016) and the area is less affected by eutrophication than the other parts of the Baltic Sea. The water column of the central Baltic Proper is permanently stratified. Due to the stratification and temperature seasonality, the mixing of deep water layers is limited, making the bottom layers more exposed to stagnant periods when hydrogen sulphide areas increase (Ulfsbo et al., 2011). As such, the Baltic Proper has the most stable conditions, best underwater light conditions, lowest nutrient concentrations, most evenly distributed salinity concentrations, and also the highest biodiversity out of the three sub-basins surrounding Estonia.

The Gulf of Riga functions ecologically as a transition zone between the nutrient-rich estuarine waters and the Baltic Proper. The cross-front differences in average salinities are not large (typical salinities in the Gulf of Riga are around 5–6.5) (Kotta et al., 2008), but nutrient concentrations may differ two to three times. As the Gulf of Riga is a shallow-water basin, the seasonality in the atmospheric forcing has a direct influence on the dynamics of both surface and deep water (strong vertical mixing during autumn storms). So, the marine species in Estonian coastal waters have to cope with an extreme environment, including high nutrient concentrations, low salinity, poor underwater light conditions, and ice cover.

The marine environment is very important for Estonian society. Historically there have been many different ways people were connected to the sea and the marine environment. Fishing, seal hunting, and marine transportation have had a very important place in the local economy. In 2010 the marine-related economy employed 3.61% of the labour, 3.03% of all taxes came from the marine cluster, and the marine-related enterprises produced 5.5% of the value added produced in Estonia (SEI, 2012). In total 20 581 people were involved in the marine-related economy in 2010. Additionally, marine-related tourism is a very important part of the local recreational business. The marine-related economy is projected to grow in the near future due to developments in offshore wind energy production, marine aquaculture, and tourism (especially in the leisure boating infrastructure).

Compared to the open sea, coastal seas are more vulnerable to changes in seawater carbonate chemistry and it is more difficult to project how complex coastal ecosystems will respond to ocean acidification (Doney et al., 2007; Melzner et al., 2013). It is well known that coastal eutrophication caused by the supply of nutrients such as nitrogen and phosphorus is the main threat to the Baltic Sea (Pyhälä et al., 2014). Over the last 20 years, there have been attempts to limit effects of eutrophication in the Baltic Sea, but until now the expected results have not been achieved.

While hundreds of papers deal with the effect of eutrophication on marine species, less is known about the changing carbon chemistry, which could influence the marine ecosystem in the Baltic Sea area (including Estonian coastal waters). Acidification in nutrient-rich coastal seas such as the Baltic Sea is very hard to detect. Several studies have indicated that eutrophication could increase the susceptibility of coastal waters to ocean acidification as coastal hypoxia contributes to ocean acidification (Cai et al., 2011; Howarth et al., 2011; Wallace et al., 2014).

The aim of this article is to summarize the existing findings of ocean acidification research in Estonia as well as to highlight the opportunities and challenges for future research. It was inspired by the conference and the public lecture 'Global change in marine environment: ocean acidification and warming', held in Tallinn, Estonia, on 28 November 2016 (http://www.sea.ee/avalehekulg/uudised/global-change-in-marine-environment-ocean-acidification-and-warming/). These events gathered ocean acidification experts from New Zealand, Canada, Sweden, and Estonia with the aim to promote awareness on ocean acidification in Estonia, share results, and develop new research thematic and collaboration. Over 80 scientists, students, and policy-makers participated in the conference and 90 citizens attended the public lecture.

OCEAN ACIDIFICATION MONITORING

Forecasting biological and societal impacts has been identified by the international community as one of the most pressing challenges in the field of ocean acidification. Projecting future responses of organisms or ecosystems to ocean acidification relies on our understanding of the present-day carbonate chemistry and its variation. For example, Vargas et al. (2017) showed that contrasting responses to ocean acidification in different populations of the same species could be explained by how much the tested partial pressure of carbon dioxide (pCO_2) scenarios deviated from the variability of the present-day carbonate chemistry. Therefore, it is of critical importance to monitor carbonate chemistry locally and at the right spatio-temporal scale and to model future changes to be able to forecast potential biological consequences.

