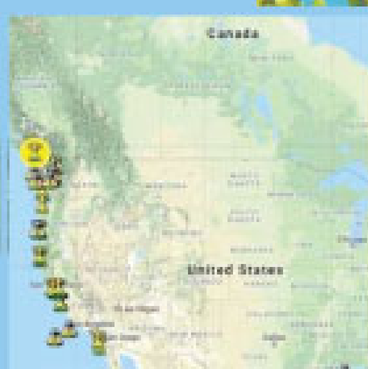
Fisheries and Oceans Canada   Pêches et Océans Canada

A COLLABORATIVE FRAMEWORK FOR JOINT DFO/NOAA OCEAN ACIDIFICATION RESEARCH AND MONITORING



OAP

NOAA OCEAN ACIDIFICATION PROGRAM

Canada

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1.0 INTRODUCTION

1.1 BACKGROUND AND CONTEXT

Global marine ecosystems are undergoing significant changes related to a combination of climate change, ocean acidification, natural variability, and other human pressures.

The rising level of atmospheric CO_2 is causing both climate change and ocean acidification. Climate change is impacting marine resources, ecosystems, and infrastructure in several different ways. Higher ocean temperatures reduce dissolved oxygen and also affect fisheries distribution, health, and timing in life cycles, such as when lobsters molt. Rising sea levels and associated storm surges damage shorelines and coastal infrastructure and harm coastal ecosystems. Ocean acidification (OA) reduces seawater pH and the availability of calcium carbonate, making it difficult for many shellfish species to grow shells and for young finfish to counter internal shifts in acid-base balances, which may lead to a cascade of biological effects, including mortality.

Bilateral cooperation between the US National Oceanic and Atmospheric Administration and Environment Canada (now Environment and Climate Change Canada) is recognized under a Memorandum of Understanding (MOU) signed in January 2008. Within this MOU, mutual interests in collaborating on ocean research and exchanging scientific and technical knowledge are outlined. The MOU also notes the need to coordinate with other engaged partners in each country, such as Fisheries and Oceans Canada.

On June 29th, 2016 Canadian Prime Minister Justin Trudeau, American President Barack Obama, and Mexican President Enrique Peña Nieto met in Ottawa for the North American Leaders Summit. At this meeting the three leaders committed to advance a competitive, low-carbon and sustainable North American economy and society, and to provide global leadership in addressing climate change. They also committed to enhance cooperation on ocean management and complementary research on oceans and climate change, including the impacts of climate change on oceans and marine ecosystems.

In support of these international commitments, Fisheries and Oceans Canada (DFO) and the US National Oceanic and Atmospheric Administration (NOAA) held a joint Ocean Acidification Meeting in St. Andrews New Brunswick, on September 20th and 21st, 2016. At this meeting, scientists and fisheries managers met to discuss the impacts of OA on species of common concern, to share research methodologies for OA monitoring and mitigation, and to identify opportunities for collaborative monitoring and field surveys. The main objectives of the meeting were:

1) To share updates on research into biological impacts of OA, especially on commercial species of shared interest;

2) To identify common knowledge gaps and areas for future research collaborations;

3) To establish a coordination mechanism for current and future ocean or coastal OA observing in the Atlantic, Pacific and Arctic Oceans; and

4) To develop a Coordination Framework for DFO-NOAA efforts into the future.

1.2 DFO MISSION AS RELATED TO OCEAN ACIDIFICATION

DFO is monitoring and studying the effects that changing ocean conditions, including increasing water temperatures and OA, are having on Canada's fisheries, aquatic ecosystems, and coastlines. Federal agencies have been tracking changing ocean conditions for well over 100 years and DFO has been conducting research and collaborating internationally on OA in all three of Canada's oceans for over a decade. DFO scientists are involved in various regional and international studies to more accurately describe the frequency and extent of acidification events, identify areas that are the most vulnerable to acidification and better understand the potential impacts on marine organisms. At an international level, DFO is involved in the Arctic Monitoring and Assessment Programme (AMAP), which leads many circumpolar environmental monitoring activities of the Arctic Council, and in the Global Ocean Acidification Observing Network (GOA-ON).

