Alaska Ocean Acidification Network

Ocean Acidification

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

2019 UPDATE

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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.

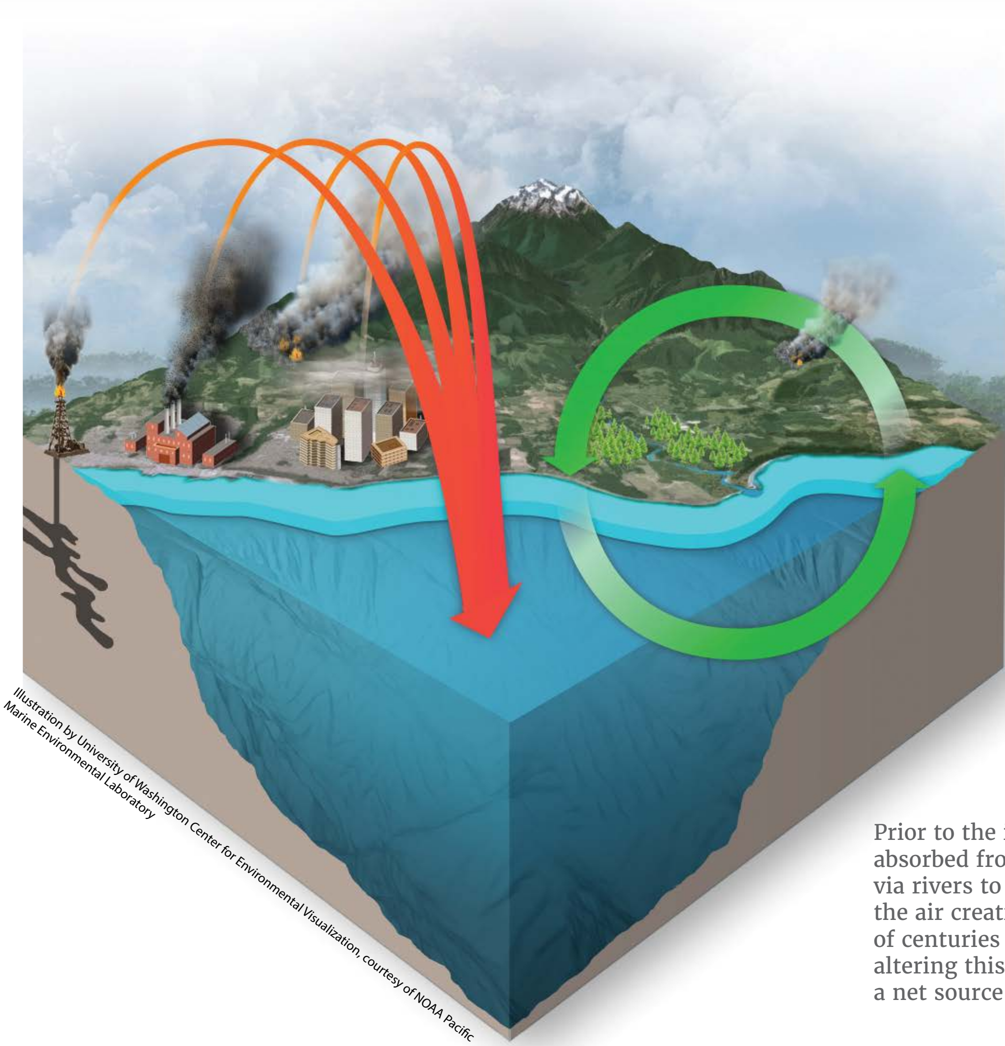
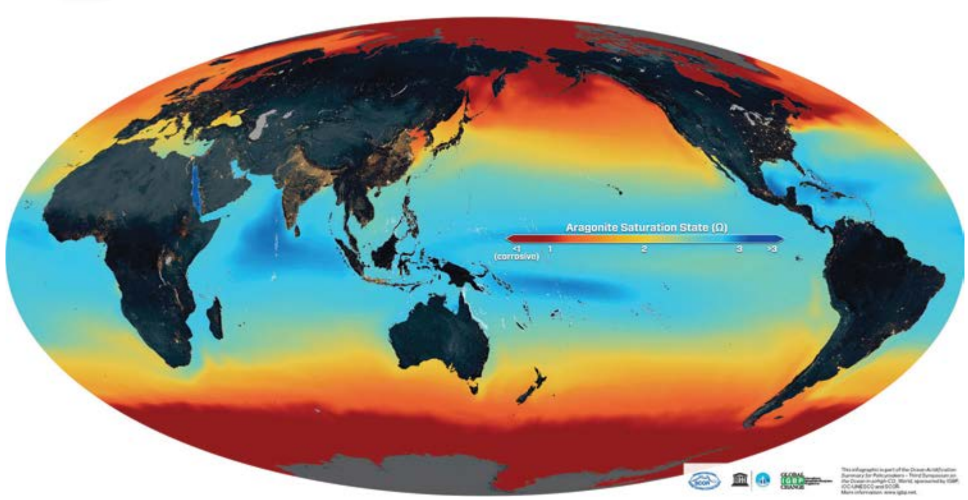