The Estonian Marine Institute (University of Tartu) is responsible for measurements in the national marine monitoring programme in Estonia. Data are collected from 25 open-sea stations visited six times a year as well as from 18–20 coastal stations visited 10 times a year. The pH is the only parameter of the carbonate system that has been measured since the beginning of the 1990s in accordance with HELCOM requirements using a potentiometric method in pH_{NBS} (National Bureau of Standards scale) (HELCOM COMBINE, 2017; Wedborg et al., 2007; ISO, 2008). A new marine monitoring programme, designed to fulfil requirements of the Marine Strategy Framework Directive (EC, 2008) and HELCOM Baltic Sea Action Plan, will cover other parameters of the carbonate system following Riebesell et al. (2011) best practices guideline.

The Department of Marine Systems (Tallinn University of Technology) made some attempts to conduct pCO_2 measurements in the flow-through systems (FerryBox) installed onboard a ferry cruising between Tallinn and Helsinki in the Gulf of Finland in 2010 (Kikas et al., 2010). They have been conducting continuous pCO_2 measurements since 2017. Since 2018, the pCO_2 measurements (together with pH, CH_4, etc.) have been carried out during the open sea monitoring cruises as a part of the BONUS INTEGRAL project. Additionally, since 2003, a fully automated pCO_2 measurement system has been deployed along the ferry line between the Gulf of Finland (Helsinki) and the Mecklenburg Bight (Lübeck), which also passes through Estonian waters (e.g. Schneider et al., 2014).

Estonian long-term pH data show a significant decreasing trend in the Baltic Proper during the spring–summer period in the bottom layer (Fig. 2). The decreasing pH trend is in accordance with results from Sweden where a significant decrease in the pH for all the seas surrounding Sweden was observed between 1993 and 2007, with the largest changes in the northern part of the Baltic Sea (Andersson et al., 2008). No significant pH trend was found for the Gulf of Finland, although Brutemark et al. (2011) showed that the winter surface pH was decreasing at two Finnish monitoring stations in the western Gulf of Finland between 1971 and 2009. Additionally, a more recent study by Almen et al. (2017) found that the pH decreased both in the winter surface and deep water of the western Gulf of Finland between 1979 and 2015. However, the decrease in the deep-water pH was higher compared to the surface layer at the same stations (pH 0.3 and 0.14, respectively).

The lack of more significant trends in Estonia may be a consequence of the quality of the measurements or of the low spatio-temporal resolution of the data collection that does not allow the high natural variability to be captured. However, far too little attention has been paid to alkalinity measurements in the Estonian waters. Müller et al. (2016) found a consistent increase of surface water alkalinity throughout the Baltic Sea in 1995–2014. Increasing surface water total alkalinity has an important role to mitigate the acidification signal and thus it is essential to measure alkalinity while investigating the behaviour of the CO_2 system of the Baltic Sea (including Estonian waters).

In the shallow Estonian coastal waters, the pH and pCO_2 show a high amplitude of natural variability. In summer in Kõiguste Bay at a depth of 0.5 m, pCO_2 may vary daily between ~150 µatm and 1000 µatm as a consequence of photosynthesis (increasing pH), respiration (lowering pH), and meteorological conditions (e.g. higher light conditions and seasonal warming) (Pajusalu, 2016). Daily changes in the pH can vary about 1 unit in shallow water macroalgal habitats (Fig. 3) (Pajusalu, 2016). The pCO_2 level was measured using an underwater (sensor) automatic CO_2 data logger (CONTROS™ DETECT 2.0, Germany). The pH_{NBS} was measured using a YSI 6600V2 environmental multiprobe (pH electrode YSI 6589FR). However, there might be large differences in pH and pCO_2 changes in different macrophyte communities

