I n 1989, our founders turned an idea into action when they started the Prince William Sound Science Center. The concept of an institute that would build an understanding of the incomparable ecosystems here among the world’s richest waters had been batted around for a while, but it was still a risky one. After all, we were incorporated just one month after the Exxon Valdez oil spill.

The region was in the throes of an environmental, social, and economic trauma that, as it turns out, would continue to have impacts for decades. Research dollars were hard to come by at first. But still, our region was unmatchable when it came to the potential for building an understanding of the way things work in natural systems that are both regionally important and globally relevant.

The opportunity to accomplish something meaningful was so powerful that our first employees came aboard when nobody quite knew where the money would come from for anybody’s paycheck. Yet everybody involved knew that this place was worth studying—not for a few weeks or a month, but over the long haul, because the resilience of our region matters.

We are positioned among thousands of miles of coastline, and adjacent to 700,000 acres of wetlands on the Copper River Delta, the northernmost extent of the coastal temperate rainforest, the largest ice field in the northern hemisphere outside of Greenland, hundreds of salmon-bearing rivers and streams, and some of the fastest moving tidewater glaciers on earth. The Science Center is the only place-based research institute set within the rich lands and rich waters of Prince William Sound and the Copper River Delta, and it is through monitoring and investigations that we have been able to build a body of knowledge and share understanding of how these ecosystems function, how they are changing, why they are so important to the resilience of the communities of our region, and why they matter in the world.

Much of what we do isn’t obvious to the casual passerby. For example, we have cameras and instruments moored in the ocean that collect terabytes of data every year and ping it to our office via cell towers so we can track ocean productivity in near-real time. These devices help us detect events such as the Warm Blob, a multi-year ocean heat wave that had cascading effects on the plankton, fish, birds, and mammals of the region.

We have a team tagging Tufted Puffins on a remote island in the northern Gulf of Alaska—and when they recapture the geolocator tags, they will learn for the first time where these birds go when they are not in their breeding colony. This information, in turn, may allow us to better understand why the Tufted Puffin population in Alaska appears to be declining. And every year, our education staff engage hundreds of Alaska’s youth in hands-on and outdoor science education programs that get them unplugged from devices and charged up by programs that require observation skills, teamwork, and creativity.

Now, after 30 years of impact, we find ourselves looking forward to what the future may hold. It’s a time of great changes in ecosystems—changes that are driving unpredictable outcomes for the things that matter to people and the planet. We’re taking the long view, because we’re deeply invested in this place—one of the last, best places on earth.

We hope by reading this publication that you’ll become more knowledgeable about and invested in this place, too. If so, please consider making a donation to the Science Center so we can continue to play a role in the region’s resilience for a long time to come.
NEW CITIZEN SCIENCE OPPORTUNITY IN THE WILDERNESS STUDY AREA

HOW IS A COPEPOD LIKE A BEAR?

BY CAITLIN MCKINSTRY
Prince William Sound Science Center
cmckinstry@pwssc.org

As a skinny bear wakes from his long winter torpor in the spring, there is only one thing on his mind: food. The goal of eating rich and nutritious meals will consume this large mammal for the next eight months. Then, as the days get shorter and food becomes scarce, the bear will return to his secluded place in the woods to sleep through the harsh winter nights relying on his hard earned fat to see him through.

If we bring out our own magnifying glasses and turn our gaze into the ocean, we can see a similar story playing out in the tinest of ocean creatures. In the spring, millions of tiny (2-8 mm), shrimp-like animals called copepods are waking up from their own unique winter naps to feed on the spring bounty. Just like bears, copepods “sleep” when food is scarce. This can start in the summer, after all the food produced during the spring phytoplankton bloom is devoured, or in the fall for those lucky copepods that found food throughout the summer. Either way, the harsh dark winters prevent their main photosynthetic source of food from growing. To get through these periods of scarcity, copepods undergo a period of rest scientists call diapause. During diapause, copepods find their own quiet place in the deepest parts of Prince William Sound and the Gulf of Alaska. They hunker down and expend as little energy as possible relying on their hard earned fat reserves (see photo) they accumulated until the next spring phytoplankton bloom begins. Environmental cues (e.g. longer days/more sunlight) let these little critters know when it’s time to wake up and start the feast. After copepods have filled their bellies with phytoplankton, they molt into adulthood to produce the next generation of zooplankton.

RICK THOMAN
Prince William Sound Science Center
thoman@alaska.edu

In 2018, 2018 was a wet year around the region, with total rain and melted snow generally 10%-20% above normal. Snowfall was also way below normal in 2018. In spite of near-normal snow in December, Valdez reported less than half of normal snowfall for the year. The April 1 snowpack at low and moderate elevations was generally only 40%-75% of normal, and in the autumn, snow packs were established later than usual. By New Year’s Eve, the snowpack was again only 40%-75% of normal. Like the rest of Alaska, temperatures averaged warmer than normal. The annual average temperature at the Cordova airport was 41.1°F, 1.5°F above the 1981-2010 normal.

TIM LYDON
U.S. Forest Service Chugach National Forest
eyldon@fs.fed.us

The Chugach National Forest has updated protocols for monitoring the condition and distribution of dispersed recreation sites in western Prince William Sound. The updated methods align with the latest national protocols and open new opportunities for citizen science. Dispersed recreation sites are beaches and other areas where human use has created physical impacts such as cut trees or reduced vegetative cover. Monitoring sites in the western Sound began in the mid-1990s with separate efforts by Chugach National Forest managers and Alaska Pacific University, led by Paul Twardock.

