PHYSICAL CHARACTERISTICS AND OCEAN ACIDIFICATION

Ocean acidification

Scottish Government
Riaghaltas na h-Alba
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13 CLIMATE ACTION

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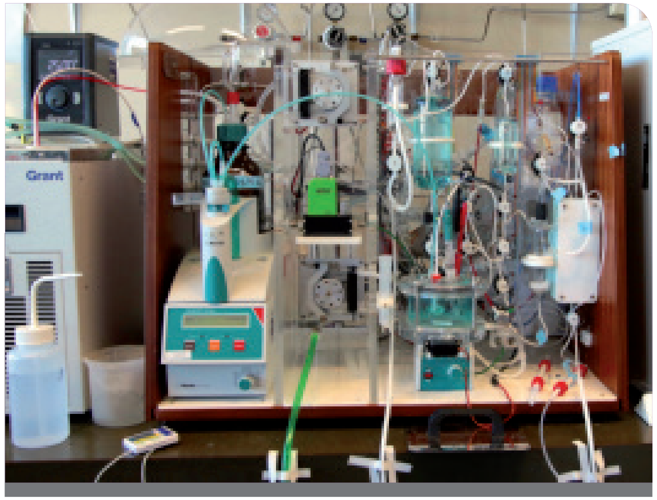
Key message

The Scottish ocean acidification dataset consists of 5 years of measurements at Stonehaven, north-east Scotland. This is insufficient to calculate accurate trends in overall pH. The data are consistent with both UK and global data for coastal/shelf sea areas with the carbonate system having a strong seasonal cycle linked to biological activity.



Background

Ocean acidification (OA) is the decrease in the pH of the ocean caused by an uptake of carbon dioxide (CO_2) from the atmosphere which has been produced by human activities (anthropogenic). When carbon dioxide dissolves in seawater a chemical reaction occurs and hydrogen ions are released resulting in a decrease in the waters pH. Associated with this change are increased concentrations of bicarbonate ions (HCO_3^-) and decreased concentrations of carbonate ions (CO_3^{2-}), which control the saturation state of calcium carbonate ($CaCO_3$) (Figure 1).

Calcium carbonate minerals such as calcite and aragonite are used by many marine organisms for production of their shells. Sabine *et al.*, (2004) reported that a third of the anthropogenic carbon dioxide produced since pre-industrial times has been absorbed by the ocean, resulting in a decrease in pH of approximately 0.1 units. The pH is a logarithmic scale and this equates to an increase in acidity of approximately 30%. Although the input of carbon dioxide from the atmosphere has only small spatial variation, some marine regions will be more rapidly affected, with the susceptibility of seawater to change dependent on the chemical composition, depth and temperature (Hoegh-Guldberg *et al.*, 2018).

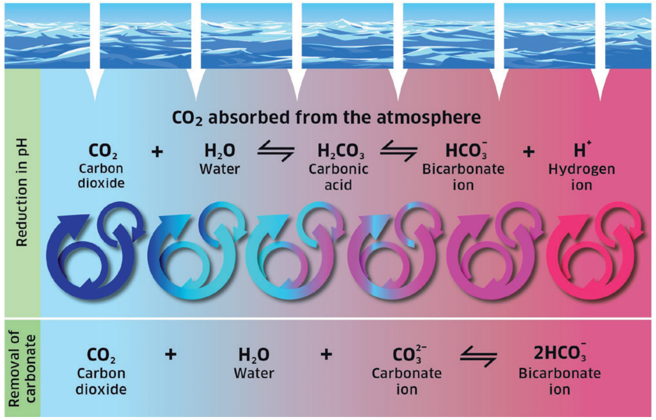


Figure 1.

The carbonate system of seawater and the potential impact as a result of absorption of CO_2 from the atmosphere. Source Baxter *et al.*, (2011).

This is a 'litmus paper' diagram; the colour changes from blue to red as more carbon dioxide (CO_2) is absorbed and the carbonate equilibria shift to release more hydrogen ions.

The effects of the decrease in seawater pH and changes to the saturation states of calcium carbonates may be corrosive to the shells, skeletons and impact larval stages of some marine organisms. Calcifying organisms such as pelagic gastropods, bivalves and corals may be particularly affected (Figure 2).

