Fisheries and Oceans Canada | Pêches et Océans Canada

OVERVIEW OF FEDERAL OCEAN ACIDIFICATION ACTIVITIES









Canada

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FOREWORD

Ocean acidification is a pressing challenge for Canada's oceans. Fisheries and Oceans Canada (DFO) is committed to keeping Canadians informed about the state of the oceans. The *Overview of Federal Ocean Acidification Activities* was created by DFO, with input from Environment and Climate Change Canada (ECCC). It highlights current federal science activities and commitments to advance understanding of ocean acidification.

OCEAN ACIDIFICATION IN CANADA

Ocean Acidification and Changing Climate

Ocean acidification[1] is happening in all three of Canada's oceans. To understand it, we first need to understand how climate change, which includes ocean acidification, is occurring.

Human activities such as energy production, transportation, and agriculture rely heavily upon fossil fuels. Burning these fuels releases greenhouse gases like carbon dioxide into the atmosphere. These gases build up and trap heat, causing Earth's climate to become warmer over time. This in turn changes weather patterns and ocean conditions, affecting the regions in which humans and other living things live. This long-term change to our world is known as climate change.

Oceans play a very important role in maintaining Earth's climate. They have helped buffer some of the effects of climate change. So far, the oceans have absorbed more than 90% of excess heat, and have likely stored more than 30% of the carbon dioxide released from the burning of fossil fuels.[2] Absorbing excess heat has made the oceans warmer over time and is changing how the ocean waters mix.

"Oceans play a very important role in maintaining Earth's climate."

As excess carbon dioxide from human activities continues to dissolve in the oceans, they are becoming increasingly acidic (lower in pH). This process is called ocean acidification. Ocean acidification, warmer ocean temperatures, and other climate change-related effects like lower oxygen levels in seawater are happening at the same time. This can negatively affect marine life, as well as the people who depend upon the oceans for food, livelihood and community.

Impact on Marine Life

Ocean acidification can have negative effects on marine life, including algae, corals, fish, plants, and shellfish, and can especially affect the early life stages of animals. It can also affect all levels of the food web, and can cause ripple effects throughout marine ecosystems.

Ocean acidification can affect:

- Calcification
- Growth and development
- Survival
- Reproduction
- Ability to deal with other stresses in their environment, such as warmer temperatures or diseases
- Ability to turn food into energy





