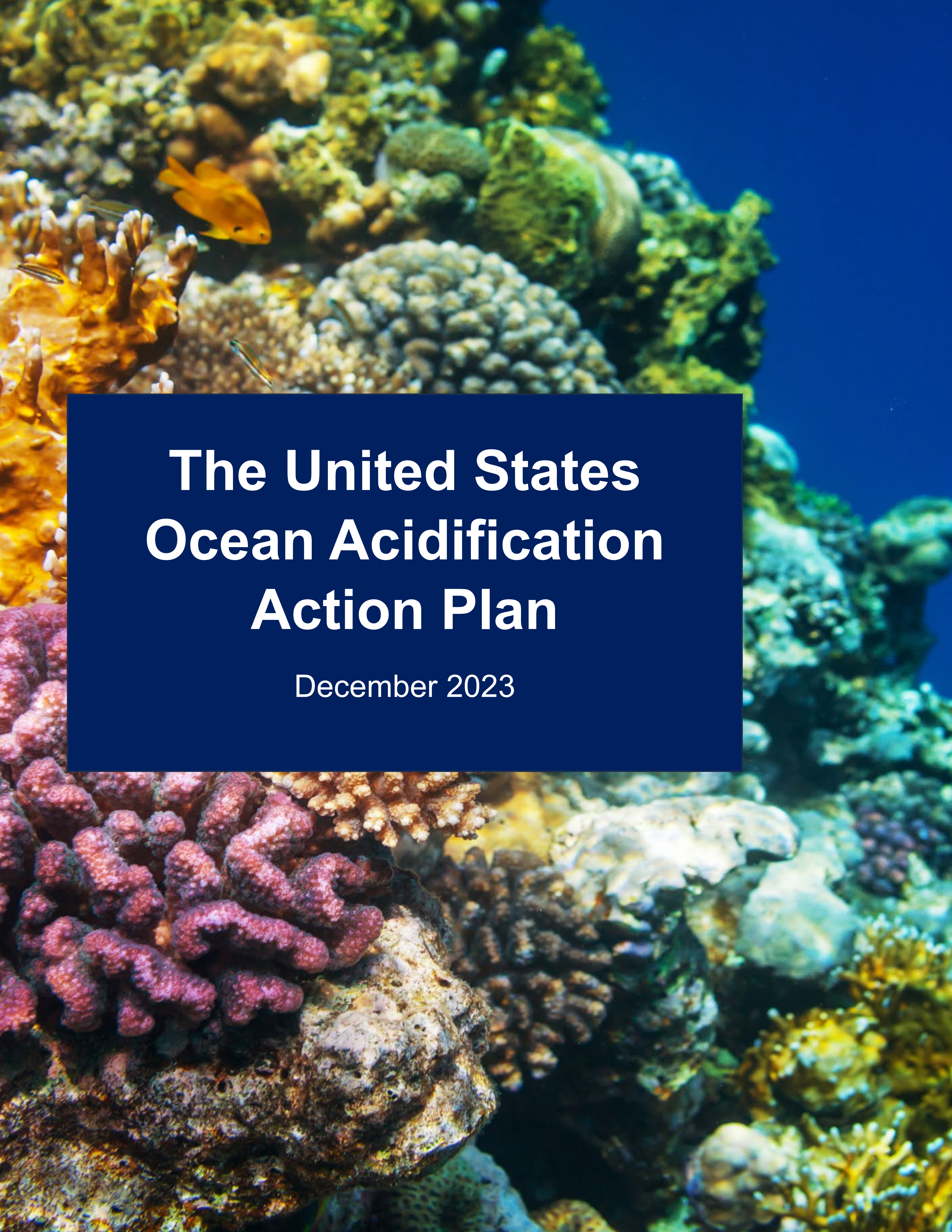

The United States Ocean Acidification Action Plan

December 2023

About this Document

The United States Ocean Acidification Action Plan (U.S. OA Action Plan) was produced by the National Oceanic and Atmospheric Administration and the Department of State on behalf of the U.S. Government. The United States joined the International Alliance to Combat Ocean Acidification (OA Alliance) in 2022 and committed to writing this plan in fulfillment of the membership requirements of the OA Alliance and as a commitment in the Biden-Harris Administration's Ocean Climate Action Plan. Ocean acidification action plans detail actions that OA Alliance members will take to better understand the impacts of acidification in their region and accelerate mitigation, adaptation, and resilience efforts.

About the International Alliance to Combat Ocean Acidification

The International Alliance to Combat Ocean Acidification (OA Alliance) brings together governments and organizations from across the globe dedicated to taking urgent action to protect coastal communities and livelihoods from the threat of ocean acidification and other climate-ocean impacts. The OA Alliance was launched at the 2016 Our Ocean Conference by four sub-national governments. Today, more than 130 members across 22 countries represent a diversity of national, state, municipal, and sovereign tribal, indigenous, and First Nation governments along with many dedicated affiliate partners like NGOs, seafood industry leaders, and local academia.

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Acknowledgements

The U.S. OA Action Plan was reviewed by members of the Interagency Working Group on Ocean Acidification (IWG-OA). The IWG-OA is composed of members representing 14 federal agencies and serves to coordinate ocean and coastal acidification activities across the federal government and fulfill the requirements of the Federal Ocean Acidification and Research Act of 2009 (33 U.S.C. Chapter 50, § 3701-3708). The IWG-OA is overseen by the National Science and Technology Council's Subcommittee on Ocean Science and Technology.

IWGOA
INTERAGENCY WORKING GROUP ON OCEAN ACIDIFICATION

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Photo credit: NOAA

Executive Summary

Ocean acidification (OA) is a reduction in ocean pH caused by anthropogenic carbon dioxide (CO2) emissions. OA is a compounding environmental threat that poses risks to the health of ocean ecosystems and marine species along with other ocean-climate impacts, such as ocean warming and deoxygenation, and changes in coastal water quality (e.g., coastal acidification, exacerbated by terrestrial pressures and land-based pollutants). This in turn is anticipated to increasingly impart negative consequences for coastal communities, including impacts on food security and economic security, across the United States, and around the world.

Since the early 2000s, the United States federal government has been a global leader in OA science, policy, and capacity building, generating best practices that have been replicated both domestically and internationally. In 2022, the United States joined the International Alliance to Combat Ocean Acidification (OA Alliance) and made a commitment through the OA Alliance and the Biden-Harris Ocean Climate Action Plan to develop a national OA Action Plan that highlights national goals on OA mitigation, research, and adaptation, and translates OA knowledge into action.

The U.S. OA Action Plan focuses on four main themes:

1. **Mitigate OA** through reducing CO_2 emissions, taking local actions to remediate OA, and investing in research on marine carbon dioxide removal (mCDR).
2. **Increase monitoring and research** to understand the impacts of OA across marine species and ecosystems.
3. **Prioritize building resilience and adaptation strategies** for coastal communities at home and abroad affected by OA.
4. **Collaborate sub-nationally and internationally** to better integrate OA knowledge across multiple levels of climate policies and marine management, encourage the expansion of OA Alliance membership, and mobilize the development of OA Action Plans.

