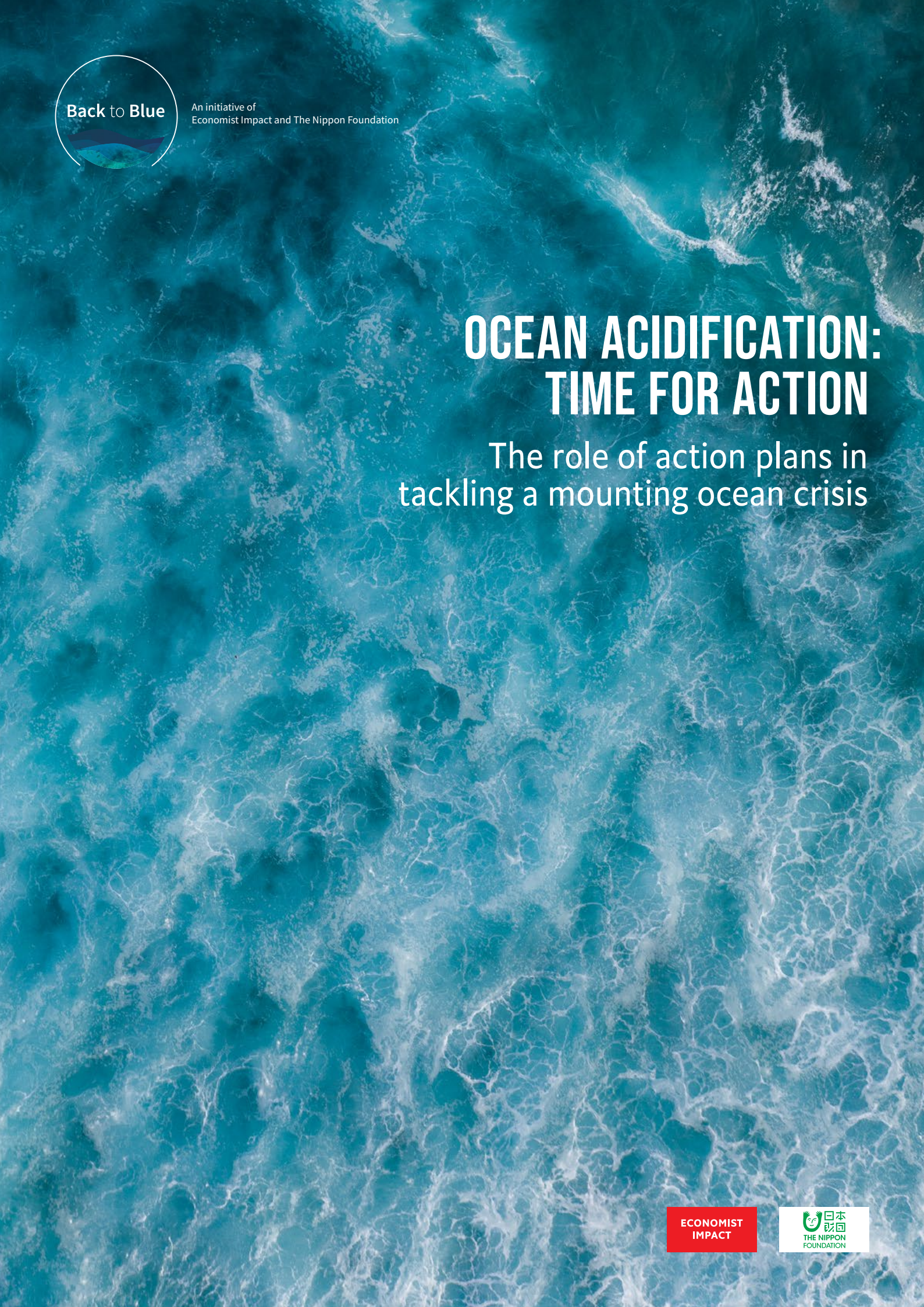

Back to Blue

An initiative of
Economist Impact and The Nippon Foundation

OCEAN ACIDIFICATION: TIME FOR ACTION

The role of action plans in tackling a mounting ocean crisis

ECONOMIST IMPACT

THE NIPPON FOUNDATION

About the report

Ocean acidification: Time for action is a report written by Economist Impact for Back to Blue, an initiative of Economist Impact and The Nippon Foundation. The purpose of this report is to highlight the organisational efforts being taken by national and subnational governments, as well as other organisations, to address the threat to marine ecosystems posed by ocean acidification and the role of action plans in those efforts.

To inform this report, we conducted a series of in-depth interviews with field experts. Our thanks are due to the following people (listed alphabetically by institution) for their time and insights:

- Jessie Turner, executive director, **International Alliance to Combat Ocean Acidification**
- Caren Braby, senior program manager, **Pacific States Marine Fisheries Commission**
- Helen Findlay, biological oceanographer, **Plymouth Marine Laboratory**
- Steve Widdicombe, director of science, **Plymouth Marine Laboratory**; co-chair, **Global Ocean Acidification Observing Network**
- Masanori Kobayashi, senior research fellow, Ocean Policy Research Institute, **Sasakawa Peace Foundation**
- Masahiko Fujii, professor, Atmosphere and Ocean Research Institute, **University of Tokyo**

This report was written by Denis McCauley and edited by Naka Kondo.

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Introduction

The world is waking up to the threat that ocean acidification (OA)—a rise in the acidity of seawater caused by excess carbon dioxide entering it from the atmosphere—poses to marine ecosystems and to the coastal economies that depend on them. Since OA's damaging effects on shellfish were first documented 15 years ago, research organisations have mobilised to collect, on an ongoing basis, huge volumes of OA-related data from the world's oceans. Based on those data, as well as data gathered in coastal areas, scientists have published a wealth of studies examining the causes and effects of OA.

Environmental advocacy groups championing ocean health, charitable foundations and intergovernmental organisations have built on this work to raise global awareness of OA, fund wider research into it and prod governments around the world to take concrete actions to combat it.

Governments, however, have been slow to rise to this challenge. Although many have voiced concerns about OA and expressed an intention to fight it through international mechanisms, at the time of writing less than a dozen have published dedicated action plans. These document specific measures governments will take—or are taking—to advance understanding and the domestic response to OA.