DISCRETE RECREATION SITE QUALITY MONITORING

This tiny copepod (3 mm) stores fat in its orange lipid sac. This fat will allow the copepod to survive during the dark winter months when its food (phytoplankton) is scarce. The photograph was created with a microscope using a technique called focus stacking. Credit: Caitlin McKinstry

Credit: Barbara Lydon

Credit: Caitlin McKinstry

BY CAITLIN MCKINSTRY
Prince William Sound Science Center
cmckinstry@pwssc.org

Popular camping areas like this beach in Blackstone Bay often show changes in the amount and type of vegetative cover. Credit: Barbara Lydon

Like the rest of Alaska, temperatures averaged warmer than normal. The annual average temperature at the Cordova airport was 41.1°F, 1.5°F above the 1981-2010 normal.

MEASUREMENTS OF CUMULATIVE PRECIPITATION AT MERLE K (MUDHOLE) SMITH AIRPORT

2018 CLIMATE SUMMARY

RICK THOMAN
Alaska Center for Climate Assessment and Policy
University of Alaska Fairbanks
rthoman@alaska.edu

Overall, 2018 was a wet year around the region, with total rain and melted snow generally 10%-20% above normal. Snowfall was also way below normal in 2018. In spite of near-normal snow in December, Valdez reported less than half of normal snowfall for the year. The April 1 snowpack at low and moderate elevations was generally only 40%-75% of normal, and in the autumn, snow packs were established later than usual. By New Year’s Eve, the snowpack was again only 40%-75% of normal. Like the rest of Alaska, temperatures averaged warmer than normal. The annual average temperature at the Cordova airport was 41.1°F, 1.5°F above the 1981-2010 normal.
FIND YOUR ROCK

PHOTO MONITORING TRACKS DRAMATIC YEAR-TO-YEAR VARIABILITY OF MARINE LIFE ON SHELTERED ROCKY SHORES

ALAN J. MEARNS
November 2020

Since 1989, during summer low tides, NOAA scientists, contractors, and volunteers have been visiting and photographing more than a half dozen shoreline sites in western Prince William Sound. Individual photos don’t reveal much, but when collected together over several decades, these annual images reveal dramatic variations in the abundance of dominant marine life: namely the cover of seaweeds, mussels, and barnacles. The composite collection from one such site in Snug Harbor, Knight Island—affectionately named “Mears Rock” by a colleague—shows 29 consecutive annual photos spanning nearly 30 years.

Rough estimates of the percent cover of common rockweed and mussels from 1989 to 2018.

Since 1989, during summer low tides, NOAA scientists, contractors, and volunteers have been visiting and photographing more than a half dozen shoreline sites in western Prince William Sound. Individual photos don’t reveal much, but when collected together over several decades, these annual images reveal dramatic variations in the abundance of dominant marine life: namely the cover of seaweeds, mussels, and barnacles. The composite collection from one such site in Snug Harbor, Knight Island—affectionately named “Mears Rock” by a colleague—shows 29 consecutive annual photos spanning nearly 30 years.

Rough estimates of the percent cover of common rockweed and mussels for each year are shown in the graph. The graph, and certainly the photos, indicate the “common” species are not always abundant: Rockweed cover varied between “big years” (such as 1991, 1997, 2006 and 2017) and “poor” years (such as 1994, 2002/2003, 2007/2008, and 2015) Mussels had only three periods of abundance at this site: 1995-94, 2008, and 2014.

Given this variability, what is “normal”? Looking at the graph, the “mean” or “average” rarely occurs. Perhaps what is normal is simply the natural range of variation itself. But you won’t know that unless you watch and better yet, photograph, over many years.

The Prince William Sound Science Center (PWSSC) is seeking annual photos, like these, for other sites in the Sound. Do you have a favorite shoreline or location that you visit, especially during summer low tides? Maybe a family site or a school field trip location? If so, think about starting your own annual photo series and sending the photos to Dr. Scott Pegau at the PWSSC! In short, find your own rock!

Special thanks to David Janka, Audubon Charter Services; Scott Pegau and Rob Campbell, OSU/PWSSC; and over a dozen other volunteers.

COMPUTERS TO IDENTIFY PLANKTON IMAGES FROM PRINCE WILLIAM SOUND

ROB CAMPBELL
Prince William Sound Science Center
rcampbell@pwssc.org

JULES JAFFE AND PAUL ROBERTS
Oregon Institute of Oceanography

Plankton form the base of the marine food web. Tiny single-cell plant plankton (phytoplankton) grow and are consumed by animal plankton (zooplankton) grazers; zooplankton are food for larger animals like fish, birds, and whales. The amount and type of plankton present changes within and among years, and measuring them is not easy. Going out and collecting them from ships costs thousands of dollars per day for the ship, taxonomists must manually identify everything that is in the sample. But new technologies, like underwater cameras, offer new 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. From over 2000 twice-daily profiles from 60 meters to the surface done so far, over 2 million images of individual plankters have been collected. Current work is 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). At present the computer can identify plankton from 34 different classes to an accuracy of about 90 percent.

RIGHT: A selection of images of plankton captured by the plankton camera.

Maps of existing vegetation support resource management by informing project-level planning efforts with vegetation data that can be used in numerous applications. For example, an existing vegetation map was completed for the 1.1 million acre Copper River Delta project area in 2011 (above). It has been used to determine locations and quantities of suitable mose habitat to identify areas that may benefit from enhancement activities. Other uses of this map have included identifying rare and sensitive species habitat and climate change analysis.

