Reframing Ocean Acidification
Addressing an emergent governance problem under existing multilateral environmental agreements

Ellycia R. Harrould-Kolieb
orcid.org/0000-0003-3347-300X

Thesis submitted in total fulfillment of the requirements of the degree of
Doctor of Philosophy
at the University of Melbourne
August 2019

School of Geography, Faculty of Science
Climate & Energy College
University of Melbourne
For Jonathan, Gabriel and Zachary.

I love you to infinity and beyond!

❤️
Declaration

This thesis comprises only my original work towards the degree of Doctor of Philosophy. Where others have contributed, in jointly-authored papers, their contribution has been clearly indicated. Due reference has been made in the text to all other material used. This thesis is fewer than 100,000 words in length, exclusive of tables, maps, bibliographies and appendices.

Ellycia R. Harrould-Kolieb
“It is a curious situation that the sea, from which life first arose should now be threatened by the activities of one form of that life. But the sea, though changed in a sinister way, will continue to exist; the threat is rather to life itself.”

— Rachel Carson, The Sea Around Us
Abstract

Ocean acidification is increasingly recognized as a potentially devastating threat to marine ecosystems and the goods and services they provide. Despite this, no existing multilateral environmental agreement (MEA) explicitly requires a response to it and the issue remains largely unaddressed in international environmental law and policy. Many scholars and practitioners have sought to address ocean acidification under existing agreements, largely via proposals for treaty amendments or the conclusion of new legal instruments such as implementing agreements or protocols. Implementation of these proposals has been limited.

The thesis takes an interdisciplinary approach to exploring the possible MEA governance of ocean acidification. This is done by analysing existing treaty texts through alternative problem frames (treaty interpretation) and comparing their capacity to respond to ocean acidification against an idealized version of ocean acidification governance (gap-analysis).

This thesis contends that the current framing of ocean acidification as a CO2 problem concurrent to climate change has resulted in the problem being regarded as predominantly outside the mandates of most MEAs, thereby narrowing the scope of responses available and creating significant gaps in the global governance architecture for ocean acidification. It argues that the utilization of alternative problem frames can situate the issue more effectively within existing MEA mandates, thereby opening up response options without the need for the development of new legal instruments.
Publications included in this thesis

Published material

Included as Chapter 3:


Included as Chapter 6:


*Impact factor: 4.797*

Material under review

Included as chapter 4:


*Impact factor: 2.312*

Included as Chapter 5:


*Impact factor: 4.816*

Included as Chapter 7:


*Impact factor: 2.125*

Included as Chapter 8:


*Impact factor: 6.194*
Additional Publications produced during candidature

Peer reviewed published articles


Book Chapters


Acknowledgements

My PhD experience has been one of ups and downs, moments of clarity followed by what seemed like endless wanderings in the wilderness. During the entire journey there have been people who have had my back, helped me celebrate the achievements, encouraged me when I was spent and shined a light when I was lost in the darkness.

To my supervisors and committee, Peter, Rachel, Ove and Jon, thank you for sticking with me for so long. You have provided guidance and advice during a daunting process and believed in me, even when I found it hard to believe in myself. You helped me pick right back up after time off to have my babies and never made me feel as though I had to choose between academia and family—a choice that many women in our field face. Thank you for showing me that academic careers can be varied and take different trajectories and that ‘activist-scholars’ truly exist. Your work is inspirational, and I hope that we have the opportunity to work together again in the future.

To all at the Climate and Energy College, thank you for creating such an amazing community, I can’t think of a better place to do a PhD. A PhD is a very isolating experience, yet the College fosters collegiality, the support offered is unwavering and no matter what the challenge there is someone who can empathise and provide advice. I have truly enjoyed coming into the office each day and have learnt so much from sitting with experts across so many different disciplines. There are too many people to name individually, but my gratitude is unending for the shoulders you have allowed me to cry on, the laughs you have shared with me, the advice you have offered and the proof-reading you have done. You are an exceptional group of warm, welcoming and brilliant people and I am honoured to have been able to call the College my home while doing my PhD. Special thanks to Malte for your fearless leadership and for encouraging me to join the College all those years ago—so long, and thanks for all the ice cream!

To my mum, Carmel, thank you for instilling in me a belief that glass ceilings are meant to be smashed. Thank you for being a strong feminist role model and for showing me how to be courageous,
compassionate and kind. To my dad, Laurence, thank you for fostering my inquisitive nature. I will always remember our long chats discussing the way things worked, particularly nature, when I was a young child. And to you both, thank you for teaching me that when you believe in something you fight for it. Hearing stories of your activism during the Vietnam War was a cornerstone of my early years and encouraged me to always look for ways to make sure I was doing my part to make our world a better place. Thank you for wearing the title ‘activist’ with pride!

To my partner Jonathan, thank you for always being my rock, my constant, my anchor when I am adrift and my north star by which I navigate. Thank you for pushing me to be better and believing that I can achieve your exceptionally high standards. Thank you for giving, even in times when there was nothing left to give. Thank you for choosing each day to continue on this journey with me. We have certainly had some rough moments over these last eight years: two children and two PhDs will do that! But we have made it to the other side and now hopefully have some smooth sailing ahead. I can’t wait to embark upon our next adventure together.

And last, but not least, to my children, Gabriel and Zachary, thank you for literally being the reason that I get out of bed every day. There is nothing sweeter than your tiny arms wrapped around my neck, your slobbery kisses on my face and your laughter in my ears. You remind me that joy can come from even the smallest of things and that there is wonder all around us, if only we take the time to look. Thank you for the never-ending renditions of The Lorax, they are a constant reminder that “unless someone like [me] cares a whole awful lot, nothing is going to get better. It’s not.”

It is for you that I did this PhD. Even though I started it before either of you were born, it was the idea of you and knowing that one day I would need to explain what I did to fix the mess that my generation left in your hands. I knew that while I may not solve the problem, I could not sit back and say that I didn’t at least try. I hope that my small contribution can help make the world a better place for you and your children.
Funding

To conduct the research for this PhD I received financial support from a Commonwealth Government Australian Post-Graduate Award/ Australian Government Research Training Program (RTP) Scholarship and research funds from the School of Geography.

During my candidature I also received: a Melbourne Academy for Sustainability & Society Award (2012), an Oceans in a High CO$_2$ World Symposium student travel grant (2016), a Balwyn Rotary Postgraduate Environmental Sustainability Award (2016), a School of Geography Student Travel Award (2018) and a Faculty of Science, Science Abroad Travelling Scholarship (2018).
# Table of Contents

Declaration iii
Abstract v
Publications included in this thesis vi
  Published material vi
  Material under review vi
Additional Publications produced during candidature vii
  Peer reviewed published articles vii
  Book Chapters vii
Acknowledgements viii
Funding x
List of Tables and Figures xiii
List of acronyms and abbreviations xiv
Chapter 1: Introduction 1
  1.1 Research Context – The Congested MEA Landscape 4
  1.2 Problem Statement – A Gap in Governance 7
  1.3 Aim 10
  1.4 Scope 11
  1.5 Theoretical Approach 13
  1.6 Research Questions 17
  1.7 Significance of this Study 19
  1.8 Methodology 20
  1.9 Thesis Overview 31

Part I: The Seascape of Ocean Acidification

Chapter 2: Literature Review 35
  2.1 The Chemistry of Ocean Acidification 36
2.2 The impacts of ocean acidification .................................................................41
2.3 Synthesis .........................................................................................................45

Chapter 3: A Governing Framework for International Ocean Acidification Policy (published paper) ......................................................................................................................47

Chapter 4: The Fragmented Nature of Ocean Acidification Governance by Multilateral Environmental Agreements (manuscript under review) ...........................................59

Part II: Reframing Ocean Acidification for Governance

Chapter 5: Framing Ocean Acidification to Mobilise Action Under Multilateral Environmental Agreements (manuscript under review) .........................................................86

Chapter 6: (Re)Framing ocean acidification in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement (published paper) ........107

Chapter 7: UN Convention on the Law of the Sea: A framework convention for ocean acidification? (manuscript under review) .......................................................................................123

Chapter 8: Enhancing Synergies Between Action on Ocean Acidification and the Global Biodiversity Agenda through the Post-2020 Biodiversity Framework (manuscript under review) ..........................................................................................................................154

Chapter 9: Conclusion .............................................................................................177

9.1 Key Findings and Implications .........................................................................178
9.3 Major Contributions ..........................................................................................186
9.2 Limitations of this Research .............................................................................187
9.4 Further Research ................................................................................................188
9.5 Concluding Remarks .........................................................................................190

Literature Cited ........................................................................................................191
List of Tables and Figures

Table 1.1: Summary of literature outlining the structural limitations preventing action on ocean acidification under existing multilateral environmental agreements

Table 1.2: Taxonomy of interpretative choices as set out by Pauwelyn and Elsig (2012)

Table 1.3: Summary of research questions, methods used to answer them and the chapters in which these appear

Figure 2.1: Changes in Aragonite Saturation, 1875-2095

Figure 3.1 (labelled as Fig. 1): A governing framework for international OA policy

Figure 3.2 (labelled as Fig. 2): An example employing the analytical framework for assessing the ability of the existing governance landscape to respond to OA

Figure 4.1 (labelled as Figure 1): Chronology of MEA responses to ocean acidification (2005-2018)

Figure 4.2 (labelled as Figure 2): Areas of Ocean Acidification Governing Framework that are filled by existing MEA responses

Table 5.1 (labelled as Table 1): Thematic clusters of all global parent conventions listed in the InforMEA database determined to be relevant for addressing ocean acidification

Figure 5.1 (labelled as Figure 1): Four ocean acidification problem frames and corresponding causal and consequence characteristics

Figure 6.1 (labelled as Figure 1): Definitions provided by the Convention that are relevant for interpreting its relevance to addressing ocean acidification

Figure 6.2 (labelled as Figure 2): The way in which ‘climate’ is understood within the context of the UNFCCC results in opposing interpretations of the obligations to address ocean acidification

Table 6.1 (labelled as Table 1): Evolution of the term climate to climate system in drafting documents of the UNFCCC

Figure 7.1 (labelled as Figure 1): UNCLOS provision that establish the foundation for a comprehensive framework for addressing ocean acidification

Figure 8.1 (labelled as Figure 1): The nine Aichi Targets of greatest relevance to addressing ocean acidification
List of acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aichi Targets</td>
<td>Aichi biodiversity targets</td>
</tr>
<tr>
<td>AOSIS</td>
<td>Association of Small Island States</td>
</tr>
<tr>
<td>AWG-KP</td>
<td>Ad Hoc Working Group on Further Commitments for Annex I Parties Under the Kyoto Protocol</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>Biological diversity</td>
</tr>
<tr>
<td>CaCO$_3$</td>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>CBD</td>
<td>Convention on Biological Diversity</td>
</tr>
<tr>
<td>CCS</td>
<td>Carbon dioxide capture and storage</td>
</tr>
<tr>
<td>CITES</td>
<td>Convention on International Trade in Endangered Species of Wild Fauna and Flora</td>
</tr>
<tr>
<td>CMP</td>
<td>Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol</td>
</tr>
<tr>
<td>CMS</td>
<td>Convention on the Conservation of Migratory Species of Wild Animals</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>COP</td>
<td>Conference of the Parties</td>
</tr>
<tr>
<td>DIC</td>
<td>Dissolved inorganic carbon</td>
</tr>
<tr>
<td>ESBA</td>
<td>Ecologically or biologically significant marine areas</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gas</td>
</tr>
<tr>
<td>H$^+$</td>
<td>Hydrogen ion</td>
</tr>
<tr>
<td>H$_2$CO$_3$</td>
<td>Carbonic acid</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>Water</td>
</tr>
<tr>
<td>HCO$_3^-$</td>
<td>Bicarbonate ion</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization</td>
</tr>
<tr>
<td>INC</td>
<td>Intergovernmental Negotiating Committee</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IPPC</td>
<td>International Plant Protection Convention</td>
</tr>
<tr>
<td>ITLOS</td>
<td>International Tribunal for the Law of the Sea</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>ITPGRFA</td>
<td>International Treaty on Plant Genetic Resources for Food and Agriculture</td>
</tr>
<tr>
<td>Kyoto Protocol</td>
<td>Kyoto Protocol to the United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>L&amp;D</td>
<td>Loss and damage</td>
</tr>
<tr>
<td>LC or London</td>
<td>Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)</td>
</tr>
<tr>
<td>LTTG</td>
<td>Long-term temperature goal</td>
</tr>
<tr>
<td>MARPOL</td>
<td>International Convention for the Prevention of Pollution from Ships as Modified by the Protocol of 1978</td>
</tr>
<tr>
<td>MEA</td>
<td>Multilateral environmental agreement</td>
</tr>
<tr>
<td>MPA</td>
<td>Marine protected area</td>
</tr>
<tr>
<td>MWO</td>
<td>World Meteorological Organization</td>
</tr>
<tr>
<td>NBSAP</td>
<td>National biodiversity strategies and action plans</td>
</tr>
<tr>
<td>NDC</td>
<td>Nationally determined contribution</td>
</tr>
<tr>
<td>NET</td>
<td>Negative emission technology</td>
</tr>
<tr>
<td>NOx</td>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>OA</td>
<td>Ocean acidification</td>
</tr>
<tr>
<td>OA-ICC</td>
<td>Ocean Acidification International Coordination Centre</td>
</tr>
<tr>
<td>PA</td>
<td>Paris Agreement</td>
</tr>
<tr>
<td>PgC</td>
<td>Petagrams of carbon</td>
</tr>
<tr>
<td>Ramsar Convention</td>
<td>Convention on Wetlands of International Importance, especially as Waterfowl Habitat</td>
</tr>
<tr>
<td>RCP</td>
<td>Representative Concentration Pathway</td>
</tr>
<tr>
<td>RFMO</td>
<td>Regional fisheries management organization</td>
</tr>
<tr>
<td>SBI</td>
<td>Subsidiary Body for Implementation</td>
</tr>
<tr>
<td>SBSTA</td>
<td>Subsidiary Body for Scientific and Technological Advice</td>
</tr>
<tr>
<td>SBSTTA</td>
<td>Subsidiary body on scientific, technical and technological advice</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>SDG</td>
<td>Sustainable development goal</td>
</tr>
<tr>
<td>SED</td>
<td>Structured Expert Dialogue</td>
</tr>
<tr>
<td>Sox</td>
<td>Sulfur oxides</td>
</tr>
<tr>
<td>SPB</td>
<td>Strategic Plan for Biodiversity 2011-2020</td>
</tr>
<tr>
<td>SRM</td>
<td>Solar radiation management</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UNCCD</td>
<td>United Nations Convention to Combat Desertification</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>UNFSA or UN Fish Stocks Agreement</td>
<td>Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1992 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks</td>
</tr>
<tr>
<td>UNGA</td>
<td>United Nations General Assembly</td>
</tr>
<tr>
<td>VCLT</td>
<td>Vienna Convention on the Law of Treaties</td>
</tr>
<tr>
<td>Warsaw Mechanism</td>
<td>Warsaw International Mechanism on Loss and Damage</td>
</tr>
<tr>
<td>WHC</td>
<td>Convention for the Protection of the World Cultural and Natural Heritage</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction
Almost a third of all anthropogenic carbon dioxide (CO$_2$) emissions are absorbed by the ocean. This results in a series of chemical changes that have come to be known as ocean acidification (Doney, Fabry, Feely, & Kleypas, 2009). Rising ocean acidity is recognised as posing a serious threat to marine ecosystems and the goods and services they provide (Bopp et al., 2013; Gattuso & Hansson, 2011; Gattuso et al., 2015; Hoegh-Guldberg et al., 2018). Unabated, ocean acidification is expected to cause substantial disruptions to biological as well as socio-economic systems over the coming decades and centuries. Impacts will include reduced access to protein (Cooley et al., 2011; Turley & Boot, 2010b), economic losses from fisheries (AMAP, 2018; Branch et al., 2013; Cooley & Doney, 2009) and tourism (Brander et al., 2012), decreased coastal protection (Cooley et al., 2009; Gattuso et al., 2015) and impacts to human health (Gattuso et al., 2015; Shi et al., 2019) and cultural identity (Cooley et al., 2009).

The most effective and least risky method of preventing future ocean acidification is the swift and substantial reduction in CO$_2$ emissions (Gattuso et al., 2014). Activities can also be implemented to reduce local acidification and to boost ecosystem resilience and adaptive capacity of social ecological systems (Billé et al., 2013; Gattuso et al., 2018). The reality is, however, that CO$_2$ emissions are not being reduced fast enough. Impacts from ocean acidification are already occurring and as emissions continue the potential to offset effects with local activities decreases (Gattuso et al., 2015). Despite this it is still possible to avert many of the impacts of ocean acidification with swift and decisive action to reduce its primary driver and with appropriate planning the impacts that cannot be averted can be managed.
Collective action to address ocean acidification is needed at the international level, and while the international community has agreed through the Sustainable Development Goals to ‘minimize and address the impacts of ocean acidification’ (SDG 14.3), there is a lack of clarity as to how this should be best achieved. Hundreds of multilateral environmental agreements (MEAs) have been created in an attempt to resolve a multitude of transboundary and global environmental problems from ozone depletion and biodiversity loss to climate change and the over-exploitation of species (Mitchell, 2003). Despite this proliferation of agreements, no MEA has been designed with ocean acidification in mind and while the issue is partially regulated by a collection of regimes, scholars agree that this governance is inadequate (Baird, Simons, & Stephens, 2009; Herr, Isensee, Harrould-Kolieb, & Turley, 2014; Kim, 2012; Oral, 2018). Moreover, ocean acidification intersects with several environmental and social issues already addressed by international treaties; including climate change, biodiversity conservation, marine environmental protection, sustainable development and economic prosperity. Ocean acidification is therefore an issue that is simultaneously of relevance to and falls between the mandates of a number of international environmental regimes, most predominantly sitting ‘at a rather cracked interface between the climate, biodiversity and oceans regimes’ (Kim, 2012, p.258).

The United Nations Convention on the Law of the Sea (UNCLOS, 1982) and the Convention on Biological Diversity (CBD, 1992) are the principal treaties mandated to govern the use and protection of the marine environment and the conservation of marine biodiversity. These two conventions, however, are limited in their ability to regulate CO\textsubscript{2} emissions (Baird et al., 2009; Kim, 2012) — the main driver of rising ocean acidity (Hoegh-Guldberg et al., 2018). They are therefore limited in their ability to reduce future acidification. Similarly, the United Nations Framework Convention on Climate Change (UNFCCC, 1992), the primary international instrument for regulating CO\textsubscript{2} emissions, has been deemed mostly inadequate for responding to ocean acidification, in large part because the calibration of the regime to the thermal impacts
of rising emissions excludes the chemical changes in the ocean (Baird et al., 2009; Kim, 2012). The apparent inability of any one MEA to holistically respond to ocean acidification raises the question of how to adequately address the collective action problem of this issue in an already congested institutional landscape.

