




# Coastal Margin Observation and Prediction (CMOP)

A program of the Columbia River Inter-Tribal Fish Commission



**Columbia River Inter-Tribal Fish Commission**

Yakama | Umatilla | Warm Springs | Nez Perce



Salmon unselfishly  
give of themselves  
for our physical  
and spiritual  
sustenance.  
In turn, we must  
employ the depths  
of our hearts and  
the expanse of  
our minds to save  
and protect them.



Since time immemorial, the salmon have faithfully followed their lifecycle from freshwater rivers and streams to the Pacific Ocean and then back, returning the bounty of the sea with them. Native cultures in the Columbia Basin depend on the return of the salmon. The interdependence of the land, the ocean, the salmon, and the people is the foremost example of the traditional Native teaching that everything is connected.

Salmon are at the center of the traditional cultures of the **Yakama, Warm Springs, Umatilla, and Nez Perce tribes**. Together, these four tribes established the **Columbia River Inter-Tribal Fish Commission (CRITFC)** to coordinate their fisheries science, management, and policy development to support the protection and restoration of Columbia Basin salmon, lamprey, and sturgeon. CRITFC's research, conservation, and restoration efforts have historically focused on watersheds, which have been degraded by hydrosystems and other human disturbances. However, salmon also depend on healthy estuary and ocean environments.

In 2020, CRITFC assumed stewardship of the **Coastal Margin Observation and Prediction (CMOP)** program. This Astoria, Oregon-based program increases CRITFC's engagement in the estuary and ocean and furthers tribal efforts to ensure climate resilience in these critical ecosystems.

# Salmon depend on the Columbia River estuary and coastal ocean

A critically important period in the lifecycle of salmon and lamprey is the time they spend in the Columbia River estuary. It is here that they make their remarkable transition from living in fresh water to salt water and back.

Juvenile salmon can spend up to several months in the estuary before migrating to the ocean. During this time, salmon occupy diverse estuary habitats, including natural wetlands, which are a crucial source of insects for prey. Salmon that spend longer in the estuary tend to have higher survival rates, and salmon benefit from intact estuary habitat, underscoring the importance of estuary habitat restoration efforts.

Before completing their migration in the open ocean, juvenile salmon often spend time in the river plume, the mass of mixed river water and seawater that forms in the ocean from river discharge. The river plume provides a prey-rich environment, and likely plays an important role in salmon survival in the early marine stage. After spending one to five years in the ocean, salmon return to the river plume and estuary. They pause here to transition back to freshwater before continuing their journey to the stream where they were born in order to spawn.

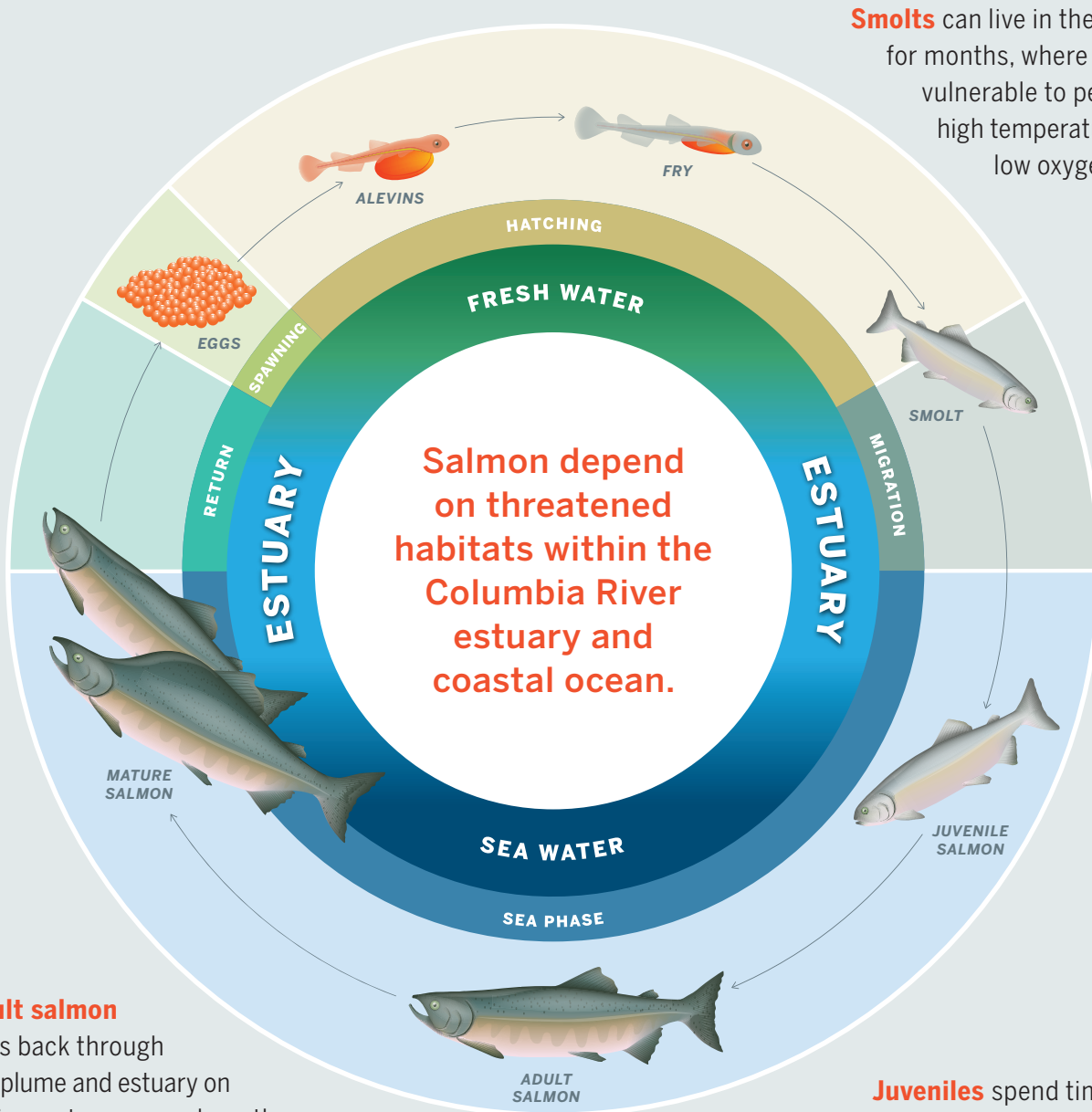
It is the important role that the Columbia River estuary plays in the salmon's lifecycle that drives CRITFC and its member tribes to further our understanding of this unique and vital ecosystem.