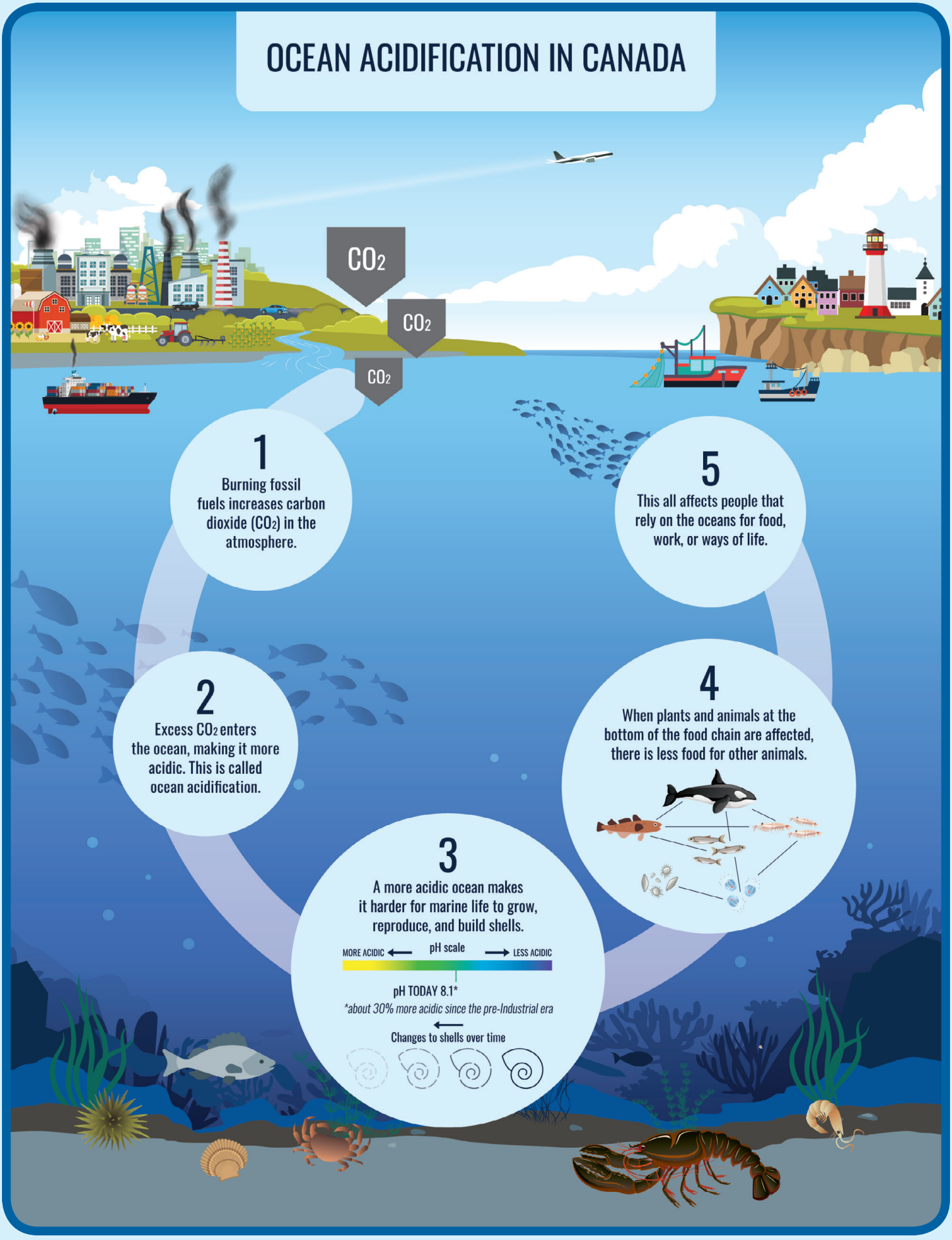
What is Calcification?

Calcification is when living things make their shells (for example, oyster and crab) or other hard body parts such as bones and skeletons (for example, corals). Calcification happens throughout their lives as they grow, and as they maintain and repair their bodies.

A more acidic ocean makes it harder for marine life to build shells, grow, and reproduce.

Shellfish, such as mussels, clams, oysters, and scallops, are especially affected by ocean acidification. These are important animals that are harvested recreationally, and as part of fisheries and aquaculture activities in Canada.[3]

Shellfish are among many other marine species that are also important as sources of food and employment for Indigenous peoples and coastal communities. When these species are negatively affected by ocean acidification, there are knock-on effects for these people and their local economies.


OCEAN ACIDIFICATION IN CANADA
CO2
CO2
CO2
1
Burning fossil fuels increases carbon dioxide (CO2) in the atmosphere.
2
Excess CO2 enters the ocean, making it more acidic. This is called ocean acidification.
3
A more acidic ocean makes it harder for marine life to grow, reproduce, and build shells.
MORE ACIDIC
pH scale
LESS ACIDIC
pH TODAY 8.1*
*about 30% more acidic since the pre-Industrial era
Changes to shells over time
4
When plants and animals at the bottom of the food chain are affected, there is less food for other animals.
5
This all affects people that rely on the oceans for food, work, or ways of life.

For simplicity, in this document the term "ocean acidification" will be used for all declines in pH across marine environments. This includes coastal acidification.

Factors Influencing Ocean Acidification in Canada

Canada has the world's longest coastline, bordering the Arctic, Atlantic, and Pacific oceans. Each ocean region has its own unique conditions and drivers, which means that the level and the impact of ocean acidification can vary from one region to another. For example, areas with colder waters are more vulnerable to acidification, because they absorb carbon dioxide more readily. Some regions — such as coastal areas, and where rivers meet the sea — may see greater, more rapid changes in acidification (called coastal acidification), due to local factors. These factors are not fully understood.

Condition: Coastal Acidification

Coastal acidification can result in faster and greater changes in acidification around shorelines and areas where rivers and oceans meet.

