2018-2019

DELTA SOUND CONNECTIONS

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PRINCE WILLIAM SOUND SCIENCE CENTER

NATURAL HISTORY AND SCIENCE NEWS FROM PRINCE WILLIAM SOUND AND THE COPPER RIVER BIOREGION

The turquoise waters of Eyak Lake are backed up by the Chugach Mountains and the Copper River Delta. Inset: A variety of ecosystems can all be found within a 100-mile radius of Cordova. *Photos by Teal Barmore.*

I have traveled on every continent except Antarctica, and no scenery has taken my breath away like that of the Chugach Mountains and Copper River Delta the first time I flew into Cordova. No matter what side of the plane you sit on, you are wise to choose a window seat for an approach into "Mudhole" Smith Airport. From that vantage point, you can see so many of the features that make our region the home of the world's richest waters.

KATRINA HOFFMAN
President & CEO
Prince William Sound Science Center

Positioned at the nexus of Prince William Sound and the northern Gulf of Alaska, the glacier-studded Copper River watershed supplies micronutrients to the ocean through both river discharge and atmospheric deposition of iron-rich dust. These injections of nutrients can have a similar impact to fertilizing your garden: they support the growth of tiny plants called phytoplankton that form the basis of the marine food web. Only, unlike a home garden, the growth of these tiny plants happens on a massive scale that is visible from satellites. And this food web, in turn, supports the economy of Alaska, where more people are employed by the seafood industry than most other sectors.

Our region is seafood centric and salmon is king. These anadromous fish benefit from intact watersheds the likes of which simply do not exist in the Lower 48. Freshwater discharge into the Gulf of Alaska from all sources is greater than the discharge of the mighty Mississippi River[1], but few people in the Lower 48 could name a single river that terminates in the Gulf of Alaska.

Our region also benefits from the introduction of water from yet another source: seawater that has been traveling the global ocean conveyer belt—a journey that can take over 1,000 years to complete. As this current passes Antarctica, it cools, sinks, and carries with it the dissolved gasses and nutrients that support life in the oceans. Hundreds of years later when some of this deep water surfaces, it does so in the Gulf of Alaska, enriching the ocean waters and making it possible for more phytoplankton to grow, which in turn feed small animals called zooplankton, which in turn support the incredibly productive populations of fish, mammals, and birds that make our region so attractive to residents and tourists alike.

Delta Sound Connections is devoted to sharing information about the research, education, economy, culture, and community that is stimulated in the places where these rich lands and rich waters meet. That's why we refer to our region as home of the world's richest waters—and one of the best places on earth.

[1] P. J. Stabeno et al. Meterology and oceanography of the Northern Gulf of Alaska. Continental Shelf Research 24 (2004) 859-897.

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Alaska Salmon Fellows group. *Photo by Josh Corbett.*

ALASKA SALMON FELLOWS

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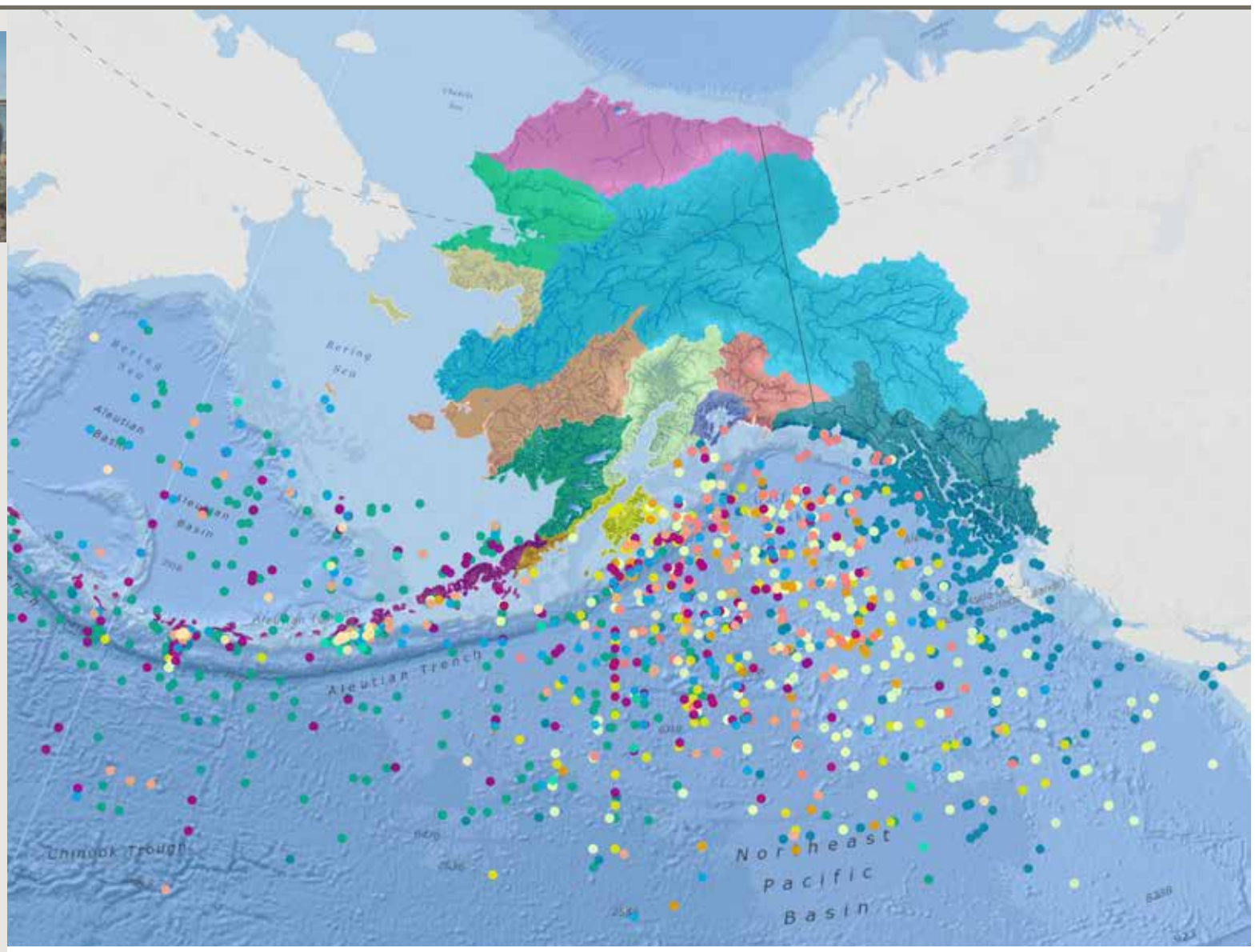
Salmon is a defining factor in the culture of Alaska; it's something we all have in common. But salmon, Alaska's third largest industry, is also frequently a flash point of conflict over difficult issues such as racial justice, the urban-rural divide, and balancing sustainability against the needs of resource development.

Alaska Humanities Forum, along with partner organizations, has designed the Alaska Salmon Fellows program to facilitate demanding conversations about salmon issues among leaders from a cross section of salmon policy, management, industry, activism, research, and cultural sectors.

Through this program each Salmon Fellow is exposed to user groups in the salmon system that they may never have interacted with otherwise. One of the prerequisites of being a fellow is the ability for one to leave their "hat" at the door and come to the conversation with an open mind while still bringing their unique perspective to the dialogue. In this way the fellows can learn from one another's experiences to better understand the system as a whole. With this more complete view of the system, fellows can examine the problems analytically and come up with novel solutions to influence change and ensure a sustainable and equitable salmon and people system for the future.

To find out more about the Salmon Fellows Program go to the Alaska Humanities Forum website at akhf.org/alaska-salmon-fellows



SASAP researchers are supported by a six-member Data Task Force and other experts whose work helps users visualize complex information about salmon. The map shows documented rivers and streams supporting salmon populations. Colored dots link ocean captures of fish to SASAP region of freshwater returns. *Map Credit: Leslie Jones, University of Alaska Anchorage.*

UNDERSTANDING THE STATUS OF ALASKA

SALMON & PEOPLE

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Unlike most global wild salmon stocks, salmon in Alaska are sustainable across much of their historic range, largely due to a long tradition of community stewardship and a science-based management system. However, the species' long-term viability is under threat on several fronts: climate change, ocean acidification, overfishing, declining research and management budgets, and incompatible development of salmon watersheds. The sustainability of the Alaska salmon system depends on a strong connection to people, which is threatened by issues such as inequitable access to salmon fisheries, graying of the fleet, and other social shifts.

The State of Alaska's Salmon and People (SASAP) project is a knowledge synthesis designed to inform the future of management of Alaska's wild salmon. The goal of SASAP is to provide a more holistic view of the complex and dynamic system that will serve to influence research priorities, develop and monitor indicators of system health, and facilitate equitable and efficient management of the system.

The SASAP process is being supported by a novel data science and synthesis partnership between the National Center for Ecological Analysis and Synthesis (NCEAS) at the University of California, Santa Barbara and more than 100 indigenous knowledge experts, scientists, and educators from academic, community, and government organizations throughout Alaska and the United States.

The knowledge generated is expected to play a seminal role informing future salmon management and research in Alaska and the North Pacific region. A major goal of the project is to share SASAP results with salmon stakeholders across Alaska. In addition to academic papers and reports supported by openly accessible data, a variety of outreach products will be available on the SASAP website: AlaskaSalmonandPeople.org.

PACIFIC SALMON, THE OCEAN, AND CLIMATE CHANGE

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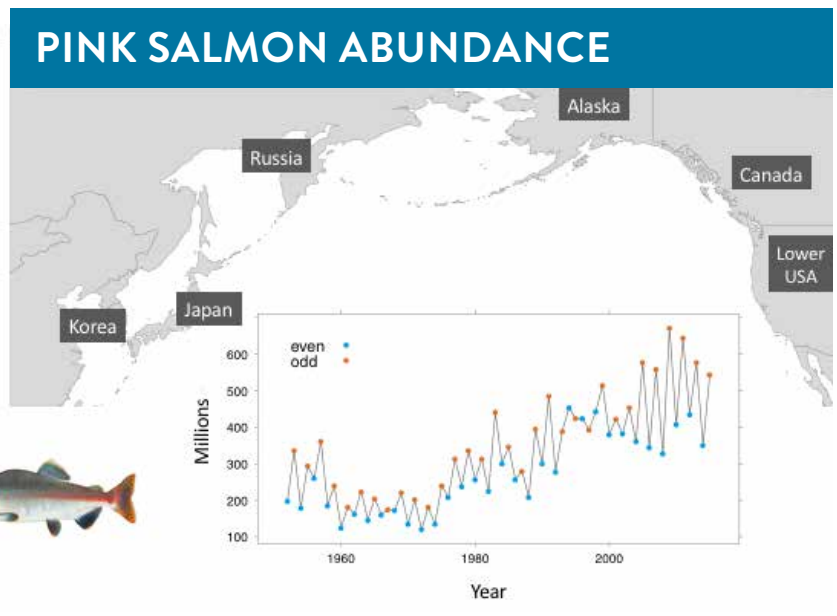
Recent reports about the North Pacific "blob" of warm water and associated seabird mortalities have reached a global audience. Satellite data and beach surveys can detect these events, but understanding how salmon may be affected is a much more difficult assignment. The Prince William Sound Science Center is leading a special working group of experts to take a closer look at data on climate and salmon and draw some conclusions that might be relevant to fisheries management.

The group, supported by NCEAS SASAP, is looking across a broad swath of the Pacific, from the Gulf of Alaska to the Bering Sea, in an effort to understand how changes in abundance and ocean temperatures might be affecting sockeye salmon. The group believes one of the key "drivers" is pink salmon, the most abundant Pacific salmon that has increased dramatically since the late 1970s (see figure). By treating the alternating odd and even year cycle in their abundance as a "natural ocean experiment," the group is focusing on how pink salmon densities, along with changing ocean temperatures, are affecting certain sockeye populations. Publications from this effort are expected later in 2018.



Trends in adult abundance of pink salmon in the North Pacific reflecting contributions from multiple countries. *Data from Ruggerone and Irvine. Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925–2015. Marine and Coastal Fisheries 10 152-168 (2018).*

Resident killer whale hunting salmon. *Photo by NGOS.*

BEYOND DELTA SOUND CONNECTIONS

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Killer whales of the region show a clear "Delta-Sound" connection, since many of them travel between Prince William Sound and the Copper River Delta. But these killer whales also show us connections between Prince William Sound, Kenai Fjords, and ecosystems across the eastern North Pacific.

Killer whales' species of preference are Chinook salmon, the largest and most succulent of the salmon species. And one would think they would be eating the Chinook returning to the Copper River and other adjacent systems. However, the southern Alaska resident killer whales (local salmon-eating types) are eating more than just Alaskan salmon. They have been found feeding on Chinook that come from as far away as the Columbia River.

We use dip nets to get samples of bits of fish and scales that remain after a killer whale feeds on a salmon. Genetic analysis tells us which river system the fish came from.

In the first 17 samples from Prince William Sound and Kenai Fjords that we analyzed, there was one fish from the Columbia River, while an additional eight were from rivers in British Columbia. In Kenai Fjords, nine of the kills sampled were Chinook from the Situk River near Yakutat (nearly 350 miles east of the kill site). Interestingly, not one fish was from the Copper River system, the closest big Chinook producer. Most likely, our sampling took place in specific Chinook migratory pathways, since the wide-ranging, eastern North Pacific Chinook spread out across the Gulf of Alaska to feed. The whales are not discriminating against Alaskan salmon, just taking what is available and concentrated in particular locations at particular times. We are in the process of analyzing more of our samples—finding more detail in their feeding patterns and determining which Chinook stocks are most important to these whales.

EnviroAtlas, EPA.

RICH WATERSHEDS, RICH COMMUNITIES

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At the Copper River Watershed Project, we talk often about the value of the Copper River watershed's salmon fisheries. Both in terms of employment and revenue generated by the commercial harvest of salmon, the figures are impressive:

- Statewide, seafood harvesting and processing is the State's fourth largest employment sector (Alaska Dept. of Labor, 2016);
- Subsistence and sport fishermen on the upper Copper River harvest over 200,000 salmon each year, with contributions to the Copper Basin economy estimated between $3 to 5 million (Ecotrust, 2009); and
- Copper River salmon generate between $20 and $38 million in seafood sales of sockeye, coho and Chinook salmon annually from the commercial salmon harvest (Alaska Dept. of Fish & Game).