Photo credit © Barrie Kovich

# Estuaries

## A place of transition in the salmon lifecycle



**Smolts** can live in the estuary for months, where they are vulnerable to periods of high temperatures and low oxygen levels.

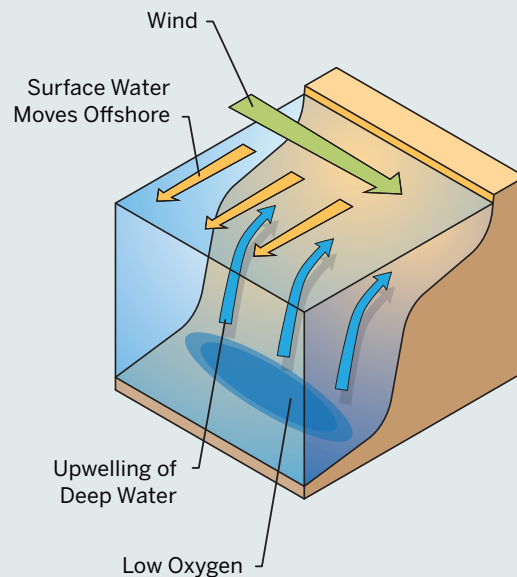
**Adult salmon** pass back through the plume and estuary on their way to spawn, where they are again vulnerable to warm and low-oxygen conditions.

**Juveniles** spend time in the river plume where prey are abundant before moving to the open ocean.

## Definitions

CMOP focuses on the Columbia River estuary and river plume—dynamic regions near the mouth of the Columbia. This research is a part of the science of oceanography. This field has specific terms for the unique ecosystems, conditions, and actions that occur in and near the ocean.

- **Estuary ecosystem**—the environment and organisms where the river meets the sea—includes unique plant and animal species. These organisms have adapted to brackish water, which is a mixture of fresh river water and salty seawater. Estuaries are among the most productive ecosystems in the world. Many animals rely on estuaries for food, places to breed, and migration stopovers.
- **Tidal estuary**—where water levels are influenced by ocean tides—extends from the coastline to Bonneville Dam. The tidal estuary includes wetlands and floodplains that provide food for resident and migrating juvenile salmon; these ecosystems have been degraded by human activities.
- **Saltwater estuary**—where water is sometimes salty—extends from the coastline to Cathlamet Bay and is a transitional zone for juvenile and returning salmon. The creation of the navigation channel likely extended this zone upriver, and sea level rise is expected to extend this zone even further.
- **River plume**—region of the coastal ocean influenced by the outflow of the Columbia River—has high densities of juvenile salmon. The extent and location of the plume varies through time.
- **Coastal upwelling**—the upward movement of deep ocean water caused by winds—has strong impacts on salmon in the estuary. When winds blow from the north for a sustained period, the rotation of the earth causes surface waters to move offshore, which brings deep ocean water that is cold, salty, oxygen-depleted, and nutrient-rich to the surface near the coastline. Tides pull this upwelled water into the estuary, where it sinks below the river water and can cause dangerously low oxygen levels at depth. Prolonged winds from the south cause the opposite process, called downwelling, which delivers high-oxygen waters to the estuary. Salmon are most vulnerable to low oxygen levels during the summer when the Pacific Northwest typically experiences upwelling.



*North winds cause the upward movement of deep ocean water.*

# Understanding the Columbia River estuary

In 2006, the National Science Foundation established a **Science and Technology Center for Coastal Margin Observation and Prediction (CMOP) program**, centered at Oregon Health & Science University, to conduct research and monitoring to increase our understanding of the complex and ever-changing interaction between the Columbia River and Pacific Ocean at the estuary. The invaluable information and research CMOP produced have been especially important to tribes and government agencies with salmon management authority.

In 2020, the Columbia River Inter-Tribal Fish Commission assumed stewardship of CMOP, seeing the potential for this program to increase engagement in the estuary and ocean and to ensure climate resilience in these regions. In the words of Jaime Pinkham, former executive director of CRITFC, “Our co-management ethos dictates that wherever the salmon go, we go with them.” CRITFC now benefits from existing CMOP products and also helps to guide the future direction of the program.