Through Fisheries and Oceans Canada's Aquatic Climate Change Adaptation Services Program (ACCASP), scientists are monitoring and studying changing ocean conditions and their effects on Canada's fisheries, aquatic ecosystems, and coastlines. The Science sector at DFO conducted risk-based assessments of climate change impacts on the biological systems in four Large Aquatic Basins (Canada's Central Freshwater Ecosystems, Northeast Pacific, Canadian Arctic, and Northwest Atlantic). Results of these assessments concluded that: DFO's coastal infrastructure, ecosystems, and species are at significant risk based on a 50-year timeframe; emergency response and the change in access and navigability of waterways risks are the highest in the Arctic; and OA is a major risk to fisheries and ecosystem health in all three oceans.

The current ACCASP focuses on building foundational knowledge of OA, as well as furthering the development of climate change vulnerability indices for coastal infrastructure and fisheries. This includes the incorporation of climate change impacts within stock assessments, improving forecasting of ocean conditions and communicating the results to other levels of government (e.g. provinces, territories, cities), marine based industries, and Canadians at large.

DFO will continue priority science activities on ocean chemistry, including hypoxia and OA. This includes research to better understand the biological impacts of OA and responses of key fisheries, aquaculture and keystone ecological species in coastal and offshore waters, and how ocean circulation affects the occurrence and rate of acidification in all three oceans.

In March 2016, Canadian First Ministers endorsed the Vancouver Declaration that committed to the development of a Pan-Canadian Framework on Clean Growth and Climate Change (PCF) that will inform the future Pan-Canadian Strategy for Adaptation and Climate Resilience. The PCF was officially adopted and publically announced following the First Ministers' Meeting on December 9th, 2016.

As the federal government moves toward implementation of the Pan-Canadian Framework, DFO will continue to work collaboratively with other federal departments, and with provinces where appropriate, to advance Canada's climate change agenda as well as DFO's mandate commitments, including using scientific evidence and the precautionary principles, and take into account climate change, when making decisions affecting fish stocks and ecosystem management.

1.3 NOAA MISSION AS RELATED TO OCEAN ACIDIFICATION

In 2009, the United States Congress passed the Federal Ocean Acidification Research and Monitoring Act (FOARAM) that allowed for the establishment of the National Oceanic and Atmospheric Administration's Ocean Acidification Program (OAP) in May 2011. The OAP aims to coordinate research, monitoring, and other activities to improve understanding of the mechanism by and rates at which the chemistry of the ocean is changing, the regional variability of that change, and the impacts of these changes on marine life, people, and the local, regional, and national economies. FOARAM also set up a US Interagency Working Group on Ocean Acidification (OA-IWG) which currently includes representatives from 13 federal agencies and is charged with broad coordination of OA research and monitoring across the relevant agencies. The OAP Director is also chair of the IWG.

The OAP is a long-term, statutorily mandated program that is a part of the Research division of NOAA. Program funding falls within seven different focal areas or themes: 1) Monitoring; 2) Biological and ecosystem response; 3) Data management; 4) Modelling; 5) Adaptation strategies; 6) Technological development; and 7) Outreach and education. As part of its responsibilities, the OAP provides grants and works in close partnership with academic institutions to advance critical research projects that explore the effects on marine organisms, ecosystems and socioeconomic impacts leading to potential adaptive strategies. The OAP also pursues a leadership role in advancing international OA monitoring and monitoring best practices.

NOAA is working to establish long-term high quality OA observations within ocean, coastal, and coral reef environments using a network of targeted and volunteer ship surveys, fixed mooring observations, and advanced technologies. This information is guiding experiments conducted on commercially and ecologically significant organisms to better advance eco-forecasting and socioeconomic modelling efforts. NOAA also continues to incorporate OA data and information into state-of-the-art Earth System Models and Regional Ocean Models for use by scientific and resource management communities. Improving understanding of how OA occurs regionally and teasing out the broad range of vulnerabilities will aid in developing local management and adaptation practices.

