Impacts of Ocean Acidification on Washington´s Marine Species

Science information sheet

WASHINGTON OCEAN ACIDIFICATION CENTER
UNIVERSITY of WASHINGTON
MARINE RESOURCES ADVISORY COUNCIL

Understanding the effects of ocean acidification on marine species – including those that are economically and ecologically important – is critical to responsive and effective management of Washington's marine ecosystems (Washington State Blue Ribbon Panel Action 7.3.2). Realizing this, the Washington State Legislature provided $170,000 to the Washington Ocean Acidification Center (WOAC) in the 2013-2015 biennium for laboratory studies to assess the effects of ocean acidification on Washington's species and ecosystems and to study their ability to adapt to ocean acidification.

What species are being investigated?

WOAC, working with partners at Western Washington University and NOAA's Northwest Fisheries Science Center, has started laboratory studies on Dungeness crab, geoducks, Olympia oysters, and krill. These species were identified by resource managers as being critical to Washington State's economy and marine ecosystems. Studies from other regions have revealed significant negative effects of low pH and low dissolved oxygen on these and similar species.

How has the state investment been leveraged?

A highly skilled team of researchers has come together to conduct these experiments. Working at specialized facilities at the University of Washington, Western Washington University, and the National Oceanic and Atmospheric Administration's (NOAA) Mukilteo facility these researchers have leveraged federal funds and resources.

Continued research on ocean acidification impacts to species is needed in 2015-17

Funds are needed to investigate ocean acidification impacts on other vital Washington species. Our native fish species are of great economic and ecological importance in Washington, and little is known about their response to changes in pH, CO2 concentration, or oxygen concentration. In other regions, fish species have been shown to be highly sensitive to changes in these variables. New experiments in the 2015-17 biennium will help to illuminate the impacts of ocean acidification on fish species in Washington.

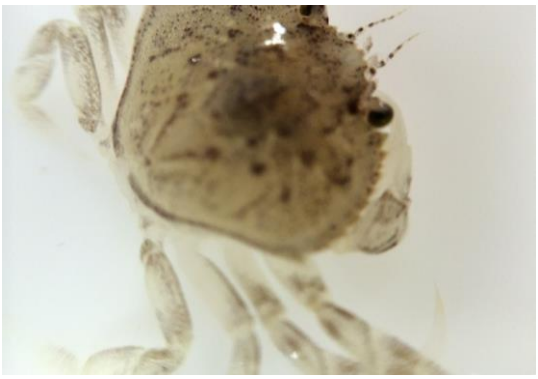
Juvenile krill

What you need to know

- $170,000 provided by State Legislature in 2013-2015 biennium for laboratory studies to assess the effects of ocean acidification on species and ecosystems
- Studies conducted on Dungeness crab, geoducks, Olympia oysters, and krill
- Initial results indicate these species are negatively impacted by higher levels of CO2 and ocean acidification conditions
- Research has leveraged $200,000 through the National Science Foundation

What are we learning about the impacts of ocean acidification on these species?

These laboratory experiments are on schedule to be completed in June 2015. Preliminary results from experiments on one species of krill showed that survival was lower among individuals exposed to higher levels of CO_2. This result is surprising given that the levels of CO_2 used in the experiments were not particularly high compared with those found in the local environment, suggesting that krill may already be experiencing negative effects of increasing levels of CO_2 in Washington waters.



Juvenile Dungeness crab

Preliminary results from experiments on Dungeness crab and a closely related species suggest that higher levels of CO_2 and lower levels of oxygen cause delayed development in early life stages. The slowest development was observed when both high CO_2 and low oxygen occurred together, a condition that is common in bottom habitats in Washington. The consequences of delayed development can translate into lower survival because of predation and other factors.

Conducting experiments to test how ocean acidification impacts species in Washington State

How do these results help us move forward?

Data collected from these experiments are critical to understanding how ocean acidification may impact Washington's marine ecosystem as changes in pH, CO_2 concentration, and oxygen concentration persist into the future. The preliminary results indicate the species vital to Washington's economy and marine environment are negatively impacted by higher levels of CO_2, and that these effects are intensified under conditions of low oxygen. These studies also show that some species are affected by conditions that we are seeing in Washington waters now, not decades in the future.