Illustration by University of Washington Center for Environmental Visualization, courtesy of NOAA Pacific Marine Environmental Laboratory

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.

New Research on Species Response

Acidification of seawater reduces the amount of calcium carbonate minerals needed for shell-building organisms to build and maintain their shells which pose a danger for species such as crab, clams, and some types of zooplankton. Changes in ocean chemistry can also affect fish. For instance, higher acidity water has been shown to reduce the ability for some fish to detect predators. The sections here present new research from 2019. For information on crab, walleye pollock, Pacific cod, northern rock sole, salmon and butter clams, please see last year's report.

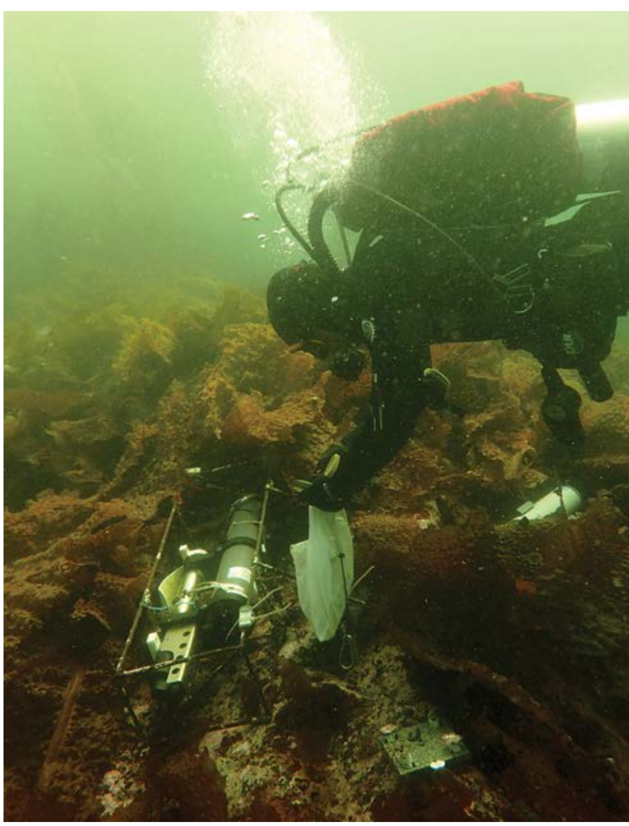
Herring

Researchers in Sitka are looking at the effects of future ocean warming and acidification on the earliest life stages of Pacific herring from fertilization to larval hatch. Preliminary results indicate that effects of warming are more pronounced than effects of changing pH, and that warmer temperatures negatively affect the oxygen uptake of herring eggs as well as the nutritional condition of the larvae at hatch. Roe raised in more acidic conditions were longer and had smaller yolks at hatch than those raised in current seawater pH, though interestingly, higher temperatures had the opposite effect on developing herring. Ongoing research will consider whether natural habitats for herring roe – such as seagrass or kelp – could mitigate the impacts of ocean acidification (OA). Like terrestrial plants, kelp and seagrass remove carbon dioxide from their environment during photosynthesis, so there is much interest in whether these species could create localized, less corrosive 'refuges' for herring in a future ocean.

CONTACT: LAUREN BELL, UC SANTA CRUZ

Lauren Bell

Angela Bowers (UAS) arranges Pacific herring eggs on pieces of giant kelp in Sitka in spring 2019 as part of an experiment to test the impacts of rising temperature and pCO_2 on developing herring roe.



