COMMENTARY:

Implications of the Paris agreement for the ocean

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In the aftermath of COP21, potential post-2030 emission trajectories and their consistency with the 2 °C target are a core concern for the ocean scientific community in light of the end-century risks of impact scenarios.

On the road to the Twenty-first Conference of the Parties (COP21) and to the United Nations Framework Convention on Climate Change (UNFCCC), ocean scientists assessed the risks of the impact arising from past and future cumulative carbon emissions. Results suggested that several key marine and coastal ecosystems will face high risks of impact well before 2100, even under the most stringent IPCC Representative Concentration Pathway (RCP2.6)[1–6]. In parallel, small island developing states (SIDS), by nature 'ocean countries', have argued for several years that a temperature increase of 1.5 °C above pre-industrial levels, rather than 2 °C, should be the UNFCCC target. During COP21, together with the European Union, SIDS initiated the 'coalition of high ambition', which gathered more than 100 nations from the least developed countries to highly developed ones[7], giving more weight to their historical pledge. Such ocean-driven scientific arguments and political efforts contributed to push the Paris climate talks towards an ambitious outcome, and the Paris Agreement[8] eventually established the goal of holding the global mean atmospheric temperature rise by the end of this century to well below 2 °C, if not 1.5 °C, above pre-industrial levels. The implementation of such an ambitious target is now a key concern for the ocean scientific community. This concern is reinforced by recent studies suggesting that end-century climate-related changes in the ocean will be more dramatic than previously reported in the Fifth Assessment Report of the IPCC (sea-level rise[9], for example).

As part of the COP21 process, 185 countries representing 94% of current global greenhouse gas (GHG) emissions and 97% of the world population have submitted their emissions pledges under intended nationally determined contributions (INDCs), mostly with a 2030 time horizon. Some organizations have projected the increase in temperature by 2100 from an aggregation of these INDCs (see the Supplementary Information). As illustrative examples, the Climate Action Tracker (CAT[10]) and Climate Interactive (CI; https://www.climateinteractive.org/tools/scoreboard. See also http://go.nature.com/X8QgvM), using different assumptions about post-2030 emissions, estimated a median global temperature increase by 2100 of 2.7 °C and 3.5 °C, respectively, with a range of uncertainty of 2.2–3.4 °C for CAT and 2.0–4.6 °C for CI. These different estimates and large uncertainties illustrate the challenge of extrapolating 2030 trajectories to subsequent decades. COP21 established a legally binding and universal agreement promoting transparency and the implementation of UNFCCC Parties' commitments as well as anchoring a new round of climate pledges. However, challenging questions remain regarding the 2030–2100 global emissions trajectory[11] because INDCs do not provide explicit information on long-term mitigation pathways. As a result, whether the implementation of the Paris Agreement may allow a trajectory compatible with a target "well below" 2 °C remains highly uncertain. Such information is imperative for the ocean scientific community to refine its projected century-scale risks of impact scenarios and to answer a fundamental question: are we on track to prevent dangerous anthropogenic interference with the ocean system?

Here we briefly review the aggregated risks of impact to the ocean for selected temperature thresholds, including the below 2 °C target and pathways derived from countries' INDCs, and draw conclusions on the need for the ocean scientific community and climate talks to inform each other.

Risks of impact for the ocean

The CAT and CI mean estimates provide a positive signal as they suggest a major deviation from the IPCC business-as-usual scenario (RCP8.5). However, this deviation is theoretical, as INDCs only describe countries' intentions. Whether the world will really avoid the RCP8.5 trajectory (or reach RCP2.6) will depend on the twenty-first century mitigation storyline — that is, on both the level of implementation of the INDCs and subsequent mitigation efforts. This raises concerns because contrasting outcomes of the combined effects of ocean changes (that is, warming, acidification, deoxygenation and sea-level rise) on marine and coastal organisms, ecosystems and ecosystem services emerge from the wide range of pathways derived from RCPs and aggregated INDCs[1–5].