For more information

See the Washington Ocean Acidification Center website:
http://coenv.washington.edu/research/major-initiatives/ocean-acidification/

Contact Washington Ocean Acidification Center Co-Directors:
Dr. Terrie Klinger, tklinger@uw.edu, 206 685 2499
Dr. Jan Newton, janewton@uw.edu, 206 543 9152

Monitoring and Adaptation to Ocean Acidification in the Shellfish Industry

Science information sheet

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Ocean acidification and the corrosive water conditions it creates can reduce survival and overall growth of juvenile shellfish. In an effort to inform managers and growers in the commercial shellfish industry about seawater conditions, the Washington State Legislature provided $150,000 to the Washington Ocean Acidification Center (WOAC) in the 2013-2015 biennium to direct monitoring efforts at six existing shellfish hatcheries (Washington State Blue Ribbon Panel Action 6.2.1). The Legislature also provided $100,000 to investigate and develop commercial scale water treatment methods to protect shellfish from corrosive waters (Washington State Blue Ribbon Panel Action 6.2.3).

How has Washington's shellfish industry helped monitor ocean acidification?

WOAC has worked with Washington shellfish growers through the Pacific Coast Shellfish Growers Association to maintain and enhance ongoing ocean acidification monitoring at six shellfish hatcheries and growing sites. Their monitoring efforts have provided new information for managers and researchers alike. Evidence shows that water chemistry in bays and estuaries each summer already falls well below the optimal growing conditions of sensitive marine species. Data collection at hatchery sites also reveals that there is a great deal of local variability in water chemistry. Understanding this variability and how corrosive conditions can be particularly acute in coastal areas is a key concern for growers in the Pacific Northwest.

Hatchery data collected through these efforts is uploaded immediately to the Northwest Association of Networked Ocean Observing Systems (NANOOS) web data portal and is

Continued monitoring and adaptation research for shellfish growers is needed in 2015-17

Funds are needed to sustain current monitoring efforts specific to shellfish sites. These data help shellfish growers make day-to-day management decisions for their businesses, and in the long term, will help the shellfish industry successfully adapt to changing marine conditions. The monitoring efforts at shellfish sites also constitute an important component of the Washington Integrated Ocean Acidification Monitoring Network, adding to a growing knowledge of water chemistry in our economically important coastal bays. Continued testing to scale up water treatment methods is also needed to ensure the shellfish industry can adapt to changing water quality.

Benoit Eudeline of Taylor Shellfish Hatchery using real-time monitoring equipment that measures pH and water chemistry of seawater.

What you need to know

- $150,000 provided by State Legislature in the 2013-2015 biennium to fund:
  - Ocean acidification monitoring at six shellfish hatcheries
  - Industry research on water treatment methods for adaptation
- WOAC leverages $527,000 federal NOAA investment by using the NANOOS web portal to share hatchery data
- WOAC coordination and support builds on $100,000 in industry research on adaptation methods

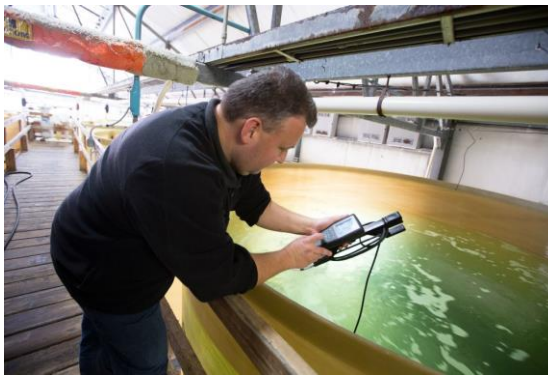
accessible on-line and by smartphones at no cost to Washington State. The real-time information can be used immediately to inform management practices at other commercial hatcheries, and to guide decisions by resource managers responsible for maintaining a variety of shellfish species important to the region. The result is improved shellfish production across Washington.

Six shellfish monitoring sites at:

- Taylor Shellfish Hatchery (Dabob Bay)
- Lummi Indian Nation Hatchery (near Bellingham)
- Grow-out sites in Willapa Bay (Tokeland)
- Ekone Oyster Company (Bay Center)
- Jolly Roger Oyster Company (Nahcotta)
- Whiskey Creek Shellfish Hatchery (Netarts Bay, OR; supported by funds through the Oregon State Legislature)

How is the shellfish industry beginning to adapt to changing conditions?

