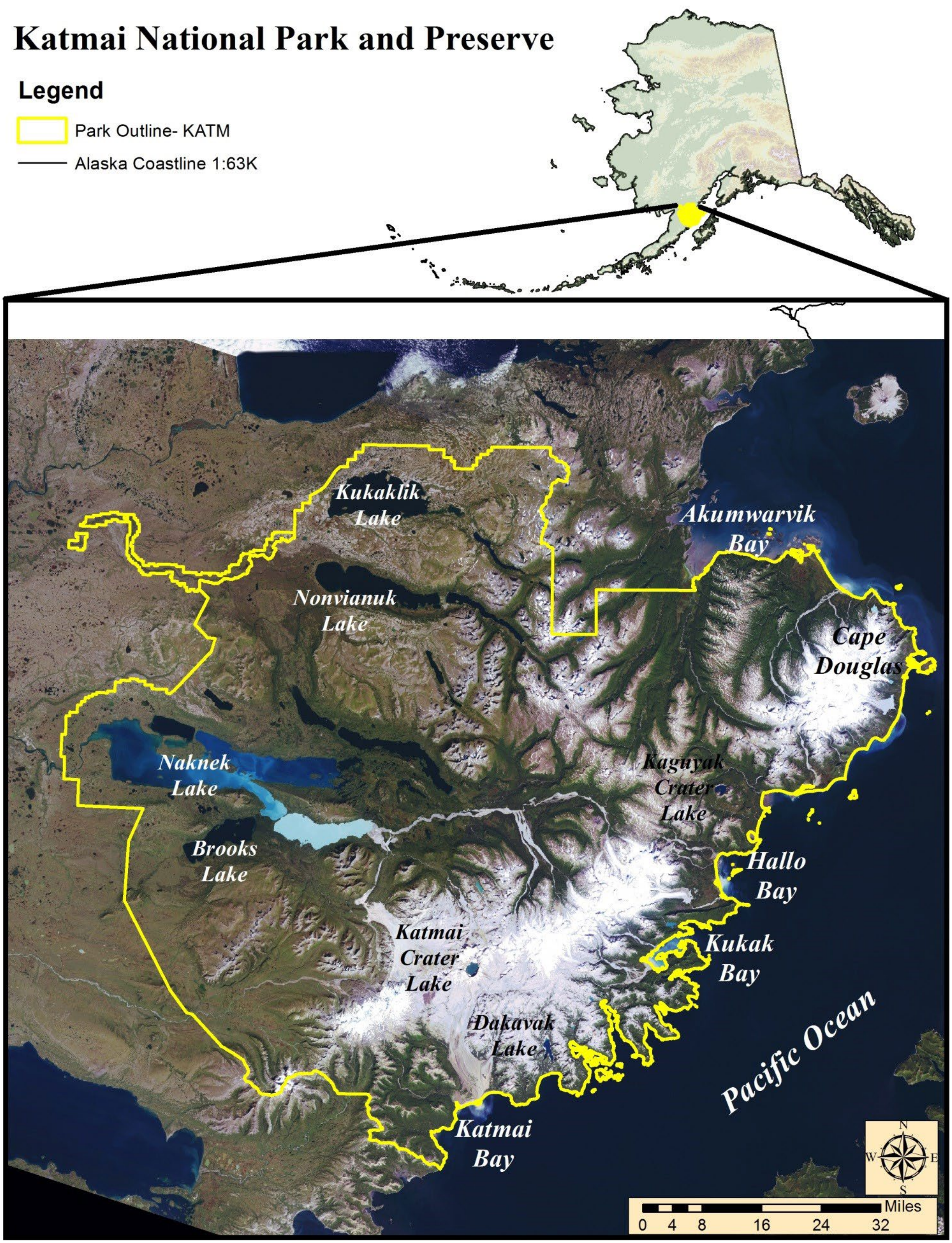
OCEAN ALASKA SCIENCE AND LEARNING CENTER

A coastal salt marsh in Katmai National Park & Preserve. NPS photo/Matt Harrington.

Katmai National Park & Preserve

A Marine Primer for Interpreters and Educators



Map and boundary of Katmai National Park & Preserve.

A curious red fox in Katmai Bay. NPS photo/Lian Law.

Introduction

Did you know that Alaska has more shoreline *than the rest of the Lower 48 states combined*? It's true, and over 3,600 miles of this shoreline is found in Alaska's national parks, including Katmai National Park & Preserve. Katmai's coastal environment is an incredibly valuable resource, yet it can be challenging to find information about this remote area and the research being conducted there.

The Ocean Alaska Science and Learning Center has developed this Marine Primer to introduce Katmai's staff to the park's marine and coastal resources. It provides an overview of the coast's history, its natural resources, and the issues facing them. We've also included a review of the Seven Ocean Literacy Principles, which offer a framework for thinking about the value of Katmai's marine resources beyond park boundaries.

While this primer is comprehensive, it is by no means exhaustive. Research in Katmai is ongoing, with new knowledge frequently emerging. We've designed this to be a working document that can be amended over time. Be sure to seek out additional resources for the most up-to-date information.

People of the Land

The area discussed in this primer—what we now call Katmai National Park and Preserve—is the ancestral homeland of the Aleut (Alutiit-Sugpiat), Yup'ik and Dena'ina people. We live and work in the Alaska Native communities of King Salmon Tribe, Naknek Native Village, and the Native Village of South Naknek (Qinuyang). We strive to improve our relationships with our closest Tribal partners and our affiliated communities throughout Bristol Bay and the Kodiak Archipelago.

Why is Katmai a park?

Katmai was originally established in 1918 as a national monument to protect the Valley of Ten Thousand Smokes following the 1912 Novarupta Volcano eruption. In 1980, the Alaska National Interest Lands Conservation Act expanded Katmai to its present size and designated it a national park and preserve (ANILCA 1980).

Katmai's purpose is to "protect, study, and interpret active volcanism surrounding the Valley of Ten Thousand Smokes, extensive coastal resources, habitats supporting a high concentration of salmon and brown bears, and an ongoing story of humans integrated with a dynamic subarctic ecosystem" (NPS 2009).

Katmai Fast Facts

Park size (acres): 4.1 million (including 1 million of coastal watersheds and 3.4 million acres of designated wilderness)

Miles of marine coastline: Approximately 500

A family of brown bears forages on an intertidal mudflat in coastal Katmai. NPS photo/Matt Harrington.

A Coastal History

The Alutiiq/Sugpiaq people (7,500 years+ ago to present)

The Alutiit/Sugpiat[1] are the modern Indigenous people of the Shelikof Strait region. They and generations of ancestors have inhabited the coastal environments of south-central Alaska for at least 7,500 years. The greater Alutiiq homeland includes Prince William Sound, the outer Kenai Peninsula, Kodiak Archipelago, and the Alaska Peninsula. On the Katmai coast, Alutiiq people resided in the key settlements of Katmai, Kukak, and Savonoski as well as in seasonal camps (Clemens & Norris 1999).

The Alutiit are a people defined by their connection with land and sea. Traditionally, they subsisted on a rich abundance of seasonal coastal and marine resources. In the spring, they fished and gathered shellfish, octopus, greens, cod, halibut, herring eggs, and seal. In the summer, the Alutiit paddled the the Shelikof Strait and Cook Inlet in *qayaqs* (kayaks) to hunt seal, sea lion, marine birds, and fish. In the fall, they focused on the park's interior for berries, salmon, caribou, and sea ducks. During the winter, they relied on food they preserved through drying, smoking, packing, or freezing (Alutiiq Museum 2020).

Three Alutiiq men from Katmai Village ply coastal waters in traditional qayaqs. Erskine Collection and the Kodiak Historical Society.

Traditionally, Alutiiq communities included specialists who made regalia from locally sourced and traded materials, including jet (bituminous coal) from the Chignik region, walrus ivory and narwhal tusks traded from the Bering Sea, caribou antler, amber, and dentalium shell. Lip plugs called labrets worn by women and men were unique pieces that incorporated designs signaling a person's social status and accomplishments. Allegiance to specific villages was also imbued in patterns found in fur or feather parkas as well as facial or arm tattoos.

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1 'Alutiiq' (singular) is used as a noun to describe one person ("She is Alutiiq") or the Alutiiq language ("I speak Alutiiq"), or as an adjective ("He is an Alutiiq artist"). Alutiit (plural) is used to describe more than two ("Forty Alutiit live here"), or to describe the people or culture collectively ("The Alutiit are proficient hunters"). Source: Alutiiq Museum.

People used beach grasses to weave waterproof socks, water-tight baskets, and for sealing seams in waterproof gut-skin clothing used while kayaking. While the abundance of salmon was often preserved by drying or smoking, ceramic vessels held oils from seal and bears that ostensibly preserved berries and other food stuffs. Villages typically included a large community house called a *qasqig* where dances and festivals were held and where masks were carved and painted; these buildings also sometimes functioned as men's houses for apprenticing youth in becoming spiritual leaders.

Although large timbers were scarce on the Peninsula, the Alutiit used driftwood to support semi-subterranean house frames and for mask making, skin working, kayak building and for the shafts of projectiles. Bentwood visors were an essential tool for kayakers—the unique, triangular cone of the hat amplified the sounds of the surrounding sea and the point of the visor functioned much like a gun sight for hunters throwing darts at diving seals, porpoises, and otters. By the eighteenth century, many homes included *maqii* or *banyas* (steam baths) and separate bedrooms from the main living space.

Bentwood visor by Alutiiq artist Jacob Simeonoff, c.1994. University of Alaska Museum of the North, Ethnology Collection, UA2003-006-0001.

The late 1700s marked the beginning of a dramatic upheaval in the traditional Alutiiq way of life. In the 1780s, Russian fur hunters pushed eastward from the Aleutian Islands into the upper Alaska Peninsula, including what is today coastal Katmai. Pursuing the lucrative Eurasian fur trade, which decimated the sea otter population along the Katmai coast, the Russians began coercing the Alutiit—whom they had observed to be adept at catching sea otter—to hunt for them.

