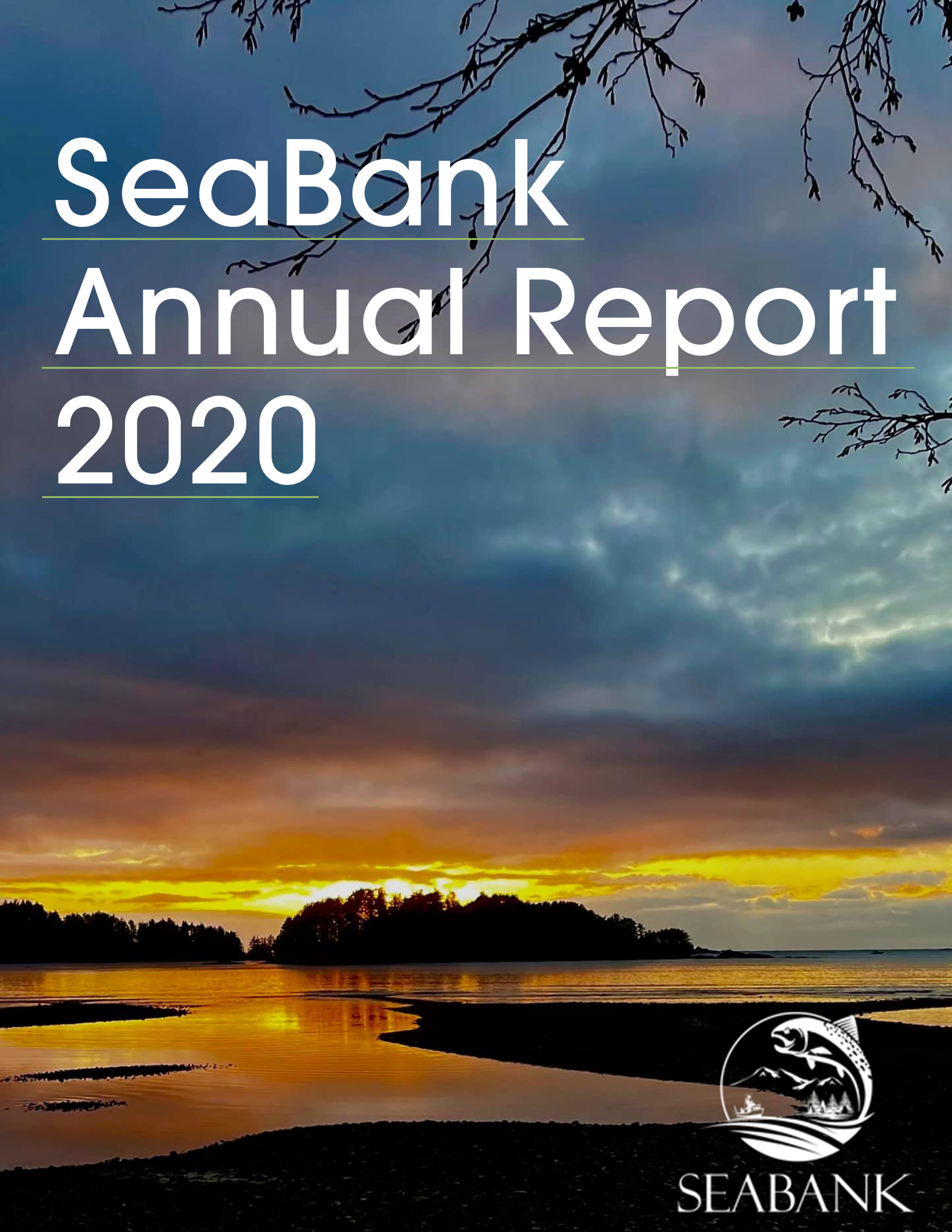
SeaBank Annual Report 2020



Introduction: Southeast Alaska's Natural Capital - the Sea Bank

Sea Bank is a wealth of natural capital located in Southeast Alaska: coastal- temperate rainforests, rich estuaries, freshwater aquatic ecosystems fueled by glaciers and precipitation, and the near-shore and off-shore marine waters. This report focuses on the primary goods and services provided by Sea Bank ecosystems: (1) the highest quality and most valuable seafood on the planet; (2) 11 million acres of forests that are a global champion in terms of carbon sequestration; (3) scenic and remote recreation experiences for hundreds of thousands of visitors each year who take away fishing stories and memories of pristine scenery ranging from rugged snow-capped mountains to glaciers and estuaries, viewing iconic marine mammals and terrestrial megafauna and (4) abundant wildlife populations utilized for subsistence, sport hunting and wildlife viewing.

This natural capital produces economic outputs from the seafood and visitor products industries worth several billion dollars a year to Southeast Alaska residents, non-resident workers, visitors and society as a whole. Ecosystem services provide this stream of income as natural capital – a complex of plant and animal communities and their environment that interact as one functional unit – Sea Bank.

The Sea Bank's economic value is Alaska's untold secret. Its annual fish dividend makes Southeast Alaska, along with Bristol Bay, one of two top ecosystems for commercial salmon production. Sea Bank's scenery, fish and wildlife and remote recreation opportunities are assets that attract over 1.5 million visitors each year – two- thirds of all visitors to Alaska and more than any other region in the state. Both the seafood and visitor products industries rely on Sea Bank's natural capital, and any activities that reduce ecosystem services are likely to adversely impact these industries.

The economic value of Sea Bank includes two ecosystems that are massive carbon sinks – meaning ecosystems of sufficient size to absorb substantial amounts of atmospheric carbon in which the rate of carbon sequestered exceeds the rate of carbon lost through respiration and export. The abundant eelgrass meadows and salt marshes that grow in the region's estuaries store blue carbon - the organic carbon sequestered and stored in vegetated coastal ecosystems. The coastal temperate rainforests store green carbon - carbon captured through photosynthesis and stored in terrestrial plant biomass. Conserving coastal blue carbon and terrestrial green carbon ecosystems is a "no regrets" mitigation policy because of the myriad of other ecosystem services provided by coastal wetlands and temperate rainforests.

Purpose and Need: Quantify the economic values of Sea Bank's natural capital: value and sales

Coastal ecosystems such as the Sea Bank which combine estuaries, coral reefs temperate rainforests and other high value natural capital provide provisioning services such as salmon and other food products and amenity services for tourism and recreation. Coastal areas are the most economically productive ecosystems in the world – not only for coastal communities but also for national economies and global trade. Coastal systems like Sea Bank comprise only 8 percent of the planet's surface but generate 43 percent of the global ecosystem service economic value.

Coastal areas are also vulnerable ecosystems experiencing rapid environmental change through developments that degrade high value habitats - coastal forests, estuaries and, coral reefs. These changes heighten the need to maintain the Sea Bank's natural capital in the face of a declining global capacity to provide ecosystem services due to habitat conversion for industrial uses. Global biodiversity is declining at unprecedented rate. This loss of biodiversity and habitat degradation will lead to long-term interruptions in the supply of natural capital for present and future generations. Climate change and an increasing human population exacerbate these risks.

In Southeast Alaska, decision makers need better information on the full range of economic values provided by coastal ecosystem services. In particular, better accounting of ecosystem services should improve decision making related to conservation and ecosystem management – particularly between competing uses such as timber and mining developments versus maintenance of fishery and recreation resources. Is it better to use estuaries for raw log export transfer facilities or to maintain them intact as carbon sinks and preserve their ecological capacity to function as nurseries for high value fish and recreational uses? Are Sea Bank's old-growth and recovering, second growth forests more important for fishery production, wildlife habitat and recreation, or for near-term degradation by timber companies? Will long-term harm to salmon populations caused by toxic watershed pollutants released by mining companies exceed the value of extracted minerals? These narrow, short-term uses of natural capital are likely to reduce outputs from ecosystem services and harm coastal communities over time.

Sea Bank's natural capital: value and sales

Natural capital generates ecosystem services which in turn produce both goods and services which are major contributors the economy. Ecosystem services fall in four main categories: provisioning (food, water, raw materials), regulating (air quality, climate, waterflow, erosion prevention, etc.), habitat (i.e. juvenile fish nursery service, etc.) and cultural services (recreation, etc.). These services provide substantial benefits for humans. Because these services generate substantial economic value, the belief that habitat conservation is bad for the economy is often wrong. Natural capital yields dividends over an extended period of time, just like any other capital asset such as a fishing permit or commercial vessel. Indeed, natural capital can generate benefits in perpetuity.

Over the past several decades resource economists have worked to quantify economic values produced by natural capital and specific ecosystem services. Their research shows that the degradation of natural capital and ecosystem services caused by converting habitats to industrial uses for agriculture, logging or fish and shellfish farming causes a net economic loss. In other words, the value of long-term, lost economic benefits flowing from natural capital exceeds the value of uses that degrade natural capital. These findings should incentivize conservation of natural capital. However, ecosystem services are chronically undervalued, particularly by decision-makers, or their value is subverted by government subsidies that favor habitat conversion for narrow, short-term benefits.

This report emphasizes sales and economic outputs flowing from Sea Bank's natural capital. Capturing the full Net Present Value (NPV) of the natural capital is beyond the scope of this report. However, for illustrative purposes, it is important to describe Sea Bank assets using estimated values per biome calculated by natural resource economists. Estimated global ecosystem service values for all Sea Bank biomes are between $125 and $145 trillion per year.

The Sea Bank's largest natural capital asset is the coastal rainforest biome, which provides asset values for multiple ecosystem services valued at $3,000 per hectare. The value of Sea Bank's 11 million acres of forested natural capital may be worth over $13 billion generated by provisioning ecosystem services for wildlife, carbon sequestration, fish habitat and outdoor recreation. Freshwater rivers and lakes biomes also provide multiple ecosystem services with values of $4,257 per hectare. The Sea Bank's 201,000 acres are worth nearly $363 million, providing fishery and recreation assets and other regulating services. The region's three transboundary rivers alone are worth $1.2 billion over the next fifty years.

Coral reefs are the highest valued ecosystems at $353,000 per hectare; there are 5,693 hectares of coral habitat protected areas in the offshore Sea Bank worth nearly $2 billion. Estuaries are among the most important and highly valuable areas for ecosystem services, supporting large numbers of fish, marine mammals, terrestrial mammals and avian species that depend on estuaries for a portion of their life cycle, particularly as juveniles, and sustain diverse flora and fauna. These services amount to $193,845 per hectare, or $22.3 billion for the 284,727 acres of Sea Bank coastal wetlands.

Southeast Alaska's estuaries are globally significant because of their high productivity. They provide multiple ecosystem services – food provisioning services, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education and research. There are 12,000 estuaries in Southeast Alaska and nearly 12,000 shoreline miles of highly productive coastal wetlands such as salt marshes and eelgrass meadows that have important resource values for nearly all Southeast Alaska's fish and wildlife assets. Estuaries support a diversity of fish species, functioning as spawning and nursery areas for finfish and forage fish, shellfish and other invertebrates. They also provide habitat features such as breeding area, refuge and forage for migratory birds, sea birds, marine mammals and terrestrial mammals.

One of the most widely known ecosystem services provided by estuaries is nursery habitat for fish. The presence of juvenile fish is dominant as numerous fish species move into estuaries as larvae, accumulate biomass and then move offshore. Three-fourths of all fish caught in Alaska utilize the regions estuaries and estuarine vegetation during some part of their life history. Eelgrass meadows in particular often host the highest density of marine species – dozens of marine finfish including major groundfish species such as halibut, sablefish, pacific cod and rockfish, and numerous invertebrates, including commercial shellfish species such as Dungeness crab and spot shrimp. Salmon rear extensively in estuaries as juveniles.

One of the most potentially valuable ecosystem services provided by Sea Bank salt marshes and eelgrass meadows is the significant atmospheric carbon (CO_2) uptake and long-term carbon storage and sequestration. These coastal wetlands capture and store carbon in salt tidal marshes and seagrass meadows within the soil, aboveground biomass such as leaves and stems, belowground biomass such as roots, and non-living biomass. The sequestration process in vegetated habitats constitutes about half of the total carbon burial in the ocean. These ecosystems also can store CO_2 for longer periods of time than terrestrial ecosystems – once captured, carbon stored in coastal soils can remain in place for millenia, resulting in large carbon stocks. The capacity of coastal wetlands to store blue carbon is highly variable, but on average, salt marshes and seagrasses store more carbon per hectare than most temperate rainforests. Eelgrass, the most prevalent seagrass in Southeast Alaska, is a potentially significant contributor to global blue carbon stocks. This value heightens the need to preserve Sea Bank's estuaries – coastal wetlands, like forests, become sources of CO_2 emissions when degraded by industrial development or other causes.

Southeast Alaska's commercial seafood harvesting and processing industry is one of the region's two largest private sector economies and depends on ecosystem services provided by all Sea Bank biomes. Seven of the top 100 seafood producing ports in the United States rely on Sea Bank's natural capital.

Sea Bank Net Sales by Community: 2018 Top National Seafood Ports

Port	Million Pounds	National Rank	Landed Value	National Rank
Sitka	45.5	21	$61,000,000	16
Ketchikan	37.5	24	$36,000,000	31
Petersburg	35.3	25	$44,700,000	24
Juneau	12	*	$21,400,000	49
Wrangell	4.9	75	$10,400,000	83
Yakutat	4.1	86	$12,400,000	72
Haines	3.8	89	$6,300,000	103

Sea Bank Sales: Representative Commercial Fishery Harvests

Asset	Sales	Ex-vessel Income
2019 Halibut & Sablefish	12.8 million pounds	$45,000,000
2019 Dungeness Crab	5.3 million pounds	$16,300,000
2019 Shellfish (Sea cucumbers, geoducks, & sport shrimp)	3.4 million pounds	$16,700,000
2019 Salmon	33 million fish	$88,000,000

Southeast Alaska's other top private sector economy is the visitor products industry, providing a $1 billion economic impact when including indirect and multiplier economic impacts. Coastal tourism is one of fastest growing global economic sectors and relies on ecosystem services provided by scenery and opportunities for outdoor adventure and wildlife viewing. The Sea Bank's natural capital provides significant competitive advantages for the visitor products economy which include intact ecosystems, dramatic attractions such as glaciers, salmon streams, scenery, marine mammals and iconic terrestrial megafauna such as bears. A decreasing global supply of high-quality outdoor recreation opportunities is likely to increase the value of these assets, which are stimulating rapid regional growth in nature-based tourism.

Sea Bank Sales: 2017 and estimated visitor products industry sales

Asset	Visitor Spending	Jobs	Labor Income	# of visitors*
Sea Bank	$705,000,000	11,925	$445,000,000	1,500,000
Wildlife: hunting and viewing	$363,000,000	2,460	$138,000,000	1,300,000
Sport fishing	$247,000,000	3,063	$99,000,000	500,000+ angler days
Glacier Bay	$113,000,000	2,090	$58,700,000	547,000
Transboundary rivers	$21,500,000	200	$10,500,000	50,000

*Sport fishing angler days and wildlife hunting and viewing numbers include southeast Alaska residents

One of the primary reasons that ecosystem degradation continues despite the massive dividends returned to fishermen, tour operators and Sea Bank communities is because “intervention failures” exaggerate the purported benefits of habitat conversion. The Forest Service and other landowners are liquidating some of the region’s most important natural capital: remaining old-growth and recovering second-growth forests. Two recent reviews show that the Forest Service spends millions of dollars annually supporting two timber companies that provide very few jobs. Timber sale revenues are so low that the agency’s taxpayer losses range between $20 million and $30 million per year. These losses are consistent with findings showing that high intensity logging is one of the big losers on a global scale, with loss of non-timber products, fish and wildlife species and carbon stocks routinely exceeding timber values.

Forests contain the largest store of terrestrial carbon by accumulating significant stocks of carbon, both above and below ground over time. Industrial logging is one of the major drivers of global forest and biodiversity loss and undermines one of the most effect climate change mitigation strategies – the conservation of green carbon. The Tongass National Forest is not reaching its full sequestration potential in large part because of recent and ongoing industrial scale logging. Logging creates an initial release of CO_2 into the atmosphere which can continue for years. Land use change, including logging, accounts for roughly a quarter of anthropogenic greenhouse gas emissions. Because of this impact, reducing emissions from logging and other causes of forest degradation is as urgent as halting fossil fuel use.

Forests use natural technology to continuously capture and store a quarter of the CO_2 emitted into the atmosphere each year. This technology starts with the sequestration and accumulation of atmospheric carbon due to tree growth. Sequestration is the process through which trees and other plants capture and convert CO_2 into terrestrial organic carbon and store the CO_2 as biomass (e.g. vegetation). Trees accumulate carbon continuously so that the largest, oldest trees store a disproportionate amount of carbon over time. The large leaf surface area, thick tree trunks and root wads hold centuries of accumulated carbon. Maturing forests are also critical because the increase in the carbon balance is highest for trees between 100 and 200 years old.