The U.S. Forest Service, in coordination with other land owners in eastern Prince William Sound, seek to expand this vegetation mapping effort to include an additional 2 million acres across eastern Prince William Sound and north to the USFS boundary in the Copper River watershed. This project area will also include Columbia Bay within the Nellie Juan-College Fjord Wilderness Study Area (below). This project will use remotely sensed imagery captured from the 2011 mapping effort to initially identify patterns in the vegetation that would define different plant community types. These patterns can be elucidated both visually and through modeling spectral signatures (i.e. the measurement of the wavelengths of light, both visible and invisible, given off by an object). The Copper River Delta effort mapped a total of 15 land cover types with 11 vegetation classes. Once map classes have been determined for this effort, plots representing these classes will be identified for visual field confirmation known as “ground truthing.” In the summer of 2019, crews will hike into these sites or inspect them visually from the air to determine their dominant plant species. This ground truthing effort will span two field seasons, producing data that will be fed into computer models to generate a final vegetation map of the area. The final map product is anticipated to be completed in 2022.
The Tufted Puffin is one of Alaska's most iconic seabirds. Populations of Tufted Puffins throughout the Gulf of Alaska, numbering well over 150,000 birds, have historically been considered at least stable or increasing. However, recent research suggests that these Tufted Puffin populations are declining and are predicted to continue to do so in the future.

From 2014 through 2016, the Gulf of Alaska experienced rapid environmental change due to a persistent marine heatwave, which included a significant die-off of other seabirds such as Common Murres. Resolving little known aspects of the ecology of Tufted Puffins is important for better understanding the species’ vulnerability to rapid changes in the marine environment. While much is known about Tufted Puffin breeding ecology, the migratory routes and wintering areas of the species in the Gulf of Alaska are currently not known. In 2018, researchers at Prince William Sound Science Center initiated a two-year study to examine the at-sea distribution of Tufted Puffins during the non-breeding season. Our study is being conducted at Middleton Island, 70 miles offshore in the middle of the Gulf of Alaska at the edge of the continental shelf where thousands of Tufted Puffin breed. In late July 2018 during the chick-rearing period, we captured adult puffins at their nest burrows. Each puffin was weighed and measured, and blood and feather samples were collected for carbon and nitrogen stable isotope analysis.

Lastly, each puffin was leg-banded with an archival geolocator tag that measures ambient light levels. This summer, researchers will recapture these tagged puffins at their burrows to remove geolocators and download the data, which will reveal the geographic locations of Tufted Puffins during winter. Stable isotope values of feather and blood samples will provide a measure of food web interactions occurring during early spring (feathers) and early summer (blood).

Future analyses will investigate the relationship between the non-breeding season location data obtained from the geolocator tags and stable isotope values derived from the blood and feather samples.
The U.S. Forest Service (USFS) Chugach National Forest, in collaboration with researchers at USFS Pacific Northwest Research Station, Loyola University, U.S. Geological Survey, and University of Notre Dame have been studying the effects of small-scale herbicide treatments on native aquatic plants, macroinvertebrates, water chemistry, and fish. The USFS is also exploring the ecological role of this invasive aquatic plant on the Delta. Treatment of three ponds and a small slough near Eyak River were completed from 2016 to 2018. Preliminary results on impacts to aquatic organisms will be available in 2020 following an additional year of monitoring. In 2019, USFS will begin treatments in a pond west of Alagnik Slough, harvesting species of salmon to determine effects of herbicide treatment on fish. A final report on the feasibility of eradication and effects of treatment, as well as the effects of Elodea on native aquatic organisms where the invasive plant continues to thrive is expected in 2022.

Crop management provides a glimpse into the life of a nesting Bald Eagle. Footage provided a glimpse into the life of a nesting Bald Eagle. Time-lapse cameras were deployed on 78 nests to monitor success or failure and identify nest predators. The camera footage provided a glimpse into the life of a nesting Bald Eagle. Though the footage was disheartening at times it was also very insightful. Eagles, coyotes, and bear were all caught with their paws (and talons) in Dusky nests. Eagles, however, were the main culprit of nest failure. Although some nests were destroyed, many of them survived. Over half of the Dusky nests monitored on the Delta in 2018 hatched grazing! Time-lapse cameras will be deployed again in 2019 to further pinpoint patterns influencing Duskys.
FILLING GAPS IN WATER LEVEL INFORMATION

Accurate and timely water level information is critical for the people of Alaska whose lives depend on the ocean for fishing, shipping, and subsistence. AOOS hosts the Alaska Water Level Watch working group combining resources from many agencies in Alaska to create an integrated water level observation network. The group produced a report identifying where the most critical gaps in information exist including up to six areas in Prince William Sound that need better coverage. The Alaska Water Level Watch working group is finding resources to fill these gaps.

AOOS has developed 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. AOOS is working with ASTRA, a private company that uses GPS receivers for space weather research and UNAVCO, a private research organization that uses GPS/GNSS receivers to measure ground movements for earthquake research to apply the same technology to measure water levels. Once this technology has been proven effective and efficient it could be used to fill gaps in water level information in Prince William Sound.
T his 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. Commerically sold shellfish is tested and deemed safe before sale.

WHAT ARE HABS?

HABs are formed when phytoplankton—microscopic, plant-like organisms that form the base 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 algae have sharp spines that harm fish gills. In especially dense blooms of other phytoplankton species, opalescent 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 AHAB 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. aahb.org/alaska-AHAB-network

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 (CO2) generated by humans. As CO2 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 occur often include the basis of the food chain, so researchers expect the effects of OA to be greatest 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 CO2. Since Alaska is already close to the tipping point due to natural factors, an increase in ocean acidification could have major impacts.