The experts we interviewed for this report are strong advocates for OA action plans. Measures to address OA have a vital place in wider climate change and other marine management initiatives, but a dedicated OA plan stands a better chance of cementing the ambition and commitment of a country, region or locality to actively address localised manifestations of OA and turn back the tide. And while some non-government organisations (NGOs) and science institutions have issued OA action plans of their own, none will carry as much weight as those led by governments.

National action plans are highly desirable, but it is state governments on the US Pacific coast that have set the standard of OA action for the rest of the world to follow. It is here that scientists first registered the deadly impacts of OA on marine life and the threat to coastal economies and jobs. As a result of that emergency and its follow-on research findings, governments in the region have committed unequivocally to combat OA with the help of dedicated, detailed and well-resourced action plans.

In examining governments' and other entities' progress on mobilising against OA, this report finds that existing North American action plans offer useful examples and insights for other jurisdictions. Far from all governments will be able to base their plans on the same depth of research or call on the same resources to draft them. But by including in their plans elements such as a vision of success, timelines, assignment of ownership, and a mandate for periodic review and updating, governments can call upon more resources and put their OA action plans on a firm footing.

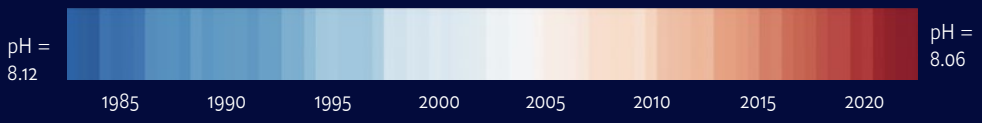
1. Why action is vital

Ocean acidification is a growing threat to many forms of marine life and to the communities that rely on them for food, jobs and economic wellbeing. OA is a direct result of the growing carbon dioxide (CO_2) emissions generated by human activity. Up to 30% of carbon released into the atmosphere each year is absorbed by the ocean, which helps to mitigate global warming. But the ocean's ability to sequester carbon cannot keep pace with rising emission volumes.[1] The result is a decline in the pH level of seawater and a rise in its acidity.

Figure 1: Ocean pH is falling

The pH level of seawater is a key indicator of ocean acidification. The pH scale runs from 0 to 14.
Over the past century, the mean surface ocean pH level has fallen from 8.2 to below 8.1.
About half of that decline has occurred in the past 40 years – a sign that acidification has been accelerating.

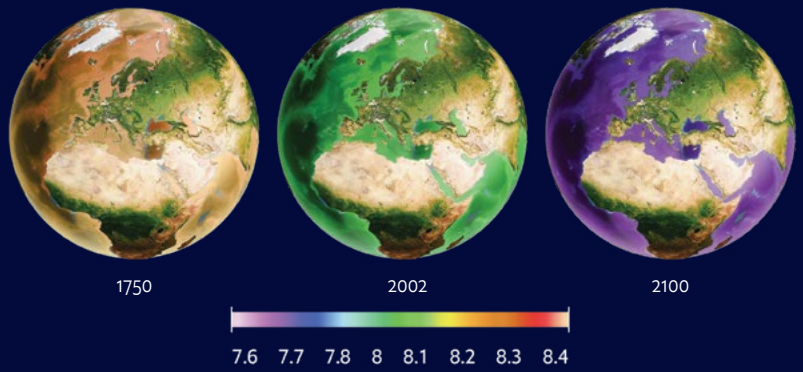
pH stripes for the global ocean (65°S - 65°N) with interannual and seasonal variability



Source: Data and timescale image from ETH Zurich

But pH is already lower than 8 in some waters, especially along some of our coasts. If global carbon emissions continue to increase at their current rate, by 2100, pH will be below 8 in most of the ocean.

Maps of sea-surface pH from the pre-industrial era to the future



Source: Courtesy of Andrew Yool. Adapted from HS Findlay and C Turley 2021. Ocean acidification and climate change. In: TM Letcher (Ed), Climate change: observed impacts on Planet Earth (Third Edition)

The detrimental impacts of acidification are more than scientific speculation. It is known to have a damaging impact on marine organisms such as oysters, mussels, scallops, crabs and other shellfish. In the Pacific North-west, large-scale losses of oyster larvae in 2007-08 were found to be tied to a rise in the acidity of hatchery waters.[2] More recently, scientists have connected OA to weaker larval shells of Dungeness crab in waters along the US Pacific coast, negatively impacting the organisms' growth and threatening a valuable source of aquaculture revenue.[3] And recent reports from the north-east Atlantic region show negative impacts from increasing OA on Atlantic cod and cold-water coral reefs, critical habitats for regional fisheries.[4]

Should CO_2 emissions remain at current levels, one study has found, the concomitant rise in ocean acidification would put pteropods, bivalve molluscs, finfish and warm-water corals, among other types of marine organisms, at a very high risk of damage by the end of this century.[5]

The threat that OA poses to biodiversity, food chains and economies is an integral part of what the UN describes as an ocean emergency. It is the reason that the UN calls for action to combat OA as part of its Sustainable Development Goals (SDGs), particularly as captured in SDG 14.3.[6]

Call to action

The International Alliance to Combat Ocean Acidification (known as the OA Alliance)—which was launched from the experiences of the US Pacific coast response to OA—specifies six categories of action that are needed to address the challenge:[7]

- Reduce atmospheric CO_2 emissions
- Advance scientific understanding of climate-ocean impacts
- Reduce local pollution that exacerbates OA
- Protect the environment and coastal communities from climate-ocean impacts
- Expand public awareness
- Sustain international and multi-governmental support for addressing this global problem

International co-operation, particularly in data collection and sharing and research capacity-building, is vital in efforts to stem OA.

But, as with other endeavours to mitigate the effects of climate change, practical actions are most effectively mobilised and implemented at national or subnational levels, and most often by governments. A handful of governments have developed action plans to guide their efforts. Many more are needed.

"OA action plans have the power to elevate the profile of OA and focus minds on addressing it," says Steve Widdicombe, who is the director of science at Plymouth Marine Laboratory (PML) in the UK and co-chair of the Global Ocean Acidification Observing Network (GOA-ON). "An action plan signifies that the government formally recognises OA as a critical environmental challenge. And a formal plan commits the government to taking concrete actions to combat OA and support those actions with appropriate resources." (The use of OA evidence to be routinely used in the creation of policy and legislation is a key intended outcome of the Ocean Acidification Research for Sustainability Programme[8], of which Mr Widdicombe is co-lead.)