Lauren Bell

Kelp Forest Communities

Researchers at the University of California Santa Cruz are looking at how natural seasonal swings in temperature and pH in southeast Alaska waters affect relationships between kelp forest species such as urchins, abalone and giant kelp. They are also looking at how future warming and pH conditions might change how these species interact. The research draws from year-round data from water sensors and SCUBA surveys in giant kelp forests, along with laboratory experiments. The aim is to tease apart how the multiple stressors associated with global change may interact, resulting in altered growth, nutrition, and feeding rates of important species at the base of the food web.

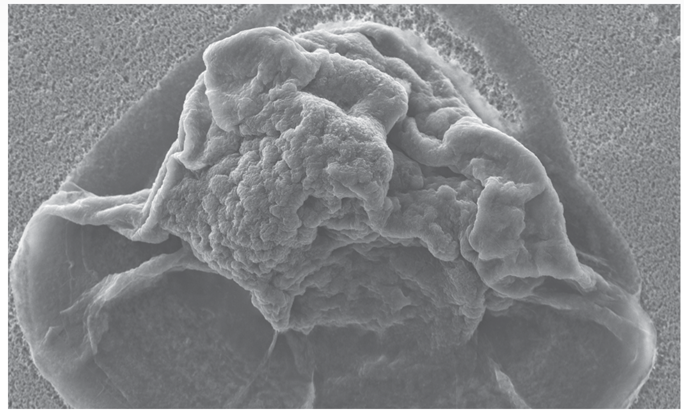
Preliminary results show that energy demands may change under future conditions of warming and acidification, which may lead to a mismatch between food needs and availability. Ultimately, this research will indicate whether certain times of the year may be more stressful to kelp communities, and how these changes may affect other commercially important species that depend on giant kelp forests.

CONTACT: LAUREN BELL, KRISTY KROEKER, UC SANTA CRUZ

Bivalves

Understanding how OA will impact bivalves is critical to forecasting the future of these fisheries. University of Alaska researchers are collaborating with Alutiiq Pride Shellfish Hatchery, to examine the susceptibility of Pacific razor clams to OA during their vulnerable early life stages. Preliminary data has shown that razor clams have a unique way of building their shells that utilizes a form of calcium carbonate early in development that may leave them more susceptible to acidification. This process, known as a concretion, delays the production of a fully mineralized shell until later in larval development. The discovery of this shell building-process in an Alaskan bivalve opens an entirely new avenue of questions about other Alaska bivalve species. It is crucial to see how a bivalve's developmental technique may dictate whether or not the species will be a winner or a loser in the face of an acidified ocean.

CONTACT: AMANDA KELLEY, UNIVERSITY OF ALASKA FAIRBANKS



Marina Washburn

A Pacific razor clam (*Siliqua patula*) larvae at 14 days old. Concretion is still the dominating shell type here, distinguished by a wrinkled texture dominating the main body and surrounded by a thin, flexible rim. Around 28 days old, this concretion will be replaced by a fully mineralized shell.