The point of departure is that the impacts of climate change on the ocean are already detectable, with reef-building corals[12] and mid-latitude bivalves at risk, as well as some ecosystem services such as coastal protection, recreational services from coral reefs and low- to high-latitude fin fisheries being at stake[1,2]. Recently published[3] impact scenarios by 2100 for two contrasting GHG emission trajectories, that is, RCP8.5 and RCP2.6, show that the present-day level of impacts on a set of key organisms and ecosystem services is expected to multiply by 1.4 and 2.7, respectively (Fig. 1 and

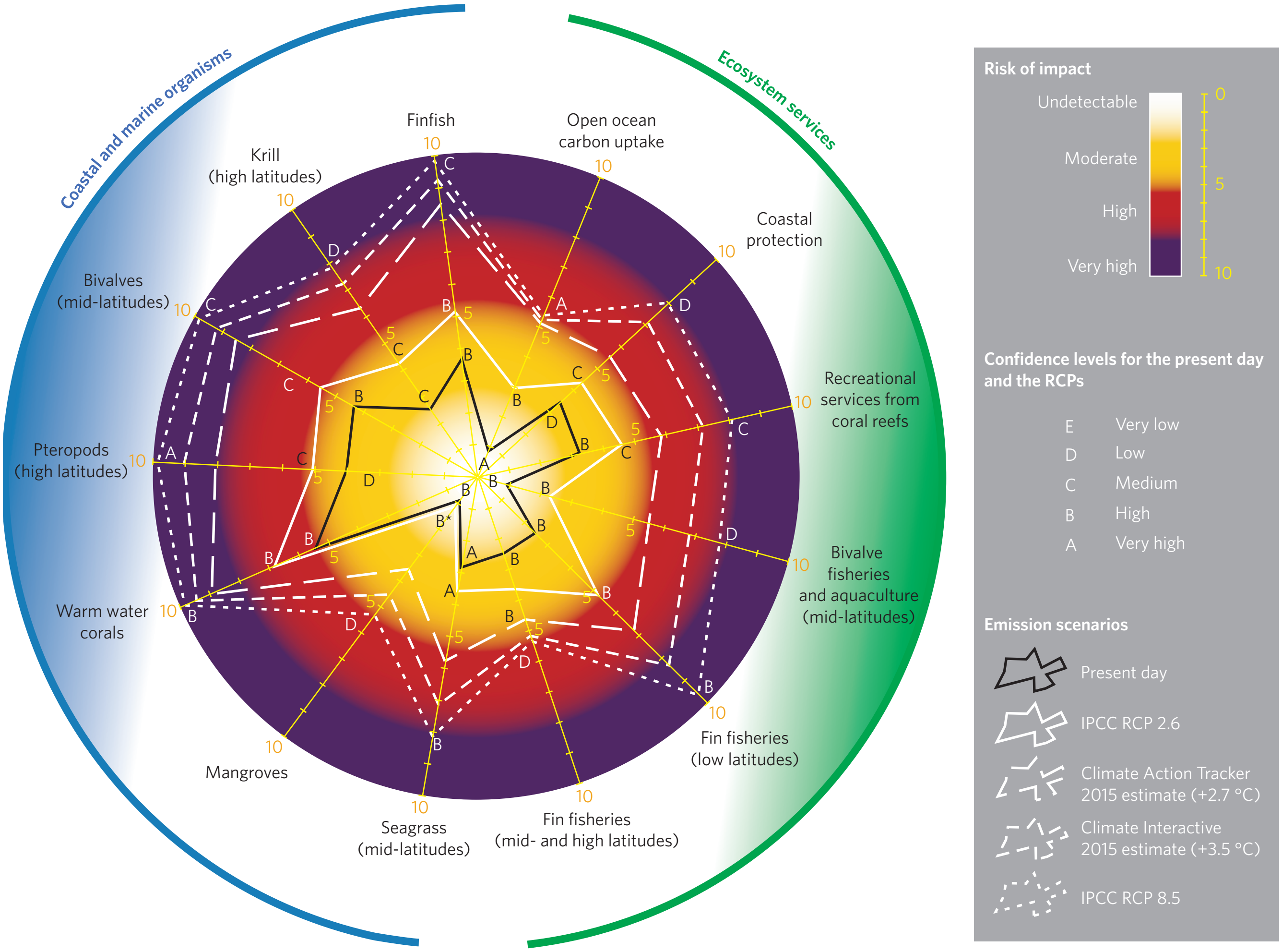

Figure 1 | Contrasting risks of impact for the ocean and society in 2100 from different GHG emission pathways. The expected changes in the impacts on key marine and coastal organisms and ecosystem services by 2100 are shown, according to low (RCP2.6) and business-as-usual (RCP8.5) GHG emissions scenarios and to estimates derived from the aggregation of the 2015 INDCs by CI and the CAT (3.5 °C and 2.7 °C respectively, see the Supplementary Information). The figure also considers the impacts for the present day. Confidence levels in the level of the impacts per organism or service for the present day, RCP2.6 and RCP8.5 scenarios are from the IPCC[1,2] and ref. 3. Compared with the present day, the aggregated risks of impact in 2100 will probably be 1.4-, 2.2-, 2.5- and 2.7-fold higher under RCP2.6, CAT, CI and RCP8.5 scenarios, respectively. The Supplementary Information provides details of the methodology.