Old-growth forest stands in Southeast Alaska store disproportionately high carbon stocks relative to other forests, making them individually and cumulatively critical to climate regulation. Southeast Alaska’s Tongass National Forest - the largest national forest in the U.S. – is irreplaceable as a carbon sink and stores more green carbon than any national forest – an estimated 650 million tons in aboveground biomass (live trees, snags & logs) - equivalent to 2.4 billion tons of CO_2.

Because of recent weather events and other documented changes, this 2020 report maintains a significant focus on climate change as a threat to Sea Bank's natural capital value. Climate change is likely to cause sea level rise, melt glaciers, heat up both freshwater and marine ecosystems, shift precipitation patterns, and alter the distribution of plants and animals. High temperatures in 2019 set records during the winter, spring and summer throughout Southeast Alaska. A prolonged drought coincided with these rising temperatures as the region experienced its lowest rainfall on record. Then the switch flipped in 2020 as the region experienced record precipitation culminating in an atmospheric river in December that caused considerable damage throughout the region. Alaska climate scientists expect that the frequency and intensity of these severe weather events will accelerate in the future.

These changes will impact one of Sea Bank's most valuable assets in terms of annual dividends – its salmon and salmon-producing ecosytems. Salmon use a combination of freshwater, estuarine and marine habitats at different stages of their life cycle, resulting in exposure to numerous climate change threats. Climate change will stress salmon stocks by disrupting migration patterns, altering the marine food web, changing stream flow patterns in summer and winter, and altering both marine and freshwater temperature regimes. This report will explain how these changes will challenge each salmon species in different ways.

Sea Bank is one of the two largest remaining productive salmon systems in the world in large part because of capital assets that include the planet's largest tract of undisturbed coastal temperate rainforest. Because of fluctuations in salmon returns and marine and freshwater habitat qualities, fishery managers are increasingly emphasizing the need to manage salmon-producing ecosystems in a way that maintains population diversity. They compare these properly functioning biological systems to well-designed financial portfolios. Investment portfolio theory refers to investment management strategies that allocate financial assets in a way that achieves a balance between gain and risk. Investment analysts developed modern portfolio theory in response to the challenges of making reliable projections for the outcomes of financial systems – and these challenges exist even when there is abundant data. The more diversity an asset portfolio has, the more stable its overall returns, over time. For salmon populations, the "portfolio effect" relies on diverse populations (assets) from many watersheds to provide some stability for commercial, subsistence and sport fisheries.

Portfolio management that maintains diverse salmon assets is critical to managing fisheries at a time of unknown risks in rapidly changing ecosystems. The salmon portfolio includes multiple assets – genes, populations, species, landscapes or ecosystems. The availability of intact aquatic and estuarine habitats is a critical salmon portfolio asset. Population diversity is also critical in terms of providing fishery reliability and informing conservation strategies. As with an investment portfolio, diversity across a regional population complex buffers, over time, against stock declines in any given year from one or several watersheds, and ensures continuing dividends to the fisheries every year. It is difficult to anticipate species- or stock-specific performance in the future, heightening the need to maintain a diverse portfolio. Reduced genetic diversity and numerous population extirpations caused by environmental degradation have likely reduced dividends from many parts of the Sea Bank's salmon portfolio in Southeast Alaska. Finally, this 2020 report adds new material on a long-term and increasing threat to Sea Bank marine assets – Gulf of Alaska and Bering Sea trawl fisheries.

Federally managed trawl fisheries in the Gulf of Alaska and Bering Sea are a major threat to Sea Bank assets because they kill many marketable high value species such as sablefish, halibut and Chinook salmon as bycatch. Many of these highly migratory fish would otherwise find their way to Southeast Alaska waters and beyond and support numerous coastal communities. These impacts are even worse because many fish taken by trawlers are declining in abundance. The Gulf of Alaska trawl fleet kills thousands of Chinook salmon each year, including unknown numbers of fish bound for Southeast Alaska's troubled transboundary rivers. Bering Sea and Gulf of Alaska trawlers typically kill more than five million pounds of halibut as bycatch each year - more than the entire Southeast Alaska directed fishery. Roughly half the bycatch by weight is small, juvenile halibut that would otherwise mature and contribute to fisheries yields for Alaska coastal communities. Trawlers also kill forage fish such as herring, millions of juvenile commercial fish species, and waste numerous other species.

In 1976, Congress enacted the Magnuson-Stevens Act to conserve U.S. fishery resources and particularly protect them from foreign trawlers. Congress anticipated that Americanizing the fisheries would conserve U.S. fishery resources. But American trawlers replaced the foreign vessels. A quarter century ago, in 1996, Congress responded to bycatch increases by amending the Magnuson-Stevens Act through the Sustainable Fisheries Act. The Sustainable Fisheries Act added National Standard 9, which requires that regional fishery councils reduce the amount of bycatch in every fishery.

Since 1996, Gulf of Alaska trawlers have killed an estimated half a million Chinook salmon. Trawlers have killed at least 181 million pounds of halibut since 1996 – an estimated 65 million pounds in the Gulf of Alaska and over 116 million pounds from the Bering Sea. Halibut and Chinook bycatch in the Gulf of Alaska may have been much higher. There have been longstanding concerns about bycatch estimates from the Gulf of Alaska trawl fisheries because of the poor quality of data obtained from the NOAA Fisheries' observer program. An emerging problem is that over the last four years, trawlers have killed over five million juvenile sablefish as bycatch. Federal fishery managers have refused to address this new bycatch concern.

The following report seeks to identify and quantify economic outputs from Sea Bank's regional natural capital – such as its salmon portfolio – to inform improved decision making that maximizes economic outputs for the benefit of coastal residents and the millions of Americans who enjoy Sea Bank's scenery, seafood and wildlife.

2020 SeaBank Annual Report

Introduction

Southeast Alaska is a single, vast, highly productive ecosystem that extends from mountaintop to open ocean. The coastline extends 500 miles from Metlakatla to Yakutat with 33,500 square miles of land and water. Over 1,000 islands comprise 40 percent of the land area and contribute to a total shoreline length of 18,500 miles. Everything is tightly interconnected: the land, water, vegetation, wildlife, resources, economies and culture. The Alaska Sustainable Fisheries Trust (ASFT) program calls this productive, interwoven nexus *SeaBank*. This report tells the story of the contributions of Southeast Alaska's ecosystem services to the economic and lifestyle needs of its residents and workers and as well as to the joy and awe of visitors from far away.

This natural ecosystem functions as a richly endowed bank that provides natural capital of several kinds. This capital, some of which automatically renews itself annually and some of which perpetually sustains economic endeavors as long as it is not “withdrawn” by development, is essential to the regional economy. The SeaBank requires no human input, no equipment, and no built infrastructure of any kind, yet it produces over a billion dollars in economic outputs flowing from fishery, wildlife, and recreation resources every year. The ecosystem can continue to provide these long-term annual dividends with responsible management of harvests and ecosystems. ASFT’s SeaBank program has several purposes. It makes people aware of Southeast Alaska’s natural bank. It measures the huge annual capital this bank provides. It quantifies the value of this bank to its shareholders (beneficiaries). And as a result, it empowers residents, visitors and policy makers to make sound long-term decisions that promote stewardship and sustainable economics.

This third annual SeaBank report serves as a baseline for:

- Understanding the natural processes that create the wealth of resources Southeast Alaska’s ecosystem provides;
- Identifying habitats or geographic locations that are important to sustained production of these resources;
- Assessing the value of these resources in both monetary and non-monetary terms to the people who live within and outside this island region;
- Identifying risk factors to the sustainability of these resources and the communities that depend on them;
- Highlighting recent work that deepens our understanding of the region’s remarkable ecosystems and their value.

The first SeaBank annual report (2018) captured in economic terms the ecological services and resource wealth of this ecosystem. The second report (2019) supplemented that focus with an emphasis on salmon and the risks to that resource associated with the cumulative effects of climate change and timber and mineral extraction. This third report updates the discussion of climate change impacts and introduces climate mitigation strategies associated with SeaBank’s green and blue carbon. Blue carbon is the organic carbon stored, sequestered or released from vegetated coastal ecosystems such as coastal wetlands, including SeaBank’s eelgrass meadows and salt marshes. Green carbon is carbon captured through photosynthesis and stored in terrestrial plant biomass such as SeaBank’s coastal temperate rainforest. New material describes ecosystem services produced by the region’s high value estuaries, including blue carbon. Finally, it has been almost a quarter century since Congress amended the Magnuson-Stevens Act to add bycatch minimization requirements. Other new material reviews the failure of fishery managers to reduce industrial trawl fishery bycatch of halibut, Chinook salmon and sablefish, and the costs of that bycatch to Southeast Alaska fishermen.

Photo credit: Eric Jordan

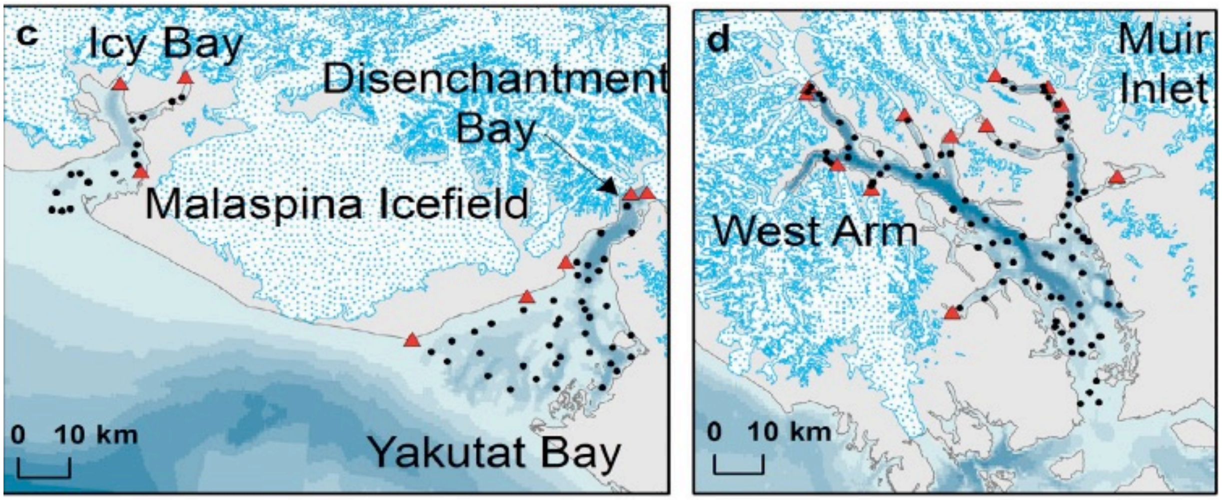
Ecology

SeaBank's Value Creation Process

Southeast Alaska's northernmost boundary is at Icy Bay, north of Yakutat and the region extends south to Dixon Entrance at the coastal border with British Columbia. Roughly 20,000 years ago, glaciers covered most of Southeast Alaska. The receding glaciers carved out the straits and inlets in the Inside Passage. Glacial retreat resulted in a terrain of steep mountains and glacial valleys. Today, this 21.6 million-acre terrestrial environment includes hundreds of islands of all sizes (the Alexander Archipelago) and a coastal mainland characterized by steep mountains interspersed with glaciers and ice fields.

SeaBank's system of temperate-region ice fields and glaciers is the largest in North America and a primary capital asset. Glaciers significantly influence coastal marine ecosystems. Glacial run-off delivers a seasonal blast of mineral rich cold water and sediment to the region's fjords and bays. This run-off contributes to high densities of phytoplankton – the very base of the aquatic food webs. Run-off also supports other primary forage fish such as krill and copepods (small crustaceans). As a result, bays and fjords affected by glacial run-off support large numbers of seabirds and productive pelagic communities of forage fish and marine consumers by providing breeding, nursery and foraging areas.

Forests cover over half of the land area and the remainder is rock, ice, unforested alpine country,



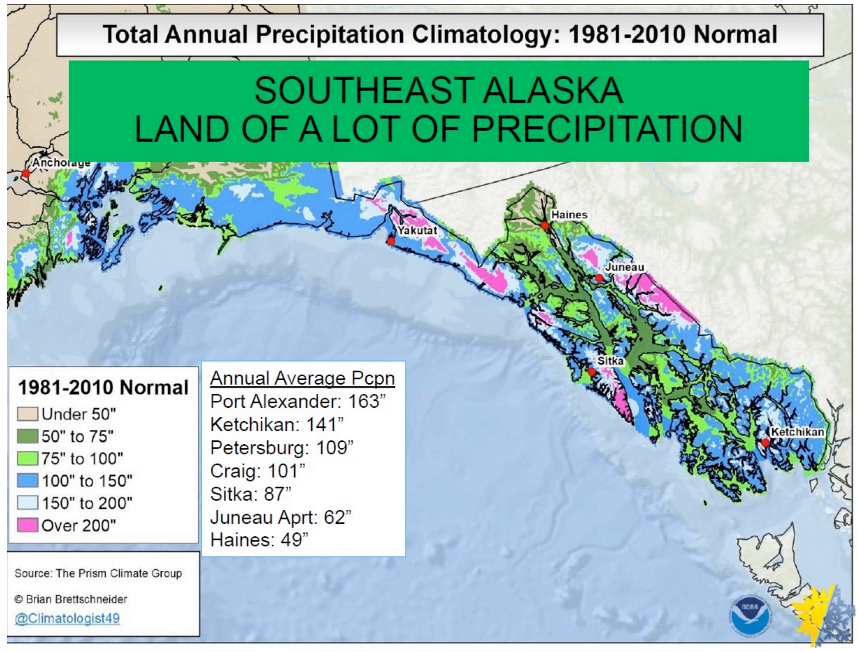
Icy Bay and Yakutat Bay along the Eastern Gulf of Alaska coast (left panel) and Muir Inlet and the West Arm of Glacier Bay (right panel) are economically significant SeaBank assets in large part because of glacial run-off. Black circles are sample sites from a 2016 scientific study measuring the productivity of these areas. Red triangles are glacial runoff sources. Credit: Arimitsu, M.L., J.F. Piatt & F. Mueter. 2016. Influence of glacier runoff on ecosystem structure in Gulf of Alaska fjords. Marine Ecology Progress Series, Vol. 560: 19-40, 2016.

and muskeg. Aquatic ecosystems include large transboundary rivers on the mainland and streams of all sizes are scattered throughout the region, including 14,000 miles of anadromous or potentially anadromous salmon habitat. The region has 11,861 square miles of estuarine habitat, making it one of the largest estuarine systems in the world. A highly scenic, protected marine highway consisting of deep fiords, large straits, narrow channels and inlets is natural transportation infrastructure that allows access to 18,000 miles of marine shoreline.

The region's diverse marine environment has nearly 47,000 square nautical miles of continental shelf, various sea bed types, and many banks and reefs. Offshore marine waters include large areas of living substrate, including slow growing, deep water corals, such as gorgonian red tree coral, that are valuable for fish habitat.

The Alaska Coastal Current moderates the region's climate by providing warmer sea temperatures in winter and cooler ones in the summer. These ocean conditions, combined with high coastal mountains, form a cool, wet environment. Land temperatures are within a narrow range, fluctuating on average by only 24° Fahrenheit between winter and summer. It is cloudy much of the year, with abundant precipitation draining into over 40,000 miles of streams and 20,000 lakes and ponds. The precipitation – mostly snowpack – fills the region's non-glacial watersheds.

Marine weather patterns are important to productivity. Winter storms mix the water column and distribute nutrients. As weather calms in the spring and days get longer, boundary layers form in the water column creating lenses of nutrient-rich water of suitable temperature for the plankton blooms



Southeast Alaska is one of the wettest areas in the United States. Graphics credit: Jacobs, A. & R. Thoman. 2020. Drought in a rainforest ... How can that be?

that form the basis for overall marine biological productivity. The Pacific Decadal Oscillation, which shifts oceanic circulation patterns, creates extended warm and cold phases that also affect productivity. Inter-annual and inter-decadal climate variability and associated ecological fluctuations govern positive and negative changes in the abundance and distribution of marine fishery resources.

Key Habitats

The key habitats that comprise Southeast Alaska's SeaBank are coastal-temperate rainforests, rich estuaries, freshwater aquatic ecosystems fueled by run-off from glaciers precipitation, and the near-shore and off-shore marine waters.

