POLICY BRIEF

Climate Change in Oceans Beyond National Jurisdictions

Introduction.
Despite their remoteness, the high seas and deep ocean in areas beyond national jurisdiction (ABNJ) are at the forefront of CO2-induced climate stress, both in their mitigation capacity, and their vulnerabilities. Carbon dioxide (CO2) emission alters ocean conditions, leading to ocean warming, deoxygenation and acidification. These ocean changes affect marine life throughout the ABNJ, from the surface to the deep sea, by changing species' distributions, migration routes, ecosystem structure and functions. Consequently, these impact the ecosystem services provided by the seep sea, including the availability of fish stocks for fisheries in both ABNJ and the coastal waters, as well as the effectiveness of existing and planned management and conservation measures.

Ocean Warming.
The oceans are hugely important in moderating Earth's climate. 93% of the heat generated by carbon dioxide emissions, and 26% of the CO2 itself, representing vast quantities of energy and carbon, are removed from the atmosphere by the ocean. The amount of heat uptake since 1997 is equivalent to that in a Hiroshima-style nuclear bomb going off every second for 75 y. Most of this happens in ABNJ, which account for 64 % of the ocean surface, but a much larger fraction of the ocean's volume, and its biodiversity. This climate mitigation service is of enormous value, but is strongly altering open/deep-ocean environments and ecosystems.

Ocean warming and deoxygenation.
The ocean is warming, not just at the surface but also throughout the water column, including at abyssal depths below 4000 m. Over 30 % of the ocean heat uptake occurs below 700 m. Although CO2 release occurs on land, largely in the northern hemisphere, CO2 heat uptake occurs extensively in ABNJ, and extensively in the southern hemisphere. Sea Surface temperature in ABNJ has increased by about 0.24 oC between 1951-1980 and 1986 – 2014 (based on Hadley Centre SST data). A warmer ocean holds less oxygen due to declining solubility of oxygen with increasing temperature. A warmer ocean is also more stratified, due to the lower density of warmer water as well as fresher water as glaciers and ice caps melt. Greater stratification reduces ventilation (introduction of oxygen from the mixed layer to the ocean interior), and combines with lower solubility to cause ocean deoxygenation. Effects are greatest at intermediate depths where waters are isolated and oxygen lost through consumption is not replaced. Other contributors to oxygen loss in the ocean are atmospheric iron and nitrogen fertilization of the open ocean along with warming-induced dissociation of gas hydrates and climate-induced intensification of upwelling winds on continental margins. Unlike the localized dead zones caused by eutrophication, the areas affected by ocean deoxygenation are vast, Since the 1960s over 4.5 million km2 of the ocean has become deprived of oxygen (hypoxic) at 200 m water depth, over broad swaths of the tropical and subtropical oceans and NE Pacific. Predicted future declines in oxygenation will move ecosystems across biodiversity tipping points in some regions, including the deep and open oceans.