The creation of a new unifying agreement for ocean acidification has been proposed as one way of managing this emergent problem (Lamirande, 2011). This, however, is arguably a ‘superfluous, confusing and unrealistic’ option, largely due to the already congested nature of the existing MEA landscape (Harrould-Kolieb & Herr, 2012, p.379). The creation of a new ocean acidification treaty would necessarily need to duplicate much of the existing governance architecture, including most importantly the elements that regulate CO₂ emissions (Harrould-Kolieb & Herr, 2012; Stephens, 2015a). Further, there is no discernible pressure for the creation of such a treaty from within the international policy community (Baird et al., 2009; Fennel & VanderZwaag, 2015). Moreover, the creation of a new treaty is a time-consuming process that, assuming its success, can take decades to come to fruition (Kanie, 2014; Matz-luck, 2009). This timeframe is inconsistent with the urgent need to address ocean acidification (Zhu & Alper, 2009). Thus, the development of a single unifying agreement for ocean acidification is unlikely. Despite this MEAs play an integral role in the global governance of environmental problems, therefore addressing ocean acidification in the future will require an enhanced effort under existing MEAs. In light of this, this thesis asks how the emergent and highly interconnected problem of ocean acidification can be governed by existing multilateral environmental agreements.

1.1 Research Context – The Congested MEA Landscape

While the term ‘governance’ is amorphous, its use in the international space conveys at its core the coming together of a community of states (and other actors) to address common problems through collective action (Boyle, 2016). Lima and Gupta (2013) argue that ‘governance refers
to institutional systems where there is steering towards a shared purpose and some degree of collective issue-management and accommodation of different interests’ (p.48). Treaties serve as one of the most important means for the articulation of collective interests, the setting out of obligations and privileges and the mediation of conflicts (Matz-luck, 2009; Weiss & Thakur, 2010). MEAs are a set of treaties that represent the most concrete form of the rights and obligations of states with regards to the environment and form one of the main sites of collective international action on environmental problems (Mitchell, 2008). It is the establishment of MEAs and their evolution that have largely driven the development of international environmental law as we know it today (Sands, 2007).

While no universally accepted definition of MEA exists, Mitchell (2003) defines an international environmental agreement as ‘an intergovernmental document intended as legally binding with a primary stated purpose of preventing or managing human impacts on natural resources’ (p.432). I utilise this definition liberally so as to include treaties that address protection of the marine environment, but not necessarily as their primary purpose, for example UNCLOS. This definition excludes soft law or non-binding instruments, including action plans, agreed measures, codes of conduct, declarations, resolutions, and similar policies. MEAs can set objectives, targets and standards for the management of particular issues or locations (Steiner, Kimball, & Scanlon, 2003). MEAs are bound by their defined mandates, which can be very specific, detailing specific regulatory standards, or more general, such as framework conventions. These agreements establish overarching objectives, commitments and institutions associated with the regime being created, specific obligations are left to be developed in subsequent agreements and protocols (Matz-luck, 2009). MEAs can also be ‘static’ in their purpose or created as ‘living conventions’ that allow for and facilitate evolving regulation (Matz-luck, 2009).

Regulation of environmental issues through the development of treaties has proceeded in a largely sectoral manner (Kim & Bosselmann, 2013). Historically MEAs have been developed
in relative isolation from one another with each addressing a particular issue area largely disconnected from others (Kanie, 2014). As the international community has attempted to address an ever-increasing number of global problems a diversity of specialised treaties has proliferated. However, as issue areas have become larger, and problems defined at the global level, areas that were previously seen as distinct are becoming linked (Zelli & Van Asselt, 2013). Thus, the proliferation of MEAs and the increasing interconnectedness of environmental issues with one another and other policy domains, including human rights and economic development, has resulted in these sectoral treaties frequently containing elements that overlap. Thus, this sectoral approach to governance has led to a congestion of international regimes with overlapping coverage of particular policy domains. These governance landscapes are described as ‘fragmented’.

The study of fragmentation and its consequences has become a focal point for many international law, international relations and global governance scholars alike (Bodansky, Brunnee, & Hey, 2008; Kanie, 2014; Koskenniemi, 2006a; Pattberg, Widerberg, Isailovic, & Dias Guerra, 2014; Van Asselt, 2011; Zelli & Van Asselt, 2013). Fragmentation is most commonly described in international law scholarship as a negative process, emphasising the disconnect between and within bodies of law and the conflicts arising due to a diffusion of law making (Koskenniemi, 2006b; Young, 2012). Global governance scholarship has taken a more neutral approach, instead concentrating on describing and analysing the types of fragmentation and its consequences, both positive and negative (Biermann, Pattberg, van Asselt, & Zelli, 2009; Pattberg et al., 2014). International relations scholarship has focused heavily upon the role of regime interaction and its implications for the effectiveness of governance (Stokke, 2001; Young, 2002). Most recently these strands of research have converged, concentrating on the management of regime interactions to increase the benefits and overcome the challenges of fragmentation (Oberthür & Gehring, 2006; Rothwell & Stephens, 2004; Scott, 2011; Van Asselt, 2014).
Keohane and Victor (2011) proposed that regime interactions and governance structures more broadly, can be described along a continuum, with fully integrated institutions at one end and weakly linked institutions at the other. In between these two extremes sit nested regimes with identifiable cores and regime complexes, which they define as ‘non-hierarchical but loosely coupled systems of institutions’ (Keohane & Victor, 2011, p.8). These varying levels of integration can be thought of as degrees of fragmentation. Biermann and colleagues (2009) describe the integration of institutions, norms and actor constellations as criteria for assessing the degree of fragmentation across governance architectures, with the more highly integrated architectures exhibiting less conflictual and more synergistic forms of interactions and therefore more coherent governance.

The existence of fragmentation does not necessarily necessitate a major reorganisation of existing institutions towards comprehensive regimes. Regime complex theory identifies that there can be significant benefits from decentralisation and that when dealing with multifaceted problems regime complexes can offer a suite of responses that are not necessarily offered by comprehensive regimes (Keohane & Victor, 2011; Zelli & Van Asselt, 2013). Oberthur and Gehring (2006) found that of the institutional interactions they studied, over 60 percent were synergistic and resulted in enhanced institutional effectiveness. Synergistic or neutral interactions across regime complexes can provide flexibility and adaptability in governing in situations of high uncertainty and policy flux. Enhancing and strengthening synergies, while simultaneously lessening conflict between existing MEAs offers one way of managing fragmentation so as to increase the benefits while decreasing the costs (Kanie, 2014).

1.2 Problem Statement – A Gap in Governance

The international community, through the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea, recognised a collection of MEAs that have a role to play governing ocean acidification; specifically, UNCLOS providing the legal framework
for all activities in the ocean, including in relation to ocean acidification and the UNFCCC through the regulation of CO₂ (UNGA, 2013b). However, no further guidance on the policy and regulatory aspects of addressing ocean acidification was provided, leaving a lack of clarity around the potential for including ocean acidification these MEAs.

The scholarship on ocean acidification governance has found the issue to be partially regulated by a collection of regimes but addressed comprehensively by none (Baird et al., 2009; Fennel & VanderZwaag, 2015; Stephens, 2015a). This collection of regimes partially addressing ocean acidification has been identified an emergent regime complex for ocean acidification (Baird et al., 2009; Downing, 2013; Kim, 2012; Scott, 2018). Kim (2012) found that no regime has assumed responsibility for the problem of ocean acidification ‘due to diffused responsibilities, legal uncertainties, policy inconsistencies and externalities’ (p.255). This sobering diagnosis included the UNFCCC, the only regime with the capacity to regulate global CO₂ emissions and therefore mitigate ocean acidification (Harrould-Kolieb & Herr, 2012; Scott, 2018). Moreover, there is no single MEA that could be singled out as sitting at the core of the ocean acidification governance architecture, and thus no trend setter in terms of norms, principles and rules when it comes to the governance of this issue (Keohane & Victor, 2011). Scott (2018) observes that while intersections and overlaps exist amongst the MEAs they have not been leveraged. Both the responses of individual MEAs and coherence across the regime complex have been found to be inadequate.

Kim (2012) suggests that these problems do not simply stem from the youthful nature of the regime complex, but rather from the limitations inherent in the mandates of the MEAs involved to comprehensively address ocean acidification. This has prevented the development of strong and coherent policies and obligations across the regime complex. This finding is echoed across much of the ocean acidification governance literature (see Table 1 for a summary of these findings).
<table>
<thead>
<tr>
<th>Multilateral Environmental Agreement</th>
<th>Relevance to Addressing Ocean Acidification (OA)</th>
<th>Barriers to Addressing Ocean Acidification</th>
<th>Literature in which Barriers are Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Nations Framework Convention on Climate Change (UNFCCC)</td>
<td>Core objective to “stabilize greenhouse gases in the atmosphere that would prevent dangerous anthropogenic interference with the climate system” (UNFCCC, 1992, Art.2)</td>
<td>Atmospheric focus of the Convention is not inclusive of OA</td>
<td>Scott, 2018; Simons &amp; Stephens, 2009; Stephens, 2015a; Kim, 2012; Baird et al., 2009</td>
</tr>
<tr>
<td></td>
<td>No obligation to address OA</td>
<td>No obligation to reduce CO$_2$ specifically over other greenhouse gases; emissions targets calibrated to atmospheric rather than oceanic impacts</td>
<td>Simons &amp; Stephens, 2009; Stephens, 2015a; Kim, 2012; Baird et al., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Promotes the idea of enhancing the oceanic sink for CO$_2$ even in such a way as to exacerbate OA</td>
<td>Fennel &amp; VanderZwaag, 2015; Simons &amp; Stephens, 2009; Stephens, 2015a; Harrould-Kolieb &amp; Herr, 2012; Stephens, 2015a; Kim, 2012; Baird et al., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>OA as a concurrent threat to climate change is not included in central obligation to combat climate change and limit its adverse effects</td>
<td>Simons &amp; Stephens; 2009; Stephens, 2015a; Kim, 2012; Baird et al., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No explicit target for OA. Temperature target is not an appropriate indicator of OA</td>
<td>Harrould-Kolieb &amp; Herr, 2012; Oral, 2018 Scott, 2018</td>
</tr>
</tbody>
</table>

**Multilateral Environmental Agreement**

<table>
<thead>
<tr>
<th>Multilateral Environmental Agreement</th>
<th>Relevance to Addressing Ocean Acidification (OA)</th>
<th>Barriers to Addressing Ocean Acidification</th>
<th>Literature in which Barriers are Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Nations Convention on the Law of the Sea (UNCLOS)</td>
<td>General obligations to “protect and preserve the marine environment” (UNCLOS, 1982, Art.192, 193) and “prevent, reduce and control pollution of the marine environment from</td>
<td>Mitigation of OA is not a principle objective of the Convention</td>
<td>Scott, 2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No binding obligation to establish global rules to regulate atmospheric pollution to the ocean</td>
<td>Scott, 2018; Downing, 2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regulations for sources of land-based pollution is under-developed</td>
<td>Kim, 2012; Scott, 2018</td>
</tr>
</tbody>
</table>
any source” (UNCLOS, 1982, Art.194.1)  | No mechanism to adopt decisions for collective actions and measures to reduce CO₂  | Oral, 2018  
---|---|---  
| No land-based and atmospheric pollution standards established | Downing, 2013; Stephens, 2015a |  
**Convention on Biological Diversity (CBD), Convention on the Conservation of Migratory Species of Wild Animals (CMS) and other biodiversity regimes**  | Central aim is the conservation of biodiversity, its sustainable use and the fair and equitable sharing of benefits arising from its use (CBD, 1992, Art.1)  | No mandate or obligation to reduce CO₂ emissions | Simons & Stephens, 2009; Downing, 2013; Kim, 2012; Baird et al., 2009  
**London Convention (LC) and London Protocol (LP)**  | Regulates the dumping of wastes and other matter, including CO₂ into the ocean  | Only relevant to issues of carbon sequestration in the marine environment and marine geoengineering, therefore limited ability to mitigate OA | Scott, 2018; Simons & Stephens, 2009; Baird et al., 2009  
**International Convention for the Prevention of Pollution from Ships as Modified by the Protocol of 1978 (MARPOL)**  | Regulates pollution from shipping, including emissions of CO₂  | Regulation of pollutants from shipping, while binding, can only make a small contribution to the mitigation of OA | Scott, 2018; Stephens, 2015a  

**Table 2.1: Summary of literature outlining the structural limitations preventing action on ocean acidification under existing multilateral environmental agreements**

The ocean acidification governance literature identifies two major impediments to addressing ocean acidification under existing MEAs. First, that the UNFCCC has neither the mandate nor obligation to address ocean acidification. Second, that other ocean and biodiversity regimes do not have the mandate to regulate CO₂ and can therefore not mitigate ocean acidification. These jurisdictional issues are seen as limiting the capacity of existing MEAs to address ocean acidification in a meaningful way and has therefore created a gap in the international governance of ocean acidification. Thus, these MEAs have been interpreted as not being fit for the purpose of addressing ocean acidification.

**1.3 Aim**

Several scholars have sought to overcome these gaps in governance by proposing ways to amend and expand existing mandates, including through the adoption of new protocols (Kim, 2012) and by encouraging strategic inconsistency amongst regimes in addressing CO₂ (Baird et al., 2009). These proposals rely heavily upon the creation of new legal instruments as a way
of overcoming the limitations of existing MEAs, a time consuming and contentious process, that may even encourage increased conflict between regimes.

The literature on the framing of problems for policy making emphasises that the availability of response options can be limited by the way in which a problem is framed and that the reframing of a problem can broaden the range of available solutions (Bardwell, 1991; Hajer, 1997). I contend in this thesis, therefore, that the way in which ocean acidification has been framed by the epistemic community has contributed to limiting the response options under existing MEAs and that a reframing of the issue offers an effective strategy for overcoming the identified barriers to governance. Accordingly, the aim of this thesis is to test whether reframing the problem of ocean acidification can provide an alternative approach for overcoming the barriers to more comprehensive governance under existing MEAs.

1.4 Scope

When referring to MEAs the scope of this research is limited to those that have global coverage. This excludes consideration of regional MEAs, however it is acknowledged that these can play an important role in the governance of ocean acidification and could be the focus of additional research in this area. The main focus of the analysis is the UNFCCC, CBD and UNCLOS, these three MEAs have been identified as being principally relevant to addressing ocean acidification (Baird et al., 2009; Kim, 2012).

This research is concerned with the architecture of governance: that is, the ‘interlocking web of widely shared principles, institutions and practices that shape decisions at all levels’ in a given issue area (Biermann et al., 2009, p.31). Research on governance architectures examines the institutional frameworks of governance and the ways in which these institutions can and do evolve over time (Earth System Governance Project, 2018). However, it must be acknowledged that governance architectures are generally thought of as being much broader than just MEAs,
often including organizations (inter- and non-governmental) and implicit norms, principles and procedures (Zelli, 2011). Further, governance architectures are populated by actors and the way that these actors animate these structures is fundamental to how policy and politics play out in the real world (Biermann et al., 2009). Moreover, while this research is concerned with the role that framing plays in aligning problems with solutions, it does not interrogate how different actors compete to frame various issues or the role of power in determined which frames will become dominant.

While exploring the broader governance architecture for ocean acidification and the roles that actors and power play in shaping this architecture are important areas for further research this research is restricted to just one component of the overall governance architecture of ocean acidification: global MEAs. Analysing this component of global governance architecture allows for a greater understanding of an issue area in which governance is not dominated by a single regime, or perhaps any regime for that matter, but rather is fragmented across various regimes. Biermann asserts that the structure and effectiveness of this macro-level of governance is still greatly under-researched and warrants further attention (Biermann, 2007). He argues further that deploying an analysis at this meta-level of governance provides the ability to look beyond individual regimes and their dyadic interactions, to allow for a more holistic understanding of the way a particular issue area or policy domain is governed (Biermann et. al., 2009). This thesis builds upon contemporary scholarship in the fields of international relations, international law and earth system governance that analyse governance architectures and whether they are fit for purpose. I acknowledge however, that the existence of an adequate governance architecture does not guarantee that it will be effective. Nonetheless, focusing on the shape of the governance architecture is required prior to assessment of its effectiveness. Given this, this research will greatly progress current understandings of the international governance of ocean acidification.
1.5 Theoretical Approach

This study is grounded in a constructivist perspective of international relations and international law. This approach seeks to understand the processes by which international governance develops and the social conditions from which they emerge, or are constructed (Haas & Haas, 2002, p.574). Ruggie (1998) explains that:

Constructivists hold the view that the building blocks of international reality are ideational as well as material; that the ideas have normative as well as instrumental dimensions; that they express not only individual but also collective intentionality; and that the meaning and significance of ideational factors are not independent of time and place (p.879).

In this study I apply these concepts to an exploration of how the options for responding to ocean acidification may differ based upon the way in which ocean acidification is framed.

This research is fundamentally related to constructivism as environmental problems and the way in which they are framed are social constructs. The way environmental problems are understood is not simply an objective account of scientific fact, but rather a translation of those facts through various ways of understanding the world, or frames. Determining what constitutes an environmental problem is highly contextual and political. Environmental problems are cases in which human activities manifest as impacts on the physical environment in such a way as to place human health or wellbeing or the sustainability of the natural or built environment in danger (Glasbergen & Cörvers, 1995). Various conditions exist around us at all times, but not all come to be deemed problems (Kingdon, 2003). This occurs when a condition is perceived as having a negative impact on society, such as on human or ecological health, or as contravening societal norms and values (Libertore, 1995). The defining of what constitutes a problem is socially determined and understood through the lens of cultural, economic and political norms that can vary by social context and over time (Libertore, 1995;
That is to say, environmental problems are socially constructed.

The term social construction is associated with a number of philosophical approaches (Demeritt, 2002). Here, I use the concept to convey the idea that the social context of inquiry constructs knowledge. This approach does not deny the ontological existence of the world. The physical environment is governed by objective factors, such as chemistry, physics and biology and therefore environmental phenomena can be understood as being ruled by these forces, or the ‘laws of nature’. However, this approach contends that ‘reality’ is an artefactual, contingent on how we understand and interpret the natural world. That does not mean, for example, that the chemistry of the ocean is only changing if we believe it to be so, rather, that the way we choose to make sense of such change is a social construction. Therefore, while the phenomenon of ocean acidification exists regardless of how we view it, it only exists as a social or political problem if we deem it to be so. This can be understood from the example of ozone depletion, a phenomenon that was not deemed an international problem because of model predictions of the physical impacts, but rather due to a widely accepted understanding that increased UV-B radiation was dangerous to human health and was therefore unacceptable (Litfin, 1994; Sloep & van Dam-Mieras, 1995). An environmental problem is, therefore, defined by both a physical disruption and a belief that such as disruption has or will result in unacceptable consequences for human or ecological communities.