WOAC also coordinated and funded investigations by hatchery managers on the use of water treatment systems to improve shellfish production under corrosive water conditions. Initial development of water treatment systems has demonstrated early success. Small-scale systems in place at the Whiskey Creek hatchery have proven effective at maintaining healthy conditions in growing tanks and have improved survival and growth among growing shellfish. Another pilot system being tested by Taylor Shellfish has shown increased shellfish survival and growth. Challenges remain in scaling up these systems to operate at commercial scales, however. Commercial-scale systems already in place at Whiskey Creek have had limited success so far.



Eudeline monitoring oxygen concentration in growing tanks at the hatchery to investigating water treatment methods.

How has the state investment been leveraged?

Much of the equipment being used in this monitoring project was secured in 2010-2012 through funding from the National Oceanic and Atmospheric Administration (NOAA), with the direct support of Senator Maria Cantwell's office. Additionally, monitoring systems in place at Whiskey Creek, Taylor Shellfish, and Willapa Bay are provided by Oregon State University, leveraging investments by NOAA and U.S. Integrated Ocean Observing System (US IOOS). Staff at Taylor Shellfish and Pacific Shellfish Institute maintain the monitoring equipment and collect samples with assistance from a University of Washington scientist. The data is shared on the NANOOS database at no cost to WOAC, leveraging over $150,000 in federal NOAA investment.

Each hatchery has dedicated more than $100,000 in private funds for equipment and research toward developing water treatment adaptation systems. The additional funding provided through WOAC has allowed hatcheries to maintain and enhance their water treatment infrastructure and to test new treatment technologies that could potentially inform adaptation throughout Washington's shellfish industry.

How do these efforts help the shellfish industry?

Ocean acidification has already had a significant economic impact on commercial shellfish production in the Pacific Northwest. Shellfish hatcheries have used real-time data collected at these monitoring stations to improve oyster production in the face of challenging and highly variable water conditions in coastal bays. Coastal economies in Washington State and across the Pacific Northwest benefit from these efforts as more oyster production translates directly into more jobs in coastal communities. As ocean acidification intensifies over time, effective water treatment systems are needed to adapt and offset increasingly corrosive conditions.

For more information

See the Washington Ocean Acidification Center website:
http://coenv.washington.edu/research/major-initiatives/ocean-acidification/

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Dr. Jan Newton, janewton@uw.edu, 206 543 9152
Dr. Terrie Klinger, tklinger@uw.edu, 206 685 2499

Integrated Monitoring for Ocean Acidification in Washington's Waters

Science information sheet

WASHINGTON OCEAN ACIDIFICATION CENTER
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MARINE RESOURCES ADVISORY COUNCIL

Monitoring ocean acidification in our waters is critical to developing tools that allow marine industries to take action against ocean acidification. To advance Washington State Blue Ribbon Panel Action 7.1.1., the Washington State Legislature provided $625,000 to the Washington Ocean Acidification Center (WOAC) in the 2013-2015 biennium to establish an ocean acidification monitoring network that measures trends in local water quality conditions and impacts to marine life. Of this amount, $150,000 was explicitly allocated to monitoring at shellfish sites (see Shellfish information sheet) as part of the larger network.

What have monitoring efforts looked like?