1.4 COORDINATION FRAMEWORK

There are currently very few coordinated research and monitoring efforts between the two agencies despite the many shared coastal resources. This Coordination Framework provides a concrete way forward and recommendations to facilitate better coordination. It identifies key areas where the two agencies can work together and may prove beneficial in expanding and refining the broad ranges of research, monitoring, and modelling efforts relevant to improving understanding of OA within Canada and the United States.

During the initial September 2016 meeting, obstacles to DFO-NOAA collaborations and potential ways to overcome them were discussed. The NOAA OAP receives funding directly from the US Congress as a permanent program, whereas DFO OA funding is currently on a 2-5 year cycle with the potential for ongoing funding in the future. As the funding cycles are not coordinated between the United States and Canada, long-term collaborative projects are difficult to manage. Collaboration is made more difficult by limited communications on the specifics of research or monitoring studies, and uncertainty surrounding the points-of-contact for the projects. In most cases, academic partners have more flexibility so, historically, collaboration between NOAA and DFO may have been limited simply because other partners had greater flexibility for travel and collaborative work arrangements with less cumbersome permission processes.

Differences in federal or state/provincial management of a species can make it difficult to understand how best to collaborate and/or share management approaches. For example, lobster is managed at the state level in the US within three nautical miles from shore but at the federal level otherwise and entirely at the federal level in Canada. Therefore, coordinating lobster management is complicated. In respect to coordinating lobster research, DFO scientists need to communicate with researchers in NOAA, and at universities. Complexities of state-level organization, federal responsibility, university involvement, priorities, and management responsibilities might limit opportunities for transboundary cooperation without facilitated long-term relationships in place.

1.5 VALUE PROPOSITION

This Collaboration Framework will address proposed coordination efforts in monitoring; research, modelling, and experimentation; and, data and information sharing between DFO and NOAA. Coordination efforts will be supported by shared expertise, capacity, and methodology; technology development; and platforms, ships, moorings, and laboratories. Improving collaboration on these shared objectives will represent a more efficient use of resources which will benefit both countries through increased capacity and shared knowledge. Results will be used to enhance ocean reporting processes, inform fisheries management of the state and extent of ocean acidification, and further develop adaptation tools to inform decisions related to fisheries and oceans management.

2.0 MONITORING

2.1 INTEGRATED MONITORING

DFO and NOAA both acknowledge the benefits that would come from coordinating monitoring efforts, specifically the development of an integrated monitoring initiative, both with each other and in partnership with academic colleagues. One example of how this could be accomplished is through better coordination of monitoring cruises, individually and between the two agencies. DFO and NOAA could also coordinate static monitoring efforts (monitoring through sensors attached to fixed structures), including sharing equipment, protocols, and data reporting, as is outlined in the NOAA-ECCC MOU. An example of coordinated monitoring (government to government and with academic colleagues) which is already happening is the East Coast OA Cruise funded by NOAA but led by university Principle Investigators (PIs) at the University of New Hampshire. Colleagues from Canadian universities also participated on this cruise in 2015.

A complementary approach is to expand coordination across North America more broadly through the establishment of a North American regional network of the Global OA Observing Network. NOAA PIs are currently working with collaborators in Canada and Mexico to create a construct for a GOA-ON North American regional network. This will not preclude direct NOAA-DFO collaboration but presents another opportunity to share approaches.

Both DFO and NOAA would like to continue to increase the collection of oceanographic data on fisheries cruises, which would be useful for OA monitoring, and further integrating these data into stock assessments. This could be done by adding water sampling to monitoring activities that are already occurring on fisheries cruises. It is also important to expand the monitoring effort during oceanographic cruises to include metrics applicable to biological organisms. This would improve understanding of the environments in which species of interest are found and inform biologically relevant laboratory experimentation for future projection scenarios. In addition data collection, identifying analysis best practices for elucidating connections between changing carbonate chemistry and biological impacts will be necessary.

