# Climate Change and Ocean Acidification

## Synergies and Opportunities within the UNFCCC

### Discussion Paper

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**Executive Summary**

Ocean acidification is arguably one of the most serious threats facing the oceans and humans this century. Ocean acidification is not a symptom of climate change; rather, it is a threat concurrent with climate change and caused by a common root problem: ongoing anthropogenic $CO_2$ emissions. It is a serious global challenge of unprecedented scale and importance that requires immediate action.

Preventing further acidification of the oceans will require stabilizing and reducing the level of $CO_2$ in the atmosphere, which is most effectively done through reducing $CO_2$ emissions. The United Nations Framework Convention on Climate Change (UNFCCC) is clearly an appropriate environmental policy regime to deal with the mitigation of ocean acidification, through $CO_2$ reductions. It is also a suitable forum for devising and providing funding for responses to ocean acidification that can be incorporated into national adaptation plans.

Many efforts are underway to raise awareness and inform policy and decision makers about ocean acidification and its potential impacts. So far, however, no concrete recommendations have been made on how ocean acidification could be integrated within the UNFCCC. This paper attempts to address this gap by offering an initial suite of possible ways to address ocean acidification alongside climate change mitigation and adaptation strategies.

**Recommendations:**

- Recognize the opportunity, while acting upon the mandate of the UNFCCC, to address and find **common solutions for climate change and ocean acidification** through the post-2012 Agreement and/or a COP decision and request follow-up activities such as a possible SBSTA work programme on ocean acidification;
- Propose ocean acidification as a priority theme to be addressed at the workshop organized in conjunction with the **SBSTA research dialogue** at SBSTA 34 in June 2011;
- Include ocean acidification in **mitigation actions** under the UNFCCC by:
    - establishing targets effective in curtailing both climate change and ocean acidification and periodically reviewing and revising as needed emission reduction targets in light of emerging scientific findings;
    - incorporating an indicator for ocean acidification alongside temperature;
    - revising the effectiveness of mitigation mechanisms such as the CDM to ensure they address ocean acidification, and modify them if necessary;
    - employing mitigation strategies that are effective in curtailing both climate change and ocean acidification and avoiding strategies that may exacerbate ocean acidification (e.g., some forms of geoengineering) ;
- Include ocean acidification into **adaptation actions** under the UNFCCC by:
    - incorporating ocean acidification as a thematic knowledge and information sharing hub into the continuation of the Nairobi Work Programme.

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# 1. Introduction

Ocean acidification – the change in seawater chemistry due to rising atmospheric carbon dioxide ($CO_2$) levels and subsequent impacts on marine life – is arguably one of the most serious threats facing the oceans and humans this century. Ocean acidification is not a symptom of climate change; rather, it is a threat concurrent with climate change and caused by a common root problem: anthropogenic $CO_2$. It is a serious global challenge of unprecedented scale and importance that requires immediate action. International and national processes and mechanisms already exist that can be effective in addressing ocean acidification.

Many efforts are underway to raise awareness and inform policy and decision makers about ocean acidification and its potential impacts. So far, however, no concrete recommendations have been made on how ocean acidification could be integrated within the United Nations Framework Convention on Climate Change (UNFCCC). This paper attempts to address this gap by offering an initial suite of possible ways to address ocean acidification alongside climate change mitigation and adaptation strategies. The paper will first briefly review the current scientific knowledge on ocean acidification, then highlight linkages between ocean acidification, climate change and UNFCCC before providing a set of opportunities for common solutions to climate change and ocean acidification.