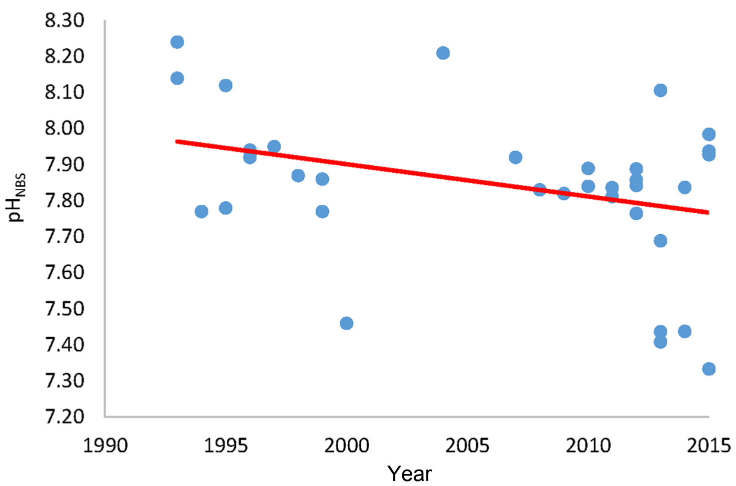

Fig. 2. Spring–summer period (April–September) time series of the pH in the Baltic Proper (station 34a bottom layer of 45 m). Significant trend ($p < 0.05$) based on Mann–Kendall test. The location of station 34a is shown in Fig. 1.

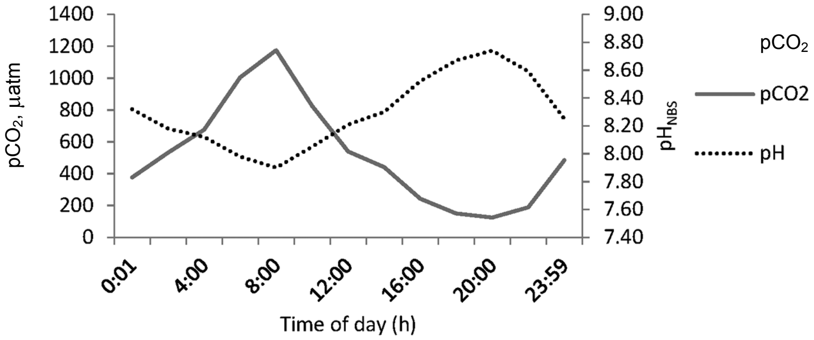

Fig. 3. Natural fluctuation of seawater pCO_2 and pH levels in shallow-water macroalgal habitats in Kõiguste Bay. An example of measurement results from 28.07.2014 (continuous recordings) (Pajusalu, 2016).

(e.g. macroalgae, charophytes, and seagrass) and between different days (unpublished data from the year of 2018 summer). Similarly, numerous studies have found that the diurnal fluctuations in the pH show a noteworthy amplitude in shallow-water macrophyte communities (e.g. Middleboe and Hansen, 2007; Cornwall et al., 2013; Saderne et al., 2013). These variations can also be modulated by direct effects of meteorological conditions leading to variability at longer time scales.

Under a low CO_2 emission scenario, a decrease in the surface water pH of about 0.26 units is forecasted by the end of this century (Omstedt et al., 2012; Schneider et al., 2015). At the same time the sea surface temperature of the Baltic Sea is also projected to increase by approximately 2–4 °C by the end of this century (Meier, 2015). This projected change in the surface water temperature in the Baltic Sea is important to understand the possible future changes in pCO_2 levels as temperature is linked to the seawater carbonate chemistry. The lack of proper carbonate chemistry data in Estonian coasts is strongly limiting the ability to predict future changes.

Challenges

Carbonate chemistry monitoring in Estonia is currently not following the best practices. To monitor ocean acidification, both in the field or in a laboratory set-up, it is critical to report at least two variables of the seawater carbonate system (e.g. dissolved inorganic carbon, total alkalinity, pH, partial pressure of carbon dioxide, or carbonate ion concentration) as well as salinity, temperature, and hydrostatic pressure. All of the variables have their own methodological specification and variables to be used in computations need to be evaluated as different pairs of variables cause a different range of errors in the calculated carbonate parameters. Estonia should move towards adopting the recommendations for best practices (e.g. Riebesell et al., 2011) as well as strategies for ocean acidification monitoring (e.g. Newton et al., 2015).

