

Centre: Plymouth Marine Laboratory (PML)

Title of case study: Ocean acidification: ensuring national and international decision makers understand this global threat to set targets and inform international agreements

1. Summary of the impact

The ocean is becoming more acidic as a result of carbon dioxide emitted from human activities, with serious consequences for marine life. Based on an extensive understanding of changing ocean chemistry, PML has investigated how marine life is responding. This knowledge has been used to demonstrate the damaging effects of ocean acidification (OA) under different future scenarios to inform policy makers. PML has been pivotal in raising awareness and inspiring action on OA at the highest political levels. This influence has culminated in the significant recognition of the ocean in the Paris Agreement, a global accord to address climate change, and the development of a UN Sustainable Development Goal target on OA (SDG14.3). PML coordinates the northeast Atlantic OA monitoring network, which contributes to the delivery of the UK's obligations under this target.

2. Underpinning research

At least one-quarter of carbon dioxide (CO₂) released by burning fossil fuels has dissolved into the ocean, decreasing the pH of seawater. In the past 200 years the ocean has become 30% more acidic [3.1], an unprecedented rate of change which does not allow enough time for all marine life to adapt. The resultant loss in biodiversity will affect fisheries and aquaculture, threatening food security for millions of people, tourism and other marine-related economies.

Since 2003, when ocean acidification (OA) was first identified as a concern, PML has significantly developed scientific thinking with over 189 papers published, receiving over 7000 citations from 4474 separate articles [3.2]. Through laboratory and field experiments, observations and ecosystem modelling PML has investigated the impacts of OA on marine organisms and their ecosystems. An early key finding was that calcification by animals could be increased in response to OA, contrary to popular belief that rates would decrease [3.3]. PML demonstrated that some organisms can increase their metabolism and rate of calcification in response to greater acidity, but at the cost of muscle wastage. This means such adaptations are unlikely to be sustainable in the long term. The research was conducted as part of a PhD project at PML under the supervision of Dr Steve Widdicombe (lead) and Dr John Spicer (University of Plymouth). These findings changed understanding of how organisms respond to OA and led to a "whole organism approach" using models to simulate the consequences of changing acidity, by considering an organism's energy requirements over its entire lifecycle.

PML's Dr Widdicombe (Professor from 2014), led the first UK research project on the environmental risks of high CO₂, *Implication for the Marine Environment of CO₂* (IMCO2). IMCO2 created a modelling capacity for exploring the effects of high CO₂ on UK shelf waters; demonstrated that decreasing seawater pH could lead to a gradual decrease in benthic diversity and identified the more vulnerable organism types; and raised awareness of OA ensuring it was considered alongside climate change as a threat to the future health of our planet [3.4].

PML has measured OA parameters since 2009 utilising its sampling platforms; the Atlantic Meridional Transect (AMT) and the Western Channel Observatory (WCO). Spanning the length of the Atlantic, the annual AMT research cruise provides basin-scale observations, whilst WCO provides weekly localised sampling. Together, these provide the longest running and most comprehensive dataset of carbonate chemistry in the UK, which is vital to quantify long-term changes in OA. This freely available data underpins much of our understanding of the interplay between the chemistry of the ocean and biological processes. This expertise has led to PML coordinating the NE Atlantic regional hub of the Global Ocean Acidification Observing Network (GOA-ON) and involvement in the OSPAR Intersessional Correspondence Group on OA.

PML evidence on the impacts of OA contributed to increased intergovernmental concern. In 2008 the first international research effort on OA, the European Project on Ocean Acidification (EPOCA), was funded by the EU. Dr Carol Turley was a member of the Executive Board and leader of one of the four themes. Dr Turley also led the development and writing of the Science Plan for the 5-year

UK Ocean Acidification Research Programme (UKOA), which was funded (GBP12,000,000) by NERC, the Department for Environment, Food and Rural Affairs (Defra) and the Department of Energy and Climate Change (DECC) in 2010. PML led 3 of the 6 UKOA consortia and made key contributions to the others, producing the first long-term multispecies and ecosystem studies on the impacts of OA across Europe, North America and the Arctic. The Benthic Consortium, led by Dr Widdicombe, developed a novel experimental system to replicate the environment under different OA conditions. This advanced investigations into the impacts of OA on seafloor organisms [3.5].

PML's research has increased our capability to generate model projections that aid understanding of what marine systems may look like in the future. By modelling climate responses and OA at regional scales the UKOA Modelling Consortium demonstrated that the impacts of warming and acidification are strongly coupled. Led by Jerry Blackford, the group showed that this coupling effect delivers a highly complex and variable response that has significant consequences for adaptation and management strategies. Understanding these effects enables policy makers to make informed decisions when setting targets [3.6].