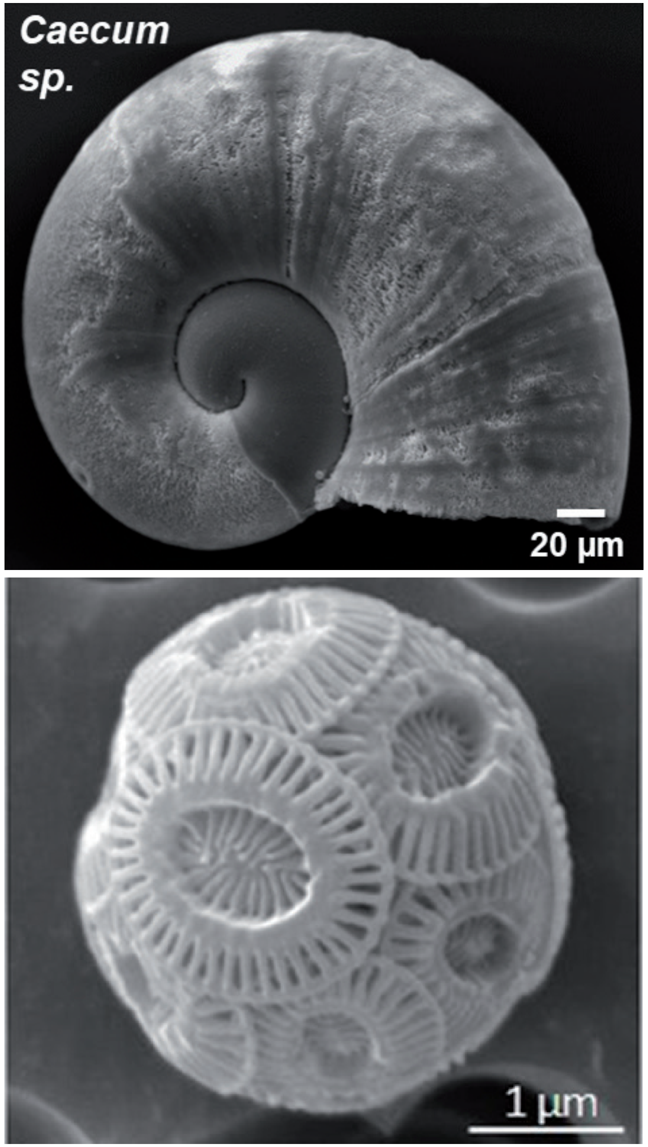


Figure 2.
Scanning electron microscope images of a pelagic gastropod larva (top picture) and *Emiliania huxleyi*, the dominant coccolithophore at the SCObs monitoring site at Stonehaven (bottom picture).

Results

There are very few monitoring data for carbonate chemistry parameters in Scottish waters. Sustained monitoring is limited to a single site within the North-east SMR at Stonehaven (Figure 3). Remaining data are from short term research projects with limited repeatability.

Water samples have been collected weekly, where possible, from the Stonehaven Scottish Coastal Observatory site (SCObs) (Bresnan *et al*., 2016), from both surface (1 m) and bottom (45 m) waters since November 2008 for carbonate chemistry analysis, with data reported in this assessment covering the period November 2008 – December 2013, with gaps in the monitoring during 2011 and 2014 - 2017 (details provided in assessment method section) (Figure 4). Water samples collected from 2018 to present await analysis (see knowledge gaps section).

The calculated pH (Total Scale) at the site varied from 8.2 to 7.8. Variability was greatest in spring/summer due to biological uptake of carbon dioxide by phytoplankton before returning to less variable levels in winter with a calculated pH (Total Scale) of ~ 8.05. The pH at Stonehaven varies inter-annually, due to a number of factors such as sporadic freshwater inputs. This is particularly the case in 2013 when the calculated pH at the site showed lower values.

