

NE Atlantic Ocean Acidification Workshop Knowledge to Local Action

Q&A Panel with Presenters

On April 28, 2021 the OA Alliance, Global Ocean Acidification Observing Network NE Atlantic HUB, and Because the Ocean Initiative hosted a NE Atlantic Ocean Acidification Workshop which brought together more than 60 partners from 12 countries.

Participants included scientists, policy and decision-makers, and non-government partners from across the region for presentations and discussion of:

- Domestic and international policy frameworks for advancing ocean acidification knowledge and regional responses.
- Biological impacts to keystone fisheries and aquaculture within the Arctic and North Atlantic.
- Targeted monitoring and regional networks that can help inform government responses and strategies.

Along with other supporting materials, this document offers extended Q&A and discussion from presenters across relevant themes and is meant as an additional resource for workshop participants.

Panelists:

- Dr. Nina Bednarsek, Biogeochemistry Department, Southern California Coastal Water Research Project
- Dr. Sam Dupont, University of Gothenburg
- Prof. Stephen Widdicombe, GOA-ON Co-Chair, Plymouth Marine Laboratory
- Prof. Richard Bellerby, Norwegian Institute for Water Research



Dr. Bednarksek, your presentation was specifically focused on establishing common indicators and thresholds for ocean acidification—which if accepted and utilized by decision makers—could be used to determine when harmful impacts of ocean acidification are being detected and need to be addressed or directly regulated.

Briefly, what is the difference between an indicator and a threshold in this context? Why is establishing an indicator or threshold for OA so difficult, compared to other parameters like pollutants that traditionally govern water quality?

Indicators and thresholds are tools that can be used to indicate or predict when the changes in chemistry from OA may start to have negative effects, which can be across various levels of biological organization (genetic, subcellular, cellular, physiological, organismal, population). Indicators are usually a chemical/biological/functional proxy with explicit trends over time (pH, chlorophyll, biomass, shell dissolution, etc.), while thresholds represent a specific value below which the negative effects will occur.

Establishing an indicator for OA requires (usually) biological data that is of comparable length in time as chemical observations. The chosen indicator needs to be scalable and of regional importance. These factors can make indicator time-series expensive to maintain. Thresholds usually require enough data (both experimental and field data) about a biological response, that are of sufficient quality and show uniform trends. Deciding on a threshold relies on an extensive synthesis and expert-consensus process. However, when the indicators and thresholds are of high quality and have been agreed by expert consensus, then they can be excellent tools to inform decision makers and trigger management actions.

What are the strengths and limitations of establishing an indicator or threshold for a phenomenon like OA?

It takes at least 20 years of data in open waters offshore, and > 30-40 years of data in the coastal habitats to detect OA trends (if they are present). To be able to draw the correlation between OA and biological impacts, biological data need to be collected for the same duration period and at the same spatial location as the chemical data. As such, indicators and thresholds can reduce the amount of data and duration needed, provide 'early-warning' response, and indicate on which level of the biological organization (eg. cellular, physiological, organismal, population) the negative effect might occur. Thresholds can also easily be integrated into the monitoring or modelled data, allowing for some predictions on when, where and which species would be the most vs. the least impacted by OA.

On the other hand, indicators and thresholds are mostly providing information on the organismal level, making it difficult to scale up predictions to the population or ecosystem level, which are often needed for policy-management actions.

One single threshold cannot be universally applied across spatial scales. Despite this, thresholds nevertheless contain a large synthesis of information. They are informative of the potential biological changes, indicate which species could be losers and winners, or which life stages are most sensitive. Such thresholds are especially important in regions with limited resources (e.g.



developing countries), lack of co-located chemical and biological observations, lack of long term biological data, or lack of extensive biogeochemical modelling infrastructure. Despite their limitations, thresholds could provide preliminary insights of the regional vulnerability and early-warning responses before more regionally-relevant data is available or a set of thresholds are developed for that specific region.

Dr. Dupont, your presentation focused on the importance of locally targeted science to help understand the adaptive capacity of species and ecosystems most vulnerable to OA in a specific area. As you noted, it is not likely that a single or standardized OA threshold will work everywhere.

How can we prioritize the most important local projects, especially, as in most cases—resources are limited, and it won't be possible to test everything?

If we want to truly address ocean acidification, we need a combination of mitigation and adaptation. This will require developing and implementing a wide range of solutions: reducing CO₂ emissions, protecting and restoring marine ecosystems to make them more resilient to stress, develop locally relevant management strategies and specific industrial and societal adaptations. For many of these solutions, we already know enough.

For other solutions, we need more science and data. An efficient way of prioritizing science is then to have a strong focus on solutions and see what is needed to implement them quickly and efficiently. A single threshold covering all regions [as also discussed in Nina Bednarsek's replies] may not be possible because marine organisms are adapted to very different chemical environment and their sensitivity to ocean acidification will also be modulated by other factors such as others stressors, food availability, ecological interactions or evolution.

