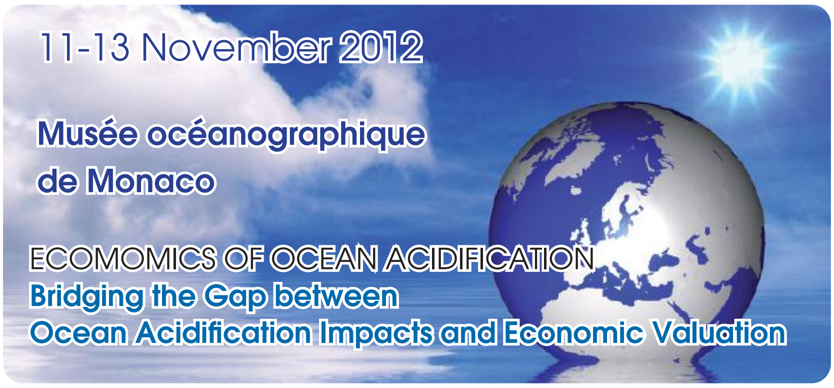



ECONOMICS OF OCEAN ACIDIFICATION

Impacts on fisheries and aquaculture

Ocean acidification has only recently been recognized as a threat for the environment with potentially severe social and economic consequences. The following statements are the major conclusions and recommendations from the second international workshop on “Bridging the Gap between Ocean Acidification Impacts and Economic Valuation.” The objective of the workshop was to assess ocean acidification impacts on fisheries and aquaculture resources in different regions of the world. The regions were artificial aggregations of the fishing areas defined by the Food and Agriculture Organization (FAO). Each region spanned multiple political, economic and ecological units.

INTERNATIONAL WORKSHOP



GENERAL CONCLUSIONS

• Ocean acidification is a global issue directly caused by increased anthropogenic CO_2 emissions to the atmosphere. It is happening now and CO_2 absorbed by the oceans will continue to rise long after emissions are reduced.

• Some ocean areas such as upwelling waters (deep water drawn upwards as wind pushes surface water offshore), polar and sub-polar regions, and some coastal and estuarine waters are natural “hot spots” of special concern for ocean acidification.

• Coastal waters are subject to warming, low oxygen, high nutrients and pollution in addition to ocean acidification, exposing aquatic species and communities to multiple stressors.

• World capture fisheries and aquaculture generated about US$ 218 billion in 2010. This provides an estimated 4.3 billion people with at least 15% of their animal protein. Over the last 30 years world food production by aquaculture has expanded twelve-fold; representing nearly half of human seafood consumption. Dependence on marine protein is expected to continue to rise with increasing human population.

• Major fisheries and aquaculture often occur in areas sensitive to ocean acidification. This puts economies and livelihoods at risk, and requires consideration and action by policy makers.

• Research on valuable seafood species is limited. Studies indicate that some shellfish used in aquaculture may be vulnerable to ocean acidification. Much uncertainty remains concerning finfish.

RECOMMENDATIONS

• Mitigate the effects of ocean acidification by reducing emissions of atmospheric CO_2.

• Establish coastal monitoring networks for standardized measurement of ocean acidification.

• Support research on valuable finfish, shrimp and other shellfish in high CO_2 conditions to enable socio-economic assessment of impacts on food security.

• Implement best practices and adaptive management of fisheries and aquaculture to increase ecological resilience of marine ecosystems.

• Increase the adaptive capacity of fishing communities through education about ocean acidification, and by training and support to diversify livelihoods where needed.

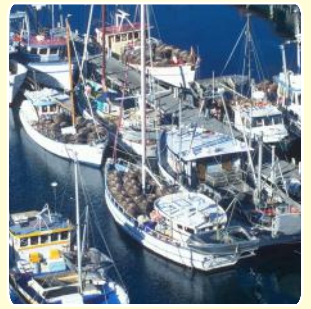
• Improve multi-stakeholder exchange of information and communication among parties (coastal communities, businesses, researchers, resource managers, international organizations and policy makers).

