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Topic: Impacts of Ocean Acidification on the Marine Environment

A roadmap for key ocean sectors to contribute to the mitigation of ocean acidification

An estimated 25-30% of the anthropogenic carbon dioxide that humans have emitted through the combustion of fossil fuels over the last 200 years or so has dissolved in the ocean as carbonic acid. While uptake by the ocean has helped to delay and mitigate the impacts of climate change on the atmosphere to a sizeable degree, it has resulted in a change to ocean carbonate chemistry through lowering the average pH of the ocean by 0.1 units, this represents an increase in ocean acidity of about 30% (pH uses a logarithmic scale). In a business as usual fossil fuel use scenario, by the late 21st century ocean pH would drop by another 0.3-0.4 pH units, or an increase in acidity of over 200%. Marine organisms spend a lot of their energy maintaining their internal pH and as external seawater pH decreases, they will likely have to divert more of the energy away from other parts of their physiology (e.g., growth and reproduction) to continue to do this. As a result of acidification, the concentration of carbonate ions in the ocean has also decreased significantly and will continue to do so with increased CO_2 emissions to the atmosphere. The calcium carbonate concentration directly influences the saturation, and consequently the rate of dissolution, of calcium carbonate minerals in the ocean. The degree of calcium carbonate mineral saturation is important in the formation of shells and skeletons by numerous planktonic and benthic organisms. As saturation levels decline further, shell forming organisms will find it increasingly difficult to form their shells and some may face possible extinction.

Under the ‘business as usual’ climate change and CO_2 emission scenario, by 2100 virtually all Arctic and Southern Ocean waters become ‘undersaturated’ with respect to the two forms of calcium carbonate (aragonite, calcite), basically bringing into question the survival of many calcifying organisms – and the broader ecosystems that depend upon them - in these ocean areas. Towards the end of this century, saturation levels of calcium carbonate will not yet be corrosive to calcium carbonate on coral reefs. However it is likely that the rate of reef calcification will decline to a level such that coral reef erosion will exceed reef growth and reef habitat and the great biodiversity provided by them will no longer be sustained in many areas of the world. To further put this issue in perspective, ocean pH is already changing at a rate not seen on earth for at least *25 million* years (Figure 1) and in the earth's geological record there is a strong correlation between mass extinctions and major ocean acidification events.

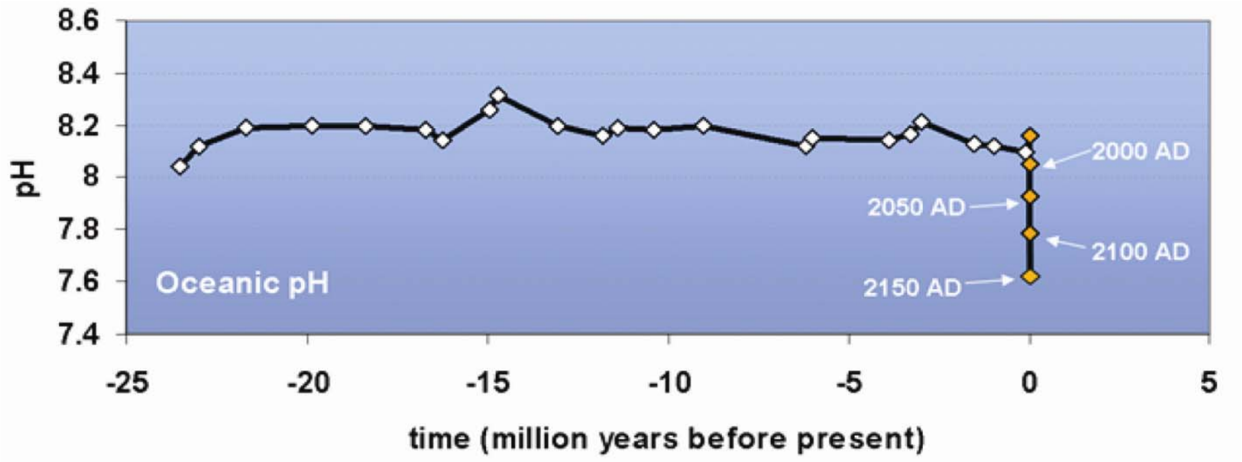

Figure 1: Changes in Ocean pH over the last 25 million years and projections in 'business as usual' fossil fuel use scenario (Turley et al., 2006)

Initial estimates of the economic costs of ocean acidification by 2100 amount to $1.2 trillion per year (Brander, 2011)), about 0.16% of global GDP, and represent about 10% of the overall projected damages due to climate change. However, these preliminary estimates only include impacts on coral reefs and mollusks and don't begin to account for the potentially catastrophic impacts on ocean ecosystems if the functioning and survival of calcareous plankton, the basis of much of the oceanic food chain, is impacted.