OA is a cross-cutting issue that intersects research, policies, and action taking in climate, ocean, and marine sciences. Advancing OA knowledge is key to informing decision-making for

the Biden-Harris Administration's climate mitigation, resilience, and adaptation goals. The U.S. OA Action Plan is drafted to be complementary to strategies put forward in the national Biden-Harris Ocean Climate Action Plan, published in March 2023, and to existing national and international OA strategies. This includes the federal Interagency Working Group on Ocean Acidification (IWG-OA)'s Strategic Research Plan, federal agency research plans and agendas, and other strategic documents related to climate change, ocean science, and marine management. The U.S. OA Action Plan also serves as a deliverable of the Ocean Decade Project 'Understanding and Addressing OA and Changing Ocean Conditions Through the Development of OA Action Plans' and supports implementation of the Ocean Acidification Research For Sustainability (OARS) United Nations (UN) Decade Endorsed Programme. Finally, the U.S. OA Action Plan is consistent with U.S. climate and ocean leadership within the international climate change regime and UN Sustainable Development Goal Agenda.

The United States OA Action Plan contains three sections:

1. Overview of U.S. federal OA actions to date (2009-2023)
2. U.S. federal priorities for OA research, knowledge applications, and policy integration moving forward; and
3. Best practices and recommendations for other national governments developing OA Action Plans.

Introduction

Overview of Ocean Acidification

Ocean acidification (OA) refers to the decrease in ocean pH (and increase in acidity) over decades due to uptake of excessive anthropogenic atmospheric carbon dioxide (CO_2) by the ocean (see figure 1). The ocean absorbs nearly one third of human CO_2 emissions, and atmospheric CO_2 concentrations continue to rise due to emissions from energy production, transportation, industrial processes, and agriculture.[1,2] Since the industrial revolution, atmospheric CO_2 concentrations have increased from 280 parts per million (ppm) to over 420 ppm. Consequently, the average pH of the global surface ocean has dropped 0.1 units, equivalent to a 26% increase in acidity.[3] The present rate of change in ocean chemistry exceeds any known change to have occurred for at least the past 56 million years.[4] Some areas of the ocean, such as upwelling zones and polar seas, may experience even greater shifts in pH.[5] This rapid change requires urgent action due to the likely effects such changes will have on global marine life and the dependent human communities that rely on them for food security and coastal production

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[1] Friedlingstein, P., O'sullivan, M., Jones, M. W., Andrew, R. M., Gregor, L., Hauck, J., ... & Zheng, B. (2022). Global carbon budget 2022. *Earth System Science Data Discussions*, *2022*, 1-159.

[2] Gruber, N., Bakker, D. C., DeVries, T., Gregor, L., Hauck, J., Landschützer, P., McKinley, G. A., & Müller, J. D. (2023). Trends and variability in the ocean carbon sink. *Nature Reviews Earth & Environment*, *4*(2), 119-134.

[3] Cooley, S., D. Schoeman, L. Bopp, P. Boyd, S. Donner, D.Y. Ghebrehiwet, S.-I. Ito, W. Kiessling, P. Martinetto, E. Ojea, M.-F. Racault, B. Rost, and M. Skern-Mauritzen, 2022: Oceans and Coastal Ecosystems and Their Services. In: *Climate Change 2022:* Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 379–550, doi:10.1017/9781009325844.005.

[4] Hönisch, B., Ridgwell, A., Schmidt, D. N., Thomas, E., Gibbs, S. J., Sluijs, A., ... & Williams, B. (2012). The geological record of ocean acidification. science, 335(6072), 1058-1063.

[5] Feely, R. A., Sabine, C. L., Hernandez-Ayon, J. M., Ianson, D., & Hales, B. (2008). Evidence for upwelling of corrosive" acidified" water onto the continental shelf. science, 320(5882), 1490-1492.

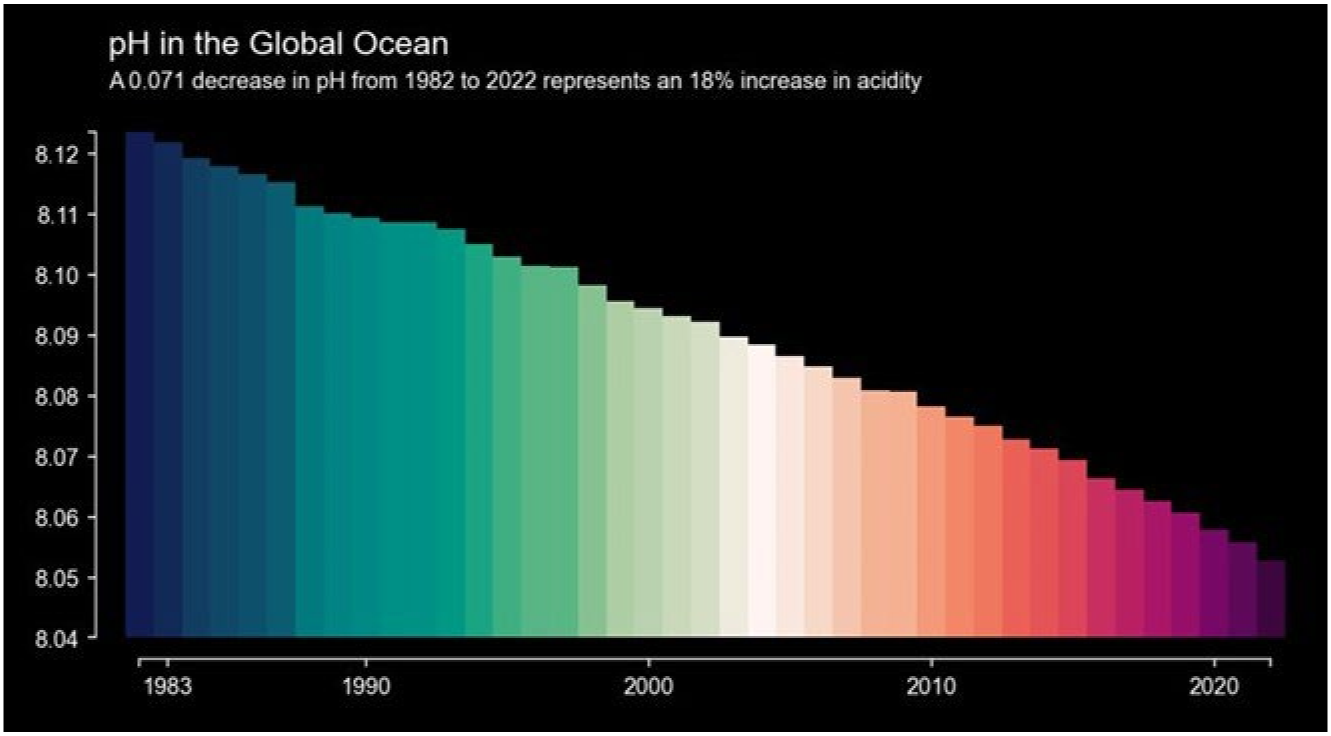

Figure 1: pH in the global ocean has decreased 0.071 units from 1982 to 2022, which represents an 18% increase in acidity (credit to ocean acidification stripes by Nicolas Gruber and Luke Gregor from ETH Zürich).

In addition, coastal systems are further impacted by local processes that increase acidity (i.e., coastal acidification). Rivers and groundwater can bring an influx of land-based nutrients carried to the ocean, stimulating outbreaks of phytoplankton that subsequently decompose on or near the seabed and further drive down local pH. Coastal acidification is differentiated from OA, which is a global phenomenon. However, both processes can result in significant changes to marine ecosystems (for the purposes of this document, “OA” will refer to both ocean and coastal acidification).