Levels of coastal acidification can be affected by:

- Fresh water from rivers
- Plants and soil from the shore entering the water
- Wastewater from treatment plants
- Nutrient runoff from farming or watersheds

The Main Factors Influencing Acidification Levels in Canada's Oceans

Along the outer coast of the Pacific Ocean, seasonal upwelling from northwest winds brings subsurface ocean waters to the surface. These waters from below are rich in nutrients but are also naturally more acidic. When this natural process combines with climate change, it can amplify ocean acidification in the region.

Cold waters absorb carbon dioxide more readily. This means that areas with colder water, like those in the Arctic, are more vulnerable to ocean acidification. In the Canadian Arctic, rising air temperatures are leading to more ice-free days on the ocean, as well as more fresh water from rivers and melting ice. All these factors, along with the addition of more acidic water from the Pacific Ocean, worsens the state of acidification in the Arctic Ocean.

In the Canadian Atlantic, many factors affect acidification levels. These factors include: the inflow of cold, acidic water from the Arctic; fresh water from rivers; and winter mixing in the deep waters of the Labrador Sea. Together, they contribute to the lower pH levels observed in this region.

Government Initiatives to Reduce Impact

Recognizing the risk of climate change to ecosystems, the Government of Canada is committed to mitigating its impact through a number of initiatives. Federally, many initiatives that help reduce greenhouse gas emissions, which is the primary cause of ocean acidification, are led by Environment and Climate Change Canada (ECCC). Because carbon dioxide is a greenhouse gas, reducing these emissions will help reduce future levels of ocean acidification.

Some initiatives are national and some are international:

- *Canadian Net-Zero Emissions Accountability Act*[4]
- 2030 Emissions Reduction Plan[5]
- *Canada's Climate Plan*[6]
- *Pan-Canadian Framework on Clean Growth and Climate Change*[7]
- *Paris Agreement* (under the United Nations Framework Convention on Climate Change)[8]
- United Nations 2030 Agenda for Sustainable Development and its Sustainable Development Goals[9]

The Department of Fisheries and Oceans Canada (DFO) manages Canada's oceans and aquatic ecosystems and associated resources. This includes leading national scientific efforts to monitor changes in ocean acidification, and how marine life may be affected by it. This document highlights some of DFO's scientific research and commitments on ocean acidification.

Aquatic Climate Change Adaptation Services Program[10]

Within DFO, the Aquatic Climate Change Adaptation Services Program helps coordinate knowledge, advice, and progress related to climate change science. Ocean acidification is one of the topics they coordinate through their themes of monitoring, vulnerability assessments and modelling.

SCIENCE ACTIVITIES AND COLLABORATIONS

Monitoring Ocean Conditions

Across Canada, DFO scientists study chemical changes in Canada's oceans, both near and far from the shore, by collecting a wide variety of important measurements from seawater samples, including **pH, carbon dioxide and oxygen levels, temperature, and salinity**.

The seawater samples that are collected can be tested on ships at sea, or taken back to the laboratory and analysed in laboratories on land. These measurements also provide information on regional changes or short-term localized events that might be affecting seawater properties and, subsequently, local ecosystems. Data collected on these long-term monitoring programs are critical to understand how oceans are changing over time, and provide valuable data that are used in science-informed decision making at DFO and other organizations.

Scientists collect and analyse seawater using different methods:

- instruments that are lowered into the ocean from ships sailing along a designated route;
- instruments attached to moorings or buoys that stay in place in the ocean;
- facilities along the coast, such as laboratories; and
- underwater robotic vehicles or gliders that move through the water to collect information.



Stationary solar-powered buoy



Remote-controlled glider



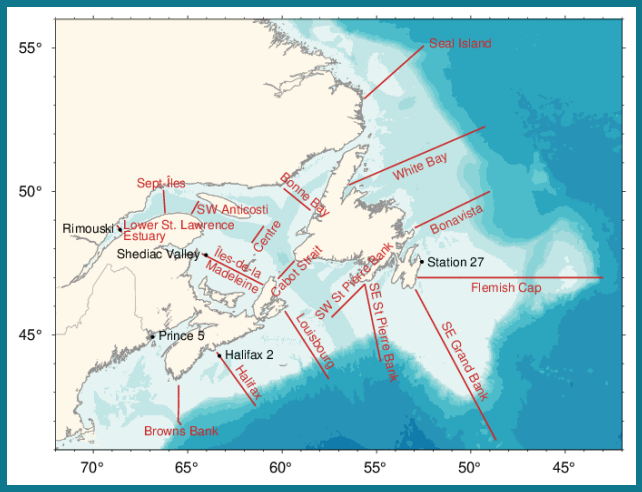
Canadian research vessel

DFO has two of the longest-running ocean chemistry programs in the world. The records they provide include information on ocean acidification. They are the Atlantic Zone Monitoring Program, and the Line P program.