The way an environmental problem is then dealt with is the result of the mediation of various interpretations of scientific knowledge in the form of various problem frames (Dryzek, 2005; Hajer, 1997). Framing has been described as the basis of social constructivism (Scheufele, 1999). Through framing, complex issues can be distilled into particular storylines, highlighting the cause of the problem, its relevance to other issues, its level of importance and the way in which it should (or should not) be addressed (Gamson & Modigliani, 1989). In his seminal work Entman (1993) describes framing as involving the processes of selection and salience.
To frame is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described. Typically frames diagnose, evaluate, and prescribe (Entman, 1993).

Problem framing is essentially an activity of selection, organisation and interpretation that establishes the boundaries in which a complex reality can be made sense of and acted upon (Radaelli, 1995). In this way, frames act to create boundaries around the problem in question (Fuller & McCauley, 2016). Therefore, the way in which we frame environmental problems defines the parameters of political debate and determines how we believe they should be solved (Dryzek, 2005). The ozone problem, for instance, was framed as a human health issue, rather than an ecological one, which established the parameters of the resulting policy action (Litfin, 1994). Problem framing is the first stage of the problem-solving process and sets the tone for the remaining stages as it delimits the problem space by reflecting values and assumptions and determining strategies and solutions (Bardwell, 1991). The way in which a problem is defined may be one of the most crucial factors in determining the types of solutions implemented and the likelihood of their success (Bardwell, 1991).

Rothman (2008) describes the use of frames as ‘the rhetoric used to define an international issue over time’ (p.3) and further explains that frames contain three types of storylines: those that establish the causal characteristics of the problem, those that define the consequences of the problem and those that prescribe solutions. Placing emphasis on particular causes and consequences can result in the prescription of vastly different policy outcomes. For example, the decline in a shared natural resource can be framed as the loss of an important commodity due to overuse by someone else, resulting in personal financial consequences. The resulting policy prescription would be the development of more effective extractive techniques to better
utilise the resource. Alternatively, the decline can be framed as the result of unsustainable use by everyone with consequences for ecosystem services and the health of future generations. This frame prescribes the development of regulation and enforcement that will ensure equitable use and prevent further decline.

An aspect of framing is therefore aligning the problem with available policy choices, a process that is necessary in light of the wide availability of response options and can be deliberate and highly contentious (Lele, Brondízio, Byrne, Mace, & Martinez-Alier, 2018). The framing process often involves those deemed ‘experts’ who delineate the domain in which solutions are to be found, the institutional commitments that need to be respected and which social conditions are fixed and which are malleable (Hajer, 1997). Frames act to articulate the connectedness of various storylines into one coherent picture that can be deployed to connect new information to existing world views and to contextualise emergent problems (Lakoff, 2010). While framing acts to emphasise particular features of a problem it also works to downplay others. The exclusion of features from the framing of a problem can be as significant to an outcome as the inclusion of others (Entman, 1993) and can result in the delegitimization of response options that may have otherwise provided effective solutions. Frames can therefore, identify whether the types of activities initiated under an MEA are relevant to addressing a particular problem and determine whether that problem falls within the scope of the MEA’s mandate. Framing can therefore define the relationship between an emergent problem and existing MEAs.

Frames are subjective conceptual units and because different actors relate to problem characteristic in different ways, multiple frames for any one problem can exist simultaneously and their dominance can shift over time (Dery, 2000). Dominant frames are those agreed upon by actors that determine the course of collective action. Dominant frames may have settled and unsettled characteristics, where actors subscribe to the overarching storylines of the frame, while some elements are defined differently by different actors. These differences can remain
unsettled if they do not cause conflict between actors. Different problem frames, or parts of frames, can co-exist at any point in time if they are not in conflict, when frames conflict actors may contest the legitimacy of other frames, trying to assert the dominance of their preferred frame (Rothman, 2008). Contestation can lead to reframing, which can alter the boundaries of a problem and change the range of available solutions (Bardwell, 1991). This is a process that frequently occurs in policy making (Hajer, 1997). Thus, the way in which a problem is framed delimits the types of activities that should be initiated in response to the problem. This can however, be changed through a reframing of a problem in such a way as to realign it with alternative solutions.

In this study, I used this theory of problem framing to explain how the current framing of ocean acidification has misaligned the issue with the mandates of existing MEAs and to argue that an exercise in reframing ocean acidification is justified.

### 1.6 Research Questions

The problem at the heart of this research is that the current governance of ocean acidification by existing MEAs is inadequate, however, the creation of an entirely new treaty is infeasible. Given this, the central research question of this thesis asks:

*How can the emergent and highly interconnected problem of ocean acidification be governed by existing multilateral environmental agreements in an already congested institutional landscape?*

As I have highlighted, existing responses to this question have argued for the creation of new legal instruments or the initiation of activities that intentionally reach beyond MEA mandates. I contend that this is not necessary and that a reframing of ocean acidification can aid in realigning the issue with solutions available within existing MEA mandates. To test this contention, I pose a series of sub-questions. The first two of which seek to establish a base line
by which to understand the existing seascape of ocean acidification governance. These two questions therefore ask:

1. What activities are needed to minimize and address ocean acidification?

2. What efforts have already been made under existing multilateral environmental agreements to address ocean acidification and where are the existing gaps in the governance of this issue?

The second set of supplemental questions seek to test the contention that reframing ocean acidification can align the problem with alternative response options under existing MEAs. These questions focus on doing this by attempting to overcome the two main barriers to comprehensive ocean acidification governance by MEAs that have been highlighted by the ocean acidification governance literature (that the UNFCCC contains no mandate or obligation to address ocean acidification, and that other MEAs are limited in their ability to respond due to their inability to regulate global CO₂ emissions). Thus, these questions ask:

3. How is ocean acidification currently framed? What are the implications of this framing and how can ocean acidification be framed differently?

4. Can reframing ocean acidification allow for a reinterpretation of the UNFCCC that is inclusive of an obligation to address ocean acidification?

5. Can reframing ocean acidification allow for a broader response to ocean acidification from biodiversity and ocean regimes?

Lastly, I recognise that governance in a highly congested MEA landscape is influenced not only by the actions of each individual regime, but also by how these regimes interact. Thus, the final supplemental question of this thesis asks:

6. Can reframing ocean acidification enhance the possibilities of synergistic regime interaction and decrease conflicts?
1.7 Significance of this Study

Given that ocean acidification has the potential to leave ‘no place in the future oceans for many of the species and ecosystems that we know today’ (Raven et al., 2005) this research seeks to provide both pragmatic real-world solutions to an existing problem, while providing theoretical insights into the role that problem framing can play in aligning problems with solutions under MEAs—an area that has not received substantial attention within the problem framing literature.

This research has three intended outcomes:

First, this research will contribute to filling the literature gap on the international activities that can be implemented to govern ocean acidification by bringing together existing literature into a unique governing framework for international action on ocean acidification. This framework can be utilised by policy-makers and marine resource managers to implement ocean acidification relevant activities. This same framework can also be used as an aspirational model against which to compare current efforts to address ocean acidification, thereby identifying gaps in the existing governance architecture. This research therefore develops both a normative and analytical tool.

Second, this research seeks to explore whether and how the reframing of ocean acidification can create new avenues for action under existing MEAs. In doing this, this thesis will argue for new ways of situating ocean acidification within existing MEAs.

Third, this thesis will analyse the role that the framing of environmental problems plays in their resolution (or lack thereof). In doing so, it will contribute to constructivist theories on problem definition and framing, regime theory in respect to the role of regime interactions in addressing interconnected, highly complex environmental problems, and international environmental law and the role of interpretation in ensuring the ability of existing MEAs to address emergent
environmental problems and enhance synergies and decrease conflicts across regime complexes.

1.8 Methodology

Global environmental problems, including ocean acidification, are frequently characterised by high levels of complexity, uncertainty and interconnectedness with other environmental and social conditions. Therefore, any attempt to solve them is best approached through an interdisciplinary lens (Acutt et al., 2000; Fox & Rohlich, 1968; Owen & Noblet, 2014). An interdisciplinary approach endeavours to answer questions by analysing, synthesizing and harmonising links between disciplines into a coordinated, integrated and coherent whole (Choi & Pak, 2006; Toomey, Markusson, Adams, & Brockett, 2015). It is for this reason that I situate this thesis in an interdisciplinary space, drawing upon insights and methodologies from international relations, international law, and earth systems governance scholarship and integrating them in a novel way so as to answer a real-world problem.

In this chapter I have identified two barriers that are preventing the development of a more comprehensive governance of ocean acidification by MEAs. First, that ocean acidification is understood as sitting largely beyond the jurisdiction of the UNFCCC. Second, that other MEAs are deemed as only being able to play a relatively minor role in responding to ocean acidification due to their inability to regulate global CO₂ emissions. I contend that the framing of ocean acidification as CO₂ problem concurrent to climate change has played a role in narrowing the perceived availability of response options under existing MEAs and that the deployment of alternative frames can play a role in overcoming these barriers.

To test this contention, I undertook three case studies. In the first, I investigated the possibility of reframing ocean acidification within the context of the UNFCCC and whether doing so would allow for a reinterpretation of the obligations and mandate to be inclusive of ocean
acidification. In the second case study, I analysed whether reframing ocean acidification in the context of UNCLOS would allow for a broadening of the perceived applicability of specific provisions to ocean acidification and whether ‘the constitution for the ocean’ can be understood as establishing the legal framework for international action on ocean acidification. In the third case study, I examined whether reframing ocean acidification can ensure an expanded response to ocean acidification by aligning components of the problem with existing conservation targets. This was explored in the context of the Post-2020 Biodiversity Framework, which is to be negotiated and agreed by 2020 under the CBD. These three case studies were designed to answer research questions 4, 5 and 6, which asked: Can reframing ocean acidification allow for a reinterpretation of the UNFCCC that is inclusive of an obligation to address ocean acidification? Can reframing ocean acidification allow for a broader response to ocean acidification from biodiversity and ocean conventions? Can reframing ocean acidification enhance the possibilities of synergistic regime interaction and decrease conflicts?

Prior to conducting the case studies, I first needed to establish a baseline by which to understand the existing governance of ocean acidification, both in terms of what is currently being done and what is missing. To do this, I set out an aspirational model of what a comprehensive response to ocean acidification would ideally look like by developing a governing framework for international action on ocean acidification. I then comprehensively reviewed the current activities deployed under global MEAs and compared these to the aspirational model in a gap analysis to identify the gaps in the existing governance architecture for ocean acidification.

**Development of a Governing Framework for Ocean Acidification**

Mazmanian and colleagues define a governing framework as ‘a decision support structure that guides public and private actions’ that rests on ‘science, identifies where collective action is needed, and prescribes an overarching policy goal’ or goals (Mazmanian, Jurewitz, & Nelson, 2013, p.1). I used this definition to identify three integral components of a governing
framework: the articulation of overarching goals, the delineation of areas for collective action required to meet these goals, and the description of activities that can be initiated within each of these areas of collective action. For clarity, I named each of these components: objectives, areas for collective action and activities.

To identify these components with reference to ocean acidification, I reviewed the existing literature on the causes of ocean acidification and the activities that have been proposed as a means for addressing it. I focused on the types of activities that could be initiated to address ocean acidification without being prescriptive as to who they should be initiated by. In this way the governing framework was designed without bias towards a specific MEA and could be seen as creating an aspirational model for action on ocean acidification as though on a completely clean slate and not within the sea of existing MEAs.

I grouped the activities for addressing ocean acidification into thematic clusters according to their intended outcomes. Six clusters of activities were identified. Each of these clusters was taken to represent one area of collective action to be pursued to address ocean acidification. These six areas of collective action were then classified according to their objectives. Three overarching objectives for international ocean acidification governance were identified. This collection of objectives, areas for collective action and activities were compiled to create a governing framework for international action on ocean acidification. The development of a governing framework answered research question 1, which asked: *What activities are needed to minimize and address ocean acidification?*

**Identification of Existing Gaps in Governance**

To identify the gaps in the existing governance of ocean acidification, I first comprehensively reviewed existing activities that have been initiated under global MEAs that were deemed of relevance to addressing ocean acidification. I then compared these activities to the aspirational
model of international action on ocean acidification developed by the governing framework. This method is a form of ‘gap analysis’.

Gap analysis was developed in the field of biodiversity conservation, where was initially used to identify the gaps in the representation of biodiversity in managed areas (Burley, 1988). Gap analysis is an outcomes-based assessment tool used to identify gaps in existing conditions and therefore assist in setting priorities for conservation policies (Jennings, 2000; Scott et al., 1993). This is done by constructing an ‘ideal type’; an aspirational model of what the biodiversity landscape would ideally look like, and then comparing it against a survey of the existing landscape, thereby highlighting the areas that are in need of greater conservation attention (Mitchell, 2014). A similar approach has been employed to evaluate regime effectiveness, where a hypothetical state of affairs that would result from a perfect regime is used to create a ‘collective optimum’ that can be compared against real world conditions (Helm & Sprinz, 2000). This type of analysis is an actual-versus-aspirational comparison that identifies gaps that need to be focused on in order to move existing conditions closer to the ideal.

The existing activities to address ocean acidification initiated under global MEAs were found by searching through the outcome documents, resolutions, treaty texts, agreements and work programmes of the regimes identified as being of relevance to ocean acidification. These regimes were identified by a search in the InforMEA database, which is a comprehensive listing of environmental agreements maintained by the United Nations information portal on MEAs (www.informea.org). The database groups MEAs into six thematic clusters and according to

1 The names and number of these clusters vary to some extent across the literature (see for e.g. Camenzuli, 2018; ECOLEX; Goeteyn & Maes, 2013; InforMEA; Kimball, 1999). Of the most common clusters, I selected four, which I short-handed as: ocean, atmosphere, biodiversity and pollution. Land is a fifth commonly used MEA cluster, however this was not utilised as the treaties in this grouping, such as those that manage plant resources and desertification, tend to be less significant in their regulation of activities that affect the marine environment. I do acknowledge that they can play a role, especially in the regulation of land-based pollution entering the marine environment, however the treaties that contain provisions that are likely to be of relevance to addressing ocean acidification were also found to straddle the biodiversity or pollution related clusters. For the purposes of this study this set of MEAs were excluded as their examination was deemed unlikely to return results that greatly differed from the MEAs found in the other more relevant clusters.
global or regional treaties. I selected all global treaties in the biological diversity, climate and atmosphere, chemicals and waste, and marine and freshwater clusters. I then searched the websites of these treaties for documents mentioning ocean acidification. This search was enhanced by a search of the United Nations Official Document System for documents pertaining to each of these treaties and ocean acidification. I then examined each of the documents collected for decisions pertaining to ocean acidification or mentions of activities that had been initiated in response to ocean acidification.

It was this assemblage of activities that I then compared to the aspirational model of international action on ocean acidification created by the governing framework, allowing me to identify where the gaps in the existing governance of ocean acidification are situated. This gap analysis method was also used in the case studies to explore the ability of each MEA to provide a comprehensive response to ocean acidification. This will be discussed further in the section addressing the case study analysis. Conducting this review of existing ocean acidification activities and analysing them utilising a gap analysis approach answered research question 2, which asked: *What efforts have already been made under existing multilateral environmental agreements to address ocean acidification and where are the existing gaps in the governance of this issue?*

**Construction of Archetypal Problem Frames**

Before conducting the case studies, I first needed to understand the role that the framing of ocean acidification has had in aligning ocean acidification with existing MEA mandates and then develop alternative problem frames that could be tested for their ability to realign ocean acidification with existing MEA mandates. To do this, I examined texts developed by the ocean acidification epistemic community to understand how ocean acidification has been framed. I then analysed the use of these frames in the scholarly literature that focuses on the governance
of ocean acidification by MEAs to understand how this framing has positioned ocean acidification in relation to the MEA mandates.

To develop alternative problem frames for ocean acidification I used Rothman’s (2008) typology of frame content, which identifies the types of characteristics that define the content of a frame. Rothman’s typology sets out three types of content characteristics: the causes of the phenomenon (causal characteristics), its consequences (consequence characteristics), and the policy alternative available to address it (prescriptive characteristics). To identify the causal and consequence characteristics, I comprehensively reviewed the scientific literature detailing the causes and consequences of ocean acidification. Four overarching causal characteristics and four consequence characteristics were found to pertain to ocean acidification.

In order to develop frames that would have the greatest potential of aligning the issue of ocean acidification with existing MEA mandates, I matched each MEA (identified previously as being of relevance to addressing ocean acidification) with the characteristics most likely to fall within its mandate. This was established by an initial assessment of the scope of each treaty, which was determined based upon the information provided in the InforMEA database. The treaties were then re-grouped according to their thematic clusters, which resulted in an aligning of each ocean acidification characteristic with a cluster. These clusters of characteristics were designated as archetypal ocean acidification frames that could be deployed. Each of the frames developed were named according to their cluster label, except the atmosphere cluster, which was renamed as the climate change frame.

The examination of the dominant framing of ocean acidification by the epistemic community, its role in aligning ocean acidification with existing MEA mandates and the development of alternative frames answered research question 3, which asked: How is ocean acidification currently framed? What are the implications of this framing and how can ocean acidification be framed differently?
Case Study Selection

Across the four MEA clusters selected, nine parent treaties were identified as either governing aspects of the marine environment or regulating compounds that are known to cause or exacerbate ocean acidification. A number of these treaties were found to straddle two clusters, including all treaties found in the pollution cluster. For this reason, I combined the ocean and pollution clusters. I selected one MEA from each of the three remaining clusters for case study examination. The UNFCCC was selected from the atmosphere cluster, as it was the only MEA deemed relevant for addressing ocean acidification from this cluster. From the ocean cluster UNCLOS was selected as it is understood as being the most significant of the ocean and pollution related treaties as it governs all aspects of activities taking place within the marine environment (Sands, Peel, Fabra, & MacKenzie, 2018). For similar reasons, the CBD was selected from the biodiversity cluster as it is viewed as being the overarching biodiversity convention that establishes the international biodiversity agenda, not only for its own Parties, but also for the other biodiversity related conventions and across the UN system more broadly (Morgera & Tsioumani, 2011). These selections align with the ocean acidification governance literature that identifies these three treaties as being the most substantively relevant for addressing ocean acidification (Kim, 2012; Oral, 2018; Potts, 2019).