Actions to combat OA, whether or not set down in a dedicated OA plan, must be seen as one important component of a country's or region's wider efforts to restore ocean health, according to Masanori Kobayashi, senior research fellow at the Open Policy Research Institute, an arm of the Sasakawa Peace Foundation. "A government must take an integrated, holistic approach to addressing the enormous challenges the ocean faces, including acidification, " he says.

That approach is likely to differ from country to country depending on local circumstances, says Mr Widdicombe. "But it is vital that measures to fight OA are integrated into a country's environmental policies and legislation," he says. "An OA action plan encourages that integration."

A core mission of the OA Alliance is to help governments and other entities develop action plans. Established in 2016, its 120 members include national, state and provincial governments, First Nation/indigenous group authorities as well as business associations, academic and research institutions, and other organisations. The OA Alliance is working with members to draft action plans and it has developed a toolkit and other supports to guide that process. Several plans have been completed (see below) but, according to Jessie Turner, the alliance's executive director, its work on action plans with most governments is, in many respects, an iterative learning experience.

"OA science and research is, in many ways, still an emerging field, particularly when it comes to characterising local impacts and identifying effective solutions," says Ms Turner. "Turning that science and information into action is even more on the cutting edge of policy development and management application. This is what governments are working to accomplish through OA action plans, and the OA Alliance is helping to share lessons learned and best practices."

Ms Turner describes progress on building an inventory of OA action plans as organic. "The OA Alliance is a 'coalition of the willing'. There are no legal mandates to create action plans," she says. "Dedicating time and resources to developing them is a big challenge, for us and for governments, but it must be done."

2. The current status

Secondary research and discussions with experts indicate that global momentum behind the development of OA action plans is slow and geographically uneven. Of the 42 government members of the OA Alliance, ten have issued and published action plans specific to OA at the time of writing.

A glance at table 1 shows that the US is home to most existing plans. It includes the state of Washington, the first entity to draft and publish a plan. Enacted in 2012, this early effort was galvanised by the OA-related losses that its oyster farms suffered a few years earlier. (The state is also the only entity thus far to formally update its OA action plan.)

A national US action plan has yet to be published, but the federal government aims to do so by the end of 2023. Its custodians are the Department of State and the National Oceanic and Atmospheric Administration, which has administered a national Ocean Acidification Program since 2011. The US action plan is described as complementary to additional strategies put forward in the Ocean Climate Action Plan published by the White House in March 2023.[9]

Table 1: OA-specific action plans in existence

Entity	Year published
State of Washington	2012, updated in 2017
Sweden	2017
State of California	2018
State of Oregon	2019
California Coastkeeper Alliance	2019
State of Maine	2019
State of Maryland	2020
State of Hawaii	2021
Port of Seattle	2021
Gullah Geechee Nation (US)	2021
Netherlands	2022
Province of British Columbia	2023

Note: The table includes action plans issued by governments or other authorities that practice stewardship over the waters adjoining their territories. It does not include plans issued by NGOs or research institutions. Two of these are highlighted on the OA Alliance website—that of the Ocean Conservancy and the University of Washington's Ocean Acidification Center.

Sources: OA Alliance website (https://www.oaalliance.org/member-examples), desk research

In Europe, the Netherlands and Sweden feature on the OA Alliance website as having "completed action plans".[10] Both of the latter, however, lack the detail and specific commitments included in the various US plans. At the same time, both governments are parties to the OSPAR Convention and members of its commission.[11] OSPAR published an OA assessment of its maritime regions in 2023, which included science and policy recommendations for the 15 European national governments of its commission to consider.[12] OSPAR is reportedly in the process of drafting an OA action plan that commits it to specific measures.

Absent from the table are any known OA action plans from Asia-Pacific, despite a 2016 Pacific Island OA vulnerability assessment[13] and a growing body of OA science and research in the region. Many Pacific Island governments have spoken about the threat of OA at UN meetings, and Fiji has incorporated OA actions as part of its National Ocean Policy.[14] The New Zealand government has been an active participant and leader of multi-government OA initiatives, including the OA Action Group, part of the Commonwealth Blue Charter. To date, however, New Zealand has yet to formalise an OA action plan of its own, although monitoring and research programmes are ongoing through the National Institute of Water and Atmospheric Research.

Japanese institutions, such as the Sasakawa Peace Foundation and the Nippon Foundation,[15] have been generous supporters of international research into the causes and impacts of OA. But efforts at the national level to draft an OA action plan for Japan have yet to bear fruit. According to Mr Kobayashi, the country's scientists need to demonstrate a stronger case for action than they have been able thus far to do. He also believes that the ocean responsibilities that are currently spread across several different government ministries need to be co-ordinated for coherent and integrated national action.

Ocean scientists such as Masahiko Fujii, a professor in the University of Tokyo's Atmosphere and Ocean Research Institute, lament this lack of progress. He acknowledges a lack of clear evidence in Japan of OA-induced damage to marine organisms along its coastlines. "This weakens the case for urgent national action to combat OA." In addition, Mr Fujii says, "the practice of issuing action plans is unfamiliar in Japan. But we know the threat posed by OA and need a national action plan to address it."

"Robust place-based monitoring and research can certainly give governments a level of comfort in drafting OA action plans," says Ms Turner. "But the lack of an extensive body of research and of observed biological impacts to keystone species doesn't mean governments can't take initiative. In many ways, an OA action plan is about helping governments outline and prioritise the knowledge gaps that are most significant to them for a variety of socioeconomic or cultural reasons."

She points out, for example, that in 2018 the Western Indian Ocean and Marine Science Association established the first ever OA monitoring project in that region in conjunction with local institutions and experts. The project resulted in a 2022 report that examines the state of OA and makes recommendations for future research across six countries: Kenya, Tanzania, Mozambique, South Africa, Mauritius and Seychelles.[16] "National governments could be taking the baton to further support and apply this knowledge generation through action plans," says Ms Turner.

"If countries like Japan wait until the evidence for OA impacts are commonplace before taking action," says Mr Fujii, "the likely scale, consequences and costs of those impacts on people's lives and livelihoods will be considerably greater than if early action had been taken."

The UK is another country yet to move ahead with a national action plan. Mr Widdicombe was among a group of scientists convened by

the UK Department of Environment, Food and Rural Affairs (DEFRA) in 2018 to recommend a series of government actions to support research, monitoring and analysis of OA trends and impacts. To date, he says, only a few of those recommendations have been acted upon.

