MCCIP Marine Climate Change Impacts Partnership

Topic

Ocean Acidification

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Executive summary

The uptake of **anthropogenic** carbon since 1750 has led to the oceans becoming more acidic with an average decrease in pH of 0.1 units. Surface ocean and UK coastal water pH will continue to rapidly decline in the future as they take up more atmospheric CO_2.

Although the effects of the current reduction in pH on the marine biosphere are as yet undocumented this is due, in part, to lack of research in this area. However, unless we substantially and urgently reduce CO_2 emissions, experiments, observations and modelling indicate that future reductions in ocean acidity will have major negative impacts on **aragonitic and calcitic** (shell/skeleton) forming organisms this century and their dependent species. There is growing evidence that the physiology (e.g. growth and reproduction) of adults, larvae and juveniles of some species are sensitive to acidification. Impacts of decreasing pH on key biogeochemical processes other than calcification is theoretically possible and serious (e.g. impact on **nutrient speciation**, primary production and nutrient, carbon and sulphur cycling) but there has been little research on this. The knock-on effects of ocean acidification on marine ecosystems, **biogeochemical cycles**, food webs and biodiversity could be considerable but difficult to quantify. Reducing CO_2 emissions is the only way of reducing ocean acidification.

Nearly half of the CO_2 derived from burning fossil fuel has already been absorbed by the surfaces of our seas and oceans and more will be absorbed in the future as we continue to increase our CO_2 emissions to the atmosphere. The ocean uptake of CO_2 is effectively buffering even more serious climate change than that predicted by clear evidence-based scientific consensus. Continued acidification will reduce the ability of the ocean to take up CO_2 from the atmosphere, which will have feedbacks to future climate change, further accelerating the accumulation of CO_2 in the atmosphere.

Full review

Atmospheric carbon dioxide concentrations have increased from 280 ppm (parts per million) to around 380 ppm over the last 250 years through human activities, in particular the burning of fossil fuels. Projections are that CO_2 concentrations will increase substantially to 540-970 ppm by the end of this century as fossil fuel reserves are consumed. However, 28% of all anthropogenic CO_2 (burning forest, fossil fuels, cement production, land use changes etc) and nearly half of the CO_2 derived from burning fossil fuel has already been absorbed by the surfaces of our seas and oceans and more will be absorbed in the future as we continue to increase our CO_2 emissions to the atmosphere (Sabine *et al.,* 2004). The ocean uptake of CO_2 is effectively buffering even more serious climate change than that predicted by clear evidence-based scientific consensus (e.g. IPCC, 2001 & 2007 a, b). However, there is a “cost”: as CO_2 reacts with seawater to form carbonic acid, the seas are becoming more acidic (Caldeira & Wickett, 2003). A strong scientific consensus is emerging about the rate and degree of change in acidity (measured in pH units) that will be experienced by surface waters (summarised in Royal Society, 2005; and for the first time reported in IPCC, 2007 a, b) should CO_2 emissions continue at the same rate. The simplicity of the chemical reaction of CO_2 with seawater makes it very predictable on global (Orr *et al.,* 2005) and more local scales (Blackford & Gilbert 2006). These models show that there has already been a decline of 0.1 pH unit (a 30% increase in H+) since pre-industrial times and surface waters may experience a total reduction of around 0.7 pH units should all fossil fuels be burnt.

It is the impact of this rate of change as well as the level of change on marine organisms and ecosystems that concern marine scientists all around the world (Royal Society, 2005; JGR, 2005; Turley *et al.,* 2006; Kleypas *et al*., 2006; Haugan *et al.,* 2006) as pH has been relatively stable for over 20 million years. Calcareous (shelled) organisms are common in the sea (e.g. warm and cold water corals, some plankton, shellfish and sea urchins) and there is increasing evidence indicating that their ability to produce their shells or skeletons will be reduced this century if CO_2 emissions continue at “business as usual” projected rates (Hoegh-Guldberg, 2005; Kleypas, 2006; Guinotte *et al.* 2006; Turley *et al*., 2007; IPCC, 2007b; Fischlin *et al.* 2007). Indeed, it is predicted that 70% of cold-water coral ecosystems will be in waters undersaturated in aragonite by the end of this century (Guinotte *et al.,* 2006). There is growing evidence that growth rate, reproduction and development of eggs, juveniles and larval stages of some planktonic and benthic organisms may be affected (Kurihara *et al.,* 2004 a, b; Kurihara & Shirayama 2004; Michaelidis *et al.* 2005; Miles *et al.* 2006).

Whilst we begin to recognise the potential impacts of increasing acidification in our oceans (e.g. a recent report by OSPAR: Haugan *et al.,* 2006: Kleypas *et al.* 2006) we have little direct evidence of what changes are actually occurring in waters around our coasts. Seawater pH does vary around UK waters because of natural processes; however, model predictions demonstrate that pH change this century due to significant atmospheric CO_2

increases exceeds this natural variation (Blackford & Gilbert, 2007). These predictions for European shelf waters agree with those for open oceans (Caldeira & Wicket, 2003; Orr *et al.* 2005). How these chemical changes might affect marine food webs and **biogeochemical cycles** are of concern (Haugan *et al.,* 2006) but are less certain because of their complexity. For instance, many other important global biogeochemical cycles (e.g. of carbon, nutrients and sulphur) and ecosystem processes (changes to community structure and biodiversity) other than calcification may be vulnerable to future changes to carbonate chemistry and to declining pH. Research in these areas is very much in its infancy.

In addition, the combined impacts of ocean acidification and climate change (e.g. increased seawater temperature, thermal stratification, storminess, mixing, currents) on UK marine waters have not yet been addressed.

There is a scientific consensus that CO_2 emissions need to be reduced urgently and drastically so that temperature increase and acidification are stabilised to sub-critical levels (IPCC 2007 a,b; Fischlin et al. 2007). Research is required to identify potential thresholds or “tipping points” to help in the determination of these sub-critical levels.

Confidence assessments

‘What is already happening’ - High

The uptake of anthropogenic carbon since 1750 has led to the oceans becoming more acidic with an average decrease in ph of 0.1 units (IPCC, 2007a) (High certainty). However, the effects of current, observed ocean acidification on the marine biosphere are as yet undocumented (IPCC, 2007b) due, in part, to lack of research in this area and long term time series.

High confidence, that ocean pH is changing and will change in the future and unless we substantially and urgently reduce CO_2 emissions that these will have major impacts on aragonitic organisms this century.

‘What could happen in the future’ – Medium

We have a moderate level of confidence that this will have a knock-on effect on marine ecosystems and foodwebs, according to evidence from modelling and experimental observations.

Impacts of pH on other organisms than aragonitic and calcitic organisms is theoretically serious (e.g. impact on **nutrient speciation** and therefore primary production and biodiversity) but there has been little research on this.

We have a high degree of confidence that reducing emissions is the only way of reducing ocean acidification.

Knowledge gaps

Many, and in all areas, as this field is very much still emerging, they are mentioned briefly in the text above and more specifically in Royal Society, 2005; JGR, 2005; Haugen *et al.*, 2006; Kleypas *et al.*, 2006; Blackford *et al.*, 2007.

Commercial impacts

Potentially fisheries will be impacted through changes to marine productivity and biodiversity and shell fisheries through reduced physiological functioning such as growth rate, reproduction and survival/recruitment of larvae and juveniles.

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