Two frames were selected for examination. First the climate change frame was explored for use in the context of the UNFCCC. The second frame selected for examination in the context of UNCLOS and the CBD was the ocean frame. This was chosen as it offers the broadest coverage of the ocean acidification characteristics and emphasises issues of marine protection and marine biodiversity, which are important elements of both the UNCLOS and CBD mandates.
Case Study Analysis

Treaty interpretation is a method that can be used to assess whether an emergent problem, not recognised at the time of the treaty’s conclusion, falls within the scope of its mandate. Interpretation is also a method that can be used to harmonise provisions from different MEAs that appear to be in conflict (Bianchi, 2010; Matz-Lück, 2012; Van Asselt, 2014). While the scope of substantive issues that fall within an MEA mandate is established by the treaty itself (Steiner et al., 2003), agents may interpret the provisions and therefore its scope very differently, each guided by differing value systems, objectives and interpretative methodologies. Thus, treaty interpretation is a social process of enacting meaning in varied contexts (Wiener, 2009). Multilateral treaties are particularly susceptible to being interpreted in multiple ways as their language is often left vague or ambiguous in order to gain high levels of buy-in from states. While the Vienna Convention on the Law of Treaties (VCLT, 1969) establishes the general rules for interpreting treaties (as set out in Articles 31 to 33) (discussed further in Chapter 6), these rules leave significant room for different interpretative approaches.

Pauwelyn and Elsig (2012) developed a taxonomy of commonly used interpretation techniques selected by international tribunals (outlined in Table 3). This taxonomy is applicable beyond the interpretative choices made by tribunals and is used to guide the approach taken to treaty interpretation in this research. An explanation of how this taxonomy guided my interpretative choices is provided below.
The image contains a table with the following content:

<table>
<thead>
<tr>
<th>Interpretative Choice</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dominant Hermeneutic</strong></td>
<td>Text: linguistic meaning; relatively broad interpretative community.</td>
</tr>
<tr>
<td>I asked:</td>
<td>Int: more subjective; small community of drafters; can overlook less dominant voices.</td>
</tr>
<tr>
<td>What serves as the primary means for ascertaining the intent of the Parties?</td>
<td><strong>Objective</strong>: teleological; value-driven; considers the spirit of the treaty.</td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td>Original: meaning at the time the treaty was concluded (static, frozen in time).</td>
</tr>
<tr>
<td>I asked:</td>
<td><strong>Evolutionary</strong>: meaning at the time the dispute is decided (dynamic; evolves with new developments), addresses problem of treaty rigidity, goes hand-in-hand with teleological interpretation.</td>
</tr>
<tr>
<td>What point in time should an interpretation reference?</td>
<td><strong>Activism</strong>: Work to rule: deferential, strict constructionist.</td>
</tr>
<tr>
<td><strong>Precedent</strong></td>
<td><strong>Gap-filling</strong>: legislative function.</td>
</tr>
<tr>
<td>I asked:</td>
<td><strong>Case-by-case</strong>: no or less weight given to earlier rulings.</td>
</tr>
<tr>
<td>Whether the broader context of international law should influence interpretation?</td>
<td><strong>Rule of Precedent</strong>: earlier rulings complement normative framework.</td>
</tr>
<tr>
<td><strong>Linkage</strong></td>
<td><strong>Self-Contained</strong>: inward-looking, reference to own legal instruments only, prone to fragmentation.</td>
</tr>
<tr>
<td>I asked:</td>
<td><strong>Systemic</strong>: outward-looking, links to general international law and other treaties and tribunals; strives to reconcile differences between treaties and reads international law as a coherent system of law.</td>
</tr>
<tr>
<td>Whether interpretation should consider regime interactions and strive to enhance synergies across regimes?</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.2: Taxonomy of interpretative choices as set out by Pauwelyn and Elsig (2012). Each choice is accompanied by the question that I asked in determining which interpretative option should be used in this study. Those selected are highlighted in blue (Table adapted from Pauwelyn and Elsig (2012)).

In this study I have taken a teleological and evolutionary approach to interpretation, given the ‘rigidity’ of treaties and the difficulties in amending or adjusting them, such an approach recognises the important role that interpretation can play in ensuring the continued relevance and applicability of treaties in the face of ever changing environmental and legal conditions.
and the progression of scientific knowledge. These choices, coupled with those that take a systemic, gap-filling, rule of precent outlook, can, I argue, enhance synergies across regimes. This is particularly relevant in interpreting environmental treaties as the norms and principles of international environmental law provide an important context in which interpretation should be situated. Thus, approaching interpretation in this way can strive to enhance synergies across environmental regimes, rather than creating conflict.

This is an appropriate methodological choice for the interpretation of environmental treaties as they are designed to govern ever changing environmental conditions and to consider constantly evolving scientific knowledge. Indeed, there is frequently an explicit recognition of this within environmental treaties. For example, the UNFCCC contains a directive for the periodic examination of Party obligations to be conducted in consideration of the evolution of scientific and technological knowledge (UNFCCC, 1992, Art.7.2(a)). This approach views treaties as ‘living instruments’ capable of adapting over time to new information and circumstances (Van Damme, 2009). Moreover, this approach situates treaties in the broader context of evolving international environmental law and strives to not only fill gaps revealed in individual treaties but attempts to enhance synergies and reconcile differences between treaties, thereby working towards a coherent system of law, despite its fragmentation.

Taking this approach, I placed significance on the underlying objectives the drafters were attempting to achieve, while also considering the state of scientific knowledge and the broader milieu of international environmental law. This does not mean that the text and intent were not considered, indeed the three hermeneutics are not mutually exclusive and the VCLT refers to the use of all three. I interpreted the text and intent of each treaty in consideration of its object and purpose, which I elucidated through close readings of the entire treaty text, paying particular attention to the preamble and substantive provisions (Gardiner, 2015), along with drafting texts available through the UN documents repository and subsequent decisions of the Parties.
To establish the relationship between the treaty’s under examination and ocean acidification I first assessed whether the various ocean acidification characteristics could be considered as falling under the objective of the treaty, thereby determining whether the normative purpose of each treaty was relevant to addressing ocean acidification. Second, I investigated whether specific provisions created an obligation on Parties to address ocean acidification. While the treaties under examination are all considered to be binding, hard-law instruments, not all provisions they contain create a legal obligation on the Parties. This depends on the language used within the particular provisions. For instance, ‘shall’ connotes an obligatory provision, ‘should’ is recommended, ‘may’ is permissive and ‘will’ is predictive. Treaties often contain a mix of this mandatory and non-mandatory language (Bodansky, 2015). The language of each provision was studied for its ability to be considered as being inclusive of ocean acidification and the type of obligation that it placed on Parties.

I then investigated how each of these relevant provisions could be implemented in an ocean acidification-sensitive way and whether doing so would enhance synergies and lessen conflicts with other treaties also addressing ocean acidification. I did this by referring to the governing framework developed in Chapter 3 and articulating how specific elements of the framework could fulfil various treaty obligations and compared this to implementation of related provisions in other treaties. The framework was also used to analyse whether the provisions identified as being relevant to addressing ocean acidification could be understood as filling the gaps in ocean acidification governance revealed by the gap-analysis conducted in Chapter 4. By applying this evolutionary, outward looking approach treaty interpretation I was able to assess the ability of various treaties to address ocean acidification, determine the ways in which this could be implemented and articulate ways that this could be done so as to enhance synergies and lessen conflict across the ocean acidification regime complex.

The methods employed by this study are summarised in the table (Table 4) below in reference to the research question they are designed to answer and the chapter in which they are used.
<table>
<thead>
<tr>
<th>Research Question</th>
<th>Method Employed</th>
<th>Chapter that Answers Research Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What activities are needed to minimize and address ocean acidification?</td>
<td>Comprehensive review of proposed activities to address ocean acidification and organisation into a governing framework.</td>
<td>Chapter 3: A Governing Framework for International Ocean Acidification Policy</td>
</tr>
<tr>
<td>2. What efforts have already been made under existing multilateral environmental agreements to address ocean acidification and where are the existing gaps in the governance of this issue?</td>
<td>Gap-analysis using the aspirational model of international action on ocean acidification developed by the governing framework for ocean acidification and compares it to a comprehensive review of existing ocean acidification activities initiated by MEAs.</td>
<td>Chapter 4: The Fragmented Nature of Ocean Acidification Governance</td>
</tr>
<tr>
<td>3. How is ocean acidification currently framed? What are the implications of this framing and how can ocean acidification be framed differently?</td>
<td>Identification of framing deployed in epistemic community texts and examination of the use of this framing in scholarly literature assessing the relevance of MEAs for addressing ocean acidification. Identification of the causal and consequence characteristics of ocean acidification and aligning of these with thematic MEA clusters to develop alternative problem frames.</td>
<td>Chapter 2: Literature review Chapter 5: Framing Ocean Acidification to Mobilise Action Under Multilateral Environmental Agreements</td>
</tr>
<tr>
<td>4. Can reframing ocean acidification allow for a reinterpretation of the UNFCCC that is inclusive of an obligation to address ocean acidification?</td>
<td>Treaty interpretation</td>
<td>Chapter 6: (Re)Framing Ocean Acidification in the Context of the United Nations Framework Convention on Climate Change and the Paris Agreement</td>
</tr>
</tbody>
</table>

Table 1.3: Summary of research questions, methods used to answer them and the chapters in which these appear

1.9 Thesis Overview

This thesis continues in two parts. The first contains Chapters 2–4 and provides important background information to understanding the problem of ocean acidification and articulates the seascape of ocean acidification governance. Part II contains Chapters 5-8, which test the contention that alternative framings of ocean acidification provide an avenue for realigning
ocean acidification with existing MEA mandates. The thesis concludes with a review of the findings and implications of this research in Chapter 9.

Chapter 2 comprehensively reviews the natural science literature detailing the causes and consequences of ocean acidification. The purpose of this chapter is to provide a complete overview of the causes of, and their contributions to, the phenomenon of ocean acidification and how it is likely to impact marine systems. This review of the scientific literature is necessary to understand what is at risk with increasing acidity and to be able to classify ocean acidification into existing environmental problem frames. As this thesis contains published and in-review material there are short reviews of the literature appearing in each publication. To limit the level of repetition, this chapter is limited to reviewing the causes and consequences of ocean acidification; the possible solutions are reviewed in the next chapter (Chapter 3) and used to construct a governing framework for ocean acidification.

Chapter 3 constructs the governing framework that is used as an analytical tool to interrogate where gaps in the current governance landscape for ocean acidification exist. This chapter is presented as a paper that has been published in the journal *Marine Policy* (Harrould-Kolieb & Hoegh-Guldberg, 2019). This paper contributes a tool that can be used as both a decision-making rubric and an analytical framework and so advances both real-world decision making and academic analysis. This paper also identifies a series of gaps in existing knowledge pertaining to the activities that can be implemented to address ocean acidification. This chapter answers research question 1 and provides the aspirational model for the gap-analysis conducted in Chapter 4.

Chapter 4 systematically reviews the activities that have been initiated by MEAs in response to ocean acidification and compares these to the aspirational model of international action on ocean acidification created by the governing framework developed in Chapter 3. This chapter identifies the gaps in the existing governance of ocean acidification and emphasises the areas
that need to be focused on in the future to create a more comprehensive governance architecture. This chapter also explores the areas in which conflicts and synergies are likely to arise between the various MEAs engaging in governing ocean acidification. This chapter is presented as a manuscript that is currently under review in the journal of *International Environmental Agreements*. This chapter answers research question 2 and provides an understanding of the existing gaps in governance and the potential synergies and conflicts that may arise between the regimes currently governing ocean acidification. These conflicts and synergies are further explored in Chapters 6-8.

Chapter 5 argues that the framing ocean acidification by the epistemic community as a CO₂ problem concurrent to climate change has been counterproductive at the international level, resulting in two main barriers to comprehensive governance. Firstly, defining ocean acidification as a concurrent problem to climate change, rather than as an impact of it, has resulted in the UNFCCC being interpreted as containing no obligation to address ocean acidification. Secondly, focussing almost solely on the reduction of the global emissions of carbon dioxide as the only global solution to ocean acidification has resulted in ocean and biodiversity-related regimes being viewed as without the recourse to respond. Through an examination of the causes and consequences of ocean acidification and the general objectives of existing MEAs, this chapter develops a set of alternative problem frames that could be deployed to mobilize action under existing environmental regimes. This chapter is presented as a manuscript that is currently under review in the journal of *Environmental Science & Policy* and answers research question 3.

Chapter 6 contends that ocean acidification can be reframed as an effect of climate change in the context of the UNFCCC. This chapter is presented as a publication that has been published in the journal *Climate Policy* (Harrould-Kolieb, 2019). This paper finds that reframing ocean acidification is not only scientifically defensible, but in line with the object and purpose of the treaty. This paper concludes by discussing the implications of this redefinition for the
implementation of mitigation under the UNFCCC. This chapter answers research question 1 and contributes to answering question 6.

Chapter 7 argues that a reframing of ocean acidification as an ocean problem better situates the issue to be addressed by UNCLOS and further contends that this Convention already creates a legal framework for responding to this emergent issue. This chapter is presented as a manuscript that is currently under review in the journal *Review of European, Comparative & International Environmental Law (RECIEL)*. This paper finds that UNCLOS covers all six areas for collective action identified by the governing framework. This paper contributes to answering research questions 5 and 6.

Chapter 8 contends that deploying the ocean frame in the context of the CBD and the global biodiversity agenda can better align ocean acidification action with the work of the biodiversity-related regimes. This chapter analyses where synergies in the existing global biodiversity agenda, as established by the Aichi Biodiversity Targets, and uses these to highlight areas for consideration in the development of a post-2020 biodiversity framework. This chapter is presented as a manuscript currently under review in the journal *Conservation Biology*. This chapter contributes to answering research questions 5 and 6.

Chapter 9 concludes the thesis and reflects on the theoretical elements posed in the Introduction. In particular, it asserts that reframing of environmental problems coupled with treaty interpretation can emphasise new avenues for responding under MEAs and can strengthen cohesion across the ocean acidification regime complex. Significantly, this chapter finds that it may be necessary for multiple ocean acidification problem frames to exist simultaneously in order to comprehensively govern this issue.
Part I: The Seascape of Ocean Acidification

Chapter 2

Literature Review
This chapter reviews the natural science literature relevant to the causes and consequences of ocean acidification. The purpose of this chapter is to provide a complete overview of the causes of, and their contributions to, the phenomenon of ocean acidification and how it is likely to impact marine systems. As this thesis contains published and in-review material there are short reviews of the literature appearing in each publication (chapters 3-7). While I have tried to provide new information here, some level of repetition is inevitable. For this reason, this chapter is limited to reviewing the causes and consequences of ocean acidification; the possible solutions are reviewed in the next chapter (Chapter 3) and used to construct a governing framework for ocean acidification.

This chapter begins with a review of the chemistry of ocean acidification in Section 2.1, examining how it is caused on a global level and the localized factors that can contribute to worsening acidification in discreet areas. Section 2.2 reviews the main biological, physiological and biogeochemical impacts of ocean acidification and how these are likely to have flow-on effects for human communities. Section 2.3 offers a summary of the main findings of this review and categorises these findings into overarching types of drivers and impacts of ocean acidification.

2.1 The Chemistry of Ocean Acidification

Carbon dioxide (CO$_2$) readily dissolves into water, resulting in a series of chemical reactions (equation 1). These reactions produce a weak acid, carbonic acid (H$_2$CO$_3$), through the bonding of dissolved CO$_2$ and water. Carbonic acid then dissociates to yield a hydrogen ion (H$^+$) and a bicarbonate ion (HCO$_3^-$), thereby increasing the concentration of bicarbonate and hydrogen ions (and therefore the acidity of the solution). Hydrogen ions produced by this reaction react with available carbonate ions to produce bicarbonate ions (equation 2).
CO₂ + H₂O ⇌ H₂CO₃ ⇌ H⁺ + HCO₃⁻  \ (Eq. 1)

H⁺ + CO₃²⁻ ⇌ HCO₃⁻  \ (Eq. 2)

The overall change resulting from the increased absorption of CO₂ is a decrease in both the pH (the negative logarithm of the concentration of hydrogen ions) and the concentration of carbonate ions and an increase in bicarbonate ions (Pilson, 1998).

Ocean acidification occurs due to the increased absorption of anthropogenic CO₂ emissions. The global ocean is estimated to have absorbed one third of all anthropogenic CO₂ emissions from 1750 to 2010 (155 PgC) (Khatiwala et al., 2013). These emissions have reduced the average pH of the surface ocean by 0.1 units below pre-industrial levels, which represents a 26 percent increase in H⁺ ions (Orr et al., 2005). This is larger than the maximum decline in pH likely to have occurred at any point over the past 65 million years (Ridgwell & Schmidt, 2010). Further, the current rate of acidification is likely to be at least 100 times faster than the maximum rate experienced over hundreds of thousands of years and likely much longer (Raven et al., 2005). This is important because when changes in CO₂ occur slowly over long periods of time (more than 1000 years) the ocean has the capacity to buffer these changes via interactions with carbonate ions. However, this buffering capacity is reduced when changes in CO₂ occur over shorter timescales (Caldeira & Wickett, 2003).

Caldeira and Wickett (2003) estimate that if emissions follow a middle range emissions scenario the pH of the surface ocean could fall to between 7.8 to 7.9 (an increase in acidity of 100 to 150 percent) by the end of this century. Additionally, they conclude that unabated emissions could result in a decline to a pH of 7.43 by 2300; a larger decline than any experienced over the past 300 million years. This would result in a significant drop in carbonate ions below pre-industrial levels; 50 percent by 2100 (Orr et al., 2005) and 75 percent by 2300 (Zeebe, 2012).
Some areas of the ocean are more susceptible to ocean acidification due to local or regional conditions, such as upwelling, which brings deep ocean waters to the surface that contain higher levels of CO$_2$. When these waters absorb additional CO$_2$ from the atmosphere a substantial spike in the acidity of the surface waters can occur (Feely, Sabine, Hernandez-Ayon, Ianson, & Hales, 2008). This has been documented to occur along the West Coast of the United States (Barton et al., 2015). Acidification can also be driven by other local conditions, such as freshwater input from rivers and meltwater, which introduce water with lower carbonate content and lower pH. River water can also contain high tannin content or other acidic compounds (Pörtner et al., 2014). Diurnal pH can also vary because of plant photosynthesis during the day and respiration at night. Vegetation, such as mangroves, can also moderate local pH. As a result, these ecosystems provide a substantial amount of carbonate alkalinity to the surrounding waters as well as the potential to act as a long term sink for atmospheric CO$_2$, hence the ability to buffer coastal acidification (Sippo, Maher, Tait, Holloway, & Santos, 2016).