## CMOP Observation Network

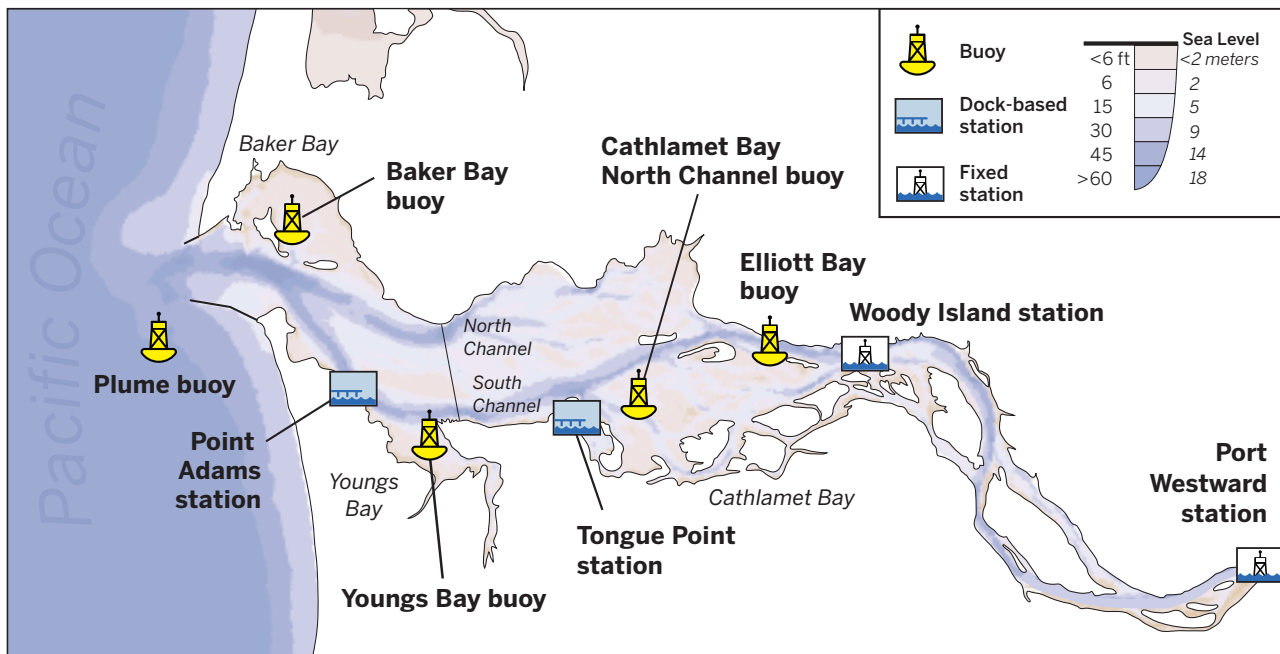
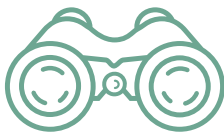


FIGURE 1: Locations of CMOP stations where temperature, oxygen, and other important water characteristics are continuously measured. Station locations include tidal wetlands, which are important habitats for juvenile salmon, and areas near the river mouth where coastal upwelling drives dangerously low oxygen levels.

# What does the Coastal Margin Observation and Prediction (CMOP) program do?



**B**ased at the mouth of the Columbia River in Astoria, Oregon, CMOP is a nationally renowned ocean and estuary research program. Using ocean sensors, models, and data products, CMOP seeks to understand the linkages between the Columbia River and the Pacific Ocean and to help guide salmon conservation and management efforts in the face of global change. The work of CMOP falls into three broad categories:



## OBSERVATION

The observation program monitors water characteristics that contribute to salmon success and investigates their long-term changes and drivers, including climate change.



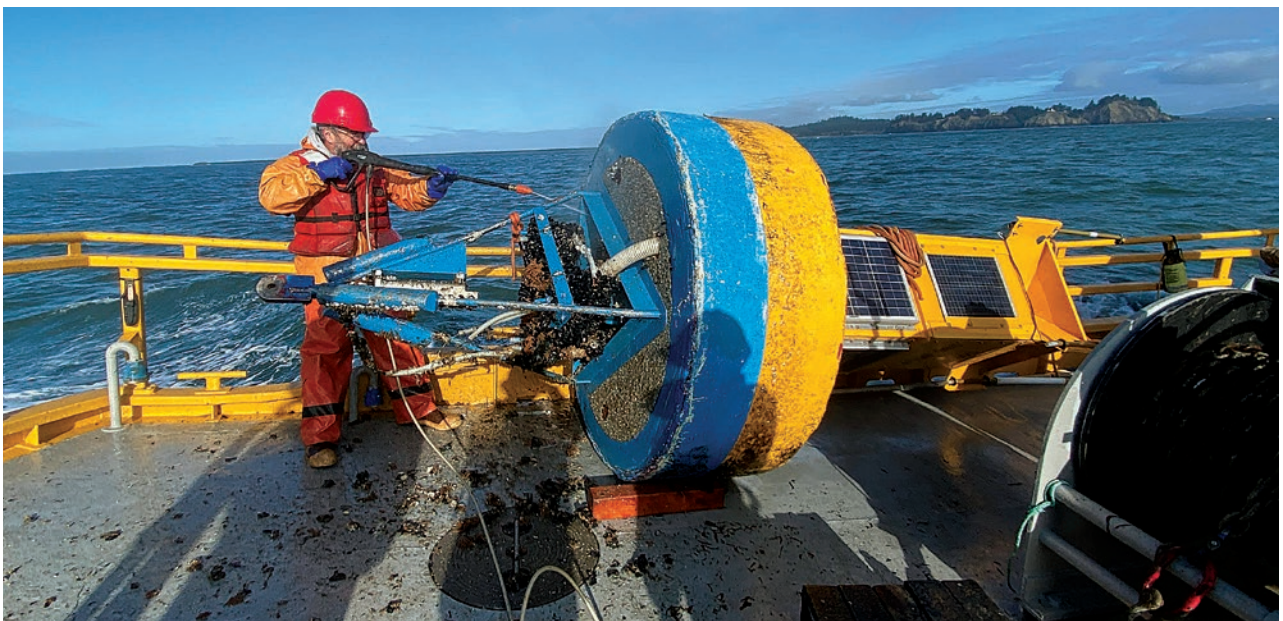
## PREDICTION

The prediction program models salmon-relevant parameters and habitat, guiding conservation and restoration efforts.