Among other effects, OA reduces the availability of carbonate ions in seawater, making it more difficult for organisms such as corals, marine plankton, and shellfish to build their shells or skeletons, and potentially compromising the health and populations of these species. Such effects in the presence of other stressors could lead to serious impacts on marine ecosystems and the services they provide, including reduced storm protection, diminished fisheries, and uptake of atmospheric carbon. OA has also been shown to negatively affect growth, survival, fertilization, embryonic and larval development, and behavior across a broad range of marine species.[6,7,8] OA has the potential to impact marine species and ecosystems across the country, which could affect the communities that depend on them. The three species categories that had the highest commercial values in 2020 all have the potential to be negatively affected by OA: crabs ($584 million), lobsters ($563 million), and scallops ($488 million).[9] These changes will particularly affect those living in coastal and Indigenous communities that depend on a healthy ocean for their livelihoods, as a source of food, and for its cultural significance.

U.S. OA Action Plan Background

To most effectively combat OA, it is of utmost importance to constrain and reduce the use of fossil fuels.[10] However, even if the global community dramatically cuts CO_2 emissions immediately, ocean chemistry will potentially take centuries or longer to recover to its pre-industrial state, with the effects of OA and its impact on organisms and ecosystems lagging further behind.[11]

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[6] Fabry, V. J., Seibel, B. A., Feely, R. A., & Orr, J. C. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science*, *65*(3), 414-432.

[7] Pörtner, H. O. (2008). Ecosystem effects of ocean acidification in times of ocean warming: a physiologist's view. *Marine Ecology Progress Series*, *373*, 203-217.

[8] Doney, S. C., Fabry, V. J., Feely, R. A., & Kleypas, J. A. (2009). Ocean acidification: the other CO2 problem. *Annual review of marine science*, *1*, 169-192.

[9] National Marine Fisheries Service (2022). Fisheries of the United States, 2020. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2020. Available at: https://www.fisheries.noaa.gov/ national/sustainable-fisheries/fisheries-united-states

[10] Terhaar, J., Frölicher, T. L., & Joos, F. (2023). Ocean acidification in emission-driven temperature stabilization scenarios: The role of TCRE and non-CO2 greenhouse gases. *Environmental Research Letters*, *18*(2), 024033.

[11] Mathesius, S., Hofmann, M., Caldeira, K., & Schellnhuber, H. J. (2015). Long-term response of oceans to CO2 removal from the atmosphere. *Nature Climate Change*, *5*(12), 1107-1113.

As a member of the OA Alliance, the United States wrote this OA Action Plan to fulfill its commitment as a national government member and further its efforts to address OA at home and abroad.

The U.S. OA Action Plan is designed to be complementary to preceding and ongoing federal actions on OA that are described in Section One (*Overview of U.S. federal OA actions to date (2009-2023)*). It highlights the need to reduce net emissions, increase support for monitoring and research, implement resilience and adaptation strategies for communities, and seek out sub-national and international collaboration. In particular, the U.S. OA Action Plan emphasizes the need to engage with local coastal and Indigenous stakeholders, as they hold valuable local knowledge about marine ecosystems and continue to be leaders in their management and conservation.

This plan is organized around federal activities to date and proposed lines of efforts across the following themes:

1. **Mitigate OA** through reducing CO_2 emissions, taking local actions to remediate OA, and developing research on marine carbon dioxide removal (mCDR).

2. **Increase monitoring and research** to understand the impacts of OA across marine species and ecosystems.

3. **Prioritize building resilience and adaptation strategies** for coastal communities at home and abroad affected by OA.

4. **Collaborate sub-nationally and internationally** to better integrate OA knowledge across multiple levels of climate policies and marine management, encourage the expansion of OA Alliance membership and mobilize the development of OA Action Plans.

Section One: Overview of U.S. Federal OA Actions to Date (2009-2023)

In the United States, a unique combination of local and national efforts makes up our response to OA. Much of this has been mobilized or supported by legislation at the state and federal level that mandates OA action. The matrix of partnerships between various levels of government, academia, and stakeholders has contributed to success in advancing OA research and the development of mitigation and adaptation strategies (see figure 2). Leaders at the state, tribal, municipal, and local levels have shown strong leadership on OA and are pivotal to implementing projects specific to their communities and local stakeholder needs.

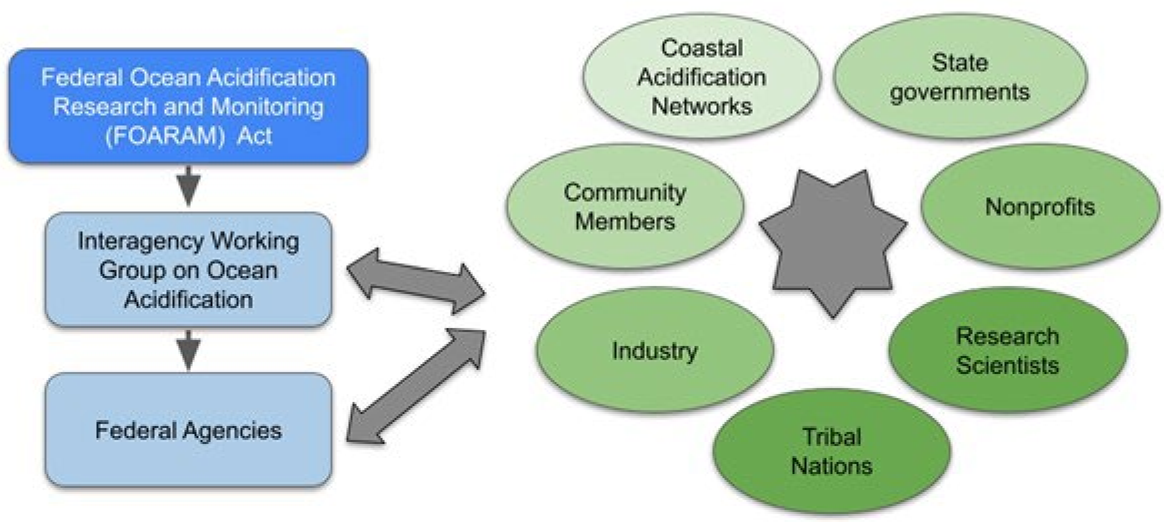

Figure 2: National legislation (i.e., the Federal Ocean Acidification Research and Monitoring (FOARAM) Act) provides guidance for both the Interagency Working Group on Ocean Acidification and individual federal agencies. The federal government has two-way partnerships with the groups displayed on the right (coastal acidification networks, state governments, nonprofits, research scientists, tribal nations, industry, and community members), who are also working collectively and individually to address ocean acidification.

The Start of OA Action in the United States: Concern about OA in the United States was galvanized by large-scale production failures at oyster hatcheries in the Pacific Northwest between 2006 and 2009. The high mortality rate of oyster larvae was soon linked to low-pH seawater, raising awareness about the threat that OA poses to the economically valuable shellfish aquaculture industry. This elicited a response from all levels of government, including the passage of federal legislation in 2009, the creation of the Blue Ribbon Panel on Ocean Acidification by Washington State in 2012, and the creation of the West Coast Ocean Acidification and Hypoxia Science Panel by California, Oregon, Washington, and British Columbia in 2013.