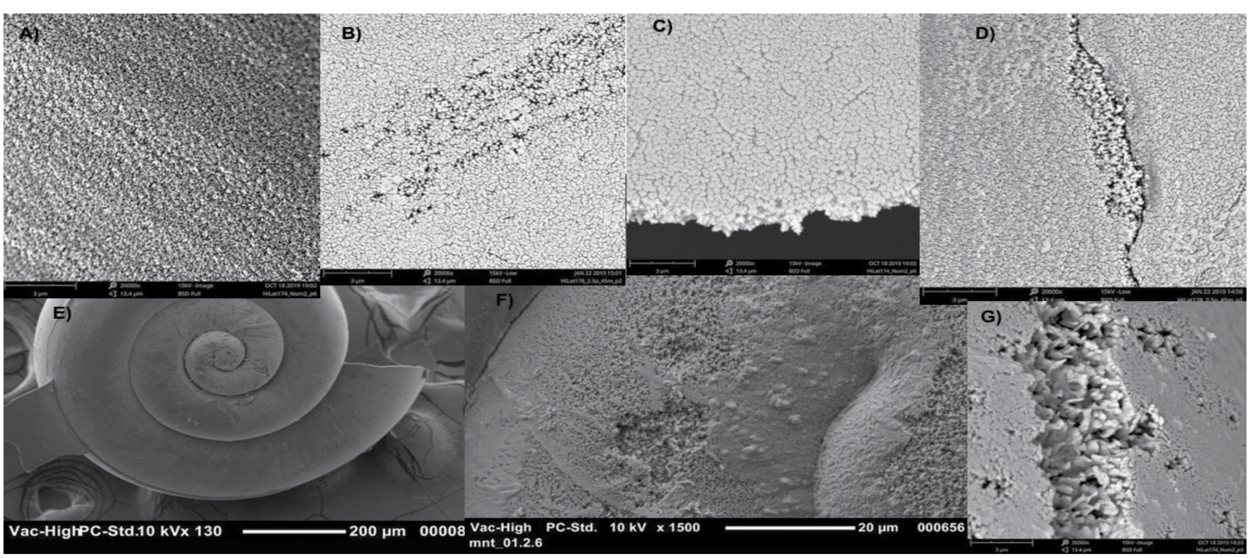
Pteropods

Pelagic calcifying snails (pteropods) are found in high abundance in the Gulf of Alaska and Bering Sea, and are a significant component of the diet of economically important fish. Pteropods have thin shells that readily dissolve, making them susceptible to increases in ocean acidification, but the impact of environmental change on pteropods' vital biological processes, and thus indirectly on the fisheries, is still uncertain.

Research supported by the North Pacific Research Board demonstrated that corrosive conditions in the western part of the Gulf of Alaska currently start around a depth of 70 meters, and intensify with increasing depth. The most corrosive conditions were present in the spring and summer.

In the Bering Sea, the study found corrosive conditions at a depth of 50 meters in some parts of the eastern basin, becoming more widespread in the central and the western part. This means portions of the Bering Sea and central Gulf of Alaska are very susceptible to future ocean acidification. There is evidence that these corrosive conditions are already harming pteropods; extensive shell dissolution has been documented in pteropods in both the Gulf of Alaska and the Bering Sea. The most severe dissolution has been seen in juvenile pteropods that are exposed to prolonged corrosive conditions in these areas.

CONTACT: NINA BEDNARSEK, SOUTHERN CA COASTAL WATER RESEARCH PROGRAM

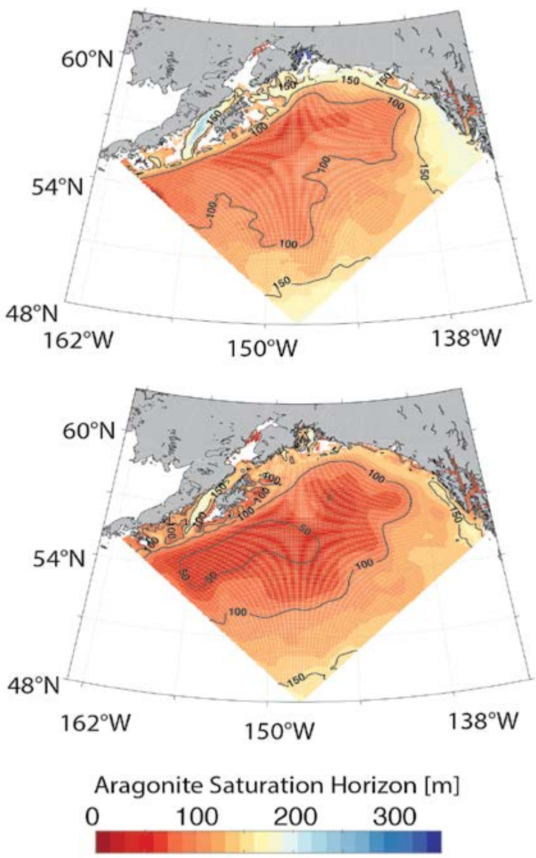


This image shows various degrees of pteropod shell dissolution from the Gulf of Alaska and the Bering Sea, ranging from mild dissolution and increased porosity (A, B), to moderate dissolution (C), to more severe dissolution (D–G)].

Looking Back at 40 Years of Ocean Change in the Gulf of Alaska

The combined effects of climate change and ocean acidification are altering the habitat of commercially important species in the Gulf of Alaska. Glacial melting, for example, may accelerate the progression of OA because freshwater dilutes the buffering capacity of seawater against carbon dioxide. However, due to a limited number of measurements, little is known about the current state and rate of change of the chemical habitat for key species.

