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Bay of Fundy, Minas Basin, NS (Credit: Shauni)

ISSUE:

Ocean Acidification
in Canada's Coastal Waters

Climate Change, Processes and Impacts

OVERVIEW

Canada has the longest coastline in the world; our Exclusive Economic Zone (EEZ) including territorial waters for all three of our oceans encompasses 6 million km^2, equivalent to 60% of our land area. As a result of increasing CO_2 in the atmosphere and a changing climate, we expect Canada's oceans to become warmer, fresher, more acidic, and, below the surface ocean, to become less oxygenated.

Observations and models indicate that warming and acidification will proceed more rapidly and more strongly at high latitudes. In this paper, we focus on the increasing acidity of Canadian ocean waters — the causes and the emerging and expected consequences to marine ecosystems (from microscopic plants and animals to whales), to commercial fisheries, and to coastal communities. Finally, we recommend a number of actions that should help to minimize the impacts on our coastal ecosystems, and on Canadian communities and industry.

WHAT IS OCEAN ACIDIFICATION?

Since 1960, roughly one-third of all carbon dioxide (CO_2) emissions from the burning of fossil fuels have ended up in the ocean. Upon entering the ocean from the atmosphere, the dissolved CO_2 gas reacts with water to form carbonic acid (H_2CO_3), which then rapidly breaks down — chemists say "dissociates" — to produce bicarbonate ions (HCO_3^-), carbonate ions ($CO_3^{=}$) and hydrogen ions (H^+). Hydrogen ions make the water more acidic, lowering the pH*. Some of the newly-released hydrogen ions combine with carbonate ions ($CO_3^{=}$), thus decreasing their concentration. This decrease makes it harder for organisms like oysters, clams, mussels and corals to find sufficient carbonate ions to combine with dissolved calcium to make the calcium carbonate ($CaCO_3$) needed to form their skeletons/shells (Box 1). Carbonate and calcium ions are building blocks; without them, it is difficult to build.

In the past, the near-surface layer in most of the open ocean contained enough carbonate ions to 'saturate' the waters with respect to calcium carbonate, and organisms typically had little difficulty in producing their shells or skeletal parts. But that is no longer the case in many parts of the sea where a declining proportion of carbonate ions leads to a state of 'undersaturation', where organisms may produce

Did You Know?

'Multiple stressors' associated with a changing climate are affecting marine plants and animals:

- increasing temperatures
- increasing acidification
- decreasing oxygen
- changes in nutrient levels
- changes in community composition

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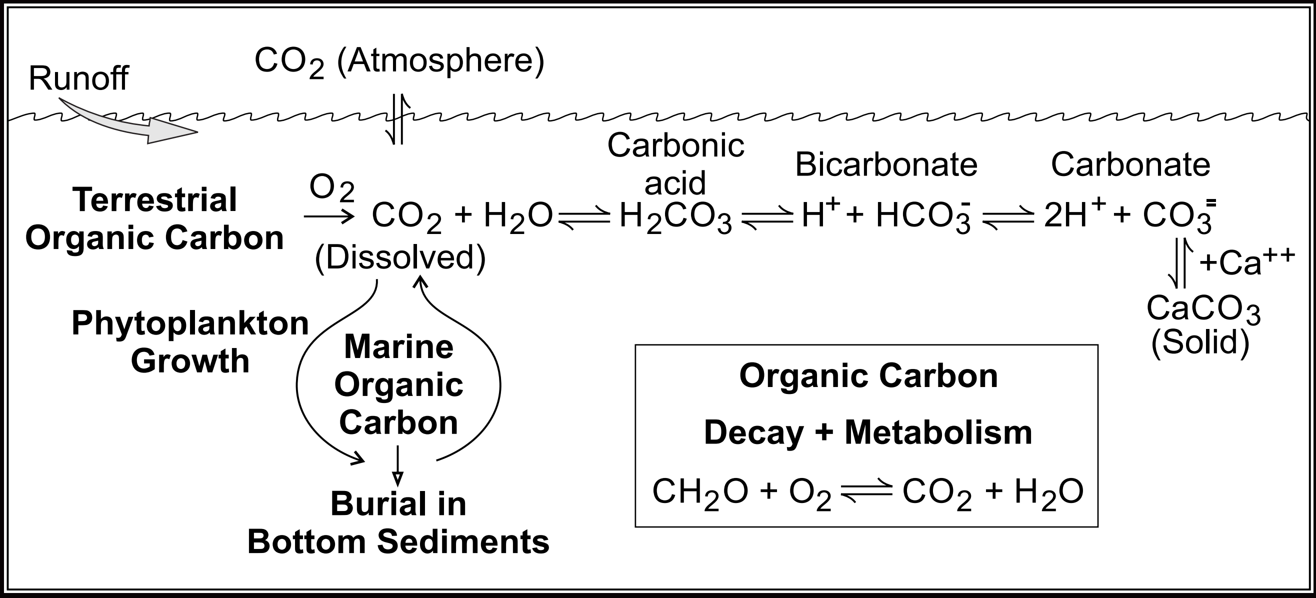
* Acidity is usually indicated by pH, the negative $\log_{10}$ of the number of H^+ ions: pH = -log10 ([H^+]).