One reason, says Mr Widdicombe, is a lack of funding that a national action plan would entail. "The government says it recognises the gravity of the OA threat, but it has not allocated resources to planning for action to meet it. Its approach, it says, is to embed OA thinking and action into existing environmental legislation, which, if implemented and resourced, would be welcome. But this doesn't give action against OA the profile and visibility it needs. There also need to be commitments to take OA-specific measures."

Barriers in moving from science to policy

While US states are clearly the pacesetters in co-ordinated planning to address OA, they are unique in that they have long history of federal and state investments in monitoring and targeted research, which "they have been able to build on and draw from to support concrete recommendations and actions," says Ms Turner.

Not all countries and regions can draw upon that experience and research base, says Ms Turner. In Africa, the Pacific Islands, Latin America and other less developed regions, she adds, there is a significant capacity and investment deficit just to gather localised data on OA that would be useful for local management response. "Governments in these regions need downscaled data and targeted research at coastal intersection level to better understand OA trends nearshore and what areas and species are most vulnerable," she says. "While some actions, like coastal habitat restoration and reduction of pollution, have many co-benefits and don't need additional data to undertake them, other actions like approaches to climate resilient fisheries and aquaculture will require additional information and funding, including from international sources."

The absence of a formal plan does not mean that countries are taking no action to monitor, research, mitigate and adapt to OA. In many cases, there is an awareness gap about what information is useful to generate and how it might be applied. According to Ms Turner: "Most governments with coastlines have strategies to reduce greenhouse gas emissions, some sort of coastal marine monitoring and research activities, some type of coastal pollution controls against agriculture runoff or wastewater leakage, and some sort of approach to managing fisheries and restoring marine aquatic vegetation." But very few, she says, will have thought about how OA information can further guide these discrete activities and strengthen a portfolio of existing policy or management goals.

Interconnecting governments' existing strategies with relevance to OA is a good start to building an action plan, but that alone is not enough. "An OA action plan should certainly leverage off ongoing activities, but it must do more than repackage what's already going on. It should lead to efforts to find out what the deficiencies or information gaps in those strategies are and then to specify steps to rectify them," says Mr Widdicombe.

Another challenge has been turnover in government administrations. "Turnover of key staff has been high in recent years. Just learning who in government knows anything about OA is a challenge," says Helen Findlay, biological oceanographer at PML, who has been seeking a DEFRA commitment to an action plan that would leverage the strong OA research base in south-west England. "We're constantly having to reinvigorate the subject and trying to get people back on board again."

Existing guides to OA policymaking

Policies and plans that are specific to OA may be limited in number, but there exist several international and regional frameworks and conventions that can help guide the development of national OA-specific policies (tables 2 and 3). In a handbook it published for ocean policymakers,[17] the Ocean Acidification Action Group of the Commonwealth Blue Charter helpfully summarised several such frameworks and agreements. It also highlighted existing climate policies in a number of countries that can be used to develop dedicated OA policies and plans (table 4). We have reproduced below the relevant tables from this handbook with the kind permission of the Commonwealth Secretariat.

Table 2: Existing policy: international

Issue	Framework	Primary goal	Relevance to ocean acidification
Biodiversity	Biodiversity Beyond National Jurisdiction (BBNJ)	This is a UN process that seeks to arrive at a new international treaty to protect biodiversity and areas beyond national jurisdiction. This agreement for conservation and sustainable use of biodiversity will consider marine genetic resources, area-based management tools, impact assessments, capacity building, and technology transfer.	Pacific Small Island Developing States have requested that ocean acidification be taken into account in the BBNJ.
Biodiversity	UN Convention on Biological Diversity (CBD)	Conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from utilisation of genetic resources. Implements strategic goals known as "Aichi targets" to address underlying causes of biodiversity loss by mainstreaming biodiversity across government and society, reducing pressures on biodiversity, and promoting sustainable use.	The CBD has made significant contributions to improving the understanding of OA, increasing adaptive capacity and awareness raising. Aichi Biodiversity Target 10 makes specific reference to ocean acidification: "By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or OA are minimised, so as to maintain their integrity and functioning and links to other targets". Aichi Targets 8 and 11 are also relevant to ocean acidification.

Climate change	UN Framework Convention on Climate Change (UNFCCC) The primary instrument is the 2015 Paris Agreement.	International treaty system with protocols for limiting global greenhouse gas emissions. UNFCCC has a commitment and mandate to secure agreement on CO_2 emission reductions. The Paris Agreement aims to keep the global temperature increase less than 2 °C above—and preferably less than 1.5 °C above—pre-industrial levels. The Paris Agreement focuses on mitigation and adaptation, via Nationally Determined Contributions (NDCs). These national pledges include national emission reductions and implementation efforts. The Commonwealth Leader's Statement on Climate Action underlined the importance of "practical and swift action" to reinforce the outcomes of the 2015 Paris Climate Conference.	UNFCCC does not expressly mention protecting the marine environment, or OA and its relationship to CO_2. However, ocean acidification is accepted as one of the "adverse effects of climate change". A country's NDCs can include actions relating to OA, such as adaptation and building resilience. Fourteen NDCs make reference to ocean acidification (Gallo et al., 2017). Domestic legislation and regulation provides the platform for implementing national contributions.
Coastal protection	The Ramsar Convention on Wetlands of International Importance	An intergovernmental treaty for the conservation and sustainable use of wetlands, it deals with adaptation to climate change impacts on the coast.	OA is a recognised threat, but there is no designated action. However, it does address coastal protection and adaptation to climate change impacts on the coast.
Marine protection	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention (1972) / London Protocol)	Limits marine pollution by regulating waste materials that are dumped into the sea. One of the first global conventions to protect the marine environment from human activities.	As CO_2 entering the oceans is not considered dumping, this has limited relevance to OA. However, it does regulate deliberate activities, such as ocean fertilisation, which may increase CO_2 in the ocean.