The Southern and Arctic Oceans are also more susceptible to ocean acidification due to their colder, saltier waters, which more readily absorb CO$_2$ than warmer waters. Seasonal aragonite undersaturation is expected to occur in surface waters of the Southern Ocean by 2030 (McNeil & Matear, 2008). Aragonite is a crystalline form of calcium carbonate that is used by many marine organisms to create shells and skeletons. The saturation state indicates how readily available this mineral is or how easily unprotected aragonite structures will dissolve. Undersaturation of the Southern Ocean is projected to increase from a period of 1 to 6 months from 2030 to 2050 and will cover approximately 30 percent of the surface waters by 2060 and more than 70 percent by 2100 (Hauri, Friedrich, & Timmermann, 2015). The aragonite saturation horizon is expected to rise, shoaling from 1000 to 83 meters by the end of the century. This substantial decrease in suitable habitat for aragonitic organisms is present under both high and moderate emissions scenarios (RCP 8.5 and 4.5), although its onset is delayed.
in the lower emissions scenario (Negrete-García, Lovenduski, Hauri, Krumhardt, & Lauvset, 2019). A similar equatorward progression of surface aragonite undersaturation is expected to occur in the Arctic, with substantial areas of the polar and sub-polar oceans projected to be undersaturated by the end of this century (Fig. 1). Coral reefs are also projected to be in a state of dissolution before the end of this century (Eyre et al., 2018; Hoegh-Guldberg et al., 2007; Silverman, Lazar, Cao, Caldeira, & Erez, 2009). The lowered saturation state will prevent reefs from being able to produce new calcium carbonate skeletons at a rate fast enough to overcome the effects of the natural erosion (due to being broken by waves and eaten by fish). This shift from accretion to dissolution is likely to take place once saturation states fall below 3 (Hoegh-Guldberg et al., 2007).

Figure 2.2: Changes in Aragonite Saturation, 1875-2095
This map shows changes in the aragonite saturation state of the surface ocean between 1875 and 2095. The lower the saturation state, the more likely aragonite structures will dissolve over time. As the saturation state drops, not only is it more likely aragonite will dissolve, but it also becomes more difficult to build these structures (Image modified from Feely et al, 2009).

While anthropogenic CO₂ is the only global driver of ocean acidification, in some areas local and regional anthropogenic factors have been shown to contribute significantly to the global trend (Cyronak et al., 2014). Land-based pollution and effluent originating from agricultural fertilizer runoff, wastewater, sewage, automobile exhaust and emissions from power
generation can all result in nitrogen pollution, which may lead to phytoplankton blooms and eutrophication (Borges & Gypens, 2010; Cai et al., 2011; Silbiger et al., 2018). These blooms increase local CO₂ concentrations when they decompose, and this decomposition increases local acidification. A number of locations have been identified as suffering from increased acidification due to eutrophication, including in the Baltic Sea (Sunda & Cai, 2012) the Gulf of Mexico and the East China Sea (Cai et al., 2011), the North Sea (Provoost, Heuven, Soetaert, Laane, & Middelburg, 2010), Chesapeake Bay (Waldbusser, 2011) and Puget Sound (Feely et al., 2010). In some areas, nutrient runoff can be a more significant driver of acidification than the uptake of CO₂ (Borges & Gypens, 2010).

Disturbances to coastal systems can also exacerbate ocean acidification via changes in the rates and types of runoff reaching marine systems as well as through changes to ecosystem function. For example, mangrove mortality and deforestation not only allows greater levels of pollution to reach marine systems, but also results in a decline in the contribution of alkalinity and dissolved inorganic carbon to the surrounding environment, a process known as outwelling (Sippo et al., 2019). The decline in outwelling decreases the buffering potential of seawater and thereby contributes to worsening acidification in some areas.

Deposition of non-CO₂ acid forming compounds from the atmosphere, such as sulphur and nitrogen oxides (SOₓ and NOₓ), also increase the acidity of seawater, lowering pH (Doney et al., 2007; Omstedt et al., 2015). While it had been thought that the impacts of these compounds were largely negligible (Doney et al., 2007), recent work considering the contribution of emissions from international shipping in heavily trafficked areas has suggested that the pH reductions from these acidic compounds are on the same order of magnitude as CO₂ driven acidification (Hassellöv et al., 2013).

Some efforts that seek to address climate change via the manipulation of ocean systems also risk exacerbating ocean acidification. For example, the disposal of captured CO₂ in the water
column or on the seafloor, to sequester carbon away from the atmosphere and prevent it from worsening climate change, are likely to produce severe local acidification (Williamson & Turley, 2012). Ocean fertilisation, which has received substantial research and policy attention (Scott, 2015), seeks to enhance the marine biological pump by fertilisation of ocean waters with nutrients naturally limited in particular areas, specifically iron, nitrogen and phosphate, thereby enhancing the draw-down of CO$_2$ from surface to deep waters via the biological pump (Lampitt et al., 2008). This process is likely to transfer ocean acidification from the upper ocean to deeper waters (Williamson & Turley, 2012).

### 2.2 The impacts of ocean acidification

The changing chemical conditions resulting from ocean acidification are likely to directly impact marine organisms in a variety of ways: including, making calcium carbonate precipitation more difficult due to the decreasing availability of carbonate ions, the dissolution of calcium carbonate structures due to the increasing areal extent of undersaturation, and the disruption of acid-base relationships (Doney, Fabry, Feely, & Kleypas, 2009). As a result ocean acidification is likely to interrupt important physiological processes, such as calcification, gene expression, reproduction, growth, development, metabolism, acid-base regulation and even behaviour in some species (Bibby et al., 2007; Dong, Eudeline, Huang, & Tiersch, 2005; Evans & Hofmann, 2012; Guinotte & Fabry, 2008; Havenhand, Buttler, Thorndyke, & Williamson, 2008; Kleypas & Yates, 2009; Kroeker, Kordas, Crim, & Singh, 2010; Kurihara, Shimode, & Shirayama, 2004; Pörtner, 2008). Impacts at the molecular, cellular and organismal levels may be expressed as disturbances at the population and ecosystem levels as well as disruptions to biogeochemical processes that contribute to Earth-system cycles (Doney et al., 2009; Gehlen et al., 2011; Le Quesne & Pinnegar, 2011). Ocean acidification can also have indirect impacts, including through changes to predator-prey relationships (Ferrari et al., 2011), the propagation of sound (Hester, Peltzer, Kirkwood, & Brewer, 2008), and the availability of, and sensitivity to, nutrients and toxins (Abbasi & Abbasi, 2011; Millero et al., 2009).
A number of *in situ* investigations and studies along natural pH gradients suggest that ocean acidification is a driver or contributing factor to reduced calcification rates in a number of species (Hall-Spencer & Harvey, 2019; Maier, Watremez, Taviani, Weinbauer, & Gattuso, 2011; Moy, Howard, Bray, & Trull, 2009). Calcification is the physiological process by which organisms secrete calcium carbonate, to form structures such as shells and skeletons. This process is integral to the survival of many marine organisms, including corals, molluscs, crustacea, coralline algae and many plankton. Calcifying organisms can exert varying degrees of control over the calcification process; those with greater levels of control may be able to better withstand the changing conditions resulting from ocean acidification, however, there is little evidence for acclimatization to increasing acidity over the short-term (Comeau et al., 2019). These processes also require substantial amounts of energy and hence come with consequences for the organism’s fitness and ability to maintain other physiological processes.

While there is considerable evidence of the impact of ocean acidification on a wide array of organisms and ecosystems, much is unknown regarding the differences in inter- and even intra-species calcification responses to ocean acidification (Doney et al., 2009). Some species exhibit reduced calcification prior to undersaturation (Fabry, Seibel, Feely, & Orr, 2008; Kleypas et al., 2006), while others appear able to maintain or enhance their calcification (Iglesias-Rodriguez et al., 2008; Ries, Cohen, & McCorkle, 2009) but often at a cost to other energy requirements (Cohen, McCorkle, de Putron, Gaetani, & Rose, 2009; Wood, Spicer, & Widdicombe, 2008). Despite these differences, it appears that the majority of species analysed to date reduce calcification when subjected to more acidic conditions (Kroeker et al., 2013; Ries et al., 2009).

Biological responses to ocean acidification are expected to vary according to life stage. Eggs, sperm and larvae appear to be more susceptible to disrupted development and death than adults under more acidic conditions (Arnold, Findlay, Spicer, Daniels, & Boothroyd, 2009; Kurihara, Kato, & Ishimatsu, 2007; Kurihara & Shirayama, 2004). However, there are some species that
show reduced fitness as adults when exposed to more acidified conditions in early life stages (Kroeker et al., 2013). The responses of higher order species, such as fish, are less well understood than those of corals and other lower order calcifiers. However, research suggests that some marine fishes will be susceptible to deleterious effects from ocean acidification, including disruptions to respiratory gas exchange, tissue and fluid acidosis, sensory deprivation and disrupted brain function (Cattano, Claudet, Domenici, & Milazzo, 2018; Devine, Munday, & Jones, 2011; Ishimatsu, Hayashi, & Kikkawa, 2008; Pörtner, Bock, & Reipschlager, 2000; Pörtner, Langenbuch, & Reipsläger, 2004; Simpson et al., 2011).

While research on the biological and physiological responses of marine organisms to ocean acidification is still developing, especially with regards to higher order species, the emerging picture is that ocean acidification poses a substantial threat that may reduce fitness and compromise the survival of many marine organisms (Hoegh-Guldberg et al., 2018). However, some species may be relatively resilient to ocean acidification and others may actually do better in a high-CO$_2$ ocean, for example, it appears that some marine plants, such as seaweeds and non-calcifying algae may be able to photosynthesize and grow faster due to higher availability of CO$_2$ (Hall-Spencer & Harvey, 2019).

In addition to these direct impacts, ocean acidification may exert indirect impacts and interact with other drivers of decline in unexpected ways. For instance, ocean acidification may exacerbate the impacts of warming resulting from climate change (Gibson et al., 2011; Harvey et al., 2013), including decreasing the threshold at which corals will bleach (Anthony et al., 2008) and reducing the ability of reefs to keep pace with sea-level rise (Yates et al., 2017). Studies on American lobsters found they exhibited physiological challenges when exposed to both acidification and warming, including reduced cardiac performance and decline in hemocyte (infection-fighting cells), compared to just warming (Harrington & Hamlin, 2019). Studies have also found that warming is increasing the growth rates in skates, however, mineralization is unable to keep up with this increase due to acidification, leading to weaker
skeletons. While there were some skeletal areas that showed increased mineralisation, which may prove a benefit, it was also predicted that these skeletons would be heavier and may result in higher energy expenditures while swimming (Di Santo, 2019).

Ocean acidification also appears to reduce the sensitivity of some species to particular pollutants, including by increasing the biotoxicity of heavy metals and their bioavailability (Millero et al., 2009). In addition to the likelihood of increased mortality, increased sensitivity to heavy metals and other pollutants can inhibit primary production and photosynthesis in marine ecosystems. This can decrease CO₂ removal from the atmosphere via phytoplankton growth, thereby increasing both ocean acidification and climate change (Zeng et al., 2015).

Modifications in carbonate chemistry, the distribution and abundance of marine organisms and the flow of matter, energy and nutrients throughout the ocean may result in changes to the ocean’s biological pumps (Gehlen et al., 2011). These changes may indirectly alter a number of feedback mechanisms to the climate system, the most important of which may be oceanic absorption and storage of CO₂ in long-term deep ocean reservoirs, decreasing the efficiency with which the ocean can absorb CO₂ and acting as a positive feedback on climate change (Gehlen et al., 2011; Riebesell & Tortell, 2011). This impact is well-understood and estimated to be responsible for a decrease in CO₂ uptake of more than 30 percent compared to the preindustrial ocean (Gruber, 2011). In addition, the distribution of elements, including oxygen, through the ocean could be altered as a result of ocean acidification, which may lead to the creation of large dead zones (Gruber, 2011). It is expected that biogeochemical consequences will result from ocean acidification, however, there are substantial uncertainties in current abilities to predict the magnitude with which these will occur (Gattuso, Bijma, Gehlen, Riebesell, & Turley, 2011).

Despite uncertainties it is possible to predict that substantial changes are likely to take place throughout the oceans if ocean acidification continues unabated. Changes in relative fitness
may result in shifts in the abundance and distribution of marine species with flow-on effects for the trophic dynamics that govern the exchange of energy and the cycling of nutrients throughout marine food webs (Riebesell & Tortell, 2011). Food webs may become destabilised as the composition and abundance of populations shift due to impacts to productivity, larval development, growth efficiency, predator-prey relationships, behaviour and competition (Fabry et al., 2008; Turley & Boot, 2010). While more resilient species will likely move into vacated niches it is unclear whether such changes would support the same diversity that exists in the ocean today. Consequently, it is expected that ocean acidification will have profound implications for marine ecological systems (Guinotte & Fabry, 2008).

The changes in marine biodiversity and ecosystems will have ramifications for human communities. Recent work has started to identify which human communities and industries might be particularly vulnerable to ocean acidification (Brander et al., 2012; Cooley et al., 2011; Turley & Boot, 2010). Ocean acidification has already changed the production techniques of shellfish farms along the West Coast of the United States (Barton et al., 2015). Other consequences are expected to include impacts to human health through reduced access to protein (Cooley et al., 2011; Turley & Boot, 2010) and changes in nutritional content (Xu et al., 2019), economic losses from fisheries (AMAP, 2018; Branch et al., 2013; Cooley & Doney, 2009) and reduced tourism (Brander et al., 2012), as well as decreased coastal protection (Cooley et al., 2009; J. P. Gattuso et al., 2015). While these studies are in their infancy they do indicate that the consequences for society could be vast, including threats to fisheries and human food security, especially for those communities highly dependent on marine resources for income, nutrition and cultural heritage.

### 2.3 Synthesis

This review has revealed that ocean acidification is a highly complex, interlinked phenomenon, with one global driver and multiple local factors that can exacerbate the global trend. There are
four key pathways through which anthropogenic activities can drive and exacerbate ocean acidification. These are: (1) the emission of CO$_2$, (2) the introduction of pollutants (both land-based and via the atmosphere), (3) the direct disposal of CO$_2$ into the ocean and the deployment of activities (geoengineering and negative emission technologies) that place substances in the ocean to enhance the drawdown of CO$_2$ from the atmosphere, and (4) the non-CO$_2$ causes of ecosystem decline. There are also four overarching types of impacts that ocean acidification has. These are: (1) changes in the abundance and distribution of marine biodiversity, (2) exacerbation of non-acidification causes of decline, (3) disruption of biogeochemical processes and (4) the loss of ecosystem services.
Chapter 3

A Governing Framework for International Ocean Acidification Policy
Chapter 4

The Fragmented Nature of Ocean Acidification Governance by Multilateral Environmental Agreements
Part II: Reframing Ocean Acidification for Governance

Chapter 5

Framing Ocean Acidification to Mobilise Action
Under Multilateral Environmental Agreements
Chapter 6

(Re)Framing ocean acidification in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement
(Re)Framing ocean acidification in the context of the United Nations Framework Convention on climate change (UNFCCC) and Paris Agreement

Ellycia R. Harrould-Kolieb

To cite this article: Ellycia R. Harrould-Kolieb (2019): (Re)Framing ocean acidification in the context of the United Nations Framework Convention on climate change (UNFCCC) and Paris Agreement, Climate Policy, DOI: 10.1080/14693062.2019.1649994

To link to this article: https://doi.org/10.1080/14693062.2019.1649994

Published online: 05 Aug 2019.
(Re)Framing ocean acidification in the context of the United Nations Framework Convention on climate change (UNFCCC) and Paris Agreement

Ellycia R. Harrould-Kolieb\textsuperscript{a,b}

\textsuperscript{a}Climate and Energy College, University of Melbourne, Parkville, Australia; \textsuperscript{b}School of Geography, University of Melbourne, Carlton, Australia

Abstract
Ocean acidification is most frequently framed by the scientific community as a concurrent threat to climate change, rather than an effect of it. This separation of the two phenomena has long been deemed as a way of garnering heightened policy attention for ocean acidification rather than having it bound up in the often contested politics of climate change. This effort, however, appears to have resulted in the inadvertent placing of ocean acidification outside of the mandate of the United Nations Framework Convention on Climate Change (UNFCCC). This has created a significant gap in the global governance of this issue with no multilateral agreement understood as having jurisdiction over the mitigation of rising ocean acidity. For these reasons this paper argues that an alternative framing of ocean acidification as an effect of climate change is warranted. This would include ocean acidification in the core obligations of the Convention, thereby filling the mitigation governance gap and avoiding perverse implementation outcomes. It is contended that interpreting the UNFCCC in this way is more consistent with its objective and purpose than the existing interpretations that place ocean acidification beyond the remit of the Convention.

Key policy insights
- Ocean acidification is best understood as an effect of climate change in the context of the UNFCCC, and therefore is included in its obligations to combat climate change and its adverse effects.
- An obligation to address ocean acidification has implications for the way that the provisions of the Convention, particularly on mitigation, are implemented. Mitigation activities that exacerbate ocean acidification or lead to emission reduction pathways that do not prevent dangerous acidification should be deemed inconsistent with the Convention.
- Protection, conservation and restoration of coastal and marine ecosystems should become a priority area for action within the UNFCCC.

1. Introduction
Almost 30\% of anthropogenic carbon dioxide (CO\textsubscript{2}) emissions are absorbed by the global ocean. These emissions are changing the chemistry of the ocean, making it more acidic. This process is known as ocean acidification and is likely to have wide-ranging ramifications for marine biodiversity, biogeochemical processes and the goods and services derived from the ocean that billions of people depend upon (Bibby, Cleall-Harding, Rundle, Widdicombe, \& Spicer, 2007; Gattuso et al., 2015; Guinotte \& Fabry, 2008; Harvey, Gwynn-Jones, \& Moore, 2013; Hoegh-Guldberg et al., 2018; Kroeker, Kordas, Crim, \& Singh, 2010). Social and ecological consequences are
expected to include, but are not limited to, impacts to human health due to reduced access to protein, changes in the nutritional content and rates of bioaccumulation of pollutants in seafood (Cooley, Lucey, Kite-Powell, & Doney, 2011; Su et al., 2019; Turley & Boot, 2010; Xu et al., 2019), economic losses from decline in fisheries and tourism (AMAP, 2018; Branch, DeJoseph, Ray, & Wagner, 2013; Brander, Rehdanz, Beukering, & Tol, 2009; Cooley & Doney, 2009), and decreased coastal protection (Hall-Spencer & Harvey, 2019). Ocean acidification is expected to manifest as substantial changes across marine ecosystems, including the loss of most coral reefs globally (Eyre et al., 2018; Hoegh-Guldberg et al., 2007; Silverman, Lazar, Cao, Caldeira, & Erez, 2009). Declines and even extinctions will likely occur across the ocean by the end of this century if ocean acidification continues unabated.