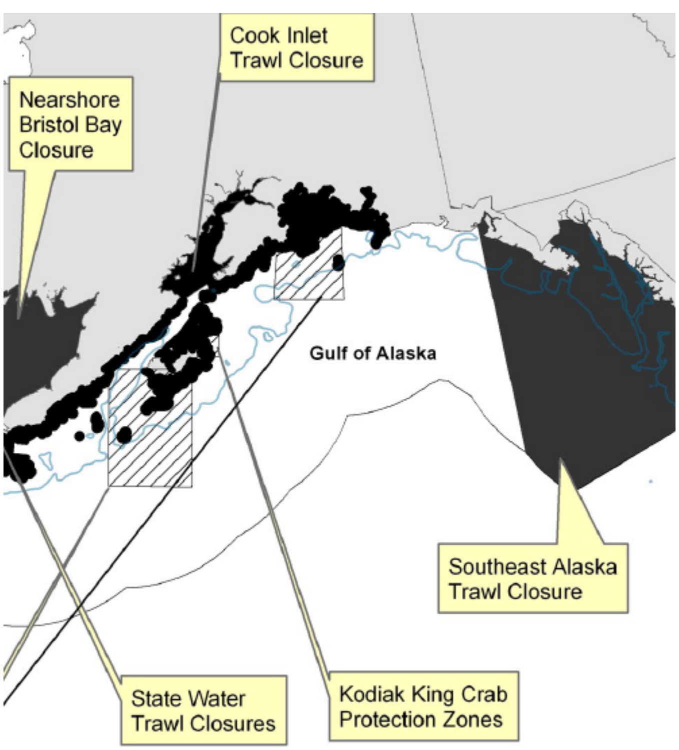
Coastal-temperate rainforests are globally significant ecosystems and provide habitat for a large number and diversity of species. Southeast Alaska and coastal British Columbia comprise the largest temperate rainforest on the planet and support fish and wildlife species that are no longer abundant in other parts of the Pacific Northwest. In addition to fish and wildlife values, the forest sequesters carbon in trees, soils and plants.

Major freshwater aquatic ecosystems include large transboundary watersheds on the Southeast Alaska mainland – the Alsek, Chilkat, Taku, Stikine and Unuk Rivers flow from British Columbia into Southeast Alaska. The Stikine is the largest watershed, encompassing 19,000 square miles. The Alsek and Taku watershed both encompass 5,000 square miles. Glacial watersheds are distinct from watersheds filled by precipitation and account for nearly a third of the freshwater discharge in Alaska. Nearly half the water flowing into the Gulf of Alaska comes from glaciers and ice fields.

Southeast Alaska has roughly 18,000 miles of marine shoreline. Most of the shoreline is a combination of rock, sediment (such as sand and gravel flats), or steep, rocky cliffs. Near shore habitat in central and southern Southeast Alaska consists of rocky shores, protected inlets and deep fjords, large kelp beds, and sandy bays. The northernmost outer coastline includes the outer coast of Glacier Bay National Park and 143 miles of exposed rocky shoreline with few accessible coves, glaciers that calve into the ocean, and a backdrop of steep mountains.

The near shore continental shelf is rocky, but in most areas tapers to a broad flat plain 2-10 miles wide with a depth ranging from 100' to 600' before transitioning to a steep, highly convoluted continental slope. The slope region is 2-3 miles wide, and the water depth rapidly transitions from 600' to 5,000' feet before the seafloor flattens into the abyssal plain. The proximity of the productive deep-water shelf/slope region to shore is a unique feature of the Eastern Gulf of Alaska, and one that makes the deep-water portions of SeaBank's fishing grounds accessible to small-scale fishermen. *These coastal seas occupy a small portion of the ocean but provide nearly a third of global marine production* including high fisheries yields and coastal wetlands.

One of SeaBank's notable marine assets is a large no-trawl area encompassing 526,000 square nautical miles.



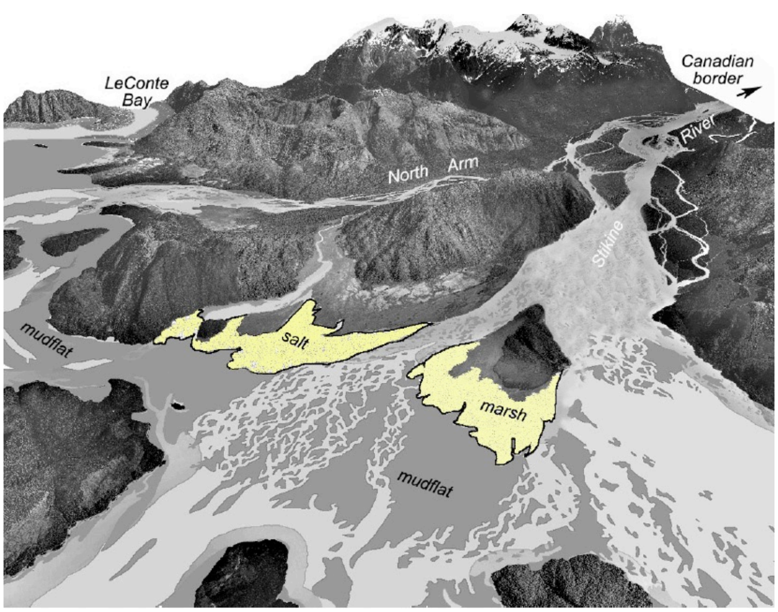
The Southeast Alaska trawl closure area is the largest area off the Alaska coast and protects coastal communities from environmental harms such as habitat loss and trawl bycatch of high values species caught by local fishermen. Graphics credit: Witherell, D. & D. Woodby. 2005. Application of Marine Protected Areas for sustainable production and marine biodiversity off Alaska. North Pacific Fishery Management Council and Alaska Department of Fish and Game.

Wave energy is the dominant influence for most of the shoreline. Wave-structured habitats are not as ecologically rich as estuaries and their coastal wetlands. Roughly 12 percent of the shoreline mileage is high value estuarine habitat – partially enclosed coastal water bodies where freshwater and saltwater meet. The different tidal zones consist of salt marshes and seagrasses, bare tideflats, and algal beds with barnacles and mussels.

On a global scale, estuarine and coastal ecosystems are heavily over-utilized. On the Pacific Coast, losses include half of the estuarine habitat in British Columbia and over two-thirds of the estuaries in Puget Sound. Additionally, a rapid global loss of coastal wetlands includes half of the salt marshes and nearly a third of the seagrasses. Global loss of seagrass areas continues at a rate of 5 - 7 percent annually. SeaBank estuary values are at risk to climate change vulnerabilities over time.

Natural resource economists identify estuaries as the highest valued ecosystems. Southeast Alaska's 350,000 acres of estuaries – two percent of its land area – produce $15,000 per acre in ecosystem services each year ($5.3 billion). This disproportionate ecological importance is because these areas are where terrestrial, freshwater and marine ecosystems connect and provide heightened ecosystem services.

Southeast Alaska's estuaries are globally significant because of their high productivity. There are 12,000 of them, of which nearly 3,000 are roughly 250 acres in size. The largest estuaries are on the mainland, including the 21,000-acre Stikine River Delta. The Yakutat Forelands are a large estuarine system that includes the 13,859 acre Dangerous River estuary and the 6,811 acre Dry Bay estuary. Two of the region's other five largest estuaries are on Kupreanof Island at Duncan Canal (9,446 acres) and Rocky Pass (5,823 acres). Those estuaries drain freshwater systems that are much smaller than transboundary rivers. The Chilkat River, Gustavus and Taku estuaries are all larger than 4,000 acres.



The Stikine River Delta is the region's largest estuary. Graphics credit: Carstensen, R. 2007. Coastal habitats of Southeast Alaska. Ch. 5.3 in Schoen, J. & E. Dovicihin, eds. Audubon Alaska and The Nature Conservancy. 2007. Coastal Forests and Mountains Ecoregions of Southeastern Alaska and the Tongass National Forest: A Conservation Assessment and Resource Synthesis.

Estuaries provide high value for much of SeaBank's's fish and wildlife assets. Estuaries support a diverse fish species, as spawning and nursery areas for finfish and forage fish, shellfish and other invertebrates. They also provide habitat features such as breeding area, refuge and forage for migratory birds, sea birds, marine mammals and terrestrial mammals.

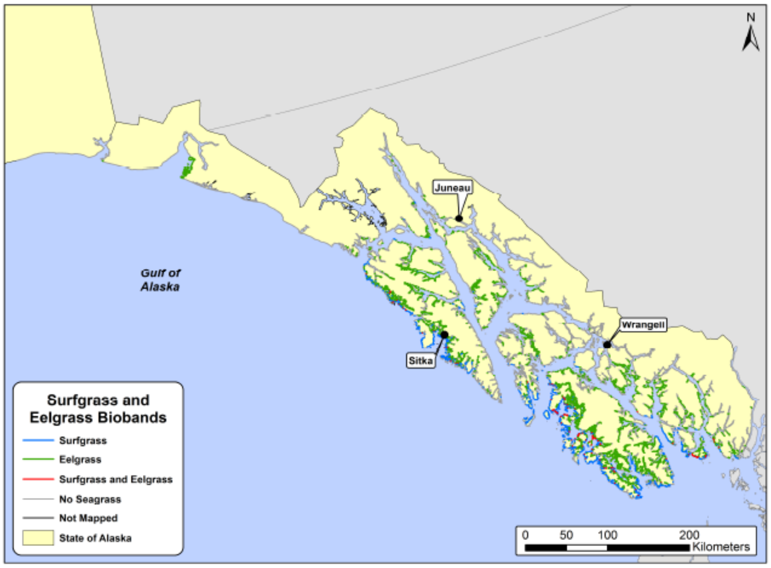
Estuaries support ocean health and water quality as a buffer between ocean and land, filtering sediment and pollutants from freshwater before they enter the ocean. Watersheds that drain into areas with substantial estuarine habitat have enhanced ecological value. One of the most widely known ecosystem services provided by estuaries is nursery habitat for fish.

> The list of terrestrial and marine species that make seasonal use of estuaries, or at least benefit indirectly from the energy exchange taking place there, is basically the complete flora and fauna of the Southeast (Alaska) bioregion.
> -Richard Carstensen, 2007. Costal Habitats of Southeast Alaska

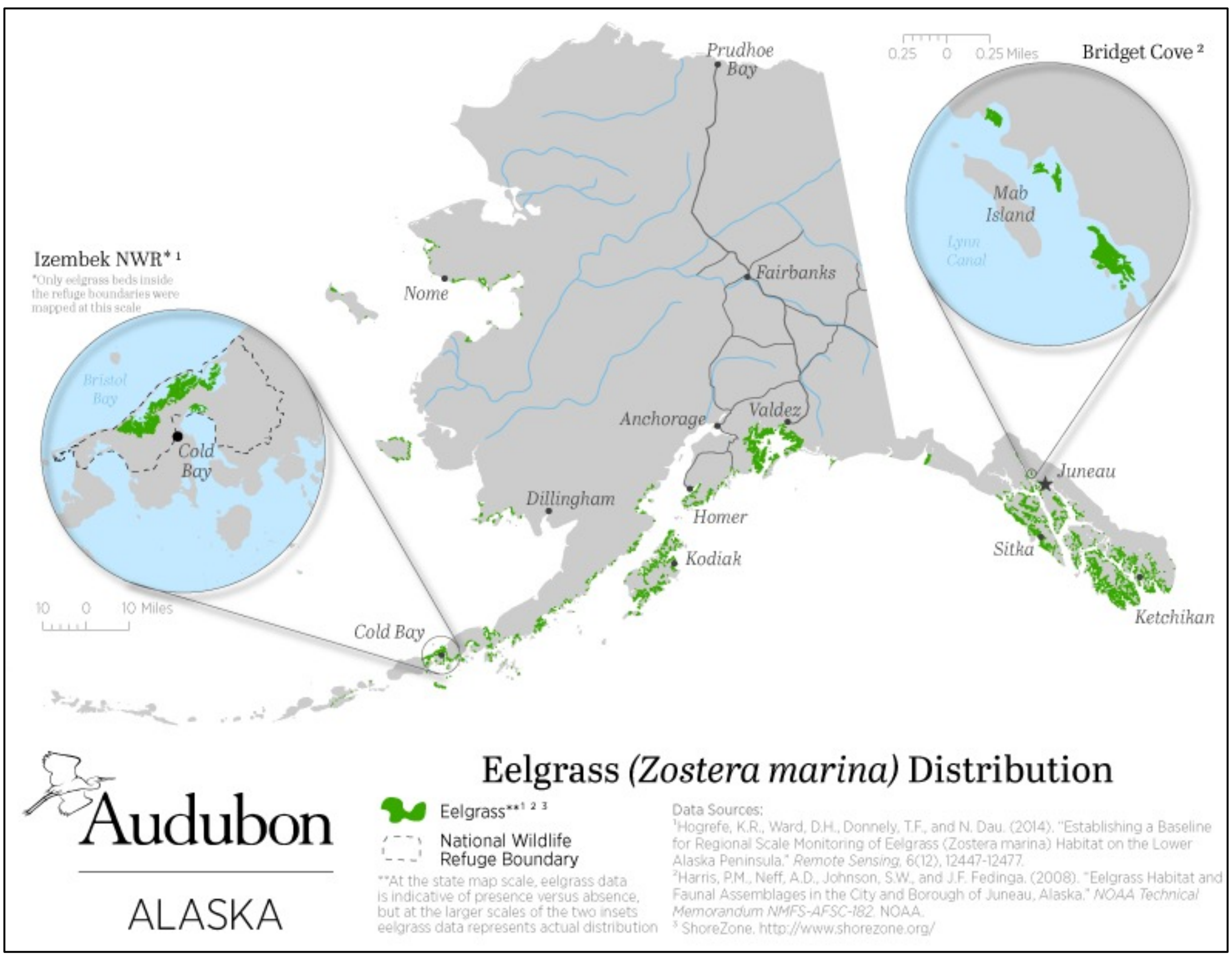
Salt Marsh, Sea Grass and Kelp Forests

Estuarine vegetation such as salt marsh grasses, seagrass meadows and kelp forests provide critical ecological functions, hosting high densities of fish and invertebrates and protecting coastal areas by stabilizing sediments and attenuating waves.

Salt marshes are a diverse grassland plant community that occupies the upper intertidal zone at the border of an estuary.   The marshes utilize wave-protected shorelines and grow behind barrier island systems and in bays and estuaries. There are 42,000 acres of salt marshes in Southeast Alaska, making them the most common shoreline plant community. They occur continuously or in patches along at least 8,000 shoreline miles.   Ecosystem services provided by salt marshes include coastal protection from waves and storm surges. Salt marsh habitat is a kingpin for economically and ecologically important fish species, by providing protection from larger fish predators and plant material for foraging. Salt marshes purify river flow and terrestrial runoff of excess nutrients, improving water quality entering the estuary and benefitting adjacent ecosystems such as seagrass meadows.



Graphics Credit: Coastal & Ocean Resources Inc. & Archipelago Marine Research Ltd. 2011. Coastal Habitat Mapping Program. Southeast



Seagrasses such as eelgrass grow beyond salt marshes in wave-sheltered shallow marine habitats such as the lower intertidal and nearshore subtidal portions of estuaries. Seagrasses provide multiple ecosystem services and are one of the most highly valued ecosystems, at $19,004 per hectare per year.

Eelgrass is the most widespread seagrass species in the northern hemisphere and most common seagrass along the North American Pacific coast. Most of Southeast Alaska's eelgrass meadows grow in soft sand and mud substrates in protected bays and inlets that have freshwater influence. Peak growth occurs in the late spring. The 3,500 shoreline miles of continuous or patchy eelgrass meadows in Southeast Alaska likely exceeds that of the combined shorelines in Oregon and Washington. The outer coast also contains surfgrass meadows which have higher wave tolerances.

Seagrass meadows provide critical ecosystem services for coastal communities, economies and lifestyles. They function as one of the planet's most productive ecosystems and provide multiple ecosystem services: supply of food; coastal protection and erosion control; water purification; maintenance of fisheries; carbon sequestration; and focal points for tourism, recreation, education and research. Eelgrass is one of the most important habitats in Southeast Alaska's estuarine ecosystems. Dozens of marine finfish, commercially utilized invertebrates such as crab and shellfish and numerous other invertebrates occupy eelgrass habitats in part or all of their lifecycles. Southeast Alaska's eelgrass meadows are its top estuarine habitat for species diversity, above kelp forestss and salt marshes. In areas where eelgrass is less common, such as the mainland and adjacent inside waters, the beds that are present may be disproportionately important for local fish populations.

Log transfer facilities and log storage destroys eelgrass and other estuarine vegetation.
Photo credit: Colin Arisman.