Supplementary Table 2). This confirms the conclusions from other recent studies, demonstrating that even RCP2.6 would considerably increase the impacts on the ocean compared with today[1–3,13].

We illustrate the risks of impact that can be expected from the Paris Agreement pledges with the 2.7 °C (CAT) to 3.5 °C (CI) projections. As shown in Table 1, sea surface temperature in a 3.5 °C and a 2.7 °C world at the end of this century rises by 2.6 °C and 2.0 °C relative to 1870–1899, respectively, compared with 3.2 °C for RCP8.5 and 1.1 °C for RCP2.6. Surface ocean pH, which describes seawater acidity, decreases by 0.34 and 0.26 units relative to 1870–1899 in the 3.5 °C and 2.7 °C scenarios compared with a decrease of 0.41 units for RCP8.5 and 0.15 units for RCP2.6. Such changes in the ocean's basic physical and chemical parameters[14] significantly aggravate the RCP2.6-related risks of impact for almost all of the organisms and services considered in Fig. 1. From RCP2.6 to the 2.7 °C estimate the risk moves from undetectable to moderate for mangroves; from moderate to high for mid-latitude seagrass, coastal protection, recreational services from coral reefs, mid-latitude bivalve fisheries and aquaculture; and from high to very high for warm-water corals and mid-latitude bivalves. This yields an increase in the aggregated present-day risk of impact by factors of 2.5 and 2.2 in the 3.5 °C and 2.7 °C scenarios, respectively (Supplementary Table 2).

Even the most optimistic assessment derived from the aggregated INDCs — that is, 2.7 °C by 2100 — profoundly and negatively affects the ocean and the services it provides to the world population. The well-below 2 °C (political) target, which includes "efforts to limit the temperature increase to 1.5 °C"[8], must therefore be considered as an upper limit beyond which severe, pervasive and partially irreversible impacts develop[15]. Staying on track to a well-below 2°C transition is thus of key importance for the world ocean and society, and this depends on two pre-2030 requirements regarding the mitigation of global GHG emissions. As shown in the following sections, it is necessary to first raise the 2030 ambition embedded in the Paris Agreement, and second avoid introducing path dependency effects that will constrain further efforts post-2030. We argue that the ocean scientific community could both contribute to and benefit from these pre-2030 requirements, in a very iterative way.

Science for negotiations

The ocean scientific community can first be proactive in pushing for more ambitious mitigation targets by 2030. Determining whether the INDC-induced mitigation trajectory can be developed to be compatible with the well-below 2 °C pathway is still matter of debate[11,16], although there is a general consensus on the need for very stringent and rapid mitigation measures after the period covered by INDCs[17]. What is certain is that countries must quickly revisit the 2015 assessment of their capacity to curb emissions by 2030. To this end, the Paris Agreement establishes a mechanism for stocktaking that starts in 2018 and for the revision of national contributions that starts in 2020 and continues thereafter every five years (see Decision 1/CP.21 paragraphs 23 and 24, and Article 4.9)[8]. It is critical that countries make full use of this five-year revision mechanism to ensure ambitious mitigation targets, and the ocean scientific community could help with this. Before COP 21, ocean scientists contributed by feeding the negotiation process with pieces of the best-available scientific knowledge. They provided negotiators with policy-oriented messages such as, for example, "your political target (2 °C) is the upper limit to minimize risks on oceans"[6]. A similar approach should be used to both push for the signature of the Paris Agreement by April 2017 and the ensuing ratification process, as well as to support the effectiveness of the five-year revision cycle.

Negotiations for science

The ability of the ocean scientific community to inform the implementation of the Paris Agreement depends on its capacity to refine the risks of impact scenarios and reflect the changes in cumulative CO_2 emissions derived from the post-2015 UNFCCC talks. This requires ocean scientists to have access to longer-term perspectives on mitigation efforts than the ones now embedded in INDCs. There are two complementary challenges to developing projections on the ocean: better capturing the changes in its basic parameters (for example, temperature, pH, oxygen content and sea level) and a better understanding of the processes underpinning the impacts on organisms and ecosystems. The latter challenge refers to the development of long-term, multiple-driver studies at community to ecosystem levels[18] to assess the ocean's capacity to cope with climate-related changes and still provide key services to humankind. The former challenge requires reliable projections of the future levels of atmospheric GHG concentrations. This calls for global mitigation pathways derived from further domestic analyses of possible long-term transitions, thus emphasizing the above-mentioned second pre-2030 requirement.

