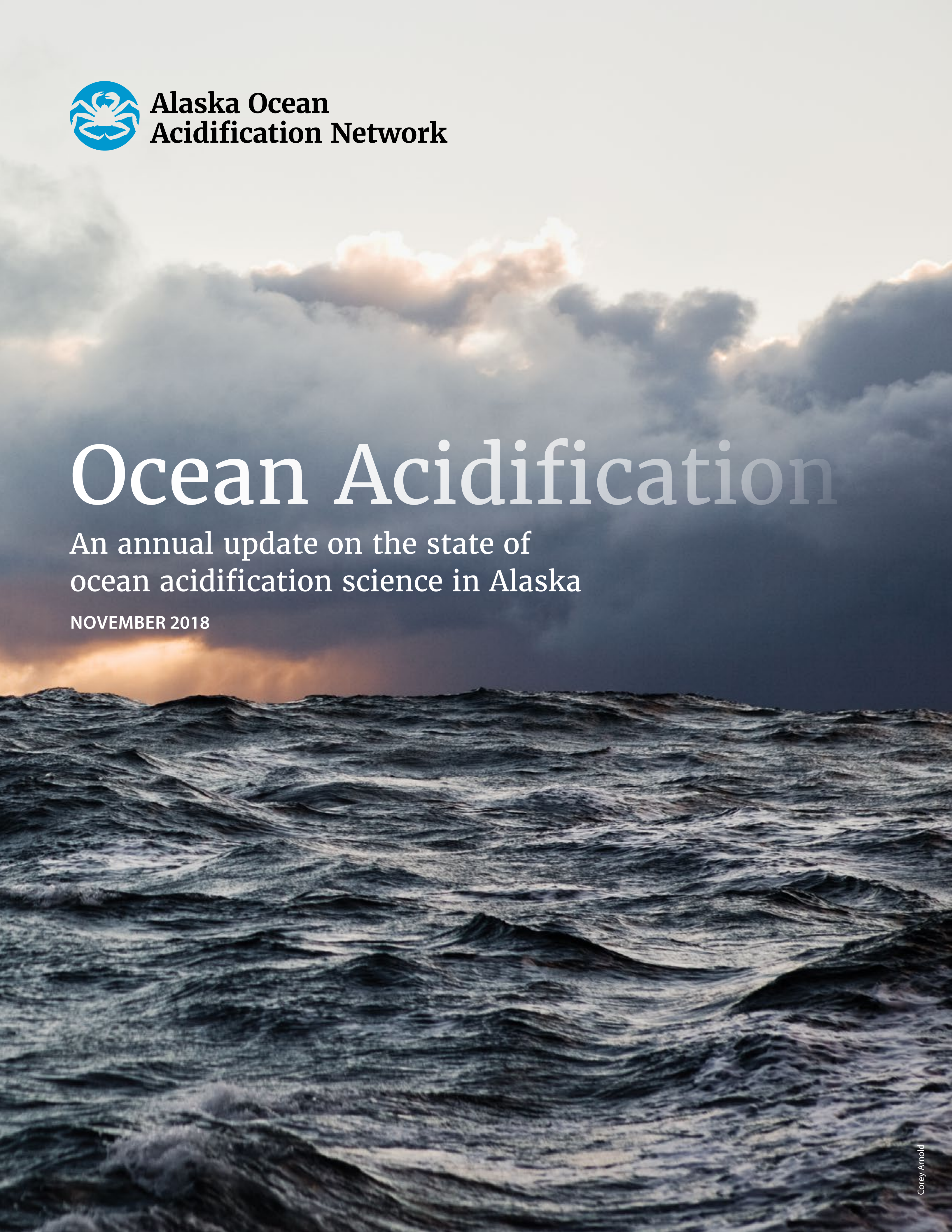
Alaska Ocean
Acidification Network

Ocean Acidification

An annual update on the state of ocean acidification science in Alaska

NOVEMBER 2018



Corey Arnold

What is Ocean Acidification?

Scientists estimate that the ocean is 30% more acidic today than it was 300 years ago, traceable to increasing levels of atmospheric carbon dioxide (CO_2) from fossil-fuel burning and land-use change, such as deforestation. As human-generated CO_2 is released into the atmosphere, about a third is absorbed by the ocean. The additional CO_2 lowers the pH of the seawater, driving the process known as ocean acidification (OA). The current pace of OA is faster than any time on record — 10 times faster than the last major acidification event 55 million years ago.