That makes salmon a quantifiable market resource that our intact watershed provides. Like trees and other plants, ground water, soil, and wild game (such as caribou), salmon are a renewable resource—they replenish their population every year.

Salmon can be considered an ecosystem service, defined as "benefits people obtain from ecosystems" (USDA Forest Service, Valuing Ecosystem Services). The Millennium Ecosystem Assessment, a four-year United Nations assessment of the condition and trends of the world's ecosystems, categorizes "ecosystem services" as:

- **Provisioning services,** or the provision of food, fresh water, fuel, fiber, and other goods;
- **Regulating services** such as climate, water, and disease regulation as well as pollination;
- **Supporting services** such as soil formation and nutrient cycling; and
- **Cultural services** such as educational, aesthetic, and cultural heritage values, as well as recreation and tourism.

In its current, intact state, the Copper River watershed ticks off everything on that list. Beyond salmon and their nutrient cycling from marine waters to freshwater streams, the benefits include providing fresh water to 5,000 watershed residents and 40,000 visitors, flood control, agricultural lands with excellent soil, and backcountry hunting and recreation lands. Resource rich watersheds can make rich communities!

WORKING TOGETHER TO FILL DATA GAPS ON A FAMOUS FISH

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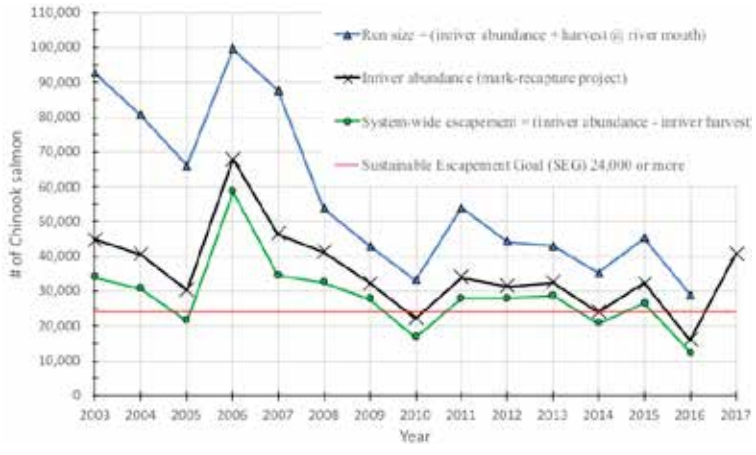
To many Alaskans, the harvest of a Copper River Chinook salmon is a time-honored tradition passed down through generations. More recently, chefs and foodies from around the world prize the high lipid content and taste of the renowned salmon. While the name "Copper River King" is widely known, the research on this important population is less known.

Beginning in 1960, aerial surveys provided the first data on escapement (i.e. numbers of fish reaching the spawning grounds). However, studies now suggest aerial surveys were inconsistent and unreliable (Savereide 2005). In 1998, the Alaska Department of Fish and Game (ADFG) began investigating mark-recapture methods for improving management data. The Native Village of Eyak (NVE) joined efforts with a feasibility study in 2001-2002. Consequently, every year since 2003, NVE has used mark-recapture methods and research fishwheels to estimate inriver abundance. This abundance estimate, paired with harvest data, provides system-wide spawning escapement and total returning run size, allowing fishery managers to track population trends and assess management techniques (see figure).

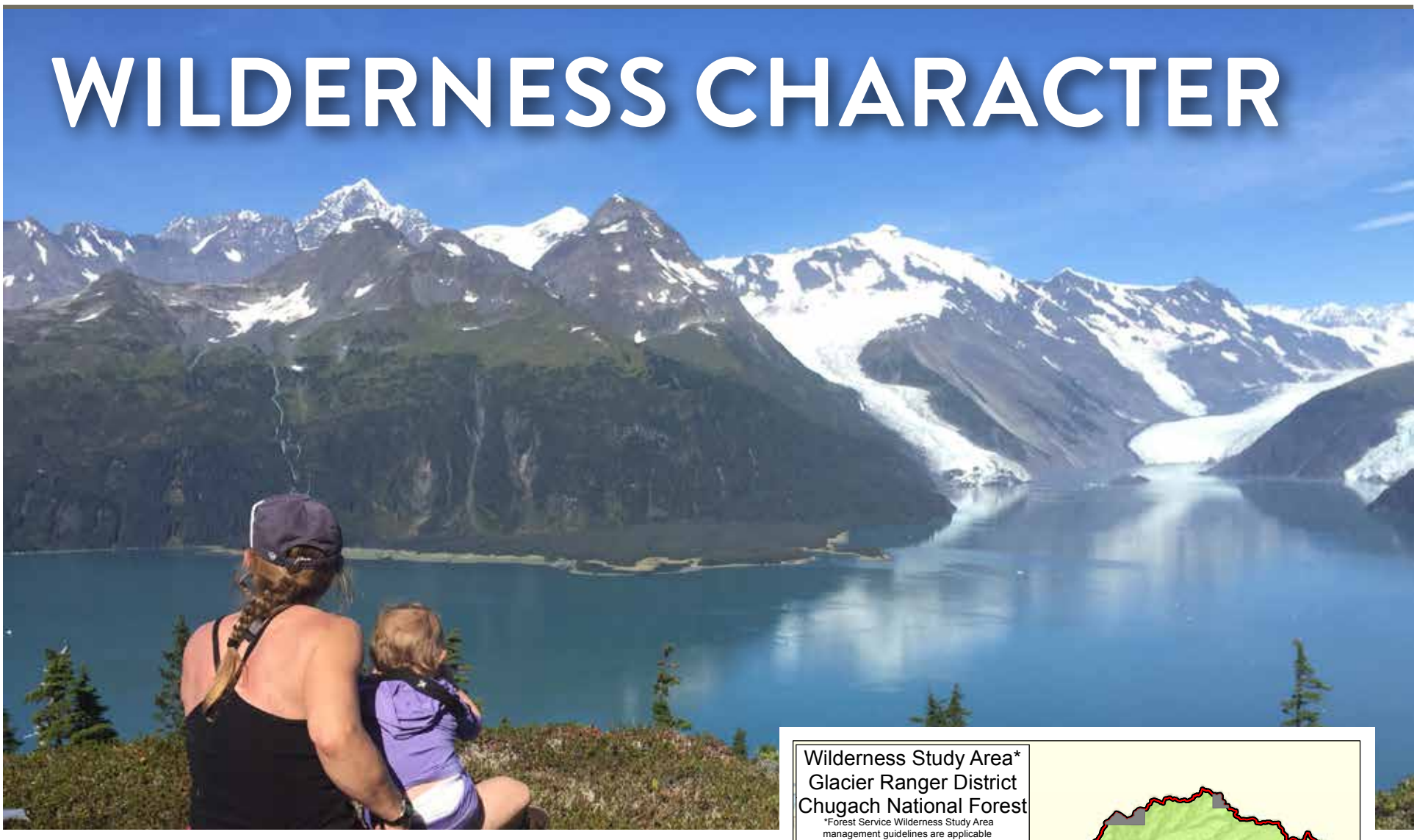


Inriver abundance, total run size, and system wide escapement of Copper River Chinook salmon, 2003-2017.

Another benefit of NVE's mark-recapture program is the collection of additional data alongside ongoing sampling efforts. A Chinook salmon radio-telemetry study provided spawning distribution and stock specific run timing throughout the watershed (Savereide 2005); a DNA study identified run timing and genetic divergence within and among tributaries (Seeb et al. 2009); and, using NVE fishwheels as a sampling platform, distribution and run timing studies have been conducted on sockeye salmon (NVE), coho salmon (ADFG), and steelhead (ADFG). Currently, NVE is assisting ADFG sampling efforts for a coded-wire tag study to provide data on juvenile salmon abundance and ocean survival of adults.

As a changing climate continues to impact ocean productivity, the collection of reliable and accurate scientific data is essential. It will help ensure that a healthy salmon population and sustainable fishery will remain on the Copper River for future generations—a goal which NVE is committed to accomplishing.

Funding provided by the Fisheries Resource Monitoring Program, Partners for Fisheries Monitoring Program, Alaska Sustainable Salmon Fund, U.S. Forest Service, and Alaska Department of Fish and Game.



WILDERNESS CHARACTER

IN WESTERN PRINCE WILLIAM SOUND

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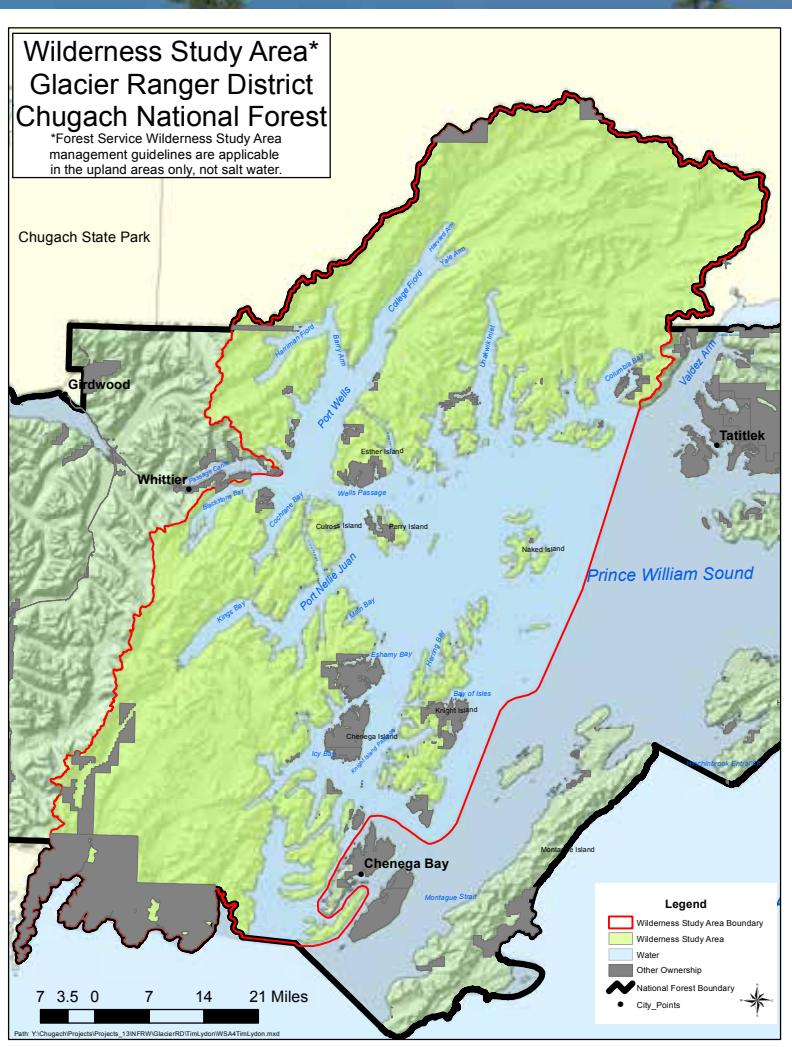
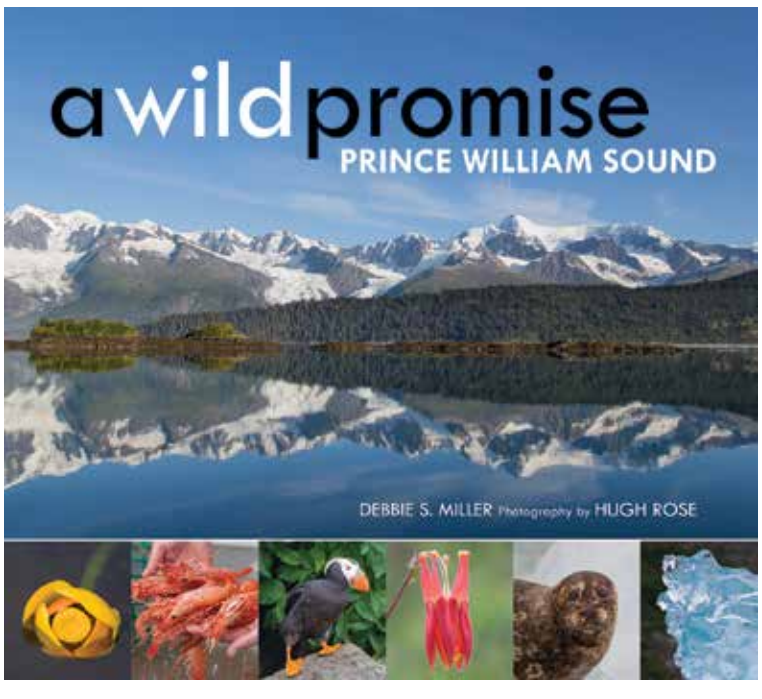
The Chugach National Forest is building on recent work to describe "wilderness character" trends for national forest lands that fall within the Nellie Juan-College Fjord Wilderness Study Area (WSA). Designated by Congress in 1980 through the Alaska National Interest Lands Conservation Act, the two million-acre WSA stretches from Columbia Bay to Port Bainbridge and includes popular areas such as Knight Island and Harriman Fjord.

Chugach National Forest policy is to maintain the wilderness character of the WSA. Nationally developed protocols are used to analyze trends in the following qualities of wilderness character: Untrammeled (ecological processes are free from intentional manipulation); Natural (condition of air, water, and plant/animal populations); Undeveloped (amount of structures/motorized uses); Solitude (remoteness from people or modified lands).

The wilderness services of the WSA remain listed as an injured resource by the *Exxon Valdez* Oil Spill Trustee Council. Analysis of wilderness character can inform continued restoration of the area. Monitoring in recent years focused on trends in the undeveloped and untrammeled qualities of wilderness character. In 2018, the U.S. Forest Service will partner with volunteers and others to gather data on visitor trends, identifying the solitude opportunities visitors often seek in Prince William Sound. National protocols will be followed to document levels of encounters with other visitors and describe conditions at popular recreation sites.