Marine protection	UN Convention on the Law of the Sea (UNCLOS)	Overarching legal framework for the regulation of activities relating to ocean and seas. The only treaty at a global level obliging states to protect and preserve the marine environment by preventing, reducing and controlling pollution of the marine environment from all sources.	Uptake of CO_2 by the ocean arguably falls under the jurisdiction of UNCLOS (Herr et al., 2014). UNCLOS has encouraged states, organisations, and institutions to urgently pursue research on OA and increase efforts to address levels of ocean acidity and its negative impact on vulnerable marine ecosystems, particularly coral reefs.
Sustainable development	UN Decade of Ocean Science for Sustainable Development (2021–2030)	A UNESCO-IOC resolution aimed at reversing the decline in ocean health and developing a common global framework to ensure ocean science supports countries in creating improved conditions for the sustainable development of the ocean. It facilitates networks, supports developing countries, and stimulates the use of marine technology and observations.	OA is recognised as a major issue and one of the most important research questions.
Sustainable development	UN Sustainable Development Goals (SDGs)	SDGs were adopted by UN member states as a universal call to action to end poverty, protect the planet and ensure peace and prosperity by 2030. There are 17 integrated SDGs, some of which include conservation and utilisation of the oceans, seas, and marine resources for sustainable development (SDG 14 Life under Water). SDGs are implemented and co-ordinated by the UN Development Agency.	SDG 14.3 seeks to "minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels". Its associated indicator SDG14.3.1 ("Average marine acidity (pH) measured at an agreed suite of representative sampling stations") encourages the adoption and compliance of standards at a national level, the collection of information from countries and regional organisations, and the estimation of global and regional aggregates. Other SDGs relevant to ocean acidification include SDG 13 (Climate), SDG 11 (Sustainable Cities); SDG 7 (Clean Energy); SDG 4 (Education); and SDG 2 (Zero Hunger).

Source: A Policymakers' Handbook for Addressing the Impacts of Ocean Acidification, Commonwealth Blue Charter Action Group on Ocean Acidification, Christina M. McGraw, Kim I. Currie, Cliff S. Law, Jesse M. Vance (2021) (https://thecommonwealth.org/new-policy-handbook-help-governments-fight-ocean-acidification)

Table 3: Existing policy: regional

Issue	Framework	Primary goal	Relevance to ocean acidification
Food security and sustainability	Regional Fisheries Management Organisations (RFMOs) There are 17 RFMOs.	International organisations formed by countries with fishing interests in an area. Some manage all fish stocks in a specific region, while others focus on particular highly migratory species, such as tuna, across large geographical areas. RFMOs are mandated to sustainably manage fishery resources and adopt binding fisheries conservation and management measures.	Limited focus and activity on ocean acidification.
Marine protection	Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)	Established in 1982 in response to an increase in commercial interest in krill as part of the Antarctic Treaty System. CCAMLR is an international convention with 26 members dedicated to conserving Antarctic marine living resources.	CCAMLR has a potential technical role in gathering information on the impacts of OA and providing additional arguments for adaptation measures, such as establishing marine protected areas (MPAs) as well as precautionary harvesting limits for Antarctic marine living resources. (Herr et al., 2014).
Marine protection	OSPAR Convention (1992)	Regulates international co-operation on environmental protection in the north-east Atlantic. Includes 15 signatory nations and representatives of the European Commission.	Investigating, monitoring and assessing the rate and extent of OA and considering appropriate responses. OSPAR Coordinated Environmental Monitoring Programme, received an additional appendix on ocean acidification in 2012.

Marine protection and biodiversity	The Cartagena Convention	Regional legal agreement for the protection of the Caribbean Sea. Three technical agreements on Protocols on Oil Spills, Specially Protected Areas and Wildlife and Land Based Sources of Marine Pollution.	Works with The Ocean Foundation to address OA, including the development and implementation of joint strategies and pilot projects in areas of mutual interest.
Marine protection and water quality	Regional Ocean Councils	Councils formed by representatives from regional states, provinces and territories. Facilitates across local to national level government agencies, regional organisations, and groups to address ocean and coastal issues at a regional scale.	Councils facilitate the understanding of OA through supporting monitoring, research, education and community outreach. They inform action plans for regional-scale policy (eg, California, Oregon, Northeast Regional Ocean Council) and the adaptation of terrestrial and freshwater policy to address coastal ocean acidification through clean water legislation (US 303d).

Source: A Policymakers' Handbook for Addressing the Impacts of Ocean Acidification

Table 4: Existing policy: national

Issue	Framework	Primary goal	Relevance to ocean acidification
Biodiversity	National Biodiversity Strategies	The 2020 Biodiversity Goals and Targets for Canada were developed in response to the UN CBD and include four goals and nineteen targets. The Belize Climate Change Adaptation Policy encourages all government agencies to incorporate climate change in their activities and policies. One of the most important aspects is to create public awareness and education to support biodiversity conservation.	Improving biodiversity requires action on OA. Biodiversity education is a lever for OA awareness and action.
Climate change	National Action Plans and National Adaptation Plans For further details of these and other Commonwealth country Climate Action plans see Scotford et al. (2017).	UK Climate Change Act (2008) includes a binding emissions reduction target and carbon budgets for each five-year period, establishment of a Committee on Climate Change to advise government, powers for introducing emissions trading schemes, and obligation for annual reporting. In 2019, the act was updated to include a legally binding commitment to achieve net-zero emissions by 2050. Fiji's National Adaptation Plan aims to address climate change through 160 adaptation measures identified through consultation with stakeholders. Papua New Guinea Climate Change (Management Act) 2015 establishes a Climate Change and Development Authority to promote and manage "climate compatible development through climate change mitigation and adaptation activities". Saint Lucia National Climate Change Adaptation Policy aims to pursue integrated adaptation actions to prepare for or respond to climate change impacts.	UK Climate Change Act (2008) refers to the actions needed to address OA since the latter is seen as one of the main risks arising from a changing climate. Fiji's National Adaptation Plan identifies OA as a threat. Fiji's National Ocean Policy also identifies OA as a major threat that must be addressed to meet sustainable ocean management goals.

Coastal protection and habitat	National Coastal Management Acts	South Africa National Environmental Management: Integrated Coastal Management Act 2008 incorporates climate change adaptation into coastal management processes.	OA could be incorporated into Marine Spatial Planning policy, which is developing at both national and international levels.
Economics		The South African government strategic initiative, 'Operation Phakisa', aims to unlock and explore the full potential of the ocean's wealth to drive economic growth, create jobs and alleviate poverty.	Twenty-two MPAs designated in 2016 will reduce fishing and pollution pressures on these ecosystems, supporting resilience development.
General sustainability		Well-being of Future Generations (Wales) Act 2015 aims to carry out sustainable development and to pursue "well-being goals" including promoting a prosperous, low-carbon society and developing ecological resilience and capacity to adapt to climate change (Scotford et al., 2017). Australian Environmental Protection and Biodiversity Conservation Act 1999 requires annual reporting of how activities accord with and promote ecologically sustainable development (Scotford et al., 2017).	Land-based approaches to sustainability and emissions reductions may have co-benefits for OA.