## 1.1 The Scientific Basis

### 1.1.1 Changing Ocean Acidity

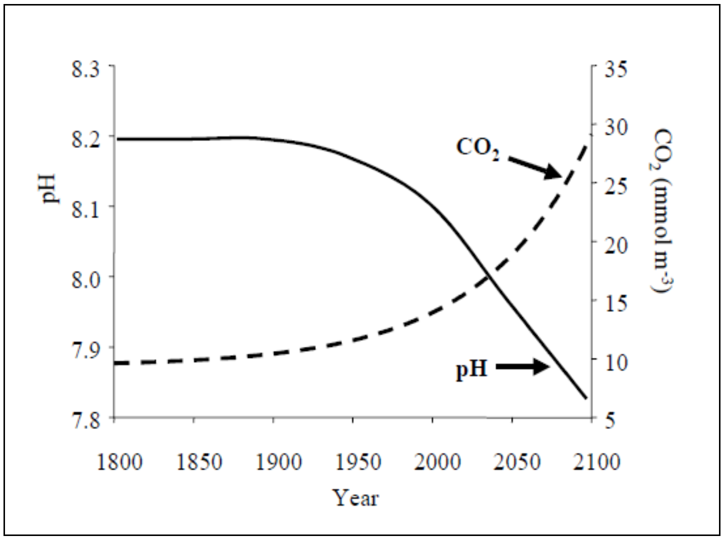
Since the Industrial Revolution, more than 1.6 trillion tonnes of $CO_2$ have been emitted into the atmosphere from the burning of fossil fuels, land-use change and other human activities[1], of which almost 30 percent have been absorbed by the oceans.[2] This huge influx of carbon dioxide is drastically changing the chemistry and pH of the oceans, making them more acidic. The average global oceanic pH has already fallen roughly 0.1 units, representing an approximate 30 percent increase in acidity since the 1750s.[3] Future changes are predicted to occur at such an increasing speed that by the middle of this century seawater pH could be lower than at any point during the last 20 million years.[4]

### 1.1.2 The Chemical Changes

As $CO_2$ is absorbed by the oceans, it combines with water ($H_2O$) to form carbonic acid ($H_2CO_3$). The carbonic acid then dissociates, forming a hydrogen ion ($H^+$) and a bicarbonate ion ($HCO_3^-$).

$$\mathbf{CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-}$$

(carbon dioxide) + (water) ←→ (carbonic acid) ←→(hydrogen ion) + (bicarbonate ion) pH is a measure of the concentration of hydrogen ions – the more hydrogen ions, the lower the pH and the higher the acidity. Hence, increasing levels of hydrogen ions from the absorption of carbon dioxide lowers the ocean's pH and increases its acidity (Figure 1).




Source: Turley et al. 2006

**Figure 1:** The projected change in atmospheric $CO_2$ concentrations and seawater pH under a business-as-usual emissions scenario[5]

Carbonate ($CO_3^{2-}$) and bicarbonate ions ($HCO_3^-$) are in equilibrium with one another in the oceans and large amounts of $CO_2$ entering the oceans produces bicarbonate ions, shifting the balance away from carbonate ions. This process depletes the amount of carbonate ions available to the marine life that depend on this building block to create their calcium carbonate shells and skeletons.

$CO_2$ + $H_2O$ + $CO_3^{2-}$ ←→ $2HCO_3^-$

(carbon dioxide) + (water) + (carbonate ions) ←→ (bicarbonate ions)

The changes taking place in the ocean have the potential to disrupt important acid-base relationships, along with other vital biogeochemical processes.

### 1.1.3 The Biological Impacts

Scientific studies show that ocean acidification may have wide-ranging impacts throughout the oceans. In fact, die offs of oyster larvae[6] and decreases in coral skeletal growth[7] have been linked to rising acidity and may be the first indicators of impacts to follow. Marine organisms have a multitude of diverse reproductive strategies, life stages, and life styles, all of which may have varying responses to ocean acidification. In some species, important biological and physiological processes such as reproduction,[8] growth,[9] calcification[10] and even respiration[11] have been found to be disrupted by increasing ocean acidity. Species as varied as fish,[12] brittle stars[13] and squid[14] have shown direct effects from increased ocean acidity.

Marine calcifiers, such as coral reefs,[15] oysters[16] and pteropods (swimming sea snails),[17] are some of the species most vulnerable to ocean acidification. In the near future, increasing amounts of absorbed $CO_2$

may make some surface waters corrosive to the shells and skeletons made of the more soluble forms of calcium carbonate.[18] This means that ocean acidification is not only likely to decrease the ability of some calcifiers to build their protective coverings by reducing the availability of carbonate ions, but could also result in the dissolution of some existing calcium carbonate structures.