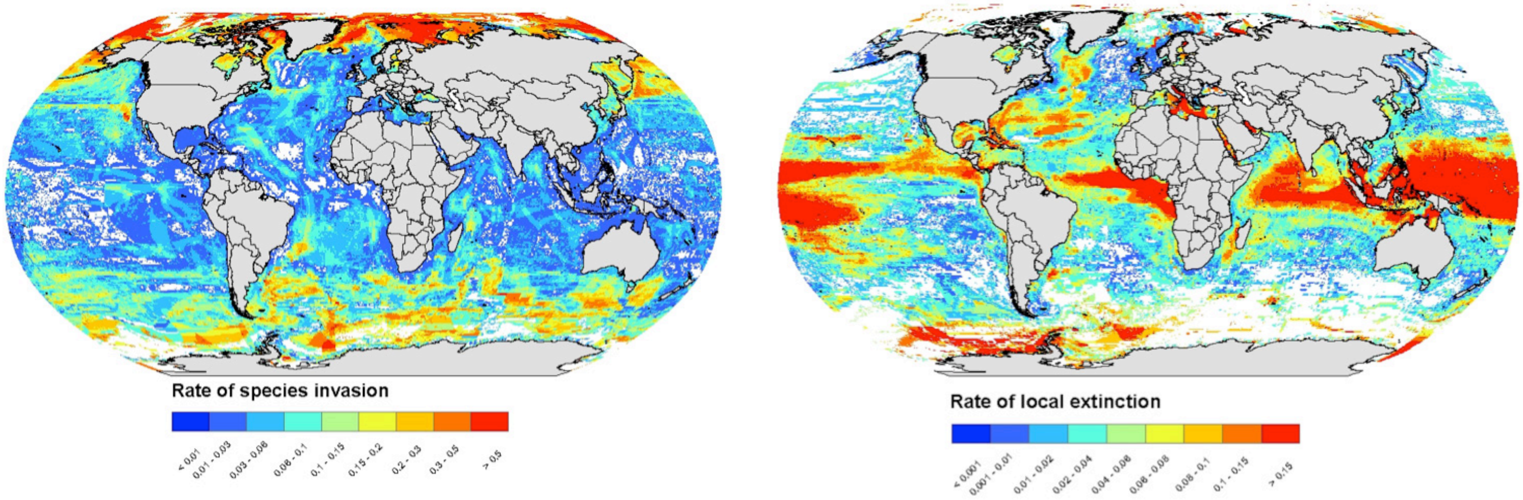

Figure 1. Rates of (A) species invasion and (B) local species extinction under "business-as-usual" CO2 emission scenario (2050s relative to 2000s). We expect a high rate of species invasion in the polar regions (upper panel) and intense local extinction in the tropics (lower panel). Based on Jones and Cheung (2015).

Ocean Acidification.
Uptake of CO2 from the atmosphere has increased the dissolved inorganic carbon content (DIC) and the production of carbonic acid, lowering pH of the ocean and the availability of carbonate ions important to the production of carbonate shells, tests and other biological structures including deep-water coral reefs. The ocean surface is 30% more acidic than it was 150 years ago. Areas most vulnerable to declining pH and carbonate saturation are the Arctic, NE Pacific and NW Atlantic. In a business-as-usual CO2 emissions scenario, pH could be as low as 7.8 (down from 8.2) and carbonate undersaturation may cause corrosive conditions by 2100 in many areas.

Combined effects, including on fisheries.
Climate change, ocean deoxygenation and ocean acidification are expected to affect biodiversity, structure of marine ecosystems and fisheries catches. Fish and invertebrates are sensitive to water temperature and oxygen level for their survival and each organism has a range of ocean conditions that they can tolerate. Marine species in ABNJ are becoming increasingly exposed to conditions beyond their tolerance level. As a result, on an individual level, some organisms show decreased growth and body size and compromised reproductive output. At the species level, some exhibit changes in distribution by moving to areas with more favourable conditions. Under a business-as-usual scenario, by 2050 relative to now, the maximum body size of fish communities is expected to decrease by 14-24% globally. The distribution of fishes and invertebrates will shift poleward by 10s-100s km per decade or into deeper waters, resulting in local extinctions in tropical waters (Fig. 1). Such distribution shifts may also modify food web interactions. Shell-forming organisms such as corals and shellfishes are most vulnerable to ocean acidification through reduced growth and increased mortality, exacerbating the impacts of warming and deoxygenation. In addition, with alteration of global net primary production under climate change, the source of energy for ocean food webs, potential fisheries catch in high latitude regions will increase but is predicted to decline in tropical oceans.

Several features of the deep ocean, which comprises the majority of the habitable volume on this planet, exacerbate biotic vulnerability to climate stressors: highly stable environmental conditions, slow growth rates and great longevity of species, high biodiversity linked to high incidence of rare and endemic species, and significant habitat heterogeneity. Predicted changes in temperature, oxygenation, pH and POC flux may drive regional species invasions, damage coral and sponge reef habitats, and enhance methane release (Fig. 2).