Ocean acidification	US Federal Ocean Acidification Research and Monitoring Act (2009)	Directs the US subcommittee on Ocean Science and Technology to create an Interagency Working Group on OA, which co-ordinates ocean acidification activities across the Federal government.	Mandates for research and/or management of resources and ecosystems likely to be impacted by OA. Has established a research programme and funding (Billé et al., 2013). For details of individual US State legislation relating to ocean acidification see the Ocean Foundation Ocean Acidification Guidebook for Policymakers.
Oceans	National Ocean Policies	Many countries have National Ocean Policies to protect marine economic resources and ecosystems.	Solomon Islands National Ocean Policy notes the importance of considering climate change and identifies strategies to minimise or mitigate risks and threats (Turner and McIntosh, 2019).
Water quality	Clean Water Acts	US Clean Water Act (CWA) requires US states to establish water quality standards as a basis for regulation.	The US CWA explicitly regulates marine pH. The California water quality control plan includes pH with a target that pH must not exceed by more than 0.2 units. States are mandated to list damaged waters and estimate maximum daily loads (Arce, 2016).

Source: A Policymakers' Handbook for Addressing the Impacts of Ocean Acidification

3. Building an OA action plan

There is no one-size-fits-all OA action plan, and brevity need not spell a lack of clarity or commitment. The action plan issued by the Gullah/Geechee Nation[18] in 2021 runs to just five pages. But it articulates a recognition of the OA threat to its waters, an ambition to help fight it and a set of actions that are within its limited resources to pursue, including building public awareness of OA and advocating for adaptation measures such as seagrass conservation and restoration.[19]

At higher levels of governance, however, concerted and long-term action to fight OA requires a considerable level of detail and clarity about the objectives to be pursued and the methods to meet them. Several of the North American action plans stand out in this regard. Along with the OA Alliance's toolkit, they contain a wealth of guidance for what a plan should include. Those from the Pacific coast contain some or all of the following elements.

A vision of what success looks like. A plan should articulate what will be achieved if it is implemented in full. Accompanying each of the six strategies in California's plan is a set of five-year goals that paint an achievable vision of the future. For example, a result of its strategy to deploy living systems to slow OA and store carbon is envisaged to be: "Conservation and restoration of seagrass meadows, kelp forests and salt marshes across all of California's estuaries and coasts are now state policy and are well underway and financed."[20]

Strategies and actions to realise those visions. The Pacific coast plans largely follow the OA Alliance's toolkit (see "Why action is vital") by setting out five or six strategies for combatting OA, along with a set of specific actions under each strategy. Typically, reducing carbon emissions is the first or second strategy mentioned. "It may seem self-evident, but we must keep repeating that emissions are the primary driver of OA," says Ms Findlay. "If we don't, people will lose sight of that and focus on other, adaptive solutions. Those are certainly worth pursuing, but without reducing carbon, we'll never make real progress against OA."

Aside from reducing emissions, the OA strategies address these areas:

- **Monitoring and research.** The Washington state plan, for example, calls for measures to "[quantify] the relative contribution of different acidifying factors to OA in Washington's marine waters" and to "[understand] the biological responses of local species to OA".[21]
- **Reduction of land-based pollution contributing to OA.** In its plan, the Port of Seattle outlines specific measures to improve marine and aviation stormwater management.[21] The Washington state plan specifies measures to be taken to "assess the need for water quality criteria relevant to OA".[23]

- **Adaptation and resilience-building.** British Columbia's plan sets forth 12 actions to "enhance mitigation, adaption and resilience to OAH [ocean acidification and hypoxia]", including establishing a funding programme for pilot projects to develop adaptation strategies, and "investing [in] restorative aquaculture as an OA mitigation tactic".[24]

- **Awareness-building.** Oregon's action plan tasks an inter-agency and multi-stakeholder body, the OAH Council, with building "a communications plan and outreach materials to communicate OAH science, impacts, and solutions". [25]

- **National and international collaboration and advocacy.** The California action plan outlines measures to participate in and lead Pacific coast regional initiatives to understand and combat OA; to build national level partnerships and co-operate with federal agencies for the same purpose; and to support international efforts to raise understanding of OA and spur actions to combat it, including through membership of the OA Alliance.[26]

- **Timeline and funding.** Oregon's plan is unique among the others in setting out a timeline for implementing each of the stipulated actions along with estimated funding needs for most of them.[27]

- **Action plan ownership.** Accountability is integral to the success of any action plan. A recent study into a different environmental challenge related to ocean health—reducing plastic pollution—found that national action plans that are not co-ordinated, not monitored and not binding are less effective than those that are.[28] Legally binding action plans may not be on the OA agenda, but a government needs to assign clear ownership and reporting mechanisms. This is especially important as the wide diffusion of related responsibilities across several different government ministries or programmes can complicate efforts to co-ordinate planning activities.

Figure 2: Key OA action plan elements

"The simplest ownership model is a governmental committee with staff who have the primary job of making sure the plan is implemented," says Caren Braby, senior program manager with the Pacific States Marine Fisheries Commission and former co-chair of Oregon's OAH Council. "An intergovernmental organisation or NGO partner could also be the plan's owner, as long as it is given the authority to implement and to request the collaboration of government agencies, departments or ministries that are needed to do it." (See "Taking stock of Oregon's first OAH action plan".)

- **A commitment to review and update.** Addressing OA is a practice of adaptive management and governance. California's plan calls for it to be reviewed and updated every five years "to incorporate what has been learned from California's experience and the experiences of others." Washington state also planned for a five-year review, which it carried out in 2017. "Regular reviews are needed to determine what's going right and what's not and then to correct the latter," says Mr Widdicombe. "Action plans must not be immutable."

Taking stock of Oregon's first Ocean Acidification and Hypoxia action plan

In her previous role as co-chair of Oregon's OAH Council, Caren Braby helped to draft the state's OAH Action Plan, covering 2019-25. Economist Impact for Back to Blue spoke with Ms Braby to learn her views on the plan's achievements, on what went well and what could be improved, and what others could learn from this endeavour.