HIGHLIGHTS:

- New State of the Science Report Published: The Alaska Ocean Acidification Network, published its first annual “State of the Science” report in November 2018. The report provides clear and understandable information explaining the process of OA, what Alaskan species are affected and how, the combined effects of OA and warming oceans, and types of monitoring being used in Alaska.
- Ocean Acidification in the Classroom: High school teachers in Alaska can now borrow ocean acidification kits to conduct hands on experiments in their classrooms. The kits are adapted from the C-MORE science program curriculum and allow students to produce and track measurable results. Additional curriculum resources can be found on the new “For Educators” page on the Alaska OA Network webpage.
- Ferry for Science: The state ferry MV Columbia has just completed one year of OA data collection 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. Keep an eye out for results!
- 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 Atlatl 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.
- Species response: How will Alaska species respond to more acidic conditions? Research in this area is expanding. The NOAA Lab in Kodiak has been involved in multi-year studies looking at crab, and for the last two years University of Alaska researchers have done experiments on clams at the Atlatl Pride Shellfish Hatchery in Seward. Starting this summer, NOAA’s Kastoria Bay Lab in Kachemak Bay and the Sitka Sound Science Center will be studying species response as well. Most species studied so far have shown negative affects to acidified waters, but scientists except there to be winners and losers. One of the big questions is the ability for Alaska species to adapt.
Thirty years ago, on March 24, 1989, the Exxon Valdez ran hard aground on Bligh Reef, Prince William Sound. This is long enough ago that much of the public has a hard time relating to the spill. For the spill-affected and scientific communities, the three decades since the spill represent a legacy of change on many levels. To set the stage, think about the technology scientists had in 1989: Intel introduced the 486 processor, Windows 2.11 MS-DOS was released, there was only dial-up access to the internet, no World Wide Web, no cellular phone service in Prince William Sound, and GPS navigation was in its infancy. Still not ringing a bell? Maybe this will—Nintendo introduced the first Gameboy.

Initially, scientists came to the spill with the expectation of conducting short one to two year injury assessment studies, but for some it became an entire career as they tried to disentangle spill effects from ecosystem variation. It eventually became clear that a new, holistic approach was needed to understand what resources were injured and whether they would recover. With help from spill affected industries and communities, the scientific approach prevailed and the Exxon Valdez Oil Spill Trustee Council established a rigorous structure for assessing impacts and monitoring ecosystems based on two key restoration objectives: 1) restoration should contribute to a healthy, productive, and biologically diverse ecosystem within the spill area that supports the services necessary for the people who live in the area, and 2) restoration will take an ecosystem approach to better understand what factors control the populations of injured resources. This framework and approach was very forward thinking in the 1990s, but has become the benchmark for studying how a changing marine environment affects commercial fisheries in Alaska, as well as oil spill recovery.

Scientists studying the effects of the Exxon Valdez oil spill on the environment have learned about the long-term persistence of oil in contaminated habitats, the many ways toxic substances can impact marine life, the prolonged duration of ecological damage, and the socioeconomic and human health effects. A wealth of information now lies in the scientific literature documenting these novel findings, but after three decades, the system has still not recovered fully, and more work needs to be done. Ultimately, research conducted by scientists in the wake of the Exxon Valdez oil spill forms the basis of our contemporary understanding of oil spill effects and is the gold standard for other such efforts around the world.
A conductivity-temperature-depth profiler waits on deck for the next sampling point as the sun sets over Kachemak Bay. Credi: Jim Schloemer, Kachemak Bay National Estuarine Research Reserve

WHAT DOES THE FUTURE HOLD FOR THE GULF OF ALASKA?

ROB SURYAN
NOAA Alaska Fisheries Science Center
rob.suryan@noaa.gov

SONIA BATTEN
Marine Biological Association

ROB CAMPBELL
Prince William Sound Science Center

SETH DANIELSON
University of Alaska Fairbanks

Can science predict the future for the Gulf of Alaska ecosystem? No... but by studying how the ecosystem responds to current and previous climate events, we can narrow down the range of possibilities. Climate and ecosystem forecasts are roughly similar to the weather forecasts models that you rely on every day. (Yes, those model forecasts that are the subject of countless daily conversations, often with a not-so-well-deserved negative reputation.) But keep in mind that weather forecasting has greatly improved over the decades and forecast models produce a range of possibilities—yet we are often only presented with a single value. Also, we tend to remember what predictions were wrong and spoiled our outing rather than the many times the predictions were correct.

The accuracy of weather forecasting has greatly improved for three main reasons: 1) massive increases in observational data from weather stations and citizen scientists, to radar, aircraft, ships, and satellites; 2) models are much more advanced and can assimilate the new data streams; and 3) computing power has greatly increased. All of the same applies to climate forecasts and anticipated ecosystem response. Were climate models accurate in predicting the recent heatwave affecting Alaska? Yes and no. Yes, the range of warming was predicted, but no, not so soon! Ocean climate will continue to exhibit periods of cooling and warming, including likely more frequent heatwaves. Long-term ecosystem monitoring projects like Gulf Watch Alaska provide critical local data streams for understanding and forecasting how local populations, including commercially important species, will respond to the anticipated climate changes.

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Alaska’s forage fish species, like Pacific herring, saffron cod, and Pacific sand lance, play a crucial role as food for predators like adult salmon. Understanding the abundance and habitat needs of these forage fish becomes increasingly important as salmon populations respond to warming oceans.

The Kachemak Bay National Estuarine Research Reserve (Reserve), in Homer, has long recognized that coastal river mouths and adjacent beaches within the Kachemak Bay estuary offer vital rearing habitat for juvenile salmon, forage fish, and other species living within the nearshore environment.

Working with KBNERR research technician and University of Alaska Fairbanks graduate student Chris Guo, the Reserve has undertaken a study to quantify ecological variations on species abundance within these nearshore habitats. During the summer of 2018 and again in 2019, Reserve staff, under Guo’s guidance, are seining (netting) forage fish and juvenile salmon and collecting zooplankton samples for identification from seven identified riverine estuaries within Kachemak Bay.

Commonly caught fish species during sampling within Kachemak Bay.