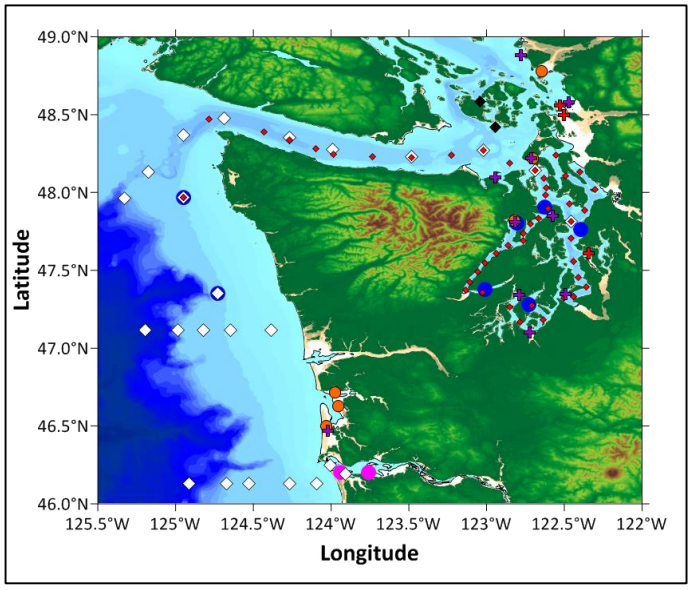
Using these funds, WOAC brought together diverse partners to create an integrated monitoring network for ocean acidification in the marine waters of the Washington coast and Puget Sound. Unlike other monitoring efforts, this network uniquely focuses on marine species as well as the chemical and physical properties of seawater in our estuarine, nearshore, and offshore environments. Funds were also used to support three monitoring buoys, monitoring cruises, and the deployment of high-quality pH sensors within the existing monitoring array. The network monitoring strategy focuses on high-priority plankton species as well as chemical and physical conditions such as pH, pCO_2, total alkalinity, dissolved inorganic carbon, oxygen, nutrients, chlorophyll, salinity, and temperature.

How has the state investment been leveraged?

The monitoring network includes a diverse array of federal, tribal, state, and local partners. WOAC's monitoring network plan includes strategic investments for integrated monitoring, and the network allows WOAC to leverage partners' experience, data, research assets, and several million dollars of investment.

Continued monitoring of ocean acidification is needed in 2015-17

Additional funds are needed in the 2015-2017 biennium to sustain integrated monitoring for ocean acidification in Washington's waters. Sustained monitoring will allow us to better understand where and how often corrosive water conditions are most severe, which species and marine industries will be most affected, and how we might mitigate the most harmful consequences. Monitoring plays a critical role in protecting our coastal economy in Washington.



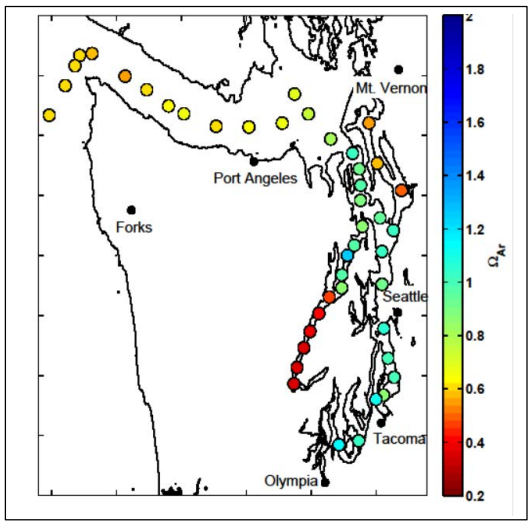
Monitoring sites of the WOAC monitoring network

In the figure above, white, red, and black diamonds are ship cruise stations; blue dots are OA buoys (or soon to be), pink dots are OA moorings; orange dots are shellfish grower sites, and crosses are nearshore monitoring stations, including those of WA DNR (purple).

What you need to know

- $625,000 provided by State Legislature in 2013-205 biennium to establish an ocean acidification monitoring network
- Funds used to assemble a network monitoring impacts to marine species and water quality on the coast and in Puget Sound ($475,000) and to support monitoring at six existing shellfish grower sites ($150,000)
- Funds also used to support three research buoys, several monitoring cruises, and improve sensor quality at nearshore, shellfish and basin sites
- Leveraged partnerships and funds with federal, tribal, state, and local entities, including $800,000 from NOAA and US IOOS

Through these efforts, WOAC leveraged federal investments of over $800,000 from the National Oceanic and Atmospheric Administration (NOAA) and U.S. Integrated Ocean Observing System (US IOOS). It used ship time funded by the National Science Foundation and the University of Washington. It also uses a real-time data portal provided by Northwest Association of Networked Ocean Observing Systems (NANOOS) funded federally by IOOS.



