Ocean Acidification: An Emerging Threat to our Marine Environment

SeaChange
Casadh na Taoide

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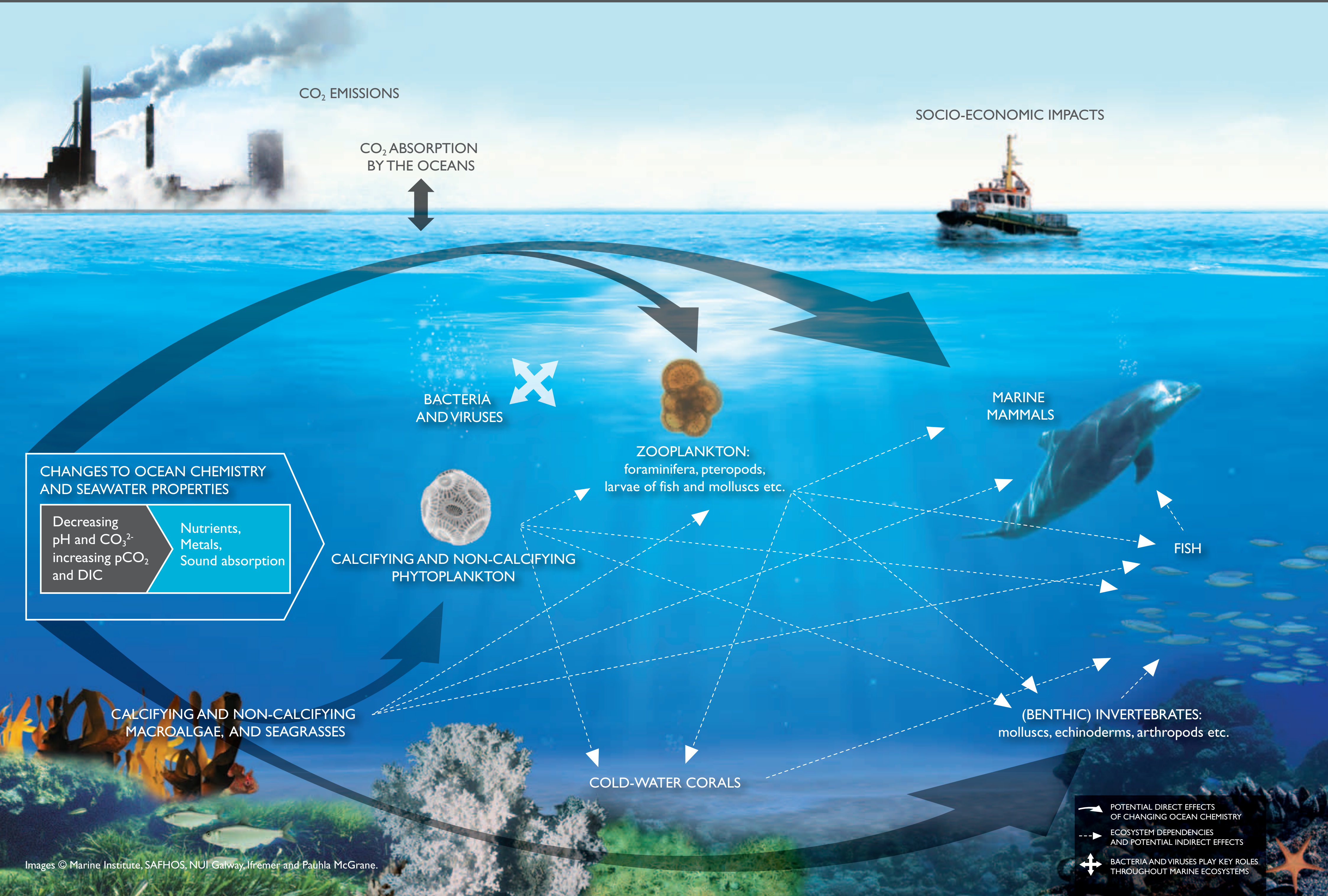
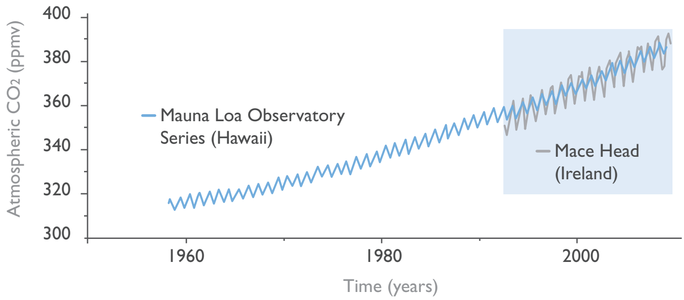
OCEAN ACIDIFICATION MAY HAVE DIRECT AND INDIRECT IMPACTS ON MARINE LIFE