Atlantic Zone Monitoring Program[11]

The Atlantic Zone Monitoring Program takes measurements along set routes near Canada's Atlantic Coast, and from stations near the shore, as indicated on the map. It began in 1998, making it one of the oldest DFO monitoring programs. Monitoring of ocean acidification began in 2014. Offshore regions of the Atlantic Ocean are monitored by the Atlantic Zone Off-Shelf Monitoring Program.[12]

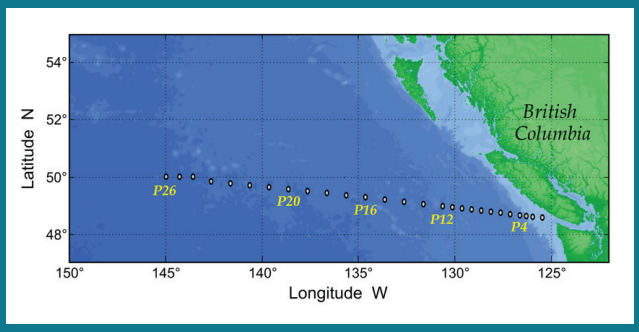
Reports containing the data collected by this program are available to the public.



Atlantic Zone Monitoring Program sampling routes (red) and high frequency monitoring stations (black)

Line P Program[13]

The Line P Program takes samples of seawater from a set of stations in the Pacific Ocean, as shown on the map. It started in 1956, making it one of the oldest ocean monitoring programs in the world. Sampling to study ocean acidification began in the 1970s.



Sampling stations for the Line P Program

This sampling program is a collaboration between scientists from DFO and other organizations. They work together to collect the samples and analyse them based on their area of expertise or research need. The high-quality data that have been generated over several decades makes this program a very important resource for studying changes in the oceans.

The Importance of Monitoring

Ocean monitoring programs, especially long-term ones, are valuable resources for understanding how the oceans work, change, and affect Earth's climate. These programs support science-informed decision making. They help show trends in ocean acidification and provide information needed to project future conditions. They also help scientists to determine if there are areas of the oceans that may be more vulnerable to ocean acidification than others in the future.

Global and Canadian Trends in Ocean Acidification

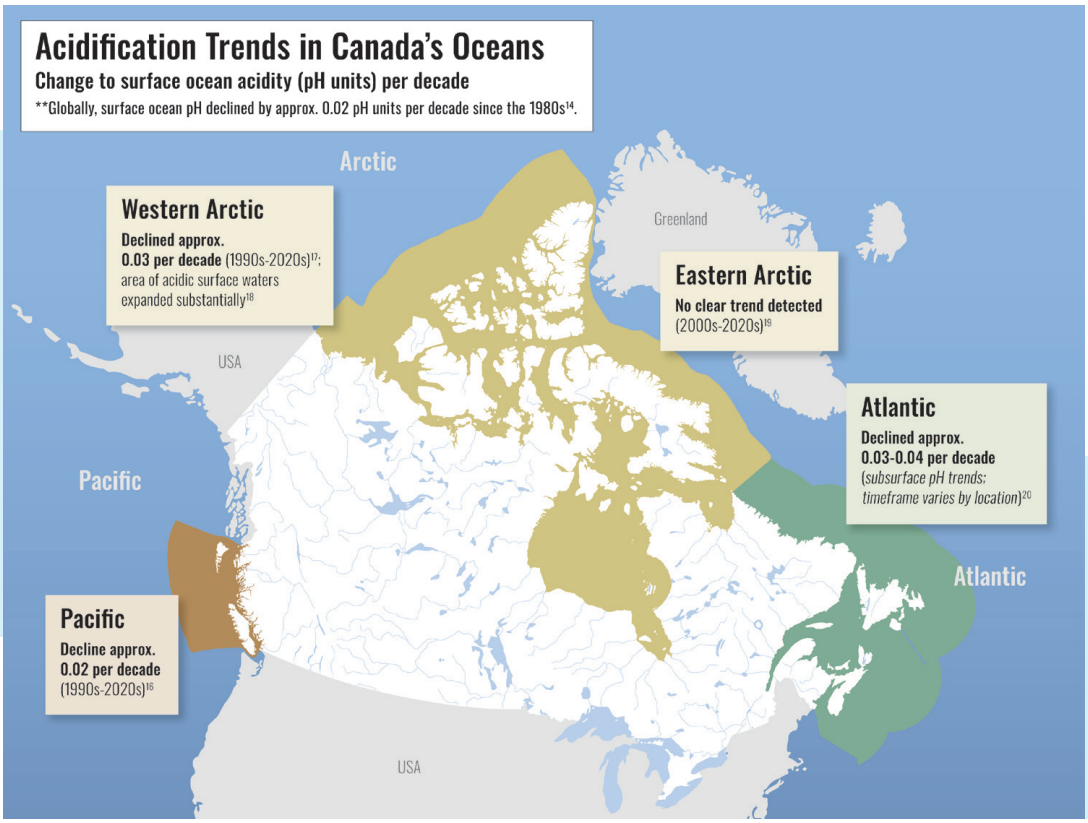
"Rate of decline in pH in Canada varies from region to region, and with water depth."