Box 1



When carbon dioxide gas CO_2 enters the upper ocean from the atmosphere:

- CO_2 gas immediately dissolves in water, forming carbonic acid, which quickly dissociates into bicarbonate HCO_3^-, carbonate $CO_3^{=}$ and hydrogen ions H^+.
- When the pH decreases due to more H^+ ions, the chemical equilibrium shifts slightly so that there is less $CO_3^{=}$, resulting in a decrease in the saturation state, making it harder for plants and animals to form their $CaCO_3$ shells or skeletal parts.
- Additional CO_2 is also released from marine organic carbon during the decay/metabolic reaction. All organisms require metabolic energy for life sustaining processes.

deformed shells, or struggle to produce shells at all. Even worse, undersaturation can cause existing shells to begin to dissolve. Ocean acidification is the direct consequence of the addition of carbon dioxide to the atmosphere from the combustion of fossil fuels. As long as we keep adding carbon dioxide to the air, the ocean will continue to become more acidic, directly threatening the integrity of marine ecosystems. Furthermore, future global measures to mitigate climate change that do not reduce the addition of new CO_2 to the atmosphere and ocean (e.g. some proposed climate modification or 'geoengineering' schemes) would do nothing to reduce or stop the continuing increase of ocean CO_2 and accompanying decrease in pH.

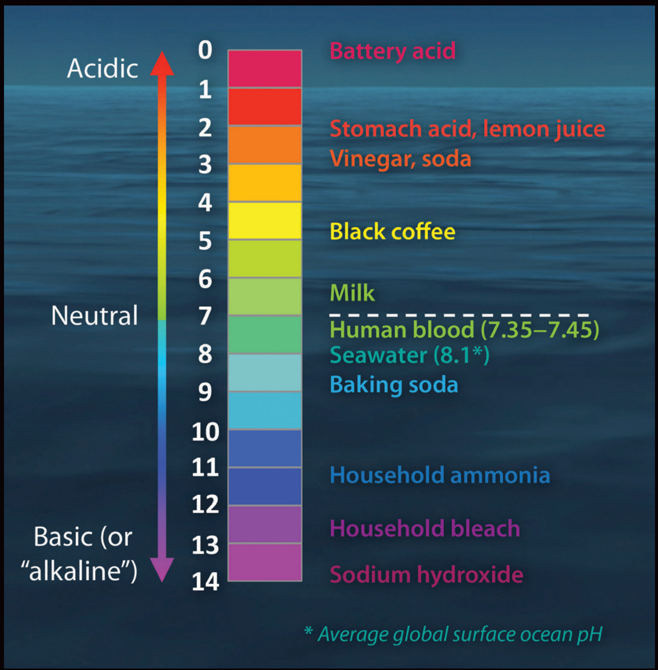
Several other processes affect the behaviour of carbon in the sea and influence the impact of ocean acidification. Dissolved calcium, for example, is relatively abundant in the open ocean so its concentration is not as important to shell-producing organisms as that of carbonate ions. However, in coastal seas that is not always the case because the input of fresh water from rivers can dilute (i.e. reduce) the calcium concentration and contribute to less saturated or undersaturated conditions. Moreover, rivers add organic carbon to coastal waters, and the decomposition of these organic compounds adds more carbon dioxide to the water column that then increases acidity.

And in coastal surface waters, phytoplankton — the plants of the sea — take up carbon as their cells grow and when they later die and sink, or get eaten, the cells largely decompose or decay, a reaction that adds carbon dioxide back into subsurface waters and again lowers the pH. Physical circulation can bring such waters back toward the surface — a process oceanographers call upwelling — thus introducing more corrosive lower pH waters to the uppermost layers of the sea. Where circulation is restricted, like in some fiords along the Canadian coastline, carbon dioxide can build up in the deeper waters as sinking organic matter decays. That process can produce relatively dramatic but local declines in pH.

A further complication is introduced by the shells or skeletons themselves. Marine carbonate-shelled organisms produce two different mineral forms of calcium carbonate: aragonite and calcite. The former is more soluble than the latter and it is thus more susceptible to corrosion in waters in which the pH is lower. Organisms that have evolved to make their shells from aragonite (e.g. oysters) are therefore more likely to be negatively affected by ocean acidification.

All of these processes are active to varying degrees in Canada's coastal waters, and all influence the chemistry of our surface waters *and* their ecological status, as described in the following pages.

Box 2



Common liquids and their pH values. The pH is a logarithmic (base 10) measure: a drop of 1 unit indicates 10 times more H^+ ions, and a drop of 2 units indicates 100 times more H^+ ions, etc. The open ocean surface pH has decreased about 0.1 since preindustrial times resulting in about 25% more H^+ ions.