NORTH AND CENTRAL PACIFIC

• In many countries of this region, finfish and shellfish make significant contributions to government revenue, food security and employment. For example, the 'Coral Triangle' is one of the world's richest marine ecosystems (containing 75% of reef-building species) and helps support over 120 million people with food, shore protection and income.

• Ocean acidification is already observable in this region; an open-ocean time-series station near Hawaii shows a decline in pH during the past 20 years.

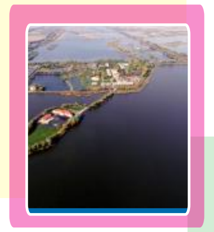
• Upwelling regions along the west coast of the United States are particularly sensitive to increasing levels of CO_2. Pacific deep waters are becoming cumulatively corrosive. Washington State oyster aquaculture is the first example of ocean acidification affecting businesses.



• Carpet shell clams, cupped oysters, scallops, shrimp, sea cucumbers, coral reef fish, and aquatic plants are all important marine harvest species in the region. Major capture fisheries include small (sardines, anchovy, mackerel and scads) and large (tuna) pelagic fish.

• The majority of laboratory studies indicate a negative impact of ocean acidification on bivalves; therefore, highly valuable aquaculture food enterprises producing clams and oysters in East and South Asia and scallops in China and Japan may be particularly sensitive.

• Despite the high economic value of pearl oysters in the tropical region, there is little work to date on the effects of ocean acidification on the production, quality and value of pearls from the black-lipped oyster. Data from a related species of pearl oyster suggest that shells are weakened by lower pH.



SOUTH PACIFIC AND SOUTHERN OCEAN

• This region consists of three main sub-regional fisheries: coastal South American pelagic fisheries including the world's largest (Peruvian anchoveta); Antarctic krill which has major development potential (biomass estimated at 500 million tons); and several demersal and pelagic species of the Southwest Pacific including blue grenadier, mackerel and squid.

• The highly productive Southern Ocean and the large upwelling zone off the coast of Peru and Chile have a naturally high-CO_2 system and may be particularly vulnerable to ocean acidification.

• Potentially deleterious effects from ocean acidification may impact key trophic links such as shelled pteropods which have already shown sensitivity to current CO_2 levels in the Southern Ocean.

• Sensitivity of molluscs to high CO_2 has been shown with effects of reduced growth, calcification, and hatching and larvae recruitment success. Some aquaculture species or strains may be susceptible; however, others may have potential to acclimate or adapt.

• Aquaculture is prevalent in both Southwest and Southeast Pacific. Key species are Atlantic and Coho salmon, rainbow trout, New-Zealand and Chilean mussels, cupped oysters, calico scallops and *Gracilaria* seaweed. Ocean acidification could constrain future harvest of some species.

• Fisheries and aquaculture sectors are composed of a few large industrial fisheries, consolidated aquaculture and aqua-feeds industry, and a large number of small-scale fishers in Latin America.

• The limited number of key actors facilitates the possibility of dialogue and action to develop engagement strategies to target key fisheries, strengthen regional governance, foster collaboration among Regional Fisheries Management Organisations, integrate actions with UN agendas, undertake selective breeding for increased resilience, and to explore risk analysis with insurance industry.

NORTH ATLANTIC AND ARCTIC OCEAN

• The North Atlantic has the highest proportion of the anthropogenic carbon distributed throughout the whole water column and the Arctic may experience corrosive surface waters in the near future.

• Ocean acidification may have pronounced interactive effects with strong background warming and expanding hypoxia.