Eelgrass is easily harmed by coastal development and environmental changes, whether in nearshore waters or on adjacent uplands. Direct disturbances – such as dredging and marine construction or scouring from boat propwash and excess sediment or other pollution from mining, agriculture and other industrial activity – are a major cause of seagrass declines. Excessive nutrient inputs can create estuarine vegetation dead zones, in turn causing fish mortality. Most shoreline development in Southeast Alaska occurs in the vicinity of larger communities, so shoreline development is not a top threat. The major threat in more remote areas is deposition of logging waste, which has been known to destroy eelgrass habitats.

Kelp forests are the other major shoreline habitat. These forests are also highly productive coastal ecosystems and provide habitat for many invertebrates and fish communities. Canopy kelps (bull kelp, (*Nereocvtis luetkeana*) giant kelp (*macrocsystis integrifolia*), and dragon kelp(*alaria fistulosa*) grow on rocky substrates and are the primary vegetation on over a third of shoreline, covering 6,200 miles. Most kelp sites are more oceanic and located in exposed locations at mouths of bays.

Nurseries of the sea

Estuaries provide protection, nutrient exchanges and abundant food sources for fish and shellfish, including – near the base of the food chain – numerous forage fish species such as herring, eulachon, Pacific sand lance and capelin. The presence of juvenile fish dominates in estuaries, as numerous fish species move there, grow in mass and then move offshore. Three-fourths of all fish caught in Alaska utilize the region's estuaries and estuarine vegetation during some part of the life history, including major groundfish species such as halibut, sablefish, pacific cod and rockfish. Juvenile sablefish occur only in a few estuaries, heightening the value of those locations.

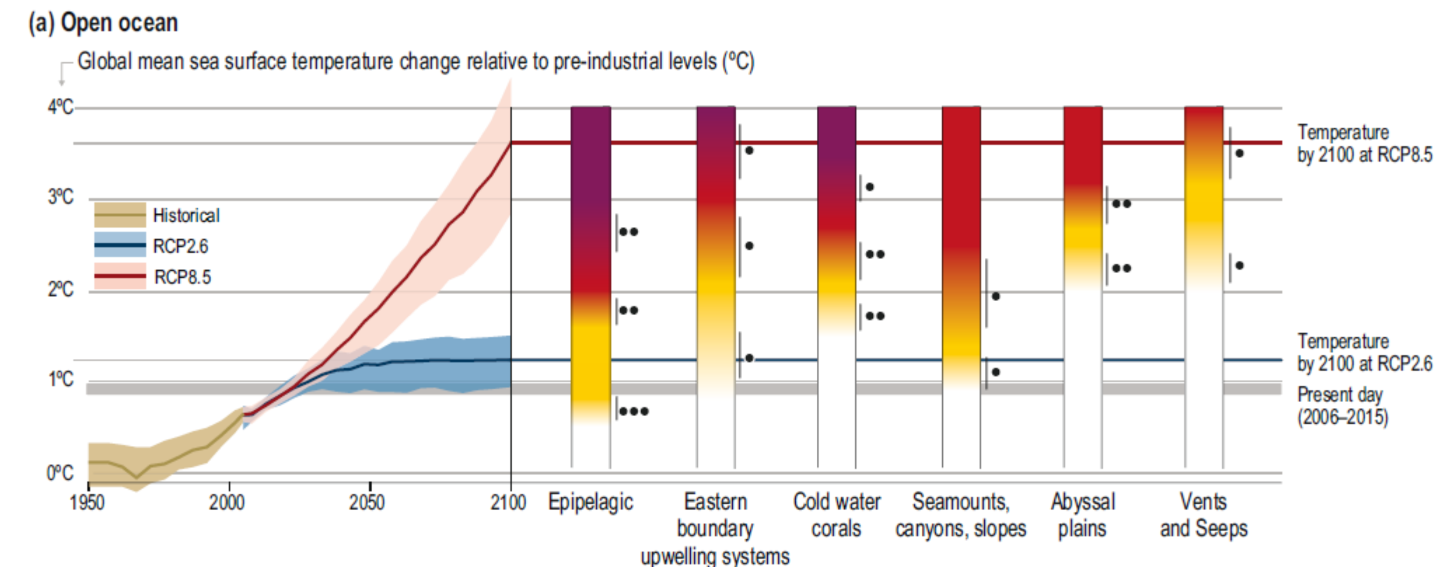
Salmon pass through estuaries twice, as this is transitional habitat between the marine and freshwater environments that salmon use during outmigration as smolts and then when returning to spawn. Juvenile salmon rear extensively in estuaries. Multiple studies of juveniles show that their initial growth and survival depend on the capacity of these systems to produce forage and provide protection from predators.

Salmon fishery harvest data often corresponds to nearby productive estuaries. The Ahrnklin River estuary near Yakutat rears chinook, coho and sockeye fry, supporting harvests of over 140,000 sockeye and coho worth $1.3 million to Yakutat fishermen. The Kelp Bay estuary on eastern Baranof Island is one of the more unique estuaries, draining the non-glacial Clear River and glacial Glacier River into the same coastal wetland, supporting birds, fish, deer and bear and tens of thousands of salmon. The Port Houghton salt chuck is one of just two salt chucks on the mainland and supports all five salmon species, including a substantial steelhead run. The Rusty River that drains into it is often the largest pink producer in Frederick Sound, with a peak escapement of half a million fish.

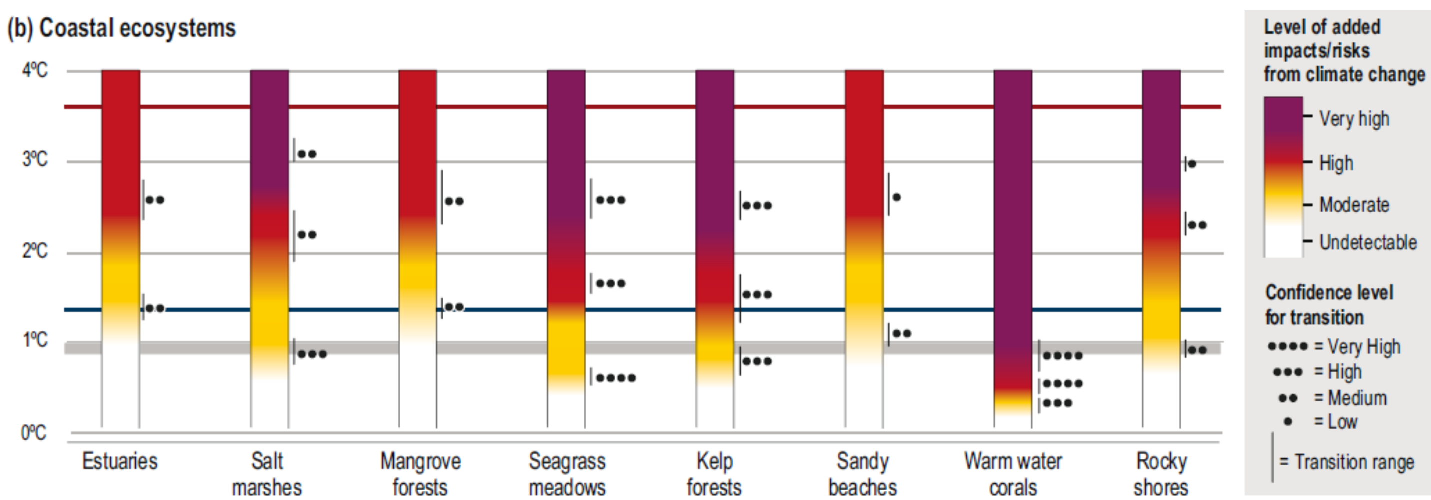
Seagrass meadows such as Sea Bank's abundant eelgrass – the primary native seagrass – are productive habitats that support a high abundance and diversity of Southeast Alaska's marine species, including dozens of forage fish and commercially important species. Juvenile fish are dominant in surveys of Southeast Alaska's eelgrass meadows in different parts of the region, showing their importance as nursery areas that provide food and predator protection.

In particular, surveys have found large numbers of juvenile pink, chum and chinook salmon in estuarine eelgrass meadows where they grow and transition to the marine environment. They occupy eelgrass meadows extensively during May and June and feed on a rich invertebrate community that can comprise up to 80 percent of the juvenile chum salmon diet. Juvenile salmon grow rapidly during this critical life cycle phase, which is critical because larger fish are more likely to survive early marine residence. Studies show that large scale eelgrass loss in estuaries often decrease invertebrate densities, reduce salmon survival rates and drastically diminished salmon returns. The importance of eelgrass goes beyond sustenance for juvenile salmon, because it also supports rich communities including, for example, mussels, shrimps and crabs. Dungeness crab and spot shrimp are the most common invertebrates in some areas and use the meadows as nursery habitat. Pacific herring use eelgrass as a spawning substrate.

Climate change severely threatens estuarine systems and coastal vegetation. The Intergovernmental Panel on Climate Change (IPCC) and scientists who study coastal ecosystems identify seagrass meadows and kelp forests as some of the world's most vulnerable ecosystems. Climate change will add to the loss of a third of coastal vegetated ecosystems degraded by development, pollution and other anthropogenic causes over the past 50 years. The two kinds of ecosystems have low or moderate adaptive capacity, including low ability to relocate, and high sensitivity to ocean warming, marine heat waves, and acidification. The IPCC projects that kelp forests and temperate seagrasses such as eelgrass will retreat with more frequent temperature extremes. Impacts to these systems will increase biodiversity loss and alter ecosystem structure and functioning. Recent IPCC studies suggest kelp forests are already experiencing large-scale changes, with decreases of roughly two percent a year over the past half century, mostly due to ocean warming and marine heat waves which can cause mass mortality events because of extreme temperature increases. The annual rate of global seagrass loss is between five and seven percent.

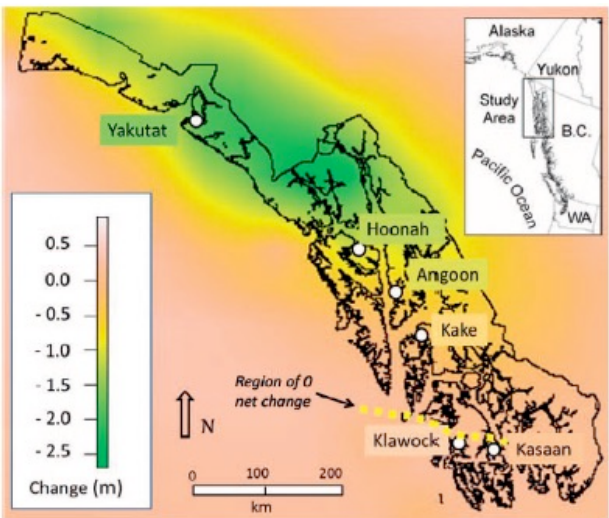


Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson, 2019: Changing Ocean, Marine Ecosystems, and Dependent Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.



The main risk to tidal salt marsh systems globally is sea level rise. However, in northern Southeast Alaska, the rate of sea level fall, or sea level lowering, is outpacing sea level rise. "Postglacial isostatic rebound" occurs when land rebounds after glaciers and icefields melt and retreat. The rates of uplift are as high as 1.2 inches annually in some portions of the region, with Yakutat experiencing the greatest rate of uplift in the world. This land emergence has significant consequences for protected bay coastlines. and naturalists project a rapid loss of coastal marshes. Terrestrial "uplift meadows" will replace salt tolerant grasses in the salt marsh zone followed by an eventual transition to spruce forests. Northern Southeast's largest uplift meadows are emerging in estuaries in the vicinity of Icy Strait and Lynn Canal – near Gustavus, Haines and Hoonah.

The expected consequent sea level lowering of between two to eight feet throughout much of this subregion is projected to cause a 30 percent decrease in estuary shoreline lengths there over the next century. The greatest change in shoreline lengths is expected to occur in low slope gradient shorelines within protected bays and estuaries – particularly those dominated by eelgrass. Researchers project a cumulative loss of 14 percent of eelgrass in Southeast Alaska over the next century, with the greatest loss – roughly a third – in productive estuaries near Kake. Some of the southern portions of the region may receive increases in shoreline eelgrass length such as near Kasaan and Klawock.



Substantial sea level lowering is occurring between Yakutat and Kake due to post-glacial rebound. Graphic credit: Johnson, A.C., Noel, J., Gregovich, D.P., Kruger, L.E., and Buma, B. 2019. Impacts of submergins and emerging shorelines on various biota and indigenous Alaskan harvesting patterns. Journal of Coastal Research, 35(4) 765-775

Key resources produced by the Southeast Alaska's SeaBank

Overview

Southeast Alaska's global reputation for its beauty and wildness often receives more recognition than its economic value. If reserved for well-managed and sustainable uses, SeaBank capital will provide long term annual dividends – ecosystem services and resources – that enrich residents, visitors, the national economy and the planet itself. The Gulf of Alaska is a highly productive marine ecosystem of global significance, providing habitat for fish, shellfish and marine mammals. In years with strong salmon returns, fishermen can harvest over 300 million pounds of SeaBank seafood worth over a billion dollars that support more than 10,000 jobs. Prior to 2020, over 1 million tourists visited Southeast Alaska each year, supporting nearly 8,000 jobs and generating another billion dollars to the local economy. Consumptive and non-consumptive uses of the region's wildlife are valuable for both quality of life in the region and the economy. Alaska residents and visitors spend over $300 million on hunting and wildlife viewing in the region.

The Resources

Southeast Alaska's marine environment and estuaries support numerous salmon, shellfish and finfish species. Fishermen harvest all five species of salmon, along with a plethora of other finfish, including halibut, sablefish, rockfish and herring. Shellfish, crab, and shrimp are also important for subsistence, sport and commercial purposes. Marine and terrestrial mammals have high value for subsistence, sport and personal use hunting and wildlife viewing. Southeast Alaska's coastal rainforests and estuaries are globally significant assets because of their carbon stores, biodiversity and other ecosystem benefits.

Climate Mitigation Resources: Blue Carbon and Green Carbon

Forests and oceans remove over half the carbon dioxide (CO_2) emitted into the atmosphere each year. Blue carbon is the organic carbon stored, sequestered or released from vegetated coastal ecosystems such as coastal wetlands. Green carbon is carbon captured through photosynthesis and stored in terrestrial plant biomass. Southeast Alaska hosts two ecosystems that are massive carbon sinks – meaning ecosystems of sufficient size to absorb substantial amounts of atmospheric carbon in which the rate of carbon sequestered exceeds the rate of carbon lost through respiration and export.

Southeast Alaska's living and dead plant biomass, sediments and organic soils store the region's carbon stocks (i.e. the quantities of carbon stored in a carbon pool). Major carbon pools – the ecosystems that have the capacity to store or release carbon – include eelgrass meadows and salt marshes and old-growth temperate rainforests. Scientists express the magnitude of carbon pools through various metrics, such as megagrams or metric tons (1.1 U.S. tons) per hectare (2.47 acres). Each U.S. ton of carbon stored in SeaBank ecosystems is equivalent to 3.67 tons of CO_2 if released into the atmosphere through logging or other forms of habitat degradation (whether resulting from activities or climate change).

Coastal Blue Carbon

Southeast Alaska's coastal wetlands are carbon sinks that capture and store carbon in salt marshes and seagrass meadows in soils, aboveground biomass such as leaves and stems, belowground biomass such as roots, and non-living biomass. The identification of coastal wetlands as major carbon sinks is a relatively recent development. The carbon sequestered and stored by three coastal vegetated ecosystems – salt marsh and seagrass ecosystems and tropical mangroves – is "blue carbon." These ecosystems are responsible for significant CO_2 uptake and long-term carbon storage and sequestration. This ecosystem service removes atmosphericCO_2 and then deposits organic carbon in estuarine sediments. The three blue carbon ecosystems cover two-tenths of a percent of the ocean floor but account for a third of oceanic carbon uptake and about half of the total carbon burial in the ocean.

Salt marshes and sea grasses store CO_2 for longer periods of time than terrestrial ecosystems. The living plants sequester carbon for decades or several centuries, but in coastal soils once carbon is captured it can remain in place for millenia, building in large carbon stocks. The oldest seagrass carbon stocks date back to the end of the Ice Age. The top sequestering seagrass system, of *Posidonia oceanica* near Spain, has stored carbon for 6,000 years. Tidal salt marsh systems in northern New England have stored carbon for 3000 to 4000 years. This long-term storage advantage results from anaerobic conditions in coastal sediments (low or no oxygen) which prevent the carbon from oxidizing.