Since industrialization began in the 1760s, carbon dioxide emissions from fossil fuels have been increasing. Measurements show that this has led to seawater becoming more acidic around the world.

Ocean acidification is often described in terms of units on the pH scale. As the numbers on the scale go down, it means that the liquid being measured is more acidic (see Ocean Acidification in Canada infographic for pH scale).

Since the Industrial Revolution, the surface layer of ocean water around the world has declined from pH 8.2 to pH 8.1.[14] Although this change may seem small, it means that seawater is about 30% more acidic than it was before.[15]

From long-running monitoring programs such as the Atlantic Zone Monitoring Program and the Line P Program, scientists have discovered that the **rate of decline in pH in Canada varies from region to region, and with water depth**. See infographic below for a quick summary of acidification trends in Canada's Oceans.[14,16-20]



Vulnerability Research

Across DFO laboratories in Canada, scientists study how ocean acidification may affect marine life, specifically assessing the vulnerability of marine species to changes in their environment. These studies focus on how marine life might be affected, both now and in the future.

Their research focuses on marine species at different life stages, including very young life stages (babies or eggs), juveniles, and adults. During the experiments, species are exposed to laboratory environments that mimic current and future ocean conditions, including ocean acidification, often along with other environmental factors (such as warming or diseases). Using a variety of tests and methods, scientists track species responses such as:

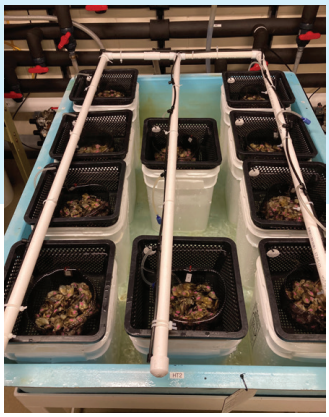
- How many survive
- How fast they grow
- Whether they develop normally

These experiments help scientists understand which species are more at risk due to ocean acidification and other changes in the environment. They can help scientists identify whether a species might struggle, which might adapt and survive, and which might thrive as the oceans change in response to climate change.

The results are then used in vulnerability assessments, which are studies that summarize how sensitive a species is to various threats (such as increasingly acidic waters), and how serious the impact could be. These assessments help inform decisions about managing Canada's fisheries, aquaculture, and marine conservation.







Understanding Future Ocean Conditions

Ocean acidification is expected to keep increasing around the world, making conditions difficult for marine species that cannot adapt.

Faced with this challenge, scientists use computer models to better understand what this means for Canada's oceans, both now and in the future. These ocean models help project how ocean acidification levels could change over time with different levels of carbon dioxide in the atmosphere. These models are built and tested using measurements collected from Canada's oceans.

DFO scientists contribute to global ocean-climate models and projections that are produced and managed by ECCC.[21] Data collected by DFO are used to evaluate and inform the models.