In the early 1790s, the Russian-American Company established an *artel*—a hunting and trading post—in Katmai village. They continued to forcibly coerce entire Alutiiq villages to hunt sea otters for trade and snare seabirds to produce the parkas the Russians used as "payment" for their labor. The Russian fur traders used a combination of conscripted and forced labor, kidnapping and relocation of hunters far away from their homes as a means of local control over several coastal Alutiiq villages. Russian Orthodox missionaries arrived in the 1830's, bringing with them a semblance of Russian Imperial law and order, vaccines, and a religious belief system the Alutiit chose to adopt as their own.

The historic villages of the Katmai coast, including Katmai Village, Kukak, and Douglas (Kaguyak) were home to several hundred Alutiiq people who built and worshipped in Russian Orthodox churches and managed trading posts next to their traditional homes and elevated food caches. Many were literate in

Russian, the Slavic language of liturgy, and a Cyrillic-based Sugpiaq written language. During the winter, people traveled by dogsled between villages to visit relatives and celebrate the holidays with dances and singing. Life continued until the 1912 Novarupta event. Despite retaining the traditional knowledge of how to respond immediately to volcanic eruptions, the deep hot ash forced the Alutiit to relocate to new homes further south and west on the Peninsula. Many Alutiiq people had already integrated into the wage economies of coastal and Bristol Bay canneries, and many were not at their winter villages when the ash buried their homes.

Today, the direct descendants of Katmai Alutiiq people live across southwest Alaska—especially in the villages of South Naknek, King Salmon, Kokhanok, Igiugig, Levelock, Egegik, Port Heiden, the Chigniks, and Perryville. Many descendants of the Katmai Alutiit are actively involved in subsistence activities and participate in Katmai's management process through the non-profit corporation Council of Katmai Descendants.

To Learn More

Building in an Ashen Land is an exhaustive historic resource on Katmai, excellent for anyone looking to dig deep into the park's human history. Chapter 2 focuses on early Yup'ik and Alutiiq people; Chapter 3 on Russian and early American influences. http://npshistory.com/publications/katm/hrs/

A Naknek Chronicle: Ten Thousand Years in a Land of Lakes and Rivers and Mountains of Fire by Don Dumond is a comprehensive history of the Katmai region based on fifty years of archeological research spanning from ~10,000 years ago to the present. The full book is available in PDF format here: https://www.nps.gov/parkhistory/online_books/katm/naknek_chronicle.pdf

The Kodiak-based Alutiiq Museum is a great resource to learn more about the Alutiiq people, past and present. Under the 'Learn' tab of their website are narratives on Alutiiq language, values, subsistence, cultural arts, and history. https://alutiiqmuseum.org/learn/the-alutiiq-sugpiaq-people

A Russian Orthodox chapel in the coastal village of Katmai, c. 1915. University of Alaska Anchorage, Archives and Manuscripts Department, National Geographic Society Katmai Expedition Collection, Box 1, 3635.

The Novarupta eruption (1912)

The Alutiit's homeland on the Katmai coast would be irrevocably changed on June 6, 1912. On that day, the largest volcanic eruption of the twentieth century—Novarupta—began. Novarupta continued to erupt for 60 hours straight, eventually releasing thirty times as much ash as the 1980 eruption of Mt. St. Helens.

Novarupta's ash cloud grew to more than 1,000 miles wide, covering most of southern Alaska and the Yukon Territory. It buried coastal Alutiiq *barabaras* (semisubterranean houses framed with wood and covered with sod or turf) with ash up to three feet deep. In Kodiak, roofs of some buildings collapsed from the ash's weight; other buildings were destroyed as ash avalanches tumbled down steep slopes. In the days leading up to the eruption, a slew of earthquakes occurred, and the villagers of Katmai Bay wisely fled to the fishing station at Kaflia Bay. Three Alutiiq kayakers paddled from Kaflia Bay to Afognak Island for help. A US tugboat was sent to the Katmai coast, rescuing about 100 Alutiiq people and bringing them back to Afognak. Shortly after, the rescued Alutiit left Afognak, eventually establishing a new community in Perryville, about 165 miles southwest of Katmai on the Alaska Peninsula coast.

It was this eruption, and the barren landscape replete with thousands of fumaroles (steaming, gas-producing vents) it created—the Valley of Ten Thousand Smokes—that attracted the 1915-1919 National Geographic Society expeditions led by Robert Griggs. These expeditions brought international attention to the area and led to the creation of Katmai National Monument in 1918. In 1980, the national monument was expanded to the present size and designation of National Park and Preserve.

To Learn More

Volume 11, Issue 1 (summer 2012) of *Alaska Park Science* is a special issue on the history, science, and impacts of volcanoes in Katmai and the Alaska Peninsula. Read the articles online here:
https://www.nps.gov/articles/series.htm?id=CFC4AD2D-1DD8-B71B-0BFA7D8F2463C0C2

Alutiiq barabaras covered with volcanic ash, 1915. University of Alaska Anchorage, Archives and Manuscripts Department, National Geographic Society Katmai Expedition Collection, Box 1, 3946.

The Kukak Bay Razor Clam Cannery (1923-1949)

Razor clams are found in intertidal flats throughout Alaska and have long been a reliable subsistence food source for Alaska Natives (as well as sea otters, bears, foxes, sea gulls, and ravens). In the early twentieth century, the burgeoning razor clam industry of Washington state and Oregon began to spread to Alaska. In 1923, the Hemrich Packing Company built a razor clam cannery in Katmai's Kukak Bay, which processed razor clams harvested about 25 miles north on Katmai's Swikshak Beach. The small, self-contained Kukak Cannery consisted of several buildings, shops, bunkhouses, and an electric power plant. It employed workers (mostly women) seasonally, usually from April to September.

For 27 years, the cannery operated intermittently under four different companies. In 1931, the cannery and its clamming beach came under Park Service jurisdiction when the monument's boundary was expanded. After having its most productive pack (15,000 cases of clams) in 1932, the cannery burned down in 1936 when a fire started in its light plant. After the fire, the company abandoned the cannery. It remained vacant until 1947, when Mainland Fisheries replaced the burnt cannery with a Quonset hut and rehabilitated some of the original structures. The cannery operated until 1949, at which point it became permanently closed. Weather and the 1964 Great Alaska earthquake have since taken their toll on the site, and today most structures are collapsed, rotting, or otherwise degraded.

As Kukak's cannery closed, so too did most of Alaska's razor clam fisheries. In 2015, the east shore of Cook Inlet—historically the state's largest sport and subsistence razor clam fishery—was officially closed due to decreasing adult clam abundance. Today, only one commercial fishery still operates in the state at Polly Creek, north of Katmai on the west shore of Cook Inlet.

Two Kukak Cannery workers, Frida and Erna Nielsen, gear up to go clamming, c. 1925. Lake Clark Katmai Studies Center, Anchorage, KATM-00296.

To Learn More

Katherine Johnson's excellent *Buried Dreams: the rise and fall of a clam cannery on the Katmai coast* (2002) chronicles the rise and fall of the Kukak cannery, places Katmai's razor clam cannery in the larger context of American history and industrialization and offers a glimpse into the lives of cannery workers. The full PDF can be accessed here: https://www.nps.gov/parkhistory/online_books/katm/clam.pdf

The Great Alaska Earthquake (1964)

On March 27, 1964, a 9.2 magnitude earthquake occurred about 12 miles north of Prince William Sound. The earthquake caused ground fissures, landslides, and structural collapse, and resulting tsunamis killed an estimated 131 people from Kodiak Island to northern California. The earthquake remains the most powerful earthquake ever recorded in North America, and the second most powerful earthquake in recorded history (next to the M9.5 earthquake in Chile in 1960).

The earthquake was caused by a rupture in the Aleutian Megathrust—the fault line between the Pacific and North American tectonic plates that parallels the Alaska Peninsula to the south. Many impacted areas experienced vertical displacement: some areas subsided (lowered) and others uplifted up to 38 vertical feet.

During the earthquake, the Katmai coastline uplifted several feet, altering tidal dynamics and hydrology and resulting in dramatic ecological shifts in some areas. The NPS Southwest Alaska Inventory & Monitoring Network (SWAN) has documented these changes through a repeat photography project in Hallo Bay. Areas that were barren tidal flats before the quake are now lush, non-tidal meadows; other areas that were formerly wet meadows are now encroached by spruce. The uplift also caused the shoreline to extend seaward, increasing the amount of coastal gravelly saline barren habitat (Jorgenson et al. 2010, Hannam et al. 2020).

To Learn More

The following two NPS reports describe ongoing coastal vegetation monitoring projects in Katmai, including the repeat photography that demonstrates the effects of the quake on vegetation communities:
https://irma.nps.gov/DataStore/DownloadFile/649820
https://irma.nps.gov/DataStore/DownloadFile/418627

The Exxon Valdez Oil Spill (1989)

On March 24th, 1989 the *Exxon Valdez* oil tanker ran aground at Bligh Reef in Prince William Sound, spilling 10.8 million gallons of crude oil. At the time, this was the largest single oil spill in US waters and the country's largest environmental disaster.

Initial attempts to contain the oil failed, and in the months that followed, the oil slick spread over ~1,300 miles of coastline including 300 miles of Katmai's coast. Roughly 250,000 sea birds, 3,000 sea otters, 300 harbor seals, 250 bald eagles, 22 killer whales, and billions of salmon eggs were killed from acute causes (Barley 2012); these figures are even higher when chronic effects of lingering oil are considered.

