

Journal: BG

Title: An Orphan Problem Looking for Adoption: Responding to Ocean Acidification Utilising Existing International Institutions

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MS No.: bg-2017-230

MS Type: Research article

Special Issue: The Ocean in a High-CO2 World IV

Author's Response to Referee #1

I would like to take the opportunity to thank Referee #1 for their very detailed and constructive comments. They have been most helpful in clarifying and strengthening my manuscript. Overall, the comments were on point and have been accepted and will be incorporated into the updated manuscript. Each comment has been laid out in the table below with an author's response.

Referee Comment	Author Response
Specific Comments	
1. There would seem three major omissions. All those actions would see important 'policy responses' to ocean acidification. i) UN Sustainable Development Goal 14 and its target 14.3 that requires SDG Parties to "Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels". ii) The role of the Intergovernmental Panel on Climate Change in assessing our scientific understanding of ocean acidification, in particular by WGII in the IPCC 5th Assessment Report, and thereby providing information to the UNFCCC and other bodies. iii) The development of internationally coordinated ocean acidification monitoring, through the Global Ocean Acidification Observing Network (with several sponsors).	Yes, these are all important policy responses to ocean acidification and are worthy of discussion. However, as will be clarified in a revised manuscript, this paper is interested in the activities taking place within treaty bodies and not within these 'soft-law' instruments. However, they are a very important component of the larger international response to ocean acidification and fodder for future research!
2. The conclusions of the paper include the statements that "substantive action (rule-making or implementation) to prevent worsening ocean acidification and to respond to impacts have largely not occurred" and that "carbon dioxide reduction efforts within the UNFCCC have been found to not be strong enough to guarantee prevention of ocean acidification in the future". The first of those conclusions is questionable, and the second seems politically and	The conclusion will be altered to reflect these comments and those made below. The conclusion will now read: "This review of activities relevant to ocean acidification taking place within treaty bodies has found that they are mostly indirect and are fragmented across a wide swath of regimes, with no central focal point of OA governance." And "Efforts within the UNFCCC to reduce carbon dioxide emissions are critical to the

<p>environmentally naïve. The only way to ‘guarantee’ that future ocean acidification will be ‘prevented’ would be to near-instantly cease all anthropogenic CO₂ emissions. The UNFCCC Paris Agreement may not have been specifically designed to combat ocean acidification, nevertheless it arguable represents an extremely ambitious global commitment that, if fully implemented, will reduce future acidification as much as is likely to be socio-economically feasible.</p>	<p>lessening of future ocean acidification. However, the current commitments need to be strengthened over time.”</p>
<p>3. There is undoubtedly a need to increase the ambition of national contributions to the Paris Agreement, and the issue of ocean acidification is clearly relevant in that context. There would also seem opportunities for closer working between the UNFCCC and other bodies with regard to ocean acidification. Whilst the desirability of such actions is recognised, it would seem somewhat dismissive to consider them as a ‘piecemeal approach’</p>	<p>Point taken and the wording will be changed to be more positive and reflect this approach as more of a “patchwork” that has the potential to fill the regulatory landscape</p>
<p>4. This reviewer appreciates the rationale for distinguishing policies that explicitly respond to ocean acidification and those that only do so indirectly. Nevertheless, there does seem to be overlap, and some repetition, as a result of the paper’s structuring. In particular, consideration could be given to combining the information in Tables 2, 3 and 4 (noting that Tables 3 and 4 are currently labelled as Tables 1 and 2 in the Discussion version of the MS). A more comprehensive table (although with somewhat different information) of policy responses to ocean acidification is given as Table 2.1 in CBD Technical Series 75 (Secretariat of the Convention on Biological Diversity, 2014); that table could be usefully updated.</p>	<p>Tables 2, 3 and 4 will be combined and structured similarly to the table provided in the CBD Technical Series No. 75. In place of table 2 a timeline of OA activities will be presented.</p>
<p>5. The topic of ‘geoengineering’ within the paper does not seem to be well addressed. It is initially defined very broadly as “Those policies aimed at manipulating oceanic or atmospheric properties to address ocean acidification, whether they be mitigation, restoration or other types of policies”. But doesn’t that include almost everything? Which particular ‘manipulations’ are included or excluded? In later text “the sequestration of CO₂ in sub-seabed geological formations” is included; however, that is not widely considered as geoengineering, unless active removal of CO₂ from the atmosphere is also involved.</p>	<p>The initial definition will be changed to “policies aimed at a direct manipulation of oceanic or atmospheric properties to counteract climate change and/or ocean acidification and their impacts”. This definition is more in line with the definition provided by the CBD Technical Series No. 84. The Reviewer’s point regarding CCS is well taken and the sections where this is addressed will now be titled “CCS and Geoengineering”. They remain grouped in the paper as they are often coupled in the discussions taking place within variuos treaty bodies. See for example: CBD Technical Series No. 84, which includes the steps</p>