Corrosiveness of Washington's Waters
Red is more corrosive and blue is less corrosive

WOAC Monitoring Network Partners leveraging state investments

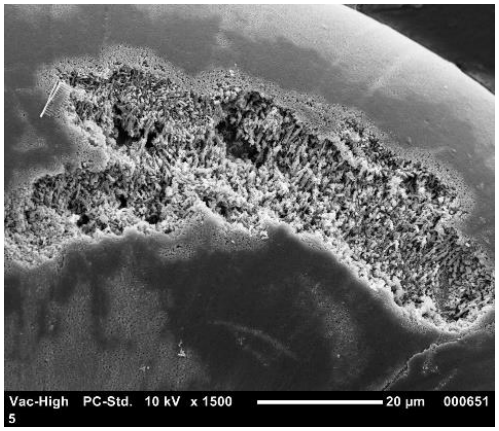
Federal: Environmental Protection Agency, National Oceanic and Atmospheric Administration, NOAA Pacific Marine Environmental Laboratory, National Science Foundation, NANOOS/US IOOS, Olympic National Park, Padilla Bay National Estuarine Research Reserve, Olympic Coast National Marine Sanctuary

Tribal: Stillaguamish Tribe

State: Washington Department of Natural Resources, Washington Department of Ecology, Western Washington University, Oregon Health and Sciences University

Local: King County, Seattle Aquarium

What are we learning through monitoring? Monitoring data show that ocean acidification conditions in Washington waters are highly variable in space and time. We need to understand this variability to develop response strategies that protect natural resources and coastal economies. For example, we now know that surface conditions generally differ from those in deeper waters and that variation in Puget Sound differs from that in outer coastal waters. Moreover, hot spots of exceptionally low pH, high-pCO_2 waters have been detected in Puget Sound. During most of the year, seawater conditions are corrosive to the shells of pteropods – a plankton species that provides food for fish. While pteropod shells collected off the coast have shown signs of corrosion due to ocean acidification, those collected from Whidbey Basin and Southern Hood Canal showed even worse corrosion, resulting in holes in the shells. Continued monitoring is needed to more fully understand this difference.



Whidbey Basin pteropod shell showing evidence of extensive corrosion

How will continued monitoring efforts help us in the future?
Washington's shellfish growers are already seeing the effects of ocean acidification on juvenile oysters. Similarly, plankton and pteropods – critical species within the marine food web – are also showing signs of harm due to ocean acidification. Sustained monitoring into the next biennium will allow Washington State to better understand the role of ocean acidification in creating corrosive marine conditions at local and regional scales and to predict future impacts to species of economic importance. Monitoring data will continue to guide Washington's industry, tribes, coastal communities, and resource managers in making sound management decisions to protect our marine ecosystems and the industries that rely on them.

For more information

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Dr. Terrie Klinger, tklinger@uw.edu, 206 685 2499

Daily Forecast Model of Ocean Acidification

Science information sheet

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To adapt to ocean acidification conditions, Washington's shellfish industry needs the ability to forecast corrosive seawater conditions on a day-to-day basis (Washington State Blue Ribbon Panel Action 7.4.1). The Washington State Legislature provided $325,000 to the Washington Ocean Acidification Center (WOAC) in the 2013-2015 biennium to develop short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern.

What is the ocean acidification forecast model?

WOAC selected a team to create a daily forecast computer model of ocean circulation for the Washington coast and Puget Sound. The model operates similar to those used in making weather forecasts, but instead of predicting rain and temperature, it predicts ocean currents, temperature, and salinity. This model also predicts ocean chemistry conditions, such as pH, and can forecast when corrosive ocean acidification will occur.

Continued expansion of the forecast model is needed in 2015-17

Funds are required to maintain the daily forecast system for Washington waters and keep it publically available. The portion of the model that is specific to Puget Sound will need additional work, and finer scale models should be incorporated for individual inlets, such as Willapa Bay, Totten Inlet, and Hood Canal. WOAC also will work with regional stakeholders and resource managers to improve the public website presentation of the forecast system to assure that it is user-friendly and delivers the information they need. This work will help Washington shellfish growers protect their shellfish stocks from corrosive waters.

Why is this type of forecast model so useful to shellfish growers?

Increased CO_2 in the atmosphere is absorbed by the ocean, increasing the acidity of the seawater. At times, these waters are actually corrosive to shelled organisms like oysters and some plankton, preventing them from forming or maintaining their shells. While ocean acidification is a global problem, the problem is made worse in the Pacific Northwest by local circulation patterns. The same ocean currents and chemistry that cause hypoxia in Hood Canal and on our coast also make the seawater more corrosive. The result has been dramatic for our shellfish industry – for most of the last decade there has been no natural set of oysters in Willapa Bay, causing growers to rely on hatcheries. The hatcheries themselves have lost oysters when especially corrosive waters are drawn in from the nearby ocean.