To this day, pockets of oil can still be found lingering under large boulders in Katmai's intertidal zone (Irvine et al. 1999). Long-term monitoring in Katmai has found that, some twenty years after the spill, sea otters and harlequin ducks still show signs of low-grade, chronic oil exposure (Esler et al. 2015). Recovery from the spill has and will continue to take decades. In 1999, in recognition of the need for ongoing, long-term monitoring and research of this recovery, the *Exxon Valdez* Oil Spill Trustee Council established Gulf Watch Alaska (GWA). GWA is a collaboration between multiple federal, state, university, and non-profit entities, including SWAN. Today, SWAN monitors various coastal, nearshore, and marine resources in Katmai, from air and water quality to marine birds and intertidal invertebrates, from kelp and eelgrass beds to sea otters, and from salmon to vegetation communities.

Ray Bane, then Katmai superintendent, digs into a thick pool of oil on the park's shoreline, hundreds of miles from the Exxon Valdez spill in Prince William Sound, May 1989. AP photo/John Quinley.

To Learn More

This 1990 historical narrative recounts the 1989 oil spill, its impacts to NPS lands, and the agency's initial response and cleanup efforts. https://www.nps.gov/parkhistory/online_books/alaska/exxon_valdez_hanable.pdf

Gulf Watch Alaska's website contains a wealth of useful information, including an overview of various long-term monitoring projects, educational resources, papers, newsletters, and reports: https://gulfwatchalaska.org/

Learn more about The Southwest Alaska Network's inventory and monitoring program in Katmai from their landing page: https://www.nps.gov/im/swan/katm.htm

The Coastal Environment

Overview

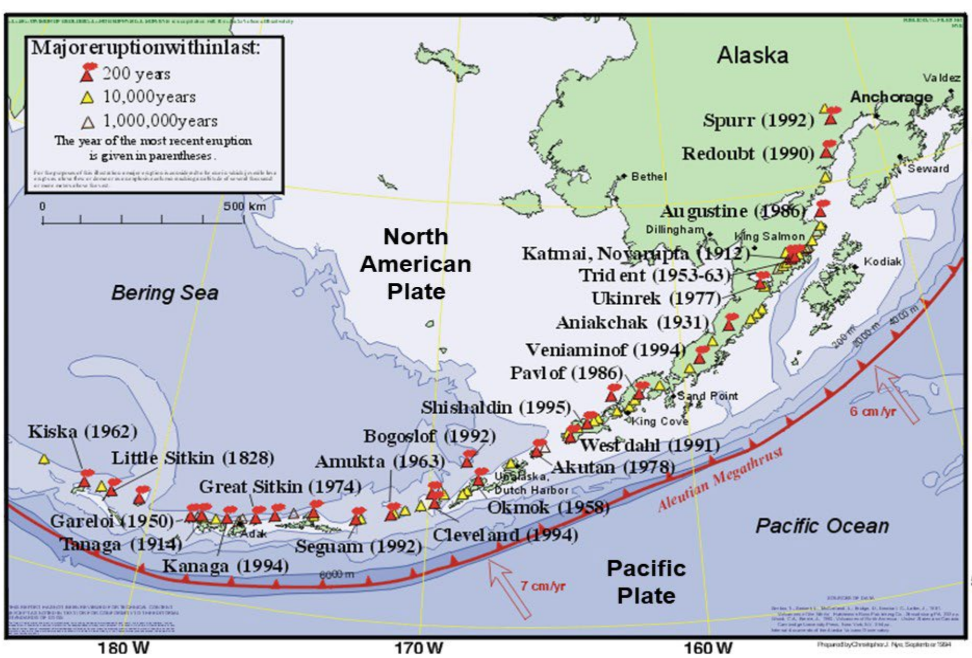
On the eastern side of Katmai's Aleutian Range lies a million-acre coastal wilderness. Extending some 500 miles along the Shelikof Strait from the mouth of the Douglas River to Kashvik Bay, Katmai's coastline is the sixth longest of any National Park Service unit (Curdts 2011). Though accessible only by boat or plane, it is an increasingly popular destination for park visitors. Some 5,000 people visit Katmai's coast each year, making it the park's second most popular area to visit after Brooks Camp.

A land of cliffs, waterfalls, valleys, bays, and beaches, Katmai's coast is a diverse and dynamic interface between land and water. Abundant in resources, the coast supports a dizzying array of wildlife, from coastal wolves and brown bears to puffins and sea lions. It is in constant flux with the tides, seasonal migrations and hibernations, and the fits and starts of volcanic activity.

For many, the defining feature of Katmai's coast is its *wildness.* While natural processes are the dominant driving forces at work here, the coast isn't immune to human impacts. As we'll see, climate change, ocean acidification, overfishing, fossil fuels, and marine debris all leave their mark on this remote coast. In a time of pervasive human impacts and vanishing wilderness, our work to preserve this wild coast—and to communicate its importance to visitors—is critical work indeed.

The Aleutian Range

The volcanic **Aleutian Range** runs southwest to northeast through Katmai, forming a divide between the park's interior and coast. Zoom out, and you'll see that these mountains are part of a much larger *volcanic arc* extending down the Alaska Peninsula to the Aleutian Islands. This 'Aleutian Arc' parallels a ~1,900-mile long underwater 'Aleutian Trench' where the Pacific Plate is actively sliding beneath the North American Plate.



Recent volcanic eruptions (triangles) in the Aleutian Arc along the underwater Aleutian trench (flagged red line) where the Pacific Plate is slowly subducting under the North American Plate. Alaska Volcano Observatory.

The Aleutian Arc is part of the larger "Pacific Ring of Fire"—where the entire Pacific Plate is actively sliding beneath other plates. This ring of fire boats over 400 active volcanoes and produces 80% of earthquakes worldwide.

Why the 10,000-foot view? Because it's important to recognize that Katmai's volcanoes are one small piece of a much larger, and very active, volcanic region.

Physically, the Aleutian Range separates interior and coastal Katmai, forming a cloud barrier and contributing to the drizzly, misty, and relatively mild maritime climate of the coast (Nagorski 2007). The Aleutians also put wind in the coast's sails. *Williwaws*—violent cold wind blasts pushed from mountains to sea, and strong enough to "blow a man off his feet"—have been documented at over 150 mi/hr on Katmai's coast (Peter Kirchner, SWAN Physical Scientist, pers comm).

Volcanic activity in the Aleutian Range has left its mark on the Katmai coast in the form of ash-laden creeks, ash deposits on soils, and igneous rock. Steaming fumaroles, earthquakes, and even the occasional eruption (i.e., Fourpeaked Volcano in 2006) still occur in the park today—reminders that while Novarupta may have been the eruption to spark Katmai's beginnings, it was certainly not its last.

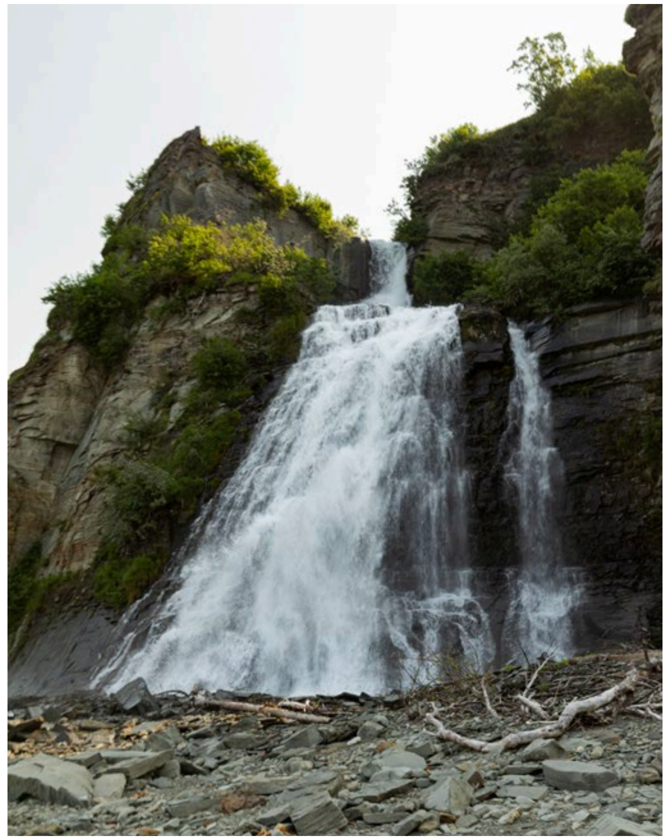
Water, water, everywhere

Katmai's **coastal watersheds** extend from the highest Aleutian peaks, down their southeast-facing slopes, and to Katmai's expansive coastline. These include every snowfield and glacier whose meltwater flows to the coast and every speck of land draining meltwater or rainfall to the coast. Collectively, coastal watersheds make up about one million of Katmai's four million acres (Nagorski et al. 2007).

Braided stream in Katmai Bay. NPS photo/Lian Law.

Short, steep streams originating in the Aleutian range carry silty snow and glacier melt to the sea. On the southern coast—where the Novarupta eruption dumped several meters of volcanic ash—streams tend to be heavily braided and choked with volcanic ash (i.e., the Katmai River and Soluka Creek, Nagorski et al 2007, Heard et al. 1969). On the northern coast, streams like the Swikshak River can also be heavily braided, but from high glacial silt loads.

The coast is home to several **lakes** including Kaguyak and Katmai crater lakes, Dakavak Lake, and numerous smaller lakes. Small ponds pockmark the coast's low-lying areas and are often interconnected by an extensive network of wetlands. Interestingly, two of Katmai's coastal lakes, Dakavak Lake and Devil's Cove Lake, contain *kokanee*—landlocked sockeye salmon that never migrate to the ocean. Along with Jo-Jo Lake in Katmai's interior, they are the only lakes in southwest Alaska known to contain kokanee (Hamon & Pavey 2012).


A cascading stream carries freshwater from the Aleutian range to the coast. NPS photo/Matt Harrington.