	taken under OSPAR to allow storage of CO ₂ in sub-seabed geological formations as part of the geoengineering discussion.
The main title of the paper “An orphan problem looking for adoption” is successful in terms of attracting attention; however, the validity of the analogy is questionable. Thus, an ‘orphan’ has lost his/her parents (in what way is that true for ocean acidification?), and the paper would seem to conclude that the ‘adoption’ by just one body is probably not the best way forward. The secondary title “Responding to ocean acidification utilising existing international institutions” is more prosaic, yet also more accurate.	Title will be changed to: Responding to Ocean Acidification under Existing Multilateral Agreements: Current Responses and Future Possibilities
Technical Comments	
Line 79: “reducing acidity using additives other than iron”. Wording seems clumsy; “adding alkalinity” would be simpler	Will change to “adding alkalinity”.
Lines 82-83: “Non-CO ₂ mitigation policies”: it is not clear whether this is intended to cover measures to reduce emissions of other greenhouse gases (methane, nitrous oxide etc)	Will include: “including non-CO ₂ greenhouse gases that contribute to OA”.
Line 93, Table 1: “Interventions for Preventing Worsening OA”. It is not clear how the policy domains of adaptation and protection, restoration and reparation ‘prevent worsening’, since the cause of OA is not addressed	Title of table will be changed to “Interventions for preventing and responding to ocean acidification”.
Line 105: ‘negative effects that are already occurring’ could also cite i) effects on oyster aquaculture (Barton et al reference given at the end of the para) and ii) the experimental coral growth studies by Allbright et al (2016) Nature 531, 362-365 (doi 10.1038/nature17155)	Both references will be included.
Line 123: UN Sustainable Development Goals (adopted in September 2015) are surely relevant here, with involvement of UNGA and (for SDG 14) IOC/UNESCO	Yes, a highly relevant development, however beyond the scope of this paper and will be included in future work.
Lines 141-166: This discussion mixes OSPAR’s concerns about ocean acidification with CO ₂ sequestration. The latter is not usually considered to be geoengineering	See comment above. Section will now be titled “CCS and Geoengineering” to clarify difference between them.
Lines 158-159: “carbon dioxide sequestration and storage, which had effectively been banned until this point”. Is that correct? Which body had been responsible for such banning?	The dumping of CO ₂ into the ocean was banned under the London Protocol as CO ₂ was not included in Annex 1. Under the LP all substances are banned from being dumped unless included in the Annex. It was the 2006 listing of CO ₂ in the Annex that then allowed for its disposal in sub-seabed geological formations. This will be clarified in the paper by the inclusion of: “which had effectively been banned until this point due

	to the exclusion of CO ₂ from Annex 1”
Lines 175-218: A very detailed account is given of CBD policy discussions on ocean acidification in the period 2008-2012, but nothing since. The CBD’s 2014 report on ocean acidification and subsequent COP decisions warrants coverage.	This will be updated to include the 2014 report and most recent COP decision XII/23
Line 253: change “preventing” to “limiting” (emission reduction can only slow further OA, they won’t prevent it. To do that, negative emissions is required)	“Preventing” will be changed to “limiting”
Line 260: Citation(s) needed to justify the statement that “At 1.5 deg C risk from acidification is likely to be on the verge of high risk”. How is ‘high risk’ defined?	This will be changed to: “Such an agreement would go a long way in reducing the rate of acidification and lessening future impacts. However, there is likely to be a meaningful difference in the impacts experienced at 1.5°C versus 2°C and thus, efforts to maintain the lower level of warming are preferable with respect to ocean acidification (Gattuso et al., 2015;UNFCCC, 2015b)”
Line 263-264: “It is difficult to conclude that the Paris Agreement, unless implemented in its most stringent form, is strong enough to prevent a worsening of acidification into the future”. That statement is technically correct – in that future worsening of acidification (compared to present day conditions) is inevitable. But it is also misleading: the Paris Agreement will, if implemented, greatly reduce the rate of worsening (RCP2.6 cf RCP 8.5; Gattuso et al, 2015)	This discussion will be reframed to focus on the inability of current NDCs to hold temperature increases to 1.5/2°C and thus there is a need for greater ambition with regards to commitments. Ocean acidification is relevant in this context. New text: “The ambitious Paris Agreement paves the way for large-scale emission reductions, resulting in decarbonisation, thereby preventing future acidification. However, cumulative emissions are still rising and emissions need to rapidly decrease to zero in order to meet the aims of the Paris Agreement (Rogelj et al., 2016). It is generally recognised that current nationally determined contributions (NDCs) do not provide a plausible avenue for meeting the aims of the Paris Agreement and holding temperature increases to well below 2°C (Holz and Ngwadla, 2016;Rogelj et al., 2016). It is suggested that current commitments would result in an overshoot of the target followed by a need for a rapid reduction in emissions including ‘negative emissions’, or the extraction of CO ₂ from the atmosphere (Hansen et al., 2017;Rogelj et al., 2016). Such scenarios would result in worsening acidification and irreversible impacts in the near future that could last for tens of thousands of years due to slow ocean processes (Mathesius et al., 2015;UNFCCC, 2015).”
Line 267-268: The focus on MARPOL seems misplaced – if, as stated, it is responsible for only 2.2% of global emissions. Thus CO2 emissions	This is the first agreement to regulate emissions from an industry globally – yes, other industries are more significant, but this provides and