There are several factors that limit the implementation of these recommendations. First, methods (e.g. Dickson et al., 2007) and measurements uncertainties (e.g. Dickson, 2010) are developed for open ocean measurements; modified methods need to be developed and validated for the analysis of samples collected in shelf seas as well as in coastal and estuarine waters. Dickson's certified reference material is in use in conjunction with other standardization procedures, but it is only valid in waters of high salinity. The average salinity of the Estonian surface sea area varies between 4 up to 7, and currently there is lack of reference material in low salinity waters. To ensure a good quality of data from measurements of carbonate chemistry variables, the understanding of the biogeochemical processes of the local area is required. It is also essential to take into account the input from biologists with knowledge of biological aspects of local marine ecosystems (e.g. commercially and ecologically important taxa).

Secondly, research in Estonia is limited by infrastructure and instrumentation. There is a lack of instruments for the measurement of spectrophotometric pH and dissolved inorganic carbon.

Opportunities

However, facilities are available in Estonia for conducting carbonate chemistry analyses. Also several sensors are available for acidification measurements: pH, pCO_2, O_2 sensors and a pCO_2 sensor in the FerryBox flow-through system. Moreover, Estonia already has long-term pH data together with long-term environmental water quality data.

BIOLOGICAL RESPONSE TO OCEAN ACIDIFICATION

Local adaptation plays a critical role in species sensitivity to ocean acidification (Vargas et al., 2017). Therefore, it is important to collect field and experimental data on key species and ecosystems along the Estonian coast. In Estonia, the knowledge of the effect of ocean acidification on marine organisms is based on short-term mesocosm experiments under natural light and temperature (Pajusalu et al., 2013, 2015, 2016a, 2016b). These studies have focused on the effect of ocean acidification on net photosynthesis of macrophytes in a brackish water environment and were carried out in the shallow semi-enclosed Kõiguste Bay, Gulf of Riga, and northern Baltic Sea. Comparing the effect of marine acidification on three different macroalgal species (*Ulva intestinalis*, *Fucus vesiculosus*, and *Furcellaria lumbricalis*), Pajusalu et al. (2013) observed the highest photosynthetic response to marine acidification for the fast-growing filamentous alga *U. intestinalis*. The red alga *F. lumbricalis* showed a small increase in photosynthesis while *F. vesiculosus* showed no response to marine acidification. Similarly, three tested soft-bottom charophyte species, *Chara tomentosa*, *C. aspera*, and *C. horrida*, showed a species-specific response to marine acidification (Pajusalu et al., 2015). Field based experiments showed that *C. horrida* and *C. tomentosa* exhibit increased net photosynthesis while the response of *C. aspera* to marine acidification is minor in a brackish-water environment. Pajusalu et al. (2016a) demonstrated that marine acidification enhances the photosynthesis of the macroalgae *F. lumbricalis*. In addition, Pajusalu et al. (2016b) investigated the effect of marine acidification on a population of the seagrass *Zostera marina* from the same region and found that marine acidification alone does not enhance the net photosynthesis of this seagrass, but it modulates the effect of temperature and light availability.

In the Baltic Sea, the studies describing the effects of elevated pCO_2 on macrophytes have given mixed results (e.g. Eklöf et al., 2012; Graiff et al., 2015; Al-Janabi et al., 2016a, 2016b). For instance, a study from the Kiel Fjord, southwestern Baltic Sea, showed increased growth in *F. vesiculosus* germlings in summer conditions (Al-Janabi et al., 2016a). At the same time, a study from the same area found reduced growth of *F. vesiculosus* germlings under elevated pCO_2 in combination with the warming effects (Al-Janabi et al., 2016b).