## DISSEMINATION

CMOP disseminates its work to tribes, academic and governmental institutions, NGOs, and private individuals and businesses to benefit a wide range of applications.





## The CMOP observation program

The CMOP observation network includes buoys, dock-based stations, and fixed stations in the saltwater estuary, the tidal estuary, and the river plume (FIGURE 1). These stations have been measuring the physical characteristics of water, such as temperature, salinity, water levels, and currents since 1996. In 2008, stations were upgraded to begin measuring chemical and biological

characteristics such as dissolved oxygen, turbidity, nitrate, and chlorophyll levels. The CMOP program collaborates with Oregon State University and the Quinault Indian Nation to monitor conditions in the coastal ocean using small robotic submarines ('ocean gliders'). CMOP observations are part of a larger regional network (NANOOS) that supplies funding for the maintenance of stations and instruments.

### The Northwest Association of Networked Ocean Observing Systems (NANOOS)

CMOP is a part of the national Integrated Ocean Observing System's regional association, the **Northwest Association of Networked Ocean Observing System (NANOOS)**. NANOOS provides funding for the maintenance of CMOP stations and connects CMOP data to a wealth of regional ocean data (<http://nvs.nanoos.org/Explorer>), enabling robust analyses of how our oceans are changing over time.

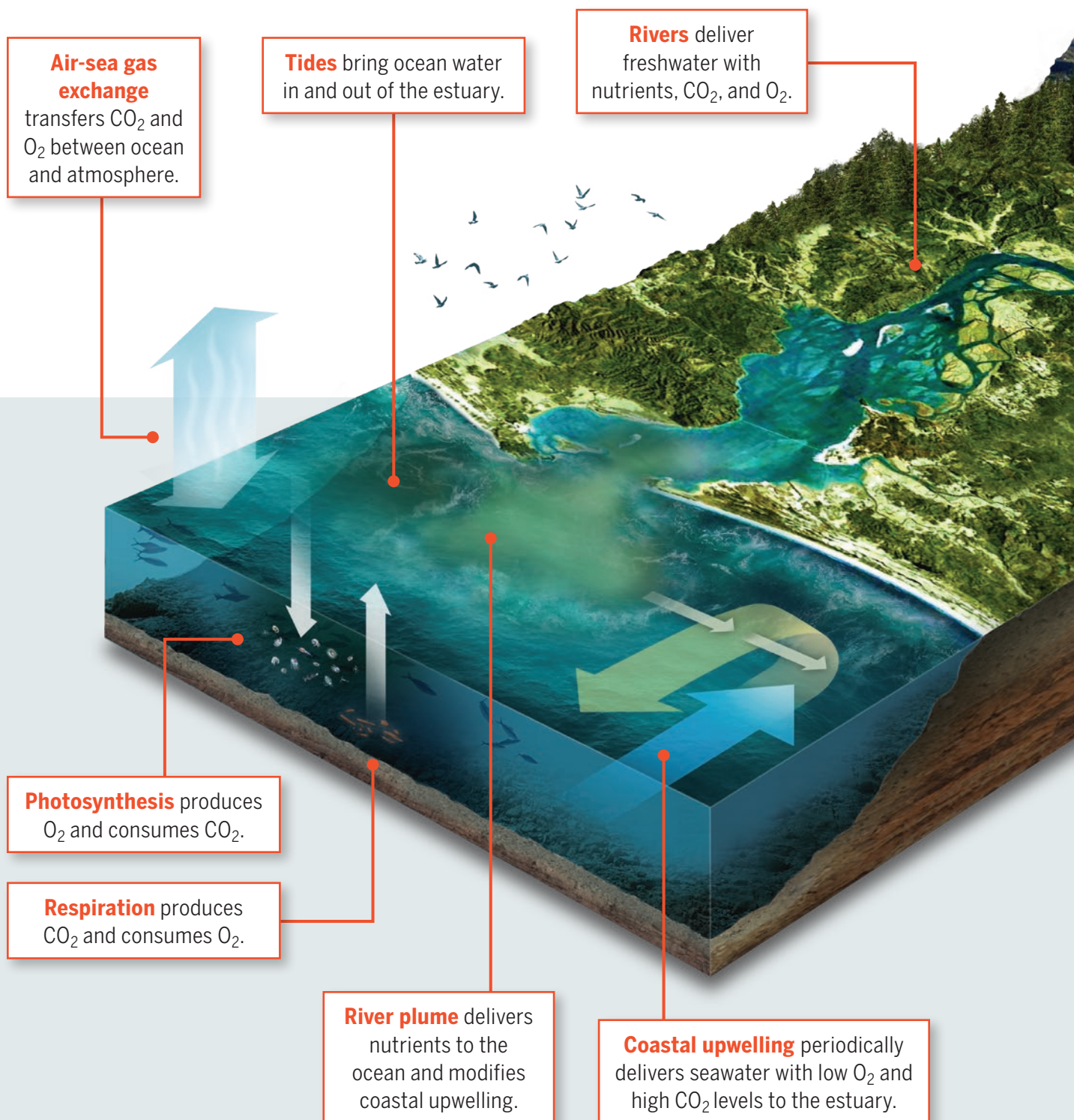
*Right: Map of 74 NANOOS regional assets that measure dissolved oxygen, including the five CMOP stations within the Columbia River estuary and plume.*