Wetlands make up an estimated 20% (~200,000 acres) of Katmai's coastal region (Nagorski et al. 2007). Occurring along streams, lakes and nearshore marine zones, wetlands form vital connections between the park's terrestrial and aquatic environments. These wetlands serve important functions, including controlling floods and erosion, regulating streamflow, cycling nutrients into aquatic systems, and purifying water.

Glaciers cover about 180,000 acres of coastal Katmai and play an important role in water and nutrient storage and cycling. They also have profound effects on the park's landscape through erosion and deposition, leading to the formation of moraines (unconsolidated accumulations of soil and rock), pro-glacial lakes, and eskers (long, winding ridges of sand and gravel). Katmai's glaciers occur primarily in the Mt. Douglas, Kukak Volcano to Mt. Katmai, and Mt. Martin areas. They terminate on land or in lakes (as opposed to tidewater glaciers, which terminate in the sea; Giffen et al 2014).

Since the end of the Little Ice Age ~160 years ago, Katmai's glaciers have been actively retreating. From the mid-1980s to 2000, glacial extent decreased by 7.7% (76 km^2) parkwide (Giffen et al. 2014). Glacial retreat has both local and global implications, ranging from transformed scenic and recreational resources for park visitors, to increasing sea levels worldwide.

To Learn More

The Southwest Alaska Inventory & Monitoring Network (SWAN) actively maps and monitors glacial extent on decadal timescales: https://www.nps.gov/im/swan/glaciers.htm

This book chapter by Giffen et al. (2014) describes glacier mapping and analysis efforts in Kenai Fjords National Park and Katmai. Their study finds that glaciers have receded by 1.5% (21 km^2) and 7.7% (76 km^2) in KEFJ and Katmai, respectively. https://irma.nps.gov/DataStore/Reference/Profile/2217328

Bivalve fossils from the Naknek formation. NPS photo/Matt Harrington.

Fossils

Spend a day walking along the Katmai coast, and odds are, you'll eventually find a fossil—the preserved remains and imprints of past life. Paleontologists are actively studying Katmai's fossils to help refine the age of various rock formations, reconstruct past environments, and better understand how this land- and seascape has evolved through time.

Many of the coast's fossils occur in the *Naknek* formation*:* greyish-bluish sand- and siltstone dating back to the Jurassic period (200-145 million years ago) when heightened plate tectonic activity was causing continents to shift, volcanoes to erupt, and mountains to form. Bivalves (i.e., scallops, clams, and oysters) are the most common fossils from this period, but ammonites (tightly wound shells containing squid-like cephalopods), belemnites (squid-like cephalopods with pointed, cone-shaped bodies), and the occasional plant fossil also occur. Other bivalve, belemnite, and ammonite fossils have been dated to the Cretaceous period (145-66 million years ago), a time of great marine productivity that eventually ended in the mass extinction of dinosaurs and much marine life (Hults & Fierstein 2016).

Collectively, these fossils help us understand that throughout the Jurassic and Cretaceous, Katmai was a shallow sea. It wasn't until about 55 million years ago, when the Aleutian Range began to form (Holbrook et al. 1999), that Katmai would move up and out of the sea.

Fossils can provoke immense pleasure and curiosity in those that happen upon them 'in the wild.' Unfortunately, fossil digging and removal is becoming a problem in many parks—though, currently, it doesn't appear to be impacting Katmai as much as other parks in Alaska. Moving or removing fossils prevents future visitors from enjoying them and decreases their value to science, since information on their age or environment can no longer be associated with a particular site.

To Learn More

Want to learn more about the geological features, history, and resource management issues in Katmai? This *Geologic Resources Inventory Report* is your one-stop shop: https://irma.nps.gov/DataStore/Reference/Profile/2235401

Want more fossils? Check out this peer-reviewed article covering paleontology inventory in Katmai: https://irma.nps.gov/DataStore/Reference/Profile/2234898

Coastal Habitats

Katmai's coast is a diverse and productive mosaic of salt marshes, mudflats, cliffs, headlands, islands, reef flats, eelgrass and kelp beds, and freshwater streams. Many commercially, ecologically, and culturally significant species frequent the coast to forage, nest, breed, and rest. The coast is a fluid interface between land and water, a place where abundant resources, nutrients, and energy are exchanged. Katmai's abundant wildlife, which draws thousands of visitors to the park each year, are inextricably dependent on the coast.

Salt marshes and mudflats

Salt marshes and mudflats occur in flat, open bays along Katmai's coast. Salt marshes—wet meadows that form where rivers or streams enter the sea—are heavily used by wildlife, migratory birds, and park visitors. Though we often picture Katmai's brown bears snatching salmon out of streams, salt marshes are a valuable early-season food source for bears, providing protein-rich sedges (grass-like plants) before the salmon run begins. Brown bears utilize salt marshes as mating and rearing grounds, and migratory shorebirds forage extensively in them (Hannam et al. 2020).

Coastal salt marshes are sensitive to a variety of disturbances including warming temperatures, storms, tectonic uplift, development-related activities, and increased visitation.

A researcher wades through a lush salt marsh on the Katmai coast. NPS photo/Matt Harrington.

Muddy, unvegetated areas in the intertidal zone function as extensive mudflats at low tide and shallow soft-sediment habitats at high tide. Mudflats, which occur mainly on the southern half of Katmai's coast, can be expansive, and they support rich communities of invertebrates including clams, crabs, and mussels. These intertidal invertebrates feed a multitude of animals ranging from sea stars, sea ducks, and shorebirds to sea otters, coastal wolves, and brown bears. During high tide, shallow waters provide excellent forage fish prey for seabirds.

Katmai's coast contains more coastal marsh and tidal flat habitat than the steeper, rockier coasts of Kenai Fjords and other Southwest Alaska Network (SWAN) parks. These salt marshes and tidal flats, combined with productive salmon streams, are extremely important resources for Katmai's brown bears as they try to gain as much weight as possible before hibernation.

Brown bears forage on a coastal mudflat. NPS photo/Matt Harrington.

To Learn More

The SWAN Inventory & Monitoring Program actively monitors vegetation change in coastal marsh habitat in Katmai, KEFJ and Lake Clark (LACL) national parks and preserves. Published by SWAN in 2020, a two-page resource brief (https://www.nps.gov/articles/swansaltmarshbrief.htm) and full-length report (https://irma.nps.gov/DataStore/Reference/Profile/2280108) describe the methods and results of this monitoring.

This newspaper article written by NPS staff Mike Hannah and Buck Mangipane provides an overview of the ecology and importance of coastal salt marshes in Katmai and LACL, how they may be changing with climate change, and what this could mean for brown bears. https://www.peninsulaclarion.com/sports/refuge-notebook-could-bears-benefit-from-changing-coastal-marshes/

The multi-year NPS Changing Tides Project investigates the link between coastal brown bears and intertidal invertebrates in Katmai and LACL and potential threats to this relationship. The following is a 'landing page' for the Changing Tides Project that contains additional links to newsletters, blog posts and articles related to the project: https://www.nps.gov/katm/learn/changing-tides.htm

Cliffs, headlands, and islands

Rocky headlands and sheer cliffs jut into the Shelikof Strait, towering over Katmai's bays and flats. Further offshore, a network of twenty islands lies within 8 km of Katmai's coastline, and thus within the park's jurisdiction. These features are made of stronger rock layers that resist erosion by waves and water (softer rock layers, on the other hand, erode to become beaches and bays).

Cliffs, headlands, and islands are generally difficult to access for most wingless animals. As a result, seabirds flock by the thousands to these protected nesting grounds, which you'll often hear called rookeries or colonies. About three-quarters of all US seabirds—some 150 million of them—nest in Alaska. Although they may spend most of their lives foraging at sea, having reliable access to safe and protected rookeries is an essential step in seabird success.

Steep, rocky headlands jut into the Shelikof Strait on the Katmai coastline. NPS photo/Matt Harrington.

A coastal brown bear makes a catch in a tidal-influenced freshwater stream. NPS photo/ Matt Harrington.

Freshwater streams

Flowing from glacial headwaters to the Shelikof Strait, Katmai's coastal streams are important conduits of nutrients, energy, and water. These coastal streams include the Big, Douglas, Kamishak, Katmai, Little Kamishak, and Swikshak rivers and Alagogshak, Hallo, and Strike creeks, among many others.

Katmai's coastal freshwater streams are critical habitat for anadromous fish, including salmon, that are born in freshwater, spend most of their life in the ocean, and return to freshwater to spawn. The streams are conduits for nutrient exchange: as salmon spawn and die upstream, their carcasses deposit marine-derived nutrients into streams, riparian areas, and forests. And these same streams carry sediment and freshwater from glaciers back to the sea, altering the chemistry, salinity, and productivity of nearshore waters (Neal et al. 2010).

Reef flats and eelgrass/kelp beds

Extensive rocky reefs can extend up to 7 km offshore and occur mainly in the northern half of Katmai's coast. At low tide, these unique intertidal reef habitats are exposed, rocky flats; at high tide, they transform into underwater reef habitat. During low tide, seals, sea otters, and sea lions utilize these reef flats (and accessible islands) as haulouts, where they can rest with relative security from predators.

Katmai's coastal reef flats support diverse assemblages of kelp and eelgrass that function a bit like marine forests. Like the trees of a forest, kelp are the major primary producers in nearshore habitats. And these marine forests perform myriad ecological functions. They filter nutrients, provide habitat for planktivorous fish, clams, and urchins, and serve as spawning and nursery habitats for forage fish and crustaceans. Since kelp and eelgrass exist in shallow water, they are more susceptible to threats such as oil spills: because crude oil floats on water, it can coat the vegetation as the tide recedes.

Kelp and eelgrass are considered a vital sign for the health of Katmai and are monitored by SWAN.

Learn more

This NPS landing page provides an overview of kelp and eelgrass habitats and contains links to articles, reports and other resources related to kelp/eelgrass monitoring and research. https://www.nps.gov/im/swan/kelp.htm

Kelp beds growing on this rocky reef are exposed at low tide. NPS photo/Matt Harrington.