Coral reefs are particularly vulnerable to decreasing pH and increasing ocean temperatures: these combined threats could result in coral reefs beginning to erode globally by the middle of this century.[19] Many marine calcifiers provide vital habitat and food for many species throughout the oceans. If their skeletons and shells are weakened or destroyed by rising acidity there will likely be flow on effects to species that depend on them. For example, salmon, herring, whales and sea birds all feed upon pteropods, which are an important part of the polar and sub-polar food webs. These species may be negatively affected if pteropods suffer deleterious impacts due to rising acidity, as predicted for some areas of the ocean by the middle of this century.[20]

There are likely to be winners and losers due to rising ocean acidity. It has been suggested that jellyfish,[21] algae[22] and seagrasses[23] could all do better in a high $CO_2$ world. However, these species are unlikely to support the diversity of species and ecosystems that exists in the oceans today and on which we depend. Marine ecosystems will likely be negatively impacted and the oceans will look and function very differently to how they do today.

### 1.1.4 The Human Consequences

Ocean acidification has the potential to drastically change the oceans and alter the availability of the goods and services they provide. The oceans, which cover 71 percent of the Earth's surface, serve as an important provider of food, livelihood, recreation and rejuvenation for billions of people. Coral reefs and related fisheries alone support hundreds of million of people. More than 100 million people are economically dependent upon coral reefs alone, with many more reliant on reefs for specific resources such as coastal protection, sustenance, materials and pleasure.[24] Fisheries also provide an important global resource with approximately 13 million people making all or part of their livelihoods directly from fishing activity, with more than 150 million people employed in jobs supported by fisheries. [25]

Coral reefs are estimated to provide some 30 to 70 billion dollars annually to the global economy through coastal protection, tourism, fishing and other goods and services[26]. Their disappearance could jeopardize this benefit to the global economy as well as cause serious health consequences and food security concerns for many subsistence fishing communities that rely on fish found in reef ecosystems for vital proteins.[27] Many coastal communities are also heavily dependent upon tourism as a source of income. Declining reefs will likely mean major losses in tourism dollars. The coastal reefs in Hawaii alone are estimated to generate 364 million dollars annually in net business revenues.[28]

Many of the world's commercial fisheries are likely to be threatened by ocean acidification: either directly, by biological and physiological changes due to increased acidity, or indirectly, through changes in habitat and prey availability. Polar and sub-polar areas, due to their colder waters that absorb carbon dioxide more readily than warmer waters, are predicted to be most severely impacted by acidification within the coming century. These areas are highly productive and support some of the world's most important commercial fisheries.[29] Mollusks (e.g., clams, oysters and mussels) appear to be particularly vulnerable to ocean acidification, both at the larval stage and because they produce shells out of a more readily dissolved form of calcium carbonate.[30] The calcification rates of both edible bay mussels and Pacific oysters have been found to decrease with increasing acidity.[31] The effects of ocean acidification on mollusks and crustaceans (e.g., lobsters, crabs, crayfish and shrimp) are likely to present great losses both economically and to ecosystem services.

Ocean acidification is hence likely to threaten food security, harm fishing industries, and increase the risk of inundation and erosion in low-lying areas by weakening natural shoreline protection. In terms of adaptation, ocean acidification threatens marine and coastal ecosystem resilience and hence weakens the ability of both humans and natural systems to adapt to ongoing changes.

## 1.2 Providing the Policy Background for Action

Ocean acidification, due to its long-term and progressive impact on the oceans, has become one of the most critical and pressing issues for ocean life and those who depend on healthy marine ecosystems, necessitating increased awareness and action. Ocean acidification needs to be taken into account when designing conservation strategies and should therefore be addressed in national, regional and international marine ecosystem and fisheries management policies and practices. However, the only effective way of preventing further acidification of the oceans is to stabilize and reduce the level of carbon dioxide in the atmosphere, which is most effectively done through reducing $CO_2$ emissions. Therefore, the United Nations Framework Convention on Climate Change (UNFCCC) is clearly an appropriate environmental policy regime to deal with the mitigation of ocean acidification through $CO_2$ reductions. It is also a suitable forum for devising and providing funding for responses to ocean acidification that can be incorporated into national adaptation plans. Ocean acidification has not as yet been addressed adequately through the UNFCCC, either in terms of mitigation or adaptation.