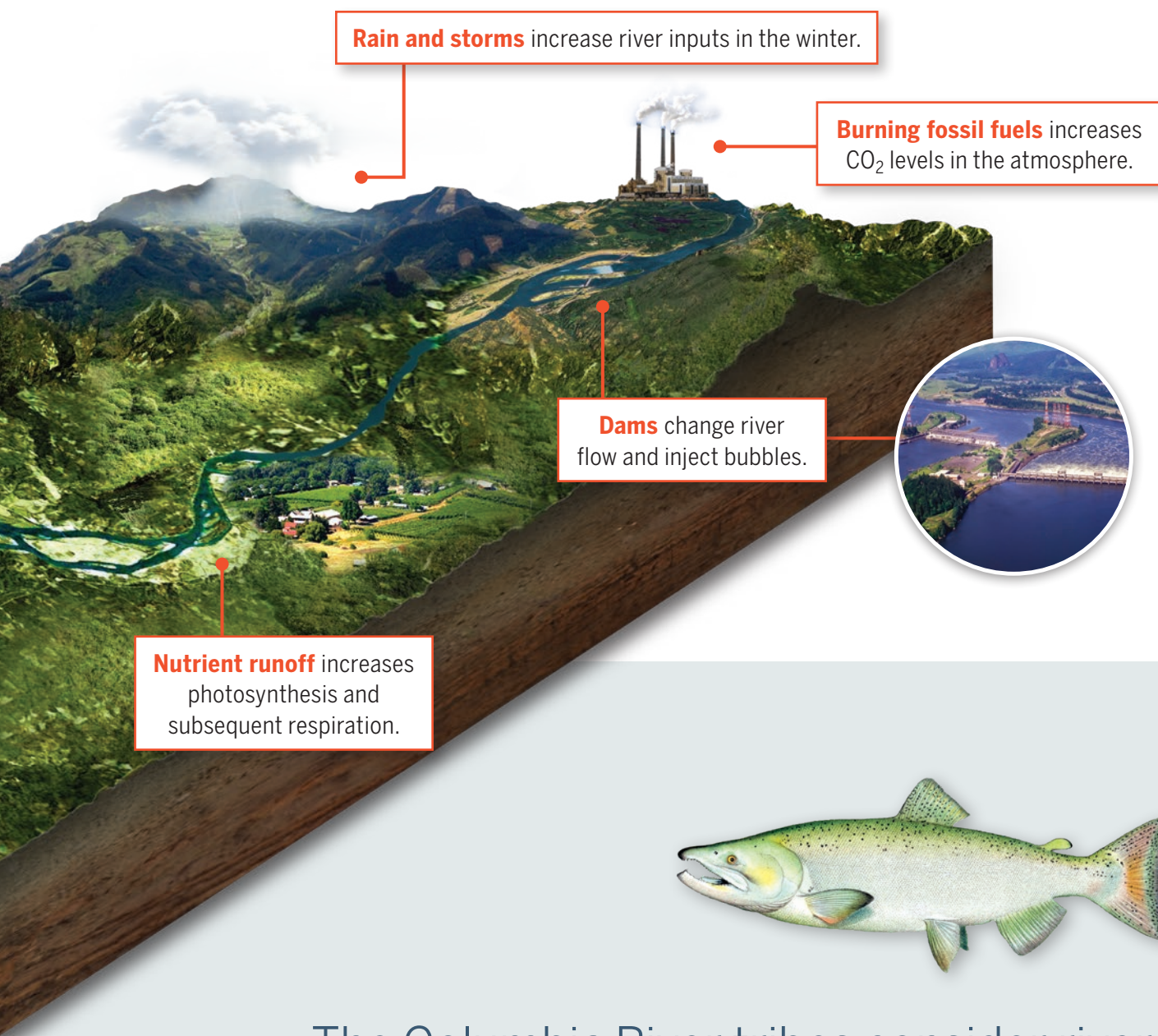
*Below: At CMOP's Point Adams station, seawater is pumped from three depths through oceanographic instrumentation housed within a shed on a fishing dock.*



FIGURE 2:

## Major processes affecting oxygen and CO<sub>2</sub> levels in the Columbia River estuary





The Columbia River tribes consider rivers and streams to be the trails that salmon use on their journey to get to the ocean—their traditional hunting ground. After several years, they follow those trails home, their bodies carrying the bounty of the sea back with them.

## How does CMOP's work relate to salmon?

CMOP's long-term monitoring data are critical for understanding the drivers of salmon survival in the estuary and ocean and predicting how salmon may respond to future environmental changes. CMOP stations measure water characteristics that affect salmon physiology, the salmon food web, and salmon habitat (FIGURE 3). These characteristics are influenced by many processes, including tides, coastal upwelling, river discharge, air-sea exchange, local biology, nutrient runoff, and climate change (FIGURE 2, previous pages).

The estuary is extremely complex due to the interactions among these processes and the different timescales on which they occur (from hours to decades); thus, understanding how humans are affecting the ecosystem requires long-term, continuous monitoring. CMOP's decades-long dataset is beginning to show evidence for long-term change in the region (FIGURES 4 and 5).

In 2022, Oregon Representative Suzanne Bonamici visited the CMOP field office at the Clatsop Community College MERTS campus to award CRITFC \$760,000 under the Federal Community Project Earmark program. These funds will allow CMOP to further expand its activities to include monitoring of ocean acidification, nutrients and contaminants in the estuary, and the effects these have on salmon.