The common high rate of carbon burial per unit area and large amount carbon stored in small areas has spurred scientific research showing that some of these systems sequester and store carbon at rates that may surpass adjacent terrestrial forests. Though the capacity of coastal wetlands to store blue carbon is highly variable, on average salt marsh and seagrass areas store more carbon per hectare than most temperate rainforests.

Globally, the high carbon capture rates of salt marshes result in sequestering millions of metric tons of blue carbon annually, and as much as 6.5 billion metric tons of blue carbon are already stored in sediments. Estimates of the carbon stored in an average salt marsh range from 162 to 255 metric tons of carbon per hectare, exceeding the storage rate of tropical and temperate forests. Applying that range of averages here, the present storage in Southeast Alaska's 17,000 hectares of salt marshes may be between 2.7 and 4.3 million metric tons of carbon. A recent study of New England salt marshes showed that a salt marsh area of 14,000 hectares sequestered over 15,000 tons of carbon in a year – an amount equivalent to emissions from 1.7 million gallons of gasoline consumption (enough fuel to power an average car around the equator more than 1600 times).

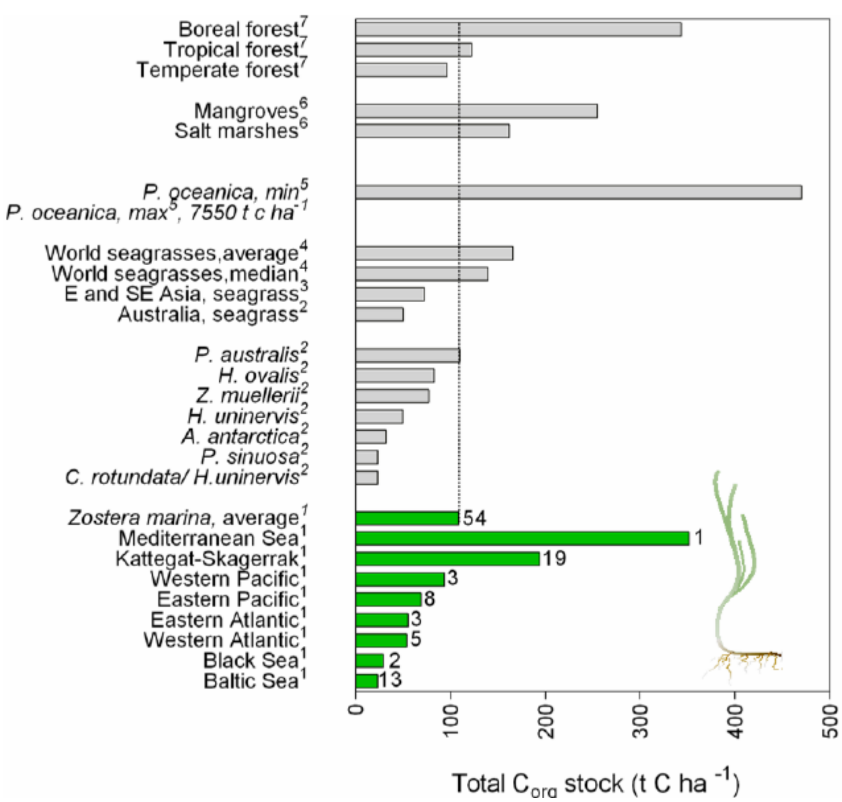
Seagrasses use CO_2 dissolved in the seawater to grow, and once the plant completes its life cycle, carbon accumulates in the sediment. Conservative estimates are that the maximum storage capacity of seagrass meadows is between 4.2 and 8.4 billion tons of organic carbon, globally. There are between 70,000 and 230,000 square miles of seagrass meadows globally, with the potential to store storing between half a billion and billion metric tons of carbon each year.

Eelgrass, the most prevalent seagrass in Southeast Alaska, has relatively rapid growth rates and forms dense meadows in intertidal and subtidal areas here and across the temperate northern hemisphere. It is the most widespread seagrass and a significant contributor to global blue carbon stocks. Researchers are working to resolve uncertainties about eelgrass carbon sequestration relative to other studied seagrasses. Around the world, many estimates of seagrasses' blue carbon capture rates derive from studies of tropical and subtropical seagrasses. Some studies of eelgrass carbon stocks in Pacific Northwest sites found much lower values. Measurements of seagrass carbon burial rates are highly variable, even for the same species. The need for additional site-specific data has made eelgrass sequestration and storage rates an emerging research and mapping priority.

Recent research covering multiple sites in the Pacific and Atlantic Oceans and adjacent seas demonstrated extreme variability in eelgrass capture rates and carbon stocks but nonetheless identified an overall high value for carbon storage. Average eelgrass carbon stocks of 108 metric tons per hectare are lower than tropical seagrass systems but are comparable to many other blue carbon ecosystems and terrestrial forest ecosystems.

There are hotspots for blue carbon storage. The largest eelgrass carbon pool in the Mediterranean Sea stores nearly 352 metric tons of blue carbon per hectare – 15 times as much carbon per unit of area as the lowest sampled stocks in the Baltic and Black Sea. The Kattegat-Skaggerak region, a sea and strait that connect Scandinavia's North Sea with the Baltic Sea, is another hotspot, averaging 194 metric tons of stored carbon per hectare of eelgrass. The Kattegat-Skaggerak hotspot has some similarities to (insufficiently studied) Southeast Alaska in latitude and ocean exposure.

Numerous environmental factors influence the high variability in eelgrass sequestration capacity, including sediment characteristics, salinity, geomorphology, temperature, seascape configuration, wave height, water depth, turbidity, and light availability. Such variability exists for other seagrass species as well. Recent research suggests that meadow size, particularly if a meadow is large and continuous meadows such as at Kattegat-Skaggerak, may influence carbon sequestration capacity. Researchers are exploring these environmental variables for use as predictors for carbon sink capacity.



Graphics credit: Maria Rohr 2021. Rohr, M.E. 2019. Environmental drivers influencing the carbon sink capacity of eelgrass (Zostera marina). Åbo Akademi University, Turku, Finland.

While there is some effort to consider investing in blue carbon restoration projects, there is uncertainty about the stability of these systems under future regimes of temperature and changing sea levels. In many landscapes there are few suitable sites for seagrass meadows or salt marshes to relocate, due to developed shorelines or steep coastal landscapes. Where sea levels rise, toxic benthic or water pollution in new or existing estuarine ecosystems as a result of flooding in developed areas, is also a concern. Less than half of restoration efforts are successful, in large part because of environmental changes caused by loss or degradation of the original meadow. Even when successful, it may take several decades before the ecosystem again becomes a carbon sink.

Clearcutting is responsible for a significant amount of greenhouse gas emissions. photo credit: Colin Arisman

These challenges lead researchers to suggest that conservation is preferable to restoration as a climate change mitigation strategy. Coastal wetlands, like forests, become sources of CO_2 emissions when degraded by industrial development or other causes. Either the loss of sequestration capacity or the emission of stored blue carbon as CO_2 emitted into the atmosphere – or both – is a shift from carbon sink to carbon source. Some research estimates the global cost of lost tidal marshes due to climate change will be billions of U.S. dollars per year.

SeaBank's terrestrial vegetation – that is, coastal temperate rainforest – is another globally significant carbon sink. Industrial logging – one of the major drivers of global forest and biodiversity loss – undermines one of the most effective climate change mitigation strategies – the conservation of green carbon. Forests contain the largest store of terrestrial carbon by accumulating significant stocks of carbon, both above and below ground over time. Land use change, including logging, accounts for roughly a quarter of anthropogenic greenhouse gas emissions. Because of this impact, reducing emissions from logging and other causes of forest degradation is as urgent as halting fossil fuel use. Some scientists have likened logging in Southeast Alaska to smoking cigarettes because of the climate change impacts.

High rates of global forest loss heighten the importance of Southeast Alaska's rainforest and the adjacent Great Bear rainforest in British Columbia – two of just four remaining relatively intact temperate rainforests in the world. Temperate rainforests are mid-latitude forests, usually found in wet coastal areas between 25° and 50° latitude either north or south of the equator. Mean annual temperatures range between 32° to 63°F. Southeast Alaska is part of the Pacific Coastal Temperate Rainforest which extends north from the coastal Redwoods in California and comprises a third of world's entire temperate rainforest biome.

Forests use nature's own technology to continuously capture and store a quarter of the CO_2 humanity emits into the atmosphere each year. This technology starts with the sequestration and accumulation of atmospheric CO_2 due to tree growth. Sequestration is the process through which trees and other plants capture and convert atmospheric CO_2 into terrestrial organic carbon and store the CO_2 as biomass (e.g. vegetation). Forests store the accumulated carbon in five pools: aboveground biomass (leaves, trunks and limbs), below ground biomass (roots), deadwood, detritus (fallen leaves, stems) and soils.

The Pacific Coastal Temperate Rainforest has some of the densest terrestrial carbon stocks in the world and has functioned as a carbon sink for roughly a dozen millenia – since the last Ice Age ended. Old-growth forest stands in Southeast Alaska store the most carbon – between 260 - 360 metric tons of carbon in biomass per hectare. Other Pacific Coastal temperate rain forests store over 200 metric tons per hectare – more than eastern U.S. forests which store between 100-200 metric tons per hectare. The disproportionate amounts of carbon storage in temperate rainforests makes them individually and cumulatively critical to climate regulation.

...even though the overall global footprint of this rainforest biome is relatively small, the climate regulation properties of these forests - because of their enormous carbon stores, along with their myriad biodiversity and ecosystem benefits, are globally significant and irreplaceable.

DellaSala, D.A. 2019. Analysis of carbon storage in roadless areas of the Tongass National Forest. GEOS Institute. 2019.

Southeast Alaska's Tongass National Forest – the largest national forest in the U.S. – is irreplaceable as a carbon sink and stores more green carbon than any national forest – an estimated 650 million tons in aboveground biomass (live trees, snags & logs). That carbon is equivalent to 2.4 billion tons of CO_2. There are 9.7 million forested acres in the Tongass National Forest. Live trees remove an estimated 2,800 pounds of CO_2 per acre per year. The live tree carbon storage capacity of 119 metric tons per hectare alone is nearly twice as high as other U.S. forests.

Because of the high proportion of Southeast Alaskan forest that is on public land, many researchers believe a focus on public forest conservation and carbon sequestration there could substantially increase the amount of carbon it can store over the course of the 21st century. Ending logging on public lands on all national forests, especially our Tongass National Forest, is a key component of a sequestration-based strategy.

This map displays stored carbon in biomass per hectare in Southeast Alaska forests. Graphic credit: DellaSala, D.A. 2019. Analysis of carbon storage in roadless areas of the Tongass National Forest. GEOS Institute. (adapted from Buma and Thompson 2019).
Megagrams per hectare:

Large old-growth trees have the highest carbon storage capacity.
photo credict: Colin Arisman

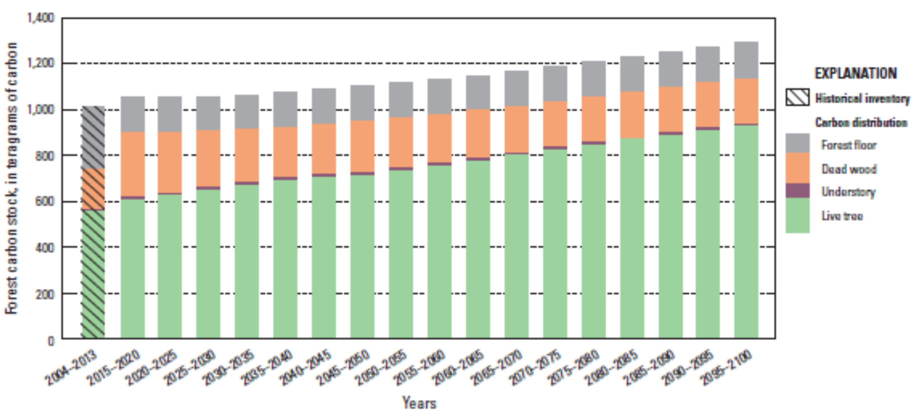
Conserving assets such as Southeast Alaska's abundant large old-growth trees and their high carbon storage capacity is one of the most important components of this climate mitigation strategy. Trees accumulate carbon continuously so that the largest, oldest trees store a disproportionate amount of carbon over time. The large leaf surface area, thick tree trunks and root wads hold centuries of accumulated carbon. The largest one percent of trees may store up to half of the stand level carbon. Maturing forests are also critical because the increase in the carbon balance is highest for trees between 100 and 200 years old and forest composition will soon include large diameter trees.

The Tongass National Forest is not reaching its full sequestration potential in large part because of recent and ongoing industrial scale logging. Cutting old growth creates an initial release of CO_2 into the atmosphere which can continue for years. Regrowing stands take at least half a century before any meaningful increase in live tree storage occurs. Direct and indirect CO_2 emissions caused by logging have negated roughly ninety percent of the atmospheric CO_2 removed by live trees through growth and recruitment.

Planned federal logging in Southeast Alaska under the 2016 Forest Plan would generate emissions equivalent to over 4 million vehicles annually on Alaska roads for the next century. It would also reduce carbon storage capacity. The recent exemption of the Tongass National Forest from Roadless Rule prohibition on logging worsens these significant climate and biodiversity risks.

The Tongass National Forest stores 2.8 Petagrams of carbon. A petagram is a billion metric tons, or a gigaton, or 2.2 trillion pounds. U.S. coal plants emit 1.1 billion metric tons of CO_2 each year. According to NOAA's Pacific Marine Environmental Laboratory: To put this in perspective, think about a trail of railroad hopper cars full of coal. One hopper car will hold about 100 tons of coal which is about 80% carbon. If that hopper car is about 60 feet long (including the couplings), then a train hauling one petagram of carbon as coal would have to be about 156,500 miles long. This railroad train would stretch around the earth more than six times.

As shown below, if land managers adopted a climate mitigation strategy that prohibited planned logging on public lands, Alaska coastal forest carbon stock – mostly in the Tongass National Forest, would increase by 27 percent (276 million metric tons) by the end of the century, from just over a billion metric tons to 1.3 billion metric tons. The biggest increase is for live tree carbon, which would increase by 68 percent.



Graphics Credit: Zhu, Zhiliang, and McGuire, A.D., eds. 2016, Baseline and projected future carbon storage and greenhouse gas fluxex in ecosystems of Alaska: U.S. Geological Survey Professional Paper 1826, 196 p Data source: USDA Forest Service Forest Inventory and Analysis Programt

Conclusion – "no regrets" climate mitigation:

Conserving coastal blue carbon and terrestrial green carbon ecosystems is a "no regrets" mitigation policy. Coastal wetlands provide numerous ancillary ecosystem services, such as benefits to biodiversity, storm protection and fisheries. Forests provide similar services such as water security and protection against extreme weather events. Scientists assert that managing the area for climate mitigation has broader benefits by maintaining these and other linked ecosystem services and biodiversity. Southeast Alaska's old-growth forests also act as a climate buffer by providing a more stable microclimate – old-growth stands (compared to logged areas) reduced maximum summer and spring air temperatures as much as 2.5° C.

Salmon

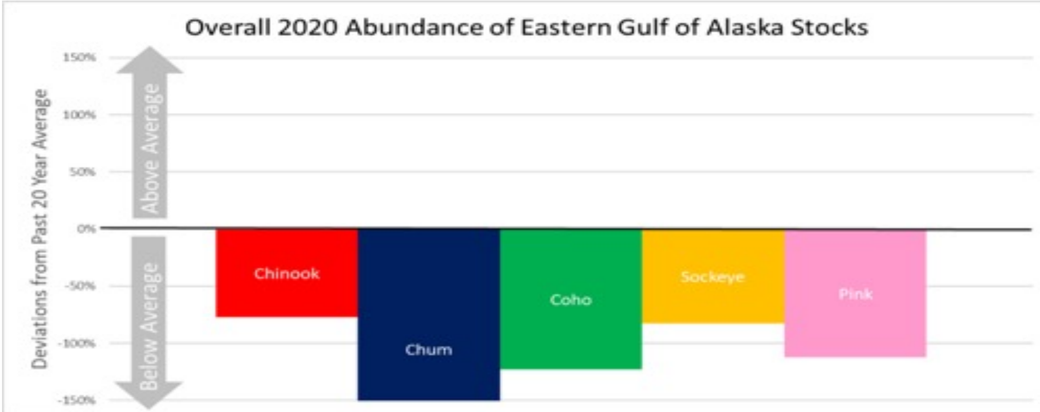
Among SeaBank's most important annual dividends are productive commercial, sport and subsistence salmon fisheries. Assets include nearly 14,000 stream miles of anadromous or potentially anadromous salmon habitat. Approximately 5,500 individual streams and tributaries support salmon with varying levels of productivity. The transboundary rivers, the Alexander Archipelago island ecosystems, and the northern outer coast from Cape Spencer to Cape Suckling are the three broad and distinct areas that produce salmon. The range of habitats normally buffers against variability in marine and freshwater conditions.