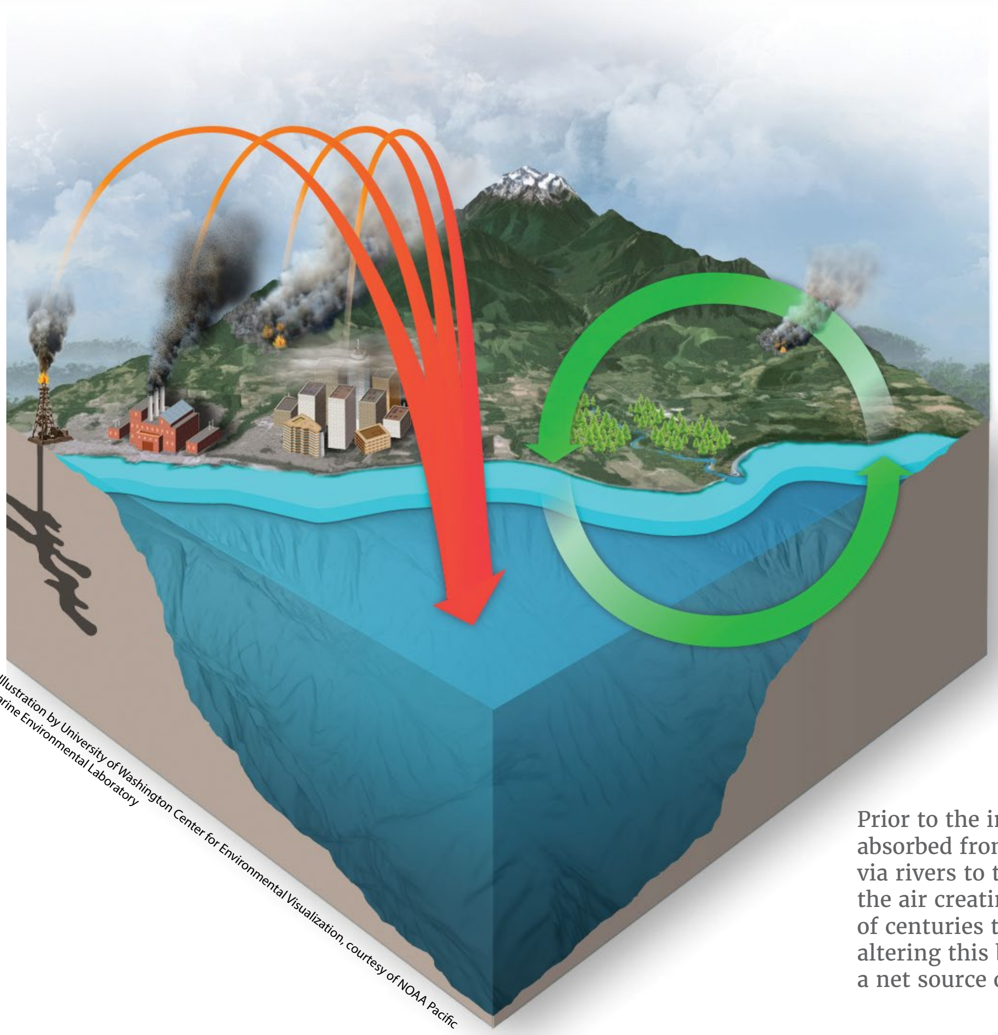
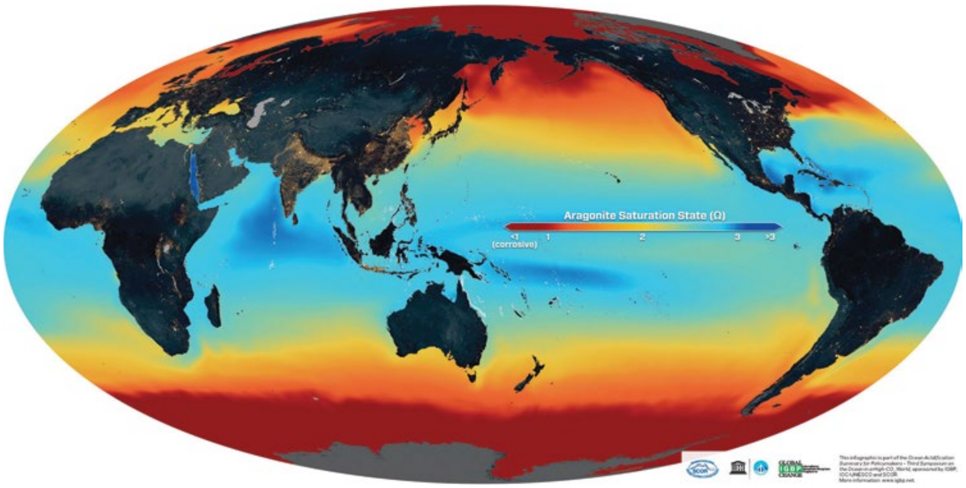