People living in coastal communities provide a valuable source of data and should be included in OA monitoring efforts. DFO and NOAA agree that it is important to communicate possible impacts of climate change and work with stakeholders to better manage oceans where possible. This could be achieved by supporting community-based monitoring programs, and involving aquaculture and fisheries industries that have broad coastal coverage. This may include monitoring buoys in areas of known commercial importance.

Joint monitoring by DFO and NOAA oceanographic cruises will be coordinated to increase spatial coverage and resolution, and to improve seasonal coverage for comparison and replicability. To the extent possible, DFO and NOAA will coordinate cruises to extend coverage of monitoring transects between Canadian and American waters, and improve time series and trend analysis. An important part of this coordination includes communicating the time and location of cruises, and what metrics will be sampled, in case either agency is interested and able to participate. This will require a strategic approach in order to maximize opportunities and shared expertise with continued forward planning, as often cruises are planned multiple years in advance.

2.2 PRIORITY REGIONS

Certain regions are high priorities for OA monitoring for both DFO and NOAA and will continue to be in the coming years. Coordinating monitoring in these regions is especially important. One means of doing so is to develop regional hubs for collaboration, with priority areas in the Arctic, the Northwest Atlantic, and the Northeast Pacific (including the Gulf of Alaska), and in known 'hotspot' areas for acidification (such as the Pacific). The Great Lakes represent another maritime region with shared interests. These regions represent areas that may be of exceptional commercial value or especially vulnerable to changing conditions associated with OA. In particular, there is a need for more year-round monitoring, near-shore monitoring, and benthic monitoring in coastal areas that are associated with important fisheries and aquaculture activities. This would improve understanding of climate change and OA risks to valuable resources and would help support dependent coastal communities.

The Arctic Ocean is especially susceptible to OA because the cold temperature increases carbon dioxide uptake and lowers carbonate saturation, resulting in a much lower pH and carbonate ion (CO_3^{2-}) concentration than in other oceans. The Arctic is a priority for both DFO and NOAA but monitoring in this area is challenging because of the large and complex area to be covered and hazardous conditions, such as the presence of sea ice, which make it difficult to access. Scientists from DFO and NOAA are participating in a draft science plan for the Synoptic Arctic Survey, a one-time initiative set to take place in 2020/2021, that involves multiple countries and research vessels, to generate a comprehensive dataset that will allow for a complete characterisation of Arctic hydrography and circulation, carbon uptake and OA, tracer distribution and pollution, and organismal and ecosystem functioning and productivity.

Another effort which could benefit from enhanced collaboration is the Distributed Biological Observatory being led by NOAA in the Chukchi Sea. The objective of the DBO is to establish geographically defined transects which various entities can commit to occupying for collection of particular pre-determined data. Information collected at the DBO areas would be made publicly available and broadly shared to all participants. Understanding Ocean Acidification impacts on the ecosystem would likely be furthered through this effort.

A common priority for DFO and NOAA is an interest in monitoring in the Atlantic Ocean focusing on the difference between the north and south oceanographic regions of the Northwest Atlantic. The Northwest Atlantic Ocean is where the highest fisheries landings in Canada occur but the region is understudied and knowledge gaps still exist. In particular, little is known about conditions and effects in the intermediate water. The intermediate water includes any water mass located at intermediate depth in the ocean, below shallow surface waters and above the deeper bottom waters. NOAA has already instrumented ships of opportunity collecting OA relevant parameters in the Northwest Atlantic. The data collected from these efforts are made broadly available. In the future, DFO and NOAA might better coordinate to identify shared needs and collect the relevant data.

To the extent possible, DFO and NOAA will prioritize monitoring in Marine Protected Areas and National Marine Sanctuaries (MPA/S). These are candidate sentinel sites for monitoring long-term changes associated with OA. DFO is currently involved in monitoring within existing MPA/S and is developing a proposed larger network of areas. NOAA is considering similar monitoring for MPA/S off the northwest coast of the US (Olympic Coast). It would be beneficial to work together to determine how monitoring at a sentinel site might be configured.