### 1.2.1 Ocean Acidification and the UNFCCC Mandate

The objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous interference with the climate system." Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally and to ensure that food production is not threatened.[32] Ocean acidification will affect marine ecosystems and has the potential to have negative consequences for food production (see 1.1.3 & 1.1.4). Hence, in order to effectively meet the objective of the UNFCCC, ocean acidification should be addressed.

Additionally, the uptake of $CO_2$ by the ocean currently moderates the rate and severity of climate change.[33] The ocean's capacity to act as a carbon sink is projected to diminish in the future,[34] which will result in more $CO_2$ remaining in the atmosphere, leading to more severe climate change. The give and take between the oceans and the atmosphere is integral to understanding the climate system and to stabilizing atmospheric carbon dioxide levels. Therefore, since the oceans act as a carbon sink and play an important role in the climate system, the impacts of $CO_2$ on the oceans must be considered within the mandate of the UNFCCC.[35]

Climate change is the consequence of increases in a range of greenhouse gas (GHG) emissions, of which $CO_2$ is the most important. Ocean acidification, on the other hand, is caused on a global scale by increased concentrations of $CO_2$ alone.[36] Solutions to mitigate ocean acidification and climate change are thus closely related, as the efforts to reduce $CO_2$ for one problem will help to mitigate the other. Given the UNFCCC focus on the reduction of $CO_2$ and other GHG emissions, it also seems pertinent to house discussions and policy actions on ocean acidification within the Climate Convention. Setting up a new international mechanism to deal solely with $CO_2$ would be confusing and superfluous.

From an adaptation point of view, a similar dynamic exists between climate change and ocean acidification. Given the ecological, social and economic importance of ocean acidification, ways need to be explored for countries to plan their adaptation strategies to enhance resilience in coastal and marine systems, reflecting the impacts of ocean acidification. Also, adaptation plans put into place without ocean acidification in mind run the risk of not being effective in the face of possible future changes.

### 1.2.2 Ocean Acidification and the UNFCCC to Date

The Subsidiary Body for Scientific and Technological Advice (SBSTA) provides a platform for enhanced communication between the scientific community and Parties to provide information on developments in research activities relevant to the needs of the Convention, including emerging scientific findings.[37] Over the last two years, at SBSTA 30 and 32, ocean acidification has been identified as one of the most pressing emerging issues under the UNFCCC, both by Parties[38]and participating regional and international climate change research programmes and organizations.[39,40,41]

The current negotiating text of the Ad-hoc Working Group of Long-Term Cooperative Action (AWG-LCA) includes mention of ocean acidification in association with proposed risk management and compensation mechanisms[42] (identified as a slow onset event[43]).

However, the significance of ocean acidification is not as yet permanently and prominently reflected within international climate change mitigation and adaptation strategies.

### 1.2.3 National Actions on Ocean Acidification

National actions and lessons learned on ocean acidification can be used to inform international policy development. Several Parties, including Australia, China, Germany, Japan, the Republic of Korea, the United Kingdom, the United States of America and the European Union, have ongoing or planned research programs looking at various aspects of ocean acidification or research coordination thereof.[44] Some countries, including Australia,[45] Chile,[46] Indonesia,[47] Ireland,[48] Japan,[49] Portugal[50] and the U.K.,[51] make reference to ocean acidification and its implications for marine ecosystems and fisheries in their national climate change plans and strategies, or more specifically, in their climate change adaptation plans.

Despite these initial efforts and related research investments which show that some countries are taking ocean acidification very seriously, specific national action plans and strategies to deal with ocean acidification are missing. A more comprehensive, international action-oriented approach to address ocean acidification is needed. Recognition of and follow up activities to ocean acidification within the UNFCCC will create international commitment and responsibility, as well as guidance for national implementation of related mechanisms and projects.