Illustration by University of Washington Center for Environmental Visualization, courtesy of NOAA Pacific Marine Environmental Laboratory

Prior to the industrial revolution, CO_2 was absorbed from the air by land plants, exported via rivers to the ocean, and released back into the air creating a balanced cycle on time scales of centuries to millennia. Today, humans are altering this balance, changing the ocean from a net source of CO_2 to the air to a net CO_2 sink.

Why is Alaska at Risk?

Ocean acidification is expected to progress faster and more severely in Alaska than lower latitudes. Waters in Alaska are both 'cold and old': cooler water temperatures and global circulation patterns mean that Alaska waters naturally hold more CO_2 year round. On top of this high baseline concentration of CO_2, other processes also make Alaska's waters more naturally acidic on a seasonal scale.



IGBP, IOC, SCOR

This map shows aragonite saturation state (Ω), a proxy for seawater corrosivity, projected to the year 2100. When Ω<1 (dark red), conditions are corrosive for shells and exoskeletons. Arctic waters are acidifying faster than the global average because cold water is richer in CO_2, and melting sea ice and glaciers worsen the problem.

How are Marine Species Affected?

Acidification of seawater reduces the amount of calcium carbonate minerals needed for shell-building organisms to build and maintain their shells. These include crab, oysters, clams, sea urchins, corals, and some kinds of calcifying zooplankton. Changes in ocean chemistry can also affect the behavior of non-calcifying organisms. For instance, the ability for some fish to detect predators has been shown to go down when seawater acidity increases. Some species may be resilient to more acidic conditions but their prey species may be compromised.

So far, only a limited number of Alaska's commercially important species have been studied for their response to OA. Marine mammals, birds, and Arctic food webs have not yet been investigated.

Crab

Studies have been conducted at the NOAA Kodiak Laboratory on red king crab, blue king crab, golden king crab, southern Tanner crab, and snow crab. The results varied among species and life stages but in general, crab survival went down at most life stages when they were exposed to more acidic water. The effects were particularly noticeable with southern Tanner crab.

When adult crabs were exposed to more acidic water during egg development, a portion of the embryos failed to hatch, and larval survival decreased. Juvenile growth was slower, shell formation was reduced, and survival was lower. In adults, changes in blood cell acidity and an increase in the number of dead blood cells suggested that the crab had to expend more energy to maintain their immune systems. Snow crabs are an exception to the general pattern; embryos, larvae, and adult females were all unaffected even at the highest acidity tested.

Finally, stock assessment and bioeconomic models for red king crab and Tanner crab predicted that the low survival rate of juveniles would lead to fewer adult crab and a substantial decrease in catch and profits over the next 50 years in the Bering Sea.

Walleye Pollock

Initial work by NOAA on walleye pollock suggested that this species is generally resilient to the effects of elevated CO_2 (more acidic conditions). However, those early experiments were conducted with fish from Puget Sound and ongoing work is being done to see if Gulf of Alaska populations would respond similarly. Additional work is being conducted to examine the potential for behavioral impacts in juvenile pollock.

Pacific Cod

Recent experiments by NOAA also examined the effects of elevated CO_2 on larval Pacific cod growth, survival, and behavior. Preliminary observations indicate that elevated CO_2 levels reduced growth during the first few weeks after hatching. However, the same conditions may increase growth in older fish and that response may be linked to a behavioral change.

Northern Rock Sole

NOAA laboratory studies found that elevated CO_2 levels appeared to reduce the growth and survival of northern rock sole larvae, but did not appear to affect survival of eggs or the size of fish at hatch.