Cumulative Impacts.
Effective management of ocean ecosystems under climate change increases the resilience of marine ecosystems and the adaptive capacity of management systems, for example by reducing other human perturbations. Climate change, ocean deoxygenation, and ocean acidification only add to the list of anthropogenic stressors affecting marine biodiversi-

ty such as overfishing and pollution. These drivers will interact with and confound marine biodiversity changes in ABNJ that result from rising CO_2 and temperature and loss of oxygen, increasing the sensitivity of marine organisms to climate stressors (Fig. 3). Impacts of climate change on marine biodiversity can therefore be moderated by reducing stresses from other human activities.

Policy Implications.
As human activities accelerate in ABNJ, the trio of warming, deoxyenation and acidification threaten the functionality and resilience of ABNJ ecosystems. There is a growing need to expand knowledge of ABNJ climate mitigation services and ecosystem vulnerabilities and incorporate this knowledge into stewardship of ABNJ biodiversity. Data and climate projections are most scarce in deep waters. Expanded long-term observations of changing conditions to full-ocean depth and new monitoring technologies are needed to facilitate placement of protected areas, and to inform deep-ocean EIA assessments in ABNJ. Projections of vulnerability to climate stressors and their effect on resilience are critical to effective spatial planning, strategic environmental assessment, environmental impact assessment, fisheries management, MPA designation and broader spatial planning. Decisions about living and non-living resource extraction in international waters should incorporate cumulative climate impacts. Like biodiversity protections, climate policy to protect the environment is largely absent in the ABNJ. As on land, CO_2 emissions from ocean activities should be regulated, their impacts documented, and their effects accounted for.

Several existing and nascent international entities offer opportunities for informing BBNJ deliberations on climate change. The IPCC is preparing a special report on the Oceans and Cryosphere, and the Preparatory Committee pursuant to UN Res 69/292 on BBNJ could request a special section on climate change in ABNJ during the scoping process. The UN Regular Process could similarly be requested to focus on the interactions of climate change with ocean health in their scoping process. The Deep-Ocean Observing Strategy (DOOS) will bring together sustained observation, promote data sharing, and facilitate climate modeling, and is in the process of identifying critical measurements (Essential Ocean Variables), geographic gaps, hotspots and important themes. The Deep-Ocean Stewardship Initiative (DOSI) Climate Change working group stands ready to respond to requests for information about deep-ocean climate change, ecosystem vulnerabilities, and solutions. The Nippon Foundation-Nereus Program aims to help inform policy discussion about the climate change vulnerability, impacts and adaptation of ABNJ conservation and management.