Additionally, water chemistry data (such as temperature, salinity, and pH), and physical parameters (including slope, substrate and rates of freshwater flow) will be collected. The resulting data will yield a deeper understanding of important habitat parameters and related fish communities within Kachemak Bay.
Capelin are abundant, small pelagic fish that serve a critical, middle role in marine food webs; they are consumers of zooplankton and prey for marine mammals, seabirds, and commercially important fishes. Each year, capelin migrate from the Gulf of Alaska (GOA) to beaches within bays and fjords along the Alaska coast to spawn and die. Shortly afterwards, their larvae are primarily dispersed offshore over the continental shelf, where they remain for several years feeding on abundant zooplankton, before returning to coastal waters to complete their life cycle.

Spatial patterns of the GOA capelin population were examined over the past two decades by integrating multiple, independent data sources with habitat and larval dispersal models that show potential connections between spawning areas and offshore foraging grounds over the shelf. Capelin are patchily distributed across the GOA, but consistently concentrate over the shelf near Kodiak Island (see above). Favorable currents near shallow banks (<100 meters) east of Kodiak function as a catcher’s mitt to retain larvae spawned locally and upstream from as far away as Southeast Alaska. This improved understanding of capelin spatial patterns aids monitoring efforts to detect changes in their abundance that potentially affects their availability to predators.

There is a well-known Alaskan t-shirt complete with a human skull and crossed salmon that says “Spawn till you die.” In contrast to this dire reproductive finale of many salmon species, many fish, including Pacific herring, spawn several times during a lifetime—a strategy known as iteroparity.

In April 2017, the Prince William Sound Science Center installed an underwater acoustic receiver array at Port Gravina. We then captured over 100 adult herring just before they spawned and surgically implanted them with acoustic transmitters that have a battery life of two years. Those transmitters have afforded us the first opportunity to determine when herring begin to return to their spawning grounds. Interestingly, we found that some herring begin to frequent the spawning grounds as early as four months before they spawn. Some herring winted in other areas, such as Montague Strait, and did not return until right before spawning. By April 2018, we also detected some herring moving over to a different spawning area from where we initially tagged them the previous year. Future tagging efforts will continue to reveal movements to and between those important herring spawning grounds.

In 2007, scientists at the Prince William Sound Science Center began deploying underwater acoustic receiver arrays to track select fish species as part of the Pacific Ocean Shelf Tracking project. Since then, with funding from Canada’s Ocean Tracking Network and the Exxon Valdez Oil Spill Trustee Council, acoustic coverage within the Sound has increased from less than 20 receivers in 2007 to about 85 receivers. The receivers are strategically located in fish migration corridors and at major entrances between Prince William Sound and the Gulf of Alaska (see map). Acoustic transmitter technology has improved alongside receiver coverage allowing researchers a view into the multi-year movements of fishes as small as 100 grams (about 3.5 ounces).

The way it works is that a transmitter, or tag, is surgically implanted into a fish. The tags are programmed to emit unique coded “pings” that are detected, decoded, and stored by the acoustic receivers. Researchers then upload the data either by hovering over and connecting to the receivers via a transducer hang-over the side of the boat, or by popping up receivers that have built-in release devices. Uploading trips happen multiple times throughout the year, allowing researchers to determine where fish are during different seasons. Currently the Science Center has over 300 Pacific herring tagged with implanted transmitters that have a life of 8 or 25 months. This study will provide new insight into herring ecology and their seasonal movements.
In the decades prior to 1990, there was a robust Pacific herring population in Prince William Sound (PWS) with a biomass of 130,000 tons. Not only are these forage fish a key link in the complex food web of PWS, but they once supported a lucrative early season commercial fishery that brought the communities of the Sound to life each spring. By 1993, that fishery had closed. Since then the herring population hovered around 20,000 tons but in recent years has experienced a rapid decline.

The current herring population in PWS has dropped to a record low of around 3,000 to 4,000 tons. This raises the question of what is causing the herring to struggle and ultimately what is contributing to the recent intensity in decline. Fortunately, the Herring Research and Monitoring (HRM) program has been exploring these questions for the last six years. 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 studies that address particular aspects of herring. These process studies help us understand why populations may change and or address assumptions in the population model that estimates the biomass of herring each year. The focus of the HRM program is on adult herring and the connections between herring condition, 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, predator populations and climate change.

### Variability in Seasonal Gonad Development of Herring

**Kristen Gorman**

Prince William Sound Science Center
kgorman@pwssc.org

One important factor fundamental to the persistence of any successful reproduction is the timing of gonad development. More specifically, information on the age structure and reproductive maturation of herring might help predict annual recruitment strength. Pacific herring are iteroparous, meaning that these forage fish reproduce, or spawn, multiple times throughout their life. The development of gonads (ovaries and testes) in preparation for spawning occurs over a nearly six-month period between the fall and spring each year. A standard measure of investment in gonads for fish is called the gonadosomatic index (GSI), which is the ratio of the weight of the gonad to the weight of the whole fish expressed as a percentage. As Pacific herring prepare to spawn, the GSI increases as gonads sequester energy and nutrients for reproduction. Although the relative seasonal timing of gonad development by Pacific herring is fairly well known, variability between years in this process is less well understood.

During 2017 and 2018, adult Pacific herring were captured in PWS throughout the year and their investment in gonads measured. Not surprisingly, herring caught during spring had more well-developed gonads, while fish caught during summer following the spawning season had small, undeveloped gonads. However, our study documented differences in gonad maturation between years (see figure above), particularly for herring caught in fall and winter, where gonads are developing rapidly. These results suggest that the timing of gonad development by females and males is variable between years and may be influenced by the abundance and timing of food availability.