Salmon rely on both marine and freshwater environments. Spawning and rearing mostly occur in freshwater streams. Juvenile fish then grow in the estuaries before migrating to the ocean to feed and mature before returning to natal streams to reproduce. Most watersheds support multiple salmon species. Each species utilizes available habitat in different ways and at different times – pink and chum salmon spawn first, beginning in early July. Adult coho return to the outer coast during the summer and spawn throughout the fall. Sockeye and Chinook return to spawn in late spring/early summer.

Forests are vital to the productivity of aquatic ecosystems by controlling sediment inputs and regulating stream temperatures. The productivity of marine habitat is variable and cyclical, increasing the importance of freshwater habitat and the buffering of forests in maintaining salmon populations during times of unfavorable ocean conditions.

Major mainland rivers – the Alsek, Chilkat, Stikine, Taku and Unuk – produce all five salmon species and can support harvests of well over a million fish per year. Some of the most economically valuable salmon species – coho and sockeye salmon – comprise the largest numbers of fish spawning in these rivers. The two most prevalent species in island ecosystems are coho and pink salmon. The Tongass National Forest produces 95 percent or more of Southeast Alaska's pink salmon harvest and roughly two-thirds of the coho harvest.

The most productive island ecosystems for salmon are north Prince of Wales Island, Kupreanof/Mitkof Islands, Revilla Island and East Chichagof Island. Prince of Wales Island provides over a thousand miles of pink salmon streams, eastern Chichagof Island has 825 stream miles and Revilla Island/Cleveland Peninsula and Kupreanof/Mitkof Island each provide over 500 stream miles. Prince of Wales Island has more coho salmon habitat than any other biogeographic province in the region. 2020 was an extremely poor year for returns of all five SeaBank salmon species:



Graphics credit: Alaska Department of Fish and Game Undersea World of Salmon and Sharks. Available at:

https://www.facebook.com/ADFGUnderseaWorldOfSalmonAndSharks

SeaBank Salmon Species

Chinook salmon (*Oncorhynchus tshawytscha*)—Chinook salmon, Alaska's state fish, are the largest and most highly valued Pacific salmon species for commercial, recreational and subsistence fisheries. Most wild spawning Chinook found in Southeast Alaska coastal and inside waters are coast-wide mixed stocks that spawn in Pacific Northwest rivers or mainland transboundary rivers shared by Alaska and British Columbia. Southeast Alaska hatcheries also produce significant numbers of Chinooks.

Pacific coast Chinooks live between 3 and 7 years. Juveniles spend 1 to 2 years in freshwater before entering the marine environment and migrating north along the west Pacific coast where the fish would spend between one and five years feeding and growing in the marine environment. There has been a long-term and consistent decline in the average size of mature, wild Chinook over the past 4 decades. The changes are most notable in Alaska, with recent studies estimating size declines of roughly ten percent. Environmental changes caused by a warming climate and highgrading of large fish by a rapidly growing orca population are common hypotheses. Scientific studies show that interactions with hatchery fish do not explain the decline.

One known factor in the size decline is a major change in age composition over the 21st century. There are fewer older and large fish in the mix, particularly fish that spend four or five years at sea. Overall, Chinook are spending less time in the marine environment, and returning to spawn at younger ages. The loss of older and larger fish is a population viability concern due to the higher productivity and fitness of older, larger fish.

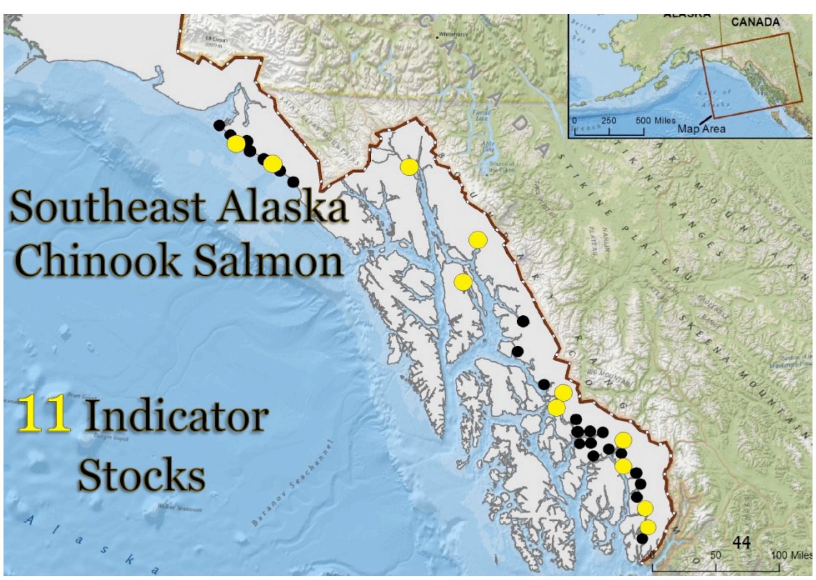
Mainland transboundary river systems and their tributaries provide habitat for most Chinook stocks that spawn and rear in the region. Most juvenile

Chinook in the region rear in freshwater for at least a year before spending three or four years maturing in the marine environment before returning to spawn in the late spring. Some stocks are "outside" rearing and spend most of their marine life-cycle in the Gulf of Alaska and Bering Sea while other stocks rear in nearshore marine waters.

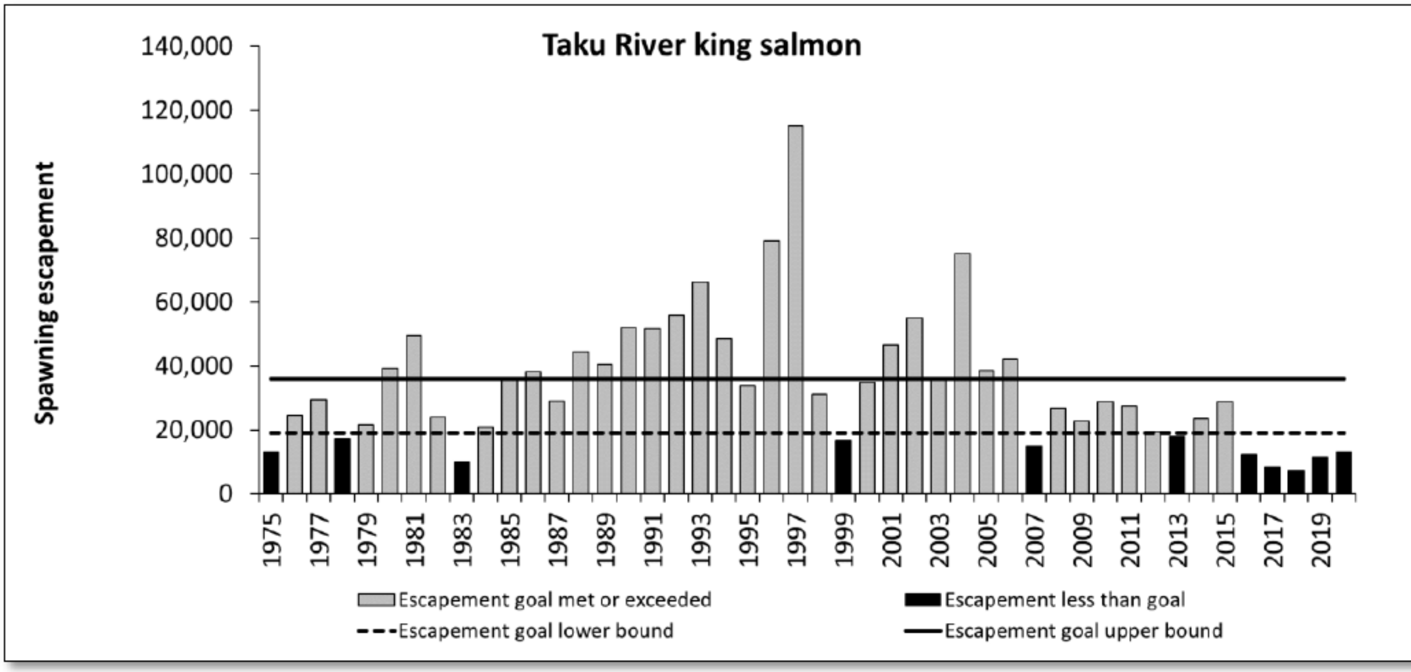
Eleven stocks account for 90 percent of Southeast Alaska's wild Chinook populations. The Taku and Stikine Rivers support the largest stocks overall - 70 percent of the region's wild Chinook. The Chilkat river near Haines, Alsek and Situk rivers near Yakutat and Chikamin and Unuk rivers near Ketchikan support other major stocks. Recent low escapements (the numbers of salmon returning to freshwater habitat to spawn) across these systems are a concern. In 2020, five of the eleven stocks failed to make escapement goals.

This year, ADF&G recommended designating the Taku and Stikine River stocks and two smaller populations as stocks of concern based on repeated failures to meet escapement goals. Stikine and Taku Chinooks spawn mostly in Canada and historically supported multiple fisheries in Alaska and British Columbia. Recent escapements at or near their lowest point since surveys began in the 1970s have led to severe fishery restrictions to prevent taking any of these fish. Both stocks failed to meet escapement goals in 2020 with low returns projected again for 2021.

Chilkat and Unuk River Chinook returns have also been below escapement goals since 2015, causing their designation as stocks of management concern in 2018. The 2019 and 2020 Chilkat River returns met escapement goals in 2019 and 2020. The 3,000 chinook return in 2020 was the largest escapement since 2009. For Unuk stocks, out of the last five years the goal was met only in 2018 and 2019. The Alaska Department of Fish and Game has closed most inside waters since 2018 in the spring to protect Chinook migrating to all Southeast Alaska freshwater systems.



11 stocks, mostly on mainland rivers, account for the majority of Southeast Alaska's Chinook populations. Yellow dots are the largest "indicator" stocks. Black dots represent other smaller stocks. Credit: Jones, E. (Alaska Department of Fish and Game). 2018. Presentation: Chinook salmon symposium. Sitka, Alaska, May 21, 2018.



Taku River Chinook escapements have dropped precipitously over the past five years. Graphics credit: ADF&G. 2020. Memorandum Re: Southeast Region Stock of Concern Recommendations. Sam Rabung, Director, Division of Commercial Fisheries and Dave Rutz, Director, Division of Sport Fish. ADF&G Divisions of Sport Fish and Commercial Fisheries, Juneau, Ak, September 30, 2020.

Coho salmon (*Oncorhynchus kisutch*) inhabit freshwater ecosystems for at least a year before migrating to the marine environment. They are the third largest salmon species. Ocean harvested fish averaged 6.1 pounds in 2020. Historically, many juveniles remained in freshwater for two years. The availability of rearing habitat in small streams, ponds, lakes and off-channel areas is a key factor in the viability of coho populations and they are highly vulnerable to changes in freshwater habitat. After rearing, coho typically spend 16 months in the marine environment before returning to Southeast Alaska's outer coast during the summer and entering streams to spawn in the fall. Like many Alaska salmon species, coho sizes are diminishing and they are shortening their marine life cycle and spawning at younger ages.

There are four thousand streams, large transboundary mainland rivers, and thirteen hatcheries that produce coho in Southeast Alaska. Most of the stocks are small populations of less than 1,000 spawners that utilize small to medium stream systems which support 60 percent of the region's annual return. Larger mainland systems such as the Chilkat, Stikine and Taku Rivers and, Tsiu-Tsivat system near Yakutat support the largest stocks in the region. The Taku River, for example, supported a peak run of a quarter million coho in 2002. North Prince of Wales Island provides 1,904 stream miles of coho habitat, making it the most important island ecosystem.

Abundance as measured by harvests averaged 2.6 million fish annually over the past decade, with peaks of over 3.7 million in 2013 and 2014. 2018 and 2019 harvests dropped to 1.6 and 1.7 million fish. The 2020 harvest was only 1 million fish, and 4 of the 8 Southeast Alaska indicator coho salmon systems failed to meet escapement goals. This is the first time more than three systems failed. Other stocks were at the lower end of their escapement goal ranges.

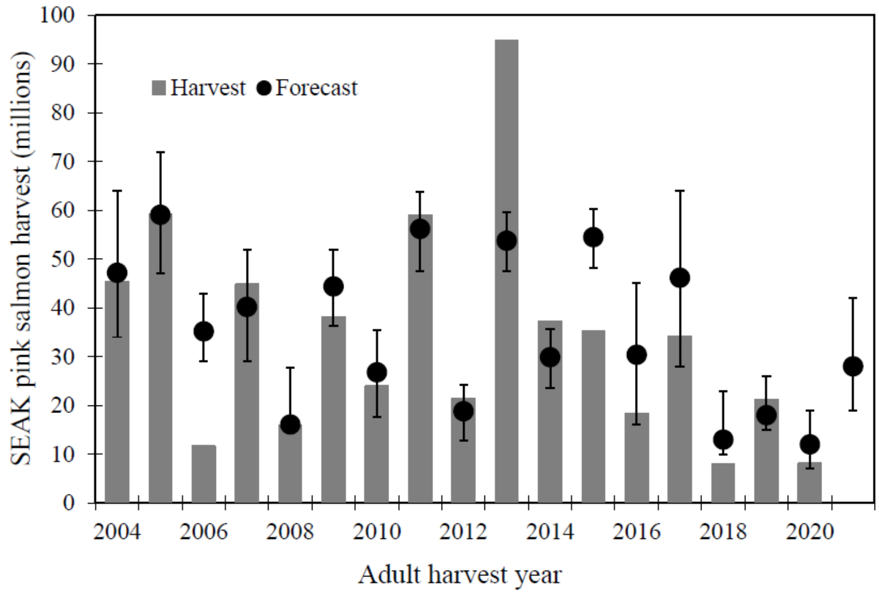
Sockeye salmon (*Oncorhynchus nerka*) can utilize various freshwater habitat types but nearly all Southeast Alaska's roughly 200 stocks spawn in systems that include lakes. Lake-type juveniles often spend 1 to 3 years rearing in lakes. Juveniles typically leave freshwater systems in the late spring and spend two to three years in the marine environment before returning to spawn. Sockeye salmon are spending less time in the marine environment accompanied by shrinking sizes. Harvested sockeye averaged 5.3 pounds in 2020.

Primary producers of sockeye include the Alsek and Situk river systems near Yakutat, the mainland transboundary rivers (Chilkat, Stikine and Taku), and lake systems near Ketchikan. Mainland rivers such as the Stikine, Taku and Chilkat allow sockeye salmon access to several lake systems that produce significant returns. Taku River sockeye populations also fluctuate considerably from year to year, with recent run sizes ranging from 120,000 to 280,000 fish. The Taku and Stikine Rivers both can support total runs (i.e. harvest and escapement) of between 300,000 and 400,000 fish. Prince of Wales Island provides the most sockeye habitat of any island ecosystem.

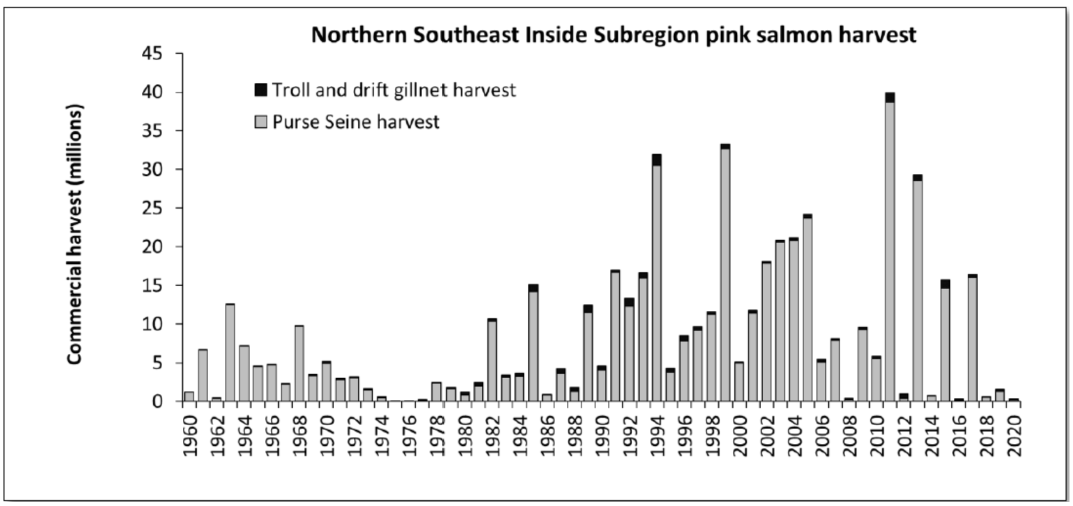
There is one sockeye stock designated since 2018 as a stock of concern – McDonald Lake near Ketchikan, which has not met escapement goals for five consecutive years. In 2020 the Alaska Department of Fish and Game also recommended designating Klusksu River (a tributary of the Alsek, near Yakutat) sockeye as a stock of management concern.