Ocean acidification – increasingly referred to as 'the other CO_2 problem' – is driven wholly by increasing levels of fossil fuel CO_2 in the earth's atmosphere. As a truly global issue, ocean acidification lends itself to a global approach. As illustrated above, there are few if any adaptation strategies for the marine organisms projected to be impacted by ocean acidification and for the human societies that depend on these marine ecosystems. As such, the primary means of reversing ocean acidification and avoiding its serious impacts is to dramatically reduce CO_2 emissions as quickly as possible, through a transition to a low carbon energy economy. Given the speed, severity and urgency of the acidification issue, this could present an opportunity to more formally embed ocean acidification within the United Nations Framework Convention on Climate Change (UNFCCC), or to consider an entirely new global instrument. For example, in addition to existing UNFCCC indicators and targets that seek to cap the increase in the average temperature of the atmosphere, additional targets could be added committing to not exceeding a lower limit on ocean pH, within the tolerance of most marine ecosystems. In addition, UNFCCC could be adjusted to ensure mitigation strategies that could exacerbate ocean acidification (such as some artificial ocean iron fertilisation schemes which would draw down massive amounts of additional CO_2 into the ocean), are not pursued, as well as recognise that ocean acidification would continue to be driven by increases in atmospheric CO_2 if climate control strategies aimed at solar radiation management (vs. greenhouse gas reduction) were implemented (Williamson and Turley, 2012).

Key ocean sectors can play a critical role in mitigating climate change through 1) increasing the energy efficiency of shipping operations and 2) leveraging the substantial carbon sequestration potential of coastal habitats such as mangroves and seagrasses. In addition, unlike open ocean iron fertilisation, effective coastal habitat protection and restoration can provide multiple development benefits to local communities and align climate change efforts with national development goals.

This first set of measures could be fostered through implementation of recent international agreements on ship energy efficiency measures while the second would be achieved by including blue carbon in the new market mechanisms for climate mitigation.

Shipping Contributions to Greenhouse Gas Emissions & Climate Change

At the present time, international shipping contributes about 2.7% of anthropogenic greenhouse gas emissions, primarily as CO_2 from the burning of ship bunker fuels. However, in the ‘business as usual’ scenario, ship emissions are projected to increase by 200% or more (from 2007 levels) by 2050 (Figure 2) at which point they could constitute 5% or more of global CO_2 emissions, depending on the world’s overall future carbon trajectory. Recent efforts by IMO to limit the carbon footprint of shipping include development of ship design (Energy Efficiency and Design Index - EEDI) and operational energy efficiency (Ship Energy Efficiency Management Plan - SEEMP) measures which have already been adopted by IMO member states. If implemented, these energy efficiency measures would lead to avoided shipping CO_2 emissions of 1 billion mt/year (as CO_2) by 2050 (1.7% of projected (UNFCCC A1B ‘balanced’ illustrative scenario) global CO_2 emissions of about 58.7 $GtCO_2$/year in 2050) and prevent shipping from becoming a more significant component of global GHG emissions. Furthermore, through implementing these energy efficiency measures, the industry would enjoy annual fuel savings of $90-310 billion/year by 2030 alone (Bazari, 2011).