A WILD PROMISE IS BORN

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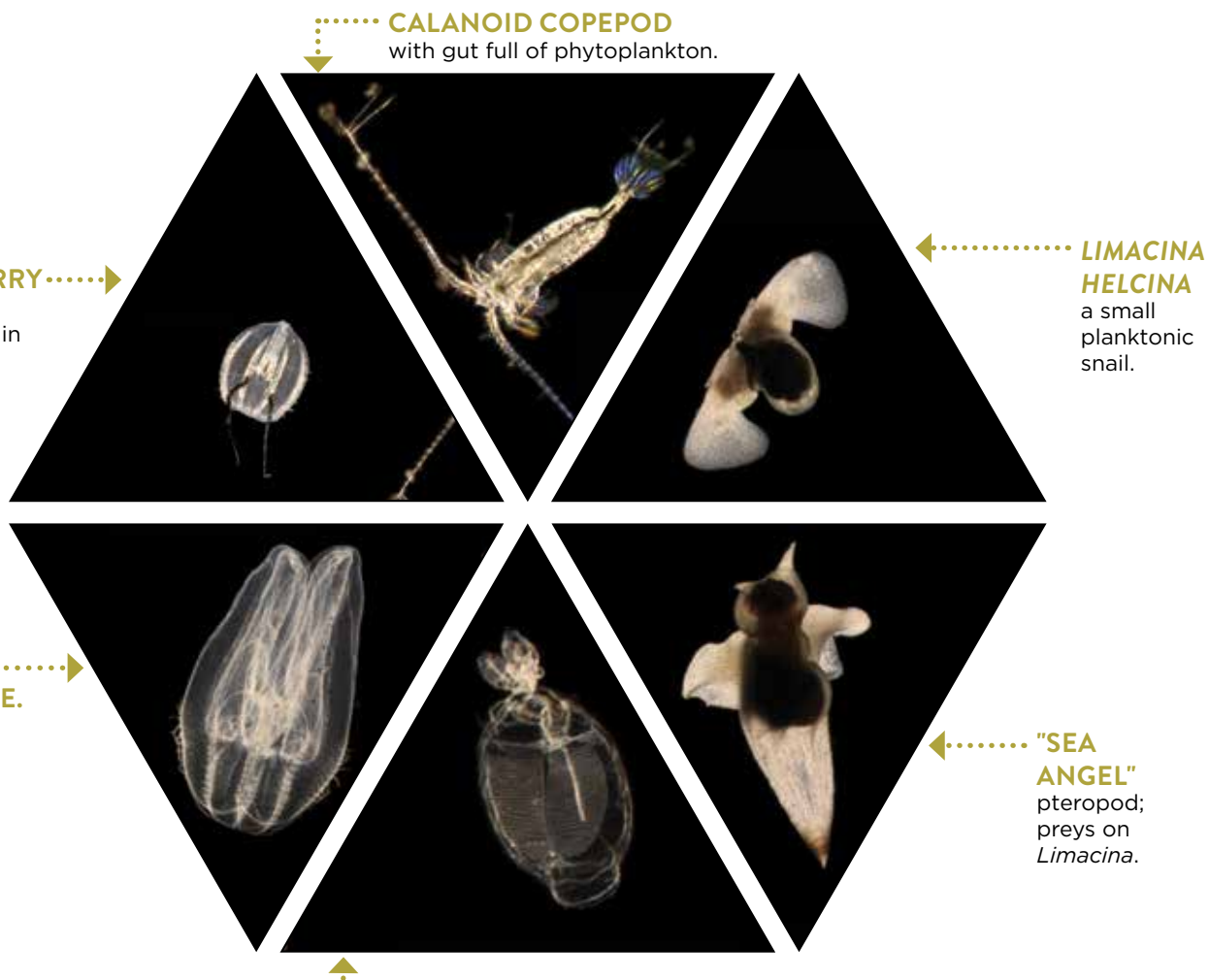
Five years ago, photographer Hugh Rose and I had just finished working on a book about the remote northwest corner of Alaska. Out on the tundra, Hugh suggested we collaborate on a book about the coastal wilderness that surrounds Prince William Sound. Having worked as a naturalist and guide on *Discovery Voyages* for many years, Hugh felt strongly that the public needed to know about the Nellie Juan-College Fjord Wilderness Study Area.

This spectacular 2.1 million acre glacier-carved region of the Chugach National Forest was vulnerable. About the size of Yellowstone National Park, not one acre of it was permanently protected as wilderness.

Hugh was convincing. As a lover of Alaska's wildest places, how could I say no? We received support from our publisher Braided River, Captain Dean Rand with *Discovery Voyages*, and Tim and Barbara Lydon, wilderness stewards for the Chugach National Forest.

As an artist-in-residence for the U.S. Forest Service, Tim and Barbara were my guides through many of the breathtaking fjords. We camped and hiked on remote islands, explored the temperate rainforest, cleaned up beaches with other volunteers, and observed the incredible diversity of wildlife—sea otters and humpback whales, tufted puffins and marbled murrelets, mountain goats and black bears—not to forget the salmon! Field notes and interviews with scientists and locals turned into stories and future chapters for *A Wild Promise*.

The Chugach National Forest is in the process of developing a new management plan for the area, so the timing is perfect for public comments. This remarkable place has been a "study area" for nearly 40 years. We hope this book inspires readers to raise their voices in support of lasting protection for the Nellie Juan-College Fjord as a formal wilderness area.



PHOTOGRAPHING PLANKTON

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Plankton form the base of the marine food web. Tiny, single-celled plant plankton (phytoplankton) grow and are consumed by animal plankton (zooplankton). In turn, zooplankton are prey for larger animals like fish, birds, and whales. The amount and type of plankton present changes over time, and measuring them is not easy. Going out and collecting them from ships costs thousands of dollars per day for the ship, and then much more money to pay taxonomists to identify everything that is in the sample. But new technologies are offering alternative ways to estimate plankton abundance.

In 2016, an in-water plankton camera was developed and installed on an autonomous robotic profiler that is deployed every year in central Prince William Sound, from spring to autumn. In 2016 and 2017, over one thousand twice-daily profiles (ranging from 60 meters to the surface) were conducted. From those profiles, over two million images of individual plankters have been collected. Current work is focused on using Deep Learning techniques similar to those used by Google to automatically identify images on the internet to identify the different kinds of plankton and what they are doing (e.g. if they are feeding or not).

Pacific cod getting sutures after the implantation of an acoustic tag. *Photo by PWSSC.*

A YEAR IN THE LIFE OF A COD

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Pacific cod ranks as the second largest fishery in the United States. In Prince William Sound, cod are fished commercially, and for management and quota purposes, are considered part of the Gulf of Alaska stock. The Prince William Sound Science Center wanted to determine if cod were migrating back and forth to the Gulf of Alaska. To do so, we implanted acoustic tags in over 100 cod in two fjords in the western Sound. We then placed underwater receivers at the entrances to the fjords. We already had in place the Ocean Tracking Network, a series of underwater receiver arrays located at the boundary between the Sound and the Gulf of Alaska.

The acoustic tag inside the cod sends out a series of pings at specified intervals that the receivers detect. From that information we know which cod leave and when. So did cod move much over the 30 month study? Surprisingly no. Many stayed in their fjords year-round or left for only short periods of time, suggesting that fjords in the western Sound provide year-round habitat. Less than two percent of the tagged cod were heard at receivers bordering the Gulf of Alaska. This study was funded by the North Pacific Research Board.

MICROSCOPIC TOURISTS

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As Alaska awakes from winter, Prince William Sound (PWS) turns a muddy green in the revived sunlight announcing spring has arrived in southcentral Alaska. Tiny single-celled algae called phytoplankton produce blooms of trillions of individuals. To hungry zooplankton (microscopic animals) waking up from a food-scarce winter, phytoplankton act as juicy hamburgers to fuel growth and reproduction. In turn, predators like salmon smolt and herring feast on zooplankton.

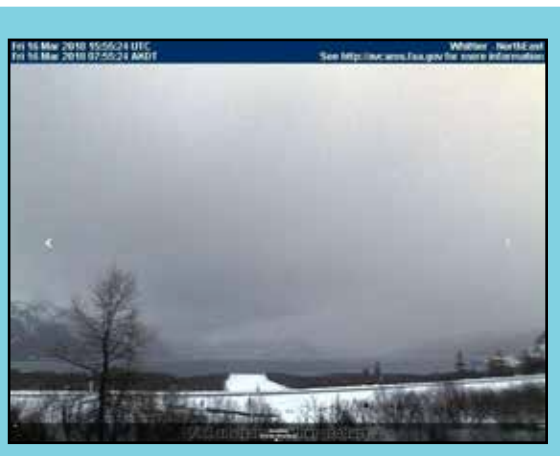
The zooplankton community includes a rich diversity of species from across the animal kingdom. In the past eight years of zooplankton monitoring for Gulf Watch Alaska, we have recorded 200 different species including copepods, larval fishes, miniature winged molluscs, and our rudimentary relatives called larvaceans.

We also observed copepods common to warmer West Coast waters. The appearance of these animals coincided with the Gulf of Alaska's warm water anomaly, The Blob. Sightings of other southern animals including sunfish and skipjack tuna were reported during this time. How these southern copepods may affect the PWS zooplankton community remains unknown. Southern copepods have smaller, less nutritious bodies than their native counterparts. Copepods remain the primary snack for developing salmon and herring. Our findings do not suggest these tourists have established permanent residency yet, but we will continue our monitoring efforts.

The predatory copepod *Corycaeus sp.* is a common resident of Puget Sound but has also visited PWS during the past few years. The white line indicates 0.25mm for scale.

OCEAN DATA EXPLORER

The Ocean Data Explorer (ODE), the Alaska Ocean Observing System's (AOOS) data portal, uses cutting-edge technology to deliver data and information about the oceans and coasts of Alaska to stakeholders. The ODE allows the user to search for current, recent, and historical information, that can then be viewed as a "layer" overlaid on a map or in the form of a graph or chart. The information can also be downloaded directly for sorting or use in its raw form. Data is all around us and important resources have been used to collect this information; the AOOS data portal provides a way for users to find what information they need and helps them use it to make decisions.



▶ CORDOVA

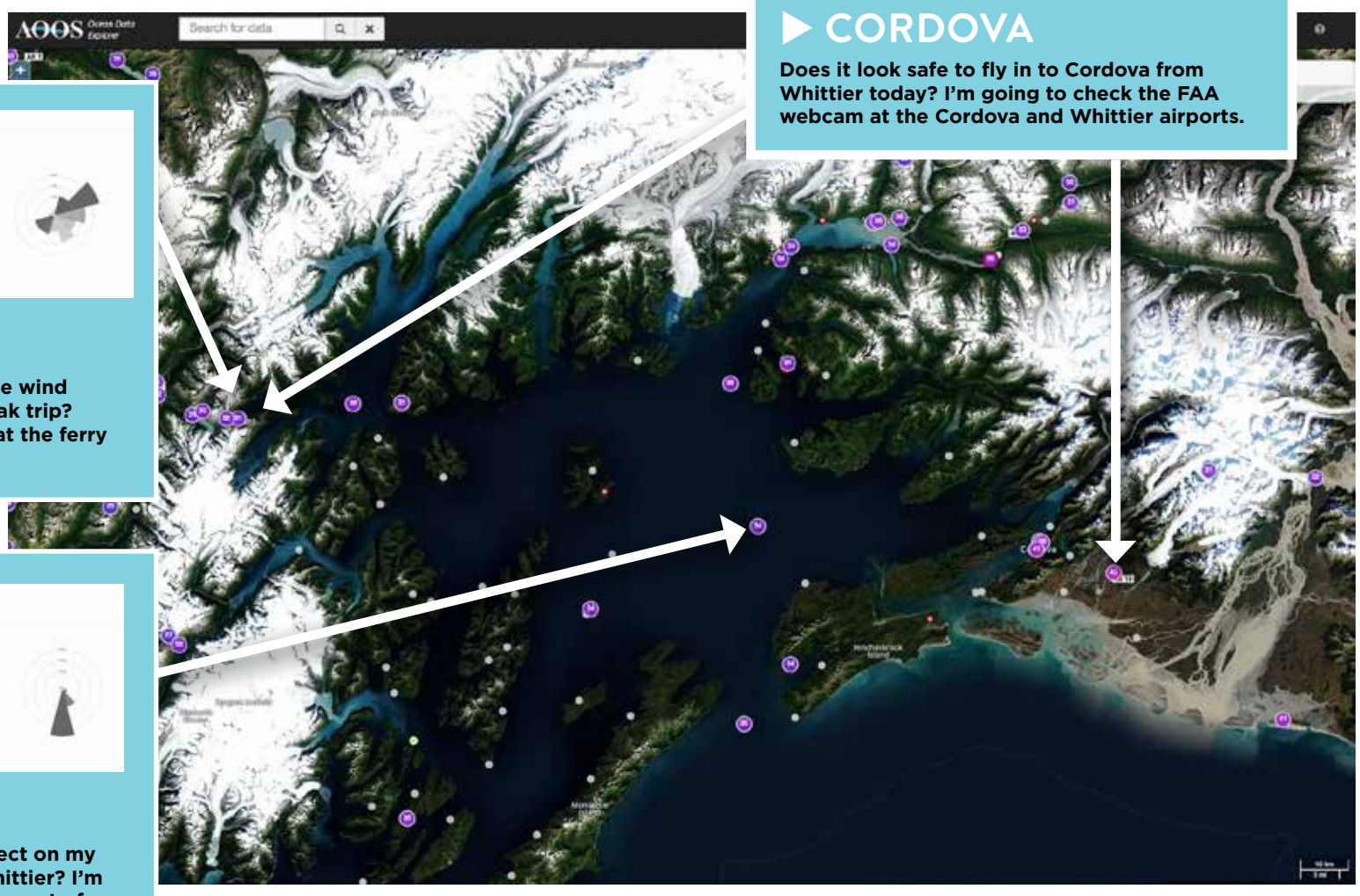
Does it look safe to fly in to Cordova from Whittier today? I'm going to check the FAA webcam at the Cordova and Whittier airports.