Table 1 | Relative changes in global mean air surface temperature (ΔSAT), sea surface temperature (ΔSST) and surface ocean pH (ΔpH) by the end of the century (since 1870–1899) and for different GHG emission scenarios.

Global emission scenario	Mean value in 2090–2099 relative to 1870–1899		
	ΔSAT (°C)	ΔSST (°C)	ΔpH
Pre-industrial (1870–1899)	0	0	0
Present day	1.1	0.83	−0.11
RCP2.6 (also the Alliance of Small Island States requirement)	1.5	1.13	−0.15
2010 Cancun Agreement	2.0	1.50	−0.19
Climate Action Tracker 2015 estimate	2.7	2.03	−0.26
Climate Interactive 2015 estimate	3.5	2.63	−0.34
RCP8.5	4.2	3.15	−0.41

This table provides the value for ΔSST and ΔpH according to various GHG emission scenarios ranging from two stringent ones (ΔSAT +1.5 °C and +2 °C) to the business-as-usual one (+4.2 °C, that is, RCP8.5)[14]. Such a range includes the estimates from CI (ΔSAT +3.5 °C) and CAT (ΔSAT +2.7 °C) based on aggregated 2015 INDCs. ΔSAT is the increase in global mean surface air temperature by the end of the century relative to the pre-industrial (that is, the same parameter used by the UNFCCC when referring to the 2 °C target). The Supplementary Information provides details on the methodology.

Simply put, the national implementation of INDCs before 2030 must consider the imperative for faster and deeper decarbonization post-2030 in a continuous process. This requires that current and future policies take into account their own influences on pathways beyond the Paris Agreement's first commitment period of 2020–2030. The pre-2030 transformations implied by the INDCs at the national level in terms of policy implementation, technological innovation, physical infrastructure and non-material changes (technology, learning, skills, institutions and so on) leave doubts about whether adequate post-2030 acceleration towards very low emissions by 2050 is still possible[19,20]. A core concern is that the transformations embedded in INDCs create path dependencies — that is, inertia and lock-in effects. For instance, given the long-lived nature of infrastructures, particularly in the energy sector (for example, power plants, buildings and transport infrastructure), decisions taken today define the context in which the economy will develop over the coming decades and constrain the leeway for further mitigation over the full lifetime of these infrastructures. Path dependencies thus have the potential to limit countries' technical capacity for longer-term GHG emission reductions[17,19].

Although asking governments to legally commit to quantitative end-century objectives may be politically pointless, the Paris Agreement rather invites countries to elaborate mid-century scenarios (Art. 4.19) and provide further transformative insights to unlock deeper, longer-term emission reductions (Decision 1/CP.21 paragraph 36)[8]. Negative emissions scenarios must also be considered[21]. This would disclose additional strategic information to the scientific community as the revision of INDCs by 2020 would ideally enable the adoption of more precise targets in sectors or technologies that are crucial to long-term decarbonization. Consequently it might be possible to build more empirically based sets of assumptions for post-2030 trajectories as well as significantly improve the assessment of cumulative GHG emission impacts and the associated risks for the ocean and societies. In summary, the Paris Agreement offers the opportunity to move from computational and theoretical representations of the future — that is, the RCPs, notwithstanding their usefulness to this point — to more empirical mitigation storylines for the twenty-first century[22], and to risks of impact scenarios for the ocean that are better rooted in the real world.

Finally, an important decision of 43rd IPCC session (11–13 April 2016) paves the way for the effective implementation of the science/negotiation dialogue. The IPCC agreed to prepare two ocean-relevant Special Reports. The first one, requested by the UNFCCC (Paris Agreement Decision 1/CP.21 paragraph 21)[8] and expected to be released in late 2018, will address the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways. The second one, building on proposals by various countries (including the government of Monaco), will focus on climate change and oceans and the cryosphere. Given the reasoning above, we argue that the synergies between these reports will provide major opportunities for the scientific community at large — and for climate negotiations more generally — to rapidly develop comprehensive reference points and global climate-related targets that support the long-term sustainability of human societies and their diverse uses of the ocean. ❐

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Author contributions

A.K.M., J.-P.G., M.C. and R.B. designed the research. A.K.M., J.-P.G. and F.J. put Fig. 1 and Table 1 together, and A.K.M., J.-P.G., O.H.-G., F.J. and H.-O.P. analysed ocean-related data and drew up the conclusions from Fig. 1 and Table 1. M.C., H.W. and T.S. analysed INDC-related material. All authors contributed to drafting and revising the manuscript as well as to the Supplementary Information.

Additional information

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