Understanding Ocean Acidification – and what we can do about it

Carbon dioxide doesn't just stay in the atmosphere and warm the planet. About one third of the carbon dioxide produced through human activities since the Industrial Revolution has been absorbed by the world's oceans, which is changing sea chemistry (see Box 1). Over the past 200 years the acidity of the oceans has increased by almost 30 per cent and is likely to increase by a further 100 to 120 per cent by the end of this century if carbon dioxide emissions are not reduced. This 'ocean acidification' threatens marine ecosystems, including micro-organisms that form the base of the food-chain for fisheries, and coral reefs already under pressure from global warming and other threats. This degradation of marine ecosystems is negatively impacting people's livelihoods, threatening food security and increasing disaster risk due to the deterioration of coastal protection provided by these ecosystems – particularly for the world's poorest and most vulnerable people.

What is ocean acidification?

Changing chemistry

The world's oceans and the living marine resources within them play a very important role in cycling the world's carbon dioxide. When the oceans absorb increased amounts of carbon dioxide, seawater becomes more acidic. This acidification has wide-ranging impacts on marine life, including disruptions in important life-cycle processes such as reproduction, growth and development, all of which could result in substantial changes in the variety and location of marine biodiversity. The chemical consequence of increasing acidity is reduced availability of *carbonate ions* in the ocean. These are a vital building block used by many marine species (such as coral reefs, oysters and swimming sea snails) to create shells and skeletons, which in turn contribute to the living habitat and food sources for millions of other species *(see* Box 1 for more on acidity*)*. Carbon dioxide is also utilised by phytoplankton, some of the family of tiny organisms that form the basis of the marine food web (and even form the sole food source for certain species of whales). However, most types of plankton are quite sensitive to acidity, meaning that the ability of the oceans to absorb carbon dioxide is also compromised when they are impacted – creating a vicious circle in which more carbon dioxide remains in the atmosphere and warms the planet.

How will marine life be affected?

Killing plankton has been compared to burning grass in a cow pasture: the adverse affects on plankton ripple through ocean food webs by starving them of what is called primary production.

Coral reefs provide food and habitat for as much as a quarter of all life found in the ocean and are highly vulnerable to ocean acidification. If carbon dioxide levels in the atmosphere continue to grow at their current rate, coral reefs may be eroded by an increasingly acidic ocean faster than they can grow. As soon as 2040, only a few tiny areas in the oceans may remain optimal for coral growth, and by the end of this century no adequate conditions may remain.[i] The loss of coral reefs could be devastating for the ocean and in particular the food supply and livelihoods from fisheries and tourism that coastal and island peoples around the world depend upon.

Increases in ocean acidity can also disrupt marine wildlife in strange ways. For example, some reef fish raised in acidic conditions respond to certain smells differently to fish that develop under normal conditions. Acidity has been found to cause certain reef fish to inadvertently swim toward a smell that they would otherwise avoid, such as the smell of their predator. Such confusion could disrupt the balance of species in an interconnected system, with potentially negative consequences for coral-reef fisheries.

BOX 1

Acidity: Imagine sucking on a lemon. This sour taste is what we call 'acidic'. The more acidic something is, the easier it can dissolve other substances (that's why lemon and other citrus fruits are used as a basis for cleaning products). In the oceans, increased acidity is having a similar disolving effect. It reduces the availability of one of the key building blocks many marine animals and plants (such as coral reefs, oysters, swimming sea snails) need to create shells and skeletons. These building blocks are called 'carbonate ions'.

How will people be affected?