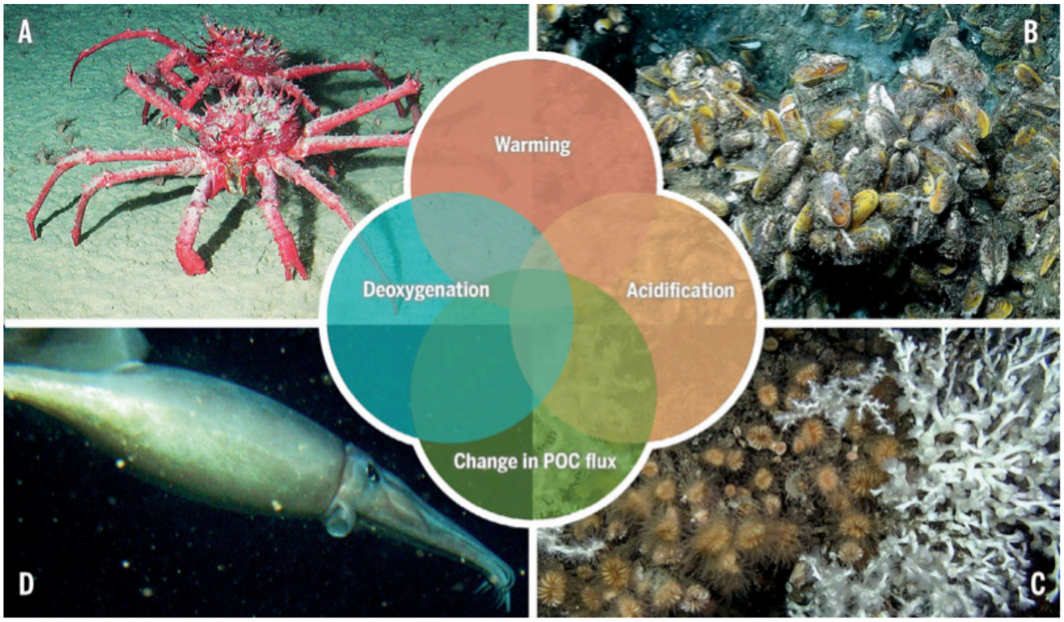

Figure 2. Winners and losers from exposure to interacting climate stressors. (A) King crabs invading Palmer deep in Antarctica enabled by warming, (B) Cold-seep fauna may expand as warming promotes methane release from the sea floor, (C) Cold-water coral reefs vulnerable to warming and acidification in Mediterranean canyons, (D) Hypoxia-tolerant Humboldt squid (Dosidicus gigas) have extended their distribution in concert with expanding oxygen minima along the E. Pacific margin. (From Levin and LeBris 2015).

Climate-specific recommendations related to issues under consideration by the PrepCom

Climate Change Implications for area-based management tools (ABMTs):

- The design and planning of ABMTs including marine protected areas (MPAs) should incorporate existing climate change (warming, deoxygenation, acidification) syntheses and projections into evaluation of vulnerability, need for protections, and resilience.
- The objectives for ABMTs including MPAs should include the reduction of direct anthropogenic stressors when the objective is to increase ecosystem resilience. Climate change can function as a physiological stressor that increases vulnerability to physical disturbance and reduces resilience.
- The design of ABMTs including MPAs should recognize that climate change-related impacts can alter habitat suitability and representativeness, redistribute species and modify biodiversity and thus designs and management should insure replication, adaptive protection of migratory corridors, and incorporate predicted habitat shifts.
- Consideration of climate change in MPA designation requires a comprehensive approach that includes all vertical realms (seabed, seabed and near-bottom waters, seabed and midwater, seabed and entire water column, surface waters).

Implications for environmental impact assessments (EIAs) and strategic environmental assessments:

- EIAs and SEAs should recognize that climate change may:
    - o Vary biodiversity independent of other stressors
    - o Be a source of cumulative impacts
    - o Compound anthropogenic disturbance-induced change (eg. Plumes generated from seabed mining may exacerbate climate-induced oceanchemistry changes)
    - o Baseline analyses and assessments of single and cumulative impacts should include climate stressors. Where possible they should be based on information gathered from no-take marine reserves used as reference areas for management.
- The scope of EIAs should include:
    - o assessment of vulnerability to climate stressors
    - o assessment of ecosystem services provided by the area of interest
    - o potential impacts to ecosystem services
- The scope of EIAs/SEAs should recognize that ecosystem services derive from multiple life stages, migrations, water or chemical movements, and other transboundary processes, and reflect the potential for cumulative impacts to these services by activities in widely separated areas.
- Triggering conditions/thresholds for carrying out EIAs/SEAs should include activities with the potential for significant adverse impacts, recognizing the increasingly vulnerable state of marine ecosystems and resources from climate-induced changes.
- Decision making processes related to EIAs/SEAs should ensure the protection of ecosystem services of deep-sea/high seas that may be altered by climate change

Implications for Technology Transfer and Capacity Building:

- New observations and observational tools are needed in remote and deep areas to record climate change & its impacts.
- Support for global ocean observation systems and regional observations systems to better monitor the effects of climate change, particularly in areas that have ABMTs, is critical to effective management and governance of ABNJ.