Many of PML's researchers, from multiple disciplines, have contributed to OA research over the last two decades. The key co-ordinators of this work have been Dr Turley (Microbial Ecologist at PML since 1990), Dr Widdicombe (Marine Ecologist at PML since 1991) and Mr Blackford (Mathematical Modeller at PML since 1991).

3. References to the underpinning work

PML authors in bold type, citations from Web of Science 7 January 2020 unless otherwise stated

- 3.1. Raven, J., Caldeira, K., Elderfield, H., Hough-Goldberg, O., Liss, P., Riebesell, U., Shepherd, J., **Turley, C.M.** 2005. *Ocean acidification due to increasing atmospheric carbon dioxide*. Policy document, No. 12/05. Royal Society, London. 68pp. [1103 Google scholar citations]. https://royalsociety.org/~media/royal_society_content/policy/publications/2005/9634.pdf
- 3.2. Web of Science. 2020. Search "ocean acid*" in all fields AND organisation "Plymouth Marine Laboratory", 2003 to date. [online] [Cited 9 Jan 2020]. <http://apps.webofknowledge.com>
- 3.3. **Wood, H.L.**, Spicer, J.I., **Widdicombe, S.** 2008. Ocean acidification may increase calcification rates, but at a cost. *Proceedings of the Royal Society B-Biological Sciences*, 275(1644), 1767-1773. doi:10.1098/rspb.2008.0343. [396 citations].
- 3.4. **Widdicombe, S.**, **Blackford, J.**, **Lowe, D.**, **Turley, C.** 2007. *The implication for the marine environment of CO₂ (IMCO₂)*, No. COAL R310, BERR/Pub URN 08/687. 81pp. https://www.pml.ac.uk/Research/Our_impact/IMCO2_2007.pdf
- 3.5. **Findlay, H.S.**, **Kendall, M.A.**, **Spicer, J.I.**, **Turley, C.**, **Widdicombe, S.** 2008. Novel microcosm system for investigating the effects of elevated carbon dioxide and temperature on intertidal organisms. *Aquatic Biology*, 3(1), 51-62. doi:10.3354/ab00061. [55 citations].
- 3.6. **Artoli, Y.**, **Blackford, J.C.**, Nondal, G., Bellerby, R.G.J., Wakelin, S.L., Holt, J.T. *et al.* 2014. Heterogeneity of impacts of high CO₂ on the North Western European Shelf. *Biogeosciences*, 11(3), 601-612. doi:10.5194/bg-11-601-2014. [27 citations].

4. Details of the impact

Informing government bodies of the risks of OA

PML led a key Defra report in 2004 on elevated CO₂ in the marine environment, which highlighted the potentially devastating consequences for marine life. Dr Turley contributed to the Royal Society working group on OA, which authored a seminal report on OA [3.1] and culminated in the recommendation that "action needs to be taken now to reduce global emissions of CO₂ from human activities to the atmosphere to avoid the risk of irreversible damage" [3.1]. The Royal Society report "raised the profile of ocean acidification with politicians and the public alike" [5.1] and formed the basis of the 2009 InterAcademy Panel statement on OA, which was endorsed by 105 national academies worldwide. This was the first time that these bodies officially recognised the threat of OA and called for action.

Ensuring OA is included in climate change assessments informing international targets

In 2005, Dr Turley ensured OA was included for the first time in an Intergovernmental Panel on Climate Change (IPCC) Assessment Report. She joined the Panel as a Lead Author of the

Ecosystems chapter and drove the inclusion of the latest OA research findings in its 4th Assessment Report (AR4). IPCC is recognised globally as the most authoritative scientific and technical voice on climate change research. Its reports have the agreement of leading climate scientists and consensus from participating governments.

Dr Turley continued as a Review Editor for the 5th IPCC Assessment Report (AR5) and ensured an increased marine prominence with two separate chapters on the ocean. AR5 was recognised as a *critical scientific input into the UNFCCC's Paris Agreement in 2015* [5.2]. PML's input was central to OA being recognised as a major climate stressor within the IPCC as evidenced by its latest Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) where Dr Turley was once again Review Editor.

Ensuring the 'ocean' is included in the landmark UN Paris Agreement

PML has participated in every United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP) since 2009. At that point the ocean received very little attention and OA was not considered. Dr Turley led an awareness raising campaign at the 2009 UN event. PML went on to lead and organise similar campaigns at every subsequent COP and other landmark meetings, including the Rio+20 Earth Summit. These activities ensured the latest research findings were communicated to delegates from across the world.

At COP21 in 2015 Dr Turley led an EU side event, was a panel member on 5 side events, co-organised Oceans Day and gave media interviews. Through a series of conversations and exchanges she was pivotal to informing political negotiators of the role of the ocean in the climate system. The landmark Paris Agreement was negotiated at this meeting, with every word debated and scrutinised to ensure agreement from all parties. On hearing that a draft agreement did not include any mention of the ocean, Dr Turley used her high profile position to galvanise action from other delegates, targeting national negotiators to emphasise that the ocean has to be considered in any action to manage and mitigate climate change. The final Paris Agreement stated *'the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity ...when taking action to address climate change.'* Dr Turley is widely acknowledged by her peers for being instrumental in ensuring the ocean was included in this global accord.