[Source: http://www.pmel.noaa.gov/co2/file/The+pH+scale+by+numbers]

CANADA'S THREE OCEANS: DIFFERENT PROCESSES AND SENSITIVITIES

Regular high quality observations of the carbonate system collected at open ocean sites in the North Pacific and the North Atlantic Oceans over the last 25 years show that increasing CO_2 concentration and decreasing pH in ocean surface waters closely track the atmospheric increase in CO_2 over the same time period (Figure 1). Since pre-industrial time, open-ocean pH has declined ~0.1 units and is expected to decrease an additional 0.35 units before the end of this century (for a 'business as usual' scenario of emissions increasing 1% per year). This means that there would be three times as many H^+ ions in the water as in 'pre-industrial' times. A few high-quality time series of carbonate chemistry have been collected in Canada (Line P in the Pacific; the deep St. Lawrence Estuary; the Labrador Sea), but they do not resolve seasonal changes, and coastal coverage is only beginning. Hence the pH 'climatology' for Canadian coastal waters is largely unknown.

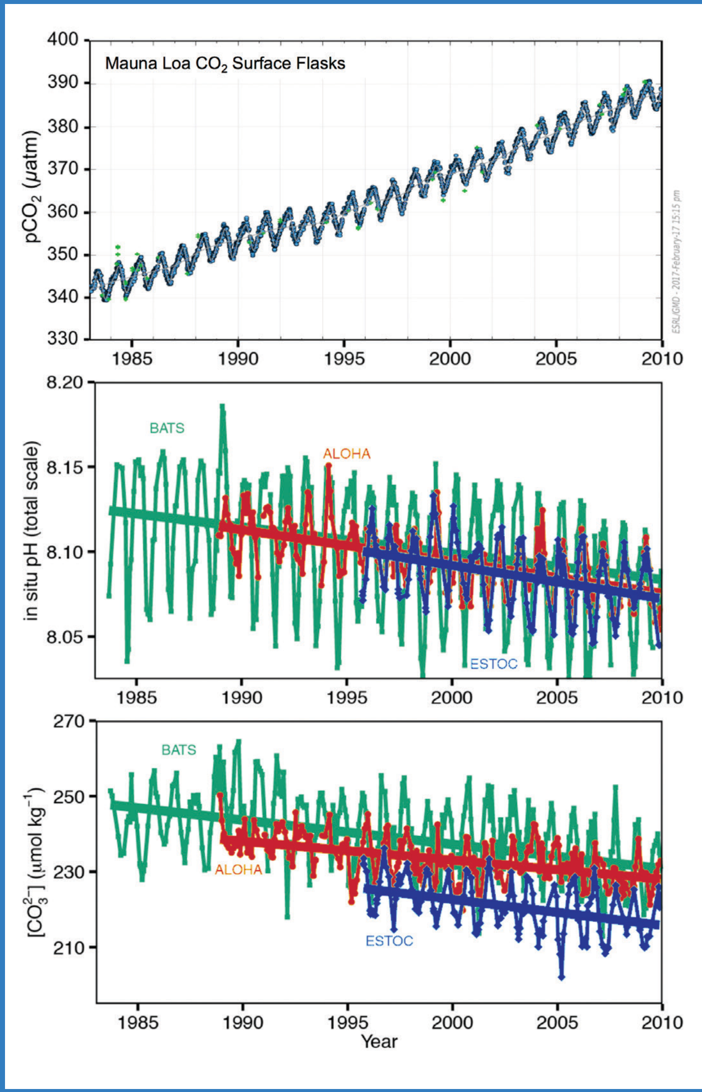
Like the open ocean, all Canadian coastal waters are gaining increasing amounts of CO_2 by exchange with the atmosphere. However, the resulting long term decrease in pH that has been observed in the open ocean will be more difficult to see in waters close to the coast where natural variation is greater. But because of that variability, low pH events are more likely to occur. These episodes of low pH in coastal surface waters will become more frequent and extreme in the future as the average pH declines. The impact of these extreme events will depend on duration, timing (relative to the life history stage of vulnerable species), and severity.

Four processes, themselves affected by climate change, contribute to natural variability in the corrosiveness of shelf surface waters to carbonate shells: upwelling, organic matter from land, restricted water circulation, and addition of fresh water by rivers or sea-ice melt (Figure 2). Fresh water inputs from land can also be altered by agriculture, forestry and damming. Thus, in addition to directly increasing CO_2 in the ocean, human activities can indirectly increase shelf sensitivity to acidification resulting from the extra CO_2.

For all these reasons, Canada's coastal regions must be assessed individually for their vulnerability to acidification. Here we attempt to do so, proceeding roughly from west to east to the Arctic.