In order for the shellfish industry to respond to this crisis, improved information is critical. This forecast model gives Washington shellfish growers the benefit of knowing about corrosive water events several days in advance. This allows them to more efficiently manage their hatchery operations.

What you need to know

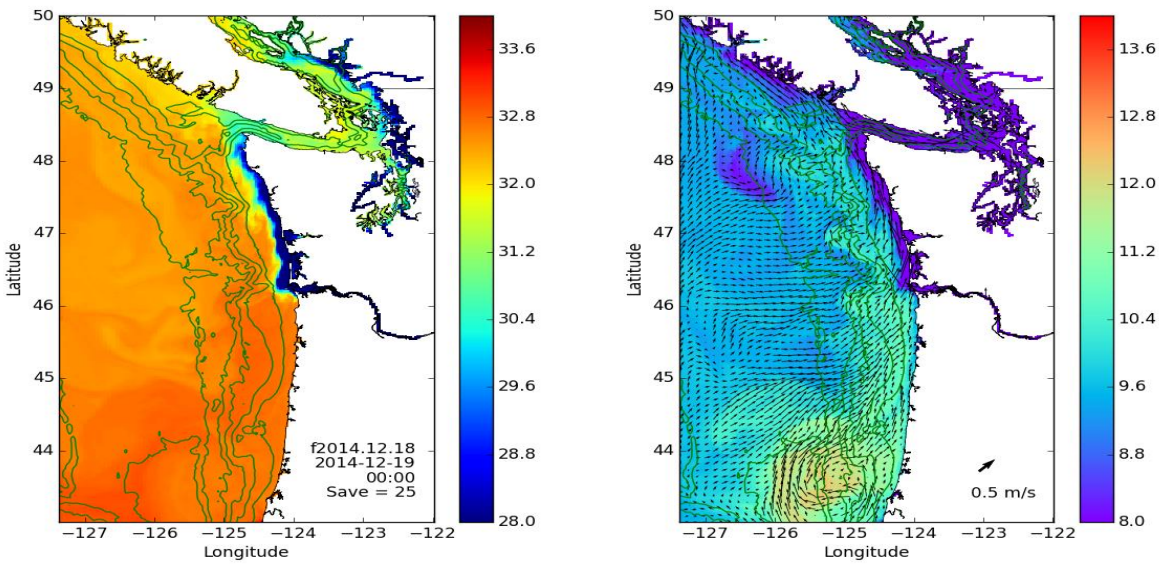
- $325,000 provided by State Legislature in the 2013-2015 biennium to assist shellfish industry in making short-term forecasts of corrosive or ocean acidification conditions
- The model provides real-time information accessible to shellfish growers and managers to track acidification on a scale of 3-7 days, giving them time to change or adjust their management practices
- Uses an online platform (created in collaboration with Microsoft Research) to make data publicly available
- Leveraged $300,000 from NOAA, the National Science Foundation, and Microsoft Research

How was the forecast model devleoped?

Ocean salinity and temperature affect pH and carbon chemistry, and are important variables to understand in forecasting corrosive ocean conditions. Other ocean processes and input from rivers can also significantly affect the pH and carbon chemistry of the coastal ocean and inland waters like Willapa Bay and Puget Sound. Through modeling salinity we have learned that the Columbia River is very important to regulating ocean chemistry, especially to nearby coastal estuaries and even the Puget Sound.

Since November 2014, the WOAC model has made daily forecasts of currents, temperature, and salinity. Additional forecast models currently in development will predict pH and carbon chemistry. By the end of the biennium, the public will be able to view these forecasts from a website.

Example model forecasts of surface salinity, temperature, and currents for December 2014. The salinity figure reveals outflow from the Columbia River forms a region of fresher water (lower salinity values) hugging the Washington coast, driven by the southerly winds typical of our winter storms. Getting the behavior of the river plume in the model correct, verified by data, is important because it strongly influences the chemistry of waters reaching the shellfish growing areas in places like Willapa Bay.



Surface Salinity **Surface Temperature (degrees C)**

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