#### 1.2.4 Ocean Acidification and the IPCC

The IPCC Fourth Assessment Report (AR4) in 2007 included a variety of references to ocean acidification while highlighting that "the main driver of these changes [lower oceanic pH and carbonate ion concentrations] is the direct geochemical effect due to the addition of anthropogenic $CO_2$ to the surface ocean".[52] The report continued by pointing out that "conditions detrimental to high-latitude ecosystems could develop within decades, not centuries as suggested previously."[53] Within the scoping process, as well as the agreed outlines for the IPCC Fifth Assessment Report (AR5), ocean acidification has been identified as a cross-cutting topic and is well reflected in the different working group outlines.[54,55]

At the thirty-first IPCC session (2009), a proposal by Japan and the UK for a Special Report on climate change impacts on marine ecosystems, including ocean acidification, raised particular interest, and the Chairman suggested that an expert meeting be organized on the subject.[56] An IPCC expert workshop on "*Impacts of Ocean Acidification on Marine Biology and Ecosystems*"[57] is now scheduled for January 2011 in Japan.

# 2. Ways to Address Ocean Acidification Within the UNFCCC

This section of the report will briefly outline and discuss opportunities for including and addressing ocean acidification within the UNFCCC. The scientific building blocks and mechanisms proposed here are not exhaustive. They should rather be seen as a first attempt to identify some of the opportunities within the existing framework while reflecting on scientific components potentially needed to steer policy development.

## 2.1 Science-Based Building Blocks

Ocean acidification, as mentioned previously, is related to climate change. Consequently, it is pertinent to address the two issues together, in one forum. However, the differences between climate change and ocean acidification must also be recognized. For instance, thresholds may be lower for ocean acidification than for climate change, which would impact the setting of mitigation targets. To ensure that ocean acidification is effectively dealt with, the UNFCCC will need to institute certain changes that bring the scientific knowledge of ocean acidification into its already existing framework and mechanisms.

### 2.1.1 Effective Indicator

Temperature is often used as a metric to indicate the limit that, once passed, would result in dangerous changes to the Earth's climate and ecosystems. Hence, it can also be viewed as the indicator by which to measure the success of mitigation programs. Temperature, however, does not drive change leading to ocean acidification, and is therefore not an effective indicator of damage or successful mitigation of ocean acidification. This would suggest that in order to build effective policy to prevent ocean acidification, an effective indicator reflecting the chemical changes in the oceans be placed alongside temperature.

To date, little discussion has taken place over which indicator should be selected when addressing ocean acidification. pH and saturation state have both been suggested as viable options.[58] The IPCC has added ocean acidification and changes in pH into its Special Report on Emissions Scenarios (SERS) for the AR4.[59] pH reflects the changes in acidity and alkalinity that are taking place in the ocean, while saturation state indicates how available carbonate ions are and whether or not calcium carbonate structures are likely to dissolve. In-depth discussions need to address this issue and so as to identify the most effective indicator for ocean acidification.

### 2.1.2 Effective Targets

Since ocean acidification is directly caused by the absorption of $CO_2$, it is necessary to reduce the levels of $CO_2$ in the atmosphere. The most effective way to do this is to reduce $CO_2$ emissions at the source. Current national and international climate discussions aim to do just this.

International agreements and domestic policies on emissions reductions usually regulate more than just $CO_2$. The Kyoto Protocol, for example, regulates four gases ($CO_2$, methane, nitrous oxide and sulphur hexafluoride) and two groups of gases (the hydrofluorocarbons and perfluorocarbons).[60] In doing so the

Protocol creates a bundle of gases from which countries can choose in order to reduce their emissions. This provides countries with more flexibility, as depending on circumstances, some gases may be cheaper and easier to reduce than $CO_2$.

Returning to a safe climate has largely been understood as keeping global temperatures as well as GHG concentrations in the atmosphere (parts per million (ppm)) below a certain level. Discussions of GHG concentrations have mainly focused on $CO_2$ equivalencies ($CO_2$-eq), which enable calculation of the overall level of GHGs in the atmosphere. This, however, does not parse out $CO_2$ from the other GHGs, which would be necessary to mitigate ocean acidification.