▶ WHITTIER

What speed and direction is the wind blowing in Whittier for my kayak trip? I'm going to check the sensor at the ferry dock in Whittier.

▶ BOAT TRIP

What kind of waves can I expect on my boat ride from Cordova to Whittier? I'm going to check the wave buoy west of Orca Bay.

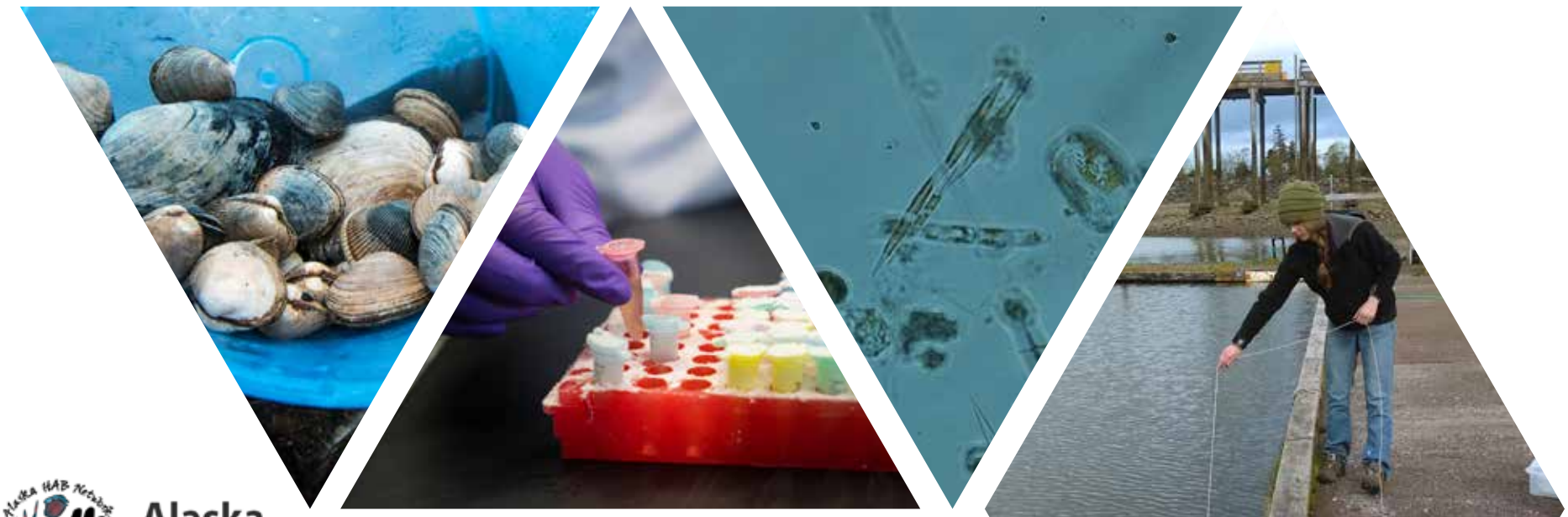


A NEW WAY TO MEASURE WATER LEVELS

An AOOS-facilitated water levels working group, which includes the National Weather Service and the State of Alaska, has targeted the western coastline of Alaska as needing a significant number of additional water level sensors to enhance marine safety and coastal flooding readiness. In response to this need, AOOS is developing unique partnerships with two organizations to use GPS reflectometry to collect high-quality water level data, with no need to put sensors in the water. Once this technology has been proven effective and efficient it could be used to increase observations of water level in Prince William Sound.

AOOS is working with ASTRA, a private company that uses GPS receivers for space weather research, to apply the same technology to measure water levels. AOOS is also working with UNAVCO (a private research organization that uses GPS/GNSS receivers to measure ground movements for seismic research) to find locations for shared-use installations that can be used for both water level and seismic observing initiatives. These installations and sensors are far less costly then traditionally used water level sensors and have the advantage of not having to be removed before freeze-up.

A UNAVCO GPS/GNSS installation on the Aleutian Chain.



Alaska
Harmful Algal Bloom Network

IS IT SAFE TO EAT THE CLAMS?

This is a common question in Alaska, where shellfish are plentiful and many people enjoy wild food. However, unlike much of the Lower 48, Alaska does not have a comprehensive state-sponsored shellfish monitoring program to test for toxins from harmful algal blooms. Consequently, no beach is officially "safe" for recreational harvest. This leaves people to harvest shellfish at their own risk, and harmful algal blooms have periodically caused sickness and occasionally death. Commercially sold shellfish is tested and deemed safe before sale.

▶ WHAT ARE HABS?

Algal blooms are caused by phytoplankton—microscopic, plant-like organisms that form the basis of the marine food chain. When phytoplankton are exposed to the right conditions they can "bloom", or multiply extremely rapidly. In general, more phytoplankton means more food and oxygen for everything else in the ocean, but occasionally plankton blooms are hazardous to human or marine life. These are known as "Harmful Algal Blooms" or HABs. Paralytic Shellfish Poisoning is caused by an algal bloom that produces a toxin ingested by shellfish.

▶ THE DANGERS OF HABS

HABs can impact humans and other marine species, and they come in a variety of forms. Some produce toxins that directly poison humans, marine mammals, shellfish, or fish. Some algal types have sharp spines that harm fish gills. In especially dense blooms of other phytoplankton species, opaque or dark-colored cells can make it difficult for marine predators to find prey. Poisoning in humans usually comes from eating a contaminated organism such as clams, mussels, or other shellfish. Symptoms of HAB poisoning include nausea, vomiting, diarrhea, skin or throat irritation, and breathing difficulties. Because HABs are more likely with warmer water temperatures, blooms in Alaska are most common in the summer.

▶ BUILDING A STATEWIDE NETWORK

The Alaska Harmful Algal Bloom Network (AHAB) was formed in 2017 to provide a statewide approach to HAB awareness, research, monitoring, and response in Alaska and to better inform recreational harvesters and prevent poisoning. AHAB coordinates a diverse group of coastal stakeholders to address human and wildlife health risks from toxic algal blooms. Among AHABs members are research institutions, public health and resource management agencies, tribes, and local communities. While monitoring efforts do not span the entire state, efforts are growing. Current monitoring takes place in specific beaches in Southeast, Kachemak Bay, Kodiak, and parts of the Aleutian islands. Visit the AHAB website to learn more and view recent monitoring results. aoos.org/alaska-HAB-network

OCEAN ACIDIFICATION UPDATE

Alaska Ocean Acidification Network

AOOS established the Alaska Ocean Acidification Network in 2016 to engage with scientists and stakeholders to expand the understanding of ocean acidification (OA) processes and consequences in Alaska.

WHAT IS OCEAN ACIDIFICATION?

Scientists estimate that the ocean is thirty percent more acidic today than it was 300 years ago, traceable to increasing levels of atmospheric carbon dioxide (CO_2) generated by humans. As CO_2 is released into the atmosphere by human activities, about half of it stays there and much of the rest is absorbed by the ocean. This lowers the pH and increases the acidity of seawater, changing the environment for the organisms that live there.

WHY IS OCEAN ACIDIFICATION A CONCERN FOR ALASKA?

Some of the species most susceptible to OA often serve as the base of the food chain, so researchers expect the effects of OA to be felt throughout the marine ecosystem. This could dramatically affect the lives and livelihoods of Alaskans, including many who rely on wild foods and the $5.8 billion Alaska seafood industry. OA in Alaska is expected to happen faster than in other regions due to its cold water, which can absorb more CO_2. Since Alaska is already close to the tipping point due to natural factors, an increase in ocean acidification could have major impacts.

HIGHLIGHTS:

▶ **10 years of data in the Gulf of Alaska:** The Ocean Acidification Research Center (OARC) at the University of Alaska Fairbanks recently completed ten years of OA monitoring along a transect that extends 230 kilometers into the Gulf of Alaska starting at a point near Seward. Researchers are just beginning to dig into the complex math and analysis required to understand the data, but several early themes are emerging, including more corrosive waters during cooler years, and that fall is a more vulnerable time of year than spring.

▶ **Ferry for Science:** Starting last November, the state ferry *M/V Columbia* began collecting OA data during its weekly run between Bellingham, Washington and Skagway, Alaska. This partnership between research entities and the Alaska Marine Highway System provides a unique window into nearshore water chemistry and seasonal trends, and will give scientists the opportunity to identify local hotspots.

▶ **Tribal involvement:** Native Alaskans depend on wild food for nutrition and culture, and are becoming key players in OA monitoring efforts. Tribes in Lower Cook Inlet, Prince William Sound, and Southeast Alaska are taking water samples near their communities and sending them to Alutiiq Pride Shellfish Hatchery in Seward or the Sitka Tribe of Alaska lab in Sitka for analysis. These samples will help build an understanding of baseline conditions and local influences that can help Tribes plan and respond. The Alaska Ocean Acidification Network recently launched an OA Tribal Research Working Group to help spread community monitoring efforts to other parts of the state.

GULF WATCH ALASKA LOOKS BEYOND 'THE BLOB'

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Some say the only constant in life is change. That is certainly true in the ocean. Tides, winds, and other forces drive waves, currents, and water column mixing—ensuring that the ocean is indeed in motion, continually changing. Mixing, along with solar radiation, also affects water temperature. Fortunately, the heat capacity of water is high, meaning that it takes a lot of energy to change the temperature of the ocean. This is one reason why the oceans are so important for global temperature regulation.

On the flip side, when a big warming event occurs in the ocean, a change in water temperature of only a few degrees can have a large effect on marine life. The recent 2014-2016 marine heat wave in the Gulf of Alaska—a combination of The Blob and El Niño—is proving to be a case in point. This prolonged warming caused pronounced effects on the marine ecosystem, impacting everything from plankton and fish, all the way up to whales.

Gulf Watch Alaska long-term ecosystem monitoring, along with many collaborators, is evaluating how local marine resources are responding to changing conditions, including the marine heat wave. The following articles on this page highlight some of our findings in a changing environment.

A humpback whale surfaces amongst a flock of foraging kittiwakes. *Photo by John Moran, NOAA. MMPA Scientific Research Permit 473-1700-01.*

A WINTER REFUGE FOR SEABIRDS

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If you find yourself in Prince William Sound during the winter, you'll notice that some intrepid seabirds choose to stay and tough out the harsh Alaskan winter. Why?

Researchers at the Prince William Sound Science Center have been monitoring marine birds in Prince William Sound during the winter for over a decade. This long-term monitoring has enabled us to document changes in density and habitat use of marine birds before, during, and after the recent marine heat wave (The Blob) in the North Pacific Ocean. We have also found that the large barrier islands sheltering Prince William Sound from the Gulf of Alaska create extensive ice-free habitat for wintering populations of over 20 marine bird species!

Common murre are the most abundant winter species in Prince William Sound. Murres and Pacific loons dive deep into the water column to reach prey. These species are often found in areas where adult herring overwinter. Marbled murrelets, small diving seabirds that nest in old-growth forests, spend their winters in shallower nearshore waters where juvenile herring are found. Gulls don't dive underwater, so they rely on diving seabirds to drive fish to the surface. We also often observe humpback whales associated with foraging seabird flocks during winter. It appears whales can key into the sounds of flocks diving around fish schools to help locate their next meal!

WASTING SEA STARS IN THE GULF OF ALASKA

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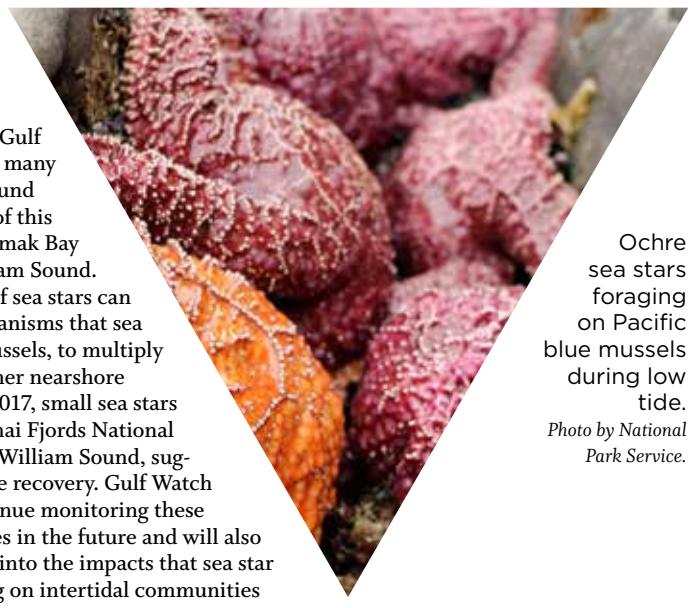
Sea stars play a vital ecological role as top-level predators, shaping nearshore ecosystems. The long-term monitoring program Gulf Watch Alaska, in collaboration with other long-term monitoring programs, have been surveying intertidal sea stars for approximately ten years in Kachemak Bay, Katmai National Park and Preserve, Kenai Fjords National Park, and Prince William Sound. Surveys have shown that the diversity and dominance of individual sea star species varies greatly among these regions.

There have historically been over a dozen sea star species in this area, but today, their diversity and overall numbers are down. This dramatic decline in sea star numbers, most likely attributable to sea star wasting, has been seen across all regions in recent years. In 2014, sea star wasting disease expanded north from California and reached the Gulf of Alaska, where many sea stars were found with symptoms of this disease in Kachemak Bay and Prince William Sound.

The absence of sea stars can enable other organisms that sea stars eat, like mussels, to multiply and drive out other nearshore inhabitants. In 2017, small sea stars were seen in Kenai Fjords National Park and Prince William Sound, suggesting a possible recovery. Gulf Watch Alaska will continue monitoring these important species in the future and will also provide insights into the impacts that sea star wasting is having on intertidal communities over time.