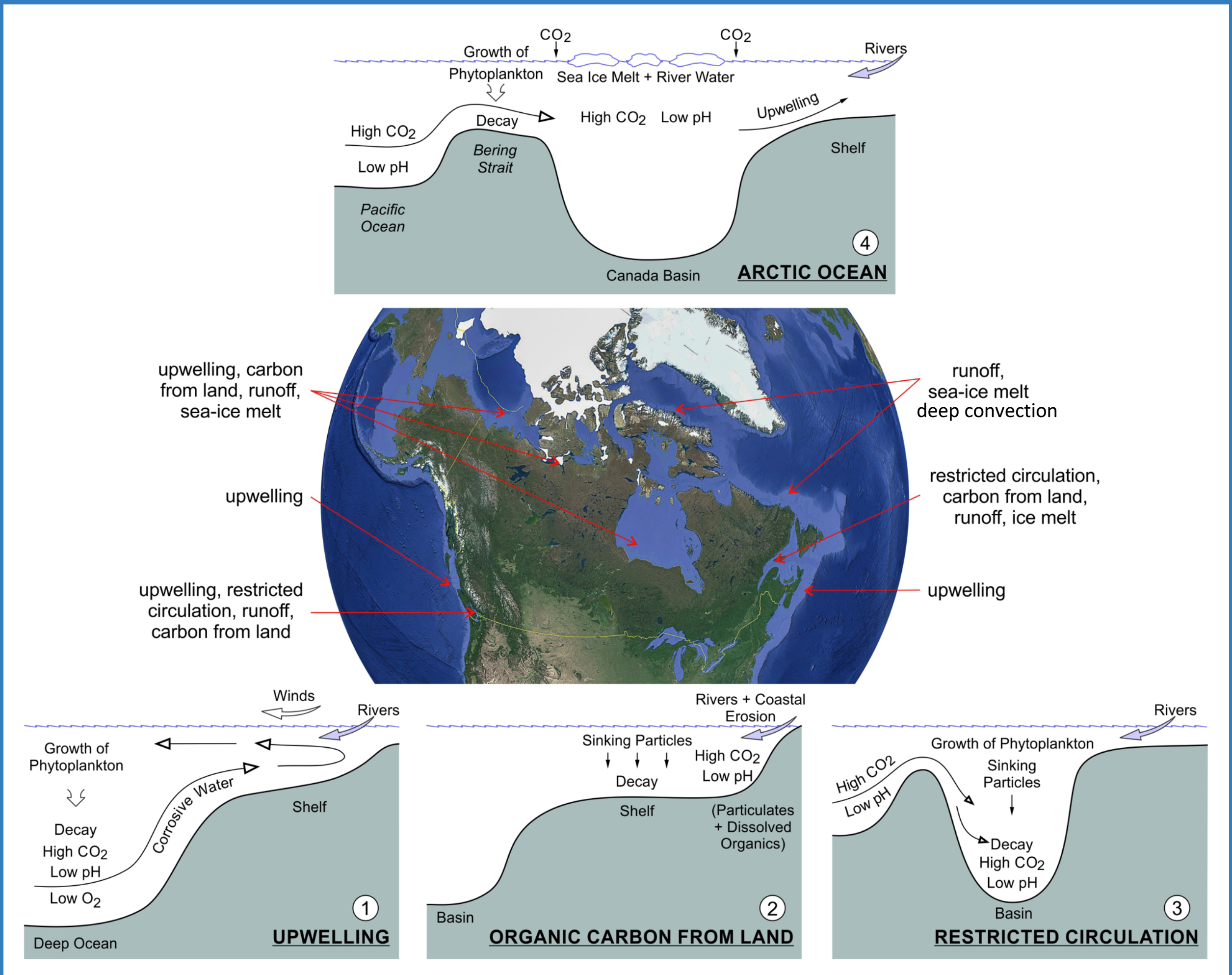
On the west coast of Canada, subsurface corrosive Pacific water wells up on the outer shelves from south of

Figure 1



Time series showing annual cycles and long term trends: (Upper panel) Increasing atmospheric CO_2 from Mauna Loa observatory Hawaii; (Middle panel) Decreasing near surface ocean pH from waters near Hawaii (ALOHA green), near Bermuda (BATS red), and near the Canary Islands (ESTOC blue); (Bottom panel) Decreasing carbonate ion (CO_3^{2-}) from the same sites [Modified from NOAA ESRL and IPCC WG1 AR5].

Figure 2



Canada's three oceans with cross-shelf schematics of four typical continental shelf flow regimes.

Vancouver Island to north of Haida Gwaii. This corrosive water also feeds into the restricted circulation of the Strait of Georgia, via Juan de Fuca Strait, and coastal fiords, which are made even more sensitive to the addition of CO_2 because they receive large inputs of fresh water and organic matter from land.

On the east coast, the Gulf of St Lawrence is especially vulnerable to CO_2 added from the atmosphere. The bottom water in this large estuary comes from CO_2 -rich subsurface west-central Atlantic Ocean and Labrador Sea waters that supply the Gulf through Cabot Strait. During the slow landward movement of this bottom water, more CO_2 is added by the degradation of sinking organic matter from phytoplankton and land-derived particulates. Over the last century, higher inputs of anthropogenic organic matter and nutrients have led to a measurable decline in the pH of the bottom waters of the St. Lawrence Estuary.

The Labrador Sea is one of the few sites of deep-water formation in the global ocean. Here, cold CO_2-rich surface waters sink to great depths in winter, sequestering massive amounts of the additional atmospheric CO_2 produced by

Did You Know?

Hudson Bay, a large, sub-arctic sea, appears especially vulnerable to acidification because its surface waters contain a large fraction of runoff and sea-ice melt in summer, especially along the south east coast, and because the Bay receives a large amount of organic carbon from land. Much of the bottom water is already undersaturated with respect to aragonite.

human activities, leading to a decrease in pH at depth. Farther south, the Scotian Shelf is now characterized by very low carbonate saturation due to increasing Arctic outflow and decreasing surface temperature.