2.3 BIOLOGICAL INDICATORS

A bioindicator is any biological species or group of species whose function, population, or state can reveal the qualitative status of the environment. DFO and NOAA agree that, when identifying bioindicators, priority will be given to commercially important species, species at risk (i.e. endangered), and critical prey species. Some metrics of bioindicator taxa that have been discussed include survival, biomass/population, spatial distribution, plankton productivity and the ratio of calcifiers to non-calcifiers. It is also important to assess impacts of acidification on primary producers, as they form the base of marine food webs and determine the ecosystem capacity to sustain commercial fisheries. Although more information is required, bivalves could be a potential bioindicator because they are sessile, are worldwide fisheries and aquaculture organisms, have been used for decades in water quality assessments, have known sensitivity to OA, and occur on both Atlantic and Pacific Coasts. Once biological indicators are identified they could be incorporated into routine fishery cruises and management actions. Global networks (e.g., Global Ocean Acidification Observing Network (GOA-ON)) are currently engaged in identifying suitable biological indicators that could be used or modified for DFO and NOAA research.

3.0 RESEARCH, MODELLING AND EXPERIMENTATION

3.1 MODELLING INITIATIVE

Models are needed to better understand patterns and relationships among observations but observations must be in the appropriate format. DFO and NOAA will make efforts to share measurements, estimates of rates, and other parameters for ecosystem models and will coordinate data collection to the fullest extent possible.

Wherever possible, DFO and NOAA will coordinate to connect ocean climate models across regions. Ocean models integrate many different atmospheric and oceanic data, such as atmospheric pressure and temperature, surface winds, salinity, water temperature, ocean colour (indicators of phytoplankton blooms), dissolved oxygen, and carbon parameters. Connecting regional climate models across North America will help to predict the impacts of climate change over larger geographic areas. For example, DFO and NOAA have separate models for the Northeast Pacific: one for Canadian waters off coastal British Columbia and another model for the Pacific Northwest coast in the US. These models could be connected with shared data to better understand regional dynamics of OA effects in the region. DFO and NOAA have regional climate models for the Atlantic and Arctic Oceans that could be connected as well.

3.2 ESTABLISH RESEARCH PRIORITIES

In order to better coordinate research activities, DFO will establish national OA research priorities through the Canadian National OA Working Group, a newly formed group whose main short-term objective will be to develop a National Research Plan. The US already has NOAA-specific and multi-agency research plans and working groups in place. Fishery target species that are research priorities for both agencies include lobster, sea scallops, blue mussels and snow crabs. In the future, DFO and NOAA can collaborate in these shared research priorities through coordinated experiments on the same species from their respective regions.

Some common research priorities in aquaculture that could be further examined for future collaboration include calcite saturation state thresholds for juvenile and adult bivalves, chemistry monitoring in coastal regions, and long-term or multi-life stage effects of OA. In general, higher spatial and temporal resolution coastal monitoring is required to better understand the current OA conditions in areas where important commercial species are fished or cultured.

4.0 DATA AND INFORMATION

4.1 DATA SHARING

Another important aspect of this Coordination Framework is the sharing of data and information. In particular, it will be important to coordinate Carbon and Biological Data Sharing. In Canada, the DFO Science Data Policy states that all data are to be made publically available within 2 years of collection. Currently, some data are available through BioChem, a database developed and maintained by DFO to hold biological and chemical data resulting from department research initiatives or that are collected in areas of Canadian interest. The US Integrated Ocean Observing System (IOOS) and the future Canadian Integrated Ocean Observing System (CIOOS) are examples of ocean data resources. In addition, all projects funded by the NOAA Ocean Acidification Program are required to archive data in the NOAA National Centers for Environmental Information's Ocean Acidification Data System (OADS). In the future, DFO and NOAA will use existing portals to make their data available for sharing as soon as possible within the regions and between the two agencies. Both agencies will contribute, to the extent possible, to the Global Ocean Acidification Observing Network (GOA-ON) with aims to improve international OA data sharing efforts and make observing data from respective national data archives more accessible.