Currently a "safe" temperature level is thought to be less than 2°C above pre-industrial temperatures, although many UNFCCC Parties, including small island and African nations, are calling for a limit of 1.5°C. Using temperature as a target is logical when looking to reduce global temperatures and stabilize the climate; however, there is no assurance that actions taken to reduce temperature will also be effective in addressing ocean acidification.

In addition to discussion about appropriate indicator(s), in-depth discussions are needed to deliberate on a possible target for atmospheric $CO_2$ alongside any $CO_2$ equivalents and temperature targets in order to ensure that levels of $CO_2$ will be adequately reduced to prevent further acidification of the oceans. While reducing temperature and methane, nitrous oxide and other greenhouse gases is a good thing for climate change, it will not be effective to protect against ocean acidification. The scientific community is increasingly refining models and predictions of different $CO_2$ emissions pathways and their possible implications for marine life and the climate system and is discussing thresholds.[61,62]

#### 2.1.3 Geoengineering

Indicators and targets that focus on temperature open the door to solar radiation management (SRM) schemes, such as painting roofs white or adding sulfur particles to the atmosphere.[63] These schemes are designed to lower global temperatures by increasing the planet's albedo; they do not lower the concentration of atmospheric $CO_2$ or reduce $CO_2$ emissions.[64] These proposals may be effective in lowering the rate of global temperature increase; they will not, however, address ocean acidification.[65]

Other geoengineering schemes, in the form of carbon sequestration management (CSM), attempt to combat climate change by removing $CO_2$ from the atmosphere, which would also prevent further ocean acidification. Proposals include schemes such as iron fertilization and deep ocean sequestration, both of which run the risk of exacerbating ocean acidification.[66,67,68]

### 2.2 Policy Actions

#### 2.2.1 Mitigating Ocean Acidification

International and national emission targets must be set at sufficient levels to allow marine ecosystems to adapt naturally to increased acidity and to ensure that marine and coastal food production is not threatened. In light of the continually emerging scientific findings, these targets need to be periodically assessed for their effectiveness and revised as needed.

Additionally, existing UNFCCC mechanisms and programs, such as the Clean Development Mechanism, should be revised with respect to both their positive and negative impacts for reducing ocean acidification.

### *Clean Development Mechanism*

The Clean Development Mechanism (CDM)[1] covers a number of GHGs, including: $CO_2$, methane, nitrous oxide, sulphur hexafluoride, hydrofluorocarbons (HFC) and perfluorocarbons. The CDM does not place preference of one GHG over another. However, there are some clear benefits in terms of their GHG potency. For example, methane has a warming effect 21 times greater than $CO_2$; therefore, for every tonne of methane, mitigated Parties gain the credits for mitigating 21 tonnes of $CO_2$. This system allows for countires to decide which gases are most cost effective to mitigate, which is effective when the ultimate goal is reducing the overall warming occurring in the atmosphere. However, it does not ensure that carbon dioxide will be reduced to sufficient levels to prevent further acidification of the ocean.

To make the CDM more effective in addressing ocean acidification would require a larger investment in $CO_2$ abatement versus other GHGs. Further in-depth discussions are needed to look more closely at this balancing issue as well as the additional factors important for the origination of a CDM project.

### *Geoengineering*

Geoengineering methods that aim to change the earth's albedo will have little to no effect on ocean chemistry and do not offer a solution to alleviate the threats posed by ocean acidification. The risks associated with large-scale manipulation of earth systems, which are great, need to be a driving factor in deciding whether or not geoengineering schemes are a viable option for combating climate change. With respect to the marine environment, these risks can include exacerbation of ocean acidification and negative impacts to marine ecosystems. When discussing how effective and/or damaging these options are, it is imperative that the impacts to the oceans and the likelihood of combating or exacerbating ocean acidification be an integral part of the discussion.

## 2.2.2 Adaptation to Ocean Acidification

Healthy, resilient ecosystems will have the best possible chance of adapting to the climatic and chemical changes that are already locked into the system. Although more knowledge is needed to develop the most effective adaptation strategies with respect to the ongoing chemical changes in the ocean, the reduction of other human-caused stressors on the marine environment, such as unsustainable fishing practices, pollution, runoff (which can exacerbate local acidification) or coastal overdevelopment, can help enhance ecosystem resilience and hence improve the ability of both humans and natural systems to adapt to ongoing changes.