### Changes in Forage Fish

**Scott Pegau**

Prince William Sound Science Center
wspegau@pwssc.org

Aerial surveys flown during June each year provide an indication of changes in forage fish populations. Forage fish are the small fish that eat oceanic plankton and in turn are eaten by fish, birds, and mammals. Not all forage fish can be observed from the air, but herring, capelin, and sandlance form schools when they are observed. During the summer, forage fish populations disperse throughout the Sound. Aerial surveys allow us to track their population in a manner that will help us understand how the fish depend on different oceanic conditions.

Map of forage fish schools from June of 2018. The distribution of young herring throughout the Sound is in contrast to the more restricted areas where other forage fish are observed. The presence of forage fish provides an indication of the health of Prince William Sound and the aerial surveys allow us to track their population in a manner that will help us understand how the fish depend on different oceanic conditions.
Pacifc herring in Prince William Sound (PWS) aggregate in large spawning groups in March and April. These spawning events are highly visible due to milt broadcast (see photo). Because spawning aggregations consist of a large proportion of the mature herring population, and the spawning events are visible to the naked eye, aerial surveys are an effective and repeatable way to monitor the abundance of herring populations over time.

Recent aerial MOM observations indicate continued declines in herring abundance, with record lows observed in 2016, 2017, and 2018. Aerial surveys measure and sum the linear extent of milt from all spawning events observed during a single year resulting in an annual index of abundance known as mile-days of milt (MOM). AD-FRG began aerial MOM surveys in PWS in 1973 to support sustainable management of PWS herring fisheries. The results of this long-term monitoring program, made possible in recent years by the Exxon Valdez Oil Spill Trustee Council, now compose the longest and most complete record of the abundance of herring in PWS. These data provide critical inputs to more detailed investigations of factors relating to the collapse and lack of recovery of the PWS herring population.

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HERRING MODELS: WHY AND HOW THEY ARE USED?

Anybody who has been to a river, lake, or ocean knows that you cannot simply look into the water and see all fish for reasons best said by Dr. Shepherd: Scientists have developed many different ways to count fish, with nets, from planes, with sonar, and directly by diving and counting themselves. Each method is prone to its own set of errors due to limitations with equipment, timing, and coverage in space that provide incorrect estimates. In other words, no single survey is typically enough to “count” fish. This is where models come into play. For herring, management agencies use a certain type of model called a stock assessment. A stock assessment is a framework of mathematical equations that calculate how the population changes based on scientific knowledge of herring biology (e.g., births, deaths, maturation), catch records, and how well the predictions from these equations match the data (i.e., how big is that error described before?). Stock assessments can produce fish count estimates using many different data but must use rigorous and sometimes very complicated statistical theory to make sure that the maximum amount of correct information is extracted from the data. Researchers improve and run the stock assessment for Prince William Sound herring every year using data from many other herring studies shown in Delta Sound Connections to provide a state-of-the-art tool that critically assesses the population’s status.

‘ICH-Y’ DISEASES IN PACIFIC HERRING

Diseases are common for Pacific herring, but their impacts on populations can vary, just like our common flu—in most years the flu is an inconvenience, but in others, it can be deadly (like the 1918 Spanish flu). Diseases can switch from slow progressing ‘chronic’ states to more lethal ‘acute’ states. Ichthyophonus sp., or Ich for short, is a common pathogen that frequently infects Pacific herring. The disease caused by Ich infections, Ichthyophonusiosis, typically progresses slowly. Studies conducted by Paul Herchberger at the U.S. Geological Survey’s Murreletwatch lab suggest that herring can maintain infections in their hearts and livers for years without dying. In some cases, however, Ich infections can be highly lethal. An epidemic off the coast of Sweden caused mortality of more than 300 million Atlantic herring in 1999, approximately 10% of the population. It is unclear what causes this switch from chronic to acute infections. Could it be added stress from changing environmental conditions? A new strain of Ich? Poor condition in a few years classes of herring? In order to understand these questions, historical samples of herring from Sitka Sound and Prince William Sound are being examined. Trends in the patterns of disease across fish age suggest that, in Sitka Sound, but not Prince William Sound, there may have been increased mortality due to Ich infections beginning around 2013. We are examining the amount of infection occurring in herring from 2009 through 2019 in order to see if higher levels of infection are occurring and might indicate higher levels of mortality. We will fit these data to population models to estimate the impact of this disease on both populations.

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TAKING THE LONG VIEW
THINKING AND ACTING ON A WATERSHED SCALE

KRISTIN CARPENTER
Copper River Watershed Project
kristin@copperriver.org

From source to sea, the main stem Copper River churns and flows almost 300 miles. This expansive system with its many tributaries is the key to its success—all those feeder streams branch out for spawning adult salmon and the next generation of juveniles. Shaping the watershed began over 60,000 years ago, when today’s Copper River Basin was filled by Lake Atna. Sequential ice dam releases drained the lake, with the remnant river carving through the Chugach Mountains to the Gulf of Alaska. As glaciers retreated, salmon moved upriver.

Salmon have been a critical resource for Ahtna Natives in the Copper River basin for at least 1,000 years. They were abundant, predictable in their seasonal arrival, and arrived at a time of year when food was scarce. The Ahtna people had place names for most fish streams and their salmon stocks: “All major streams are named . . . that have some useable resources. A stream name often is derived from the name for a nearby hill or mountain” (Simeone and Kari, 2002). The Copper River’s force and its salmon not only shaped the land, it shaped the Ahtna people’s worldview and the language they used to communicate.

Just over 100 years ago, Major John Wesley Powell offered the U.S. Senate a radical approach to western development. He proposed settling the West based on watersheds rather than surveyor’s grids: “Powell understood that a mountain ridgeline determined the flow of water into larger rivers and finally into the sea” (Ross, Smithsonian.com, 2018).