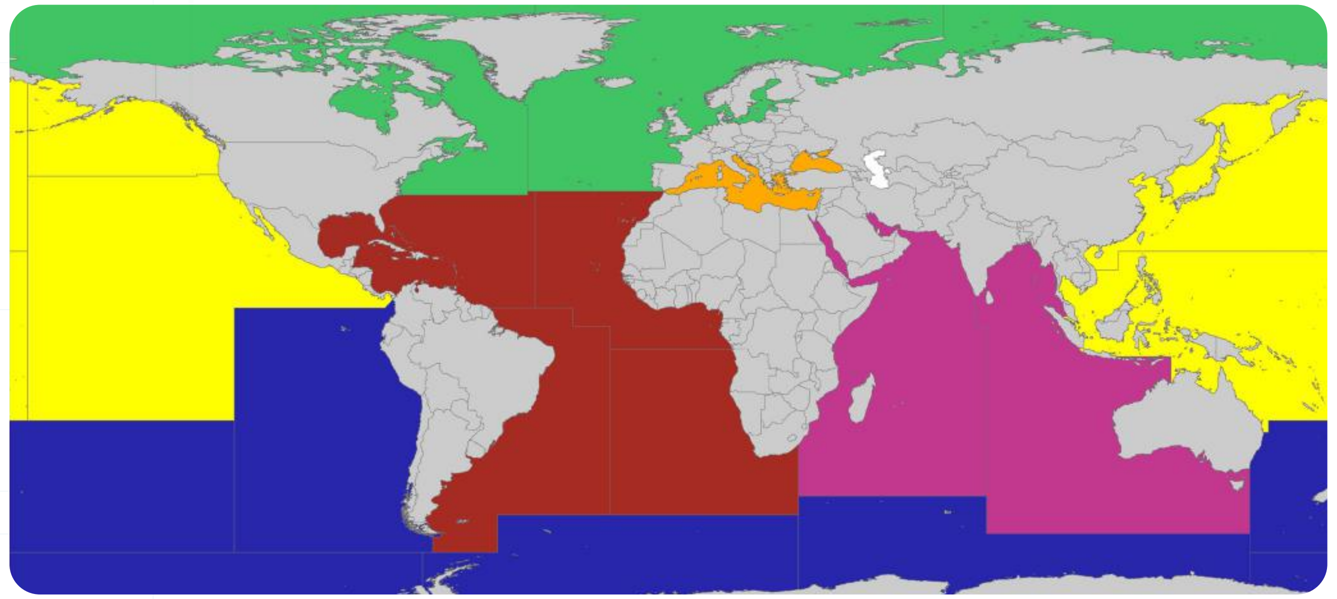
• While ocean warming may increase general productivity in the North Atlantic, which may lead to an increase in fish catch, ocean acidification could constrain this increase in catch potential.

• Bivalves are likely to be impacted by ocean acidification, whereas effects on adult fishes may be small and indirect. The long-term resilience of cold water coral reefs to ocean acidification is a concern and their continued role as a nursery habitat for fishes is unknown.

• Fisheries and aquaculture in North America and coastal European countries are of major regional political, social and cultural importance and are a large fraction of the economies of Greenland, Iceland and the Faroe Islands.

• North America and Europe are substantial import markets for seafood, and thus are dependent on ocean acidification impacts in other areas of the world.

• Ocean change due to warming and acidification has implications for production and trade patterns of natural wild (and invasive) fish stocks and aquaculture. Issues of industry adaptation, relocation and employment can be anticipated.



INDIAN OCEAN AND RED SEA

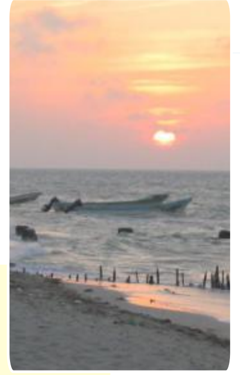
• More information is needed on carbon chemistry and fisheries in the Indian Ocean. Much of the wild fisheries catch is unreported or unidentified.

• Monsoon-induced upwelling along East Africa, the Arabian Sea and the Andaman Sea makes these coastal waters seasonally high in primary productivity. This supports productive fisheries, but the upwelled high-CO_2 water also make these areas particularly sensitive to ocean acidification.