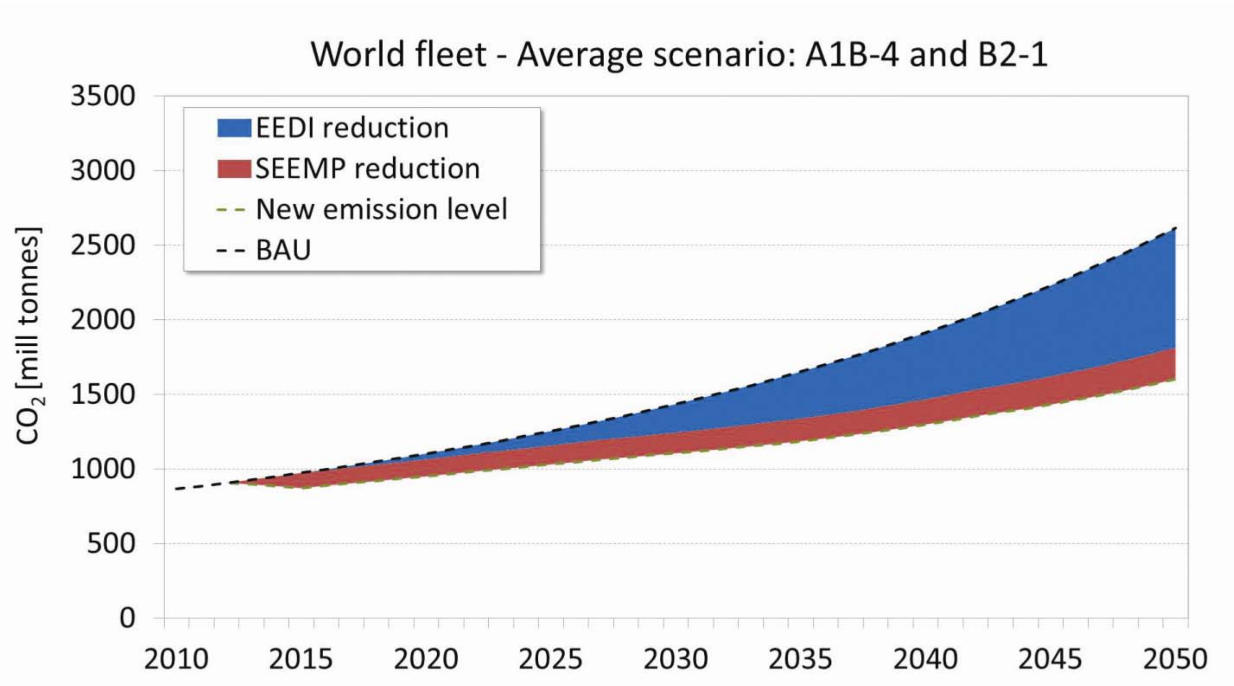

Figure 2: Impact on shipping CO_2 emissions of implementation of IMO Ship Energy Efficiency Management Plans (SEEMP) and Energy Efficiency Design Index (EEDI) measures, 2010-2050 (IMO, 2011)

Developing countries account for the largest portion of the world's fleet by tonnage, the majority of the world's shipyards and 90% of the busiest ports. At the same time, the knowledge base, legal/policy framework and technical and institutional capacity required to give effect to any international regime for GHG emissions from shipping pose severe constraints for most of the developing countries. The barriers/root causes behind these constraints include:

- International and cross-boundary character of the shipping industry;
- Existing institutional and legal arrangements are insufficient or inadequate to address GHG issues;
- Lack of a global carbon market incorporating shipping contribution to GHG emissions;
- Lack of readily available, cost effective and viable technologies to address the issues;
- Broad lack of awareness regarding GHG emissions, its potential impacts and options for management; and,
- Poor and inconsistent regional cooperation on this issue.

Not surprisingly, these barriers are quite similar to those that initially faced the international community when the ship ballast water issue was starting to be assessed. A similar suite of stakeholders needs to be targeted including policy makers and national maritime and port administrations; ship and port operators; and ship designers and shipbuilders. A concerted technical and institutional capacity building programme for these target groups could ensure that developing countries are able to meet the new IMO energy efficiency obligations and make a sizeable contribution to global efforts to mitigate climate change. Building on these new and emerging global legal frameworks presents an excellent opportunity to deliver transformational impacts towards environmental sustainability in the shipping industry. Costs, benefits and total catalysed finance for such a global initiative are estimated below.

Public Costs - Shipping: Building on similar experiences (such as the GEF-UNDP-IMO GloBallast programme on reducing risk from invasive species carried in ship ballast water) for grant finance needed to catalyse shipping sector transformation, initial public costs are estimated at $20 million for GEF or other financed Climate Change Mitigation project(s) to assist developing country and private sector shipping stakeholders in adopting and implementing IMO ship energy efficiency guidelines through development and promulgation of tools, methodologies, standards and guidelines for EEDI/ SEEMP compliance.