What is Ocean Acidification?

An international scientific consensus is emerging that rapid and unprecedented changes are occurring to fundamental ocean chemistry. This is often called the "other CO_2 problem".

- Atmospheric carbon dioxide (CO_2) is currently about 30% higher than the pre-industrial level.



Measurements at Hawaii show steadily increasing atmospheric CO_2 over five decades. Measurements over 17 years at the NUIG Mace Head atmospheric research facility confirm this trend. *(Prepared from information courtesy of Dr. Pieter Tans, NOAA/ESRL and Michel Ramonet, IPSL, France, and Colin O'Dowd, NUI Galway.)*

- The oceans have absorbed nearly a third of anthropogenic CO_2 emissions since the industrial revolution. This is altering the equilibrium of inorganic carbon in seawater and reducing the pH . This process is referred to as ocean acidification.
- Absorption of CO_2 has resulted in a reduction of the pH of surface ocean waters from 8.2 to 8.1 pH units, equating to an increase in acidity of approximately 30%. This is occurring at a rate 100 times faster than any previous change for millions of years.
- With an IPCC 'business as usual' scenario a further drop of 0.4 ± 0.1 pH units is forecast by 2100 due to a doubling of atmospheric CO_2. This is a change which has probably not occurred for more than 20 million years.

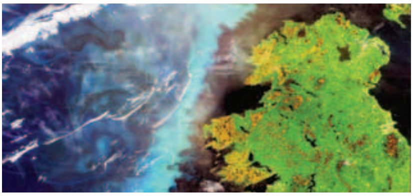
How does Ocean Acidification threaten marine life and fragile ecosystems?

The potentially serious ecological consequences are only just beginning to emerge. The extent of impact will depend on the ability of species to adapt to an unprecedented, rapid change in ocean chemistry.

Calcifying marine organisms are most obviously at risk, due to impaired building of calcium carbonate (aragonite or calcite) shells or skeletons. In expanding zones of calcium carbonate under-saturation, shells and skeletons will have a tendency to dissolve.

- Calcareous organisms at risk include calcifying phytoplankton (coccolithophores), planktonic foraminifera and pteropods, tropical and cold water corals, coralline algae including maërl, bivalves and gastropod molluscs (e.g. mussels, oysters, clams) and echinoderms (e.g. star fish, sea urchins). The responses of individual species will be varied and often complex.

- As calcifying organisms play key roles in the oceanic food web, the potential for large scale ecosystem-wide effects is of concern.
- A range of field observations suggest that ocean acidification is already having a detectable impact on a number of marine calcifiers. Natural cold CO_2 seeps also provide evidence of ecosystem changes at projected pH levels, providing an insight into the changes that can be anticipated.
- Geological records of a past ocean acidification event, which occurred over much longer time-scales, coincide with the mass extinction of some calcareous marine organisms.
- The depth to which calcifying organisms will be found will become shallower as *saturation horizons* (i.e. the depth below which dissolution of aragonite or calcite is favoured over precipitation) rise. This may limit habitats available to calcareous marine organisms such as cold-water corals on the Atlantic shelf margins. It is only in recent years that we have begun to appreciate the extent of cold-water coral reefs in Irish waters and little is known about these ecosystems compared to their tropical counterparts.