## Measurements at CMOP stations matter for salmon in the estuary



**Temperature:**  
salmon need cold  
water to survive



**Salinity:**  
determines juvenile  
salmon habitat



**Turbidity:**  
affects  
salmon vision



**Oxygen:**  
needed to breathe



**Carbon dioxide:**  
ocean acidification  
affects the food web



**Chlorophyll:**  
tracks plants  
and algae



**Nitrate:**  
nutrient needed by  
plants and algae

FIGURE 3: Examples of how water characteristics measured at CMOP stations affect salmon in the estuary and coastal ocean

## Importance of long-term, continuous oxygen monitoring in the estuary

Salmon need oxygen to breathe: they grow fastest in water with high oxygen levels (~7-8 mL/L), growth slows when oxygen levels are low (<4.3 mL/L), and very low oxygen levels (<2.1 mL/L) can be fatal. Thus, it is important to monitor, understand, and predict the drivers of dissolved oxygen in the estuary. Oxygen levels are affected by physical and biological processes (FIGURE 4), but coastal upwelling and downwelling have the most dramatic effect (FIGURE 5).

CMOP data show seasonal and long-term trends in oxygen levels within the Columbia River estuary. Plots to the right show that oxygen levels in the estuary are lowest during the summer, when coastal upwelling occurs, and that levels sometimes drop low enough to be lethal for salmon.



Dead Dungeness crab wash up to shore after suffocating in low-oxygen ocean water.

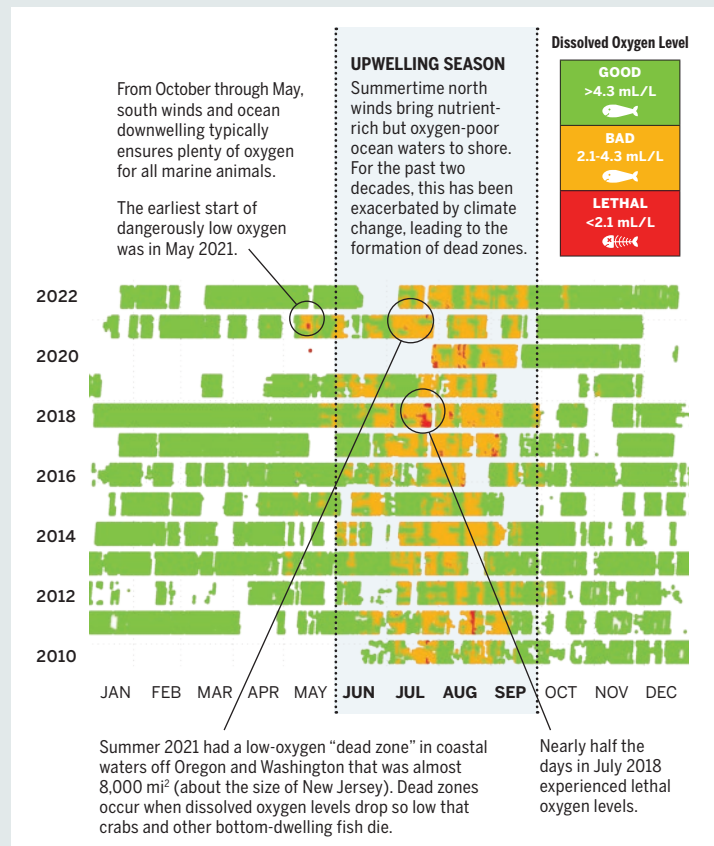


FIGURE 4: 12 years of oxygen data from the near-bottom depth at Point Adams, color-coded by the threat to salmon. Time is shown on the y-axis and month of year is shown on the x-axis.

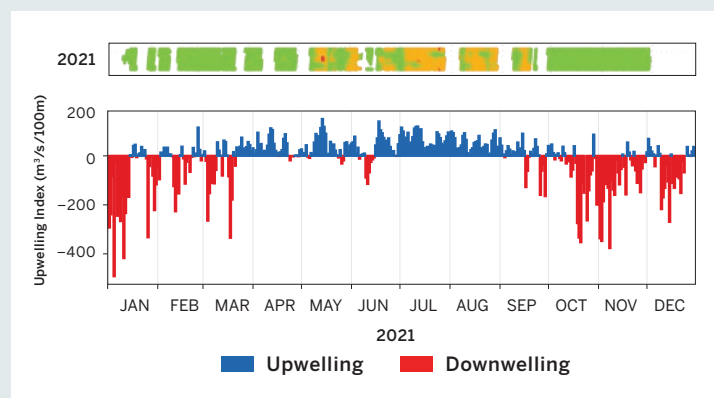


FIGURE 5: The 2021 graphs for dissolved oxygen and ocean upwelling (or downwelling) show how closely connected the two phenomena are. Sustained upwelling (the blue lines) leads to low oxygen conditions.