Billions of people and many nations rely on the essential goods and services provided by oceans and the plants and animals they sustain. Roughly one half of the global population lives within 100 kilometres of the coast and on average worldwide, coastal settlements are growing faster than inland cities and towns. Of these billions, it is the poor and vulnerable coastal populations directly dependent on marine goods and services that will be most adversely affected if ocean acidification and other climate change impacts on oceans continue to worsen. The ocean and its coastlines provide habitat, energy, and important sources of food: molluscs, fish and crustaceans found in reef areas offer the option of a nutritious food source for many island and coastal communities and support valuable commercial fisheries. The ocean also provides energy sources (oil and gas, wind, wave, tidal, thermal, bio-fuel), regulates the carbon cycle, aids in nutrient cycling, and provides recreational, educational, aesthetic, and spiritual benefits to people around the world. The ocean also supports economic activity, including jobs, fisheries, food, marine transportation, trade, fuel, and energy. Tropical coral reefs provide food and livelihood security for some 500 million people worldwide[ii] and economists say that reefs support people to the value of 30 to 172 billion US dollars per year[iii].

However, many small marine animals that form the basis of food chains which support these fisheries will be increasingly affected as the oceans become more acidic. At the same time, world coastal population is expected to continue growing, increasing the demand for ocean food products[iv]. Fishing pressure and pollution from the land represent the most significant pressures on coastal ecosystems, and ocean acidification further threatens the availability of catches by impacting on the tiny plankton plants and animals at the base of the ocean food chain.

Another concern relates to small island atolls. Not only are they under threat from sea level rise over the coming decades, but the atolls themselves may not be able to continue to provide the land that is required for reefs to regenerate and in turn sustain the atolls. If the health of the reefs surrounding atolls declines due to ocean acidification and environmental degradation, the survival and prosperity of the atolls – and the people they support -- will be seriously jeopardized.

Coral reef degradation has begun and will worsen as carbon dioxide levels increase

CO2 Concentration Parts per million* (ppm)	Condition of Coral Reefs
380 ppm (already reached in 2006)	Reefs change due to ocean acidification, however they continue to contain corals
450 ppm	Density and diversity of corals on reefs will decline, including the loss of coral associated fish and other species that live with or on corals
450 – 500 ppm	A possible tipping point for corals, if exceeded, reefs as we know them would be extremely rare at best. It would take millions of years for coral reefs to return to their former diversity and density

Sources :Adapted fromEllyciaHarrould-Kolieb, Jacqueline Savitz (June 2009), CAN WE SAVE OUR OCEANS FROM CO2?, OCEANA, 32p
NOAA website : Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/).
**'Parts per million' is a measurement of the amount of greenhouse gases In the atmosphere.*

What other factors also degrade reef ecosystems?

One of the pernicious aspects of ocean acidification is that it exerts a compounding effect on ecosystems that are already under stress from a variety of climate and non-climate related factors. First of all, not only are oceans becoming more acidic due to climate change, they are also becoming warmer. The combined effects of each of these two threats may have a greater impact than either on its own. *Warming* and acidification together result in faster reef degradation. Recent research by scientists has shown that coral will die at much lower temperatures if exposed to acidity at the same time[v]. Other animals, such as crabs, show more sensitivity to warming when placed in more acidic waters[vi]. Rapid reef destruction can result in serious consequences for people as well; for example, dwindling fish stocks can affect food security and income of local populations, and those dependent on the tourism sector for livelihoods may see their opportunities decrease as coral reefs become less alluring as exotic hotspots for recreational activities.

Rising sea temperatures also cause coral bleaching, which means that corals lose colour when the tiny animals that live in them die due to heat stress. Sea surface temperatures in the tropics have increased by almost 1°C over the past 100 years and are currently increasing at the rate of approximately 1-2°C per century[vii]. This may not seem like much, however many marine species can only survive within very small ranges of temperature. In 1998, the world lost 16 per cent of its corals in a single global event of mass coral bleaching, caused by an El Niño cycle. While this phenomenon was a natural event, it served as an additional stressor that compounded general warming trends. Such bleaching events could become commonplace within twenty years due to continued warming beyond the temperature tolerance range of corals.

Sea level rise decreases the amount of light reaching reefs which they require for growth. Sea level rise also increases the risks of storm surge and puts enormous stress on coastal habitats such as mangroves or sea turtle nesting beaches as well as obvious pressures on coastal communities as it becomes more difficult to continue to live and prosper on shrinking areas of land with saltwater intrusion of freshwater aquifers.