Corey Arnold

Salmon

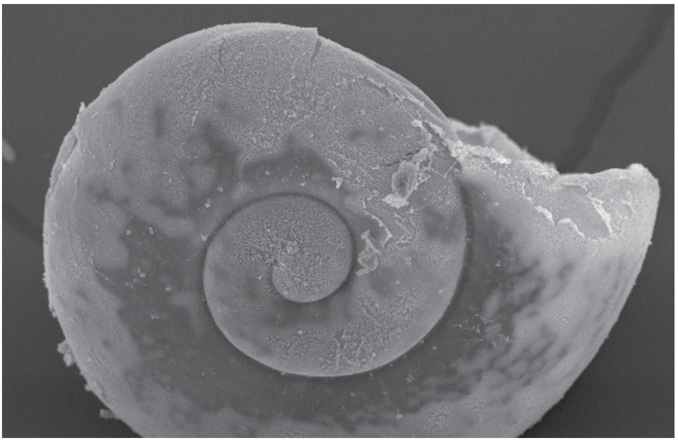
Research on salmon response to OA is in the early stages. A study on coho conducted by the University of Washington focused on behavior, neurophysiology, and gene expression, and looked at salmon's ability to smell and respond to the scent of a feeding predator in a higher CO_2 (more acidic) environment. Experiments that monitored the response of nerves in the nose and brain showed that salmon's noses function normally under more acidic conditions, but the way their brains process the scent was impaired. In other words, they could smell predators, but were unable to respond appropriately to the information. Research has not yet been conducted on the impact of acidification on the ability of salmon to find their way back to their spawning grounds.

Another study from the University of British Columbia focused on the response of pink salmon to projected future levels of ocean acidification during the development stage in freshwater and early seawater entry. The results showed reductions in growth, yolk-to-tissue conversion, and oxygen uptake capacity, as well as impacts to sense of smell, anti-predator behavior, and anxiety.

NOAA is funding a project to investigate the implication of ocean acidification thresholds and major ecosystem shifts in the Gulf of Alaska as they relate to salmon and to inform salmon management decisions.

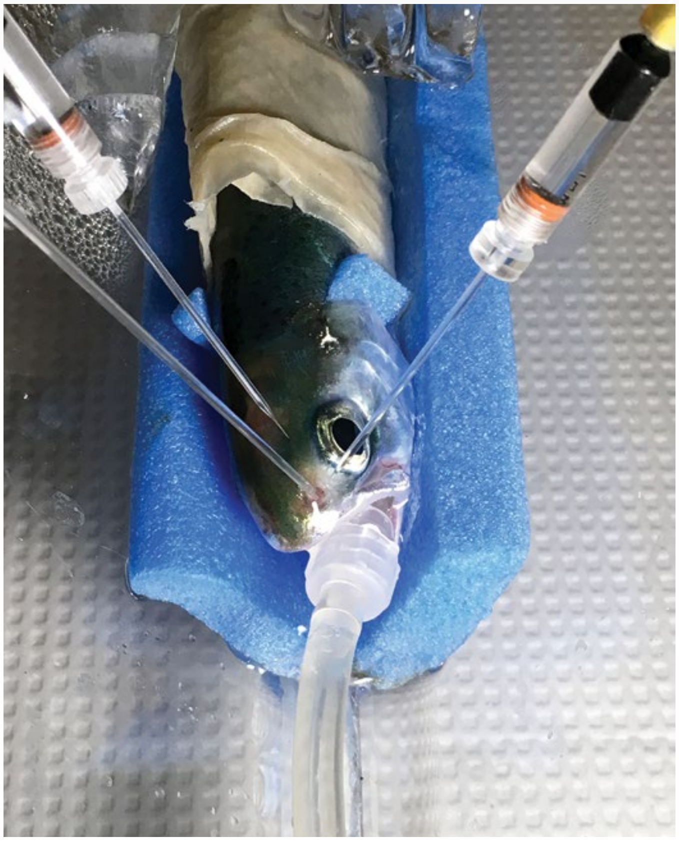
Pteropods

Swimming sea snails, known as pteropods, are sensitive to ocean acidification which can cause their shells to dissolve. Reduced abundance of pteropods could have implications for a variety of fish that feed on them, including juvenile salmon, sole, and pollock. In particular, pteropods provide a source of fat to juvenile fish that are not able to produce those fats themselves. Absence of these fats can lead to delays in juvenile fish development.