Large-scale models are useful for showing general trends, but they do not provide enough detail to indicate how ocean conditions might affect local fish populations or habitats, at a scale that can be used for decision making. To meet DFO's needs, scientists downscale ECCC's global ocean-climate models to create more detailed, regionally-relevant models.

Downscaling

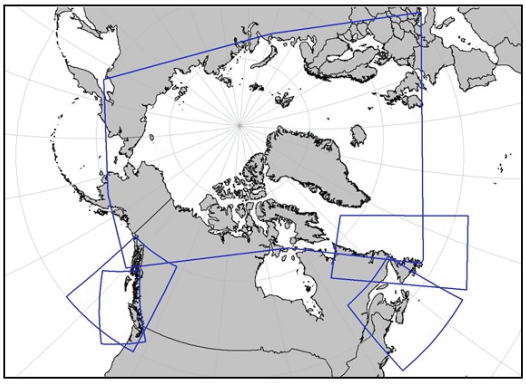
Downscaling is when scientists run localized models that allow details to emerge that are smoothed out by large-scale models. This helps make the results more accurate and relevant for smaller areas, which is important when providing scientific advice.

When these computer models include chemical information such as acidification and lower levels of the food web, such as plankton (see Ocean Acidification in Canada infographic for food web), they are called biogeochemical models. Information from these models is used to support laboratory studies, to test a range of future scenarios, and to inform climate-vulnerability assessments and decision making related to fisheries and aquaculture.

Climate and biogeochemical computer models have been developed for Canada's Pacific, Arctic, and Atlantic oceans.[22, 23, 24]

These computer models tell us that some regions of the Arctic and Atlantic oceans are already at risk from ocean acidification, and that some shallow nearshore areas of the Pacific Ocean are experiencing accelerating ocean acidification.

These models also suggest that, in the future, ocean acidification will continue in all of Canada's oceans which, in turn, increases the risks for sensitive species.



Canadian regions used in computer models[23]

Learning About Ocean Acidification Together

DFO does not work alone on advancing scientific understanding of ocean acidification. There are a number of partnerships and committees that coordinate and share scientific information about ocean acidification and other climate change effects. Whether within government, with national and international organizations, between foreign governments, or with people who live in Canada, these collaborations help spread knowledge and understanding about ocean acidification, and guide adaptation planning.

Indigenous Knowledge and Collaborations

Knowledge gained through partnerships, engagement, and collaboration with Indigenous communities helps scientists develop a better understanding of how ocean acidification is affecting marine species and ecosystems. This exchange benefits all involved, and plays a key role in shaping DFO's scientific research, planning, and decision making for sectors such as fisheries and aquaculture, or marine conservation. In remote, understudied regions such as the Arctic, knowledge-sharing and partnerships are important for gaining insights into past events and recent observations, and to advance current understanding.

DFO scientists and collaborators improve understanding of ocean acidification and its impact by sharing observations and resources, and by collecting biological, physical, and chemical data (such as pH, temperature, and salinity) through a range of initiatives and programs. Examples include the Canadian Rangers Ocean Watch program,[25] the Coastal Environmental Baseline Program,[26] the Aquatic Climate Change Adaptation Services Program,[10] the co-management of marine protected areas,[27] and collaborations with local governments and community organizations such as the Nunatsiavut Government and Haida First Nation,[28] and local hunters and trappers' organizations.

This exchange can help guide science and decision making that weaves together all perspectives and knowledge systems.

Non-Governmental Organizations, Universities, Industry and More

Federal departments work with many partners and organizations that focus on the topic of ocean acidification. These organizations are located both within and outside of Canada. Examples include, but are not limited to, universities, industry, non-profit organizations, provincial groups and governments, and local groups.

Working with these organizations, such as the Canadian Ocean Acidification Community of Practice,[29] helps improve everyone's understanding of the impact of climate change on marine ecosystems. These initiatives aim to increase understanding, knowledge-sharing, and collective action on ocean acidification.