As you note, ocean acidification is one of the many stressors that organisms are facing. Why is it important to explore and identify what the main stressors in one location may be, and to then to explore key species sensitivity in relation to those stressors? How can multiple stressor be prioritized to support decision making?

You cannot manage what you do not measure and understand. To make it even more difficult, the picture is different in different countries, habitats, etc. Prioritizing solutions requires us to identify key priorities at a given location. If you want to prioritize science, develop and implement solution in a region, you first have to identify what are the key ecosystems services under threat and then the key stressors challenging these services. These will be a combination of exposure (how intense is a given stress in a location) and sensitivity (how sensitive is the species, ecosystem or service under threat). This will allow you to define what are the main challenges and potential solutions. While ocean acidification is an important driver, it is also important to recognize that it may not be the main priority in some regions.

Understanding this will require both monitoring of the threats (exposure) and mechanistic understanding of the biological impacts (sensitivity). The biology part may be quite challenging as multiple combined stressors can act in complex ways and may require complex scientific



strategies to resolve. It is important to remember that the level of understanding that we need depends on the questions you are trying to answer and the solution you are trying to develop.

Professor Widdicombe let's make things more complicated! You noted that in order to determine if an organism is being affected by OA, research needs to consider the interconnected physiological and ecological processes that result in whole organism health and performance, not just a single indicator of organism health.

How can we scale up from single process or single species experiments to understand the wider population level impacts?

The best way to do this is through the creation and testing of conceptual models. We are never going to run experiments that involve all the relevant elements of an organism's energy budget, life cycle or the components of a complex ecosystem. However, we can use targeted experiments to parameterize and validate energy budget, population or ecosystem models to allow use to appreciate the impacts of ocean acidification on the whole organism, a population or a whole ecosystem. In turn these models can guide experimentalists to help run experiments that explore the processes and responses needed to test the predictions of these models as well as to fill gaps in understanding. So, the simple answer is that we need to use the results of experiments to underpin our conceptual understanding of complex and then retest this understanding with more experiments.

In addition, as technologies improve, we may be able to conduct more complex experiments that help to test more responses and processes simultaneously. One example of this are Free Ocean CO₂ Experiments (FOCE) and a good summary of these can be found in Stark et al (2019) Free Ocean CO₂ Enrichment (FOCE) experiments: Scientific and technical recommendations for future in situ ocean acidification projects. PROGRESS IN OCEANOGRAPHY 172: 89-107. DOI: 10.1016/j.pocean.2019.01.006

Given the challenges of scaling up, how can ecophysiology best be used to inform local management and policy?

As outlined in the previous answer the best way of scaling up is to develop conceptual models that can allow us to explore different scenarios. The outputs of these models can then be used to test the effects of different management interventions or policy outcomes.



Professor Bellerby, many presenters—including yourself—discussed the importance of increasing communication and awareness around this issue, both to local decision makers and to the public.

Can you describe how the project you worked on, Acid Coast, was managed? Specifically, how did it engage social scientists and community members?

The project was managed by social scientists. Different levels of management stakeholders, from national government to town councils were invited to project meetings. Further engagement was entrained through invited workshops with invitees identified by external managers. Finally, engagement was increased through open-invitation meetings with the general-public.

Additionally, can you describe the local management outcome that the Acid Coast project produced? Do you have any further examples of local management actions that can increase resilience of coastal waters to OA?

Stronger regulation of local grey water coastal discharges has been put in place. Opportunities for local management are wide-ranging and substantial and include river flow regulation, land-use management, nature-based and industrial solutions around ecosystem management (e.g. kelp management and restoration and farming) managing aquaculture effluent, etc.

Additionally, deploying or preserving seaweed and kelp provides an important opportunity for local mitigation, and is our core focus in an on-going EU project FutureMARES.

If there was one message that you could deliver to policy makers and/ or the public about the importance of—and capacity for—understanding and managing for ocean acidification impacts, what would it be?

Professor Widdicombe: *While we wait for carbon reduction policies to have an effect, do everything you can to protect and restore marine habitats, by removing human impacts and actively managing the improvement of the environmental conditions. This will support the health and well-being of marine ecosystems and give them the best chance possible to resist and respond to the negative impacts of ocean acidification.*

Dr. Bellerby: *Management strategies must reflect the individual challenges on a local case-by-case basis. The rate and degree of ocean acidification will be very different for each coastal system and for each ocean/coastal service. The use of general IPCC scenarios should be avoided, and local observations and modelling must be undertaken to understand relevant scales of the OA challenge. Only then, will management actions be relevant.*

Dr. Dupont: *We have overwhelming evidence that ocean acidification will have dramatic consequences for marine species, ecosystems and associated services. What we need now is a more efficient way to communicate our science to drive societal and individual changes.*