Fresh water from rivers and sea-ice melt is distributed widely in Canadian coastal surface waters. Relative to seawater, river water and sea-ice melt have low concentrations of Ca^{++} and $CO_3^{=}$ ions, which react with dissolved CO_2. As a consequence, if the same amount of gaseous CO_2 were dissolved into seawater, river water and sea-ice melt water, the pH of river water would decrease about twice as much as in seawater, and in the sea-ice melt about eight times as much.

Water circulation along Canada's coasts, in places like the Strait of Georgia or the St. Lawrence Estuary, is restricted by shallow sills and/or narrow passages. There the typical estuarine circulation increases the residence time of deep water at the head of the inflowing current. In these locations, production of organic matter in surface water, and its subsequent sinking and decay at depth, produces CO_2 which cannot easily escape from the subsurface water to the atmosphere, and may therefore accumulate for up to a year or more.

Low-lying wetlands present risks of extreme acidification events in restricted coastal regions. Wetlands accumulate carbon including organic acids, which can be flushed into the adjacent sea during episodes of heavy rain, rapid snowmelt or coastal inundation due to storm surge. Sea-level rise and, in the Arctic, permafrost thaw, are increasing the likelihood and severity of such events.

In the western Arctic Ocean, seawater is supplied by the inflow of subsurface Pacific water, rich in CO_2. After passing through Bering Strait, this water becomes even more corrosive over the Chukchi Shelf due to decay of sinking plankton. The high CO_2, low pH subsurface water then wells up on the Canadian Arctic shelves, and supplies subsurface water to the Canadian Archipelago and downstream to Hudson Bay and to the Labrador Shelf. Seasonal inputs of sea-ice melt and river inflow, colder water temperatures favouring CO_2 uptake from the atmosphere, and the addition of large amounts of organic matter from land make the coastal waters of the Arctic among the most sensitive to acidification globally.

Did You Know?

Shellfish Dominate!

In 2015, shellfish accounted for 89% of the value of Canadian exports of fish and seafood products:

shellfish	**\$5.283 billion (535,000 tonnes)**
total	**\$5.959 billion (620,000 tonnes)**

Shellfish accounted for almost 90% of the landed value of Atlantic Canada's wild fisheries:

shellfish	**\$2.51 billion (430,000 tonnes)**
total	**\$2.82 billion (673,000 tonnes)**

EFFECTS ON PLANTS AND ANIMALS

In the last decade, research into the effects of ocean acidification on plants and animals in the ocean has been extensive. Clear negative effects have been documented in species that form calcium carbonate $CaCO_3$ for their shells or skeletal body parts. They include: photosynthetic coccolithophores in the laboratory, planktonic pteropods in the ocean, and the larvae of cultured oysters and other shellfish, all found in Canadian waters.

For photosynthetic organisms such as phytoplankton that require CO_2 for growth, more CO_2 could however be beneficial. For this reason, some studies predict that ocean acidification (increased CO_2) will benefit phytoplankton and seaweeds and sea grasses. The story may however be different for phytoplankton species having skeletal parts made of calcite, a primary mineral form of $CaCO_3$. For these species, many laboratory studies have shown that high CO_2 concentrations lead to a breakdown of their skeletal parts due to the corrosive nature of low pH seawater (Figure 3). Some zooplankton species also use calcium carbonate to build their shells. For example, pteropods, tiny swimming snails which are considered to be a vital food source for juvenile salmon, have been shown to suffer corrosive effects on their shells in the open ocean (Figure 4).

Effects of low pH are expected to be negative for shellfish with calcium carbonate in their shells, especially during the first few days of shell formation (Figure 5). Decreasing pH or, more accurately,

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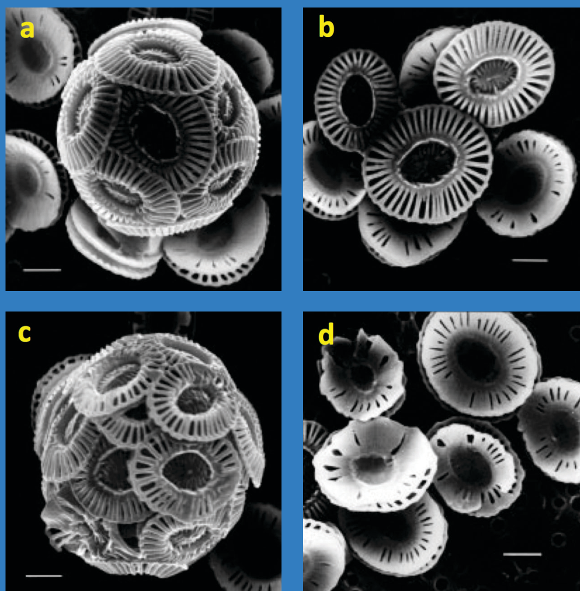
Figure 3