EI: What do you consider the OAH Action Plan's key outcomes to date?

CB: Three stand out for me, two directly relating to state impact and a third of wider significance. The first is the strategic lens it provided for our state legislature to invest in OAH research, a long-standing demonstrated interest of policymakers. With our vetted action plan in place, it was clear how current and future investments met state needs and how they would lead to other tangible climate or coastal outcomes. For example, thanks to the legislative funding, Yaquina Bay in central Oregon—home to nurseries for fisheries and other maritime resources as well as a world-class oceanographic institute (at Oregon State University)—now has a monitoring station to measure OAH parameters as well as other water conditions, including temperature, salinity and oxygen. That was a big geographical gap in Oregon's OAH monitoring network that needed to be filled because of its significance to fisheries.

A second valuable outcome has been to start defining and highlighting the connection between clean water and OAH. Under the US Clean Water Act, the state Department of Environmental Quality (DEQ) has built evaluation tools into its pollution regulatory system to include the impacts of harmful algal bloom biotoxins, oxygen depletion (ie, hypoxia) and acidification on water quality conditions. All three of these parameters are meaningful in documenting and responding to ocean change, because they can help us use local management levers to reduce OA impacts. Targeted reductions in local land-based pollution can greatly reduce the already negative trends on ocean and coastal health caused by climate change. While additional work needs to be done to implement this clean water approach to minimising OA and hypoxia, DEQ is the first state agency in the US to build Clean Water Act evaluation tools for OAH and ocean change.

Our most notable success, in my view, is a collective Pacific North-west one, shared with California, Washington and British Columbia. Since we published our respective action plans, there has been a groundswell of interest and commitment from jurisdictions all over the world who've come to us and said, "This is a useful approach. This is something that we can do." Many have joined the OA Alliance, and many have their own innovative approaches to action planning that are uniquely place-based while improving our collective tool set for responding to OA across local, regional and global scales.

EI: What was the rationale for including estimated funding needs for specific plan actions, something other US states have not included in their plans?

CB: Oregon's is a relatively small economy, and funding is particularly challenging. We felt that putting tangible numbers next to tangible actions would make it easier for a legislator or external funder to look at the need and say, "We can fund that. We can get that done." Without specifying figures, the perception could be created that the actions require funding on a grand scale of millions of dollars. It was a way of communicating the scale of the step that we were suggesting should be taken. House Bill 3114 funded most of the actions. They were all relatively modest but meaningful projects, and most of them are still in progress.

EI: Is there something that you would do differently in the plan's drafting or implementation?

CB: I would put even more energy into securing ownership for the plan's implementation on a recurring basis. A weakness of the plan from the beginning was that the OAH Council has a limited implementation and funding authority. The council is a policy group tasked with making recommendations, not necessarily carrying out or funding the work. That means that the plan's success rests on the ability of council members (including agency representatives) to do the heavy lifting to find resources for implementation. We've proven this can work, but it would be much more effective to either have it implemented by a government committee that has the resources, or have a policy mandate for state agencies to implement it.

EI: Do you have any recommendations for other jurisdictions or entities that are embarking on the work of drafting an OA action?

CB: I have two. One is to adopt the framework developed by the OA Alliance and adhere to it closely throughout the drafting process. The six themes that the alliance has laid out are incredibly useful as an organising framework, which helps in co-ordinating across jurisdictions, communicating shared goals and leveraging larger funding for regions to implement action plans. I have yet to encounter any action that doesn't fall into one of those six themes. Using the framework as a scaffold, you can then hang specific unique actions and ideas on the framework that are right-sized and appropriate for your jurisdiction, based upon your priorities, policy goals and capacity. Used in this way, it is a powerful organisational and communication tool.

The other recommendation is to be specific as well as aspirational. The real value in a short-term action plan is identifying achievable management actions and outcomes.

Grassroots education about OA

Alone among the OA action plans cited in this report, that of Washington state describes in some detail the initiatives undertaken with schools, aquariums, seafood businesses, tribal communities and other local groups to build awareness of the OA threat to marine life.[29] The state may have longer experience with this activity than elsewhere, but grassroots educational activity is ongoing in several places, even if not always guided from above.

In the UK, some ocean scientists have taken it upon themselves to try and raise public awareness of the issue. Helen Findlay of PML is one example. When not immersed in scientific research, she is out educating people about the OA threat in the waters off south-west England. In addition to national and local officials, her audiences include employees of fisheries and other businesses as well as young students. "There is a huge lack of knowledge about acidification," she says, and making OA understandable to non-scientists is an uphill task. "Many people get scared by the chemistry, and most find it difficult to envision what acidification is and the impacts it can have. It's not as tangible as something like plastic pollution, which is plainly visible to the eye." To get through to the audience, Ms Findlay focuses on OA's potential cost implications and damage to food chains (to policymakers and businesses) and its effect on the resilience of familiar shellfish species such as oysters and scallops (to students).

Greater awareness of the OA challenge can lead citizens to support programmes that address it, and to become advocates for governmental OA action. Mr Widdicombe believes it can also have more direct benefits. "If farms near river estuaries take action to reduce fertiliser run-off, for example, or allow tracts of pasture to break down into salt marsh, local awareness-building will be worth the effort."

Conclusion

This report makes clear that the rest of the world lags well behind North America, and its Pacific coast states in particular, in mobilising large-scale efforts to combat OA with the help of action plans. Due to space limitations, the report omits mention of the many commendable OA-related initiatives and capacity-building that governments and other stakeholders are undertaking in different parts of the world without a formal action plan to guide them. Part of the OA Alliance's work, says Ms Turner, is to help governments inventory these disparate OA-specific measures being taken within their jurisdictions and to fortify, co-ordinate and use them for policy and management. She expects that several more OA action plans will be completed by the UN Ocean Conference in 2025, including from Asia-Pacific, Latin America and Africa, as well as Europe and North America.

The practical work of drafting an action plan, of course, requires human and financial resources. The Pacific coast governments could call on existing inter-agency and multi-stakeholder ocean protection committees to spearhead the drafting process. Outside North America, few governments have such existing capacity to call on. The OA Alliance offers its expertise to entities looking to get started, and funding and other assistance are often available from intergovernmental organisations such as the UN and International Atomic Energy Agency and charitable institutions such as the Prince of Monaco Foundation, Ocean Foundation and others.