Federal Legislation

To date, the United States is globally unique in having national legislation explicit to OA as well as a history of long-term federal funding for OA research and monitoring dating back more than a decade. This has allowed for continued focus and resources to be dedicated to this topic from the national level. In 2009, the U.S. Congress passed the Federal Ocean Acidification Research and Monitoring (FOARAM) Act. The law directed the National Science and Technology Council's Subcommittee on Ocean Science and Technology to form an Interagency Working Group on Ocean Acidification (IWG-OA) to coordinate federal activities on OA for the purpose of better understanding potential impacts on marine ecosystems and social vulnerability. FOARAM and the creation of the IWG-OA served as a catalyst for interagency engagement in OA research and monitoring across the federal government and to facilitate multi-agency coordination. The IWG-OA is chaired by the National Oceanic and Atmospheric Administration (NOAA) and consists of 14 federal agencies (see figure 3 below).

Figure 3: The logos representing the 14 federal agencies who comprise the Interagency Working Group on Ocean Acidification.

FOARAM also gave mandates to the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) to address OA and directed NOAA to establish the Ocean Acidification Program (OAP). The OAP is tasked with supporting interdisciplinary research, establishing a long-term OA monitoring program, identifying adaptation strategies for ecosystems affected by OA, and conducting public outreach. FOARAM also gave OAP the authority to provide competitive grants for research on the effects of OA on ecosystems and its socioeconomic consequences.

FOARAM was amended by the Coordinated Ocean Observations Act in 2020 and the Chips and Science Act in 2022; these amendments introduced new requirements for the IWG-OA.

The Interagency Working Group on Ocean Acidification was given responsibilities from three pieces of legislation.

The list below describes responsibilities delegated to the IWG-OA by each piece of legislation:

1. **Federal Ocean Acidification Research and Monitoring Act of 2009**
   - Writing a Strategic Research and Monitoring Plan every five years (see Strategic Research and Monitoring second plan released in 2023)
   - Writing biennial reports summarizing federally funded OA Activities (see Ocean Acidification Research and Monitoring Priorities seventh report released in 2023)
   - Creating the Ocean Acidification Information Exchange as an online platform for sharing information with policymakers and stakeholders
2. **Coordinated Ocean Observations and Research Act of 2020**
   - Writing a Vulnerability Assessment every six years that identifies impacts of OA on coastal communities (see Vulnerability Assessment first report released in 2023)
   - Writing a Monitoring Prioritization Plan following the first Vulnerability Assessment
3. **Chips and Science Act of 2022**

- Establishing a 25-member advisory board to advise the IWG-OA
- Expanding the focus of the strategic research plan to include additional topics, such as social science research and research on co-stressors.

1.1 Mitigate OA

To mitigate OA, it is imperative to address its root cause: anthropogenic CO_2 emissions. The United States is tackling this challenge in a variety of ways, including by:

- Setting a nationally determined contribution under the Paris Agreement that targets a reduction of U.S. greenhouse gas emissions by 50 to 52% below 2005 levels in 2030.
- Passing the Inflation Reduction Act (IRA), the largest investment in climate and energy in American history, and the Bipartisan Infrastructure Law (BIL). The IRA and BIL include provisions to support the growth of clean energy jobs, increase the deployment of renewable energy infrastructure like wind and solar, and build climate resilience for ecosystems and human communities.
- Producing a national Ocean Climate Action Plan to coordinate ongoing and planned ocean-based climate mitigation and adaptation activities by the federal government across short- and long-term timescales.
- Setting an emission-reduction goal to reach 100% carbon pollution-free electricity by 2035 and net-zero greenhouse gas emissions economy-wide by no later than 2050.
- Advancing decarbonization of the U.S. economy, reduce industrial emissions announcement, decarbonize Americas blueprint, and industrial and manufacturing sectors.
- Accelerating carbon capture, removal, use, and storage technologies.
- Mobilizing climate finance through initiatives such as the Blended Finance for the Energy Transition (BFET) program (U.S. Agency for International Development

(USAID) and State), Climate Finance+ (Millennium Challenge Corporation and USAID), continued support to the Green Climate Fund, and other funding mechanisms.

- Acting as a global leader in the effort to keep the 1.5°C limit on warming within reach by launching initiatives like the Global Methane Pledge and the Green Shipping Challenge.

- Supporting the development and implementation of net-zero, climate-resilient targets and roadmaps at the sub-national level through initiatives such as the sub-national Climate Action Leaders' Exchange (SCALE).

- Advancing habitat conservation and restoration as climate solutions, including through the America the Beautiful Initiative, which seeks to restore, connect, and conserve 30% of U.S. lands and waters by 2030.

- Supporting resilience-building and climate change adaptation through the President's Emergency Plan for Adaptation and Resilience (PREPARE), a whole-of-government initiative that aims to support more than half a billion people in developing countries to adapt to and manage the impacts of climate change by 2030. PREPARE has three main pillars: climate information services, including early warning systems; mainstreaming adaptation into policies, programs, and budgets; and adaptation finance.

- Implementing the Justice40 Initiative to implement a national commitment to environmental justice; for example, the Net-Zero Game Changers Initiative is a historic whole-of-government effort to develop clean energy technologies to achieve net-zero emissions by 2050 while ensuring these innovations provide transformational benefits to all Americans.

While reducing CO2 emissions is of paramount importance, all scenarios considered by the IPCC that limit warming below 1.5°C rely on some degree of carbon removal. Considering its importance, the Biden-Harris Administration's Ocean Climate Action Plan calls for an acceleration in research and development for marine carbon dioxide removal (mCDR). mCDR is a subset of negative emissions technologies that focuses on manual enhancement of the ocean's role as a sink for anthropogenic carbon. Some methodologies may also mitigate OA at local scales. While research into these methodologies is in its infancy, the United States has already made important investments into mCDR research. In 2023, the OAP led a funding opportunity on behalf of the National Oceanographic Partnership Program that led to $24.3 million in funding for research that expands understanding of various aspects of mCDR approaches, risks and co-benefits, including OA mitigation, and science needed to build regulatory frameworks for testing and scaling of mCDR. The Department of Energy (DOE)'s Advanced Research Projects Agency-Energy (ARPA-E) has also funded research on mCDR techniques and their potential co-benefits (including reducing OA), environmental impacts, and measuring, monitoring, reporting and verification.

1.2 Increase Monitoring and Research

Monitoring and research is central to understanding the risk posed by OA and providing the necessary science-based tools to mitigate, better adapt, and ensure resilience against ocean change. The United States supports OA monitoring, modeling, research, data management, and education activities as comprehensively summarized in the IWG-OA biennial reports.

Examples of work to date include the following:

- Investing in data management, such as the creation of the Ocean Carbon and Acidification Data System (NOAA).
- Creating the National Ocean Acidification Observing Network (NOA-ON) to monitor how OA conditions are changing. This network comprises buoys; regional research cruises roughly every four years off Alaska, the West Coast, the East Coast, and the Gulf of Mexico; and ships of opportunity (NOAA).

- Investing in technology developments that have led to new advanced monitoring capabilities, including autonomous vehicles such as Saildrones, BGC-Argo floats, and gliders (NOAA, NASA, NSF).

Photo credit: NOAA

- Conducting OA monitoring in estuarine and nearshore coastal environments, including at National Estuary Program sites and National Parks around the country (Environmental Protection Agency (EPA); National Park Service (NPS); U.S. Geological Survey (USGS)).

- Supporting the U.S. Global Ocean Ship-based Hydrographic Investigations Program (U.S. GO-SHIP) to make sustained ocean carbon and biogeochemistry observations; the program has expanded to include a number of biological variables as well to assess ecosystem change (NSF, NOAA, NASA).

- Contributing to the Ocean Observatories Initiative and the Bermuda Atlantic and Hawaii Ocean time series to advance OA-relevant observations (NSF).