### *Nairobi Work Programme*

The Nairobi Work Programme (NWP)[2], which is currently up for review, could be used as a platform to improve not only the understanding and assessment of impacts, vulnerability and adaptation to climate

[1] The CDM is a mechanism, defined by the Kyoto protocol, whereby projects with a component that induces the reduction or sequestration of GHG emissions are implemented. The CDM allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of $CO_2$. These CERs can be traded and sold,and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol. http://cdm.unfccc.int/about/index.html

[2] The Nairobi work programme is a five year programme (2005-2010), implemented by Parties, intergovernmental and non-governmental organizations, the private sector, communities and other stakeholders. Its objective is to assist all Parties, in particular developing countries, including the least developed countries and small island developing states, to: 1. improve their understanding and assessment of impacts, vulnerability and adaptation to climate change; and 2. make informed decisions on

change, but also to ocean acidification. The NWP could also be effective in helping to make informed decisions on practical adaptation actions and measures to respond to ocean acidification on a sound scientific, technical and socio-economic basis, taking into account current and future impacts of ocean acidification.

While the NWP has generated increased momentum in the adaptation community at large, Parties and organizations in their submissions have indicated ways in which this could be further enhanced.[69] An overhaul of the NWP could include regional or thematic partnerships and a knowledge and information sharing hub, with a view to enhancing the integration of efforts and interactions among Parties, partners and other stakeholders and to strengthen education, training and awareness-raising activities.[70,71] A thematic partnership or knowledge hub on ocean acidification could be created.

### 2.2.3 Ongoing Research and Science-Policy Dialogue

#### ***Research dialogue***

The SBSTA affirmed the valuable role of the research dialogue in providing new scientific information that emerges from climate change research in between publication of the IPCC Assessment Reports. It also noted the importance of such information for informing deliberations within the UNFCCC process.[72,73] SBSTA 33 includes references to the need for addressing the economics of ocean acidification.[74]

SBSTA will be discussing the organization of a workshop in conjunction with its thirty-fourth session to allow further in-depth consideration to be given to issues addressed in the research dialogue.[75] This offers, as already suggested by Belize,[76] an opportunity to discuss ocean acidification as a priority theme at this workshop.

### 2.2.4 SBSTA Work Programme on Ocean Acidification

The integration of ocean acidification into existing and new processes is yet to be undertaken. An ocean acidification work programme, established under SBSTA, could provide a strong basis for identifying future needs and priorities for understanding and responding to ocean acidification and ensuring the coherent and effective inclusion of ocean acidification into existing UNFCCC and other SBSTA work programmes and agenda items.

Within the framework of such a work programme, Parties to the Climate Convention could request the UNFCCC Secretariat, in collaboration with Parties, other governments and relevant organizations and other relevant conventions, to compile and synthesize available scientific information on ocean acidification, its interference with the climate system and its impacts on marine biodiversity and habitats. Parties could also request that the Secretariat review the effectiveness of the current set of climate change mitigation strategies for reducing ocean acidification, make such information available for consideration at a future meeting of the SBSTA and forward to the COP.

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practical adaptation actions and measures to respond to climate change on a sound scientific, technical and socio-economic basis, taking into account current and future climate change and variability.
http://unfccc.int/adaptation/nairobi_work_programme/items/3633.php

## 3. Integrating Ocean Acidification More Fully Into the UNFCCC

Opportunities exist to address ocean acidification and climate change together within the framework, the bodies and the mechanisms of the UNFCCC. Parties could take initial steps by recognizing ocean acidification under the framework and call for follow-up activities by both Parties and the relevant UNFCCC bodies. This could happen both via a decision of the Conference of the Parties (COP) or by integrating appropriate language into the ongoing negotiations for a post-2012 Agreement.