Benefits/Avoided Costs - Shipping: In a balanced fossil fuel growth scenario (UNFCCC SRES A1B illustrative scenario; IPCC (2000)), by 2050 shipping grows to about 5% of global GHG emissions vs. 3.3% under energy efficiency measures, so we assume 1.7% reduction in total climate change impacts by 2050 due to implementation of ship energy efficiency measures. Recent estimates (Stern, 2007) of the net projected global economic impacts of climate change in business-as-usual (BAU) 'high climate impact' scenario are 5% of global GDP or .05 x $104 trillion = $5.2 trillion/year (2050). This delivers a benefit estimate of 0.017 x $5.2 trillion = $88 billion/year in avoided global climate change costs from ship energy efficiency by 2050. Additional benefits (avoided costs) of SEEMP/EEDI compliance realised by the shipping sector have been estimated as $90-310 billion/year in fuel savings by 2030 (Bazari, 2011).

Catalysed Private Sector Finance – Shipping: New IMO EEDI requirements are expected to catalyse sizeable investments in design of more efficient new ships including expected features such as more efficient engines, efficiency optimised auxiliary machinery, waste heat recovery systems, new lightweight construction, hybrid electric power, shaft propulsion generators, solar power, decreased design speed (power), advanced hull coatings, etc.; no estimates are yet available of projected new net investment in the sector but clearly it will be 'multiple billions of dollars' stimulated by the new EEDI requirements; this is conservatively estimated at $20 billion one-time private sector finance. This is underscored by the fact that annual capital costs associated with new ships relative to annual fuel costs has changed significantly such that annual fuel costs are now much higher than capital costs. This effectively drives the economics of building new ships in the same direction as the EEDI regulation: diminishing the increased construction costs of EEDI compliant ships while emphasising the fuel savings.

Blue Carbon for Climate Change Mitigation

As noted earlier, loss of critical coastal habitats such as coral reefs, mangrove and seagrasses, continues unabated in nearly all locations around the world. Stressors causing these losses include unsustainable fishing practices, pollution and sedimentation, poorly planned coastal development, growth in coastal aquaculture, and others. While there is broad agreement in the environmental community that these ecosystems provide a wide range of valuable ecosystem services, ranging from nurseries for fisheries of commercial interest, to protection from storm surges, to nutrient sinks, unfortunately few of these ecosystem amenities have been converted into services that can be bought and sold in functioning markets. Selected coastal habitats, particularly seagrasses and mangroves, while relatively small in areal extent on a global basis, have extremely high carbon sequestration values when looked at from the perspective of mass of carbon sequestered per hectare per year. On this basis, these ecosystems are believed to store carbon at rates several times higher than the more widely recognised terrestrial carbon sinks such as tropical rain forests and temperate forests. In the aggregate, protection and restoration of these coastal carbon sinks could sequester as much as 0.4 - 3.0% of present day global anthropogenic CO_2 emissions (Pendleton, 2012). Maintenance of these habitats also delivers climate change adaptation benefits by helping to protect coastal communities from the impacts of sea level rise and storm surge. In the same context as the UN-REDD (Reducing Emissions from Degradation and Deforestation) programme, communities interested in reversing the loss of these coastal ecosystems and the services they provide are increasingly looking at them from the perspective of their value as carbon sinks – so-called "blue carbon".

Efforts are underway by a number of international and non-governmental organisations (UNEP, IOC/UNESCO, Conservation International, IUCN, etc.) to develop robust methodologies to quantify the carbon sequestration values of seagrass and mangrove ecosystems. Local and national ICM policies and plans, and regionally adopted SAPs, could incorporate blue carbon in the mix of policy instruments municipalities and countries adopt through these frameworks. If such methodologies can be advanced, verified and formally adopted by appropriate international bodies (UN Framework Convention on Climate Change, Clean Development Mechanism, UN-REDD), this could present a transformative opportunity to bring the very high carbon sequestration value of these critical coastal ecosystems into global carbon markets and lead to rapid upscaling of 'blue carbon' as a key vehicle to both help mitigate and adapt to climate change, and to protect and restore these key coastal habitats in the context of ICM.