- Funding research and monitoring to understand OA, carbonate chemistry dynamics, and effects to resources on the outer continental shelf (Bureau of Ocean Energy Management (BOEM)).

- Investing in improving inorganic carbon measurements from space and funding *in situ* measurements of both particulate and dissolved inorganic carbon for validation (NASA).

- Researching OA impacts on ecologically and economically important species and habitats such as scallops, lobster, mussels, salmon, flounder, sand lance, krill, pteropods, Dungeness crab, corals and coral reefs (NOAA; NSF; EPA; USGS).

- Investing in both biogeochemical and ecosystem modeling. Regional models have been applied to developing valuable decision support products that include a now-cast in the Chesapeake Bay, seasonal outlooks off the Pacific Northwest, and multidecadal projections in the Gulf of Maine.

Photo credit: NOAA OAP

1.3 Prioritize Building Resilience and Adaptation Strategies

The negative impacts from OA on important fisheries and corals can have large impacts on the well-being of human communities. OA can also result in detrimental cultural impacts, limiting communities' ability to engage with healthy ocean ecosystems for recreational activities or spiritual practices. Ensuring communities are aware of the impacts of OA and are prepared to deal with the changes it may bring is key to the United States' efforts to build resilience.

This is being achieved by:

- Sharing research findings on OA impacts with communities, industries, and other stakeholders who might be impacted and helping these communities understand what can increase their resilience to future impacts.
- Supporting Coastal Acidification Networks (CAN) in the Northeast, Mid-Atlantic, Southeast, Gulf of Mexico, California Current, and Alaska (described in section 1.4 below).
- Funding regional vulnerability assessments that identify connections between the biological and ecosystem impacts from OA and impacts on industries and coastal communities that are reliant on these vulnerable marine resources. These assessments have worked with a wide number of communities around the country, from Tribes in the Pacific Northwest to the Atlantic sea scallop fishery in the Northeast, to better understand their vulnerability to OA and identify potential adaptation measures.

Photo credit: NOAA OAP

1.4 Collaborate Sub-Nationally and Internationally

The United States collaborates across levels of government to build a national and international community that is better coordinated to be resilient in the face of OA. These collaborations include a wide cross section of stakeholders including policymakers, resource managers, scientists, Indigenous peoples, and local communities. A key part of this coordination work is exchanging knowledge, increasing data collection and synthesis, and building capacity across the world.

Sub-national:

Coastal Acidification Networks

These networks started as a grassroots effort to coordinate OA monitoring and research priorities within regions and were formalized under NOAA's Integrated Ocean Observing System (IOOS) Regional Associations (RAs). Members include academic scientists; local, state, tribal, and federal government representatives; industry members; and natural resource managers. The networks increase awareness of OA, share new research findings, and work to understand potential adaptation strategies for the region.

Bilateral:

Collaborative Framework for Joint Canada/U.S. OA Research and Monitoring

In 2017, NOAA and Fisheries and Oceans Canada (DFO) launched the DFO-NOAA OA Coordination Committee to enhance scientific exchange, collaboratively address OA impacts on shared resources, share research methodologies for OA monitoring and mitigation, and identify opportunities for collaborative science. NOAA and DFO have conducted joint monitoring in the Arctic, the Northwest Atlantic, and the Northeast Pacific, developed joint OA models and species vulnerability assessments, and supported the training of U.S. and Canadian early career scientists studying OA.

Regional:

Pacific Islands Ocean Acidification Center

In 2021, the United States, in coordination with The Ocean Foundation, launched the Pacific Islands Ocean Acidification Center (PIOAC) in Suva, Fiji. The PIOAC is managed by the Pacific Community (SPC) and co-hosted with the University of the South Pacific, in partnership with the New Zealand National Institute of Water and Atmospheric Research (NIWA) and the University of Otago. This Center acts as a regional training hub and supports local scientists through mentoring and training to equip the region with skills and technology through the Global Ocean Acidification Observing Network (GOA-ON) in a Box Kits (see more below) to implement a region-wide OA observing program.

Caribbean Engagement on OA

The OA Caribbean GOA-ON Hub was recently established by a steering committee of Caribbean community members to provide a collaborative network that tackles identified regional needs for addressing OA. The creation of this GOA-ON Hub was facilitated by NOAA OAP, including the GOA-ON Secretariat within NOAA OAP, and spurred out of a Caribbean OA Needs Based Assessment Survey. This survey was designed by the Caribbean OA Community of Practice (CoP) (formed in 2021 with government members, university partners, and non-profit representatives from the U.S. and the Caribbean). This survey indicated community interest in increasing opportunities to address OA, including capacity building, access to equipment, regional networking within the wider Caribbean and the U.S. territories (Puerto Rico and U.S. Virgin Islands), and interest in establishing an OA Caribbean GOA-ON Hub to assist with these goals.

Global:

Global Ocean Acidification Observing Network

The Global Ocean Acidification Observing Network (GOA-ON) is a collaborative network of over 900 members from more than 114 countries. It works to understand the drivers of OA and the impacts of OA on marine ecosystems, and it uses this information to optimize models that predict OA and its impacts. GOA-ON is organized into nine regional hubs with topic-specific working groups (such as biological and ocean-based carbon dioxide removal working groups) and an International Carbon Ocean Network for Early Career (ICONEC) community. The United States was instrumental in launching GOA-ON by funding the first international workshop at the University of Washington in 2012. The United States has since provided funding to support the GOA-ON data portal, co-chairs, and executive secretariats. The United States has also supported capacity building through the distribution of GOA-ON in a Box Kits and the launch of the Pier2Peer Program, a global scientific mentorship program which pairs early-career researchers with experienced scientists to create an international network of OA practitioners.

Figure 4: The United States engages in OA capacity building through the international Global Ocean Acidification Observing Network (GOA-ON). As of 2023, there are 9 hubs in GOA-ON.

The hubs in Figure 4 are as following:

- North American OA Network
- Latin American Ocean Acidification Network (LAOCA)
- Caribbean OA Hub
- Northeast Atlantic Hub (NEA Hub)
- Arctic OA Hub
- OA Mediterranean Hub (OA Med Hub)
- Ocean Acidification Africa Network (OA-Africa)
- South Asia Regional Hub on Ocean Acidification (SAROA)
- Pacific Islands and Territories Ocean Acidification Network (PI-TOA)

Ocean Acidification Research for Sustainability

The UN Endorsed Ocean Decade Programme from GOA-ON, Ocean Acidification Research for Sustainability (OARS), aims to foster the development of the science of OA. The goals of OARS include: providing systematic evidence of the impacts of OA on the sustainability of marine ecosystems, enhancing OA capacity, increasing observations of ocean chemistry changes, enhancing communication to policy-makers and communities to mitigate and adapt to OA, and facilitating the development and evaluation of strategies to offset future impacts. U.S. ocean professionals serve as OARS co-chair, executive secretariat, and co-champions.

International Alliance to Combat Ocean Acidification (OA Alliance)

In 2022, the United States joined the International Alliance to Combat Ocean Acidification (OA Alliance) as a national member, following in the footsteps of several tribes and U.S. sub-national governments that have been key leaders in the Alliance, including California, Maryland, Oregon and Washington. The State Department and NOAA serve as co-leads for the U.S. Government in the OA Alliance.

Section Two: U.S. Federal Priorities For OA Research, Knowledge Applications, and Policy Integration Moving Forward.