Ocean acidification has been coined ‘the other CO₂ problem’ (Turley, 2005) and ‘the evil twin of climate change’ (Kolbert, 2009). These colloquialisms hint at the perceived nature of the relationship between climate change and ocean acidification; that they are separate, albeit related problems. Climate change is understood as encompassing the effects associated with changes in the planetary heat budget due to increases in atmospheric greenhouse gas levels (predominantly CO₂). These changes are responsible for global warming and changing weather patterns, however they do not include ocean acidification as it is not driven by changes in global temperature, but rather increasing CO₂ emissions (Sabine, 2012). It is for this reason that ocean acidification is widely described not as an effect of climate change, but rather as a concurrent problem caused by the same driver, namely, rising CO₂ emissions in the atmosphere.

Studies of public perceptions of ocean acidification have highlighted the risk of polarization along value-based attitudes when ocean acidification is linked too closely with climate change (Capstick, Pidgeon, Corner, Spence, & Pearson, 2016; Cooke & Kim, 2019). For this reason, the ocean acidification epistemic community has long advocated for the two problems to be framed as concurrent issues as a means of raising ocean acidity on political agendas without it being swamped by, or entangled with, the politically contentious issue of climate change. This has likely been an effective strategy in some cases, particularly in the United States, where domestic ocean acidification policies have largely succeeded due to the ability to overcome partisan politics.

The strategy of framing ocean acidification as a separate problem to climate change is reflected in its virtual absence from the work of the United Nations Framework Convention on Climate Change (UNFCCC, 1992). The UNFCCC is the primary mechanism through which the international community is seeking to regulate CO₂ (and other greenhouse gases) in order to address climate change and its impacts. Despite consideration of ocean acidification within a number of UN bodies, including: the UN General Assembly (UNGA, 2006) and the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNGA, 2013); a specific ocean acidification target within the Sustainable Development Goals (SDG 14.3); extensive discussion of the issue within the Intergovernmental Panel on Climate Change (IPCC) (Hoegh-Guldberg et al., 2018; IPCC, 2014); and its recognition as an emerging issue with relevance to the UNFCCC by the Subsidiary Body for Scientific and Technological Advice (SBSTA, 2011); ocean acidification has not been taken up across the working of the UNFCCC regime. Indeed the only mention of ocean acidification in any outcome documents of the Conference of the Parties (COP) is in a footnote to the 2010 Cancun Agreements, where it is referred to as a slow onset event (UNFCCC, 2010). The issue has not been actively considered in the setting of mitigation targets, nor in policy discussions of the COP. Of the 161 NDCs examined by Gallo, Victor, and Levin (2017), only 14 (8%) were found to have even mentioned ocean acidification and none of these included explicit activities or goals to be employed to address it.

It is widely agreed within the ocean acidification governance literature that the UNFCCC is pragmatically the logical place to address the mitigation of ocean acidification given its mandate to regulate CO₂ emissions (Harrould-Kolieb & Herr, 2012; Scott, 2018; Stephens, 2015). However, there is disagreement over the extent to which the Convention’s obligations apply to ocean acidification, if at all (Baird, Simons, & Stephens, 2009; Harrould-Kolieb, 2016; Kim, 2012; Oral, 2018). While some scholars argue for a more inclusive reading of the Convention, all agree that ocean acidification does not fit comfortably within the existing regime, primarily because climate change is understood as pertaining to the thermal impacts of greenhouse gas emissions on the climate system and not the chemical changes to the ocean. The framing of ocean acidification as a concurrent problem to climate change appears to have inadvertently resulted in the perverse outcome of ocean acidification being
largely excluded from the work of the primary global instrument for regulating CO₂, thereby creating a significant gap in the global governance architecture for ocean acidification.

Most scholars have attempted to overcome this governance gap by proposing ways to amend and expand the existing UNFCCC mandate, including through the adoption of a new protocol (Kim, 2012), explicit recognition of ocean acidification by the COP (Harrould-Kolieb & Herr, 2012) or even the conclusion of an entirely new treaty (Lamirande, 2011). This paper takes an alternative approach, arguing that it is possible to reframe ocean acidification as an effect of climate change. This re-framing would overcome the structural limitations that have been identified within the UNFCCC when ocean acidification is framed as a concurrent problem to climate change, to clarify how ocean acidification fits within the mandate of the climate change regime without the need to amend existing legal instruments or create new ones.

This paper proceeds in Section 2 by providing a brief overview of the methodological approach to treaty interpretation utilised. This is followed in Section 3 by a review of existing interpretations of the UNFCCC with reference to ocean acidification and an exploration of the implications of framing ocean acidification as a concurrent problem to climate change. Section 4 provides a scientifically defensible argument for describing ocean acidification as an effect of climate change under the Convention, which leads into a discussion, in Section 5, of why this interpretation is more consistent with the object and purpose of the Convention and should prevail over the interpretation that results in ocean acidification largely sitting beyond the mandate of the climate change regime. Section 6 analyses the implications of re-framing ocean acidification for the implementation of the UNFCCC and the Paris Agreement. Section 7 concludes with a review of the main findings of the paper.

2. Methodological approach

In order to determine how ocean acidification can be understood in the context of the UNFCCC, this paper will utilise the widely accepted norms of treaty interpretation established by the Vienna Convention on the Law of Treaties (VCLT, 1969). The VCLT establishes the general rules of treaty interpretation under Articles 31–33 which guide the interpretative process. Article 31 stresses that the primary means for interpreting a treaty is ‘in accordance with the ordinary meaning’ and that this should be understood in light of its context and the treaty’s ‘object and purpose’ (VCLT, 1969, Art.31.1). Article 32 offers guidance for situations where there are multiple meanings for terms that appear in a treaty, particularly when outcomes of interpretation might be ‘ambiguous’, ‘unreasonable’ or even ‘manifestly absurd’ (VCLT, 1969, Art.32). To confirm a meaning resulting from the tests offered by Article 31 or if a meaning that results from them is unreasonable or manifestly absurd, supplementary means of interpretation, including the preparatory work of the treaty and the circumstances of its conclusion can be employed (VCLT, 1969). These interpretive rules will be employed to determine how the UNFCCC should be applied to the treatment of ocean acidification.

3. Existing interpretations of the UNFCCC with respect to ocean acidification

It is widely accepted that ocean acidification can be understood as being an anthropogenic interference with the climate system (Baird et al., 2009; Harrould-Kolieb & Herr, 2012; Schubert et al., 2006). The ‘climate system’ is defined under the Convention as ‘the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions’ (UNFCCC, 1992, Art.1.3). Ocean acidification is a result of interactions between the atmosphere and hydrosphere (ocean), it impacts both the hydrosphere and biosphere (plants and animals) and it alters the interactions between the atmosphere, hydrosphere and biosphere through feedback mechanisms. Broad interpretations of the Convention, therefore, consider ocean acidification as falling under the general obligations established by Articles 2 and 3.1 to protect the climate system (Harrould-Kolieb, 2016; Schubert et al., 2006). Consequently, Parties are understood as having a duty to consider ocean acidification in their implementation of the Convention. However, most of the substantive provisions of the Convention, including the core commitments set out in Article 4, as well as some of the principles in Article 3, refer to combating, preventing and minimising climate change and its adverse effects, rather than referring to the climate system. As discussed in more detail below, ‘climate change’ is defined in Article 1 as an alteration of the ‘climate’,
not the climate system, which has generally been interpreted as encompassing only the thermal changes in the climate system (Sabine, 2012). In this sense, efforts to combat climate change are not understood as being inclusive of ocean acidification (Harrould-Kolieb, 2016; Kim, 2012). Thus, while Article 2 is understood as encompassing ocean acidification, most of the substantive provisions of the Convention do not. This appears to create an ambiguity in the Convention with respect to ocean acidification so that it is unclear to what extent chemical changes to the ocean should be considered in its implementation.

Many legal scholars have addressed this ambiguity by arguing that the Convention’s focus on combatting climate change as the means for achieving Article 2 connotes that the obligation to protect the climate system pertains only to the thermal impacts resulting from increased greenhouse gas emissions and not to the chemical changes in the ocean (Downing, 2013; Fennel & VanderZwaag, 2015; Stephens, 2015). Consequently, the climate change regime is understood as having neither the mandate nor the obligation to extend its work to encompass ocean acidification (Baird et al., 2009; Kim, 2012; Scott, 2018). Baird et al. (2009) suggest that these structural limitations render the Convention, in its existing form, ‘incapable of adequately addressing ocean acidification’ (p. 464) and Kim (2012) concludes that future incorporation of this issue without structural changes would be a difficult task at best. Describing climate change as encompassing the thermal impacts to the climate system and framing the chemical impacts as a separate problem has resulted in ocean acidification being deemed as sitting largely beyond the mandate of the climate change regime.

The situation of ocean acidification largely beyond the remit of the UNFCCC carries implications for the way in which the obligations of the Convention are interpreted. Most importantly, the long-term temperature target established by the regime and most recently enshrined by the Paris Agreement is viewed as not applying to ocean acidification (Harrould-Kolieb & Herr, 2012; Scott, 2018). The aim of the Paris Agreement is to hold ‘the increase in the global average temperature to well below 2°C above pre-industrial levels’ and to pursue ‘efforts to limit the temperature increase to 1.5°C above pre-industrial levels’ (UNFCCC, 2015a, Art.2.1(a)). This target does not readily appear to apply to ocean acidification as the changing chemistry is not a result of increasing global temperatures and efforts to meet this target could foreseeably result in emission pathways that limit rising temperature without averting the dangerous impacts of ocean acidification (Scott, 2018). This perverse outcome could be realized if the reduction of non-CO2 greenhouse gases is prioritized over that of CO2 (Harrould-Kolieb & Herr, 2012), if geoengineering techniques such as solar radiation management are used to reduce global temperatures (Cao, 2018), or if marine geoengineering techniques that exacerbate ocean acidification are deployed (Williamson & Turley, 2012).

It has been argued that Article 4 encourages the use of marine geoengineering techniques that enhance the draw-down of CO2 from the atmosphere, such as ocean fertilization, along with the direct injection of CO2 into the water column (Baird et al., 2009). Article 4 places a duty on Parties to ‘[p]romote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases’ (UNFCCC, 1992, Art.4.1(d)). Baird et al. (2009) and Kim (2012) both read this Article as inadvertently allowing for the exacerbation of ocean acidification, suggesting that ‘the uptake of atmospheric CO2 by the ocean is presented in the climate change regime as part of the solution to climate change, rather than as a problem in and of itself’ (Baird et al., 2009, p. 464). Framing ocean acidification as a concurrent problem to climate change has resulted in an interpretation of the climate change regime that allows ocean acidification to remain unaddressed or even exacerbated due to its narrow focus on the thermal impacts of rising greenhouse gas emissions. This paper now turns to an analysis of the implications of reframing ocean acidification as an effect of climate change, rather than a concurrent problem. Prior to embarking on this analysis, the next section discusses the scientific defensibility of describing ocean acidification as an effect of climate change and whether this description can be understood as fitting the definitions provided by the Convention.

4. Ocean acidification as an effect of climate change

Describing the relationship between ocean acidification and climate change hinges on the way in which ‘climate change’ is defined. Article 1 sets out the definitions for the purposes of the UNFCCC (see Figure 1). As noted above, here, climate change is defined as ‘a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere’ (UNFCCC, 1992, Art.1.2). While ocean
Acidification can be attributed to human activity that alters the composition of the global atmosphere (anthropogenic CO₂ emissions), it is unclear from this definition whether rising acidity is to be considered a change in ‘climate’.

The UNFCCC does not provide a definition for climate, nor is it defined later in supplementary legal instruments or the work of the regime. Further, there is no universally agreed definition that could be easily applied to provide an ‘ordinary meaning’ in the context of the treaty. Indeed, the IPCC, which cooperates closely with the COP and other Convention bodies to provide up-to-date scientific advice, a relationship established by Article 21.2 of the Convention, offers two definitions of climate, stating that:

Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years.

Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2018, emphasis added).

In light of this it can be understood that there are two scientifically defensible ways of interpreting climate and therefore climate change under the Convention. First, that climate change is a change in the average weather and encompasses only the thermal impacts of greenhouse gas emissions on the climate system, and second, that climate change is a change in the state of the climate system beyond just the thermal impacts. The first has been used to describe the relationship between ocean acidification and climate change within the Convention until now, however, the second is arguably more consistent with the Convention given that ‘climate system’ is defined and utilised throughout the text, whereas ‘climate’ is not. This second broader interpretation of climate change is inclusive of changes to the ocean resulting from an altered composition of the atmosphere from human activity. Given that ocean acidification is a result of the absorption of anthropogenic CO₂ into the ocean from the atmosphere it can therefore justifiably be understood as being an adverse effect of climate change under the Convention.

### 5. Determining the meaning of ‘climate change’ under the treaty

It is evident that there are two scientifically defensible ways of interpreting climate change under the UNFCCC: one focussed on the average weather, the other on the climate system. Each interpretation results in almost

---

**Table: Definitions provided by the Convention that are relevant for interpreting its relevance to addressing ocean acidification.**

<table>
<thead>
<tr>
<th>Article 1</th>
<th>DEFINITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the purposes of this Convention:</td>
<td></td>
</tr>
<tr>
<td>1. “adverse effects of climate change” means changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human health and welfare.</td>
<td></td>
</tr>
<tr>
<td>2. “Climate change” means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.</td>
<td></td>
</tr>
<tr>
<td>3. “Climate system” means the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.</td>
<td></td>
</tr>
</tbody>
</table>
opposing implications for the treatment of ocean acidification under the Convention. The first excludes any treatment of ocean acidification in a meaningful way, while the second is inclusive of ocean acidification not only in terms of protecting the climate system, but also across provisions that require climate change and its effects be addressed (see Figure 2).

In situations where multiple meanings of terms used within a treaty exist, the VCLT establishes a series of tests that can help to determine which meaning should be applied under the treaty. One test is to assess which meaning better meets the object and purpose of the treaty (Linderfalk, 2015). The objective of the UNFCCC is centred upon the protection of the climate system. This is evinced by the ultimate objective, which calls for the ‘stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system’ (UNFCCC, 1992, Art.2, emphasis added). This is mirrored by the preamble and the obligation established by Article 3 that ‘[p]arties should protect the climate system for the benefit of present and future generations of humankind’ (UNFCCC, 1992, Art.3.1 emphasis added). Given that the objective of the Convention is focused on protecting the climate system, reading climate as the state of the climate system is arguably more consistent with the object than reading it as the average weather.

Moreover, protecting the ocean and the role it plays in storing CO2 is a necessary condition of protecting the climate system. It is now widely accepted that the ocean is a significant driver of the global climate system and on time scales of millennia determines the concentration of CO2 in the atmosphere (Falkowski et al., 2000). The ocean itself is understood to be a critically important store of CO2 holding more than 50 times the amount of dissolved inorganic carbon than the atmosphere (Falkowski et al., 2000). Ocean acidification can alter the atmospheric concentration of CO2 through direct (air–sea exchange) and indirect (biogeochemical processes) mechanisms (Gehlen, Gruber, Gangsto, Bopp, & Oschlies, 2011). Significantly, increasing acidity can cause a drastic decrease in the capacity of the ocean to take up and store CO2, resulting in a larger accumulation in the atmosphere and increasing global temperatures. Ocean acidification threatens to further destabilize the climate system, therefore a reading of the UNFCCC that is inclusive of changing ocean chemistry is more likely to better meet the objective of the Convention than one that excludes it from consideration.

Defining climate as the state of the climate system is also supported by the drafting history of the UNFCCC. In May 1991, early proposals for the treaty included definitions of climate, rather than climate system. In these proposals climate was defined in the narrower sense as pertaining to the statistical description of the average weather over long periods of time (INC, 1991b; for wording used by specific country delegations see Table 1). Nowhere is the climate system referred to in any of the papers provided by national delegations. However, a submission by 31 delegation scientists posited that the goal of their paper was to ‘establish a

Figure 2. The way in which ‘climate’ is understood within the context of the UNFCCC – as either average weather, or the entirety of the climate system – results in opposing interpretations of the obligations to combat, minimize and prevent climate change and its adverse effects established by Articles 3 and 4 in regards to the need to address ocean acidification.
<table>
<thead>
<tr>
<th>Date</th>
<th>Document Type/Code</th>
<th>Preamble</th>
<th>Definitions</th>
<th>Objective</th>
<th>Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 1991</td>
<td>Informal papers provided by delegations (A/AC.237/Misc.1/Add.1-9)</td>
<td>UK: ‘Affirming that States have an obligation to protect and conserve the Earth’s climate for the benefit of mankind and, to this end, have a duty to cooperate with each other in seeking to limit, reduce, modify and control human activities that result in, or are likely to result in, adverse effects on the Earth’s climate.’</td>
<td>UK: “Climate” means the statistical description of weather taken over a period long enough to be generally representative of a locality. India: “Climate” means the statistical description of weather taken over a period long enough to be generally representative.</td>
<td>–</td>
<td>UK: ‘The Parties shall take appropriate measures … to limit, reduce, modify and control human activities that result, or are likely to result, in adverse effects on the global climate.’</td>
</tr>
<tr>
<td>December 1991</td>
<td>Consolidated Working Document (A/AC.237/Misc.17)</td>
<td>‘Determined to protect the atmosphere for present and future generations’</td>
<td>USA: “Climate” means the average weather (including its appropriate components, such as temperature, precipitation and wind) over a period of years, together with the natural variations of those components.</td>
<td>–</td>
<td>The ultimate objective of the Convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with climate.’</td>
</tr>
<tr>
<td>February 1992</td>
<td>Revised Consolidated Text Under Negotiation (A/AC.237/Misc.20)</td>
<td>‘Determined to protect the atmosphere for present and future generations’</td>
<td>‘Climate system’ means the totality of the atmosphere, hydrosphere, including cryosphere, oceans and all seas, biosphere and geosphere and their interactions.</td>
<td>The ultimate objective of the Convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with climate.’</td>
<td>‘[3. All States have an obligation to protect the [global] climate system for the benefit of present and future generations of humankind …]’</td>
</tr>
<tr>
<td>May 1992</td>
<td>United Nations Framework Convention on Climate Change (A/AC.237/18(Part II)/Add.1, Annex 1)</td>
<td>‘Determined to protect the climate system for present and future generations’</td>
<td>‘Climate system’ means the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions.</td>
<td>The ultimate objective of the Convention … is to achieve … stabilization of greenhouse gas concentrations in the atmosphere at a level which would prevent dangerous anthropogenic interference with the climate system.’</td>
<td>‘1. Parties should protect the climate system for the benefit of present and future generations of humankind’</td>
</tr>
</tbody>
</table>
basis for the Parties to initiate and cooperate in … the conduct of research, systematic observations and scientific assessments related to natural and anthropogenic changes in the global climate system’ (INC, 1991b, p. 98, emphasis added). A few months later, in December 1991, the secretariat of the Intergovernmental Negotiating Committee (INC) prepared a consolidated working version of the Treaty text. This text was indicative of the state of play in the negotiations with square brackets reflecting sections of text not yet agreed to by the Parties. While no definitions were included in the document, they were to be included at a later stage; the text generally mirrored the earlier narrow definition of climate as the average weather. The draft preamble stated that Parties were ‘determined to protect the atmosphere for present and future generations’ and the objective called for the stabilization of greenhouse gases in the atmosphere at a level that would ‘prevent dangerous anthropogenic interference with climate’ (INC, 1991a, p. 8 and 13, emphasis added). However, the draft principles refer to an obligation to ‘protect the climate [system]’ (INC, 1991a, p. 10). This is the first appearance in the negotiating texts, although not agreed to at this stage by all Parties, of the phrase ‘climate system’. By February 1992, in a revised consolidated text, the Parties appear to have agreed upon the usage of ‘climate system’ within the draft principles and definitions sections in preference of ‘climate’. However, the draft preamble and objective maintain the use of ‘atmosphere’ and ‘climate’ respectively (INC, 1992b). The final text prepared in May 1992 sees the preamble and objective amended to include ‘climate system’ in place of ‘atmosphere’ and ‘climate’ that appear in earlier versions (INC, 1992a).