Ochre sea stars foraging on Pacific blue mussels during low tide. *Photo by National Park Service.*

DALL'S PORPOISE:
LIFE IN THE FAST LANE

Dall's porpoise are frequently found "bowriding " in Prince William Sound. *Photo by John Moran, National Marine Fisheries Service, Permit # 18529-01.*

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It's a sunny day in Prince William Sound and you are out picking berries in bear country. You know where there is a nice patch of blueberries, but it is near a stream in thick brush, and the salmon are spawning. Unless you are completely naïve to Alaska's bears, the thought of an encounter with a large predator probably crosses your mind. Is it worth the risk?

Killing and eating is not the only way predators affect their prey. Predators influence where and when species forage, through fear. Dall's porpoise are one of the fastest marine mammals, relying on speed to outswim their main predator, killer whales. But they need room to run, which is why they prefer open water and long passages. Getting trapped in a bay means they could run out of water before a pursuing killer whale loses steam and gives up on the chase.

However, in Prince William Sound, there can be good foraging for fish in bays, especially when herring are running. What do they do? In the past, they stuck with the open water. The risk of being trapped and tossed through the air by an eight-ton predator wasn't worth a tasty fish. But things seem to have changed.

The population of mammal-eating AT1 pod killer whales was hit hard by the *Exxon Valdez* oil spill and their numbers are dropping. With their main predator on the decline, Dall's porpoise face less risk feeding in confined waters. In recent years, we have found that Prince William Sound's herring are back on the menu for porpoise. The risks are low and the rewards are high.

Ecosystems are complex and interactions between species are not always straightforward. It can be hard to predict how changes in one species will affect others. Perhaps in the eyes of a herring, the AT1 killer whales offered protection from the speedy Dall's porpoise.

PRODUCTIVE PLANKTON IN THE WORLD'S RICHEST WATERS: THE ROLE OF NUTRIENTS IN THE ANNUAL PLANKTON CYCLE.

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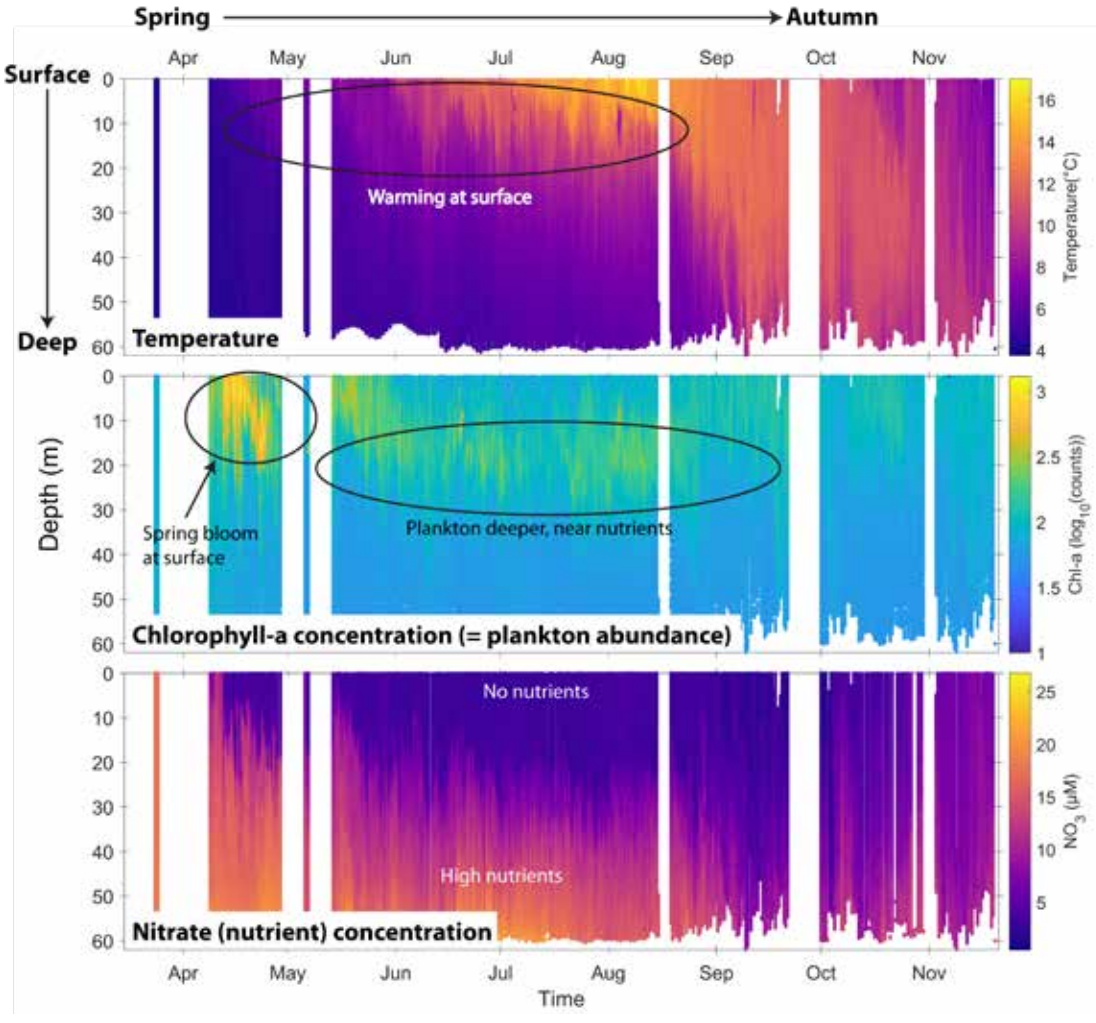
In Prince William Sound, annual productivity of the marine ecosystem is mostly driven by the availability of nitrogen-containing nutrients to the surface. Deep waters in Prince William Sound derive from the North Pacific and are very high in nitrogen (in a form called nitrate). During winter storms, these deep waters get mixed up to the surface. By springtime, when the days are longer, there is usually abundant nitrate near the surface. Phytoplankton (single celled plants that contain chlorophyll) find themselves in a situation where they have lots of nutrients and light available, whilst surface waters are warming up and they can grow faster.

The resulting growth explosion by the phytoplankton is called the "spring bloom" and is when a large percentage of annual production happens. Following the spring bloom, the phytoplankton use up all the nutrients in the surface layer and are mostly found deeper down, where they are still near the surface (and sunlight), but also have access to nitrate. Measurements of temperature, chlorophyll-a (a proxy for the amount of phytoplankton), and nitrate, by an oceanographic profiler deployed every year in central Prince William Sound by Gulf Watch Alaska scientists, tracks this transition at very high resolution.



Time series of temperature (top panel), phytoplankton abundance (middle panel), and nitrate concentration (bottom panel) in the surface waters of central Prince William Sound in 2017. The left axis is depth, with the surface at the top of each panel and the maximum depth sampled (60 meters) on the bottom. The bottom axis is time, from when measurements started in mid-March to mid-November, when the profiler was recovered. The color scale corresponds to the amount of each quantity, with hot colors indicating more and cool colors indicating less.

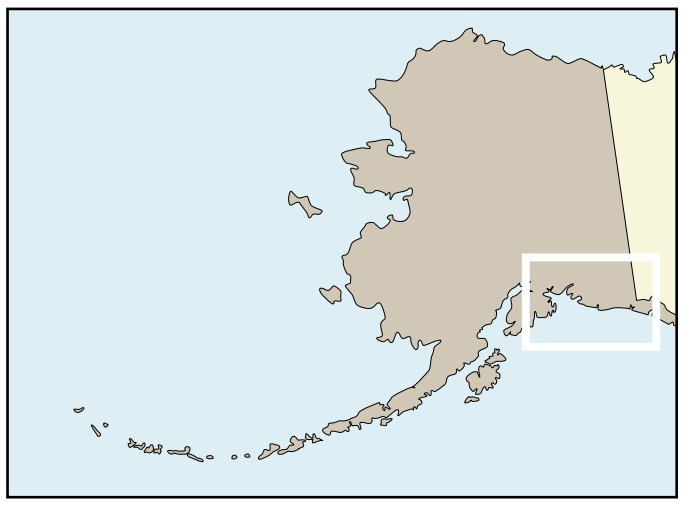
63°N
62°N
61°N
60°N
Paxson
Chiste
Gakona
Gulkana
Talkeetna Mountains
Talkeetna
Glennallen
Mendeltna
Tazlina
Copperville
Copper Center
Kenny
Lake
Chitin
Wasilla
Chugach
M
Valdez
Anchorage
Portage
Whittier
Tatitlek
Bligh Reef
Prince William Sound
Simpson Bay
Cordova
Eshamy Bay
Knight Is.
Egg Is.
Hinchinbrook Is.
Copper River
Hinchinbrook Entrance
Chenega
Montague Is.
Seward
Montague Strait
Middleton Is.
N
25
50
Miles
150°W
148°W
146°W

Highways

Trans Alaska Pipeline

USA-Canada Border

PRINCE WILLIAM SOUND SCIENCE CENTER



Map and design by Kristin Link

estasta

Lake

Slana

ochina

Wrangell Mountains

Mt. Wrangell
14,163 ft

Kennecott Copper
Mine
McCarthy

na

Chitina River

ountains

Copper River

Bagley Icefield

Mt. St. Elias
18,008 ft

Bering Glacier

Icy Bay

Flats

Kayak Is.

Yakutat Bay

Yakutat

Gulf of Alaska

144°W

142°W

HERRING RESEARCH AND MONITORING

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In the decades before 1990, there was a robust Pacific herring population in Prince William Sound (PWS). Not only are these forage fish a key link in the complex food web of PWS, but they supported a lucrative early season commercial fishery that brought the communities of the Sound to life each spring. By 1993, that fishery had closed. The current stock of nine thousand tons is well below the historical peak of 130 thousand tons.

The Herring Research and Monitoring program is a mix of monitoring studies that provide data necessary to understand changes in the PWS herring population and process studies that address particular aspects of herring. These process studies help us understand why populations may change or address assumptions in the population model. In the first five years, the program focused on the overwinter survival of young herring and addressing assumptions in the model and measurements. Currently, the focus is more on adult herring and the connections between herring condition and recruitment and environmental conditions.

Measurements continue to be collected to detect changes in the PWS herring population, observe where herring go after spawning, and determine when herring mature and become part of the spawning population. Diseases continue to be examined to determine their role in limiting the herring population. Additional effort is being spent examining how the herring condition and recruitment is dependent on environmental factors, such as food availability and predator populations.

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Management of the Pacific herring population in Prince William Sound (PWS) relies on an assessment model that predicts annual spring biomass. The forecasted quantity of herring is used by fisheries managers to set harvest rates. Since the late-1990s, the PWS herring fishery has been closed due to biomass estimates that remain below the State of Alaska's regulatory threshold of approximately twenty thousand metric tons. Contributing factors to the lack of recovery by herring in the Sound vary, but include aspects of toxicity from the *Exxon Valdez* oil spill, disease, changing oceanographic conditions, and increases in predation rates and competitive interactions for food.

Ongoing research supported by the *Exxon Valdez* Oil Spill Trustee Council aims to refine the PWS herring assessment model. To this end, one important factor estimated by the model is the reproductive maturity schedule for PWS herring (i.e. the proportion of immature and mature three-, four-, and five-year-old herring that are in the spawning stock). A new study that began in 2017 is testing the herring assessment model's reproductive maturity schedule using data derived from field captured adult herring.

Over the last year, adult herring were collected during spring spawning (April), late summer (September), and early winter (November) primarily from the Gravina region of PWS (Figure 1). Fish scales were retained for aging, and measurements of fish length, weight, and gonad weight were obtained to develop a reproductive maturity index based on the ratio of gonad weight to body weight scaled as a percentage (gonadosomatic index). Preliminary data from spring 2017 indicate that the spawning stock was primarily comprised of age three- and four-year-old herring. Preliminary data from spring 2017 indicate that the vast majority of three- and four-year-old herring were reproductively mature, as nearly all fish had a gonadosomatic index above five percent (Figure 2).

Figure 1: Collection location for adult Pacific herring from the Gravina region of Prince William Sound, Alaska.