• The commercial fish catch of the Indian Ocean region consists of tuna, sardines, mackerel, jacks, scads, pomfrets, kawakawa, octopus and squid. Primary shellfish harvests include clams, scallops, abalone, oysters and pearl oyster farms. Tropical coral reefs are found throughout the region. Ocean acidification impacts are likely to have negative effects on coral reefs, which may lead to altered reef fish habitat.

• The Indian Ocean region consists of mainland eastern and southern Africa, the Indian Ocean Island States, South Asia, and western and southern Australia. An estimated 800 million people live within 100 km of the coasts surrounding the Indian Ocean. Many members of coastal communities are undernourished, impoverished and highly dependent upon fishing for sustenance. Changes to harvest could therefore be a threat to food security.

• Most of the seafood harvests are small-scale artisanal fisheries. Negative effects of ocean acidification are anticipated for mollusc fisheries and mariculture. Aquaculture in sub-Saharan Africa and South Asia is increasing with large future potential. Shifts toward new production methods and cultured species may provide benefit to household livelihoods and small and medium enterprise development.



CENTRAL AND SOUTH ATLANTIC

• This region includes sub-regions with special features such as the eastern Atlantic high-productivity coastal upwelling areas (Guinea and Benguela Currents) and the Caribbean Sea.

• Large upwelling areas are associated with high-CO_2 waters. These conditions may become more extreme in the future as the ocean takes up more atmospheric CO_2.

• Large rivers drain into this region, which are able to strongly alter the seawater pH near shore beyond what may occur due to atmospheric CO_2. The complex biogeochemical controls on seawater CO_2 chemistry make it difficult to detect trends of ocean acidification in coastal areas.

• Small scale fisheries of small pelagics (sardines, anchovies and herring) and some large scale fisheries for demersal (hake), large pelagic (tuna) and small pelagic fish are found in all sub-regions of the Central and South Atlantic.

• The western Atlantic has major shellfish aquaculture activities, large-scale in the United States and artisanal in Brazil, which may be sensitive to ocean acidification.

• The sensitivity of open ocean finfish fisheries to ocean acidification *via* physiological or food-web effects is not yet known, but is of concern for coastal western and southern Africa.

• The Caribbean has important but degraded coral reef areas, which can be negatively impacted by ocean acidification. Alteration of the reefs will change the fish populations and regional productivity.

• Impacts that decrease harvests by small scale fisheries have the potential to reduce food security and worsen food distribution inequalities that already exist in the region.

MEDITERRANEAN AND BLACK SEA

• The coast is subject to strong human pressures with an estimated population of 132 million and intensive farming and industrial activities.

• Capture fisheries total 1.4 million tons landed each year, primarily small pelagic fish; marine and brackish aquaculture produces 180,000 tons of shellfish and more than one million tons of fish annually.

• In the Mediterranean Sea, fisheries and aquaculture provide 380,000 direct and 210,000 indirect jobs.

• Synergistic effects of warming and ocean acidification may increase the negative impacts on shellfish, especially early life stages, and other calcifiers such as red corals in this region. For aquaculture, recruitment and seed production are likely to be the main bottleneck for shellfish farming in the Mediterranean Sea.

• Impacts of ocean acidification on fish are not well-studied, but may occur through changes in essential fish habitats or on other parts of the food web.

• Northern Mediterranean countries have more diversified fisheries-related economic activity with higher production, consumption and export than southern Mediterranean countries, where production is largely intended for local consumption and export to the north.

• The socio-economic impacts of ocean acidification will reflect the differences in economy and livelihood dependence on fish characterizing Mediterranean and Black Sea countries.

HOW DOES OCEAN ACIDIFICATION AFFECT FISHERIES?