The replacement of ‘climate’ and ‘atmosphere’ with ‘climate system’ in the text has been described by a research scientist at the time as reflective of the growing appreciation of the significance and interconnectedness of the climate system as a whole and particularly a recognition of the emerging science that was beginning to shed light on the ocean’s role in the management of the global carbon cycle and its regulation of both the global climate and atmospheric CO₂ levels (W. Howard, personal communication, 6 August 2014). This suggests that the definition of climate evolved over the course of the negotiations from a narrower focus on the average weather to a broader focus on the climate system as a whole.

The inclusion of the climate system as the subject of protection in the Convention hints at the purpose with which the Convention was written, namely to consider the ocean and atmosphere as indivisible parts of the one climate system, driven by feedback mechanisms, and that the treatment of one should be considered when dealing with the other. This suggests that had ocean acidification been recognized as a serious problem¹ at the time of the Convention’s negotiation it would likely have been incorporated into its considerations. This is further supported by the Treaty’s explicit recognition that scientific knowledge and the understanding of climate change and its impacts will develop over time and the requirement to take this in to consideration when reviewing the obligations of the Parties and the institutional arrangements under the Convention (UNFCCC, 1992, Art.7.2(a)). The negotiators did not intend for the treaty to be frozen in time, but rather for it to be a dynamic instrument that could adapt and respond to the growing understanding of climate change and its impacts. Given this, the ordinary meaning of climate, as the state of the climate system, should be adopted. This would ensure that work under the Convention is to be inclusive of ocean acidification and therefore more likely to achieve the object and purpose of the treaty.

6. Implications of reframing ocean acidification for implementation

Interpreting climate change as the state of the climate system and ocean acidification as an adverse effect of climate change repositions the issue in the context of the UNFCCC. No longer would ocean acidification be an issue to be addressed incidentally to climate change, but rather it would become a factor that needs to be addressed to successfully achieve the object and purpose of the Convention. Implementation of the Convention, and in particular operationalization of the Paris Agreement (UNFCCC, 2015a), would therefore need to be done in a manner sensitive to changes in ocean chemistry. Ocean acidification would need to be considered in the implementation of the central aim of the Paris Agreement ‘to strengthen the global response to the threat of climate change’ (UNFCCC, 2015a, Art.2.1). This would need to be operationalized both in the way in which the long-term temperature goal is pursued (UNFCCC, 2015a, Art.2.1(a)) and in increasing the ability to adapt to the adverse impacts of climate change (UNFCCC, 2015a, Art.2.1(b)). Framing ocean acidification as an effect of climate change would also require that Parties consider the issue in efforts to address loss and damage
under Paris Agreement Article 8, including slow onset events, which are specifically mentioned in that Article (recalling that the one reference to ocean acidification in any COP document has been to list ocean acidification as a slow onset event (UNFCCC, 2010)). The remainder of this paper explores the implications of reframing ocean acidification for the implementation of the mitigation goals of the Paris Agreement, namely the long-term temperature target and the balancing of sources and sinks of greenhouse gas emissions. Adaptation, and loss and damage, are not discussed further, but remain critical areas for further research.

6.1 Long-term temperature goal

One issue needing particular attention with reference to ocean acidification is the implementation of the mitigation goals established by the Paris Agreement, primarily through the long-term temperature goal found in Article 2.1(a) and the steps for achieving this goal set out in Article 4, which include:

... global peaking of greenhouse gas emissions as soon as possible ... and ... rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases by the second half of this century (UNFCCC, 2015a, Art.4)

Efforts have been made to explore the ways in which ocean acidification can be better integrated across the mitigation work of the climate change regime, including through the adoption of a separate target for CO₂, the setting of a goal for ocean acidification alongside that of temperature, greater inclusion of ocean acidification in national climate change mitigation plans and the NDCs, and a formal recognition of ocean acidification as a concurrent threat to climate change by the COP (Engler, VanderZwaag, & Fennel, 2019; Harrould-Kolieb & Herr, 2012; Scott, 2018; Stephens, 2019). These analyses all focus on the integration of ocean acidification across the climate regime as a concurrent threat to climate change. The reframing of ocean acidification, however, changes the focus for action within the UNFCCC; no longer is it imperative that the COP acknowledge ocean acidification as being contained within the mandate of the UNFCCC to be addressed alongside climate change, or that a legally binding target be set for ocean acidification adjacent to the climate change temperature target. Rather, ocean acidification as an adverse effect of climate change becomes an integral thread in understanding the complete picture of global climate change and the health of the climate system, and can inform policy choices on emission limits and adaptation strategies.

This is already being done to some extent through the work of the World Meteorological Organization (WMO), which has developed a set of seven climate indicators that include ocean acidification, along with sea level, ocean heat and surface temperature (GCOS, 2017). These indicators provide a more nuanced picture of the state of the global climate than just temperature alone and form the basis of the annual WMO statement submitted to the COP each year. These indicators could be adopted under the ‘global stocktake’ mechanism for measuring progress under the Paris Agreement. Incorporation of such indicators would signal the importance of addressing ocean acidification and ensure its greater consideration in the development of NDCs.

The incorporation of such indicators would also acknowledge the limitations of temperature goals in capturing all changes in the climate system that result from climate change. This was highlighted by the structured expert dialogue (SED) process facilitated by the COP to review consideration of strengthening the regime’s long-term goal in the run-up to the 2015 Paris Climate Conference (UNFCCC, 2015b). While many effects of climate change scale with global temperatures, others do not, with ocean acidification scaling with the change in atmospheric CO₂ concentration. Other effects, including sea level rise, are dependent upon not only the magnitude but also the rate of change of temperature and will continue to increase even after temperature stabilization (Allen et al., 2018). On the face of it, it appears that the temperature goal articulated by the Paris Agreement is not readily applicable to ocean acidification (Scott, 2018). Ultimately, however, the SED found that a long-term goal defined by temperature is adequate and serves its purpose well, even when considering impacts that are not driven by changing temperature, such as ocean acidification. However, the higher it is set, the less effective a temperature goal becomes at ensuring these other impacts are captured. Therefore, the SED recommended that in order to take into account the limitations of the temperature-only goal, the goal should be set below 2°C (UNFCCC, 2015b). The SED language was thus influential in establishing the aim of the Paris Agreement, in which Parties commit to ‘[h]olding the increase in the global average temperature to well below 2°C
above pre-industrial levels and pursing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (UNFCCC, 2015a, Art. 2(a)). Thus, the Paris Agreement’s temperature goal in effect considers ocean acidification, at least indirectly.

Despite this, it has been suggested that since ocean acidification is caused primarily by CO₂ and not the other greenhouse gases regulated by the Convention, the practice established by the Kyoto Protocol (whose second commitment period ends in 2020 and is to be superseded by the Paris Agreement) of treating all greenhouse gases, including CO₂, as a basket of gases (UNFCCC, 2006), could result in an exacerbation of ocean acidification while simultaneously reducing temperature (Baird et al., 2009; Harrould-Kolieb & Herr, 2012). While reducing CO₂ to net zero (or negative) is a necessary condition of stabilising both ocean acidification and global temperatures (at any level) (Rogelj et al., 2018), different emission pathways do this at different rates and in varying proportions with other greenhouse gases. The pathways available for achieving the Paris Agreement’s temperature goals and achieving a balance between sources and removals of emissions could therefore result in fairly significant differences in impacts on ocean acidification depending on how quickly and at what scale various greenhouse gases are reduced. It is possible that some emission pathways will result in a decrease in CO₂ emissions that lags behind decreases in non-CO₂ greenhouse gases, such as methane, thereby resulting in an increase in ocean acidification in the short-term that may result in the passing of ecological thresholds before CO₂ is reduced. Other pathways that rely upon the draw-down of CO₂ from the atmosphere after a temperature overshoot may also result in long-term changes to marine systems from ocean acidification (Hughes, Linares, Dakos, Van De Leemput, & Van Nes, 2013; Mathesius, Hofmann, Caldeira, & Schellnhuber, 2015). It is therefore critical that emission pathways be examined for their potential to limit ocean acidification and avoid dangerous changes to marine systems and the goods and services they provide. Those pathways unable to achieve this should be deemed inconsistent with the objective of the Convention, and should not be pursued.

6.2 Balancing sources and sinks of greenhouse gases

A requirement for achieving the long-term temperature goal is achieving a ‘balance’ between anthropogenic sources and sinks of greenhouse gases, and for this reason the Paris Agreement reiterates the provision of the Convention ‘to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases’ (UNFCCC, 2015a, Art.5). As discussed above, it has been suggested that this provision inadvertently calls for the active sequestration of CO₂ into the ocean (Baird et al., 2009). Such activities, whether focused on the surface or deep ocean, would, in the strictest sense, exacerbate ocean acidification (Williamson & Turley, 2012). However, reading the Convention and Paris Agreement as being inclusive of an obligation to address ocean acidification would mean that interpreting this provision as calling for activities that would increase acidification would run counter to the ultimate objective of the Convention to prevent dangerous anthropogenic interference with the climate system as well as contradict the obligation to combat climate change and its effects. Both outcomes are an unreasonable reading of this provision.

Further, the requirement to enhance sinks and reservoirs is tempered by the phrase ‘as appropriate’, which would suggest that active sequestration into the water column should be ruled out as it is widely understood as being unsustainable due to its ineffectiveness, its likely impacts on marine ecosystems and the potential for its exacerbation of ocean acidification (Buesseler et al., 2008; Denman, 2008; Joos, Siegenthaler, & Sarmiento, 1991; Russell et al., 2012; Sarmiento, Slater, Dunne, Gnanadesikan, & Hiscock, 2010). Indeed, it is unlikely that this provision would be interpreted as calling for a conversion of all arable lands to forests so as to sequester CO₂ and in the process jeopardize food production; such activities would be seen as inappropriate. So too should the enhancement of the oceanic carbon sink in such a way as to exacerbate ocean acidification. Such an interpretation would be consistent with efforts of the broader international community to prohibit unsustainable active sequestration activities through other international regimes (Harrould-Kolieb, 2016; Scott, 2015). Therefore, interpreting these provisions in a way that is inclusive of ocean acidification would enhance synergies across these regimes and reduce the likelihood of conflict around the area of marine sequestration.

The general provision to enhance sinks and reservoirs, however, should not be seen as inconsistent with efforts to respond to ocean acidification, as Baird et al. (2009) and Kim (2012) suggest. In fact, the converse is more likely to be true (Harrould-Kolieb, 2016; Oral, 2018). This provision should more reasonably be
understood as being in line with the obligation to combat ocean acidification as it threatens the future potential of the most important CO$_2$ reservoir. This provision should be understood as focusing attention on the role of marine and coastal systems, such as coastal wetlands, kelp forests, mangroves, salt marshes and seagrass beds, in climate policy. Protecting and restoring marine and coastal ecosystems will enhance their potential to act as sinks and reservoirs, a store known as ‘blue carbon’ (Mcleod et al., 2011). In addition to enhancing the sequestration potential of these systems, such activities also offer substantial co-benefits, including enhanced ecosystem resilience and health, the moderation of local carbonate chemistry and the reduction of ocean acidification, as well as the alleviation of sea level rise and erosion (Gedan, Kirwan, Wolanski, Barbier, & Silliman, 2011; Mazda et al., 2002; Sippo et al., 2019; Unsworth, Collier, Henderson, & McKenzie, 2012). Coastal wetlands are some of the most threatened systems on earth (Mcleod et al., 2011) and their protection, conservation and restoration should be seen as an integral way to fulfil the requirement of this provision to enhance reservoirs and sinks and simultaneously offer a means for limiting ocean acidification and building adaptive capacity and resilience within socio-ecological systems. It is for this reason that the protection, conservation and restoration of coastal and marine systems should become a priority area for action under the UNFCCC.

7. Conclusion

Framing ocean acidification as a concurrent problem to climate change has inadvertently resulted in the perverse outcome of ocean acidification being largely excluded from the work of the primary global instrument regulating CO$_2$. This has created a significant gap in the global governance architecture for ocean acidification with no multilateral environmental agreement understood as having jurisdiction over the mitigation of the issue. This paper has argued that interpreting ‘climate change’ as meaning ‘a change in the state of the climate system’ is most consistent with the object and purpose of the UNFCCC, which is further evinced by its drafting history. Interpreting climate change in such a way means that ocean acidification should be considered to be an adverse effect of climate change, and as a result, the Convention should be understood as placing an obligation on Parties to prevent dangerous acidification.

Such an obligation has implications for the way in which the Convention is implemented and the Paris Agreement operationalized, particularly in the way that mitigation is approached. Importantly, efforts to enhance the oceanic sink for CO$_2$ that result in an exacerbation of ocean acidification and emission reduction pathways that are unable to prevent dangerous ocean acidification should be deemed as being inconsistent with the Convention and Paris Agreement, and their use ruled out. In addition, the commitment to enhance sinks and reservoirs should focus on the protection, conservation and restoration of coastal and marine ecosystems, both for their ability to sequester carbon and the co-benefits these systems, when healthy, offer.

Reframing ocean acidification as an effect of climate change would result in the need for a paradigm shift in the approach to addressing ocean acidification under the UNFCCC: no longer would the issue be seen as a problem to be addressed in addition to climate change, but rather its attenuation would become a yardstick by which to measure the success of efforts to combat climate change.

The purpose with which the UNFCCC was adopted - to create a dynamic instrument capable of acknowledging the progression of science and responding to it in turn - should ensure the incorporation of ocean acidification into its mandate and prevent its preclusion due to a semantic technicality. The inclusion of ocean acidification across the working structure of the climate change regime will help ensure that the legacy of the UNFCCC is effective in protecting the climate system for the future of humankind.

Note

1. Ocean acidification first came to be recognized as a threat to calcifiers and coral reefs in the late 1990s with the publication of several papers documenting the responses of marine calcifiers to changes in ocean chemistry (Gattuso, Frankignoulle, Bourge, Romaine, & Buddemeier, 1998; Kleypas et al., 1999; Leclercq, Gattuso, & Jaubert, 2000). The name ocean acidification come to be associated with the current phenomenon as a result of a 2003 publication by Ken Caldeira and Michael Wickett (Caldeira & Wickett, 2003). The issue gained wider attention within the scientific and environmental communities after the publication of two synthesis reports on ocean acidification, one by the Royal Society in 2005 (Raven et al., 2005) and the other by the German Government in 2006 (Schubert et al., 2006).
Acknowledgements

I would like to thank Peter Christoﬀ, Rachel Hughes, Ove Hoegh-Guldberg and Tim Baxter for comments on draft versions of this article.

Disclosure statement

No potential conﬂict of interest was reported by the author.

Funding

This research was supported by an Australian Government Research Training Program (RTP) Scholarship. Also the funding is provided by the Commonwealth Government of Australia.

References


SBSTA. (2011). *SBSTA 34 Dialogue on developments in research activities relevant to the needs of the Convention. Report by the Chair of the SBSTA*. Bonn.


Chapter 7

UN Convention on the Law of the Sea
A framework convention for ocean acidification?
Chapter 8

Enhancing Synergies Between Action on Ocean Acidification and the Global Biodiversity Agenda through the Post-2020 Biodiversity Framework
Chapter 9

Conclusion
This thesis is an outgrowth of a desire to contribute to enhancing the international governance of ocean acidification. At the core of this desire sat an understanding that the existing governance by MEAs was inadequate and that a pragmatic solution was needed that did not require the development of new legal instruments that would entail long drawn-out negotiations and likely add to the existing regime congestion. Accordingly, the central research question of this thesis asked:  

*How can the emergent and highly interconnected problem of ocean acidification be governed by existing multilateral environmental agreements in an already congested institutional landscape?*

To answer this question, I drew upon the scholarship on problem framing to make the argument that the way in which ocean acidification has been famed has resulted in a narrowing of the perceived response options under existing MEAs and that a reframing of the problem could align the issue with new opportunities for action. Regime theory and the insights from international law scholarship on regime interactions were also utilised to explain how the reframing of ocean acidification could enhance synergies between regimes, thereby creating a more coherent international response.

In this chapter I assemble my key findings and implications for each of the research questions I posed in Chapter 1. I also reflect upon the limitations of this study, outline its main contributions and offer suggestions for further research.

### 9.1 Key Findings and Implications

In Part I of this thesis I provided the context needed to answer the primary research question. I did this by first reviewing the causes and consequences of ocean acidification (Chapter 2), then establishing a governing framework for international action on ocean acidification (Chapter 3). Lastly, by comparing this governing framework, as an aspirational model, to responses under
existing MEAs, I was able to identify under-addressed areas in the current governance of ocean acidification (Chapter 4). This part of the thesis answered research questions 1 and 2.

Research question 1 asked:

*What activities are needed to minimize and address ocean acidification?*

This was answered by comprehensively reviewing the literature on the activities that can contribute to addressing ocean acidification. These activities were then categorised and organised to construct a governing framework for international action on ocean acidification. This study found that while the reduction of CO$_2$ emissions is the only way to mitigate future acidification, there is a large collection of other activities that can be implemented to alleviate and redress the impacts of rising acidity, and that these activities are becoming increasingly important as the impacts of ocean acidification begin to emerge. The implications of this study suggest that it is critical that MEAs engage with the issue of ocean acidification beyond the regulation of global CO$_2$ emissions.