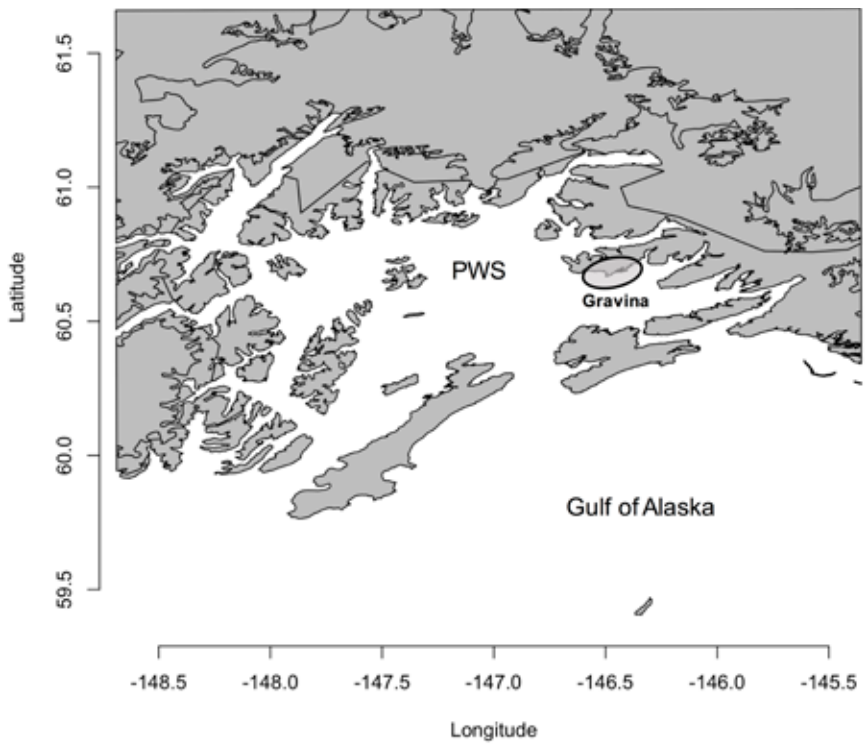
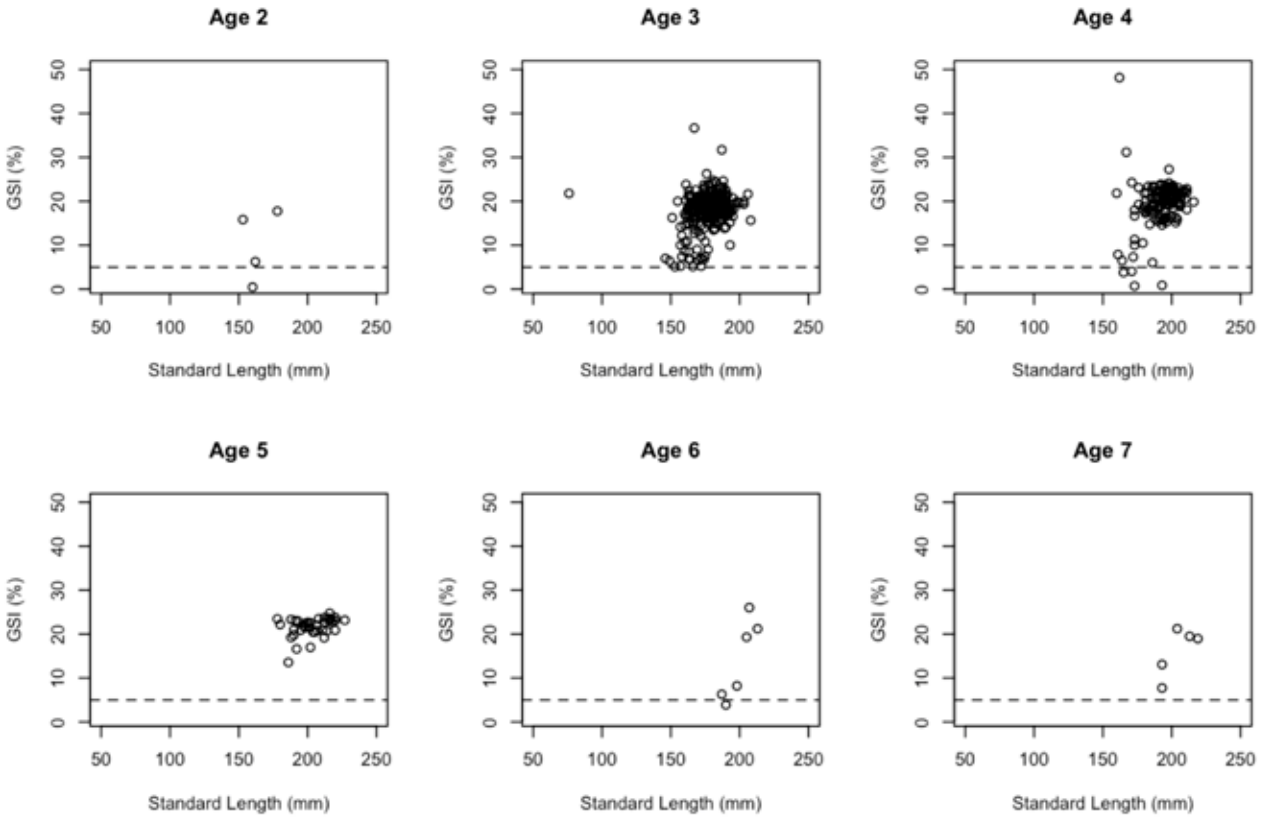


Figure 2: Relationships between length and gonadosomatic index for age cohorts (2-7) of Pacific herring caught during the 2017 spring spawn. Dotted lines indicate the gonadosomatic index value above which herring are considered reproductively mature (>5%).



AERIAL SURVEYS OF PACIFIC HERRING

ADF&G Biologist Shane Shepherd uses a cast net to collect samples of spawning herring for age, sex, and size processing. *Photo by S. Vega, Alaska Department of Fish and Game.*

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In the spring, Pacific herring gather to spawn in large numbers. This provides an opportunity to get information on the biomass and age composition of the spawning stock. Aerial surveys are used to measure the miles of spawn, estimate biomass, and map congregations of birds and mammals. The Alaska Department of Fish and Game has conducted spring aerial surveys of herring spawn in Prince William Sound since 1973.

During aerial surveys, information is recorded on electronic tablets, and photographs are taken from the air to document and quantify the distribution of spawn. This information is critical to monitoring the herring population in Prince William Sound and feeds into an age-structure-analysis model used to estimate the return for the next year.

During vessel surveys using the *R/V Solstice*, herring are collected using seines, gill nets, and cast nets. These samples are analyzed to determine age, weight, length, and sexual maturity of the fish. Samples are also provided to the herring disease and maturity projects (see related articles). Age structure and size-at-age data from herring samples are used in the age-structured-analysis model and also provide information on target strength for the acoustic survey project (learn more here: pwssc.org/adult-biomass-surveys).

Aerial- and boat-based monitoring is integral to herring research in Prince William Sound and provides data, samples, and research platforms to herring research projects.

Herring milt from spawning event observed during aerial surveys. *Photo by S. Shepherd, Alaska Department of Fish and Game.*

FORECASTING DISEASE POTENTIAL IN PACIFIC HERRING

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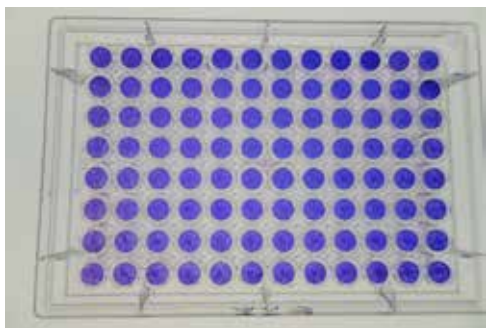
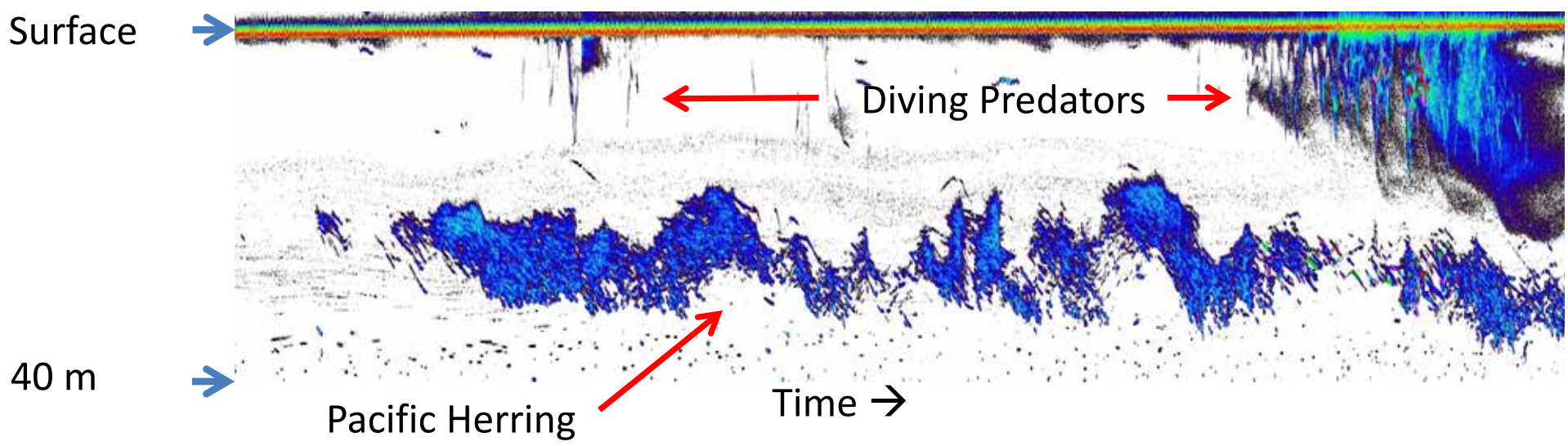
Calculating levels of natural mortality in marine fish populations remains difficult for fishery managers who need to provide annual forecasts of population size. Although some percentage of fish certainly die from predation, disease, and starvation, the relative contributions of these natural mortality factors are random and can change dramatically from year-to-year. To address the annual contribution of disease mortality to Pacific herring populations, a novel quantitative technique (plaque neutralization test, or PNT) was developed; it is capable of proactively forecasting disease potential in a population and retroactively deducing whether a disease epizootic may have occurred.

The PNT works on the concept of adaptive immunity, whereby herring that are naive to a particular virus (viral hemorrhagic septicemia virus, or VHSV) are susceptible to future disease outbreaks because they do not contain protective antibodies, whereas those that have survived prior exposure are protected from future outbreaks because of the presence of protective antibodies. The PNT is capable of detecting and quantifying these circulating VHSV antibodies in Pacific herring. Final validation experiments are currently underway to interpret how these PNT values correspond with levels of herd immunity, but preliminary results indicate that VHSV antibody levels often differ in herring between Prince William Sound and Sitka Sound.



Typical 96 well plate from a plaque neutralization test. The purple areas of each well indicate the presence of cells. The clear areas within some of the wells (plaques) indicate where virus was present and killed the cells. Wells containing fewer plaques indicate herring plasma samples where antibodies were present and neutralized the virus. *Photo by A. MacKenzie, U.S. Geological Survey.*



ABOVE: Echogram representing about one hour of recording just after midnight on April 11, 2016. Tracks near the surface represent predators (e.g. seabirds and sea lions); herring schools appear midwater.

BELOW: The autonomous echosounder prior to deployment on the sea floor in Prince William Sound. *Photo: Dave Janka.*

THE DYNAMICS OF HERRING AND PREDATORS IN PRINCE WILLIAM SOUND

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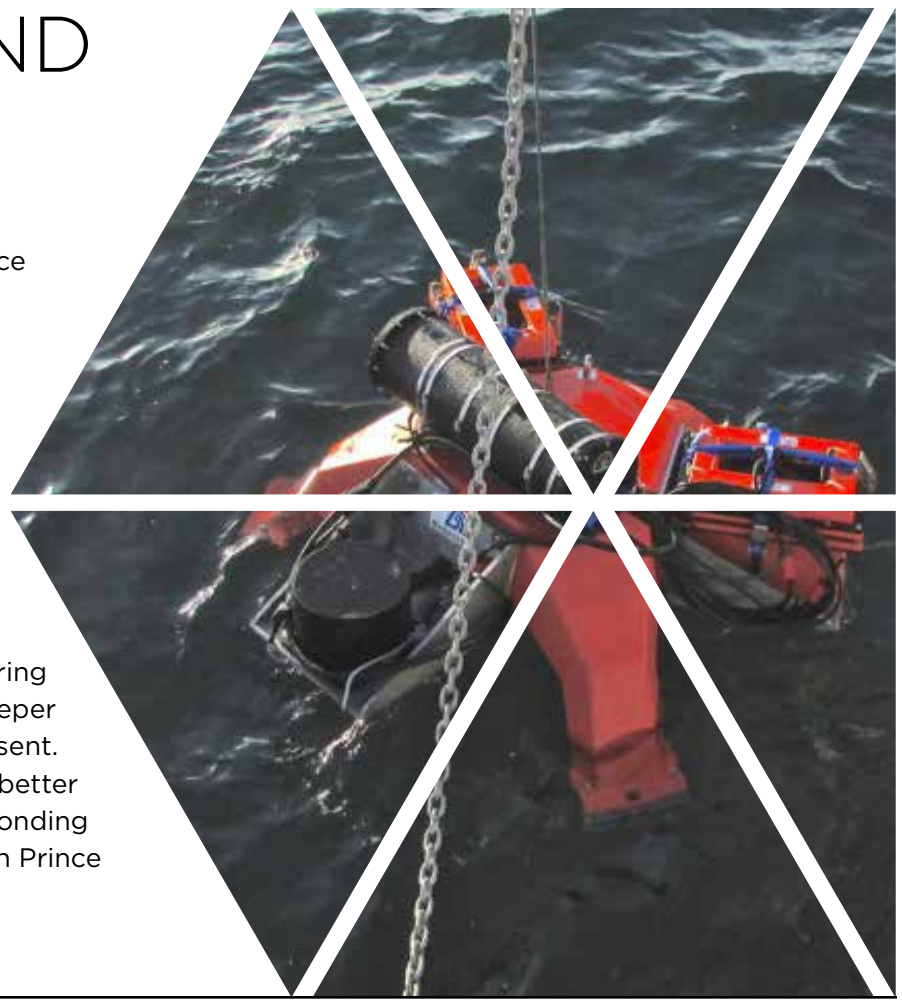
Abundance of Pacific herring has remained low in Prince William Sound since the 1990s. Predators may play an important role in their recovery. To monitor the response of herring schools to surface predators, we recently deployed new technology in eastern Prince William Sound: an autonomous, split-beam echosounder, produced by BioSonics.

Mounted on the seafloor with the transducer looking up toward the surface, the unit is capable of tracking the three-dimensional paths and speed of targets (both predator and prey) that pass through the beam. This gives us an unprecedented view of how herring respond to the presence of surface predators in a completely natural setting.

While it is not possible to distinguish the species of predators in the echogram (see figure), based on observations during our research cruise, we noted a number of different seabirds and sea lions diving on the school. We found predator speeds to be twice as fast as herring speeds, and herring occupied deeper depths when predators were present. This can be an important tool to better understand how herring are responding to changing predator dynamics in Prince William Sound.