The ocean moderate the rate and severity of climate change by absorbing large amounts of CO_2 generated primarily from man-made activities. The uptake triggers large-scale changes in seawater chemistry, referred to as ocean acidification due to the increase in seawater acidity (decrease of pH). In turn, these chemical changes may alter biological processes. Ocean acidification negatively affects many organisms that produce a calcium carbonate shell or skeleton, such as shellfish and corals. Other effects of high CO_2 include changes in growth rate, reproductive success or animal behaviour. The magnitude of the effect depends on the capacities of species to acclimate or adapt. Some organisms may be influenced by ocean acidification effects on components of the marine food web. For example, sea snails (shelled pteropods), which are food for salmon in the North Pacific, are threatened by acidification of high latitude waters. Effects are expected to be exacerbated when combined with other stressors, such as increased temperature, depleted oxygen, and pollution. Ocean change may have major consequences for some keystone species, which may potentially lead to extinctions.

GENERAL INFORMATION ABOUT OCEAN ACIDIFICATION AND FISHERIES:

- Knowledge of effects of ocean acidification on fish is currently inadequate
- Effects of lowered pH on fish eggs and larval development have not been sufficiently studied
- Coastal upwelling of deep ocean water to the surface can produce localised acidification
- Impacts of ocean acidification on fisheries may include altered food webs
- Small-scale artisanal fisheries employ 90% of the world capture fishers, and are important to food security and poverty alleviation
- Nutrition from fish and seafood provides essential fatty acids, minerals and vitamins, and is a primary source of protein for one billion people
- Fisheries and aquaculture production, distribution and marketing employs 660-800 million people, representing 10-12% of the world population

FILLING THE GAPS IN KNOWLEDGE

OCEANOGRAPHIC AND BIOLOGICAL EFFECTS:

- Effective monitoring of ocean acidification can establish cause and effect between changes in fisheries harvests and ocean acidification and provide early warning to fish farmers and fisheries managers.

- Ecosystem models need to be developed to project future acidification conditions in vulnerable and sensitive productive ecosystems.

- Reducing uncertainty through research of the effects of ocean acidification on seafood is necessary to evaluate direct economic impacts to society. Priority areas of research include, finfish, high-value crustaceans (shrimp, crab, lobster), and early life stages of seafood species.

- More research is needed on combined effects of environmental factors on target organisms to gain better understanding of the conditions that challenge natural communities.

- Little is known about how ocean acidification effects will alter marine food webs. Also, little is known about how ocean acidification will impact species in high value coastal habitats such as seagrass, mangroves and coral reefs.

ECONOMIC VALUATION AND SOCIAL IMPACT:

- Communities need to have a clear understanding of how ocean acidification may alter local economies and the possible scale of potential economic impacts based on assessment of exposure, sensitivity and adaptive capacity.

- The biological effects of ocean acidification are still poorly understood, therefore assessing the impact on jobs and the economy is challenging. Case studies need to be undertaken on the economic and social impact of ocean acidification on fisheries for the species most vulnerable to ocean acidification, including cultured species and species important for marine leisure activities.

- Comprehensive risk assessments should be designed and implemented to prioritize adaptive responses.

OCEAN ACIDIFICATION CASE STUDY IN AQUACULTURE

In 2008, oyster hatcheries on the northwest coast of the United States were near collapse and a US$ 270 million industry employing over 3,200 people was under threat. New-born oysters were dying off with production levels reduced by 80% and the cause of the losses unknown. Research eliminated the bacterial pathogen *Vibrio* as culprit. Instead, the oyster deaths were strongly linked to water quality - to ocean acidification. The hatcheries are open circulation systems supplied from the coastal ocean and the production failure was correlated to deep-ocean, corrosive waters brought to the surface. Working together, oyster businesses and scientists established actions to take. Production levels were restored to 70% of normal by 2010. In response to the crisis, the State of Washington budgeted US$ 3.3 million to regional efforts concerning ocean acidification in coordination with national agencies. Hatchery managers now monitor coastal waters to identify approaching upwelled water and take steps to protect their operations.

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Workshop websites:

www.iaea.org/monaco/EconomicsOceanAcidification
www.centrescientifique.mc/csmfr/informations/2012_11_OA.php

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