Research question 2 asked:

*What efforts have already been made under existing multilateral environmental agreements to address ocean acidification and where are the existing gaps in the governance of this issue?*

This question was answered by first extensively reviewing how existing MEAs have engaged with the issue of ocean acidification and then by comparing these responses to the aspirational model of international action set out by the governing framework. This study led to three key findings. First, that there is a collection of environmental regimes are partially regulating the problem of ocean acidification, but that the activities they have implemented by way of a response are woefully inadequate and unlikely to result in minimising and addressing ocean acidification. Second, that ocean acidification is largely being governed unintentionally by
MEAs, in that there are numerous activities that fall under their existing work that will influence the state of ocean acidification, yet these activities have been implemented without any consideration of ocean acidification. Third, that given the engagement of multiple overlapping regimes there are several potential conflicts that could arise in the future that could weaken efforts to address ocean acidification.

The implications of this study are twofold. First, that the development of new instruments to address ocean acidification do not seem necessary as several already exist that have the potential to govern the activities that can be employed to prevent future acidification and alleviate its impacts. Second, that the potential areas of conflict identified between the regimes partially governing ocean acidification are not the result of genuine conflicts in obligations, but rather can be avoided through reinterpretations that consider the implications of particular provisions for ocean acidification.

By answering research questions 1 and 2, I found that there are substantial gaps in the existing governance of ocean acidification and that there are a variety of ways that MEAs can help to minimize and address this issue beyond the regulation of CO₂ emissions, which would help to fill these gaps. The findings of this part of the thesis are significant as they challenge the dominant narrative in the ocean acidification governance literature that those MEAs lacking the capacity to regulate global CO₂ emissions have a very limited role to play in addressing ocean acidification. Rather, I suggest that engaging with this issue through not only mitigation, but also adaptation and redress is critical for protecting marine biodiversity and the goods and services it provides.

In Part II of this thesis I presented three case studies in which I investigated the potential of reframing the problem of ocean acidification for broadening the field of options available for responding under particular MEAs. I began this part of the thesis by answering research question 3, which asked:
How is ocean acidification currently framed? What are the implications of this framing and how can ocean acidification be framed differently?

To answer this question, I examined how the dominant framing of ocean acidification by the epistemic community as a CO₂ problem concurrent to climate change has been deployed by scholars exploring the role that MEAs can play in governing ocean acidification. I found that the use of this frame has resulted in the UNFCCC being interpreted as containing no obligation to address ocean acidification and that other regimes, which do not have the mandate to regulate global emissions of CO₂, are viewed as being largely irrelevant in addressing ocean acidification at the global level. These findings imply that a reframing of ocean acidification in the context of global MEAs is warranted to better align the issue with existing mandates.

To develop a set of alternative problem frames for ocean acidification, I distilled the causes and consequences of ocean acidification into eight overarching problem characteristics. I then aligned these with corresponding MEA thematic clusters and found that there are two main framing of ocean acidification. First, as a problem of climate change—the framing that is currently deployed by the epistemic community. Second, as an ocean problem.

There are two versions of the climate change frame that can be deployed, one that defines ocean acidification as a concurrent problem to climate change and the other that defines ocean acidification as an effect of climate change. These two versions of the climate change frame are in conflict in the context of the UNFCCC, where they are likely to result in different interpretations of the treaty, however, in the context of other ocean and biodiversity-related regimes these two variations are more likely to be able to co-exist and not cause conflict in the way that the treaties are interpreted.

The ocean frame emphasises the characteristics of ocean acidification that sit beyond the climate change discourse and link the problem to the broader issue of global ocean change, which is not strongly emphasised under the climate change frame. Two other versions of this frame were also
found that focused on biodiversity and pollution. These frames were not found to be in conflict with the ocean frame, which is broader and encompasses all elements of the two narrower frames. Thus, it was concluded that the ocean and climate change frames were the two that would be further investigated in the case studies.

In Chapter 6 I examined the potential for, and implications of, reframing ocean acidification as an effect of climate change in the context of the UNFCCC. In Chapters 7 and 8 I investigated the implications of reframing ocean acidification as an ocean problem for opening up possible responses under UNCLOS and the CBD respectively.

The UNFCCC case study answered research question 4, which asked:

*Can reframing ocean acidification allow for a reinterpretation of the UNFCCC that is inclusive of an obligation to address ocean acidification?*

This case study found first, that it is scientifically defensible to frame ocean acidification as an effect of climate change. However, to do so in the context of the UNFCCC the term ‘climate’, which is not defined by the treaty or subsequent action of the regime, would need to be taken as meaning ‘the state of the climate system’. In this study I found the use of this meaning is more consistent with the object and purpose of the treaty and correlates with the evolution of knowledge over the period of the treaty’s drafting. I, thus, conclude that reframing ocean acidification as an effect of climate change in the context of the UNFCCC is warranted and can lead to a reinterpretation of the treaty as containing an obligation to address ocean acidification. I, therefore, argue for turning the way that ocean acidification has been framed until now on its head, creating a new paradigm for addressing ocean acidification under the UNFCCC. No longer would ocean acidification only be addressed incidentally to climate change, but rather it would be repositioned as a yardstick for measuring the regime’s success at addressing climate change.
The UNCLOS and CBD case studies both contributed to answering research question 5, which asked:

*Can reframing ocean acidification allow for a broader response to ocean acidification from biodiversity and ocean regimes?*

To answer this question, I first examined the implications for reframing ocean acidification as an ocean problem in the context of UNCLOS and found that the provisions that address the protection of the marine environment and conservation of marine resources can be understood as applying to ocean acidification. Moreover, UNCLOS provisions address all six of the areas of collective action needed to minimise and address ocean acidification and therefore can be understood as establishing the overarching legal framework for international action on ocean acidification—a capacity that does not appear to be filled by any other MEA.

I then investigated the consequences of reframing ocean acidification as an ocean problem under the CBD and found that while the biodiversity regime is already the most active regime on ocean acidification, reframing the issue would align it with a number of other action areas that could provide positive outcomes for the conservation of marine biodiversity, that are currently not being utilised. Rather than examining the treaty text, I analysed the Aichi Biodiversity Targets, which act to set the global biodiversity agenda, and found great potential for wider integration of ocean acidification across the Aichi Biodiversity Targets and the post-2020 biodiversity framework.

Importantly, in both case studies I found that it is the ocean acidification storylines downplayed by the CO₂ frame that most strongly align ocean acidification with the provisions in these two treaties, these being that pollution and other local factors can exacerbate the global ocean acidification signal and that enhancing ecosystem resilience can play an important role in alleviating the impacts of ocean acidification in the short-term. Consequently, I found that reframing ocean acidification as an ocean problem, which emphasises these two storylines, will
be more effective at aligning ocean acidification with the objectives of both the law of the sea and biodiversity conventions than the dominant CO$_2$ framing.

All three case studies contributed to answering research question 6, which asked:

*Can reframing ocean acidification enhance the possibilities of synergistic regime interaction and decrease conflicts?*

In Chapter 4 I identified two areas of potential conflict within the ocean acidification regime complex. The first, pertaining to the provision to enhance sinks for CO$_2$ under the UNFCCC, which could enable the deployment of marine geoengineering techniques that may exacerbate ocean acidification. This deployment, however, would be in direct conflict with several provisions under UNCLOS, the CBD and the London Protocol. In the UNFCCC case study, I found that this conflict could be avoided by reinterpreting the UNFCCC while considering ocean acidification as an effect of climate change. Doing so would lead to an interpretation of the obligations to combat climate change and alleviate its impacts as being inclusive of ocean acidification. It follows that the deployment of marine geoengineering technologies that exacerbate ocean acidification would therefore run directly counter to the obligation to combat climate change and its effects. Therefore, a reinterpretation of this provision considering the need to address ocean acidification would bring coherence across the regime complex, with all relevant regimes in agreement that marine geoengineering that risks exacerbating ocean acidification should be avoided.

Reinterpretation of the UNFCCC considering ocean acidification as an effect of climate change would also alleviate the second potential conflict identified in Chapter 4, which may arise if states attempt to regulate global CO$_2$ emissions under UNCLOS and other regimes to mitigate ocean acidification. These efforts would cut across the competency of the UNFCCC. In the UNFCCC case study, I found that attempts to do so would likely create conflict and confusion and would be unnecessary if the UNFCCC provisions to combat climate change and its effects were
reinterpreted as being inclusive of ocean acidification. These two examples demonstrate that the potential for conflicts arising between regimes can be lessened if ocean acidification is reframed as an effect of climate change in the context of the UNFCCC.

In Chapter 4, I also identified areas where synergies across the ocean acidification regime complex could be strengthened. These were further explored in the UNCLOS and CBD case studies where I found that reframing ocean acidification as an ocean problem offered the potential to enhance synergies under both regimes. Reframing ocean acidification under UNCLOS would help to emphasise the comprehensive legal framework for international action that has been created by this treaty. This framework offers the means for identifying the rules and standards within other regimes that should be implemented in consideration of ocean acidification. While these regimes may not contain explicit obligations to consider ocean acidification, adherence with UNCLOS obligations requires that ocean acidification be addressed. Therefore, interpreting UNCLOS as requiring a comprehensive response to ocean acidification can ensure that other treaties are interpreted in such a way as to consider ocean acidification, thereby strengthening coherence across the regime complex.

Reframing ocean acidification under the CBD would also help to align the issue with work under the biodiversity-related regimes that has largely remained separate from efforts to address ocean acidification. Rather than exploring the ability to address ocean acidification under each individual biodiversity convention, I explored the potential for enhancing the integration of ocean acidification across the CBD’s post-2020 biodiversity framework, as this framework is expected to establish the global biodiversity agenda and play a significant role in coordinating action across the biodiversity-related conventions. I found that there are several areas in which consideration of ocean acidification should be explicitly considered in the post-2020 framework and that doing so would strengthen efforts to address ocean acidification in a synergistic way across this cluster of regimes.
In both the CBD and UNCLOS case studies I found that reframing ocean acidification as an ocean problem may help to enhance synergies in the way that regimes are likely to implement action on ocean acidification. Further, the UNFCCC case found that reframing ocean acidification as an effect of climate change may result in a reinterpretation of the treaty that would lessen the potential for conflict with other regimes, which are more likely to arise if ocean acidification is not considered. Through these case studies I have therefore shown that reframing ocean acidification would not only enhance the responses to ocean acidification under individual MEAs, but also strengthen coherence across the ocean acidification regime complex.

9.2 Major Contributions

This research has made a number of contributions to moving forward the governance of ocean acidification. First, the governing framework, which was published in the journal *Marine Policy*, created a tool for policy-makers and marine system managers that can be used to enhance and prioritise decision-making around ocean acidification. In particular it has shown that existing conservation and management efforts could be reconsidered to make them sensitive to the needs of addressing ocean acidification.

Second, this research has revealed some of the problems associated with the current framing of ocean acidification and has demonstrated the real-world implications that need to be considered by the epistemic community when framing ocean acidification in the future. Through this research I have shown that it is imperative that the epistemic community not only consider the political ramification of framing, as has been the practice until now, but also the legal implications. There is a need for enhanced dialogue between scientists and legal scholars to ensure that unintended consequences of framing ocean acidification in a particular way do not result in creating barriers to governance, as has occurred with the current framing.

Third, this research has offered new avenues for addressing ocean acidification under existing MEAs. Each of the three MEAs investigated in this study have previously been explored for their
applicability to addressing ocean acidification, however, this study presented new and innovative interpretations of these treaties. Each of these case studies show that the MEAs under examination can be interpreted as requiring a far more comprehensive response to ocean acidification than has been previously perceived.

Fourth, this study has contributed a new analytical framework that can be used to assess the potential of activities to address ocean acidification. This framework was used in Chapter 5 to assess the existing governance efforts and in the UNCLOS and CBD case studies to assess their potential for creating comprehensive responses to ocean acidification. This framework can be used in future studies to assess ocean acidification governance at all levels, from the local to the international scales.

Fifth, this study has also advanced the scholarly thinking on the linkages between problem framing and treaty interpretation and has shown that the way in which an environmental problem is framed can lead to vastly different interpretations of the same treaty. This has implications for way in which scientists and international law scholars consider environmental problems and how these considerations interact. This research shows that while the deployment of various frames may align a problem with existing values and political interests, there are limits to framing that are determined by the jurisdictional scope of treaties. Accordingly, it is evident that that the legal implications of problem framing can be significant and should be considered when deploying various frames. Thus, the rules of treaty interpretation should be a component of problem frame development when addressing environmental problems under MEAs.

9.3 Limitations of this Research

There were two identified limitation of this study. First, the scope was limited to global MEAs, which was justified as a reasonable way of examining the international governance of ocean acidification due to their central importance to the governance of environmental problems and, thus, was seen as a practical way of answering the primary and secondary research questions in
the limited time available for a PhD project. However, governance architectures extend beyond just MEAs with global scope and an investigation of other international instruments and regional MEAs could provide a more complete picture of both the existing governance of ocean acidification and the potential for conflicts and synergies across the governance architecture. Moreover, this study did not extend to an examination of either the actors at play within this architecture or the effectiveness of the regimes in question. Exploration of these two areas could provide a more nuanced understanding of ocean acidification governance and begin to highlight where issues of power and underlying value systems come into play in the decisions that have been made about governing ocean acidification to date.

A second limitation of this study was the use of archetypal frames, rather than frames either in use or those that could be derived from discussions with the epistemic community. While the archetypal frames served their purpose of examining the role of framing in aligning a problem with particular solutions, they are untested for their acceptance by the epistemic community or policy communities active in this space and it is therefore unclear whether they offer a feasible solution for addressing ocean acidification in the real world.

9.4 Further Research

While conducting this study a number of avenues for novel research were revealed. Here I briefly discuss five areas for future research that could build upon and enhance this current study. First, investigating the perceptions of members of the epistemic community with regards to the archetypal framings of ocean acidification would help to test their real-world applicability. This is critical as it is ultimately the epistemic community that would push forward a new ocean acidification frame and would decide which frame to use in which venue.

Second, the explanations as to why ocean acidification governance has not developed further have not been empirically tested. One way of doing this would be to interview UNFCCC negotiators regarding their perceptions of the relationship between the UNFCCC and ocean
acidification. Of particular interest would be their understanding of why greater efforts have not been made to address ocean acidification under the climate regime.

Third, while this study has focused on the role of global MEAs in governing ocean acidification, there are other international instruments that play a substantial role in governing environmental problems. One important instrument is the Sustainable Development Goals, which have established the global development agenda until 2030. Goal 14.3 calls for ocean acidification to be minimized and addressed, however ocean acidification also poses a direct challenge to meeting many of the other SDGs. Investigating the linkages between ocean acidification and the other SDGs would be one avenue for future research, as would an exploration of whether the inclusion of ocean acidification in this normative goal-setting process has influenced the work initiated under existing MEAs.

Fourth, the UNFCCC case study found that reframing ocean acidification as an effect of climate change would reposition ocean acidification within the regime, from an issue to be addressed incidentally to climate change to an issue that would need to be addressed to successful achieve the objectives of the treaty. One implication of this finding is that emission reduction pathways that are unable to maintain safe levels of acidification should be deemed as being inconsistent with the aims of the Convention. One way of doing this would be to test exiting modelled pathways for their ability to maintain a pH threshold. This would provide critical advice to policy-makers in terms of selecting timelines and targets for emission reductions in the future.

Fifth, in Chapter 5 I found that ocean acidification has long been considered a slow-onset event under the UNFCCC; however, there is little guidance as to how these processes should be managed. An investigation of the possible responses to these types of events and their ability to address the impacts of ocean acidification would help to fill this substantial knowledge gap.
9.5 Concluding Remarks

The aim of this research was to present new ways of responding to ocean acidification in an already congested MEA landscape. I have achieved this by exploring the implications of reframing ocean acidification under three regimes. In each case study I found that reframing ocean acidification will align the issue with more closely with existing mandates and that doing so could lead to a comprehensive and coherent international response to ocean acidification. The two main barriers to governance that were identified in the introduction, namely, the interpretation of the UNFCCC as having no obligation to address ocean acidification and the limited potential for other regimes to engage with ocean acidification, were found to be overcome when ocean acidification was reframed. This research has clearly shown that existing MEAs have the capacity to address ocean acidification in a more comprehensive way than they currently are and that this latent capacity can be tapped into through a reframing of the problem. Reframing ocean acidification would help to unleash the full potential of the existing system of MEAs without the need to develop additional legal instruments. Accordingly, this research has demonstrated that problem reframing coupled with treaty interpretation (when following the rules of the VCLT) offers an effective and indispensable strategy for overcoming limitations of mandate scope and institutional fragmentation in order to address an emergent environmental problem.
Literature Cited

Full reference list including those from published papers and manuscripts under review


AWG-KP. (2009). Consideration of the scale of emission reductions to be achieved by Annex I Parties in aggregate, of the contribution of Annex I Parties individually or jointly, consistent with Article 4 of the Kyoto Protocol, to the scale of emission reductions to be achieved by Annex I Parties in aggregate, and of other relevant issues arising from the implementation of the work programme of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol as contained in document FCCC/KP/AWG/2008/8, paragraph 49 (c) Bonn: United Nations Framework Convention on Climate Change.


CBD. (2010d). Further Information Related to the Technical Rationale for the Aichi Biodiversity Targets, Including Potential Indicators and Milestones: *Note by the Executive Secretary. UNEP/CBD/COP/10/INF/12/Rev.1.*

CBD. (2010e). Provisional Technical Rationale, Possible Indicators and Suggested Milestones for the Aichi Biodiversity Targets: *Note by the Executive Secretary. UNEP/CBD/COP/10/27/Add.1.*


CBD. (2016a). Decision XIII/11. Voluntary specific workplan on biodiversity in cold-water areas within the jurisdictional scope of the Convention *CBD/COP/DEC/XIII/11.*

CBD. (2016b). Enhancing synergies among the biodiversity-related conventions at the national and international levels. *Convention on Biological Diversity, UNEP/CBD/COP/13/15.*


LC-LP. (2006). *LC-LP.1/Circ.5 Notification of amendments to Annex 1 to the London Protocol 1996*


SBSTA. (2008). *Information provided by regional and international climate change research programmes and organizations on developments in research activities relevant to the needs of the Convention*. Montreal: United Nations Framework Convention on Climate Change


SBSTA. (2011b). *Summary of proposed themes for the research dialogue meeting and the related workshop to be held in conjunction with SBSTA 34*. Bonn: United Nations Framework Convention on Climate Change

SBSTA. (2014). *Report on the workshop on technical and scientific aspects of ecosystems with high-carbon reservoirs not covered by other agenda items under the Convention, Note by the secretariat*. Bonn: United Nations Framework Convention on Climate Change