HOW TO TAG A HERRING

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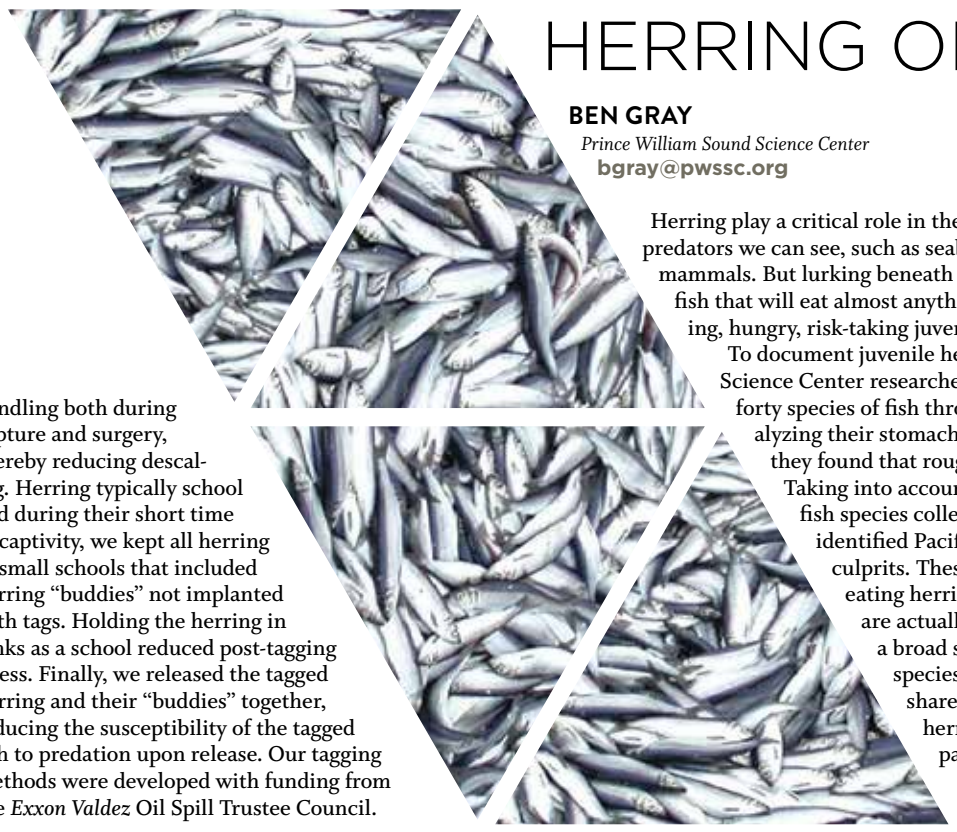
Pacific herring, a small forage fish, has long been considered sensitive to handling. As a result, there are few herring tagging studies. In the past ten years, lab experiments showed tags could be successfully implanted in herring. Building on these results, scientists from Prince William Sound Science Center and NOAA implanted tags in wild-caught Pacific herring during spring while they were on their spawning grounds. After their release, we were able to detect them for up to nine months (when transmitter batteries died) at the Ocean Tracking Network arrays, a series of underwater receivers placed in strategic locations within the Sound.

The secrets to our success? We minimized handling both during capture and surgery, thereby reducing descaling. Herring typically school and during their short time in captivity, we kept all herring in small schools that included herring "buddies" not implanted with tags. Holding the herring in tanks as a school reduced post-tagging stress. Finally, we released the tagged herring and their "buddies" together, reducing the susceptibility of the tagged fish to predation upon release. Our tagging methods were developed with funding from the *Exxon Valdez* Oil Spill Trustee Council.



HERRING ON THE MENU

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Herring play a critical role in the Sound's food web, but who eats them? Some predators we can see, such as seabirds, humpback whales, and other marine mammals. But lurking beneath the surface, there are a variety of predatory fish that will eat almost anything they can capture—especially overwintering, hungry, risk-taking juvenile herring.

To document juvenile herring predation, Prince William Sound Science Center researchers used longlines and gill nets to collect over forty species of fish throughout the Sound over three winters. By analyzing their stomach contents (over nineteen hundred of them!), they found that roughly half of the fish species consumed herring. Taking into account these findings, and the overall abundance of fish species collected throughout the surveys, researchers have identified Pacific cod, walleye pollock, and big skate as major culprits. These species do not necessarily specialize in eating herring, they just happen to eat a lot of them. They are actually considered generalist species and consume a broad subset of what is readily available. Since these species are fairly abundant in the Sound, and they share habitat with juvenile herring, it's no wonder herring are such fan favorites with these three particular predators.

PROTECTING WINTER WILDLIFE FROM OIL SPILLS

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"What lives here in the winter?"

Steller sea lions are just one species of many found in Prince William Sound during the winter.

Photo by Dave Janka.

This is a question anyone might ask when visiting Prince William Sound in the off-season. It is also a question recently asked by local organizations in order to better protect these rich waters and their wildlife occupants year-round from oil spills.

The Prince William Sound Regional Citizens' Advisory Council worked with the Prince William Sound Science Center in 2016 to complete a biological resource inventory of winter species in the Sound. The goal of this project was to develop a detailed bibliography documenting the presence of all wildlife studied in the Sound during the winter since 1989. This project allows this information to be shared with anyone working or visiting the region.

The resulting paper also identifies gaps in knowledge regarding the Sound's winter species to be filled by future researchers. It provides valuable, scientifically accurate information that can be used by the Council and others to identify sensitive biological resources which informs oil spill contingency plans and helps spill responders and spill drill participants better consider winter species when protecting sensitive areas from harm. To see the list of winter species documented and the final report: pwsrcac.org/announcements/protecting-winter-wildlife-oil-spills

THE ROV CHALLENGE

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Every February, Alaska's regional competition of the National Ocean Sciences Bowl, the Tsunami Bowl, is held in Seward. For the past seven years, PWSSC has hosted a Remotely Operated Vehicle (ROV) Challenge for participating teams. Teams of students from around the state are tasked with engineering an ROV and putting it to the test in the high school pool.

Using PVC piping, teams have one hour to strategize the overall design of the ROV, including motor placement and the ROV's capabilities of completing a handful of underwater obstacles. After the initial build, teams test their ROVs in the pool and make modifications to ensure it will have neutral buoyancy to "fly" unencumbered. This can be the most demanding part of the build.

First-time ROVers, Shrimp Happens, an all-female team from Eagle River High School, said they were really nervous about the build. Team Captain Keryl Kozon admitted calling her brother, an engineer for NASA, right before the build to get some advice. However, once the team began sorting pieces and planning their design, they realized they were completely capable. Unfortunately, when their ROV hit the water, design issues became evident. Pieces kept falling off and the ROV would only drive in one direction, making it difficult to maneuver a couple of the tasks. At the end of the challenge, the team was still in good spirits and wisely noted that when faced with a new challenge sometimes… "shrimp happens!"

Shrimp Happens, from Eagle River High School. Team Captain, Keryl Kozon, stands second from the right. *Photo by Stefanie Tschappat.*

This program is made possible by a variety of supporters, including the Prince William Sound Regional Citizens' Advisory Council, the Oil Spill Recovery Institute, and Alyeska Pipeline Service Co.

EXXON VALDEZ A TIMELINE

MARCH 23, 1989:

On March 23, 1989, the oil tanker *Exxon Valdez* left the Valdez Marine Terminal at 9:12 p.m., bound for California with a full load — approximately 53 million gallons — of North Slope crude oil.

The tanker Captain, Joe Hazelwood, was granted permission to change course to avoid icebergs from nearby Columbia Glacier. He gave orders to the Third Mate to maneuver the tanker to the new course and then retired to his quarters. For reasons that remain unclear, the tanker was never returned to its proper course.

MARCH 24, 1989:

Just after midnight on March 24, the *Exxon Valdez* oil tanker grounded on Bligh Reef, spilling at least 11 million gallons of crude oil into Prince William Sound, the largest oil spill in U.S. waters.

The initial response to the spill was slow, uncoordinated, and ineffective. Seas and winds were calm for three days, but almost no response equipment was available.

MARCH 27, 1989:

On March 27, a storm blew in with winds up to 70 mph, spreading the oil spill to the southwest along at least 1,400 miles of shoreline (see figure, above).

More information on the immediate and long-term impacts of the spill, as well as links to other oil spill resources can be obtained from the legacy organizations established after the spill.

- The *Exxon Valdez* Oil Spill Trustee Council oversees the 1991 $900 million civil settlement for restoration of injured resources and services. The restoration plan includes habitat protection, research and monitoring, and direct restoration.
  evostc.state.ak.us
- The Oil Spill Recovery Institute was established by Congress in 1990 to focus on improved technologies and ecological research related to oil pollution in the marine environment of Arctic and Subarctic regions.
  pws-osri.org
- The Prince William Sound Regional Citizens' Advisory Council is an independent nonprofit organization whose mission is to promote environmentally safe operation of Alyeska Pipeline's Valdez Marine Terminal and associated oil tankers.
  pwsrcac.org

EVALUATING THE TREATMENT OF *ELODEA CANADENSIS*

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U.S. Forest Service Chugach National Forest

Elodea canadensis is Alaska's first aquatic invasive plant, and it has established itself in various waterbodies across the Copper River Delta. Complete and timely eradication of *Elodea* could be a difficult task, so the U.S. Forest Service is currently assessing the feasibility of treating *Elodea* across the Delta on a small scale. This project is using fluridone (an aquatic herbicide) to evaluate the ecological response of the native ecosystem to both the presence of and the treatment of *Elodea*.

This study began in 2016 when two ponds and a slough within the Eyak Cannery Complex were treated with fluridone multiple times at low doses. Water turnover proved to be occurring at higher rates than expected, which affected the effectiveness of the treatment. However, target concentrations of fluridone were maintained in at least one pond, meaning it may not need further treatment.

Plans for the 2018 season are to continue treatment in the Eyak Cannery Ponds with adjusted application rates. In 2019, treatment will begin on Wrong Way pond, a salmon-bearing waterbody, to assess *Elodea* and fluridone effects on salmonids and their food web. The results of this study will inform potential broader-scale treatment of *Elodea* across the Copper River Delta.

Densely regenerated Sitka spruce and western hemlock in an old clearcut at Knowles Head. *Photo by Nathan Wesely.*

KNOWLES HEAD WILDLIFE HABITAT RESTORATION THINNING

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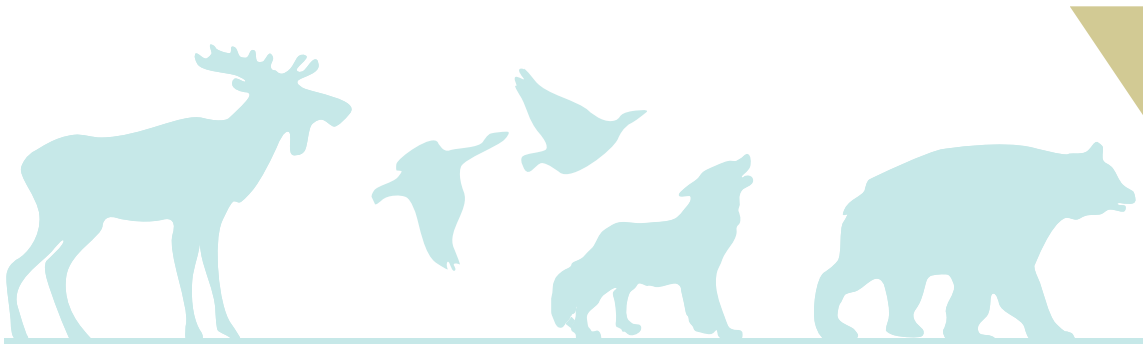
Marbled murrelets were injured by the *Exxon Valdez* oil spill in 1989 and are still classified as "not recovered." These birds nest primarily in old-growth forests and have experienced a simultaneous reduction in potential nesting habitat due to clearcut harvesting in Prince William Sound (PWS).

Knowles Head peninsula was managed as an industrial forestland with approximately twenty-eight thousand acres being clearcut between 1989 and 1996. After clearcutting, second-growth forests grow back exceptionally dense and can take hundreds of years to again develop old-growth characteristics (e.g., large trees, canopy heterogeneity). Sitka spruce forests in PWS naturally develop under repeated small scale disturbances (e.g., wind damage) as opposed to large scale disturbances (e.g., canopy fire). Managers can use these principles of natural disturbance to accelerate the development of old-growth characteristics in managed forests. Specifically, variable-density thinning is a technique that mimics small scale disturbance, increasing the size of trees while introducing spatial heterogeneity.

In 1999 the Knowles Head peninsula was conveyed to the National Forest System and became a part of the Chugach National Forest. The U.S. Forest Service will be implementing a variable-density thinning project at Knowles Head to improve and restore nesting habitat for murrelets.



CAN YOU SPOT THE BIG 10?