MID 20th Century

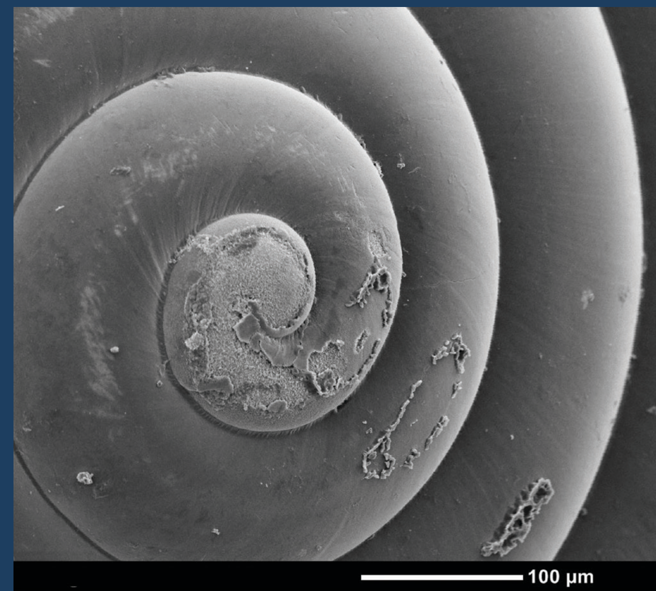
Mid 22nd Century



Scanning electron micrographs of the coccolithophore *Emiliania huxleyi* under different CO_2 concentrations. a, b: about 300 ppm and c, d: 780±850 ppm, respectively. Horizontal scale bars represent 1 µm. Note the difference in the coccolith 'discs' (including distinct malformations).

[With permission from U. Riebesell]

Figure 4



Scanning electron micrograph of the pteropod (swimming snail) *Limacina helicina* from the Washington, US coast. Rough areas show dissolution/corrosion from low pH waters

[With permission from N. Bednaršek].

decreasing saturation state, which includes the combined effect of decreasing concentration of calcium (Ca^{++}) and carbonate ($CO_3^{=}$) ions, makes it harder for shellfish to build and maintain their shells. It takes more energy for organisms to extract Ca^{++} and $CO_3^{=}$ from impoverished seawater.

However, experiments on adult calcifiers and on finfish have often yielded variable results. Results, even on the same species, are highly dependent on life histories prior to the start of an experiment. Did the population live in a highly variable environment such as in most Canadian coastal regions, or in a more quiescent region such as the open ocean in the subtropics (e.g., near Hawaii or Bermuda)? Also in determining the magnitude of an effect, the absolute pH value may not be the whole story. The pH in most coral reef environments is not as low as in the Canadian Arctic, yet widespread damage to coral reefs has been well documented, usually due to the combination of extremely high temperature (responsible for their 'bleaching') and low pH events.

Did You Know?

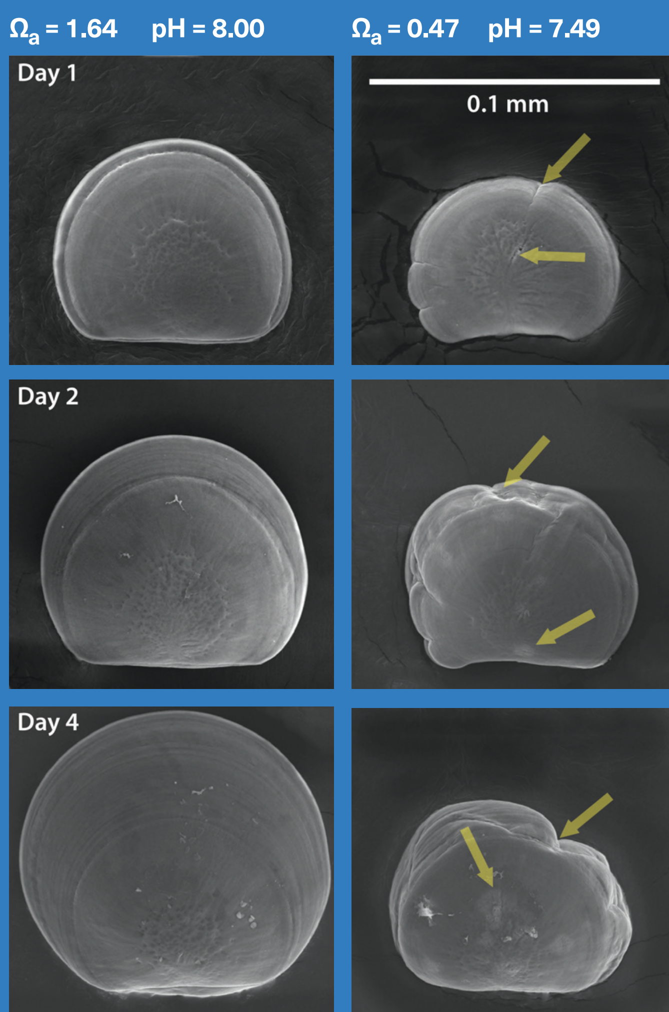
It is estimated that from 1992 to 2011, fish and shellfish harvesting alone amounted to a total of 65,000 tonnes per year for the Beaufort Sea, the Canadian Archipelago and Hudson Bay.