For the Copper River, we’re advocating the same approach as others that came before us: think and act on a watershed scale. Copper River salmon migrations benefit those who harvest salmon with fish wheels, dip nets, fishing rods, and drift gillnets, and feed a complex web of wildlife throughout the drainage. We’re working to keep it intact and thriving for a long time to come.
WHOSE LAND IS IT ANYWAY?

DAVE ZASTROW AND ERIN COLE
U.S. Forest Service Chugach National Forest
erin.cole@usda.gov

The Copper River Delta and Prince William Sound are wild and remote landscapes. Living or traveling through these regions provides a true wilderness experience. Roads are few, and flying or boating is common. When traveling the islands of the Sound or wetlands of the Delta, it may be a surprise to those unfamiliar with the area to discover that there is a mosaic of property ownership and allowable access. Land is owned or managed by federal, state, Native Corporation, and private entities, who tend to expect the general public to know the land they are on and its permissible uses. Few physical markers exist to help the public to know the land they are on and its ownership. Learning to navigate through this landscape difficult. To assist travelers, the Forest Service manages a variety of roads, trails, and boat launches providing public access to public lands.

The Forest Service has strong partnerships with land owners and resource managers throughout the Copper River Delta and Prince William Sound. To continue enjoying the benefits of public land access, add property ownership to your trip planning and respect the boundaries of private property.

Visit the Cordova Ranger District office in Cordova or call 907-424-7661.

Aerial photo of the Copper River Delta. Credit: Mads Burman

INSPIRING FUTURE LEADERS THROUGH PLACE-BASED EDUCATION ADVENTURES

KATE MORS
Copper River Watershed Project
kate@t-copperriver.com

Every summer since 2009, ten high school students from the Copper River watershed have embarked on a place-based learning adventure as part of the Copper River Stewardship Program (CRSP). Some of the first program participants reflect on their experiences as they were finishing college and preparing for their next life adventure.

“[The CRSP] really helped me understand the scope of the watershed as a natural resource . . . it’s important to understand that fish support many communities in multiple ways. They feed families and traditions further upriver than many of us in the CRSP had ever gone. This program is a powerful lesson in sharing resources, and understanding the watershed and its many connections . . . For me, personally, the CRSP actually helped me become a steward. The program helped me realize that I could actually have a life and career centered around conservation.” (Angie Kelly, 2010)

“I would definitely say that it has made me appreciate our rivers and view how important every stream that feeds into the Copper River is. Now as a road worker I understand the importance of having the proper procedures to not pollute the streams.” (Dillon McCarthy, 2011 & 2013)

“[The CRSP] influenced me to go into the sciences, be outdoorsy, love nature, and have a desire to do what I can to protect it” (Sarah Hoepfner, 2011)

Some things that have continued to form since that trip: a deep care for the environment (I actually adopted a stream!), a strong stewardship ethic, inspiration for future career paths, and desire to sustain the incredible natural world. From that trip, I am a better outdoor person who is an advocate for sustainability and conservation. The program was a powerful lesson in sharing resources, and understanding the watershed and its many connections. For me, personally, the CRSP actually helped me become a steward. The program helped me realize that I could actually have a life and career centered around conservation.” (Angie Kelly, 2010)

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“The words of the participants demonstrate why education partners invest resources into developing place-based, hands-on learning adventures. Beyond the smiles, fun memories, and creative reflections and projects that result from these trips, a unique and exciting theme. This year’s adventure was set in the theme of “Movement,” a fitting refrain for the dynamic landscape of the Copper River watershed. Not only did we physically move throughout the watershed using vans, rafts, canoes, ferries, a sailboat, and our own two-feet, we also studied the movement of elements that we encountered along the way; Copper ore at the Kennecott Mines, glacial silt from the Kennecott Glacier all the way to the mudflats of the Copper River Delta, and plants propagating through movement of wind and water.

In Prince William Sound we sampled zooplankton, little animals behind the largest daily-migration on the planet, and studied the movement of ocean currents. As we revegetated floating nest islands for Dusky Canada Geese on the Copper River Delta, we learned about the long journey they make to breed here. We could fill this entire publication with everything we discussed—the movement of people, animals, resources, and so much more. The 2018 stewards explain it best through their final projects and as one student summarized: “Movement. It is everywhere, steady or irregular, fast or slow, big or small. Everything moves, especially in Alaska.”

STEWARDSHIP
PRINCE WILLIAM SOUND SCIENCE CENTER PWSSC.ORG
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MOVEMENT
LAUREN BIEN
Prince William Sound Science Center
lbien@pwssc.org

While the Copper River Stewardship Program is an annual event, each year has a unique and exciting theme. This year’s adventure was set in the theme of “Movement,” a fitting refrain for the dynamic landscape of the Copper River watershed.

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POEMS BY JOSEPHINE BEAUCAMP, 2018 CRSP STEWARD

WATER
I am life, I
I am endless, I
I am either not wanted,
I am forever and always there,
And allow death,
You see me every day,
Through the wind and water.
You can find me everywhere you go,
I go around in cycles,
Looking around for a place to land,
Without a care in the world,
For 70% of you is me,
I am non-stopping,
My final destination I do not know,
In different forms,
You find me in the mudflats of the Copper Riv-
For I am Water.

SEEDS
In the wind I blow,
My final destination I do not know,
Having no idea where I’ll go,
Through the wind and water.
Oh, way up high,
Looking around for a place to land,
Dusky Canada Geese on the Copper River
Hidden around the world or obviously
And fertile dirt I give,
I will forever stay,
It doesn’t have to be anything grand,
If I change,
I will forever be around,
In several ways,
If I fall apart,
And allow death,
For I am your ground,
In different forms,
And I am Water.