The occurrence of drifting algal mats has been a widespread phenomenon in Estonian coastal waters (based on databases of the Estonian Marine Institute, University of Tartu; Paalme et al., 2004). So far, this phenomenon has been mainly associated with an increased nutrient loading of coastal sea areas. Pajusalu et al. (2013) showed that the 'CO_2 fertilisation effect' is caused by increasing CO_2 concentrations in seawater accelerating the growth of filamentous fast growing macroalgae that form drifting algal mats in the Estonian coastal waters. Perhaps the most glaring gap in our knowledge surrounds this 'CO_2 fertilisation effect' and there is a need to pay more attention to ocean acidification as it may have an important impact on marine life in the Estonian coastal waters.

In addition, as an example, most macrophytes already grow at the limit of their salinity tolerance in the NE Baltic Sea. This may not only increase their sensitivity to other stressors such as ocean acidification but models predict that future salinity levels may become lower in the Baltic Sea (Meier, 2015) leading to complex negative interaction between salinity and ocean acidification (Boyd et al., 2018).

Challenges

For biological experiments, different technologies are available to manipulate the carbonate chemistry and some can be easily implemented. For example, the 'kit' developed by Global Ocean Acidification Observing Network (GOA-ON), the Ocean Foundation, the International Atomic Energy Agency (IAEA), and the Ocean Acidification International Coordination Centre (OA-ICC) includes inexpensive pH-stat systems allowing manipulation of the pH in a wide range of experimental systems from small aquariums to large-scale mesocosms (e.g. Dupont et al., 2008). For this reason, the main limitation is the available infrastructure: scarcity of fully equipped biology laboratories, marine stations, access to seawater, etc.

Opportunities

Laboratory facilities are available at the Estonian Marine Institute in Tallinn for conducting small-scale laboratory experiments. In addition, there are mesocosms to carry out short-term biological experiments at the Kõiguste field station located in Saaremaa Island. These facilities provide a range of equipment including CTDs, light loggers, and a chemistry analyser for measurements of seawater nutrient concentrations. There is also SCUBA diving equipment for the collection of samples and several research vessels/boats for fieldwork.

Several international initiatives are working toward simplified methodologies and improved capacity building for ocean acidification research and monitoring. These include the OA-ICC, the Ocean Foundation, the IAEA, and the GOA-ON. There is also an integrated Carbon Observation System (ICOS), which is a European research infrastructure, includes a marine component, and could be a relevant framework for carbon system studies. These and other ocean acidification research communities are working toward the development of simplified methodologies for carbonate chemistry measurements (‘kits’) as well as the organization of training for ocean acidification researchers (taking into account practical limitations of hosting institutions). Estonia is part of this community as one of the 367 members from 68 countries. This will provide Estonia with opportunities to develop the needed capacity and collaboration and use data in an optimal way. For example, participation in or hosting an international calibration exercise covering a range of regional water types with different salinities and nutrients loads would be highly valuable.

Long-term water quality data (e.g. oxygen, nutrient concentrations, salinity, temperature) and plankton community survey data are already available in Estonia. Mooring stations are also collecting real-time data on oxygen, temperature, and salinity. This is a unique opportunity to expand carbonate chemistry measurements and use these as a baseline for monitoring chemical and biological impacts of ocean acidification.

Additionally, scientific cooperation with countries that have long-term ocean acidification research programmes will help to further develop research in Estonia. Law et al. (2017) review the current understanding of ocean acidification and its impacts in New Zealand waters, regional and temporal trends in pH, followed by an assessment of the sensitivity of different biotic groups. Their work began in 2006 and the Ocean Acidification Research Theme established in 2007 at the University of Otago was the key in the development of ocean acidification research in New Zealand (see https://www.otago.ac.nz/oceanacidification/index.html). The theme supports research, funds yearly workshops, and promotes collaboration between biologists and carbonate chemists. Collaboration and an inclusive approach to research has built a broad research field in New Zealand, which includes a nationwide monitoring network that includes a long-term transect extending from neritic to oceanic water masses, laboratory facilities that can carefully manipulate seawater pH, and research that extends across a range of commercially and ecologically important taxa and biogeochemical processes (Law et al., 2017). Recent workshops and student and researcher exchanges between Estonia and New Zealand are helping to quickly develop capacity in Estonia and share successful approaches to research in this field.