Other effects on plants and animals are less well known. The release of energy for life processes ('animal metabolism') produces CO_2 internally, which must be forced out through cell membranes (or fish gill membranes for example) into the surrounding water. But, as the dissolved CO_2 in seawater rises due primarily to human activities, animals must expend more energy to get rid of internal CO_2 generated through metabolic processes.

Plants and animals are being affected simultaneously by 'multiple stressors' from climate change. They include warming, changing levels of dissolved oxygen, and shifts in species distribution and community composition – that are due primarily to differential poleward drift of species as temperatures increase locally.

Global trends of declining subsurface dissolved O_2 and increasing CO_2 are further linked through decay and metabolism of organic carbon (Box 1). The behaviour of animals can also be affected: there is documented evidence of animals becoming disoriented in low pH/high CO_2 coral reef environments such as exhibiting reduced 'flight' response in the presence of predators. Studies of the response of organisms to multiple stressors are essential, but logistically difficult, time consuming and expensive.

Figure 5



Pacific oyster larvae from the same spawn, raised by the Taylor Shellfish Hatchery in natural waters of Dabob Bay, WA: for favorable (left column) and unfavorable (right column) carbonate chemistry conditions (Ω_a represents the saturation state for aragonite: greater than 1 stable; less than 1 unstable). Images are scanning electron micrographs of representative larval shells from each condition from 1 to 4 days post-fertilization. Yellow arrows show areas of deformation/corrosion

[With permission from E. Brunner/G. Waldbusser]

IMPACTS ON ECOSYSTEMS AND HUMANS

From our current knowledge of the effects of ocean acidification on plants and animals, we can assert that interference with the production of carbonate hard body parts in shellfish or plankton, especially for developmental stages (e.g., oyster spat, mussels, crabs, coccolithophores, and others), provides the most direct and widely recognized risk from acidification. There is already evidence that acidification is having adverse effects on shellfish and their aquaculture. Carbonate dissolution alone can further lead to large change in ecosystems by, for example, diminishing or removing sources of food (e.g., carbonate plankton or bivalves) for the higher trophic levels. Acidification could, among other stressors, also cascade through coastal ecosystems to affect wild fisheries and aquaculture.

It is difficult to project impacts of ocean acidification on whole ecosystems. This is partly due to the diverse and sometime not well known relationships between the organisms involved, and their specific sensitivity to other stressors, such as rising temperature, invasive species, selective harvesting of marine resources, changes in land-ocean coupling, organic and inorganic contaminants and, in the Arctic, dwindling multi-year sea-ice and widely-distributed permafrost thaw.

Equally problematic is our poor capacity experimentally to expose entire ecosystems to the changes in pH as will occur in nature, although recent studies in very-large-volume containers emplaced in the ocean have shown promise. Variations in sensitivity to acidification among natural settings means that large-scale predictions or detailed ecosystem studies for one region cannot be applied directly to other regions. We can however consider the potential economic ramifications of damage from ocean acidification to harvestable marine resources in Canada's three oceans.

In 2015 on the Pacific coast, the total landed value of British Columbia fisheries was $867 million (aquaculture: $497 million; wild: $370 million). The aquaculture salmon harvest was 84,000 tonnes ($464 million), oysters 9,100 tonnes ($14.4 million), and all other shellfish 1,900 tonnes ($3.7 million). Landed value for shellfish was $149 million (wild) and $18.1 million (cultured) with over 1,150 people directly employed by these fisheries. Total export value of crabs, shrimp and prawn, and geoduck clams was $201 million.

Shellfish farming operations in the Salish Sea already report detrimental effects from acidification, especially at the larval stage of the species mentioned here. West coast Indigenous Peoples have long valued wild fisheries both culturally and economically, featuring salmon, herring, halibut and shellfish in their food basket. Today, this subsistence harvest has been augmented by sport and commercial fisheries.

In Atlantic Canada, in 2015 the total landed value of the fisheries was $3,268 million (aquaculture $443 million, wild $2,825 million). Wild ground fisheries accounted for 82,000 tonnes ($216 million), pelagic fisheries for 161,000 tonnes ($102 million) and shellfish for 430,000 tonnes ($2,500 million) The predominance of shellfish (especially lobsters) in this region reflects a recent study of landed values in the US by region: shellfish accounted for 80% of the landed value of New England commercial fisheries, by far the highest of any region in the US.

In Prince Edward Island with a population less than 150,000 people, cultured shellfish (mussels, oysters and clams) accounted for 22,000 tonnes ($40.7 million, of Canada's total $89.6 million). Wild shellfish accounted for 21,000 tonnes ($171 million, of a total wild fishery in PEI worth $178 million). When the risk of storm surge flooding from rising sea level is added to the risk from ocean acidification, PEI is perhaps the most vulnerable province in Atlantic Canada.

Canada's Arctic does not presently sustain an important commercial fishery. Marine biota, however, have an enormous importance culturally, spiritually and nutritionally to Indigenous Peoples. These resources already face wide-scale threats from climate change in the form of warming, sea-ice loss and thawing of permafrost. Threatened resources include species that live entirely within the Arctic (e.g., many fish, seals, polar bears), and migratory species that depend on the Arctic seasonally for nutrition and reproduction (fish, whales, and birds).