Nina Bednarsek, SCCWRP

When exposed to higher CO_2 water, pteropod shells start to dissolve with characteristic pitting and shell corrosion patterns.



Chase Williams

Scientists at the University of Washington are studying the behavior of salmon under higher CO_2 conditions.

Corrosive conditions have been observed in the western Gulf of Alaska in waters as shallow as 150 ft, raising concerns for pteropods in that region. Preliminary research results from the Southern California Coastal Water Research Project suggest there is increased pteropod shell dissolution in the western Gulf of Alaska, which could have a potential impact on the commercial fisheries in that region. The same corrosive conditions were not observed in the eastern Gulf, and further research is needed to better understand food web links between pteropods and specific fish species.

Bivalves

To date, very little is known about the effects of ocean acidification on bivalves in Alaska. Preliminary studies on the butter clam found significant levels of shell dissolution after a two-week exposure to levels of acidity expected for the year 2100. Currently, there are studies underway by the University of Alaska Fairbanks investigating OA impacts on larval razor clams, juvenile basket cockles, and juvenile littleneck clams. This work, in collaboration with the Alutiiq Pride Shellfish Hatchery in Seward, aims to better understand how OA-related stress affects shell formation, growth, metabolism and acid-base regulation of these important clam species. These studies seek to identify clam species that are the most sensitive to OA.

Melting glaciers contribute to ocean acidification by reducing the buffering capacity of the water.

Mandy Lindeberg/NOAA

OA and Warming – Combined Effects

OA is not the only stressor that is predicted to affect Alaska waters; temperatures are expected to rise at the same time. Both OA and warming will have an effect on species and ecosystems, but the effects of OA and warming combined are not always simple to predict. For example, research at NOAA's Kodiak Laboratory showed that juvenile crab appear to benefit from some warming even in acidified conditions. But too much warming combined with acidified conditions causes higher mortality than would be predicted from either OA or warming alone. Researchers are just starting to scratch the surface of how these combined stressors will affect Alaska.

Regional Differences

Ocean chemistry fluctuates seasonally, and regions around Alaska are vulnerable to OA for different reasons and at different times of year.

In the Arctic, winds and storms can bring colder and older — and more acidic — waters to the surface, which can flush important shallow habitats in the Chukchi and Beaufort Seas with corrosive water. As Arctic sea ice cover decreases exposing more open water, research by NOAA shows that the intensity and frequency of these events are increasing.

In the Bering and Chukchi Seas, OA hotspots often result in areas where multiple natural mechanisms combine to create intense OA events. For example, NOAA researchers found that large build-ups of CO_2 occur in areas where tides and currents are slow and do not dilute CO_2-rich conditions.

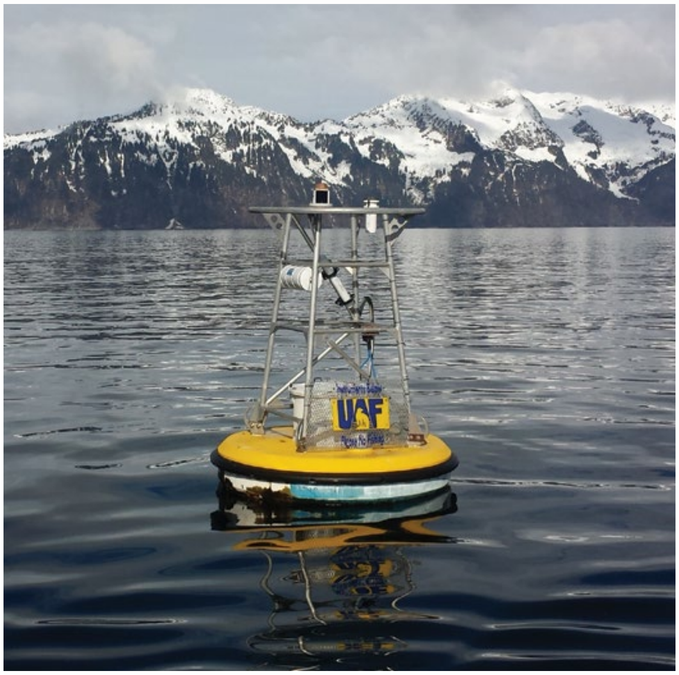
In Southeast Alaska, climate change-related factors are accelerating the rate of OA. Melting glaciers in the Gulf of Alaska add freshwater that drains directly into the ocean, reducing the calcium carbonate minerals available for organisms to build their shells.