Coastal and Marine Wildlife

Coastal Brown Bears

Katmai is a land of brown bear superlatives. It is home to the largest population of brown bears in North America—some 2,200 bears (Zanon et al. 2015). Rich in food sources, Katmai's coast boasts some of the highest densities of brown bears ever documented. And Katmai is also home to some of the world's largest brown bears.

Brown bears frequent the salt marshes and intertidal zones, subsisting on sedge grasses and other plants (e.g., lupine root and wild celery) and intertidal invertebrates, particularly razor clams, after hibernation. As the season progresses, they shift their focus from grasses and invertebrates to salmon as the fish begin their annual run. Coastal brown bears will also hunt and scavenge sea otters (Monson et al. In review) and feed opportunistically on washed-up whale carcasses.

Bear viewing is one of the main reasons that visitors come to coastal Katmai. Hallo Bay and Geographic Harbor are the coast's most popular bear viewing areas (SWAN 2021).

Katmai's salt marshes aren't just for brown bears. Coastal wolves, red fox, songbirds, shorebirds, seabirds, sea ducks, the occasional moose, and small mammals such as redback voles, short-tailed weasels, and least-weasels can also be found in and around the coast.

For a full list of mammals in the park: https://irma.nps.gov/NPSpecies/Search/SpeciesList/KATM

To Learn More

This NPS blog post describes brown bear ecology in Hallo Bay and some of the experiences a visitor to Hallo Bay may have. https://www.nps.gov/katm/blogs/Thoughts-on-Hallo-Bay.htm

An exhaustive list of frequently asked brown bear questions (and answers) is maintained on Katmai's website: https://www.nps.gov/katm/learn/photosmultimedia/brown-bear-frequently-asked-questions.htm

A brown bear forages on the Katmai coast. NPS photo/Matt Harrington.

A coastal wolf pauses on the Katmai coast. Its light, sandy-colored coat is typical of coastal wolves. NPS photo/Monica Bradburn.

Coastal Wolves

Coastal wolves are the same species as interior gray wolves (*Canis lupus*), but they spend most of their time on the coast, have different hunting habits and diet, and are typically lighter in color.

Coastal wolves rely heavily on marine food resources including seals, otters, salmon, crab, and flounder. Current research suggests that, unlike their interior kin, coastal wolves don't typically hunt large ungulates (i.e., moose or caribou) that require coordinated, pack hunting. Instead, they tend to be more solitary hunters.

Coastal wolf packs are relatively dense—recent studies suggest there are at least six different packs on the coast (Kelsey Griffin, Katmai Coastal Wildlife Biologist, pers comm). Again, it is likely the abundant food sources on the coast that enable such dense populations.

To Learn More

This insightful blog post from Katmai's Changing Tides Project describes a dramatic, intimate encounter with a coastal wolf. It provides a sense of coastal wolf behavior, ecology, and wildness. https://www.nps.gov/katm/blogs/notes-from-the-field-the-eye-of-the-wolf.htm

Marine Mammals

Katmai's coast is home to several marine mammals, including but not limited to northern sea otters (*Enhydra lutris kenyoni*), Steller's sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*), humpback whales (*Megaptera novaeangliae*), killer whales (*Orcinus orca*), and harbor porpoises (*Phocoena phocoena*).

Northern sea otters

Sea otters have the thickest fur of any animal—up to one million hair follicles per square inch! This fur keeps them warm in icy waters and has been highly desireable to another species: humans. In the 1800s, sea otters were heavily hunted for their fur. By the early 1900s, they were extinct from the Katmai coast (Coletti et al. 2016). Thanks to successful restoration efforts, Alaska's sea otter populations have rebounded. Today, 90% of the world's sea otters live in coastal Alaska.

It's good sea otters made a comeback: they're a keystone species! In other words, they have a dramatic effect on the species and structure of their environment. For example, we know that sea otters feed heavily on urchins and other intertidal macroinvertebrates in nearshore, rocky habitats. By consuming the animals that eat kelp, sea otters drastically change the structure and complexity of kelp beds, keeping them diverse and lush. Take sea otters out of that system, and urchin populations can get out of hand, resulting in less diverse, over-grazed kelp beds.

In 2005, sea otter populations in southwest Alaska were listed as threatened under the Endangered Species Act. Six thousand miles of southwest Alaska coastline, including Katmai's coast, were designated as critical sea otter habitat.

It's worth encouraging visitors to ponder the significance of Katmai's coastline to threatened sea otters.

A sea otter floats on its back in the ocean. NPS photo/Jim Pfeiffenberger.

Steller sea lions

Steller sea lions forage near and offshore along Katmai's coast for fish and cephalopods (i.e., squid and octopus). They typically hunt at night in the water, returning to beaches or rocky reefs to mate, give birth, and rest.

Steller sea lions require relatively undisturbed habitat to thrive. Disturbances like habitat fragmentation, fishing, illegal hunting, and vessel strikes caused stellar sea lion populations to decrease by 80% by 1990, when they were listed as threatened under the Endangered Species Act. Today, Katmai's coast is included as critical habitat for the Steller sea lion.

Both sea otters and sea lions may be spotted on beaches, rocky reefs, or islands—areas known as *haulouts*. They're hauling out for a reason—to rest—and visitors should never approach or disturb marine mammals resting on a haulout (or in the water, for that matter).

Steller sea lions bark in chorus on a haulout. U.S. Fish & Wildlife Service photo/David B. Ledig.

Birds

Some 180 bird species are documented or expected to occur in Katmai, including 81 land bird, 64 inland waterfowl, and 35 seabird species (Zanon et al. 2015). Sea ducks including harlequin ducks, goldeneyes, mergansers, buffleheads, and scoters overwinter and breed on the Katmai coast. Seabirds, including common murres, horned and tufted puffins, pigeon guillemots, and black-legged kittiwakes, forage on zooplankton and small, cold-water fish. They typically nest on the coast and may be resident or migratory. Shorebirds, including black oystercatchers and glaucous-winged gulls, forage in the intertidal zone for invertebrates like snails, mussels, clams, and limpets (SWAN 2014, Coletti 2018).

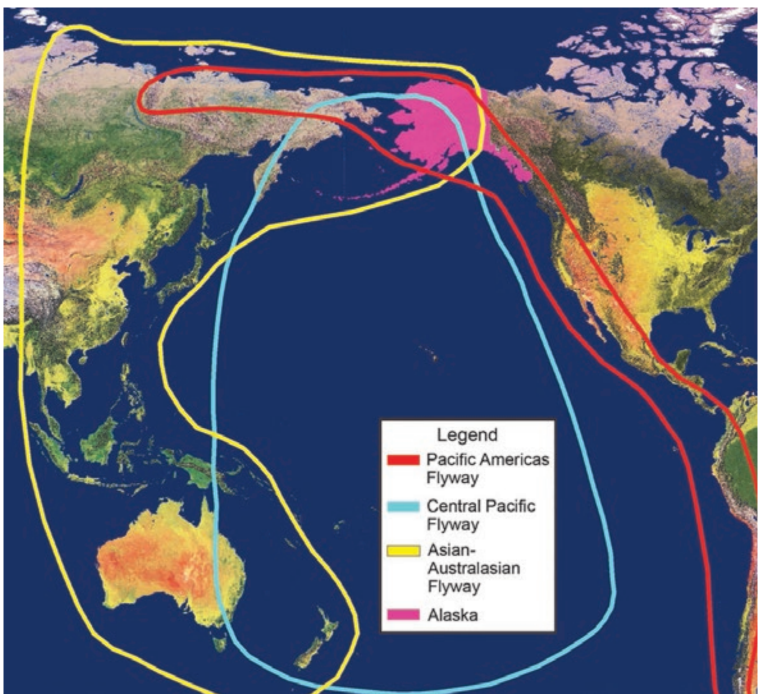
Marine birds are highly sensitive to changes in nearshore environment, including human impacts like commercial fishing, oil spills, and vessel traffic. Because they are reliable indicators of change, SWAN monitors marine birds, particularly those that forage intertidal invertebrates, as a vital sign.

In recent years, massive seabird die-offs have been documented in Katmai and elsewhere. These die-offs appear to be linked to marine heatwaves. This is discussed further in the 'Threats' section below.

For a full list of birds in the park: https://irma.nps.gov/NPSpecies/Search/SpeciesList/KATM

Flyways

Worldwide, there are nine major flyways of migratory waterbirds. Three of these bring birds to Alaska: the Asian–Australasian, Central Pacific, and Pacific Americas flyways (EAAFP 2020). Find Katmai in the map below. Does it fall within all three flyways? How important do you think Katmai's coast is to annual bird migrations?



Migratory birds in three major flyways cross paths in south-western Alaska. U.S. Geological Survey/Mary Whalen.