## The CMOP prediction program

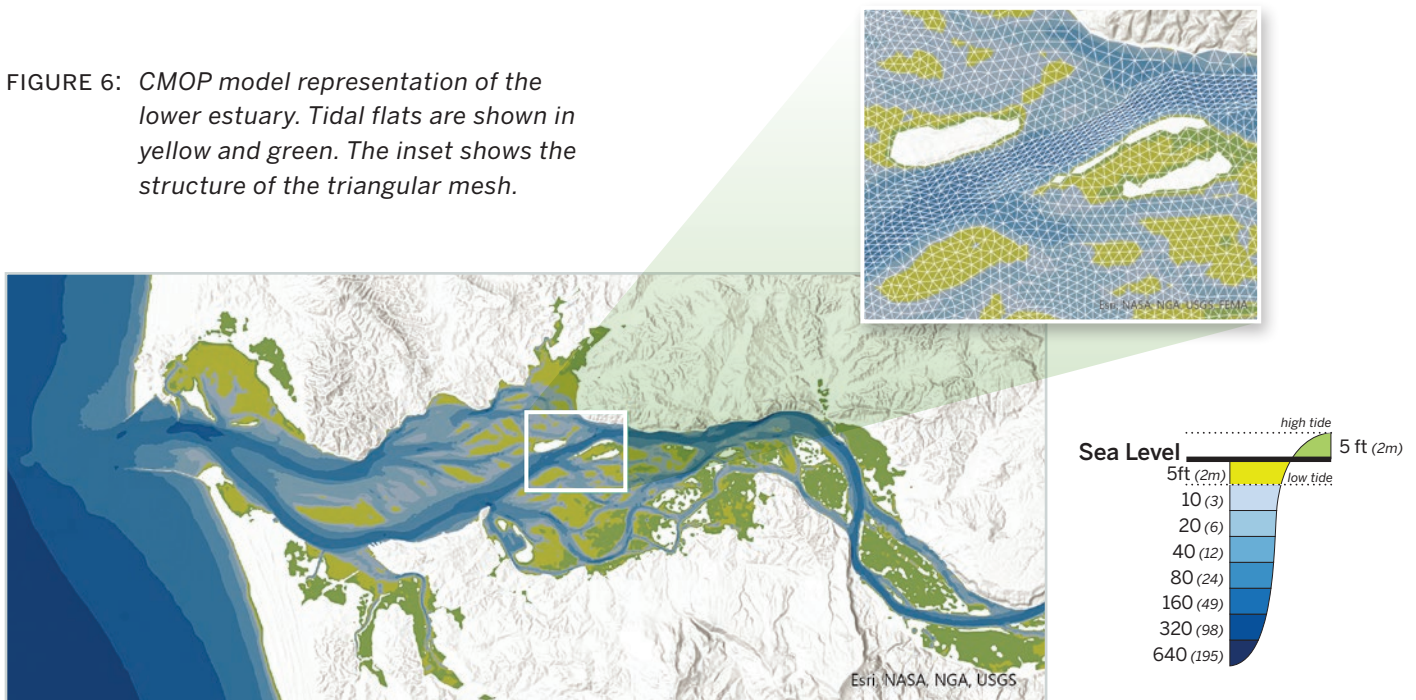
The CMOP prediction program uses computer models to simulate the physics of water movement from Bonneville Dam (the upper extent of the tidal estuary), through the zone where freshwater and saltwater mix (the saltwater estuary), out into the coastal ocean, and beyond. These models represent the river and ocean using a mesh of triangles and rectangles, with triangles as small as 300 feet across for small channels and tidal flats, and as large as 8 miles to efficiently represent the open ocean (FIGURE 6). The models also include multiple depth layers to represent the different movements of surface and deep water. Supercomputers process these models, generating a minute-to-minute, multi-year history of the behavior of the estuary and ocean.

CMOP model outputs include water temperature and salinity (FIGURE 7) as well as water levels and currents. The models are run in several different ways:

- Conditions from the past generate historical behavior
- Conditions from weather forecasts generate short-term forecasts
- Potential future conditions—including sea level rise, changes in river discharge, and temperature changes—are simulated to generate long-term forecasts

Together, using the models in these ways allow us to predict past, current, and future salmon habitat in the tidal estuary and coastal ocean.

FIGURE 6: CMOP model representation of the lower estuary. Tidal flats are shown in yellow and green. The inset shows the structure of the triangular mesh.



The main CMOP model focuses on the Columbia River and coastal ocean, but CMOP has also recently developed a new model of the entire Pacific Basin, which will be used to predict ocean behavior over the full oceanic range of Columbia River salmon populations. The CMOP prediction program is also working to develop models of the mid-Columbia stretch between Bonneville and McNary dams to assist in planning to redesign tributary deltas to be less harmful to migratory salmon.

The CMOP prediction program is currently planning to model the impacts of multiple

scenarios on migrating salmon in the estuary and coastal ocean. The scenarios planned include:

- Historical conditions before the navigation channel was dredged and tidal wetlands and floodplains were lost to agriculture and urbanization
- Future sea level rise
- Increased temperature from climate change, due to both ocean heatwaves and warmer river temperatures
- Changes in river flow from changes in hydrosystem management, linking to CRITFC's efforts in hydrosystem modeling



## Historical uses of CMOP models to understand and conserve local salmon populations

The CMOP models have been used to evaluate threats to salmon habitat in the estuary and to better understand how estuary and coastal ocean conditions affect migratory salmon. These past efforts included:

- Evaluating impacts of the Channel Deepening project in 2002 and 2013 on salmon habitat, based on salinity intrusion into freshwater tidal wetlands in Cathlamet Bay.
- Estimating the size and position of the Columbia River plume to evaluate how this feature contributed to salmon survival on ocean entry.

- Helping develop a salmon habitat opportunity metric based on juvenile salmon tolerance to salinity, temperature, currents, and water depths, and using this metric to evaluate past and future changes.

- Contributing to individual-based models, which predict travel paths of individual migrating salmon

These salmon-relevant metrics have also been evaluated in combination with scenarios of sea level rise, and with changing river discharge as part of the Columbia River Treaty review process, including evaluating CRITFC-generated ecosystem-focused discharge scenarios.