What sorts of outcomes can be expected from OA action plans and when? As welcome as they would be, it would be unrealistic to expect significant positive changes in ocean chemistry within the first five or six years of a plan's life. But there are action plan outcomes that can start having a positive impact not long after they are in place. State and local authorities installing new stormwater and wastewater infrastructure that reduces harmful run-off is an example. Government legislation setting aside coastal tracts for seagrass meadows, mangrove forests or salt marshes is another. Research and analysis that identifies the impact of acidification on local marine species with greater precision can lead directly to the design and testing of remedial measures. Such gains do not require decades to be realised.

Nevertheless, OA action plans must be written with the long-term in mind. "An action plan is something that we can create in a year, but the implementation of it is, to some extent, forever," says Ms Turner. "We need to incorporate OA knowledge and evidence across climate change policy and marine management in perpetuity."

End notes

1 With the exception of 2020, global CO_2 emissions have grown consistently over time, reaching an estimated 37.5 billion tonnes in 2022. Global Carbon Project, Global Carbon Budget 2022.
See: https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pdf

2 The hatchery losses and the successful measures taken by scientists to eliminate them by reducing seawater acidity are documented in A Barton, G Waldbusser, R Feely et al, "Impacts of Coastal Acidification on the Pacific Northwest Shellfish Industry and Adaptation Strategies Implemented in Response" (2015). See: https://ir.library.oregonstate.edu/downloads/5425kc600

3 N Bednaršek et al, "Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients", Science Direct 716 (10 May 2020).
See: https://www.sciencedirect.com/science/article/abs/pii/S0048969720301200

4 E McGovern et al, OSPAR, "The 2023 Quality Status Report for the North-East Atlantic" (2023).
See: https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/other-assessments/ocean-acidification/

5 JF Gattuso et al, "Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios", Science 349 (2015).
See: https://www.science.org/doi/10.1126/science.aac4722

6 SDG target 14.3 reads: "Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels." See: https://www.undp.org/sustainable-development-goals

7 OA Alliance, Action Plan Toolkit.
See: https://static1.squarespace.com/static/6006d84247a6a51d636dd219/t/601974f15fb0532cfdd71eb4/1612281246910/OAlliance_APToolkit_FNL.pdf

8 GOA-ON, "Ocean Acidification Research for Sustainability Programme". See: http://www.goa-on.org/oars/overview.php

9 "Ocean Climate Action Plan: A Report by the Ocean Policy Committee". Issued by the inter-agency Ocean Policy Committee.
See: https://www.whitehouse.gov/wp-content/uploads/2023/03/Ocean-Climate-Action-Plan_Final.pdf

10 The Principality of Monaco published a Monaco Ocean Acidification Plan in 2015. Rather than a commitment to taking specific actions, however, it was a call for international collaboration in conducting research, collecting and sharing data, and boosting public awareness of OA. See: https://www.iucn.org/sites/default/files/import/downloads/monacoactionplan_6june_1_1.pdf

11 The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic came into force in 1998.

12 E McGovern et al, OSPAR, "The 2023 Quality Status Report"

13 Secretariat of the Pacific Regional Environment Programme, "Pacific Islands Ocean Acidification Vulnerability Assessment" (2016).
See: https://www.sprep.org/publications/pacific-islands-ocean-acidification-vulnerability-assessment

14 Republic of Fiji National Ocean Policy 2020-2030.
See: https://library.sprep.org/sites/default/files/2021-05/Fiji-National-Ocean-policy-2020-2030.pdf

15 The Nippon Foundation has partnered with Economist Impact to advance the Back to Blue initiative, of which this report is part.

16 Western Indian Ocean Marine Science Association, Report on Ocean Acidification Monitoring in the Western Indian Ocean (2022).
See: https://www.wiomsa.org/wp-content/uploads/2022/11/WIOMSA-2022.-Report-on-Ocean-Acidification-Monitoring-in-the-Western-Indian-Ocean-WIOMSA-Series-4.pdf

17 A Policymakers' Handbook for Addressing the Impacts of Ocean Acidification, Commonwealth Blue Charter Action Group on Ocean Acidification, Christina M. McGraw, Kim I. Currie, Cliff S. Law, Jesse M. Vance (2021)
(https://thecommonwealth.org/new-policy-handbook-help-governments-fight-ocean-acidification)

18 People belonging to the Gullah/Geechee Nation descend from African slaves transported to the American South. They reside along the eastern seaboard coast and islands, extending from North Carolina to Florida.

19 Gullah/Geechee Nation Ocean Action Plan.
See: https://static1.squarespace.com/static/6006d84247a6a51d636dd219/t/60465ada4527ce729fe97d4f/1615223516458/GullahGeechee-Nation-Ocean-Action-Plan-1.pdf

20 State of California Ocean Acidification Action Plan (2018).
See: https://static1.squarespace.com/static/6006d84247a6a51d636dd219/t/6046586055514f45a465cee4d/1615222991968/California-OA-Action-Plan-Final-1.pdf

21 2017 Addendum to Ocean Acidification: From Knowledge to Action. Washington State's Strategic Response (2017).
See: https://oainwa.org/wp-content/uploads/2023/01/2017_Addendum_BRP_Report_fullreport.pdf

22 Port of Seattle Ocean Acidification Action Plan (2021). See: https://www.portseattle.org/sites/default/files/2021-07/Port_OA_Action_Plan.pdf

23 Addendum to Ocean Acidification: Washington State's Strategic Response

24 British Columbia Ocean Acidification and Hypoxia Action Plan (2023).
See: https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/climate-risks/bc-ocean-acidification-hypoxia-action-plan.pdf

25 Oregon Ocean Acidification and Hypoxia Action Plan, 2019-2025 (2019).
See: https://www.oregonocean.info/index.php/ocean-documents/oah-hypox/oah-action-plan-2019-2025/1958-8-19-19-oah-action-plan-d9/file

26 State of California Ocean Acidification Action Plan

27 Oregon Ocean Acidification and Hypoxia Action Plan

28 University of Portsmouth Global Plastics Policy Centre, Effectiveness of national action plans (2023).
See: https://plasticspolicy.port.ac.uk/wp-content/uploads/2023/05/National-Action-Plans-Policy-Brief-GPPCxDAL.pdf

29 Addendum to Ocean Acidification: Washington State's Strategic Response

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