4.2 INVENTORIES OF SCIENCE CAPACITY

In order to improve coordination of research and monitoring activities both agencies will create inventories of their existing science capacity, similar to current regional efforts through the Pacific Coast Collaborative Ocean Acidification and Hypoxia West Coast Monitoring Inventory. An inventory will be created of all OA manipulation facilities, including details about species being studied, co-stressors being manipulated, experimental designs, and response variables being measured. Another inventory will be created that lists OA analytical chemistry facilities including details about the parameters and instruments being used. A third inventory of OA researchers working at DFO and NOAA will be compiled which will include researchers' biographies, species studied, response variable, location, and any other relevant details. These inventories will aid communication between DFO and NOAA, as well as with internal and external partners in academic institutions and other stakeholder communities. NOAA is leading the development of a new web based platform – the OA Information Exchange – that may facilitate this sharing.

4.3 COMMUNICATION

Improving and facilitating communication between DFO and NOAA is essential for future coordination. The governance structure of a DFO-NOAA Ocean Acidification Coordination Committee and two working groups will be established (Annex) to continue discussions and to develop more concrete plans for the future. Regional hubs may also be created within the monitoring working group to connect scientists working in the same region who might face similar challenges, such as the Arctic, Northwest Atlantic, and Northeast Pacific.

It is important to improve and continue communication within and between DFO and NOAA for more interaction between the two agencies as well as with the regions and the non-science client sectors. To expand on this idea, scientists at DFO and NOAA need to develop science plans in partnership with the client sectors in order to improve communication on clients' needs and data sharing. NOAA has a communication model in place through a series of Coastal Acidification Networks (CAN) that encompass clients, scientists, and government managers. These CANs support this communications goal and NOAA will share information with DFO to help improve communications among interested regional parties in Canada, especially for informing management and other fisheries sectors and OA research findings in their respective sectors. Additionally, the Marine Environmental Observation Prediction and Response Network (MEOPAR) is currently gauging interest in developing a Canadian Community of Practice on OA which could help to improve communication within Canada.

5.0 SUPPORTS FOR COLLABORATION

5.1 BEST PRACTICES

DFO and NOAA would benefit from coordination in the establishment and use of shared protocols for best practices. DFO and NOAA will explore possible intercalibration exercises and calibration experiments. To their best ability, both agencies will establish methodologies and procedures according to the Guide to Best Practices for Ocean CO_2 Measurements (http://cdiac.ornl.gov/oceans/Handbook_2007.html). To aid in this process, scientists from DFO might attend workshops at the Scripps Institution of Oceanography with Andrew Dickson, as space and funding allow.

In general, both DFO and NOAA can work together to better coordinate platforms, synchronize and calibrate instrumentation according to established Best Practices.

5.2 SHARING CAPACITY, EXPERTISE, AND METHODOLOGIES

Coordination efforts between DFO and NOAA will be supported by sharing capacity, expertise, and methodologies. Efforts will focus on exchanging human resources to maximize the use of existing facilities. New DFO funding is available for learning opportunities and the exchange of scientists internationally through the Partnership Fund which can be used to support the sharing of capacity and expertise with NOAA and the US. Early career scientist exchanges or interchange of employees for temporary assignments (e.g. Interchange Canada) is encouraged to support exchange of knowledge and improving networks between DFO and NOAA.