Regional sockeye harvests peaked at 1.7 million in 2014. The average harvest for the decade was 1.1 million fish per year. In 2019, most northern Southeast Alaska sockeye returns were healthy, including major sockeye systems near Juneau, Sitka and Yakutat. Chilkat systems near Haines were highly productive, supporting a harvest of nearly a quarter million sockeye. In contrast, 2019 southern Southeast Alaska sockeye harvests were poor, particularly for stocks spawning in the Stikine River and lake systems near Ketchikan. Sockeye returns were poor regionwide in 2020, with a total harvest of 373,000 fish.

Pink salmon (*Oncorhynchus gorbuscha*) utilize over 2,500 smaller streams in the region for spawning. Pinks are the most numerous of the five salmon species and also the smallest in size, with a 2020 average weight of 3.5 pounds. Nearly all the pink salmon in Southeast Alaska are wild. From 2009-2018, Southeast Alaska commercial fishermen harvested an annual average of 37 million pinks. Pink salmon returns have plummeted over the past five years. 2016-2020 harvests averaged 18 million fish each year.



A significant downturn beginning in 2006 deepened the disparity between even and odd year harvests. Graphics credit: Piston, A. (ADF&G). 2020. 2021 Southeast Alaska Pink Salmon Harvest Forecast



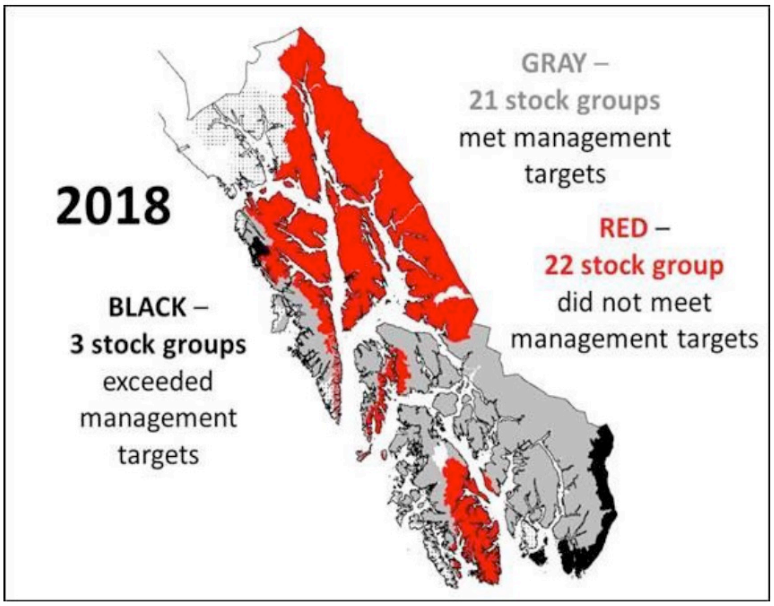
Poor pink returns in northern Southeast Alaska inside waters have caused extensive fishery closures, with much of Chatham Strait, Stephens Passage, Icy Strait, and Peril Strait closed entirely. Graphics Credit: ADF&G. 2020. Memorandum Re: Southeast Region Stock of Concern Recommendations. Sam Rabung, Director, Division of Commercial Fisheries and Dave Rutz, Director, Division of Sport Fish. ADF&G Divisions of Sport Fish and Commercial Fisheries, Juneau, AK, September 30, 2020.

Stocks have a distinct separation between the northern and southern portions of Southeast Alaska and managers divide the stocks into 3 subregions Southern Southeast, Northern Southeast Inside and Northern Southeast Outside. The Southern Southeast area, especially regulatory districts adjacent to Prince of Wales Island and near Ketchikan, provide most of the pink salmon harvest during the even year cycle and in some years as much as ninety percent of the harvest. Even year cycles of pink salmon runs have historically been much lower than odd years and odd year productivity is more uniform across the region.

A stock of concern designation for Northern Southeast Inside pink salmon, based on a failure to meet escapement goals for four of the past five years (2016-2020), is recommended by the Alaska Department of Fish and Game. This subregion's even-year returns failed to make escapement goals for four out of five even years this decade. Odd-year cycles were attaining escapement goals until 2019.

Pink salmon have declined throughout the region. The 2016 return of 18 million fish was a declared federal fishery disaster, and parented a 2018 run of 8 million fish harvested – the lowest since 1976. The 2019 pink salmon harvest of 21.1 million fish was the lowest odd-year harvest in over three decades. The poor 2018 parent year and a near record low juvenile pink salmon index value in 2019 led to expectations of another poor return in 2020 which concluded with another 8 million fish harvest. Drought conditions and marine heat waves are probable causes of the decline.

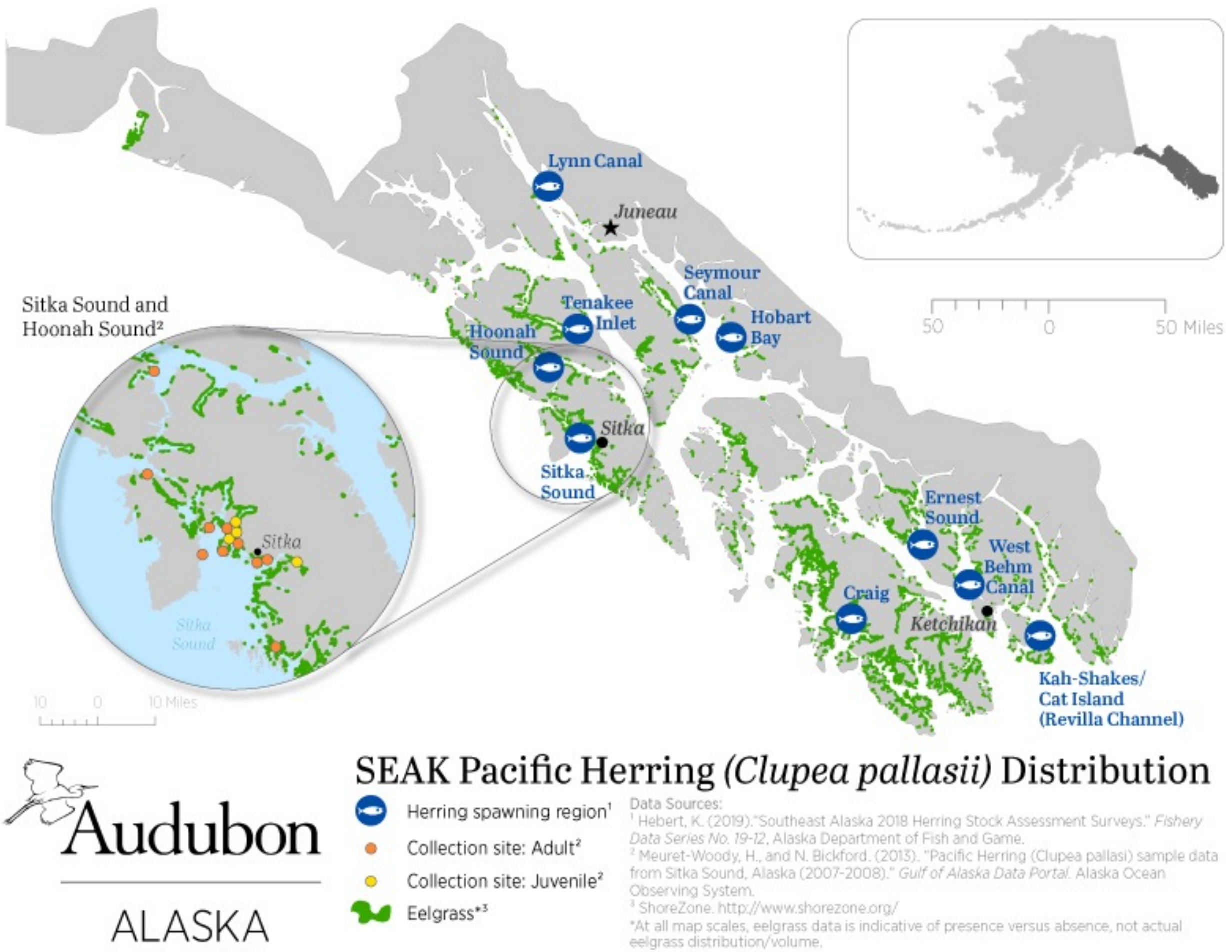
2018 Escapements



In 2018, numerous pink salmon systems, including most northern Southeast Alaska inside waters and the eastern coast of Prince of Wales, failed to meet escapement goals for pink salmon. The offspring from this run also returned in small numbers in 2020.Graphics credit: Salomone, P. 2019. Petersburg-Wrangell Management Area 2019 Season Summary and 2020 Outlook. 2019 Purse Seine Task Force.

There is hope for a stock rebound. 2019 pink returns met escapement goals for the Southern Southeast and Northern Southeast Outside subregions. The 2020 juvenile pink salmon index is an improvement over recent years, implying better freshwater and early marine survival. Juvenile pinks heading to the marine environment in 2020 experienced more moderate sea surface temperatures in the Gulf of Alaska, relative to much warmer conditions that persisted from 2014 - 2016 and in 2018 and 2019. Fishery managers project higher pink returns for 2021, with a forecasted harvest of 28 million fish.

Chum Salmon (*Oncorhynchus keta*)— also known as dog salmon, are the second largest salmon in Alaska, averaging nearly seven and half pounds in 2020. Chum are also the most widely distributed of all the Pacific salmon. Chum leave freshwater shortly after emergence and then spend three to three and a half years in the ocean. Since the 1980s, commercial chum harvests have more than tripled because of hatchery production. 2020 chum returns throughout Alaska were the poorest in three decades. Most of those chum entered the ocean during the end of the 2014-2016 marine heatwave. Southeast Alaska hatchery managers believe warmer temperatures caused very low marine survival rates that reduced returns.



Herring (*Clupea pallasii*)—Pacific herring are a major schooling forage fish. Herring reach sexual maturity at 3-5 years of age and then spawn every year. Southeast Alaska herring typically live for 8 years. Spawning occurs in the spring in shallow, vegetated areas in intertidal and subtidal zones. The eggs are adhesive and attach to vegetation or the bottom substrate. Eggs hatch about two weeks after fertilization and the young larvae drift and swim in the ocean currents. Once the larvae undergo metamorphosis into their juvenile stage, they rear in sheltered bays and inlets. In the fall, the schools of juveniles move to deeper water where they will spend the next 2-3 years.

Commercial harvests started in 1878 with a small harvest for human consumption. By 1882, a reduction plant at Killisnoo in Chatham Strait was producing 30,000 gallons of herring oil. Reduction plants then proliferated throughout the region. In 1929 seiners harvested a record 78,745 tons of herring for all uses, including bait. Intensive harvests continued for three decades, and populations plummeted. By 1967 the fishery had crashed.

Substantial harvest for sac roe, or herring eggs, began in Southeast Alaska in 1971. Seiners also harvest herring for use as bait in the halibut, groundfish, crab, and salmon troll fisheries. Southeast Alaska commercial herring fisheries are in flux as weak markets and small fish caused an early closure of the 2019 Sitka Sound herring fishery and the 2020 fishery did not open due to similar market and size conditions.

Environmental changes likely drive major fluctuations in herring stocks. A threat to Pacific herring is the loss of spawning grounds. Dredging, construction activities, log storage facilities, oil spills and reduced water quality have degraded or destroyed herring spawning habitat. Global warming may also pose a threat to herring by reducing the availability of their prey: zooplankton and phytoplankton. In addition, the recovery of populations of predator species, such as humpback whales, may impact herring stocks.

The herring spawning biomass built through the late 1990s, peaked between 2008 and 2011, and then began to decline, particularly stocks in inside waters. The outer coastal stocks around Sitka and Craig stocks typically account for 80 percent of the spawning biomass in Southeast Alaska and both populations are growing. The inside stocks probably remain at low levels, but there have been no surveys since 2016. There were twofold increases in the observed spawning biomass in Sitka and Craig between 2018 and 2019. The estimated Southeast Alaska herring spawning biomass in 2019 reached 169,514 tons - 167 percent of mean regional spawning biomass over the past 40 years. The 2021 estimated Sitka Sound mature herring biomass is 210,453 tons.

The 2020 estimated egg deposition in Sitka Sound was the highest on record since 1976. The 2020 egg deposition and high 2021 biomass reflect an unusually large year class from 2016. The now five-year old fish comprise 86 percent of the spawning herring biomass. Twelve percent of the remaining mature herring are older (ages 6-8) and there is a much smaller population of 3- and 4-year old fish. Observations of other 2019 and 2020 coastal herring populations in Prince William Sound and Kodiak showed similar dominance by herring spawned in 2016. The class hatched during the spring of 2016 and may have benefitted from the tail end of the 2014-2016 marine heatwave. Elevated sea temperatures may have helped to produce marine conditions favorable to larval and juvenile herring.

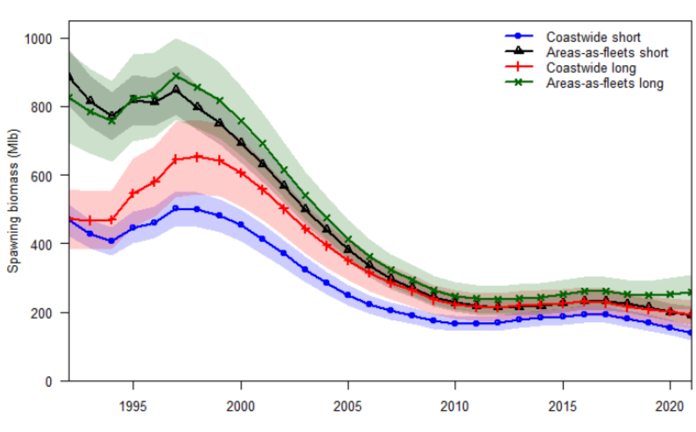
Halibut

Pacific halibut (*Hippoglossus stenolepis*) live on or near the continental shelf through much of the northern Pacific Ocean. Halibut typically live near the bottom over a variety of benthic habitats and sometimes swim up in the water column to feed. They usually inhabit waters between 20’ and 1,000’ deep, but will occupy depths up to 3,600’. Halibut are laterally flat, and swim sideways, with one side facing down and the other facing up. The upper side is typically gray to brown, or nearly black, with mottling and numerous spots to blend in with a sandy or muddy bottom. Halibut are a long-lived species with individuals up to twenty years old caught in the commercial fishery. Female halibut grow faster and reach larger sizes than male halibut. The maximum reported size is over eight feet in length and over 500 pounds. Male halibut rarely reach a length of three feet. Most male halibut are sexually mature by about eight years of age, while half of the females are mature by about age twelve.

Most halibut spawn between November and March at depths of 300 to 1,500 feet. Larvae initially drift with deep ocean currents. As the larvae mature, they move higher in the water column and ride surface currents to shallower and richer coastal waters. Juvenile and some adult halibut migrate generally eastward and southward, into the Gulf of Alaska coastal current, countering the westward drift of eggs and larvae. Halibut tagged in the Bering Sea have migrated as far south as the Oregon coast– a trip of over 2,000 miles. Because of the extensive movements of juvenile and adult halibut, fishery managers assess the entire population as a single stock extending from northern California to the Bering Sea.

Halibut size-at-age has changed over time. The average length and weight of halibut of each age increased from the 1920s to the 1970s and has decreased since then. By the 2000s, 12-year-old halibut were about three-quarters the length and about one-half the weight they were in the 1980s. Reasons for the decline are unknown. The reduced size-at-age slowed and stabilized over the past decade. Currently, individual size at age is increasing for young halibut in some areas. It is unclear if these recent observations are a long term trend or annual variability.

The Gulf of Alaska (International Pacific Halibut Commission (IPHC) Area 3) hosts the largest proportion of the halibut stock. Significant distribution shifts have occurred over the past fifteen years. Over 70 percent of the biological stock distribution (i.e. the proportion of the total stock found in these areas) in 2005 was in Area 3. After 2005 stock distribution increased in IPHC Areas 2 (Southeast Alaska to California) and 4 (Bering Sea). By 2019 Areas 2 and 4 had reached historical highs while the proportion of the stock in the Gulf of Alaska decreased to less than half of the stock. In 2020 the distribution trend changed, with slight increases in Area 3, slight decreases in Area 2 and no changes in Area 4.