The United States is committed to its continued leadership in mitigating, understanding, and adapting to OA. This section is intended to provide a high-level overview of the suite of actions the United States aims to undertake to address the challenges of OA, with an eye towards "whole-of-government" streamlining efforts across the federal government and across scales of implementation. It does not represent a fully inclusive list of all OA-related actions that U.S. federal agencies plan to implement.

2.1 Mitigate OA

Addressing climate change and OA requires rapid stabilization and reduction of atmospheric CO_2 levels. Reducing CO_2 emission levels remains a grand challenge for our global society, and this must be done to abate OA and prevent irreversible damage to marine species and ecosystems.

The Biden-Harris Administration's Ocean Climate Action Plan (OCAP) calls for pursuing ocean-based climate mitigation actions carefully, recognizing simultaneously the importance of conserving marine ecosystems, advancing sustainable ocean economies, and protecting human health and well-being. The below priorities include lines of effort highlighted in OCAP that are particularly related to OA include, as well as additional priorities for OA mitigation.

Integrate OA into Existing Efforts to Reduce CO2 Emissions

The Biden-Harris Administration has set bold emission reduction targets and is committed to decarbonizing the U.S. economy. Actions to reduce emissions across all sectors will have the largest impact in mitigating future harm from OA. OA should be integrated into climate policy discussions as a co-benefit of emissions reductions, leveraging the ongoing federal, state, local, and tribal actions focused on addressing climate change.

Decarbonize Ocean-Based Activities

The ocean is impacted by climate change, but is also a largely untapped source of climate solutions. Investment in ocean-based climate actions that reduce CO_2 emissions could narrow the “emissions gap” between current and projected emissions by as much as 35% on a 1.5°C pathway, as well as mitigate the effects of OA in ocean, coastal, and Great Lake ecosystems.[12] Innovative ways to decarbonize our ocean should be explored and further researched.

For example, investing in offshore wind energy and marine energy and taking steps to decarbonize the shipping sector are promising pathways to achieving a carbon-neutral future. Advancing such solutions will require investment from all sectors: private, government, and non-government.

Support Research on Blue Carbon Habitats

Coastal “blue carbon” habitats such as seagrasses, wetlands, mangroves, and salt marshes remove and store large amounts of carbon in plant biomass and underlying carbon-rich sediments, and can contribute to net CO_2 emissions reductions. They also

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[12] Hoegh-Guldberg, O., Northrop, E. et al. 2023. "The ocean as a solution to climate change: Updated opportunities for action." Special Report. Washington, DC: World Resources Institute. Available online at https://oceanpanel.org/publication/ocean-solutions-to-climate-change

can contribute to local-scale OA mitigation by taking up excess CO_2 from seawater. Better understanding of the carbon sequestration and OA mitigation potential of these ecosystems is needed in many regions. Federal research priorities on blue carbon include: monitoring, quantification, and mapping of known coastal blue carbon habitats; research to determine blue carbon potential of other coastal and marine ecosystems; and development of standards for blue carbon monitoring and management.

Invest in Research on Marine Carbon Dioxide Removal

Marine carbon dioxide removal (mCDR) could potentially contribute to both climate objectives and localized OA mitigation. However, it is also important to recognize that, if not done carefully, mCDR could also exacerbate OA in some vulnerable environments (for example, through transport and decomposition of organic biomass on the shelf or hydrodynamically constrained systems so as to promote hypoxia). As outlined in OCAP, there is an urgent need to build sufficient knowledge about the efficacy and tradeoffs of different methods for mCDR. This improved knowledge base on mCDR is needed to determine if and how various proposed techniques are viable options for the United States to reduce net CO_2 emissions. The OCAP calls for implementation of a comprehensive and responsible federal research and scaled testing program for mCDR approaches, considering recommendations from the 2021 NASEM ocean-based CDR report and similar science community reports as a starting point (such as the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) Working Group 41 on marine geoengineering). The OCAP also recommends that the existing domestic and international regulatory framework (including under the Marine Protection, Research, and Sanctuaries Act, Clean Water Act, Rivers and Harbors Act) for mCDR research and implementation be clarified. A robust regulatory framework protects human health, the marine environment, and potentially affected communities, and ensures safe and effective long-term carbon dioxide removal.

NOAA has developed a CDR research strategy, and new federal research and development initiatives are underway, as described in section 1.1. The DOE Carbon Negative Shot has also proposed future funding opportunities for small mCDR removal pilots to demonstrate the feasibility, cost, and scalability of both biotic and abiotic ocean-based approaches, including direct ocean capture of carbon dioxide, ocean alkalinity enhancement (mineral and electrochemical), and micro- and macroalgae-based pathways.

Implement Local Actions to Improve Water Quality

Existing federal, state, and local programs working to address nutrient pollution and poor water quality should be leveraged as a way to mitigate coastal acidification. This can include nutrient abatement initiatives, improvements to waste water infrastructure, and land-use policies and existing efforts like the EPA's regulatory and non-regulatory programs to protect water quality and combat nutrient pollution. Outreach is needed to communicate the co-benefits these policies have for coastal acidification and to integrate coastal acidification considerations into existing water quality programs. In addition, as a potential local OA mitigation and mCDR technique, the option for alkalinity to be added to wastewater discharge requires additional research.

2.2 Increase Monitoring and Research

Although large strides have been made in monitoring and research, many questions remain about the progression and variability of OA, how marine species and ecosystems will be impacted, and how they will adapt. Highlighted below are actions that could support the expansion of OA research and monitoring. These actions complement the goals outlined in existing federal guiding documents such as IWG-OA's Strategic Plan for Federal Research and Monitoring of Ocean Acidification, and NOAA's Ocean, Coastal, and Great Lakes Acidification Research Plan: 2020-2029.

Utilize Emerging Technology to Expand Understanding of OA and its Impacts

Data Science and Modeling

To better support action at regional scales, the OA observing system can be modified to make aggressive use of emerging technologies such as statistical and dynamic modeling, data assimilation, artificial intelligence (AI), and machine learning to enable high-fidelity 4D biogeochemical (BGC) monitoring at relevant scales and depths for species of interest. Some possible applications of AI and machine learning include:

- Extrapolate limited and targeted measurements geographically and better characterize the entire water column, across benthic environments, within coastal systems, and more.
- Predict near-term to seasonal forecasting of acidification events (e.g., driven by upwelling, freshwater inflow to coastal waters, or related to hypoxic conditions).
- Project time-of-emergence whereby regional conditions are pushed beyond their historical conditions or past species-specific critical thresholds whereby habitats may be unsuitable.
- Develop indicators that are readily measured across marine environments (i.e., oxygen and nutrients) that can be used to quantify and differentiate anthropogenic CO_2 addition from local processes.
- Leverage data science approaches for data interpretation and management.
- Make OA data openly and publicly available.

Uncrewed Systems

Reimagined observing networks to research and monitor OA also require robust sampling systems, which should involve a significant role for autonomous sensors, vehicle fleets, and uncrewed systems. Advancements in autonomous vehicle fleets have been spearheaded by many U.S. institutions. Uncrewed platforms are a high priority for the United States and should continue to expand in application, as exemplified by the IWG-OA Strategic Plan and the NOAA Uncrewed Systems Strategy released in 2020. The following actions can help support the development and application of uncrewed systems:

- Uncrewed fleets should have ready access to suitable sensors to directly, accurately, and reliably measure the carbonate system and/or be configured for proxy measurements like oxygen and nitrate.