University of Alaska Fairbanks researchers developed a model of the ocean circulation, chemistry, and biology for this region to get a better idea of how the system may have already changed, look for regional hotspots, and identify environmental controls that either enhance or mitigate ocean acidification. The model was run from 1980 through present day and is capable of reproducing recently observed conditions, such as the seasonal occurrence of on-shelf aragonite undersaturation in subsurface waters ("undersaturation" = corrosive to shell-building organisms).



These images show the modelled expansion of corrosive water in both depth and breadth between 1980 (top image) and 2013 (bottom image). The color refers to the depth at which the water below is undersaturated with respect to aragonite (corrosive to shell building organisms). In 2013, corrosive water has expanded closer to the surface, shown in the dark red.

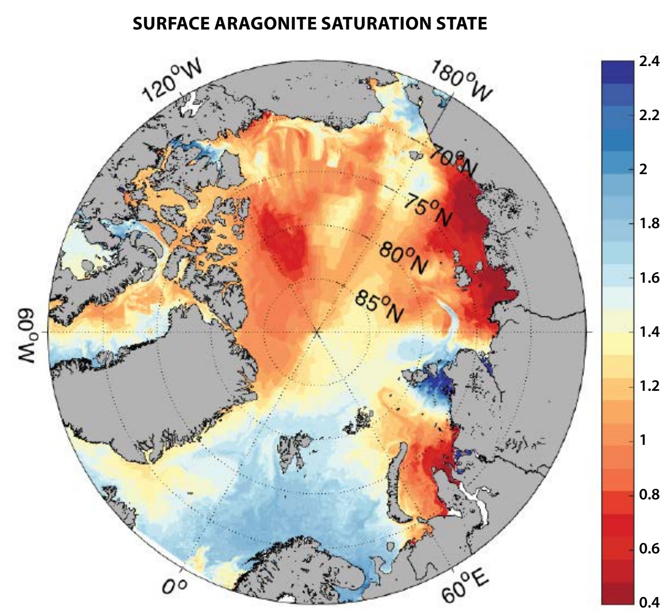
This simulation of the past proposes that certain areas on the continental shelf have been undersaturated for the past 40 years; however present conditions show undersaturation lasts longer and is more widespread. Preliminary results also suggest that aragonite saturation state is decreasing (becoming more corrosive) by about 0.06 per decade - some of it driven by the human contribution of CO_2 emissions into the atmosphere and some by increased freshwater inflow to nearshore areas as a result of climate change. The researchers are currently looking into daily, seasonal, interannual, and decadal variability to better distinguish between natural and human-caused changes. In collaboration with marine biologists, the simulation will be used to study how these environmental changes may have already shaped the distribution of organisms in the Gulf of Alaska.

CONTACT: CLAUDINE HAURI, UNIVERSITY OF ALASKA FAIRBANKS

Arctic Modeling

Researchers from the University of Alaska Fairbanks also developed a model of the Chukchi Sea and greater Arctic, similar to the Gulf of Alaska model described above. Like its southern counterpart, this model includes ocean circulation, chemistry, and biology, and provides a look back in time from 1980 to the present day. The model will improve our understanding of carbon dynamics and which controlling forces may enhance or mitigate ocean acidification.

CONTACT: CLAUDINE HAURI, UNIVERSITY OF ALASKA FAIRBANKS



This map shows a model of the surface aragonite saturation state. Values under 1 are "undersaturated" or corrosive to shell-building organisms.

Southeast Alaska - What We've Learned from a 1,854-mile Ferry Transect

Since November 2017, the Alaska Marine Highway System (AMHS) M/V *Columbia* has been monitoring for ocean acidification during its weekly route from Bellingham, WA to Skagway, AK. The vessel has taken surface measurements of temperature, salinity, dissolved oxygen content and carbon dioxide partial pressure (pCO_2) every 2 minutes along its 1,854 mile route, and has produced more than 700,000 pCO_2 measurements over 135 transits. These four variables were analyzed together and used to assess the patterns in surface ocean pH and the saturation state of aragonite (Ω_{arag}). Ω_{arag} is an important parameter that describes the stability of aragonite, the most soluble form of calcium carbonate used by shell-building organisms. When Ω_{arag} is less than 1, aragonite tends to dissolve and conditions are corrosive for shells.