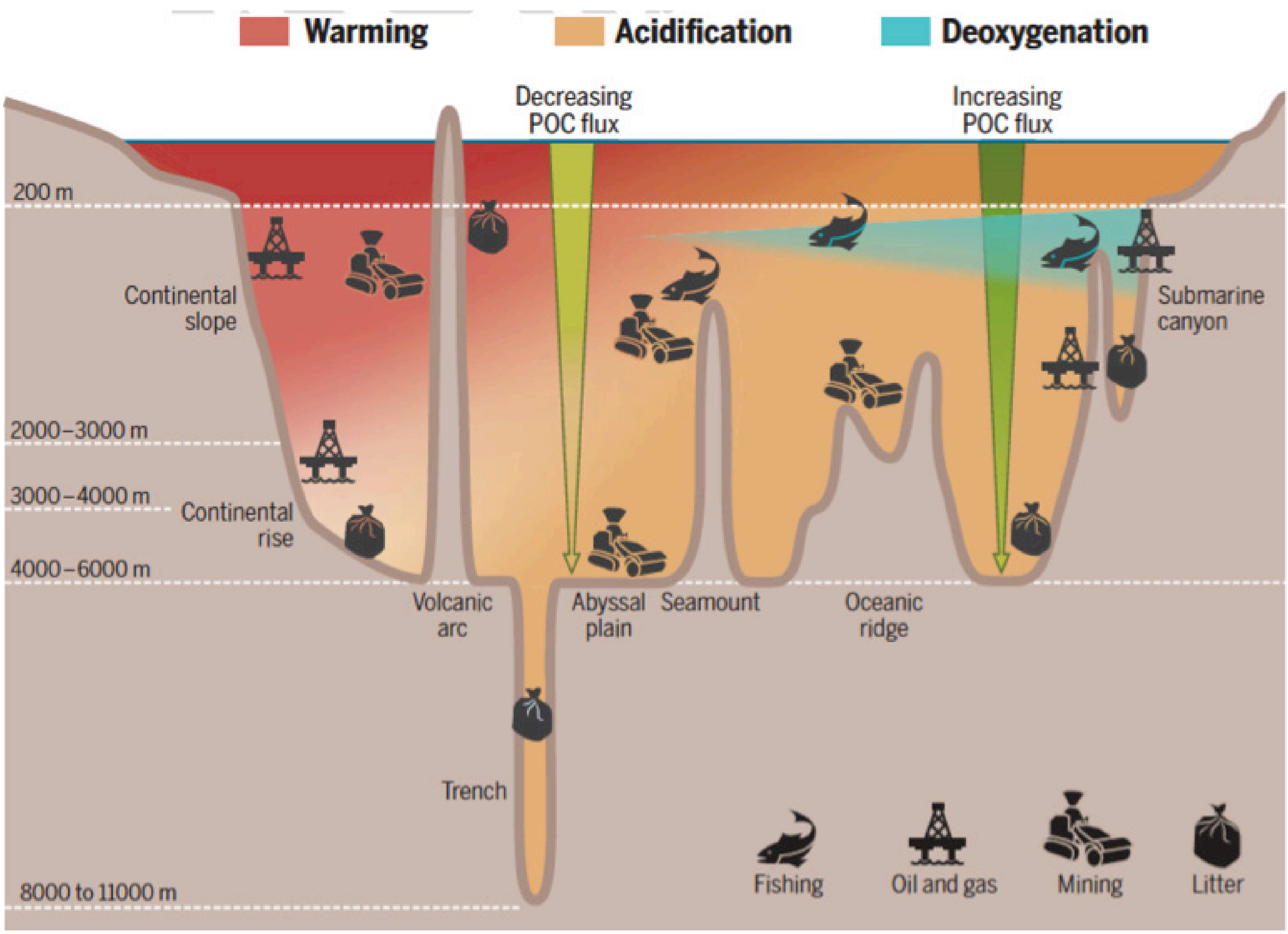

Figure 3. Humans and climate change in the deep ocean. The schematic illustrates the depth-resolved confluence of human exploitation activities and waste with CO2-induced change in the temperature, pH and oxygenation of the deep ocean. Changes throughout the deep ocean will compromise ecosystem services globally. (From Levin and LeBris 2015).

Suggested Reading:

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Acknowledgement

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