To Learn More

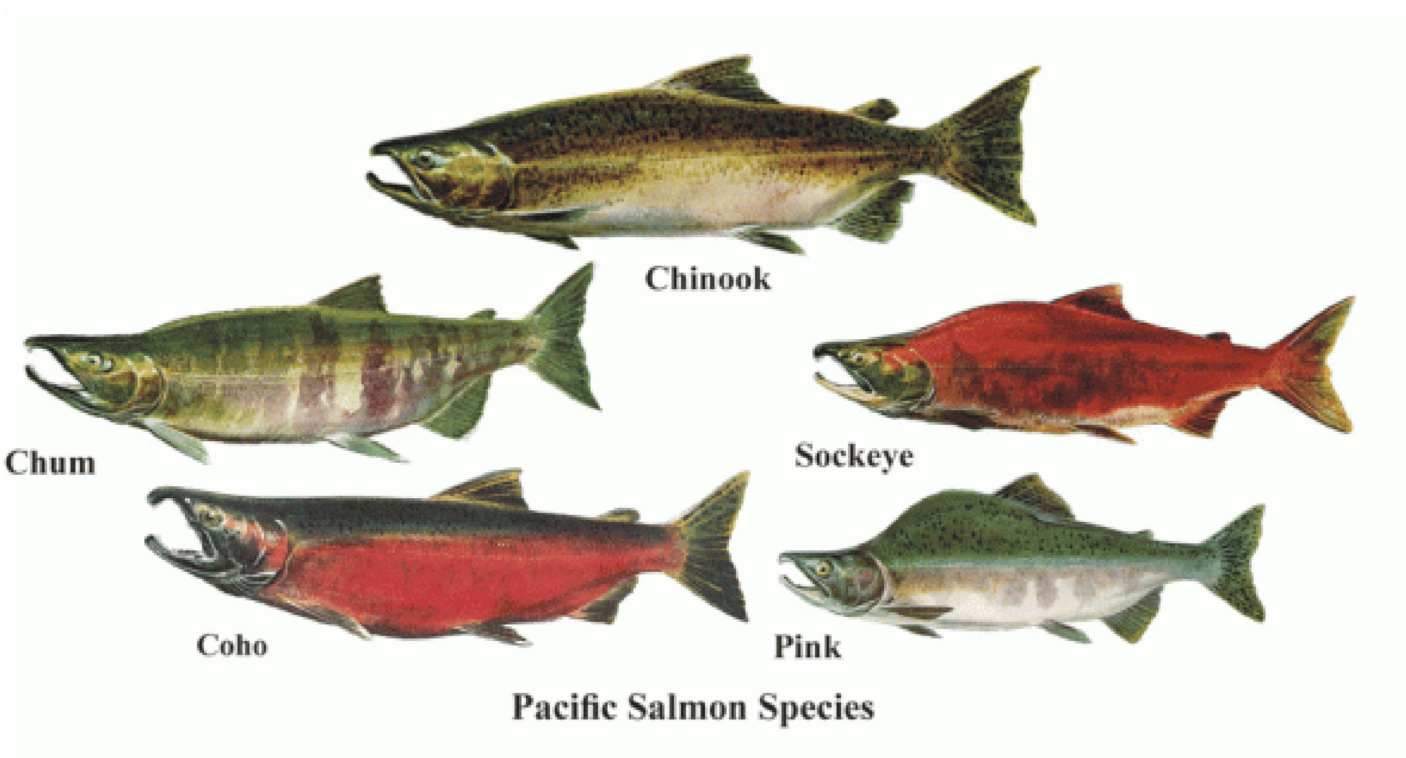
You can learn more about these flyways on the Partnership for the East Asian – Australasian Flyway's website: https://www.eaaflyway.net/

Salmon

Point to a person in Alaska, and chances are salmon are important to them. In fact, 96% of Alaskans surveyed state that salmon are essential to their way of life (USFS 2017).

Salmon are connected to Katmai in such a profound manner that they are part of its enabling legislation. Five species of salmon can be found within the coastal waters of Katmai: coho, chinook, chum, sockeye, and pink (Zanon et al. 2015). They are an incredibly important resource for subsistence, sport, and commercial fisheries.

Every year, salmon return to their spawning grounds in Katmai. As salmon "run" upstream, they provide a significant late-season food source for brown bears, bald eagles, and other wildlife. After spawning, salmon don't return to the ocean—they die and are recycled back into the streams. Collectively, their carcasses deposit significant amounts of 'marine-derived' nutrients into streams and riparian soils (Nagorski et al. 2007).



All five species of Pacific salmon spawn in Katmai's coastal freshwater streams. Robin Barefield image.

Stressors

Although the Katmai coast is relatively "natural," various stressors still pose a threat to its diversity, stability, and integrity. As you read through each section below, think about how multiple stressors may be *related* and *interact,* resulting in a heavier collective impact.

And remember that this is by no means an exhaustive list. In a rapidly changing and increasingly interconnected world, environmental stressors will continue to emerge, grow, and change.

Climate change

Arctic regions, including Alaska, are on the frontlines of climate change.

Since the mid-1990s, Alaska has warmed twice as fast as the global average (Markon et al. 2018). The state experienced its warmest year on record in 2016, and then surpassed that record again in 2019 (~6°F above the long-term average, NOAA 2020). Zoom in to Katmai, and from 1947 to 2018, average annual air temperatures in King Salmon increased nearly 5°F (SWAN 2020). We can expect at least 2-4°F additional warming by the year 2050 (Markon et al. 2018).

Although annual precipitation is expected to increase with climate change in Alaska, increased evaporation (from warming) and growing season length will counteract this, reducing water availability in most of the state (Markon et al. 2018).

These changes in temperature and moisture will have rippling effects on the Katmai coast, ranging from massive seabird die-offs to ocean acidification.

Marine heatwaves and seabird die-off

As the air warms, so too does the ocean. A *marine heatwave* is a prolonged period of warmer-than-usual ocean temperatures—and marine heatwaves have become more prevalent and intense over the last century (Piatt 2020).

The largest marine heatwave on record began in late 2013 and lasted through the winter of 2016, warming waters from southern California to the Gulf of Alaska anywhere from 5-11°F above average (Piatt 2020). As a result of this heatwave, massive die-offs of several seabird species occurred. An estimated 0.5-1 million common murres (marine birds that feed on forage fish and are sensitive to marine disturbances including oil spills, gillnetting and climate change) died of starvation in the Gulf of Alaska. But how was this happening?

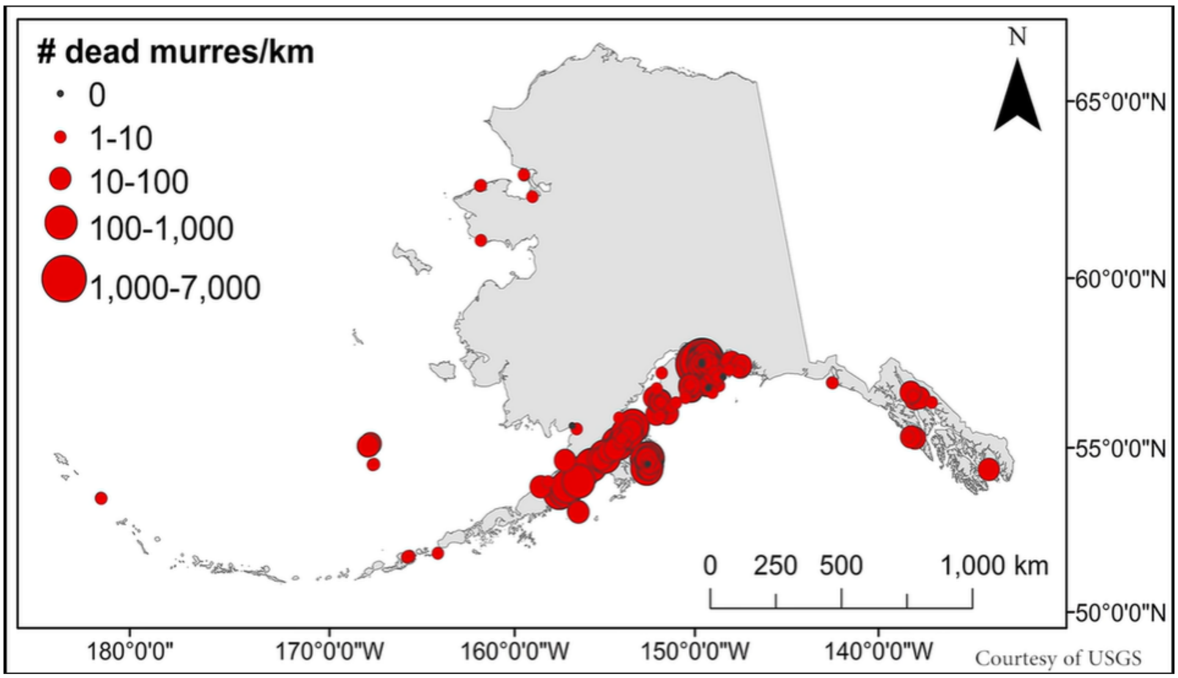
Each year, some 150 million seabirds nest in Alaska, drawn to the abundant zooplankton and small fish thriving in Alaska's cold waters. These nutrient-dense food sources nourish growing chicks and provide energy for long migrations.

Because they live in such exposed, cold environments, seabirds need to consume a lot of food to thrive and reproduce! Common murres, for example, eat over 50% of their body mass everyday (i.e., 60-120 fish). Ideally, these food sources are high-quality, lipid-rich fish. If their food source isn't as energy-rich or there isn't as much of it, murres will quickly lose weight. In fact, they die of starvation after 3-5 days without food.

These seabird die-offs were occurring because the birds starved to death. They starved because their food source changed: as the ocean warmed, there were less phytoplankton and forage fish available; what was available was smaller, leaner, and less nutritious (Piatt et al. 2020).

In addition to seabirds, many other species were affected by the heatwave. For example, significant die-off events of marine mammals, including sea lions, fur seals, and humpback and fin whales, have been linked to this marine heatwave. Seabird die-offs have been documented every year since 2015, impacting a variety of species in the Gulf of Alaska and Bering and Chukchi seas.

As our oceans continue to experience marine heatwaves (they are predicted to occur more often and with greater intensity), Katmai's coastal, nearshore, and marine environments may not be able to support the same populations of seabirds, marine mammals, and other species that it is now able to. We will likely continue to see large-scale die-off events as ecosystems struggle to keep up in a warming world.



Density and extend of dead common murres found during 2015-2016 winter surveys. U.S. Geological Survey, Alaska Science Center image.