More frequent and intense rainfall events are expected in many parts of the world and this is another factor affecting the chemistry and other aspects of water quality that compound the impact of acidification in coastal waters. More run-off from land causes lower salinity (saltiness) around reef systems and increased amounts of particles, both of which can kill corals, with dire consequences for the human populations dependent on the reefs.

Coral reefs degraded by coastal development, over-fishing and pollution

Coastal areas have been transformed by the development of agriculture, mariculture (the farming of fish, algae and shellfish), the construction of dwellings and other infrastructure. In many cases, this has reduced the cover of mangrove forests as natural buffers which are also part of coral-reef ecosystems and provide protection to populations exposed to storm surges. What is more, the growth of population in the coastal zone, the increase in shipping activities, and the increase in pollution effluent from sewage, garbage or oil spills and ballast discharges all contaminate coral ecosystems. Sediment increases as a result of many of these human activities can also smother reefs.

What can we do about the problem?

Global action: Reduce carbon dioxide emissions

There is only one way to decelerate ocean acidification: we must drastically reduce the amount of carbon dioxide and other greenhouse gases that are produced globally. To protect coral reefs and the ecosystems that we depend on, we must also take steps to stabilise carbon dioxide in the atmosphere. According to the United Nations Environment Programme (UNEP) when the level of carbon dioxide of 390 ppm was reached there was already evidence of the impact on coral reefs around the globe. We do not as yet know precisely what level of carbon dioxide is too much but we do know that a level of less than 450 ppm is essential for the survival of the reefs and for the well-being of all the people who depend on or benefit from them[viii].

Local action (including national)

If local stressors other than acidification, such as over-fishing, pollution and habitat destruction, are controlled, this can alleviate some of the compounding effects of acidification. If these measures are taken, not only will coral reefs be able to regenerate and recover faster, but communities will also be able to adapt better to climate change. Action at the local level will have to be considered on a place-based basis but could include:

Conducting assessments

Do risk assessments with coastal communities in order to identify their vulnerabilities and capacities and develop risk reduction action plans that consider environmental management.
Encourage networking and partnerships in order to gather scientific information on the impacts of ocean acidification and associated stress factors on coral reefs and fisheries.
Strengthen community groups and social networks working towards healthy coasts.
Access climate information for risk reduction in coastal areas.

Mitigation of risk and capacity building

Disaster management

Reinforce preparedness and emergency response to potential extreme events in coastal areas such as storms, tsunamis, high tides, floods.
Improve coastal infrastructures to reduce the risks related to storm surges and run-off into the sea
Implementation of early warning systems (e.g. protocol to prepare for storm surges, waterborne disease, etc.).

Develop planning skills (anticipate short and/or long term migration to non coastal areas in case of rising sea levels/storm surges).

Food security

Encourage diversification within fisheries to reduce the trend towards the extinction of specific species.
Decrease resource dependency by enhancing and diversifying livelihoods.

Health

Enhance capacities and health status of fishing and coastal communities.

In Bali, Indonesia, community action teams have identified the need for coastal protection from the effects of intense cyclones and coastal erosion, exacerbated by climate change. Over 30,000 mangroves have been planted in these areas, and fishermen are already reporting improved incomes from the sale of shrimp and fish that thrive in mangroves. Healthier reef and coastal ecosystems are also able to tolerate acidification and warming better than degraded ecosystems.

Education and raising awareness

Develop an interest in adapting to climate change through workshops, forums, awareness campaigns.
Develop knowledge of coral reef management, including ocean acidification concerns.
Develop knowledge and awareness of “healthy coastal ecosystems”, including pollution reduction from domestic and shipping activities, alternative livelihoods and reducing degradation of coastal environments such as seagrass beds and mangroves.
Develop knowledge and awareness of greenhouse gas reduction behaviour and lifestyle adjustments.