A Special Look at the Gulf of Alaska

Intensive observations of CO_2 chemistry in the Gulf of Alaska over the last 10 years have shown a large seasonal variability. Data have been generated from ocean buoys near Seward, Kodiak, and Chatham Strait, as well as through targeted research on the influence of glacial melt in both Prince William Sound and Glacier Bay National Park. Through a partnership led by the Hakai Institute, the state ferry *Columbia* has also been fitted with a continuous carbon measurement system and tracks OA on its weekly route between Bellingham and Skagway.

CO_2 levels are generally higher in winter than summer months, and highest in southeast Alaska. This is primarily due to winter storms that vertically mix the water column, bringing corrosive water towards the surface. Weaker winds in the summer months allow deep water (> 300 ft) naturally high in CO_2 to spread out over the continental shelf without mixing vertically.

Phytoplankton blooms also play a role in the seasonal cycle of CO_2. In the summer, phytoplankton draw down CO_2 from the sunlit portion of the water (similar to plants on land taking up CO_2 from the air for photosynthesis) and make the water less acidic.


Natalie Monacci/UAF

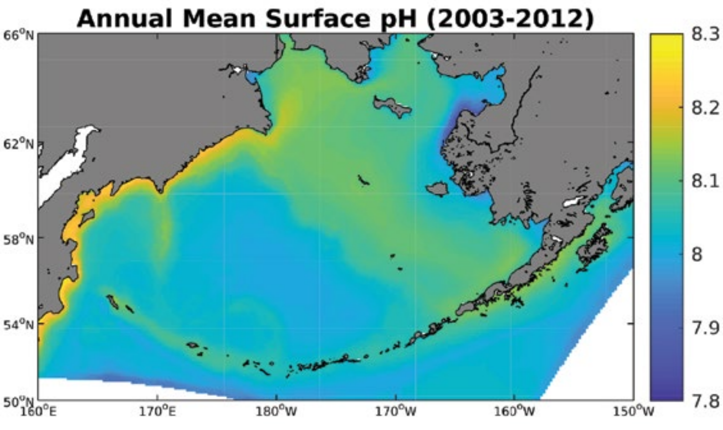
A research buoy, nicknamed GAKOA, has been collecting OA data every three hours at the mouth of Resurrection Bay since 2011.

Glaciers are also a contributing factor to observed nearshore CO_2 system variability. Warm temperatures in the summer result in large freshwater input to the nearshore coastal zone in the form of glacial melt. The chemistry of glacial water is variable, depending to a degree on whether the glacier is tidewater or mountain-hanging. The addition of freshwater with variable CO_2 chemistry has dramatic seasonal implications for the nearshore marine environment.

Can We Forecast into the Future?

Current forecasts for ocean acidification in Alaska waters come from global climate and Earth System models, which work well at the global scale, but are less useful for making region-specific forecasts.

The Joint Institute for the Study of the Atmosphere and Ocean at NOAA is currently incorporating OA into regional models for Alaska to improve understanding of OA on a local level. This will include important features such as local water carbon chemistry influenced by river and glacial run-off.



Darren Pilcher, JISAO, NOAA

This graphic shows the output from a model looking back in time at surface pH in the Bering Sea. Note the darker blue (more acidic) waters in the nearshore due to the influence of river run-off.

Regional models have already illustrated the influence of freshwater run-off, both from the Yukon River and tidewater glaciers, in generating corrosive water conditions. In the Bering Sea, NOAA has also simulated the effect of recent climate variability between the warm and cold periods on corrosive water conditions. This model also captures a decreasing trend in pH over a 10-year timeframe, which is consistent with OA. However, due to the short time period of the study, it is too early to attribute what part of the change is due to OA versus natural variability. The next goals for these regional models are to provide more accurate long-term projections and 9-month seasonal forecasts of OA conditions.

Monitoring Approaches


UAF OARC

Fixed Moorings: OA sensors tethered to the ocean floor are located in the northern Gulf of Alaska, Kachemak Bay, Bering Sea, Chukchi Sea, and Beaufort Sea.