North American

DFO also plays a leading role in advancing ocean acidification research on the continent. DFO scientists are part of the Global Ocean Acidification Observing Network's North American Hub,[30] which supports continental collaboration and shared approaches. Knowledge-sharing and scientific advancement also occur with other international federal agencies — such as the Ocean Acidification Collaboration between DFO and National Ocean and Atmospheric Administration (NOAA).[31]

International

Federal departments also contribute ocean acidification knowledge to international assessments and advisory reports administered by international organizations. These include the Arctic Monitoring and Assessment Program,[32] the Intergovernmental Panel on Climate Change Assessment Reports,[33] and the Intergovernmental Platform on Biodiversity and Ecosystem Services.[34]

SCIENCE GUIDANCE, INTERNATIONAL ENGAGEMENT, AND DATA ACCESS

Science Informs Decision Making

DFO provides scientific expertise to inform federal government priorities for current and emerging aquatic climate change research, including ocean acidification. This ensures that federal climate change research is aligned with the science advice needed to inform government decision making in aquatic environments. The 2025 DFO Climate Change Science Needs Evaluation Technical Report[35] provides an analysis of the science needed to support climate resilient planning.

Scientific information, such as ocean observations, modelling studies and climate-vulnerability assessments, is used to generate advice, including through the DFO science advisory process,[36] to help support science-informed decisions about managing oceans, fisheries and aquaculture in Canada.



Federal Departments also provide information on ocean acidification status in national climate reports such as the State of Canada's Oceans reports[37] and Canada's Changing Climate Report.[38]

Federal scientists have also provided advice and contributed to related initiatives such as the development of the British Columbia Ocean Acidification and Hypoxia Action Plan,[39] and a publication titled: "Ocean acidification in Canada: the current state of knowledge, and pathways for action."[40]

Ocean acidification action plans can explain the steps needed to better understand the issue and respond to its impact. These Action Plans can be used to focus on how ocean acidification can affect a particular region, while also providing avenues and steps to take to enable more detailed adaptation and resilience planning. British Columbia is the first province or territory in Canada to develop an ocean acidification action plan: the British Columbia Ocean Acidification and Hypoxia Action Plan.[39]

On the International Stage

DFO advances understanding of ocean acidification around the world by being a part of many international efforts. DFO scientists and policymakers contribute to several multidisciplinary collaborations. Some of the projects and initiatives are undertaken as part of the United Nation's (UN) Ocean Decade: Ocean Acidification Research for Sustainability Program.[41] This program aims to coordinate science and knowledge mobilization on ocean acidification.

With national coordination, DFO also contributes acidification data from each of Canada's oceans to the UN Sustainable Development Goal (SDG) Indicator 14.3.1. This Indicator supports SDG Target 14.3: "Minimize and address the impact of ocean acidification, including through enhanced scientific cooperation at all levels."[42]

In addition, Canada adopted the Kunming-Montreal Global Biodiversity Framework,[43] which includes a target that calls upon countries to reduce the effects of climate change and ocean acidification on biodiversity, and to strengthen ecosystems using nature-based solutions and climate actions.

DFO also participates in the OA Alliance's Leadership Circle (International Alliance to Combat Ocean Acidification).[44] This initiative brings together governments and organizations from around the world to discuss efforts towards minimizing ocean acidification.

DFO Ocean Acidification Data

The Open Data Policy of the Government of Canada promises that the federal government will make scientific data accessible and usable. As part of this, DFO is committed to widely sharing ocean acidification information with the public.

Information related to the impact of ocean acidification on marine life can often be found in scientific publications and synthesis reports, such as those on the DFO Publications website.

Ocean acidification data can also be found on various Canadian and international platforms, such as:

- Canada's federal Open Data Portal[45]
- DFO's Biological and chemical marine data: BioChem database[46]
- DFO's Marine Environmental Data Program[47]
- Canadian Integrated Ocean Observing System[48]
- Ocean Carbon and Acidification Data System[49]
- Surface Ocean CO_2 Atlas[50]
- Global Ocean Acidification-Observing Network[51]
- Global Ocean Data Analysis Project[52]

ONGOING AND FUTURE WORK







DFO is committed to supporting healthy and productive oceans, through sound science including conducting research on factors that affect ocean health including climate change and ocean acidification.

Monitoring and research on climate change and ocean acidification help Canadians understand how Canada's oceans are changing, and how these changes affect marine life. It also helps us to understand how changes to Canada's oceans can affect people who live, work, or spend time around the ocean.