Current negotiations for a post-2012 climate regime are unfortunately advancing less rapidly than what is currently needed. Negotiations will continue in the year to come, despite the possible agreement on some of the building blocks at COP16. This should be seen by Parties as an opportunity to integrate ocean acidification into the next Agreement.

To address the common driver of ocean acidification and climate change, Parties to the UNFCCC may wish to:

- Acknowledge ocean acidification as a consequence of increased anthropogenic $CO_2$ in the atmosphere, acting alongside climate change and interfering with the climate system;
- Acknowledge that ocean acidification is a common concern of humankind that will intensify with continued anthropogenic $CO_2$ emissions;
- Note with concern the progressive and rapid decline of the ocean's pH and its potential serious and even irreversible impacts on marine ecosystems and many ocean-related benefits to society and commit themselves to action even if there is lack of full scientific certainty;
- Affirm the urgent need to take meaningful action to reduce the impacts of ocean acidification.

A decision by the COP or parts of the post-2012 Agreement could further:

- Invite Parties to strengthen and support already ongoing national research efforts on ocean acidification, especially on socio-economic impacts, and include scientific findings into their national climate change actions and strategies;
- Encourage Parties to explore a range of actions, identify options and undertake efforts to address ocean acidification long-term under the existing mechanisms and process of the UNFCCC;
- Request SBSTA and other appropriate bodies within the UNFCCC to take up relevant work.

With respect to the post-2012 Agreement in particular, deliberations under the current negotiation stream Ad-hoc Working Group on Long-term Cooperative Action (AWG-LCA) on "Shared Vision" and "Enhanced Action on Adaptation" would benefit from the recognition of the need for enhanced action on climate change *and* ocean acidification and follow-up activities. Reference could be made to the need to build resilience of socio-economic and ecological systems in face of ocean acidification, including through economic diversification and sustainable management of natural resources, as already set forth in the current AWG-LCA negotiation text.

## 4. Recommendations

This paper briefly highlights the possible severe impacts of ocean acidification on marine life and its ramification for humans and indicates the relation between ocean acidification and the climate system. The paper has also shown the linkages between ocean acidification and the UNFCCC and has proposed a set of opportunities for how to integrate ocean acidification into the climate Convention and its actions.

Opportunities for Parties to better incorporate ocean acidification into the UNFCCC framework include:

- Recognizing the opportunity, while acting upon the mandate of the UNFCCC, to address and find **common solutions for climate change and ocean acidification** through the post-2012 Agreement and/or a COP decision, and request follow-up activities such as a possible SBSTA work programme on ocean acidification;
- Proposing ocean acidification as a priority theme to be addressed at the workshop organized in conjunction with the **SBSTA research dialogue** at SBSTA 34 in June 2011;
- Including ocean acidification in **mitigation actions** under the UNFCCC by:
    - establishing targets effective in curtailing both climate change and ocean acidification and periodically reviewing and revising as needed emission reduction targets in light of emerging scientific findings;
    - incorporating an indicator for ocean acidification alongside temperature;
    - revising the effectiveness of mitigation mechanisms such as the CDM to ensure they address ocean acidification, and modify them if necessary;
    - employing mitigation strategies that are effective in curtailing both climate change and ocean acidification and avoiding strategies that may exacerbate ocean acidification (eg., some forms of geoengineering);
- Including ocean acidification into **adaptation actions** under the UNFCCC by:
    - incorporating ocean acidification as a thematic knowledge and information sharing hub into the continuation of the Nairobi Work Programme.

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[42] Enhanced Action on Adaptation Option 1. *8. Establishes* an international mechanism to address [social, economic and environmental] loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change [and/or to the impact of the implementation of response measures], including impacts related to extreme weather events and slow onset events, through risk management, insurance, compensation and rehabilitation; (FCCC/AWGLCA/2010/14; 13 August 2010)

[43] The rehabilitation/compensatory component shall address loss and damage resulting from the progressive negative impacts of climate-related slow-onset events, including sea level rise, increasing sea and land temperatures, ocean acidification (e.g., land loss, coral bleaching, impacts on potable water availability, reduction in fisheries, desertification etc.) (FCCC/AWGLCA/2009/INF.1; 22 June 2009)

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