National policy level ideas

National governments can establish the policy and regulatory environment to encourage action by individuals, households and private sector businesses. For example governments can assist by providing the frameworks for reducing stress to sensitive ecosystems such as land based pollution, over fishing and establishing marine protected areas with communities. Climate change adaptation goes hand-in-hand with disaster risk reduction and development programmes, and governments have one of the most important roles to play in these issues. Governments can strengthen the knowledge base and provide the policy and legal framework for climate and disaster risk reduction measures related to land use planning, health and food security sectors. They also ensure that infrastructure investments take climate, natural disasters and human threats into account.

There is much climate change adaptation planning occurring around the world. Red Cross red Crescent National Societies can play a role in ensuring that it is linked with disaster risk reduction, and more widely in national and local development planning. In countries that will be affected by ocean acidification, the impacts on human settlements must be considered, and a holistic approach to development of coastlines should be taken into account to at least prevent the situation from worsening.

A final word

Ocean acidification must be considered in international and regional climate change adaptation policies. The expected consequences of ocean acidification and climate change on the world's poorest and most vulnerable should serve to inject more urgency and ambition towards reducing carbon dioxide emissions. In addition, we must invest in maintaining and restoring coastal ecosystems in order to improve the health of reefs and the vital goods and services they provide for humanity. This can build a key foundation for managing the unavoidable impacts of climate change.

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[i] EllyciaHarrould-Kolieb, Jacqueline Savitz, June 2009, *CAN WE SAVE OUR OCEANS FROM CO2?*, OCEANA, 32p

[ii] UNEP, 2010, *Environmental consequences of ocean acidification: a threat to food security*, UNEP emergencies issues, 12p

[iii] EllyciaHarrould-Kolieb, Jacqueline Savitz, June 2009, *Protecting the world's Oceans*, OCEANA, 22p

[iv] UNEP, 2010, Environmental consequences of ocean acidification: a threat to food security, UNEP emergencies issues, 12p – pp4

[v] WWF, The University of Queensland, 2009, *CORAL TRIANGLE AND CLIMATE CHANGE : ecosystems, people and societies at risk*, 40p: pp19

[vi] UNEP, 2010, *Environmental consequences of ocean acidification: a threat to food security*, UNEP emergencies issues, 12p.

[vii] OveHoegh-Guldberg, Climate Change, coral bleaching and the future of the world's coral reefs, Greenpeace, 28p

[viii] UNEP, 2010, Environmental consequences of ocean acidification: a threat to food security, UNEP emergencies issues, 12p – pp7

Additional references :

- H. Anlauf et al., 2011, *A corrosive concoction: The combined effects of ocean warming and acidification on the early growth of a stony coral are multiplicative*, Journal of Experimental Marine Biology and Ecology pp397
- Robert W. Buddemeier et al., 2004, *Coral Reefs and global climate change, Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems,* Pew Centre on Global Climate Change, 56p
- Cinner, J.E., et al., 2011, *Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries.* Global Environ. Change, doi:10.1016/j.gloenvcha.2011.09.018
- IFRC, ProVention Consortium, *Climate Change Adaptation strategies for local impact, Key Messages for UNFCCC Negotiators,* 2009, 11p
- UNEP Bulletin on ocean acidification and food security:www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf

Websites:

http://www.epoca-project.eu

European Project on Ocean Acidification was launched in June 2008 with the overall goal to advance our understanding of the biological, ecological, biogeochemical, and societal implications of ocean acidification. The EPOCA consortium brings together more than 160 researchers from 32 institutes and 10 European countries

http://www.ocean-acidification.net/

Website of the world's leading scientists to discuss the impacts of ocean acidification on marine ecosystems, and socio-economic impacts.

http://www.reefresilience.org/

Comprehensive website publications on building reef resilience to climate change.

Films:

Very useful film explaining Ocean Acidification:
Ocean acidification: Connecting science, industry, policy and public (12 minute movie from Plymouth Marine Laboratory)
http://www.youtube.com/watch?v=_BPS8ctVW2s&feature=relmfu

A short, powerful and entertaining 8 minute animation about the issue of ocean acidification, produced by Ridgeway School and Plymouth Marine Laboratory.
http://www.youtube.com/watch?v=F5w_FgpZkVY

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