Ocean acidification may affect important calcifying species such as cold-water corals (left) on the continental slopes and coccolithophores, calcifying phytoplankton that can form massive oceanic blooms (right).
Coral photograph taken by Marine Institute's deepwater ROV Holland I. © NUIG (courtesy of Anthony Grehan).
Satellite image courtesy of ESA/Envisat | Instrument: MERIS | Acquisition: Jun-2006.

There are likely to be many other direct and indirect consequences of ocean acidification on critical ecosystem processes and functioning, including effects on primary productivity and nutrient chemistry:

- Ocean acidification may have direct and indirect effects on a range of physiological processes in marine organisms such as algal (phytoplankton and seaweeds) primary production and nutrient uptake, reproductive ability and survival rates of different developmental stages (eggs, larvae and juveniles) and host-pathogen relationships.

How will Ocean Acidification affect us?

Ocean acidification is a threat to industries relying on marine biological resources such as fisheries and aquaculture. Additionally there will be complex climate interactions which will influence climate change.

- The oceans provide essential services to mankind. They play a key role in earth's biogeochemical cycling, contain much of the planet's biodiversity and provide resources and livelihood for coastal inhabitants.
- As the pH of surface ocean waters decreases, the ability of the oceans to absorb atmospheric CO_2 is lessened, exacerbating global warming.

- Other ecosystem responses may influence climate processes and, vice versa, climate change may also influence the rate of ocean acidification.
- Broad ecosystem impacts could do untold damage to economically important fisheries. Ocean acidification needs to be considered within a whole-ecosystem approach to fisheries management.
- Economically important calcareous species in aquaculture may be affected, including mussels and oysters.
- The adaptive ability of different species and ecosystems, the fisheries industry, coastal communities and end-users of marine products and services, including seafood consumers, will dictate the economic costs of ocean acidification.


Sustainable harvesting of marine living resources relies on healthy ecosystems.
Photos Left – Right: Fishing Image © Marine Institute (courtesy of Fisheries Science Services)
Mussels © Marine Institute

What needs to be done?

Ocean acidification is a global problem and a direct consequence of increasing atmospheric CO_2 levels. It needs to be addressed in climate change and environmental policy development at national and international level.

- Curbing CO_2 emissions is the most immediate action required and future international agreements on emission targets should consider the potentially serious ecological and socio-economic consequences of acidification.
- There are no practical methods to reverse ocean acidification and natural recovery of the ocean's chemical equilibrium will require tens to hundreds of millennia.
- Some strategies suggested for mitigating climate change, such as "geoengineering" solutions to reduce surface solar radiation, may not be effective for mitigating ocean acidification as they do not influence atmospheric CO_2 levels.
- A number of methods are currently being considered for the capture of CO_2 and storage of carbon in the oceans or sub-seabed. The risk to the marine environment needs to be understood.
- The environmental status of all marine waters is threatened by ocean acidification. Ireland, in cooperation with other European maritime states, has a legal obligation to protect the North-east Atlantic through several international conventions, for example OSPAR (1992), and EC directives such as the Marine Strategy Framework Directive (2008),
- A much better understanding of the biological and ecosystem impacts of ocean acidification is required to allow predictions of potential socio-economic consequences. Expanded monitoring and research is essential to underpin development of mitigation and adaptation policies.

Impacts of Increased Atmospheric CO_2 on Ocean Chemistry and Ecosystems

A National University of Ireland Galway & Marine Institute collaborative SSTI-funded Project (2008 – 2010) under the Marine Institute Sea Change Programme

The objectives of the project include:

- initiation of research into ocean carbon processes in Irish shelf sea waters including the investigation of air-sea CO_2 fluxes;
- establishment of high-quality chemical measurement capabilities to describe dissolved inorganic carbon (DIC) chemistry in seawater;
- deployment of automated systems on moorings and on the *R.V. Celtic Explorer* to measure CO_2 in seawater;
- consideration of the potential indicators of ecological impacts of ocean acidification; and,
- formulation of recommendations for future Irish research and long-term monitoring.

