**A CASE FOR THE DEEP OCEAN**

**Submitted by the Deep Ocean Stewardship Initiative Climate Working Group**

**Contacts: Nadine LeBris (**[lebris@obs-banyuls.fr](mailto:lebris@obs-banyuls.fr)) and **Lisa Levin** ([lllevin@ucsd.edu](mailto:lllevin@ucsd.edu))

Covering over half of the planet, and comprising 95% of its habitable volume, the deep ocean (>200 m) merits dedicated attention in the new Oceans and Cryosphere IPCC special report for several major reasons:

- the deep ocean has a predominant role in the sequestration of heat and carbon, with tight linkages to the upper ocean and atmosphere through vertical mixing, species migrations and particulate sinking, and a diverse range of ecosystems making it critical to any analysis of ocean roles in climate mitigation and adaptation.

- the deep ocean provides a broad range of ecosystem services that are just beginning to be inventoried; greenhouse-gas regulation, support to biodiversity (including genetic diversity), food supply and energy production.

- the deep ocean is increasingly impacted by human activities including contaminant inputs, overfishing, and disturbances from seafloor and terrestrial extractive activities. There is currently little understanding of how these direct impacts will interact with climate stressors.

Despite this, the deep ocean has received little specific attention in the AR5, appearing primarily in discussions of geoengineering (CO2 disposal in deep water) with tangential mention of the effects of hypoxia effects on mesopelagic fish and acidification effects on deep-water corals.

Key adaptations to climate change will require new knowledge, including the broadening of deep-water observing programs, to enable the design of marine protected areas encompassing vulnerable regions in deep waters, and to inform environmental management of industrial activities and development of new policies addressing deep national and international waters.

There is an unprecedented need to integrate the deep ocean into ocean science and policy. Knowledge of deep hydrology, hydrography, pelagic and seafloor ecology are critical to climate predictions and societal impact assessments (e.g. Mora et al. 2013) because of the strength of

connectivity between the oceans, atmosphere and the terrestrial realm. New international regulations (e.g. for mining) and treaties (e.g. for biodiversity), environmental management, and spatial planning also must incorporate climate and the role of deep processes.

We recommend attention to the following themes, which make the case for deep-ocean significance.

**Ecosystem services of the deep:** Life in the deep ocean provides or regulates many valuable services that sustain the planet (Armstrong et al. 2012; Thurber et al. 2014); key among these are CO2 and CH4 sequestration, nutrient cycling, substrate, food and nursery grounds provisioning for fisheries by a variety of habitats. The deep ocean is the largest reservoir of carbon on Earth and constitutes the ultimate sink for most anthropogenic carbon. The biogenic deep-sea carbon component is poorly quantified, but chemosynthetic ecosystems with high carbon fixation rates and vertical transport by pelagic species may significantly contribute to ‘blue carbon’ sequestration (Marlow et al. 2014, Trueman et al. 2014, James et al. 2016).

**Thermal energy budgets.** The ocean absorbs 90% of the extra heat trapped by anthropogenic greenhouse gas emissions, with 30% of this being stored at depths >700 m (IPCC 5th assessment report) and is thus a more accurate indicator of planetary warming than surface global mean temperature (Victor and Kennel, 2015).In this stable and mainly cold environment (except in the Mediterranean Sea and at bathyal depths in tropical regions), thermal limits shape species distributions. The consequences of warming in deep-ocean waters will profoundly influence ecosystems and their biodiversity. Examples of rapid changes in deep-sea benthic ecosystems have been documented in downwelling, upwelling and polarregions (e.g. Danovaro et al. 2004, Smith et al. 2012, Soltwedel et al. 2016), although discriminating natural cycles from climatic impacts in the deep sea will require unprecedented time series data (Smith et al. 2013).

**Biogeochemical changes**. The deep ocean supports major biogeochemical recycling functions; these are expected to undergo major changes. Declines in O2, pH and aragonite saturation have been observed and are predicted to strongly impact intermediate water depths under future emission scenarios (Bopp et al. 2013). Deep-water oxygenation is tightly coupled to the overturning circulation and O2 trends inform changes in global or basin-scale ocean circulation. As a regulator of the biogeochemical cycling of N, Fe, P, and S, O2 is key to potential synergistic responses. N2O production is expected to increase as oxygen declines (Codispoti, 2010), potentially linking O2 decline and climate through a positive feedback, though large uncertainties remain (Martinez-Rey et al. 2015).

**Cumulative impacts of changes.** There are many climate change-related stressors affecting deep-sea ecosystem functions (Levin and Le Bris 2015). Deep-sea ecosystems may be particularly vulnerable to change due to their environmental stability or to tight links with surface productivity or hydrodynamic regime. Deep-sea diversity patterns are shaped by export production (Woolley et al. 2016) and CMIP5 models predict overall decreases in integrated primary productivity with climate change. Large reductions in the tropics and the North Atlantic (Bopp et al. 2013), suggest possible negative impacts for deep-sea diversity. We need to assess how and where these cumulative changes, including warming, ocean acidification, aragonite undersaturation, shifts in nutrient fluxes and deoxygenation, will challenge ecosystem stability and species capacity to adapt (Lunden et al. 2014, Gori et al. 2016). This involves gathering sufficient knowledge about cumulative impacts of multiple stressors to build accurate scenarios of vulnerability.

**A need for deep observations**. The sparse nature and typically small spatial resolution of deep-ocean observations, combined with overly large spatial resolution of models, results in knowledge gaps and uncertainties. This includes natural variability, the coupling of climate to biogeochemical cycles, and the responses of biodiversity hotspots (e.g. seamounts and canyons). In addition, multicellular life in the deep pelagic realm is still largely unexplored, though this realm represents over 95% of the living space on our planet. Seafloor observatories and long-term time series have started providing insights into how deep-sea ecosystems respond to climate perturbations (Soltweddel et al. 2016, Smith et al. 2013). Long-term integrated ecological studies, covering a range of deep-sea systems and the most vulnerable hotspots, are needed to identify threats to critical ecosystem services and the potential feedbacks to the climate system and humans.

**Synergies of direct human-induced stressors.** Beyond the complexity of multiple climate stressors, deep-ocean ecosystems are facing an onslaught from pollutants, fishing, mining, energy extraction, and debris (Mengerink et al. 2014), with deep seabed mining now on the near-term horizon. New efforts to develop requirements for environmental impact assessments, environmental indicators, spatial planning and create marine protected areas in deep water will need to incorporate the interplay with climate change.

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