NOAA

Autonomous Vehicles: Saildrones can cover large geographic areas over weeks and months at relatively low cost. Pilot voyages in the Bering and Chukchi Seas in 2017 and 2018 have brought back useful results.

AMHS

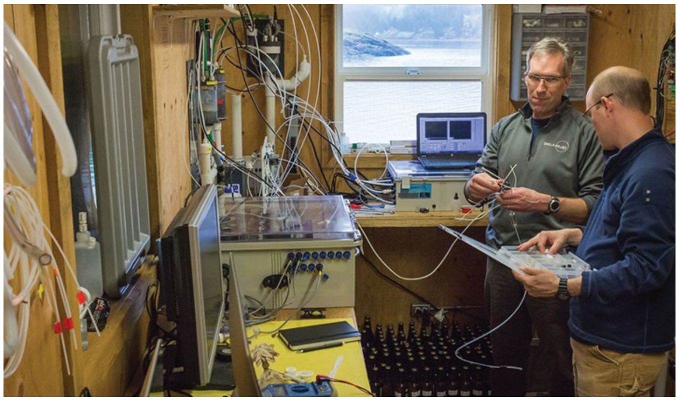
Sensor-equipped Vessels: Starting in 2017, the Alaska Marine Highway ferry M/V *Columbia* collected OA data during its 1,854 mile round-trip weekly run between Bellingham, WA and Skagway, AK.


GulfWatch Alaska

Ship-based Water Samples: For the last 10 years, water samples from a transect extending into the Gulf of Alaska have been analyzed for OA parameters. NOAA also completes a ship-based monitoring effort in Alaska every 4 years.

KBNERR

Shoreside Sampling: Community-based efforts in the Southcentral, Southeast, and most recently the Arctic have produced weekly water samples, helping to provide local pH level data at a regional scale.


Hakai Institute

Burke-o-Lators: Often co-located at hatcheries or labs, these high-accuracy systems analyze multiple OA parameters and provide a clear picture of real-time conditions. Burke-o-Lators are located in Seward, Ketchikan, Sitka, and Kodiak and maintained with expertise from the Hakai Institute.

What is the Network?

The Alaska Ocean Acidification Network was developed to expand the understanding of OA processes and consequences in Alaska, as well as potential adaptation strategies and mitigation actions. The network helps connect scientist and stakeholder communities to identify knowledge gaps, recommend regional priorities, share data, and determine best practices for monitoring in Alaska.

What You Can Do

- Join the Network!
- Subscribe to the monthly eNews
- Host a speaker in your community
- Join a community sampling effort
- Help inform and educate decision makers
- **Reduce carbon emissions**

PARTNERS

- Alaska Ocean Observing System (coordinator)
- Alaska Bering Sea Crabbers
- Alaska Center for Climate Assessment and Policy
- Alaska Department of Fish & Game
- Alaska Marine Conservation Council
- Alaska Marine Highway System
- Alaska Native Tribal Health Consortium
- Alaska Ocean Observing System
- Alaska Trollers Association
- Alaska Sea Grant – Marine Advisory Program
- Alaska Seafood Marketing Institute
- Alaska Shellfish Growers Association
- Alutiiq Pride Shellfish Hatchery
- Armstrong-Keta Hatchery
- Bering Sea Aleutian Island LCC
- Blue Evolution
- Bristol Bay Regional Seafood Development Association
- Hakai Institute
- InletKeeper
- Kachemak Bay Research Reserve
- Kasitsna Bay Lab
- National Park Service
- Native Village of Kotzebue
- NOAA Alaska Fisheries Science Center
- NOAA Arctic Program
- NOAA Ocean Acidification Program
- OceansAlaska Marine Science Center & Hatchery
- Prince William Sound Science Center
- Southeast Alaska Tribal Ocean Research
- Sitka Sound Science Center
- Sitka Tribe
- UAF Ocean Acidification Research Center
- UAF School of Fisheries and Ocean Sciences
- UAS Alaska Coastal Rainforest Center
- UAA Institute for Social and Economic Research
- United Fishermen of Alaska
- U.S. Arctic Research Commission

Alaska Ocean Acidification Network

www.aoos.org/alaska-ocean-acidification-network