Within Arctic planktonic communities, pteropods appear to face the greatest risk. These carbonate shell-forming animals provide crucial food for other important species including fish, whales and birds. In some regions, pteropods contribute over 90% of the zooplankton biomass. It has been projected that pteropods will be unable to form their shells in Arctic waters by the end of this century.

Holly Wood Oyster Farm, BC (Credit: Hans Peter Meyer)

Did You Know?

In 2015, the aquaculture salmon harvest in British Columbia was 84,000 tonnes ($464 million), oysters 9,100 tonnes ($14.4 million), and all other shellfish 1,900 tonnes ($3.7 million). Landed value for shellfish was $149 million (wild) and $18.1 million (cultured) with over 1150 people directly employed by these fisheries. Total export value of crabs, shrimp and prawn, and geoduck clams was $201 million.

In the absence of appropriate studies, projecting the effect of ocean acidification on humans in the Arctic is almost entirely speculative, and cannot be separated from the effects of other stressors like climate change and contaminants. Household economies in Canada's north depend crucially on subsistence harvesting of marine resources. While the total population depending on such resources is small (~ 50,000 northerners live within 50 km of the ocean), the cultural and spiritual benefits of traditional harvesting are exceptionally large.

Over the past few decades Canadian commercial fisheries have been changing rapidly: commercial aquaculture (finfish and shellfish) has emerged as an important economic activity and source of employment (15,200 full-time jobs Canada wide), with British Columbia the largest producer in Canada. Unlike wild fisheries, most aquaculture fisheries are nearshore, where the impact of ocean acidification may be the most severe.

Ocean acidification is a measurable ongoing process that will continue for decades, even if a total ban on all CO_2 emissions could be achieved. Almost all organisms show some level of sensitivity to the process, and in most cases, the effect is negative. How whole ecosystems will respond in concert with other stressors associated with a changing climate remains an open question. But we know that the disappearance or mere decline in abundance of some key species will inevitably result in a profound reorganization of marine ecosystems, both in Canadian waters and worldwide.

RECOMMENDED ACTIONS

Canada:

Observations

- Canada has the longest coastline in the world, so we need to initiate/continue a strategic selection of high quality ocean acidification monitoring sites, with methodology consistent with that of the Global Ocean Acidification Observing Network (GOA-ON).

Research Needs

- Initiate well-designed experiments on the impact of increasing ocean acidity on key commercial species in Canadian waters.
- Initiate potential ecosystem impact analysis on Canadian fisheries in different regions. Potential impact is highest in shellfish-dominated ecosystems.
- Continue to increase research/socio-economic impact studies on coastal communities.

Adaptation and Mitigation Measures for Industry

- Real time monitoring is needed at facilities that breed oyster and other shellfish spat to avoid introducing new spat during low pH events.
- Measures need to be adopted to control pH, temperature, and saturation state, in aquaculture facilities.
- Undertake selective breeding to identify and develop more robust species/strains of animals using up-to-date genetic tools.
- In collaboration with scientists, identify and protect areas in which wild fisheries are vulnerable to ocean acidification.
- Reduce fluvial input of organic matter (such as sewage) and nutrients to reduce eutrophication, which leads to hypoxia.

International:

- Global action on reducing fossil fuel CO_2 emissions would slow down the rate of acidification. But proposed climate manipulation (geoengineering) schemes that do not involve reducing CO_2 emissions, would not mitigate the effects of ocean acidification.

Future Challenges:

- **Extreme Events**: Serious damage to marine ecosystems is most likely to occur during extreme (e.g. high temperature and/or acidification) events. Many ‘return times’ of extreme events (e.g., 30°C+ daily maxima) are already getting shorter. For example, a 35°C day may have been expected once every 30 years (‘return time of 30 years’) but, in the new climate of today, that is now expected once every 10 years.

- **Multiple Stressors**: Experiments that look at the effects of multiple stressors associated with climate change (increasing temperature, ultraviolet light, and CO_2, decreasing dissolved oxygen, pH and saturation state) are just now getting underway. Such multi-variable experimental work is difficult, but of high importance.

- **Ecosystem Level Studies**: To date, little research has been undertaken beyond the species level, yet the scope for unexpected complex feedbacks is large. Without knowledge of how whole ecosystems might respond and evolve, we have little capability to predict changes in diversity and in turn impacts.

FURTHER READING

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Eel Lake Oyster Farm, PEI (Credit: Valerie Lugonja)

Prince Edward Island's economy is highly dependent on its vulnerable shellfish industry. With a population of less than 150,000 people, cultured shellfish (mussels, oysters and clams) accounted for 22,000 tonnes ($40.7 million, of Canada's total $89.6 million), while wild shellfish accounted for 21,000 tonnes ($171 million, of a total wild fishery in PEI worth $178 million).

Clyde River, Eastern Baffin Island (Credit: Robie Macdonald)

Sockeye salmon returning to the Adams River, BC (Credit: Pacific Salmon Foundation)

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Support for this IP#6 was generously provided by Fisheries and Oceans Canada