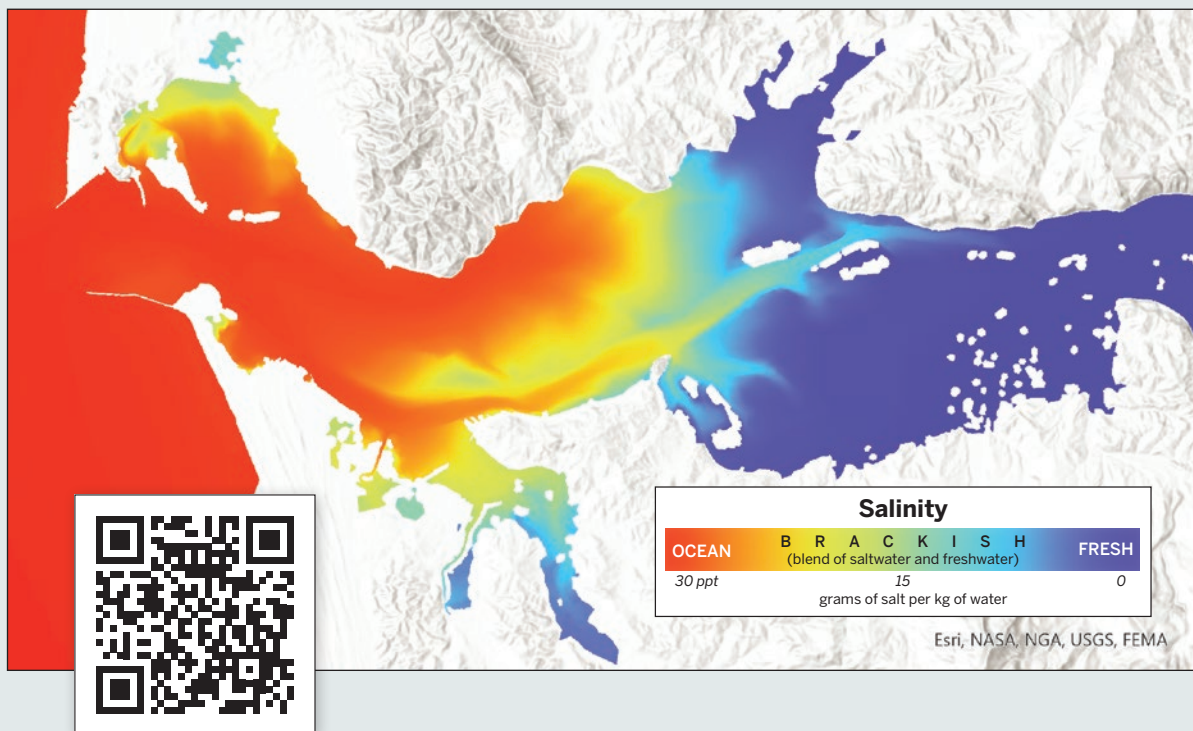


FIGURE 7: Maximum salinity intrusion in September at the river bottom in the Columbia River estuary, from CMOP models for 1999-2018. Scan the QR code for an animation showing how salinity changes with the tides.



## Data Dissemination: CMOP provides valuable data to regional stakeholders

The observational data and model products produced by CMOP have important uses beyond CRITFC and salmon conservation. Most CMOP data are publicly available through NANOOS (see page 7), where they are used by stakeholders including fishers and Columbia River bar pilots, FEMA storm surge planners, the Oregon Coastal Management Program (to determine the boundary between brackish tidal habitat and freshwater habitat), and the US Army Corps of Engineers and others (to monitor how the salinity intrusion responds to the deepening of the navigation channel).

## Future prospects

CMOP is pursuing opportunities to begin collecting new, important datasets and implementing critical model improvements. In 2022, CRITFC was awarded Congressionally directed funding (an 'Earmark'), allowing CMOP to:

- Install an ocean acidification monitoring system at the Point Adams station. Ocean acidification—the dramatic change in seawater chemistry resulting from the ocean's uptake of anthropogenic CO<sub>2</sub>—is expected to harm calcifying (shell-building) marine organisms, including critical components of the salmon food web.
- Expand modeling capacity to better represent tidal wetlands by increasing model resolution in wetlands, including water flow from smaller rivers and streams, and modeling the growth of aquatic vegetation and its impact on water flow. These new features can be combined to study the behavior of tidal wetlands, their suitability as habitat for resident juvenile salmon, and their food (insect) resources for juvenile salmon traveling through the estuary.

- Monitor for toxic contaminants that can bioaccumulate in the tissues of juvenile salmon. These contaminants—including PAHs, PCBs, and PBDE—have been previously detected at high concentrations near the mouth of the Columbia River, where CMOP stations are located.

CMOP staff are also collaborating with other scientists in the region to better understand how conditions in the Columbia River estuary affect salmon today and how estuary habitat will change in the future. For instance, staff are seeking funding to develop an environmental DNA sampling program at dock-based stations, which would enable DNA-based monitoring of salmon populations in the context of measured water characteristics. Staff are also seeking funding to use the expanded modeling capacity to better predict the impact of climate change on Upper Columbia salmon and steelhead use of the estuary and to find ways to prevent defenses against sea level rise from causing further loss of wetland habitat.



Photo courtesy Bonneville Power Administration / USACE



**Columbia River Inter-Tribal Fish Commission (CRITFC)**

700 NE Multnomah St., Suite 1200 • Portland, Oregon 97232 • [www.critfc.org](http://www.critfc.org)

For more information, visit [cmop.critfc.org](http://cmop.critfc.org)