There are many data gaps that remain on ocean acidification, and areas that can be advanced include:

- Continued measurements of seawater conditions in the Pacific, Atlantic and Arctic oceans. Consistent collection of these long-running measurements is critical to understanding changes in the environment.
- Measurements of coastal acidification along Canada's three coasts. This is important because coastal acidification differs from place to place along Canada's extensive coastline.
- Increased knowledge about special-interest areas. Examples include ecologically- and biologically-significant areas, conservation areas, key fisheries-recruitment areas, and aquaculture-production areas.
- Research on how ocean acidification, when combined with other climate change factors such as warming and climate extremes, affect marine species. This includes understanding how well the species can tolerate changes to their environments, the ranges where they can live, and how species composition in an ecosystem may change.
- Research on the vulnerability of marine species, at their various life stages, to ocean acidification and ocean extremes, including species that are socially, culturally, or economically important. This information can help provide advice on marine management.
- Continued work with ECCC to update and improve ocean biogeochemical models, when new climate data are available. This work will include models for coastal areas. Well-informed and better biogeochemical models will result in better assessments of future risks to ecosystems.
- Continued collaboration with other scientists and partners to increase collective knowledge about the impact of ocean acidification. These collaborations can include scientists from within DFO, in Canada, or around the world.
- Investigation of how known and emerging ocean carbon-mitigation activities may affect marine life and ocean chemistry at small and large scales.

Ocean carbon and climate mitigation approaches include blue carbon ecosystems and marine carbon dioxide removal and storage strategies such as:

- **Ocean alkalinity enhancement**
- **Ocean nutrient fertilization**
- **Seaweed cultivation and sinking**
- **Direct ocean carbon capture and storage**
- **Artificial upwelling and downwelling**
- **Offshore carbon capture and storage**

ACKNOWLEDGEMENTS

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We are grateful for the input from colleagues at Environment and Climate Change Canada.

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3	National Statistics for Aquaculture, Commercial fisheries, Recreational fishing, Trade, and Marine sectors in Canada	https://www.dfo-mpo.gc.ca/stats/stats-eng.htm
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6	Canada's Climate Plan	https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan.html
7	Pan-Canadian Framework on Clean Growth and Climate Change	https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html
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32	Arctic Monitoring and Assessment Programme	https://www.amap.no/publications?keywords=ocean+acidification&type=
33	The Intergovernmental Panel on Climate Change	https://www.ipcc.ch/
34	Scientific outcome of the IPBES-IPCC co-sponsored workshop on biodiversity and climate change	https://zenodo.org/records/5101125
35	DFO Climate Change Science Community Needs Evaluation 2025	https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41307537.pdf

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36	Canadian Science Advisory Secretariat (CSAS)	https://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm
37	State of Canada's Oceans	https://www.dfo-mpo.gc.ca/oceans/soto-rceo/index-eng.html
38	Canada's Changing Climate Report	https://changingclimate.ca/CCCR2019/
39	British Columbia Ocean Acidification and Hypoxia Action Plan	https://www2.gov.bc.ca/assets/gov/environment/climate-change/adaptation/climate-risks/bc-ocean-acidification-hypoxia-action-plan.pdf
40	Ocean Acidification in Canada: The Current State of Knowledge and Pathways for Action	https://doi.org/10.3389/fmars.2026.1761703
41	UN Ocean Decade Ocean Acidification Research for Sustainability Program	https://oceandecade.org/actions/ocean-acidification-research-for-sustainability-oars/
42	United Nations Sustainable Development - Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	https://sdgs.un.org/goals/goal14
43	Kunming-Montreal Global Biodiversity Framework	https://www.cbd.int/gbf
44	International Alliance to Combat Ocean Acidification	https://www.oaalliance.org/
45	Government of Canada Open Government Portal	https://search.open.canada.ca/opendata/
46	Biological and chemical marine data: BioChem database	https://www.dfo-mpo.gc.ca/science/data-donnees/biochem/index-eng.html
47	Marine Environmental Data Program	https://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/program/index-eng.html
48	Canadian Integrated Ocean Observing System	https://cioos.ca/
49	Ocean Carbon and Acidification Data System	https://www.ncei.noaa.gov/products/ocean-carbon-acidification-data-system
50	Surface Ocean CO_2 Atlas	https://socat.info/
51	Global Ocean Acidification-Observing Network Portal	https://portal.goa-on.org/Explorer
52	Global Ocean Data Analysis Project (GLODAP)	https://glodap.info/