To learn more

This landing page contains a wealth of information on seabird die-offs in Alaska. You can learn more about different affected seabird species, see maps and statistics on die-off events by year, view an excellent story map on the 2015-2016 die-off, and connect to various other articles and media on the topic. https://www.nps.gov/subjects/aknatureandscience/alaskaseabirddieoffs.htm

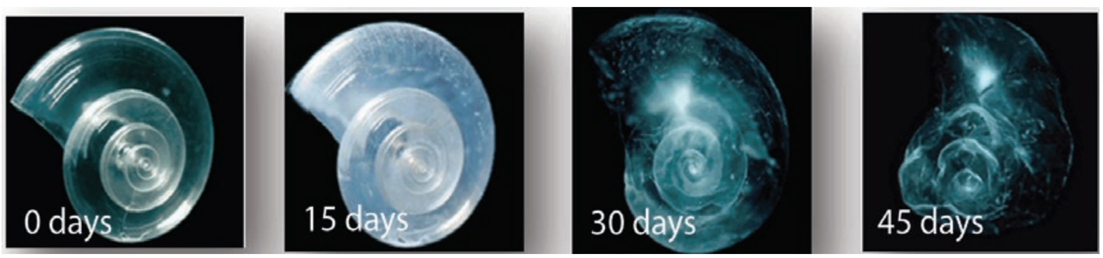
Piatt et al. 2020, "Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016." This peer-reviewed article examines the common murre die-off resulting from the 2014-2016 heatwave event and provides the bulk of the information discussed here. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0226087

Weitzman et al. 2021, "Changes in Rocky Intertidal Community Structure During a Marine Heatwave in the Northern Gulf of Alaska." This peer-reviewed study examines how Pacific marine heatwaves affect nearshore/intertidal ecosystems, including rockweed, barnacles, and mussels. Katmai is one of four sites included in the study. https://www.frontiersin.org/articles/10.3389/fmars.2021.556820/full

Ocean Acidification (OA)

The ocean naturally absorbs about 30% of atmospheric carbon dioxide (CO_2) which is in turn used by marine algae and other organisms to grow and produce oxygen. But since the start of the industrial revolution and the burning of fossil fuels, atmospheric CO_2 levels have increased dramatically. As atmospheric CO_2 concentrations increase, so too do marine CO_2 concentrations. This causes ocean chemistry to change, in turn affecting the trillions of organisms that live in or depend upon the ocean.

As more CO_2 enters the ocean, it reacts with sea water to form carbonic acid, a weak acid that easily separates into hydrogen and bicarbonate ions. The amount of hydrogen ions in a solution determines its acidity and is also what the pH scale is based on. The more hydrogen ions in a solution, the lower its pH (and the more acidic it is). As CO_2 and sea water continue to react and form more hydrogen ions, the pH of the ocean is decreasing—becoming more acidic—a phenomenon we call *ocean acidification.*



Time sequence of pteropod shell dissolution in water simulating seawater pH projected for year 2100. National Geographic image/David Liittschwager.

The pH scale is logarithmic, so when a change of one pH unit occurs, the concentration of hydrogen ions has increased by 10. In other words, a small change in pH represents a very big change. Since the industrial revolution, the pH of the ocean has decreased from 8.2 to 8.1—meaning it has become 30% more acidic than it was ~300 years ago.

Because Alaska's waters are relatively 'cold and old', Alaska is expected to be particularly sensitive to ocean acidification. Because of cooler temperatures and global circulation patterns, Alaska's waters naturally hold more CO_2 year-round. In addition to this higher 'baseline' level of CO_2, other seasonal processes in Alaska—like winds and storms that bring 'cold and old' water to the surface and melting glaciers that bring more freshwater to the ocean—are also accelerating the rate of acidification in Alaska.

Ocean acidification poses a challenge to many marine species, especially those that build shells, like clams, oysters, mussels, crabs, certain plankton species, and pteropods (small mollusks with winglike extensions used for swimming). All these organisms need calcium carbonate to build their shells—but as the ocean becomes more acidic, there are less carbonate ions to go around. Less calcium carbonate means shell-building organisms grow slower and form weaker shells, leaving them more vulnerable to damage and predation.

Many of these shell-forming organisms form the foundation of marine food webs. Marine food webs are complex, connected to nearshore, coastal, and terrestrial ecosystems in ways we're just beginning to understand. Changes to the base of these food webs can have profound effects on higher trophic level critters in the ocean and on land—including everything from salmon to bears to humans.

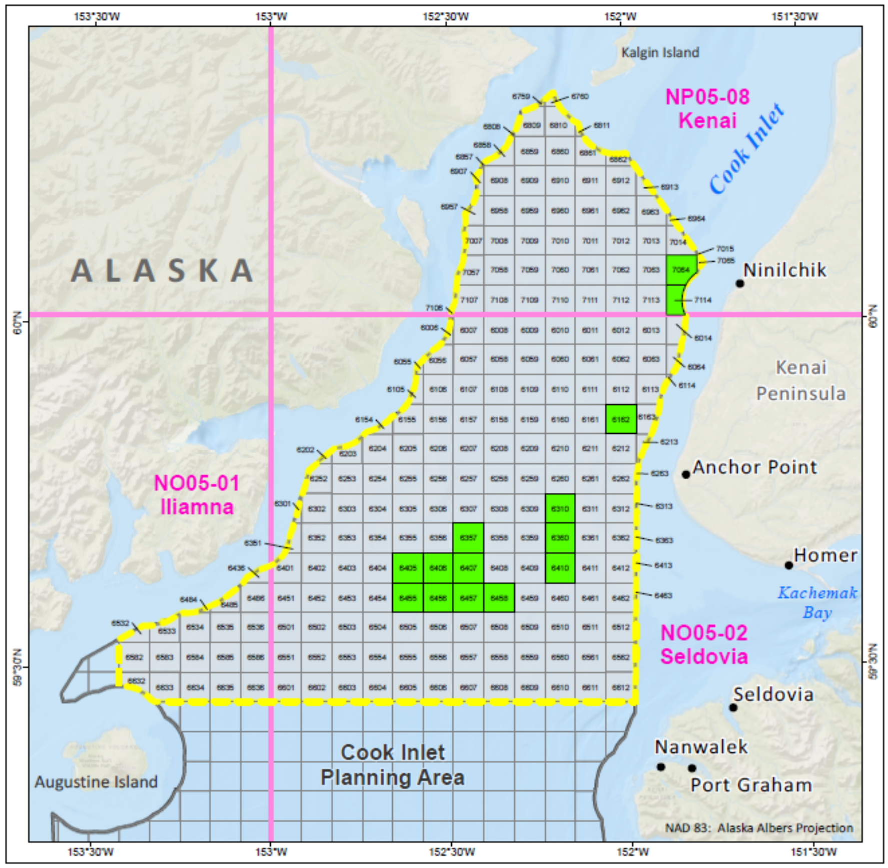
To Learn More

The Alaska Ocean Acidification Network is a great resource to learn more about ocean acidification:
https://legacy.aoos.org/alaska-ocean-acidification-network/about-oa/what-is-ocean-acidification/

Oil Development

The oil and gas industry is deeply embedded in Alaska's economy. Revenues from the industry fund most of the state's government; every eligible state resident receives an annual dividend based on oil royalty revenues (EIA 2021). Yet its impacts—habitat fragmentation, spills, contamination, and climate change—pose a continual threat to Alaska's lands and waters.

Cook Inlet is Alaska's oldest producing oil and gas basin (BLM 2021). In 2018, Alaska approved ~1 million acres of Cook Inlet for oil and gas lease sales (ADNR 2018), although it's unclear how much of this will be sold and developed (lease sales were canceled in 2006, 2008 and 2010 due to lack of industry interest). Existing and potential development in Cook Inlet, coupled with the billions of barrels of oil transported through the Trans-Alaska pipeline's nearby Valdez Terminal, continues to threaten Katmai's coastline.



The area of the proposed Cook Inlet sale (northeast of Katmai) outlined in yellow. Green blocks were purchased in the 2017 sale. Bureau of Ocean Energy Management (BOEM) image.

In 2014, NOAA completed an environmental vulnerability assessment for the entire state of Alaska. Considering a variety of variables (historical spill data, species vulnerability, habitat vulnerability, time of year, etc.), the report concluded that several regions surrounding Katmai (including Kodiak/Shelikof Strait, Cook Inlet, Prince William Sound, and South-Central Alaska) had a high rate of oil spill incidents (1995-2012) and continue to face a high relative risk for future spills.

Although Katmai's borders are protected from development, the wildlife that frequents the park's coastline are not always within these borders and can be exposed to detrimental substances either from oil spills or the accompanying increase in vessel traffic that could lead to vessel groundings and leaked contaminants. If a spill were to happen, the impacts could be severe. Marine, intertidal, and subsistence communities within the park and outside its borders would likely suffer.