ROCKS
No matter what happens I always
I stay forever, I
take it
Looking around for a place to land,
I will forever stay,
I will stay forever,
I can neither die nor live,
If I fall apart,
I will stay forever,
And fertile dirt I give,
If I change,
I will forever be around,
For I am Water.

Until my time is done.
Where I can soak up the sun,
And probably expand,
For I am Water.

Poems by Josephine Beaucamp, 2018 CRSP Steward.
Oil on canvas.

Artwork by Lindsey Gordon, 2018 CRSP Steward.
**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 5.5 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 spill preparedness. Two weeks after the spill occurred the Alaska Department of Environmental Conservation (Alaska Pipeline Line Service Company (Alyeska)) to create a response system with sufficient equipment, vessels, manpower, and support to handle a 10 million gallon spill or risk being shut down. After long days of intense analysis and reluctant compromise, Alyeska presented an Internship Plan which included many of the elements later incorporated into state law and regulations, which are still the standard today. The system was designed to restore public confidence in the safety of oil tanker operations without crippling the industry responsible for bringing Alaska oil to market. “Nobody get everything they wanted, but in the end we all got something we could live with,” said Michael Williams, BP representative.

- A report from Prince William Sound Regional Citizens’ Advisory Council and Nuka Research and Planning Group reconstructs the story of those fervent months and their outcomes. The story is 30 years old, but the lessons are poignant today. Every individual interviewed for this report was adamant that if the system created after the 1989 spill were to be weakened or removed, Alaskans would face the risk of another major oil disaster in the Sound. Read the full report at www.bit.ly/ExxonValdezLegislation

**PWS REGIONAL CITIZENS’ ADVISORY COUNCIL**

In the weeks and months following the 1989 Exxon Valdez oil spill, an unlikely alliance of visionaries and mavericks—government, industry, and citizens alike—came together to transform oil spill preparedness. Two weeks after the spill occurred the Alaska Department of Environmental Conservation called Alyeska Pipeline Service Company (Alyeska) to create a response system with sufficient equipment, vessels, manpower, and support to handle a 10 million gallon spill or risk being shut down. After long days of intense analysis and reluctant compromise, Alyeska presented an Internship Plan which included many of the elements later incorporated into state law and regulations, which are still the standard today. The system was designed to restore public confidence in the safety of oil tanker operations without crippling the industry responsible for bringing Alaska oil to market. “Nobody get everything they wanted, but in the end we all got something we could live with,” said Michael Williams, BP representative.

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**AQUATIC ROBOTICS**

**CHRIS IANNAZZONE**

**Prince William Sound Science Center**

If you walk into Seward High School in late February, you may notice the hallways are more crowded than usual. That’s because for the past 22 years, Seward has been the host site for the Tsunami Bowl, Alaska’s regional competition of the National Ocean Sciences Bowl. For the previous eight years, PWSSC has hosted a Remotely Operate Vehicle (ROV) challenge for participating teams at the competition.

Before giving students the task of engineering their very own ROV capable of completing various underwater challenges, participants are briefed on what ROVs are, how they are used, and in this challenge scenario—vital importance in oil-spill prevention efforts. Equipped with a kit of PVC piping, motors, a battery, control box, and some electrical tape, teams have one hour to design and build a functional ROV capable of completing five challenges. Competitors are tasked with attaching an anchor chain to a submerged structure, cleaning up a mock oil spill, navigating through an underwater hula hoop, and more.

During the build process at this year’s event, a returning Mat-Su senior and former ROV competitor commented, “The design process is always new and exciting, and our design this year will be different from previous years.” Once the ROVs enter the water, teams have an opportunity to test their designs and make last minute adjustments, with buoyancy being a critical modification to ensure their ROVs can complete the tasks without sinking or floating to the surface. The ingenuity, comradery, and perseverance demonstrated throughout the competition by each team was by far the most exciting part!

Many thanks to the supporters of the ROV Challenge, including Prince William Sound Regional Citizens’ Advisory Council, Oil Spill Recovery Institute, Alyeska Pipeline, and Alaska Tsunami Bowl.
Trends come and go, but slime has stuck around for decades. Today you can find endless DIY recipes online. Here is one of our favorites, with a couple of options for variety. Try them out, and then experiment with your own ideas.

**TIPS:**
- Younger children will need help from an adult.
- Store slime in an air tight container.
- Slime-making equipment can be washed with soap and warm water.

**KITCHEN CHEMISTRY IS A GREAT WAY TO EXPERIMENT WITH EASILY AVAILABLE SUPPLIES.**

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**WORK SEARCH**

- ALASKA
- BIRD
- COPPER
- DELTA
- EGGS
- FISH
- LEARN
- OCEAN
- OIL
- PLANTS
- ROCK
- SLIME

**REGULAR OR GLITTER SLIME**

(See footnote on how to turn this into fluffy slime)

- 3 oz (6 TBSP) washable glue or glitter glue
- ½ tsp baking soda
- 2 TBSP water
- 1 tsp saline solution
- Baby oil
- Food coloring (optional)

**INSTRUCTIONS**

Add glue to bowl. If using food coloring, add a few drops and mix until combined.

Add baking soda and mix.

Add water and mix.

Add saline solution. First, mix with a spoon or wooden craft stick. As the slime starts to form, use your hands to knead the mixture. It will be really sticky at first; it takes a few minutes for everything to combine. If the slime is still sticky after two or three minutes of kneading, add a few drops of baby oil to your hands and work into the slime. Repeat if necessary.

* Make sure your saline solution contains boric acid and sodium borate—without these ingredients, the slime will not form.

† If you want to make fluffy slime, simply mix in 1-1½ c. of foamy shaving cream to your bowl after step four. You might need to add extra food coloring to make a darker color. Fluffy slime will lose its fluff after a day, but it's still fun for play!
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