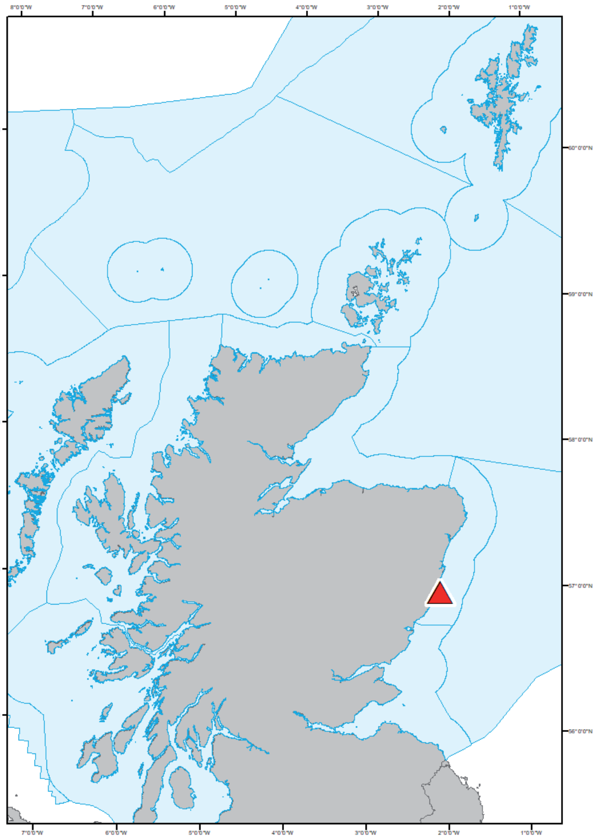


Figure 3:
Ocean acidification Scottish Coastal Observatory (SCObs) sampling Stonehaven site location (red triangle). Blue lines around Scotland indicated the Scottish Marine Regions (SMRs, coastal) and Offshore Marine Regions (OMRs).

The saturation state calculated from the carbonate chemistry parameters was greater than 1 in all samples, indicating that seawater at Stonehaven was supersaturated with respect to carbonate. Therefore carbonate concentration is not a limiting factor for the formation of shells of marine organisms throughout the year. However, shell dissolution was detected in pelagic gastropods, mainly in early life stages, associated with decreases of aragonite during winter months.

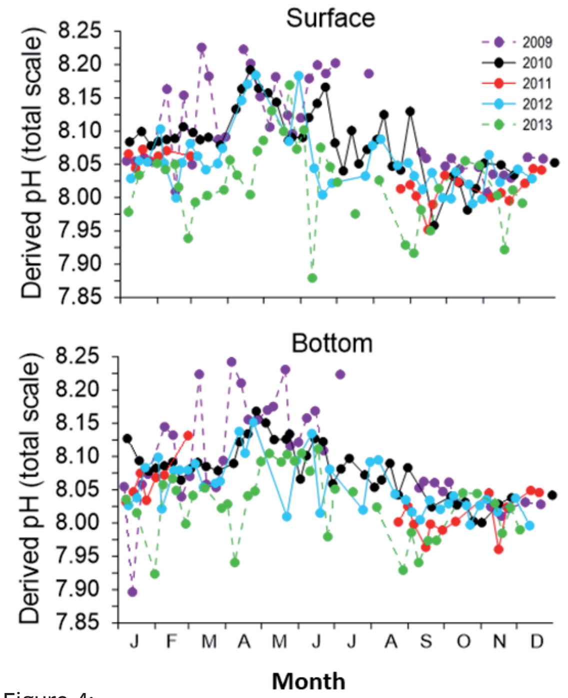


Figure 4:

Plot of calculated pH (total scale) at the Stonehaven monitoring site. The letters on the X-axis refer to the first letter of the month beginning with January.

Conclusion

The data show a strong seasonal carbonate chemistry cycle at the Stonehaven site with variability in the calculated pH being greatest during spring and summer, the period when uptake of carbon dioxide by phytoplankton is greatest.

The Stonehaven hydrography is characterized by a coastal southward flow, with sporadic inputs of freshwater and offshore Atlantic waters influencing the site. The pH varies inter-annually, particularly in surface waters, and this may be linked to a number of factors, such as runoff and hydrography.

The saturation state, of both aragonite and calcite, calculated from the carbonate chemistry parameters, was > 1 in all water samples, indicating that seawater at Stonehaven was supersaturated with respect to calcium carbonate, although shell dissolution of pelagic gastropods was observed mostly during the winter months.

The carbonate chemistry variability observed at the single sustained monitoring site and relation to phytoplankton dynamics highlights the need for consistent, multi-parameter, long-term monitoring to differentiate natural variability from that driven by an anthropogenic input in dynamic coastal waters.

Knowledge gaps

There are very few sustained carbonate chemistry monitoring data from Scottish waters, and those that are available have been collected over a very short timescale, < 20 years. To differentiate natural seasonal and inter-annual variation from anthropogenic driven impacts, data would be required over a multi-decadal timescale, it has been suggested 25 years of data are required (Fay & McKinkley, 2013).

There are currently no assessment criteria in place for the status assessment of carbonate chemistry parameters and no indicator or potential indicator species groups recommended for monitoring ecosystem response to OA. These will require development for future assessments.

Status and trend assessment

There is currently only one sustained monitoring site covering the Greater North Sea. This site has data collected over a limited time period and therefore it is not possible to undertake a traffic light assessment currently.

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