<p>from industry, agriculture, land-use change, aviation and land transport (i.e. the other 97.8%!) are much more important.</p>	<p>example of the regulation of a transnational industry.</p>
<p>Line 269: What has been the effect of the MARPOL (and IMO) measures to increase fuel efficacy in shipping?</p>	<p>As with the point above, yes, these measures may have resulted in only modest emission reductions, however, it is an important governance model that is not often spoken about.</p>
<p>Line 279: Additional references desirable to justify statements on importance of S and N deposition from ships causing local acidification. This effect has been questioned by Hunter et al. (2011) "Impacts of anthropogenic SO_x, NO_x and NH₃ on acidification of coastal waters and shipping lanes." Geophysical Research Letters 38</p>	<p>Will update reference to Hasselov et al. (2013) who finds that: "The calculated near-coastal season acidification of 0.0015-0.002 pH is without a doubt significant: deposition of shipping emissions not only matches the CO₂-driven acidification but also reduced the alkalinity of the water."</p>
<p>Lines 281-29: The discussion on ocean fertilization policy discussions by the LC&P and the CBD is not up to date. For update, see Williamson & Bodle (2016) CBD Technical Series 84</p>	<p>This will be updated to include: "Recent developments include the 2013 resolution under the London Protocol (LP.4(8)) that created a new annex, in which prohibited marine geoengineering activities are listed. These activities are prohibited unless they constitute 'legitimate scientific research' and are authorized under a permit (Williamson and Bodle, 2016). To date, the only activity listed under Annex 4 is ocean fertilization."</p>
<p>Line 305: What is considered to be a 'hotspot' for ocean acidification? Isn't that where protection or other measures might be needed most?</p>	<p>It has been suggested that maintaining resilience via MPAs is most effective in areas that are least vulnerable to OA, thus, not OA hot spots. To avoid confusion this wording will be updated to: "be specifically located to maintain and support resilience..."</p>
<p>Line 336-7: "leniencies built into the agreement mean that this is not guaranteed". Is it realistic to expect guarantees? The global commitment to keep the temperature increase "well below 2C" is generally considered to be very ambitious, rather than lenient. It is possible that it may not be fully implemented; nevertheless, it is extremely unlikely (=impossible?) that international agreement could have been reached on anything more demanding.</p>	<p>As above this discussion will be reframed around current and required NDCs. New text: "cumulative commitments are not currently consistent with the aims of the Paris Agreement, thus, the Paris Agreement institutionalises an iterative process that establishes an expectation of progressively stronger action over time. Parties are expected to take stock of their collective progress and put forward new commitments that increase ambition in future emission reduction plans (Bodansky, 2016). This <i>ambition mechanism</i> will bring Parties back together in 2018 for a 'Facilitative Dialogue', which will then be followed by 'global stocktakes' every five years starting in 2023. These assessment and review mechanisms offer an important role in bridging the gap between the aim of the Agreement and national commitments by raising ambition over time (Holz and Ngwadla, 2016). Reports generated by</p>

	<p>the various UNFCCC subsidiary bodies and the Intergovernmental Panel on Climate Change (IPCC), including the IPCC report on 1.5°C and the UNFCCC periodic review, will help to inform the decision-making process. These offer one avenue for greater consideration of ocean acidification and the risks likely to result from different emission reduction scenarios.</p>
<p>Lines 520-532: the first seven references do not seem to be in alphabetical order.</p>	<p>These will be amended.</p>