What kind of costs might be required to bring blue carbon fully into carbon finance markets? The principal barriers at play are technical and informational; what's primarily needed is broad agreement and formal adoption of a robust methodology to quantify the net annual carbon sequestration value of mangroves and seagrasses, and building of necessary national, local and community capacities to establish baselines and annual carbon storage values for specific blue carbon sites, along the same lines as REDD's Measurement, Reporting and Verification (MRV) system. Efforts to scale up blue carbon could build upon three proven strategic planning instruments – Integrated Coastal Management (ICM), Transboundary Diagnostic Analysis/Strategic Action Programme (TDA/SAP), and building on existing regional or global legal frameworks (Hudson and Glemarec, 2012). Estimates of the costs, benefits and catalysed finance deriving from a major scaling up of blue carbon follow.

Public Costs – Blue Carbon: We use the experience of REDD as a proxy of about $10-20 million per country to establish robust blue carbon inventories, build national capacities for applying blue carbon, and for ongoing monitoring, reporting and verification, targeting high carbon sequestration mangrove and seagrass habitats. According to FAO data (FAO), 40 countries contain 96% of the world's mangrove habitat by area. Unfortunately similar data on the areal extent of seagrasses do not appear to be available; however, visual inspection of WCMC global seagrass maps (http://data.unep-wcmc.org/datasets) indicates important seagrass areas in about three-fourths of the world's 153 coastal nations; the WCMC data also indicate a very high degree of overlap between countries with both mangrove and seagrass habitat so the 40 country figure is used as an overall proxy for the number of countries that could benefit most from participation in a blue carbon approach. Combining these figures produces an estimate for the enabling public finance required of about: 40 countries x ($10-20 million/country) = $400-800 million (one time cost).

Benefits/Avoided Costs – Blue Carbon: A global scaling up of blue carbon could reduce GHG emissions from loss of coastal habitats by around 0.15-1.02 $GtCO_2$/year (Pendleton, 2012); with global GHG emissions presently at about 33.5 $GtCO_2$/year, and using same A1B scenarios as for the shipping calculation (58.7 $GtCO_2$/year by 2050),this would reduce the economic impacts of climate change by about 0.3-1.8% or (0.003-0.018) x $5.2 trillion/year (Stern, 2007) = $16 - 94 billion/year by 2050. Substantial additional economic benefits would add to this in terms of adaptation benefits (protecting coasts from storm surges, etc.) and maintaining other ecosystem services of these habitats (fish spawning areas and nurseries, recreation, etc.).

Catalysed Finance - Blue Carbon: Blue Carbon catalysed finance assumes 0.15-1.02 $GtCO_2$/year x $2-5/mt carbon price for blue carbon credits = $0.3 - 5.1 billion/year; given that blue carbon sinks would need to remain largely undisturbed to maintain their carbon sequestration values, these sizeable financial flows could be directed in part towards the establishment and sustainable management of coastal MPAs in mangrove and seagrass habitat.

As discussed above, the avoided CO_2 emissions from the shipping industry deriving from successful implementation of recently adopted (and in force 1 Jan 2013) IMO ship energy efficiency standards, would prevent shipping emissions from rising to around 5% of global emissions, limiting it to about 3.3% of present day emissions by 2050 or about 1.6 $GtCO_2$/year. In parallel, successful efforts to mainstream and scale up 'blue carbon' schemes to protect and restore key coastal carbon sinks could deliver net CO_2 emissions reductions ranging from 0.15-1.0 $GtCO_2$/year or the equivalent of about 0.38 - 1.8% of projected "BAU" emissions in 2050. The approximate consonance of the high end (1.0 $GtCO_2$/year) blue carbon CO_2 reduction estimate with the projected lower shipping contribution to global emissions under SEEMP/ EEDI implementation scenario (1.6 $GtCO_2$/year) suggests that the ocean sectors which contribute to climate change could in effect move towards overall climate neutrality. This scenario is wholly achievable if the required methodologies and policy signals are put in place over the next twenty years. Of course, ocean acidification (and climate change) can only be successfully mitigated if land-based sectoral sources of CO_2 (power, transport, agriculture, buildings, etc.) also move towards a low carbon pathway. This presents an important opportunity for ocean sectors to show leadership in demonstrating that addressing climate change remains well within the realm of possibility, and identifies an initial roadmap for approaching climate neutrality in the ocean sectors.

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