- To develop robust regional algorithms, aggressive and high-quality field campaigns should be conducted, similar to coastal OA surveys.
- Technological development for sensors aboard uncrewed and autonomous platforms should be prioritized to provide scalable solutions for local measures across global scales while potentially reducing the carbon footprint of oceanographic measurements.

Photo credit: NOAA NCEI

Low-cost, Open-Source Technology

Low-cost, easy-to-use, reliable technology should be accessible through open-source opportunities to enable global community-based sampling and increase access to science equipment. As public awareness of OA increases, coastal communities are more interested and motivated to participate in efforts to understand their local conditions of OA that will inform decisions related to aquaculture, fisheries, and water quality. Despite the recent development of inexpensive, replicable, and easy-to-use technologies, they are not readily available due to production challenges with minimal profits and a relatively small user base.

Therefore, open source technology should be supported through the following actions:

- Development of open-source technology should be encouraged through public/private funding opportunities.

- Low-cost, open-source technology should be supported by accessible templates for manufacturing to enable interested communities around the world to build instruments.

- Resources should shift towards funding components and distributed manufacturing capabilities (e.g., 3D printing) that enable communities to build open-source technology.

- Global communities should consider establishing technical support to help build and troubleshoot open-source technology.

- Capacity building workshops can provide the basic skills to upskill interested users and support building open-source technology.

Understand Basic Biological Response and Adaptive Capacity of Key Fisheries, Aquaculture, and Marine Resources

In the last decade, experiments focusing on the impacts of OA in a multi-stressor environment have increased in frequency, leading to a better understanding of the potential responses of certain organisms to environmental changes. Despite necessary efforts to perform such experiments, there are many more ecologically and economically important species as well as stressors that exceed the capabilities to be individually tested in multi-stressor experiments. Such experimental research also benefits greatly when embedded in a framework of long-term monitoring of ocean chemistry and ecosystem responses.

Therefore, the following actions can help extrapolate these efforts to larger ecosystem scale:

- Develop fundamental understanding of basic mechanisms and biological indicators that are transferable to other species to help determine their OA vulnerability and adaptability.

- Characterize locally relevant species to apply general fundamental understandings and indicators based on other species to determine OA vulnerability and adaptability for more species.

- Utilize small-scale biogeochemical manipulation experiments performed on a small ecosystem (such as a small reef) to help understand long-term environmental and biological impacts within a changing ocean. This can also contribute to mCDR research and experiments.

- Increase field experiments within the U.S. to link laboratory and tank studies to real-world applications. These efforts would require interagency collaboration that is tied to transdisciplinary regional modeling with careful planning, permitting, and execution.

- Sustain long-term monitoring of ocean ecosystems needed to detect impacts from OA.

- Conduct experiments on multiple life stages of valued species.

- Expand the use of environmental DNA (eDNA) techniques that could be used to detect sub-lethal effects and provide for field indicators of OA response.

- Continue to conduct multigenerational experiments to better elicit potential adaptive capacity of species that could suggest a natural resilience or offer adaptive strategies in terms of selective breeding.

Photo credit: NOAA Ocean Acidification Program

Ensure Long-Term and Reliable Global Access to Standardized Reference Materials

As OA monitoring and research expands globally, it is critical to increase accessibility to carbon-in-seawater reference materials (RM) for all regions. Reference materials are necessary for measuring the carbonate chemistry system, especially total alkalinity, yet their production has not been globally available. The IWG-OA is working to create a more resilient model for RM production, which is based in the United States, yet can be used as a model around the world.

This global model could include:

- Standing up multiple centers of production for RMs (also commonly referred to as Certified Reference Materials, CRM) around a region, in partnership with a central certifier, likely a National Meteorology Institute (NMI). For example, in the United States the National Institute for Standards and Technology (NIST) will be the certifier.
- Creating capacity for laboratories within a region to establish in-house RMs based on standard operating procedures.
- Support the establishment of a quality assurance program which regularly conducts interlaboratory comparisons to ensure the quality of RMs. Such a program will provide critical community-wide technical support and will aid under-performing labs to meet globally established specifications.
- Collaborating globally across regional centers to ensure that standards are upheld for all RMs.

Dedicate Monitoring Attention to the Coasts and Beneath the Surface

Much more is known about how OA is impacting surface waters than coastal and subsurface waters. While existing assets could be leveraged to deploy additional sensors to monitor OA in these regions, the majority of the cost comes from supporting personnel to maintain, calibrate, and service the sensors, and from funding data management and synthesis. In order to collect more comprehensive data, efforts should be taken to explore options for reducing these costs.

2.3 Prioritize Building Resilience and Adaptation Strategies

As OA impacts become more prevalent, communities will need to build resilience and prepare to adapt in the face of changing OA conditions. This section will outline some priority lines of effort that have been identified.

Support Further Vulnerability Assessments and Social Science Research to Better Understand Community Risks and Needs

Vulnerability assessments of coastal regions are necessary to understand local impacts specific to each community, the risks they face, and their adaptation needs. In 2023, the IWG-OA published the first national Ocean Chemistry Community Vulnerability Assessment, which describes potential social impacts from OA. This report describes large-scale monitoring and research gaps, including those in social science, which need to be addressed to better understand social vulnerability to OA and develop effective adaptation measures. Efforts should be made to promote and, when possible, fund interdisciplinary studies of OA that include social factors that inform adaptation priorities, such as socioeconomic and demographic data. When designing such studies, stakeholders should be included in the early stages of development and efforts should be made to integrate their perspectives into projects through co-design practices. Additional targeted regional vulnerability assessments can provide further clarity on the risks posed to certain communities and what adaptation measures will be most effective. To date, no regional assessments have been conducted for communities in the U.S. Southeast Atlantic Coast, Gulf of Mexico, U.S. Virgin Islands, American Samoa, or the Commonwealth of the Northern Mariana Islands.

Support Efforts to Build Resilience in Food Systems and Seafood Economies that are Vulnerable to OA Impacts

OA is already impacting and will continue to influence the productivity of local fisheries and aquaculture that communities rely on for income and food security. For example, Eastern oysters provide millions of dollars in income to communities on the U.S. East Coast, a valuable fishery expected to be impacted by OA. Efforts should be made to support communities, local governments, and industries in locally-led efforts to diversify or proactively build resilience for vulnerable economic and food systems. This could include supporting efforts to locally mitigate OA impacts for the benefit of protecting vulnerable fisheries, engaging in marine spatial planning efforts to identify new locations for aquaculture facilities, promoting diversification of local economies dependent on a single vulnerable species, or supporting job training and education for those whose livelihoods may be impacted by reduced fishery productivity. Continued support for socioeconomic models that predict impacts to fisheries and other systems could also help communities understand what change they may need to prepare for.

Support the Protection and Restoration of Marine Ecosystems that can Locally Mitigate OA

As highlighted in Section 2.1, marine primary producers, including seagrasses and mangroves, have been shown in some cases to locally mitigate OA through the uptake of dissolved CO_2 required for photosynthesis. The protection and restoration of these ecosystems has the potential to act as a critical buffer for local effects of acidification; further research could help local communities understand the benefit to local habitats. Additionally, supporting these ecosystems also provides communities with myriad co-benefits, including carbon sequestration, enhanced marine biodiversity, and storm protection.

Enhance Education, Training and Capacity Building Efforts to Support OA Resilience

Educational initiatives and public outreach programs that increase awareness of OA and its impacts are important tools for generating public interest in OA and building support for action. Training and capacity building programs are vital for developing and empowering local OA practitioners, who are often champions for OA action in their communities and key implementers of research, monitoring, mitigation, and resilience-building efforts. Prioritizing this work will be key for growing an informed, engaged, and skilled network of citizens across the United States that are prepared to address OA and its impacts.