Specific activities within the project include:

- development of capabilities for making specialised high precision measurements of the carbonate system and subsequent determination of accurate pH;
- deployment of a meteorological and ocean chemistry buoy at Mace Head. This provides continuous sea surface measurements for various parameters to parallel atmospheric measurements made at the NUIG Mace Head atmospheric research centre;
- measurements of air-sea CO_2 fluxes at Mace Head and on research surveys using specialist equipment installed on the *R.V. Celtic Explorer*; and,
- seasonal baseline surveys of the carbonate system. Sampling is undertaken on transects across the shelf and in deeper waters of the Rockall Trough and in the Porcupine Seabight on board the *R.V. Celtic Explorer*. These studies are tied into broader multidisciplinary surveys to facilitate cost-effective collection of integrated datasets. DIC, dissolved oxygen and nutrient data are collected alongside other oceanographic data.

For further information see Marine Institute Foresight Report No. 6 2009. The report was prepared as a deliverable within the National University of Ireland (NUI) Galway – Marine Institute project Impacts of increased atmospheric CO_2 on marine chemistry and ecosystems. The project is SSTI funded under the Marine Institute Sea Change research initiative.

Left to right: The *R.V. Celtic Explorer*, the Marine Institute's inshore monitoring buoy at Mace Head and the NUIG atmospheric research facility at Mace Head have been deployed to study air-sea processes and ocean chemistry.
Photos Left – Right: C. Explorer © David Brannigan, OceanSport, courtesy of the Marine Institute Mace Head Bouy © Marine Institute - courtesy of James Ryan and Mace Head Research Facility © NUIG.

Ocean Acidification – Essential Facts for Policy Development

Ocean acidification is caused by increasing anthropogenic CO_2 levels in the atmosphere and the subsequent uptake by the oceans. Recent research has shown that this phenomenon has resulted in a 30% increase in global surface ocean acidity since the industrial revolution. It is projected that the acidity of seawater will increase a further 120% by 2100.

Impact on Ocean Ecosystems: Although the overall impact of ocean acidification on marine life and ecosystems remains uncertain, there is growing international concern that key species, especially calcifying organisms, and habitats are threatened. This includes important components of the food web in Irish waters such as primary producers, cold water coral reefs, shellfish and crustaceans. This could have profound consequences for entire marine ecosystems and their functioning.

Socio-Economic Consequences: Marine and coastal ecosystems provide essential goods and services to mankind and play a vital part in the economy of maritime nations. The impact of ocean acidification on the ocean and its ecosystems is likely to have major consequences for climate processes, food production, biodiversity and sectors reliant on these services, such as fisheries and aquaculture.

Policy: Ocean acidification is essentially irreversible on practical human timescales. Mitigation can only be achieved through early commitment to a reduction of CO_2 emissions. Protection of the Irish marine environment, underpinned by science-based assessment, is a legal requirement under international obligations such as the OSPAR Convention and Marine Strategy Framework Directive (Dir. 2008/56/EC).

Research Needs: Research on ocean acidification and impacts on marine ecosystems is in its infancy. Much more information is required on the environmental change taking place and the effects on biological processes so as to better forecast the ecological impacts and socio-economic consequences. This information is essential to develop mitigation and adaptation management policies including risk analysis.

Research Capabilities: Ireland has a unique geographical location for conducting research into ocean acidification and its impacts in important North Atlantic margin and shelf waters. Significant expertise and infrastructure is already in place which can form the basis of an effective and cost-efficient monitoring and research programme.

Key recommendations

- The potential consequences of ocean acidification need to be addressed in climate change and environmental policy development, especially in relation to mitigation strategies to reduce carbon emissions.
- A nationally coordinated multidisciplinary marine climate change and ecosystem monitoring and research programme should be firmly established for Irish waters with ocean acidification monitoring as a cornerstone. Priority activities should include measurements of the inorganic carbon system and monitoring of key marine species and habitats at risk. This should take place within the framework of international monitoring obligations and policy requirements. Strong links and partnership should be developed with ocean acidification programmes in other European countries.
- Specialist capacity and expertise is further required and existing infrastructure needs to be further developed and maintained. This is essential to undertake a viable and cost effective research and monitoring programme. It will also facilitate future involvement of Irish researchers in international projects in this field. Focussed research into impacts of ocean acidification will enable progressively better evaluations to be made of the threat posed to the Irish marine environment and economy.

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