The M/V *Columbia* takes measurements every 3 minutes along it's weekly route between Bellingham, WA and Skagway, AK. This project was made possible with support from the Hakai Institute, NOAA, AOOS, and the Alaska Coastal Rainforest Center.

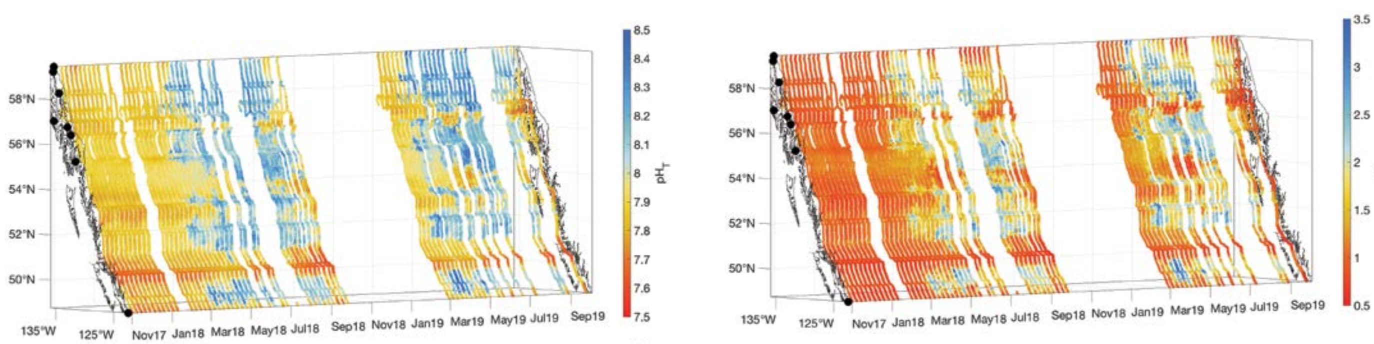
What can we see in the data?

The records of surface ocean pH and Ω_{arag} derived from the ferry data provide a first-ever view of the large variability that occurs through time along the coast. Clear seasonal changes are evident with winter pH values near 7.8 and and Ω_{arag} near 1; while summer values can exceed a pH of 8.4 and Ω_{arag} of 3. The higher pH and more favorable Ω_{arag} conditions in the summer are due in large part to the high rates of phytoplankton productivity that feed the productive fisheries in this region (the phytoplankton remove CO_2 from the surface water through photosynthesis).

Winter-like conditions persist year-round in specific areas where intense tidal mixing occurs, such as in Wrangell Narrows between the communities of Wrangell and Petersburg (AMHS terminals marked with black dots in the figure below). Freshwater also influences these parameters, particularly in late summer in the northern reaches of the transit (i.e. around Juneau and north into Lynn Canal). In this setting, the source of freshwater is melting glaciers that results in unique pH and Ω_{arag} conditions with pH near 8.2 while Ω_{arag} is reduced to levels below 1. This means the pH is relatively high but that chemical conditions are unstable for shell-builders to produce a shell.

The information from the ferry has proven invaluable for mapping patterns of surface of pH and Ω_{arag} conditions at a resolution we have not been able to achieve before. However, these patterns have and are changing, and this information provides an important baseline to assess the changes in pH and Ω_{arag} that have occurred as a result of the growing contribution of anthropogenic (human-caused) CO_2 in these waters. A forth-coming publication will provide this new information for this region.

CONTACT: WILEY EVANS, HAKAI INSTITUTE



Surface seawater pH (left) and aragonite saturation state (Ω_{arag}; right) captured from the M/V *Columbia*. These data are plotted according to where they were collected (that latitude and longitude position along the outlined coastline) and the time they were collected (November 2017 to October 2019). The black dots along the coastline mark the AMHS terminals, which from south to north are: Bellingham WA, Ketchikan AK, Wrangell AK, Petersburg AK, Sitka AK, Juneau AK, Haines AK, and Skagway AK. Data gaps were due to either AMHS service interruptions or issues with the instrumentation on the vessel. Year 1 data is available here: https://dx.doi.org/10.21966/zxzr-e472.