CONCLUSIONS

The Global Ocean is playing a key role in the Earth’s climate and provides countless services to society in all aspects of life (e.g. cultural, historical, biological, and economic) (Dupont and Fauville, 2017). In Estonia, there are long-standing traditions in coastal fisheries. There are many different ways in which people are engaged with the marine environment such as fishing, seal hunting, marine transportation, and tourism. In recent years, there has been an increasing interest in offshore wind energy production and marine aquaculture. Three major legislative instruments are driving the marine environmental monitoring activities in the Baltic Sea. These are European Directives: Marine Strategy Framework Directive (MSFD) (EC, 2008), Water Framework Directive (EC, 2000), and Habitats Directive (EEC, 1992). None of these instruments requires the assessment of the status of the sea area using ocean acidification parameters except for the MSFD (Annex III), which requires the characterization of the marine environment by also describing the content of organic carbon and dissolved gases (pCO_2, O_2) and pH. However, a new marine monitoring programme, designed to fulfil requirements of the MSFD and HELCOM Baltic Sea Action Plan, will cover also parameters of the carbonate system following best practices.

More recently, scientists and societal actors have organized a bottom-up movement, which has ultimately led to the United Nations General Assembly proclaiming a Decade of Ocean Science for Sustainable Development (2021–2030) (Visbeck, 2018). The United Nations also developed the ‘Transforming our world: the 2030 Agenda for Sustainable Development’ in a process involving 193 Member States. This includes 17 global ‘Sustainable Development Goals’ (SDG) that have been recently adopted in New York. Goal 14 focusses on the sustainable use of oceans, seas, and marine resources. More specifically, goal 14.3 aims at ‘minimizing and addressing the impacts of ocean acidification, including through enhanced scientific cooperation at all levels’. To fully address this target, Estonia as well as most countries in the world will have to invest into infrastructure, equipment, training, and research. This will require increased national and international cooperation at all levels, from multidisciplinary science to policy actions and increased awareness.

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Ookeanide hapestumise uuringud Eestis: väljakutsed ja võimalused

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Ookeanide hapestumine on üleilmne keskkonnaprobleem, mis on otseselt seotud inimtekkelise süsihappegaasi (CO_2) emissiooniga atmosfääri. Hapestumise all mõistetakse ookeanide pH langust, mida põhjustab peamiselt suurenenud atmosfäärse süsinikdioksiidi neeldumine pinnavees. Asjakohaste teadmiste hulk ookeanide hapestumise mõjust mereökosüsteemidele suureneb tehtud uuringute põhjal kiiresti. Käesoleva ajani on märkimisväärne osa Läänemere-teemalistest teadusuuringutest keskendunud eutrofeerumise mõjule mereorganismidele. Samal ajal on vähem teada, kuidas CO_2 emissioonist põhjustatud merevee happesuse suurenemine mõjutab Läänemere ökosüsteemi. Käesoleva töö eesmärk on anda ülevaade olemasolevatest teadmistest ja tehtud teadusuuringutest ookeanide hapestumise teemal Eesti merealas, samuti arutleda hapestumise uuringute võimaluste ning väljakutsete üle tulevikus. Eestil on riiklik rannikumere seire programm, kuid praegu veel ei mõõdeta selle raames merevee hapestumise näitajaid (süsihappe-gaasi partsiaalrõhku, leeliselisust, anorgaanilist süsinikku ja osas veekogumites puuduvad ka pH mõõtmised). Andmete puudus piirab ennustusmudelite tegemist Eesti mereala kohta. Samuti on praktiliselt uurimata merevee happesuse suurenemise mõju Eesti rannikumere elustikule. Tuleviku perspektiivi vaadates on Eestis olemas laborid merevee hapestumise katsete/eksperimentide läbiviimiseks ja erinevad CO_2 ning pH sensorid süsinikukeemia näitajate mõõtmiseks.