"The product of [Dr Turley's] collaborative activities was the inclusion of ocean ecosystems in the Paris Agreement, the development of an ocean acidification goal in the UN SDGs and in-depth recognition of the issue by high level negotiators worldwide" US National Oceanic and Atmospheric Administration [5.3].

PML continues to be very active in COPs and has worked closely with numerous parties, including Government Departments, to organise science to policy events to bring the latest scientific understanding to climate negotiators and other delegates. PML advised Defra on the UK government's ocean approach to COP24 (2018) and COP25 (2019) and worked with them to arrange science events and displays at the UK Pavilion at COP25. PML researchers presented, led and partnered in more than 10 important ocean-focused events and contributed to 5 major reports that were presented at the event. These activities contributed to a greater acceptance of the importance of the ocean in climate change in the *COP25 Outcome Document*, which includes unprecedented action for better integration of ocean and coastal ecosystems in future COPs.

"Dr Turley first told the story of the up-to-that-point unknown effects of ocean acidification on marine species and processes at COP 2009, making the delegates and other decision makers aware of these very troublesome effects for the very first time. Her extraordinary influence has been key to each subsequent COP and most recently was crucial to getting a greater acknowledgement of the importance of the ocean in the COP25 outcome document in 2019". President Global Ocean Forum [5.4].

"PML is a trusted partner, providing scientific expertise and advice to support Defra's engagement at the UNFCCC COP. PML's presence at COP25 alongside Defra helped to raise the profile of the ocean in climate change, and helped to ensure a greater acknowledgement of the importance of the ocean in the conference's outcome document. PML is recognised as a world leader in climate research, monitoring and action, and supported the UK Government to showcase and engage with international partners on climate change and ocean change issues at this important event". Chief Scientific Advisor, Defra [5.5].

Informing UN resolutions and voluntary commitments to deliver action under the SDGs

In 2017 PML played a key role in the high-level UN Conference to Support the Implementation of Sustainable Development Goal (SDG)14 – Life Below Water. Dr Turley was a member of the Informal Preparatory Working Group for SDG14.3, focused on minimising the impacts of OA. The conference included plenary meetings and partnership dialogues. Dr Turley was an invited science representative as one of 4 panellists on the *Minimizing and addressing OA Partnership Dialogue*. Dr Turley presented on OA, directly influencing the UN Secretary General's Special Envoy for the Ocean who requested her slides to inform his speeches.

1,395 voluntary commitments for the implementation of SDG14 were registered during the conference, with approximately USD25,400,000 (06-2017) in monetary resources pledged. 236 of these related to OA, either as the main component, or as part of a broader range of management and conservation actions [5.6].

Dr Turley contributed to writing the session summary from the Partnership Dialogue that fed into the final conference report, *Our ocean, our future: call for action*, which was agreed by all parties to the conference. The report, aimed at supporting the implementation of SDG14, was officially endorsed by the UN on 6 July 2017 [5.7]. A further UN resolution on SDG14 (9 May 2019) formally recognised *'the important contributions of the partnership dialogues and voluntary commitments made in the context of the Conference'* [5.8].

"After listening to Carol Turley speak about ocean acidification in the Partnership Dialogue at the UN Ocean Conference in New York in 2017, the full seriousness of the issue was brought home to me. In the ensuing years, I have been pleased to lend my support to events on the topic that she has organised at the COPs of UNFCCC. She does a great job of bringing the science of ocean acidification to policy makers, making them more aware of this key reason for greater ambition in reducing CO₂ emissions and meeting the Paris Agreement." UN Secretary General's Special Envoy for the Ocean [5.9].

In 2011 Dr Turley was recognised for her services to science and awarded an OBE in the New Year's Honours list, her work on OA was a key element of the nomination. *"In my view, Dr Turley has achieved higher policy impact on behalf of NERC than any other individual during the past 5 years (if not 50 years)"*, University of East Anglia [5.10].

Ensuring the delivery of OA monitoring data to meet SDG14.3

As part of the delivery of SDG14.3 member states are required to provide pH measurements to be used as an indicator for OA (target 14.3.1). PML co-ordinates OA monitoring efforts for the northeast Atlantic region, facilitating 12 countries to deliver their commitments towards SDG14.3. PML coordinates the NE Atlantic hub, part of the Global Ocean Acidification Observing Network (GOA-ON). The hub ensures a common methodology for recording measurements, enabling submission to the UN through National Data Centres, and cataloguing of the data on a central global portal that maps effort and identifies gaps.