To Learn More

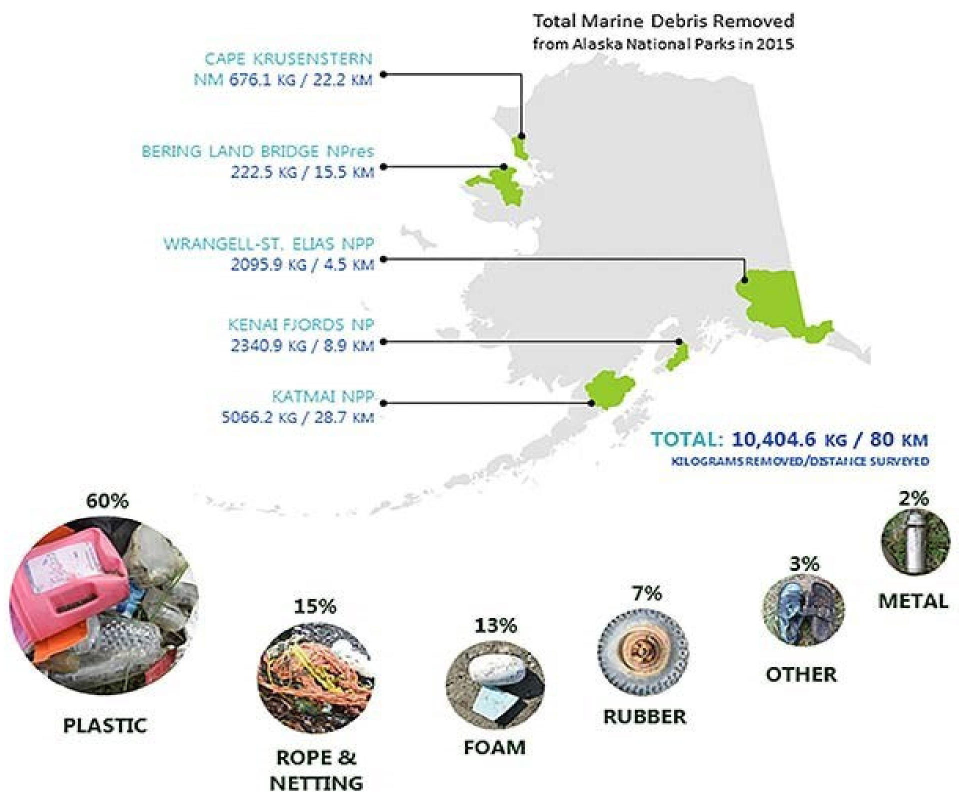
For the most up-to-date information on the Cook Inlet Oil and Gas Planning Area including status, maps, and timelines, see this BOEM page: https://www.boem.gov/ak258

The Cook Inlet Areawide Oil and Gas Lease Sale Final Findings document (2018) outlines the approved lease sales in Cook Inlet, associated habitat, fish, and wildlife, and potential impacts. http://dog.dnr.alaska.gov/Documents/Leasing/BIF/Cook_Inlet/20181102_Final_CI_BIF.pdf

Marine Debris

Up to 20 million tons of plastic end up in the ocean each year. Plastic, and any other man-made material intentionally or accidentally discarded in the ocean is called *marine debris*. Ocean currents, vessel traffic, and storm surges can transport marine debris hundreds of miles from its source before washing it ashore. Debris from as far away as Russia, Japan and China has been found on Alaska's beaches.

Marine debris is harmful to sea mammals and birds that ingest, become entangled in, or are even strangled by it. It can transport invasive marine organisms that cause ecological and economic harm. And marine debris is just plain unsightly, detracting from the wilderness experience that thousands of visitors seek in Alaska's coastal parks, including Katmai, each year.



The amount types of marine debris removed from five Alaska parks in 2015.

Most plastics never really 'go away' in the ocean. Instead, they break down into smaller and smaller pieces. We call these pieces "microplastics" if they are less than 5mm long (about the length of a grain of rice). These microplastics can be easily ingested by a variety of wildlife (both marine and terrestrial). There is a long list of issues caused by ingestion including but not limited to: acute mortality, increased absorption and biomagnification of chemical contaminants, transfer of microplastics up the food chain and physiological disorders (Egbeocha 2018).

Katmai, as well as many other coastal park units in Alaska, have doubled down on marine debris in recent years through various organized beach cleanups. In 2013, Katmai partnered with the Alaska SeaLife Center to remove ~4,400 pounds of debris from 3.3 miles of coast in Hallo Bay.

In 2015, the NPS and various partners removed over 11 tons of marine debris from five Alaskan parks, including Katmai. More debris was collected in Katmai than in any other park—11,155 pound, to be exact. Over 60% of the debris removed from Katmai was plastic, with rope/netting, foam, rubber, and metal comprising the remaining materials.

From 2021 to 2022, the largest marine debris removal effort in Katmai to date is taking place. The project, funded by the NOAA Marine Debris Program, aims to remove over 25 tons of ocean plastic and improve some 500 acres of habitat along the park's coast. In 2021, seven metric tons were removed from three beaches (Kelsey Griffin, Katmai Coastal Wildlife Biologist, and Andy Schroeder, NOAA Project Lead, pers comm).

While these efforts are an immensely important step to address the current state of marine debris, plastic use throughout the world continues to pollute even the most remote shores of Alaska. In addition to cleanup efforts, everyone needs to think about alternatives to plastics in our daily lives, no matter where we live.

NPS staff sort and bag marine debris during a Katmai coastal cleanup. NPS photo.

To Learn More

NOAA's website on marine debris is a great place to start to learn more about marine debris. You'll find educational resources, blog posts, photos, factsheets, videos, and a region-specific page for Alaska. https://marinedebris.noaa.gov/

Learn more about the 2015 efforts to clean marine debris from five Alaska national parks in the following article https://www.nps.gov/articles/aps-15-1-10.htm and story map https://nps.maps.arcgis.com/apps/MapJournal/index.html?appid=b778e39204d14302bccf74b9a148466f

Find more information on the 2015 marine debris cleanup efforts, including park-specific information on the quantity and type of debris, in this peer-reviewed journal article: https://irma.nps.gov/DataStore/Reference/Profile/2239436

Declining fisheries

Salmon run up a freshwater stream in Katmai. NPS photo/Lian Law.

The marine waters of the Kodiak Commercial Fishing Management Area (including Katmai's nearshore environment) are among the most productive in the North Pacific. Offshore upwellings and abundant freshwater runoff create cold, nutrient-rich waters and support over one hundred species of native marine fish including Pacific herring, crab, halibut, cod, and five species of salmon (chinook, sockeye, pink, chum, and coho). The Kodiak area is Alaska's fifth largest salmon fishery by value, having generated $1.7 billion in revenue since 1975 (SASAP 2021).

A significant decline in the region's salmon fisheries would be catastrophic to the many communities and animals that depend on them. In Kodiak, as in many other parts of Alaska, subsistence, commercial, and recreational fishing are extremely important to local economy, culture, and identity. Katmai's coastal food web, including much of the park's charismatic wildlife, is also intimately tied to the region's fisheries stock. Think: brown bears, coastal wolves, and bald eagles, and the fertilizing effect that decaying salmon carcasses have on stream, riparian, and forest habitats.

Unfortunately, salmon fisheries *have* been declining for several decades across Alaska. Escapement data collected by the Alaska Department of Fish & Game, US Fish & Wildlife Service, and NPS show that, for the past 15 to 20 years, salmon have been returning from sea younger and smaller. Some years, there are also significantly less salmon returning overall. Climate change, unsustainable commercial fishing practices, increased predation, and competition with hatchery-raised salmon may all be contributing to the decline.

To Learn More

This comprehensive 2017 report examines the relationship between Alaska's commercial fisheries and climate change: https://alaskaseagrant.org/wp-content/uploads/2018/02/Climate-Change-and-Fisheries_Johnson_WEB.pdf

This news article, published in August 2021, discusses how climate change and other factors are disparately impacting Indigenous subsistence fishermen, for whom salmon is the center of their culture: https://civileats.com/2021/08/12/salmon-is-life-for-native-alaskans-salmon-declines-pose-existential-crisis/

State of Alaska's Salmon and People (SASAP) publishes reports on each of Alaska's regional salmon fisheries. View the Kodiak report here: https://alaskasalmonandpeople.org/region/kodiak/

This NPS web article/resource brief describes the long-term salmon monitoring that SWAN conducts in Bristol Bay, Katmai, and Lake Clark NP&P: https://www.nps.gov/articles/salmonswan.htm

Visitation

National parks are, at their core, for current and future generations to visit and enjoy. Yet human visitation is a form of disturbance—an ecosystem stressor not unlike the other stressors we've discussed.

Tourism in Katmai is a major regional economic driver—and it's growing rapidly. At least 5,000 visitors travel to the coast each year from Homer, Kodiak, or Anchorage to bear-view, fish, or sightsee. Hallo Bay, Geographic Harbor, Kukak Bay, and Swikshak Lagoon are the coast's most popular destinations.

As Katmai experiences increasing visitation each year, park managers have begun to ask how human presence affects this otherwise extremely remote area. A recent time-lapse photography study suggests that Katmai's brown bears are very tolerant of bear viewers: bears' foraging behavior doesn't change when people are present. However, numerous and large groups of visitors can and do displace and/or alter coastal brown bear behavior (Griffin 2021). Rumbling planes alter an otherwise natural soundscape and increasing vessel traffic means more collisions with marine mammals and additional disturbances to marine life in ways we're just beginning to understand. As people continue to visit the same areas, social trails, campsites, and other lasting human imprints form on the landscape.

As we interpret Katmai's spectacular resources and environmental threats, can we encourage visitors to think deeply about their *own* impacts to marine and terrestrial environments—in Katmai and beyond?

Coastal brown bear viewers at Geographic Harbor. NPS photo.

To Learn More

This NPS natural resource report examines the spatial-temporal distribution of brown bears and visitors on Katmai's coast using time-lapse photography: http://npshistory.com/publications/katm/nrr-2021-2216.pdf

This page discusses visitation trends in Katmai: how many people, when and where they visit, and what they do while they're here. Interestingly, because there are no entrance stations, these data are collected by commercial operators (lodges, guides, and air taxis) that bring visitors to the park: https://www.nps.gov/articles/visitor-use.htm

Ocean Literacy Principes

The seven principles of Ocean Literacy are important concepts we can insert into our interpretation and education messaging. How can you incorporate these principles as you interpret the material presented in this primer?

Principle 1: The Earth has one big ocean with many features

Principle 2: The ocean and life in the ocean shape the features of Earth

Principle 3: The ocean is a major influence on weather and climate

Principle 4: The ocean made Earth habitable

Principle 5: The ocean supports a great diversity of life and ecosystems

Principle 6: The ocean and humans are inextricably connected

Principle 7: The ocean is largely unexplored

Learn more about each principle and find resources for educators on the Ocean Literacy website:
http://oceanliteracy.wp2.coexploration.org/

Researchers walk the coastline near Katmai Bay. NPS photo/Lian Law.

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Still not enough? Dig into the nitty gritty of reports, articles, and webpages referenced throughout this document:

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