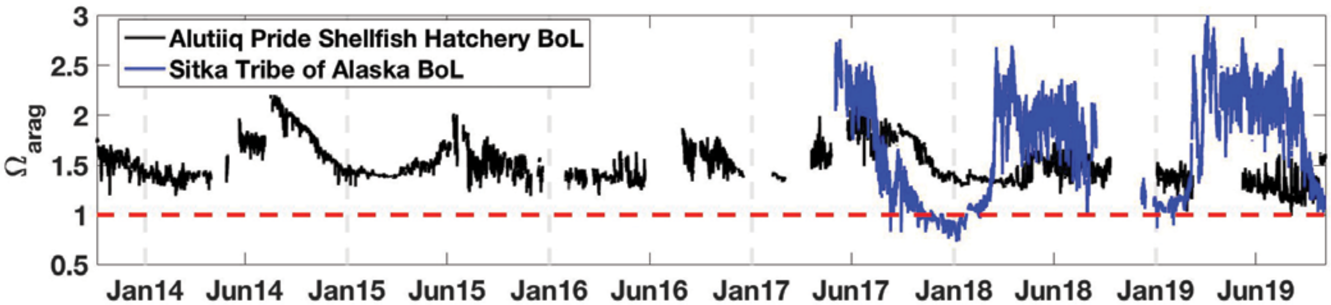
Nearshore Observations from 'Burke-o-Lators' in Alaska

Burke-o-Lators, which are shore-based machines that analyze the carbon chemistry of seawater in real-time, are a critical part of our ocean acidification observing portfolio in Alaska as well as along the North American Pacific coast. Four Alaskan sites maintain Burke-o-Lators: (1) the Alutiiq Pride Shellfish Hatchery in Seward, (2) the Sitka Tribe of Alaska's Environmental Research Laboratory in Sitka, (3) the OceansAlaska aquaculture facility in Ketchikan, and (4) the NOAA Alaska Fisheries Science Center Kodiak Laboratory. The Seward and Sitka sites have produced the longest data records to date and are highlighted below.

Shown in the figure below is the Ω_{arag} of the intake water drawn from a depth of 70 m at the Alutiiq Pride Shellfish Hatchery (APSH; black) and from a depth of 1 m at the Sitka Tribe of Alaska's Environmental Research Laboratory (blue). Winter values at both locations are lower relative to the summer values due predominately to the effects of winter storm mixing and high rates of phytoplankton productivity in summer. Year-to-year differences are evident in the records, with the now 6-year time series from Seward representing one of Alaska's longest near-shore ocean acidification observing records. To date, observations from APSH have not captured corrosive conditions, while winter values at the site in Sitka have observed Ω_{arag} less than 1. These time series locations not only provide important seasonal context of variable Ω_{arag} conditions, but ultimately will provide information on the rate of change for these parameters in Alaska's coastal waters.

CONTACT: WILEY EVANS, HAKAI INSTITUTE

Burke-o-Lators are high-accuracy systems that analyze multiple ocean acidification parameters and provide a clear picture of real-time conditions. Wiley Evans of the Hakai Institute (right) oversees the maintenance of Alaska's four Burke-o-Lators. He's pictured here with Burke Hales of Oregon State (inventor of the Burke-o-Lator).



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
- Hoonah Indian Association
- InletKeeper
- Kachemak Bay Research Reserve
- Kasitsna Bay Lab
- Kodiak Area Native Association
- Meridian Institute
- National Park Service
- Native Village of Kotzebue
- NOAA Alaska Fisheries Science Center
- NOAA Arctic Program
- NOAA Ocean Acidification Program
- NOAA Pacific Marine Environmental Lab
- North Slope Borough Dept of Wildlife
- OceansAlaska Marine Science Center & Hatchery
- Prince William Sound Science Center
- Southeast Alaska Tribal Ocean Research
- Sitka Sound Science Center
- Sitka Tribe
- Southern California Coastal Water Research Project
- UAF College of Fisheries and Ocean Sciences
- UAS Alaska Coastal Rainforest Center
- UAA Institute for Social and Economic Research
- University of Wyoming
- United Fishermen of Alaska
- U.S. Arctic Research Commission
- Yakutat Tlingit Tribe

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**

Alaska Ocean Acidification Network

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