As well as coordinating the NE Atlantic hub, 1 of 7 global regions, PML was a founding member of this global network. Through involvement in international workshops in 2012, PML was instrumental in the development of GOA-ON, contributing to its visions and goals. Dr Findlay is currently the only UK representative on the network's Executive Council and Dr Widdicombe represents GOA-ON on OSPAR's Intersessional Correspondence Group on OA.

GOA-ON co-ordinates international action to expand OA observations, addresses capacity gaps, connects scientists, and disseminates the latest OA findings. The network helped to ensure pH was recognised by the UN as an effective indicator for SDG14.3 (SDG14.3.1) and produced the methodology for this measurement. As such the network has underpinned the upgrade of the indicator from a Tier 3 to a Tier 2, demonstrating that the *'Indicator is conceptually clear, has an internationally established methodology and standards'*. A central goal of GOA-ON is to ensure that data are regularly produced by at least 50% of countries so that the indicator can be upgraded to Tier 1 by the UN. This is being initiated by PML through implementation of the methodology across the NE Atlantic hub.

"PML have been key partners in the Global Ocean Acidification Observing Network since its inception in 2012 and are leading and setting-up the NE Atlantic Hub, crucially delivering on

SDG14.3 and ensuring the implementation of GOA-ON's methodology across the region." Co-chair GOA-ON Executive Council [5.11].

In 2018 Dr Widdicombe was appointed by Defra to contribute to an OA group to review the current monitoring of OA at the UK and global scale to ensure the UK demonstrates global leadership. Its recommendations to Defra included utilising existing platforms and technology to effectively monitor OA and identifying where additional resources were needed. Dr Widdicombe was instrumental in integrating GOA-ON methodology and approaches as well as PML's long-term monitoring capabilities into the group's report and recommendations. He provided the group with long-term data plots from WCO and AMT to inform discussion, emphasising the value of PML's existing capabilities and the need to build on these to meet international monitoring requirements. Implementation of the report's recommendations resulted in Defra funding PML to co-ordinate the NE Atlantic Hub, providing the UK's contribution to GOA-ON. The remaining recommendations are with the UK government and will inform the planned UK OA Action Plan, which PML has been commissioned by Defra to produce in 2020.

"PML is a trusted partner to support this [GOA-ON] co-ordination of international monitoring efforts which contribute to the UK obligations under the SDG14.3 to minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels... The joining up of international expertise via the NE Atlantic Ocean Acidification Hub will enhance our knowledge of the environmental change, which for Defra is vital to underpin policies." Head of Ocean Climate Policy & Marine Evidence, Defra [5.12].

5. Sources to corroborate the impact

- 5.1. Global Biodiversity Sub-Committee of the Global Environmental Change Committee. 2007. *Section 1.3. Ocean acidification - current research activities and known research gaps*. Defra and JNCC, London. 11pp. http://archive.jncc.gov.uk/pdf/GBSC_OceanAcidificationreport.pdf
- 5.2. Schleussner, C.F., Rogelj, J., Schaeffer, M., Lissner, T., Licker, R., Fischer, E.M. *et al.* 2016. Science and policy characteristics of the Paris Agreement temperature goal. *Nature Climate Change*, 6(9), 827-835. doi:10.1038/Nclimate3096.
- 5.3. 7 March 2016. Letter of support for Dr. Carol Turley's application for a Knowledge Exchange Fellowship from the Natural Environment Research Council. *National Oceanic and Atmospheric Administration, US Department of Commerce*.
- 5.4. 15 March 2016. Letter of support for Dr. Carol Turley's application for a NERC Knowledge Exchange Fellowship. *President, Global Ocean Forum*.
- 5.5. 8 January 2020. Letter of support for UNFCCC Convention of Parties 25 events. *Chief Scientific Advisor, Department for Environment, Food and Rural Affairs*.
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- 5.8. United Nations. 2019. *2020 United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development*, No. A/RES/73/292. Resolution adopted by the General Assembly on 9 May 2019. 23pp. <https://undocs.org/en/A/RES/73/292>
- 5.9. 20 November 2019. Quote for ocean acidification impact story [email]. *UNSG's Special Envoy for the Ocean*.
- 5.10. 8 March 2016. Knowledge Exchange Fellowship proposal by Dr Carol Turley, Plymouth Marine Laboratory. *NERC Science Coordinator*.
- 5.11. 13 January 2020. Letter of support. *Co-chair GOA-ON Executive Council and focal point for IOC UNESCO reporting on SDG14.3*.
- 5.12. 8 January 2020. Letter of support for Global Ocean Acidification Observing Network NE Atlantic Ocean Hub. *Head of Ocean Climate Policy & Marine Evidence, Marine and Fisheries, Department for Environment, Food and Rural Affairs*.