5.3 OTHER PARTNERS

Further coordination and cooperation with University-based researchers and non-governmental organisations will be explored to support DFO-NOAA efforts. A notable potential partner is the Marine Environmental Observation Prediction and Response Network (MEOPAR), a national network that was established in 2012 to reduce vulnerability and strengthen opportunity in Canada's marine environment. MEOPAR has been renewed for funding for a second five year cycle and will continue to treat OA as a priority research area, as it did during its initial five year funding cycle that began in 2012. A number of scientists from DFO participate in the MEOPAR OA projects and NOAA-funded US scientists serve on its advisory board. MEOPAR projects have begun to study OA in the Atlantic and the Pacific coasts and its impact on organisms/ecosystems and people who depend on them, though they are not yet at the stage of advising governmental resource management.

5.4 TECHNOLOGY

In many cases, monitoring efforts are limited by ineffective technology. To the extent possible, DFO and NOAA will collaborate by sharing knowledge and expertise in technology development. For example, new technology is required to better study the benthos and subsurface water column as well as the biology of toxic algal blooms. DFO and NOAA will share information on sensor performance and availability of less-costly technology to constrain carbonate chemistry, especially systems which might measure at least two carbonate measurements (such as the partial pressure of CO_2 (pCO_2) and Dissolved Inorganic Carbon (DIC), or Total Alkalinity (TA) and pH) simultaneously and in a highly accurate way. Technologies suitable for citizen science efforts should also be included to enable quality data collection from more locations. In addition to the sharing of information, DFO and NOAA can standardize the calibration of sensors to the extent possible, which will lead to a more consistent sampling regime and more comparable results between countries.

5.5 PLATFORMS, SHIPS, MOORINGS, AND LABORATORIES

To support coordination efforts, DFO and NOAA agree to share research platforms such as ships, moorings, and laboratories to the extent possible. A plan will be developed to coordinate the timing of cruises, and access to berth spaces of the ships will be provided as needed. Given that scientists, at least in the US, must start securing ship time two years ahead, this coordination will require a long lead time. The coordinates of existing moorings will be shared and maintenance help can also be provided if needed. Access to laboratories, such as the St. Andrews Biological Station, will be encouraged to promote the opportunity to work together on large multifactorial experiments, further supporting research coordination between DFO and NOAA and enabling more efficient determination of biological impacts and potential mitigation strategies.

6.0 CONCLUSION

6.1 SUMMARY OF ACTIONABLE ITEMS

A governance structure has been developed to implement the steps outlined in this Coordination Framework (Annex). Working groups will be established in 1) monitoring; and 2) research, modelling, and experimentation (Annex). For example, the monitoring group will coordinate the timing and capacity of planned cruises and identify opportunities for collaboration. The two working groups will be coordinated by an overarching DFO-NOAA Ocean Acidification Coordination Committee that will provide central leadership and promote communication between the working groups (Annex).

DFO will establish a National Research Plan for Ocean Acidification which will help to establish priorities on a national level that can later be expanded to determine further shared research priorities with NOAA. DFO and NOAA will use existing data portals, including the GOA-ON portal, to promote broad sharing of OA information between the two countries and provide web-based information exchange. Inventories of science capacity of both agencies will also be created and shared to promote communication and coordination.

Better coordination between NOAA and DFO will benefit both countries by providing increased capacity and sharing knowledge to improve understanding of OA within Canada and the United States. Effective bilateral collaboration will represent a more efficient use of resources in pursuit of the shared objectives identified above because of the many shared commercially important species and contiguous coastlines, and because of the similar ongoing monitoring and research activities in Canada and the US. Actionable items will continue to be identified to determine a concrete way forward for both agencies.

6.2 FUTURE MEETINGS

DFO and NOAA commit to enhancing cooperation on oceans and climate change, and finding new ways to work together on monitoring and researching the impacts of ocean acidification. Going forward, meetings will be held as needed to continue discussions on coordinated research and monitoring, and on progress made since the most recent meeting.