Integrate Environmental Justice into OA Efforts

Environmental impacts, including the effects of OA, are often disproportionately felt by communities of color, low-income communities, tribal and indigenous communities, and other marginalized groups. There is an opportunity to advance environmental justice and equity by ensuring that underserved communities, including the U.S. territories, receive necessary resources to prepare for and deal with the impacts of OA. The Biden-Harris Administration's Ocean Justice Strategy, currently in development, seeks to address many of these challenges and will be a pivotal resource to inform best practices for engaging with and meeting the needs of communities that have been historically marginalized by decision-makers with regards to ocean issues like OA.

2.4 Collaborate Sub-Nationally and Internationally

Increase OA Capacity Across Scale and Levels of Governance

Increased international, regional, territorial, and sub-national capacity can better support the expansion of OA monitoring and research. Increased capacity across scales can enable different implementers to focus on monitoring within their waters and understand the vulnerability of culturally and economically important species specific to their area.

Efforts to increase capacity across levels of governance can include:

- Engaging in international and interregional scientific collaborations, such as through GOA-ON, to create platforms to learn from each other and further their expertise.
- Promoting monitoring capacity regionally by hosting technical assistance workshops to connect technical experts with on-the-ground monitoring personnel.

- Incorporating diversity and inclusion into capacity building efforts, in particular elevating women and girls, indigenous and tribal community members, and people of color in OA-related careers

Meaningfully Engage with Stakeholders when Developing Plans to Study and Build Resilience to OA

Various stakeholders are experiencing the impacts of OA firsthand. Intentional, meaningful, and accessible engagement with these groups is critical to facing the challenges of OA and designing and implementing resilience-building solutions.

The stakeholders include:

- indigenous peoples
- local communities
- non-governmental organizations
- the private sector
- sub-national government entities

This should include space for communities to raise their experiences with OA and its effects on their ecosystems, economies, and cultures. Most importantly, this should include space for collaboration between local stakeholders, local governments, national governments, and international partners in the process of creating research, mitigation, and adaptation plans.

Work with Communities to Establish CANs in U.S. Territories

As described above, the United States has established CANs in six regions: the Northeast, Mid-Atlantic, Southeast, Gulf of Mexico, Alaska, and the California Current. CANs do not operate in Hawai'i or the U.S. territories in the Pacific and the Caribbean. Establishing CANs in the Pacific Islands and the Caribbean can help to ensure research investments are suitably aligned with regional interest, but further engagement is required to empower community members to lead these efforts in line with regional needs.

Harness the Power of U.S. Sub-National, Tribal and Indigenous OA Action Plans

The OA Alliance was launched in 2016 by the governments of Washington, Oregon, and California and the province of British Columbia. As such, sub-national leadership has always been at the forefront of action on OA. State, tribal, and local leadership has driven progress on our national understanding of OA and its impacts on U.S. communities and is critical to the implementation of OA research and resilience-building efforts.

Several U.S. sub-national and Tribal OA Action Plans precede this national OA Action Plan, including:

- Washington OA Action Plan
- Oregon OA Action Plan
- California OA Action Plan
- Hawaii OA Action Plan
- Maine OA Action Plan
- Maryland OA Action Plan
- Port of Seattle OA Action Plan
- Gullah Geechee Nation OA Action Plan

Promote Coordination with Sub-National and Tribal Members of the OA Alliance

The forward-leaning work of sub-national and tribal and indigenous leaders, and the OA Action Plans they have already developed, set the tone for achieving ambitious action on OA at the federal level. The national U.S. OA Action Plan seeks to work hand-in-hand with state, local, and tribal and indigenous OA practitioners to both support their efforts and ensure cohesive implementation of U.S. action on OA. In order to capitalize on the immense leadership and expertise of sub-national and tribal and indigenous OA Alliance members, the United States federal government will seek to convene an annual meeting of OA Alliance sub-national members for the purposes of sharing best practices and resources, harmonizing policy and action on OA across the United States, leveraging funding opportunities, and working together to address shared challenges.

Leverage Membership in the OA Alliance to Mobilize National-Level and Global Action on OA

As a member of the Executive Committee of the OA Alliance, the United States is collaborating with other national governments to mobilize national-level action on OA, and increase efforts in international fora to tackle carbon emissions and adapt to and build resilience to ocean-climate impacts including OA. Through the OA Alliance, the United States will share best practices on OA research, monitoring, and policy with other national governments, and encourages other national governments to join in these efforts.

Section Three: Sharing Best Practices and Recommendations for Other National Governments Developing OA Action Plans

The United States is committed to working with communities around the world to share knowledge and build capacity to address the shared challenges of OA. Through membership in the OA Alliance, bilateral relationships, and international scientific collaboration, the United States will continue to share best practices on OA research, management, and resilience-building policy with the international community, so that communities around the world can implement policies and practices that work for them.

As a member of the OA Alliance, the United States intends to leverage its global leadership on OA to build momentum for additional national OA Action Plans for other national government members, as well as supporting broader international initiatives on OA. This could include supporting international, regional, or national efforts as described in figure 5 below.

Prioritize Local Research

- Assess variability and trends in ocean and coastal chemistry
- Synthesize local and regional OA information to prioritize and evaluate OA risks and needs
- Assess impacts of OA to ecosystems, marine resources, and socioeconomic systems

Support Networks and Connections

- Deepen connections between science and management to prioritize studies and improve local interventions
- Facilitate information sharing among member governments and non-government affiliate members of the OA alliance
- Strengthen public and private funding opportunities for OA related projects

Connect to Policy

- Utilize national policy or legislation to promote investment in OA research, capacity building, and adaptation efforts
- Implement climate and ocean actions consistent with the UN Framework Convention on Climate Change, the UN Sustainable Development Goals agenda, the UN Decade of Ocean Science, and other applicable international agreements and frameworks

Figure 5: While all countries will have their own strategy for addressing OA in a way that meets their needs, the described actions taken in the United States may be beneficial to other national governments undertaking this work.

As the United States is the only country with existing supporting legislation for OA research and monitoring, it is hoped that this document and the outlined policy framework implemented in the United States can serve as a resource for other governments to consider when drafting their own OA Action Plans.

The United States will also continue to encourage other countries to join the OA Alliance and support additional legislation, awareness, and capacity building on OA. Sub-national and Indigenous members are also encouraged to engage with these efforts and produce OA Action Plans to better inform how national and regional efforts can support their communities.

It's important to remember there is no "one size fits all" approach to this work. Approaches to developing an OA Action Plan should be place-based and unique to the ecology, capacity, and policy or management goals of the nation or region.

Conclusion

The United States remains committed to tackling OA through mitigation by reducing anthropogenic CO_2 emissions, continuing research and monitoring, and continuing to build resilience and advance adaptation actions. Though much work has been done, much remains to be achieved. This plan, in conjunction with other federal plans and strategies described above, seeks to continue building momentum for translating OA understanding into concrete, effective action across the federal agencies. It is important to acknowledge that continued action requires continued resources, through both sustained funding and staffing. The United States also acknowledges the important role all national and sub-national actors, as well as intergovernmental organizations like the OA Alliance, play in advancing this collective action. The United States is committed to working collaboratively across all levels to deliver on climate and ocean goals for the health of the planet and future generations.