- ❑ Killer whale
- ❑ Steller sea lion
- ❑ Sea otter
- ❑ Harbor seal
- ❑ Harbor porpoise
- ❑ Sitka black-tailed deer
- ❑ Brown bear
- ❑ Mountain goat
- ❑ Beaver
- ❑ Moose

Bird and wildlife checklist

RECOMMENDED BIRD/MAMMAL GUIDE: *Sibley's Field Guide to Birds of Western North America* by David Allen Sibley and the *Guide to Marine Mammals of Alaska* by Kate Wynne. List compiled by the Prince William Sound Chapter of the Audubon Society.
U = UNCOMMON • **S** = SEASONAL

LOONS AND GREBES
- ❑ Common loon
- ❑ Red-throated loon
- ❑ Pacific loon (s)
- ❑ Yellow-billed loon (s,u)
- ❑ Horned grebe
- ❑ Red-necked grebe

SHEARWATERS AND PETRELS
- ❑ Fork-tailed storm-petrel
- ❑ Sooty shearwater (u)

CORMORANTS
- ❑ Pelagic cormorant
- ❑ Double-crested cormorant

HERONS
- ❑ Great blue heron

WATERFOWL
- ❑ Surf scoter
- ❑ White-winged scoter
- ❑ Long-tailed duck
- ❑ Barrow's goldeneye
- ❑ Common goldeneye
- ❑ Bufflehead
- ❑ Harlequin duck
- ❑ Mallard
- ❑ Canada goose
- ❑ Common merganser
- ❑ Red-breasted merganser

SHOREBIRDS
- ❑ Black oystercatcher
- ❑ Semipalmated plover
- ❑ Least sandpiper
- ❑ Yellowlegs (lesser and greater)
- ❑ Red-necked phalarope (s)
- ❑ Surfbird (s)
- ❑ Black turnstone (s)
- ❑ Dunlin (s)
- ❑ Western sandpiper (s)

GULLS/TERNS
- ❑ Glaucous-winged gull
- ❑ Herring gull
- ❑ Mew gull
- ❑ Bonaparte's gull (s)
- ❑ Black-legged kittiwake
- ❑ Parasitic jaeger
- ❑ Pomarine jaeger
- ❑ Arctic tern (s)
- ❑ Aleutian tern (s,u)

SEABIRDS
- ❑ Tufted puffin (s)
- ❑ Horned puffin (s)
- ❑ Marbled murrelet
- ❑ Kittlitz's murrelet (u)
- ❑ Parakeet auklet (u)
- ❑ Pigeon guillemot
- ❑ Common murre

RAPTORS
- ❑ Bald eagle
- ❑ Peregrine falcon

HUMMINGBIRDS
- ❑ Rufous hummingbird (s)

KINGFISHERS
- ❑ Belted kingfisher

PASSERINES
- ❑ Tree swallow
- ❑ Violet green swallow
- ❑ Bank swallow
- ❑ Chestnut-backed chickadee
- ❑ Winter wren
- ❑ Common raven
- ❑ Northwestern crow
- ❑ Black-billed magpie
- ❑ Steller's jay
- ❑ Hermit thrush
- ❑ Varied thrush
- ❑ American robin
- ❑ Wilson's warbler
- ❑ Orange-crowned warbler
- ❑ Song sparrow
- ❑ Fox sparrow
- ❑ Savannah sparrow

MAMMALS
- ❑ Humpback whale
- ❑ Minke whale
- ❑ Dall's porpoise
- ❑ Black bear
- ❑ Land otter
- ❑ Marmot
- ❑ Mink
- ❑ Weasel

Testing out chest waders on the Copper River Delta. *Photo by PWSSC.*

H2O HEADWATERS TO OCEAN SUMMER CAMPS

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There is nothing quite like the sound of ten eight-year-olds stepping into a river with chest waders on. The squeals of excitement—elicited by the strange pressure of water that is in fact NOT soaking their clothes—ring out over the Copper River Delta. The theme of the day is 'wetlands,' and these H2O campers are looking for juvenile salmon in the pools. Discussions involve everything from the salmon lifecycle to the movement of sediment in a glacial river. After trapping and identifying salmon fry, the group heads back to camp for hot dogs, s'mores, and an overnight in the cabin (for many, their first night ever away from family).

PWSSC's environmental science camps are an opportunity for students to experience the amazing landscape that surrounds us in an educational and exciting way. During our H2O day and overnight camps, kids hike through the rainforest, observe glaciers up close, canoe through wetlands, and explore tide pools. We are dedicated to helping campers develop their understanding of the world around them through scientific inquiry, positive outdoor experiences, leadership skills, and ecosystem stewardship. Our camps, set in the beautiful Copper River Delta, focus on our deep connection between ourselves and natural habitats. From headwaters to ocean, it's all connected.

Young campers take in the splendor of the Copper River Delta, with Childs Glacier in the distance. *Photo by PWSSC.*

Dipping into some glacial mud while exploring Sheridan Glacier. *Photo by PWSSC.*

A mom and her tot exploring the heart-centric activities at Sea Squirts. *Photo by Teal Barmore.*

YOUNG SCIENTISTS

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The new Prince William Sound Science Center education program, *Sea Squirts*, is designed to get your tot thinking like a scientist. During the program, kids are introduced to a topic through a storybook and then free to explore several hands-on activity stations designed to engage them in simple wonders and delights of the world they live in.

Some *Sea Squirts* topics include: kitchen chemistry, geology, stars and space, snow, and density. The February *Sea Squirts* program topic was hearts. When asked, "Why do we need a heart?" a small voice spoke up and said, "To love."

The *Sea Squirts* activities were designed to introduce them to the anatomy and function of a heart. Tots roamed activity stations, lathering blue (oxygen) and red (blood) frosting onto graham cracker heart models, building homemade stethoscopes to listen to heartbeats, and tracing the flow of blood through a pop-up heart model. So while most young participants arrived thinking "to love" was the only purpose of a heart, they left with the understanding that the main job of the heart is to pump oxygen rich blood to every part of the body so it can move, think, grow, (and love).

AFTER 19 YEARS, TUESDAY NIGHT TALKS STILL GOING STRONG

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The Prince William Sound Science Center, with help from Alaska Sea Grant and the local Audubon Society chapter, fuels discussion and education on natural science in and around Cordova through their weekly Tuesday Night Talks program.

Since the program's start, there have been numerous research talks and videos on subjects ranging from bears with GoPro cameras to K9 detection of oil. On average, 25 visiting and local speakers present annually.

Tuesday Night Talks began as a way to bring research and natural science to Cordova. The program is also a practice venue for local high school students preparing for the annual Alaska Tsunami Ocean Sciences Bowl.

"We keep casting our nets," Sea Grant's Torie Baker said of the numerous and diverse speakers featured over the past 19 years. Coordinators are now exploring use of Facebook Live to broaden audience reach.

Cordovan Karen Swartzbart and her husband Paul have been attending since the program's beginning in 1999.

"Typically, the speaker is talking to a range of audience," she said. "It's not specific to just the scientific community," Swartzbart added, explaining that the speakers do a good job of making the information easy to understand for those who do not have a background in science.

THE WORLD AROUND US

SIMILAR TO THE SEA SQUIRTS ACTIVITIES ORGANIZED BY PWSSC—YOU TOO CAN HAVE FUN DOING KITCHEN CHEMISTRY WITH JUST A FEW HOUSEHOLD SUPPLIES.

CAN YOU MAKE A GAS BY COMBINING A LIQUID AND A SOLID?

This experiment creates a dramatic chemical reaction by mixing baking soda (a solid) with vinegar (a liquid). What do you think the result will be? Try this and see for yourself!

▶ SUPPLIES:

- Spoon
- Funnel
- 2 tsp baking soda
- Balloon
- 1/3 cup white vinegar
- Old plastic or glass bottle with narrow mouth, 12oz or less

▶ STEPS:

STEP 1 Using the funnel, put baking soda into the deflated balloon.

STEP 2 Using the funnel, pour vinegar into the bottle.

STEP 3 Stretch the mouth of the balloon over the bottle's opening, keeping the baking soda in the body of the balloon.

STEP 4 Dump baking soda from the balloon into the bottle.

STEP 5 Watch as the balloon inflates.

▶ WHAT'S GOING ON?

When baking soda and vinegar are combined there is a chemical reaction. A chemical called carbonic acid is made. The carbonic acid quickly decomposes into carbon dioxide (CO_2) gas. Just like the CO_2 bubbles in a carbonated drink, the CO_2 in your mixture rises to the top of your solution as foaming bubbles. With nowhere else to go, the CO_2 rises up into the balloon, causing it to inflate.

▶ WHAT IS A CHEMICAL REACTION?

When one or more substances react to form a new substance, or a substance breaks down to form one or more substances, we call that a chemical reaction.

Chemical reactions are happening everywhere you look. Photosynthesis in plants, rust forming on old metal objects, roasting marshmallows in a campfire, and even using soap to rid your hands of grime!

▶ DID YOU KNOW?

The chemical reaction that makes the balloon inflate also happens when baking soda is used in cake and cookies. When baking soda combines with the heat of the oven, a chemical reaction occurs, making the cake or cookies rise.

THE WEIGHT OF GAS

We are surrounded by gases. The air we breathe in and the air we exhale are the most common. Other examples are helium that makes balloons float and propane that fuels gas grills.

Because we can't see most gases, we often don't think about them as having weight, or one type of gas weighing more than another. In this follow-up experiment, we can find out what weighs more: carbon dioxide or the air that we exhale (which consists roughly of 80 percent nitrogen and 20 percent oxygen).

▶ SUPPLIES:

- Ruler
- Binder clip
- Pencil
- Heavy weight (e.g. book, stapler)
- 1 balloon, plus the inflated balloon from the first experiment
- 2 paper clips or tape
- Permanent marker

▶ STEPS:

1. Set up your scale by centering the binder clip on the ruler, stick a pencil through the clip handle, lay the pencil on the edge of a table, and hold it in place with a heavy object.
2. Tie the balloon filled with carbon dioxide gas and write CO_2 on it with a permanent marker.
3. Fill up a second balloon with air and write O_2 on it with a permanent marker.
4. If your ruler has two holes on either end, bend your paper clips to be hooks for your balloons. Otherwise, use tape to attach the balloons to each end.

▶ THE RESULT?

The scale tips towards the balloon filled with carbon dioxide because it is denser, and thus heavier, than the balloon filled with the nitrogen-oxygen blend of air.

NEVER STOP EXPLORING

REVEAL THE MYSTERY WORD

1. Find answers to the clues throughout the publication.
2. Write your answers horizontally in the grid.
3. Reveal the mystery word in the vertical bold squares.

▶ CLUES

Gas that is absorbed by the ocean. (p.7)

Sea bird that nests in old-growth forests. (p.16)

One of the fastest marine mammals. (p.9)

Whale that feeds on Chinook salmon. (p.3)

Animal that is found in Prince William Sound during the winter. (p.15)

Plankton that feeds on Limacina. (p.5)

Book about the Nellie Juan-College Fjord Wilderness Study Area. (p.4)

Type of net used for catching Pacific herring. (p.13)

Day of the week for the PWS Science Center's weekly lecture. (p.17)

▶ FILL IN THE BLANKS WITH THE MYSTERY WORD TO COMPLETE THE QUOTE BELOW:

Science is fun. Science is _____. We all have natural _____.
Science is a process of investigating.
It's posing questions and coming up with a method. It's delving in.

—Sally Ride,
American physicist and astronaut

For the answer key, go to pwssc.org/home/delta-sound-connections

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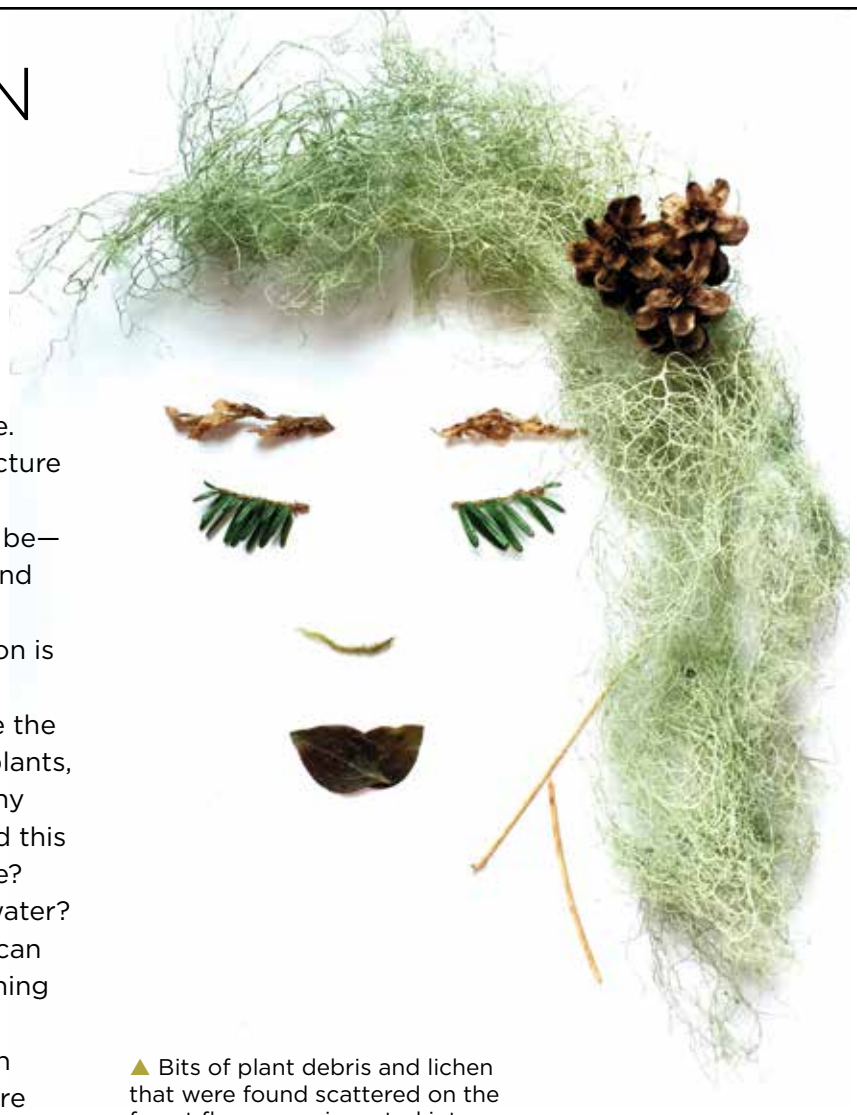
IMAGINATION FLOURISHES OUTDOORS

Curiosity and science go hand in hand. But imagination is another important skill we can use for science. With a bit of imagination, you can picture things differently than they are. You question what the possibilities could be—opening up doors to new creations and discoveries.

A fun way to enrich your imagination is through "nature art."

Nature art allows you to investigate the world around you. You'll learn what plants, animals, and rocks can be found in any given setting. You might ask: How did this object get here? Did it fall from a tree? Get blown by the wind? Carried by water? As you ponder these questions, you can also reimagine these items as something entirely new.

Try these fun ideas or come up with some of your own. The possibilities are limitless!



▲ Bits of plant debris and lichen that were found scattered on the forest floor are reinvented into something new and unexpected!
Designed by Signe Fritsch; inspired by Kazoo Magazine.

Limpets (marine snails) have conical-shaped shells. Empty shells that wash up onto the beach can be arranged into fun patterns.

Colorful rocks collected along the beach inspire a rainbow design. *Photo by Erica Owens.*

Sedimentary rocks can be found in all shapes and colors. Turn them into a sunburst!

Snap a photo or draw a picture of your nature art. Then share it with us on Facebook, Instagram, and Twitter! Be sure to tag us @pwssc and #NatureArt!

THE NEXT GENERATION
A CHANGING WORLD

What happens here in the world's richest waters influences the globe. We're the region's nonprofit with boots on the ground, boats in the water, and students in the field 12 months per year.

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