ANNEX: GOVERNANCE

Fisheries and Oceans Canada (DFO)

At DFO, ocean acidification work is carried out nationally through the Aquatic Climate Change Adaptation Services Program (ACCASP) within the Ecosystems and Oceans Science Sector of DFO and coordinated by the Ocean Sciences Branch in national headquarters. The mission of ACCASP is to conduct the science, research and monitoring necessary to identify climate change impacts and vulnerabilities, develop adaptation tools, and improve ocean forecasting in vulnerable coastal regions to inform Departmental decisions related to adapting fisheries and oceans management and coastal infrastructure. At the national level, the Assistant Deputy Minister (ADM), Ecosystems and Oceans Science (EOS), has the overall accountability for ACCASP development and delivery. At the regional level, the Regional Directors of Science (RDSs) are responsible for the Program delivery and have a line reporting relationship to Regional Director Generals. The RDSs also take part on the Science Executive Committee (SEC) which is chaired by the ADM EOS and is responsible for resource allocation as well as setting the direction and monitoring the performance of all Science programs.

The Ocean Sciences Branch (OSB) of the Ecosystem Science Directorate located in National Headquarters is responsible for the overall coordination and national delivery of the program, providing national policy direction, strategic advice, and liaison with other DFO sectors, federal departments, provincial governments, national industry, non-governmental organizations and international bodies (e.g. IOC). Also part of OSB is the Marine Environmental Data Section (MEDS), which is responsible for managing, long-term archiving and disseminating in situ ocean data collected by DFO and real-time data acquired through national and international programs.

The majority of Ocean Acidification activities take place in the regions. Ocean Acidification research scientists & technical staff are mainly located in seven regional science institutes: the North West Atlantic Fisheries Centre in St. John's Newfoundland; The Freshwater Institute in Winnipeg, Manitoba; the Bedford Institute of Oceanography in Dartmouth, Nova Scotia; the St. Andrews Biological Station in St. Andrew's New Brunswick; the Maurice Lamontagne Institute in Mont-Joli Quebec; the Pacific Biological Station in Nanaimo; and the Institute of Ocean Sciences in Sidney, British Columbia. The regional science institutes are responsible for data collection, quality control and submission to data centres.

National Oceanic and Atmospheric Administration (NOAA)

The NOAA Ocean Acidification Program (OAP) is part of NOAA's Oceanic and Atmospheric Research (OAR) line office. The mission of OAP is to better prepare society to respond to changing ocean conditions and resources by expanding understanding of ocean acidification, through interdisciplinary partnerships, nationally and internationally. OAP activities are guided by the OAP Director, who reports to the Assistant Administrator for OAR.

OAP leads ocean acidification activities across NOAA including in collaboration with NOAA Fisheries and funds investigators at NOAA-affiliated labs across the U.S. and at academic institutions through Federal

Funding Opportunities (FFOs). OAP also collaborates with other federal agencies such as the US National Science Foundation, NASA, and the US Geological Survey, on OA research through the Interagency Working Group on Ocean Acidification (IWG-OA), which is chaired by the OAP director, and partners with a range of stakeholders including academic institutions, cooperative institutes, fishers, and hatchery owners.

OAP, in collaboration with the NOAA Integrated Ocean Observing System (IOOS) supports regional associations including Coastal Acidification Networks (CANs), and the Pacific Coast Collaborative in their OA observing inventory activities. Internationally, OAP is a major contributor to the Global Ocean Acidification Observing Network (GOA-ON).

ECCC-NOAA Memorandum of Understanding

Ocean acidification is one of the thematic areas for collaboration included under the Memorandum of Understanding (MOU) between NOAA and the Department of the Environment and Climate Change Canada (ECCC) for Collaboration on Weather, Climate and Other Earth Systems for the Enhancement of Health, Safety and Economic Prosperity. The DFO-NOAA OA Coordination Committee will be governed according to the MOU and will report to the ECCC-NOAA Cooperation Steering Committee (CSC), which is responsible for the oversight and coordination of the activities under the MOU.

The following diagram illustrates a proposed new governance structure for the DFO-NOAA Collaboration Framework which will be implemented in 2017. This work will include finalizing the governance model and the formation of the required governance committees with Terms of Reference identifying mandate, accountabilities, decision making processes, criteria for priorities, communication, reporting, etc.

Governance Model