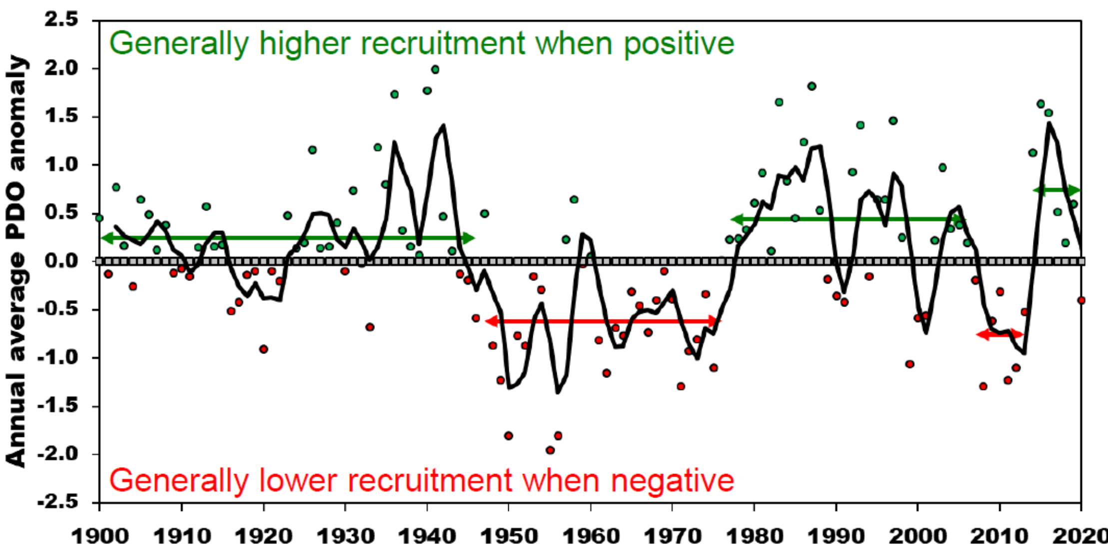


The figure shows estimated spawning biomass trends from 1992-2021 based on four stock assessment models used by the IPHC. Credit: IPHC Secretariat (I. Stewart, A. Hicks, R. Webster & D. Wilson. Summary of the data, stock assessment, and harvest decision table for Pacific halibut (Hippoglossus stenolepis) at the end of 2020. IPHC-2020-IM096-08 Rev_1.

Lower harvests this decade reflect a steady decline in the halibut biomass from the late 1990s until 2012, primarily because of the reduced size-at-age. Recruitment strengths were also weaker. The spawning biomass gradually increased through 2016 but then again slowly declined, decreasing 17 percent from 2016-2021. The estimated spawning biomass at the end of 2020 was 192 million pounds, a slight drop from an estimated 194 million pounds at the beginning of 2020. IPHC scientists anticipate a continued decline in the spawning biomass. The 2005 year class is currently the largest coastwide contributor in numbers of fish. The 2006-2010 classes which comprise much of harvestable and spawning biomass were small. The 2011 and 2012 year classes are likely the strongest classes since 2005. These fish appeared in the 2020 fishery and are the largest proportions of catch in some areas. IPHC scientists identify considerable uncertainty in estimating the size of these classes, which may be extremely important as other incoming recruitment classes are small.

Over the past century, halibut have supported harvests ranging from 34 to 100 million pounds. Average removals, including trawl bycatch, have been 40 million pounds over the past five years. 2020 total halibut mortality was near a 100-year low, at 35.5 million pounds. Estimated mortality for 2021 from directed harvests, bycatch and other uses is 40.25 million pounds.

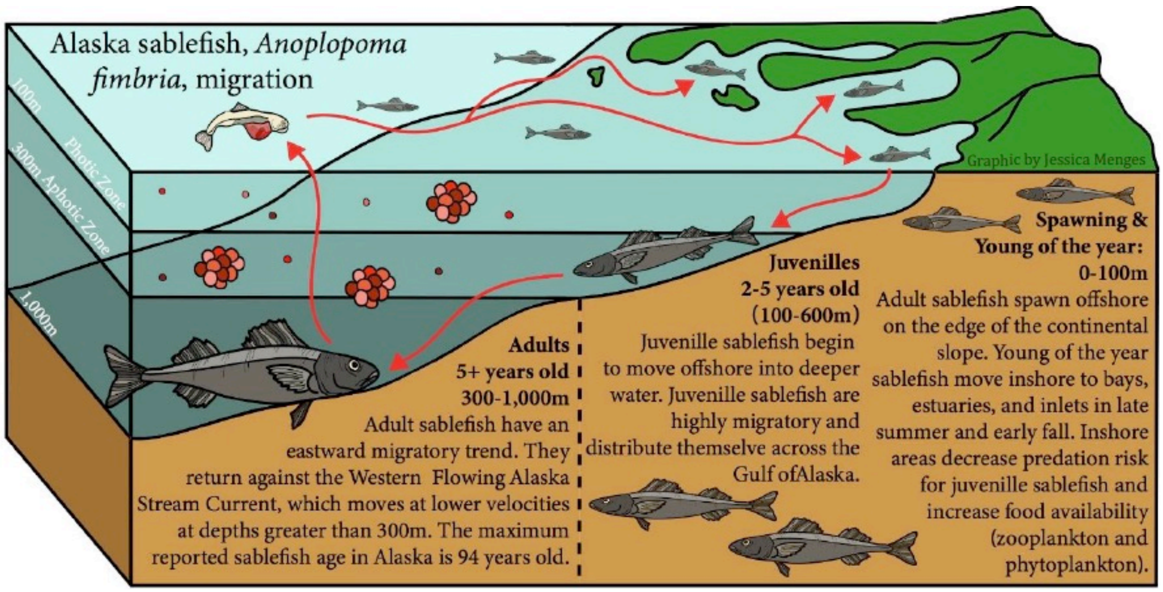
Ecosystem conditions: Pacific Decadal Oscillation



Graphics credit: Summary of the 2020 data and stock assessment and decision table for 2021. Im096-08 Rev_1.

Linkages between environmental conditions and halibut productivity are unclear. Overall halibut abundance, like many fish species, appears to benefit from the positive phase of the Pacific Decadal Oscillation (PDO) – a widely used indicator of North Pacific productivity. Average halibut recruitment was historically higher during favorable PDOs. IPHC scientists are now cautioning the PDO correlation with high recruitment may be less useful in future environmental conditions. Climate change risks may include prey depletion, since juvenile halibut rely on species that are vulnerable to ocean acidification.

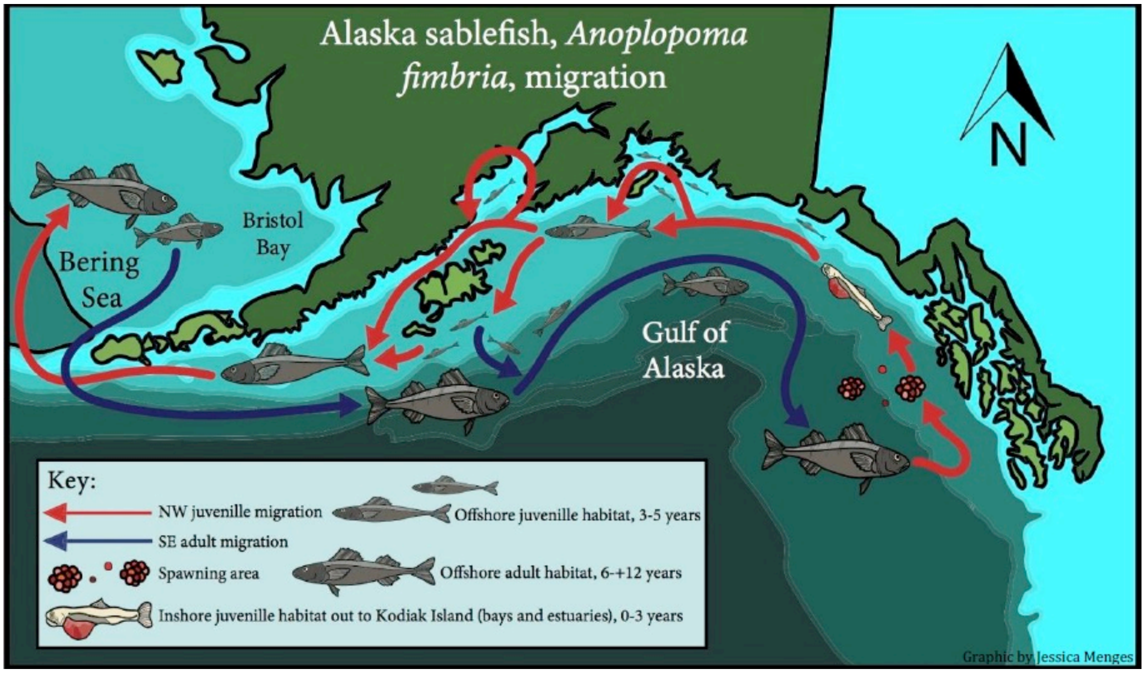
Sablefish



Sablefish (*Anoplopoma fimbria*), also known as black cod, are a groundfish species with a range that spans the North Pacific coast from Baja Mexico to Alaska, with the highest abundance centered in the Gulf of Alaska. Sablefish are a highly migratory, long-lived species with individuals up to forty years old commonly caught in the commercial fishery. Adult sablefish utilize a variety of deep-water benthic habitats, ranging from 600' to 4,800', along the continental slope, in shelf gullies, or in fjords. Adults spend most of lives in depths between 1,000 & 3,000 feet.

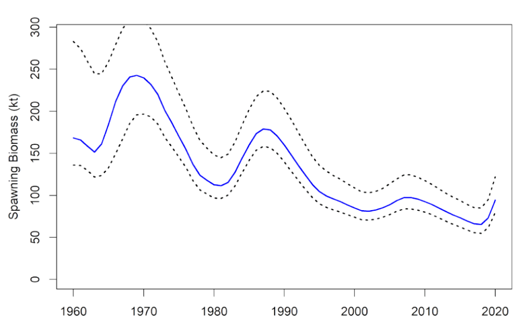
Gulf of Alaska bathymetry and current patterns drive sablefish migration. Sablefish reach reproductive maturity when five to seven years old and usually spawn annually thereafter. Spawning occurs in deep water (900' to 1,800') in winter or spring in Alaska. The fertilized eggs develop at depth to larvae and drift in surface waters. This drift is the beginning of an extended spring through summer pelagic phase during which "young of the year" sablefish feed in surface waters and settle into nearshore areas in the early fall of their first year as juveniles. These young of the year sablefish feed mostly on small crustaceans like krill, and copepods, a type of zooplankton. The availability of these prey species is relevant to early juvenile survival and the development of strong year classes, which often correlate with years of high copepod abundance.

Southeast Alaska's nearshore waters provide important habitat for juvenile sablefish during this phase as they grow rapidly in nearshore pelagic habitats, including estuaries such as St. John the Baptist Bay near Sitka – the only specific location juveniles are known to occupy on a regular basis. The young of the year remain in nearshore habitats and shallower waters (>300 feet) as prevailing northwest currents carry them along the Gulf of Alaska, eventually depositing them as far west as the Bering Sea. As juveniles grow during this phase they also migrate deeper, into waters 300-1,800 feet in depth around age two. They will migrate throughout the Gulf of Alaska and Bering Sea before settling into their deep-water habitat as adults at four to five years of age, when they become sexually mature. Older juveniles and adult sablefish feed opportunistically.



Sablefish abundance has fluctuated over the past half century with increases and decreases tied to the presence or absence of strong year classes. Prior to 2014, there had been only one large year class since 1999. A slow but persistent decline in abundance occurred over the past two decades. Climate and environmental conditions appear to have the greatest effect on sablefish abundance and recruitment. Some of the largest year classes followed near historic low abundances. Changes in the PDO, particularly a switch in ocean conditions from cooler sea surface temperatures to above-average temperatures, have triggered large recruitment events. These conditions often correlate with high copepod abundance, helping early juveniles grow rapidly during warm years.

Sablefish are "highly fecund" meaning that they are generally capable of producing abundant offspring. Recently warm ocean temperatures may have contributed to overwinter and nearshore conditions favorable for juvenile sablefish. The 2014-2016 marine heat wave may have contributed to two recent large year classes. Fishery scientists initially estimated that the 2014- and 2016-year classes were as much as four to ten times larger than average.



The sablefish spawning biomass has mostly declined since the 1990s but is projected to increase over the next few years. Graphics credit: Oceana. (Adapted from figure 3.17 in Goethel et al. 2020 Sablefish stock assessment). Values in kilotons.

There is now considerable uncertainty with those estimates. The most recent stock assessment downgraded the original estimates of the 2014 class size by 56 percent. It is also likely that estimates of the 2016 class size were also too high. It is unknown whether estimation errors or higher than normal natural mortality caused the lower estimates. Even so, the two classes comprised estimated 33 percent and 14 percent components of the 2020 spawning biomass, respectively. The 2014 class is about 50 percent mature while the 2016 class was less than 15 percent mature in 2020.

The extent to which environmental conditions will affect those classes in the future is uncertain. It is unknown how warming oceans will affect maturing sablefish. Ecosystem indicators for adults and juveniles migrating to adult habitat have been poor. The body condition of juveniles arriving in adult habitat has been below average since 2014, and poor for the 2014 and 2016 classes. The poor condition may reflect a higher level of competition and predation by arrowtooth flounder. There also have been declines in slope habitat conditions and ecological health since 2015.

Stock assessment scientists project rapid spawning biomass increases from 2020-2022 based on the maturation of the 2014 and 2016 classes in the next few years. The stock may then stabilize assuming average recruitment after the 2016 year class. One major concern for the stock is a lack of older fish. There has been a dramatic decrease in the mean age of spawners since 2017, continuing a downward trend. Stock assessment scientists recommend caution in harvest rates in order to allow a young population to further mature and more fully contribute to the spawning biomass.

There are two related populations that inhabit Southeast Alaska's inside waters in Clarence Straits and Chatham Straits and support state-managed fisheries. State of Alaska sablefish stocks in Clarence Straits and Chatham Straits also are recovering from recent low abundance levels.

Rockfish

Long-lived yelloweye rockfish are the most popular SeaBank rockfish for consumers and sportfishermen, but a declining biomass has resulted in restrictions for all users. Photo credit: Alaska Department of Fish and Game.

Rockfish (*Sebastes Sp.*)—Rockfish are among the longest-living vertebrates on earth. Non-pelagic species generally live longer than pelagic species. Yelloweye rockfish, for example, reach ages over 100 years. Rougheye and shortraker rockfish occasionally exceed 150 years of age. Most rockfishes do not start reproducing until they are at least 5-7 years old, and some may not reproduce until they are 15-20 years old. Juvenile rockfish associate with complex habitat such as rockpiles and pinnacles. As juvenile fish grow and mature they move to adult habitats in deeper water (40-150 fathoms). Most rockfish species rely on an internal air bladder for buoyancy, which minimizes energetic requirements underwater but results in barotrauma and mortality in rockfish brought to the surface.

Oceanographic factors such as temperature, currents, and food availability affect the survival of larval rockfish. Rockfish have evolved to live long and produce millions of offspring each year, allowing their populations to persist through long periods where conditions are unfavorable for survival of offspring. Because they are slow growing and long-lived, rockfish populations are vulnerable to excessive harvest.

Sampling and surveys indicate an ongoing decrease in the biomass of yelloweye rockfish, which has declined sixty percent since 1994 even with increasing harvest controls and tighter limits for all fisheries. A decrease in average weight and decrease in density estimates are driving factors. Yelloweye rockfish can live for well over a century, and do not reproduce until between ages 18 and 22. Recent surveys are showing fewer older fish and fewer young fish entering the fishery. Stock rebuilding is slow for long-lived rockfish species such as yelloweye because of their vulnerability to overexploitation, late maturation and high fidelity to specific locations.

Shellfish - Crab, Shrimp, Geoducks, and Sea Cucumbers

Dungeness crab (*Cancer magister*)—Dungeness crab range from the Pribilof Islands to Magdalena Bay in Mexico. Southeast Alaska Dungeness crab utilize shallow mud and sand substrate habitats throughout the region, occupying both marine and estuarine waters. Egg-bearing females use nearshore substrates when incubating eggs.

Southeast Alaska's Dungeness crabs mostly inhabit bays and deep fjords. Shallow coastal water habitats and estuaries are the most important areas and support the highest densities of juvenile Dungeness crab. Estuarine habitats contain higher prey densities for juveniles and intertidal vegetation that provides protection from predators.

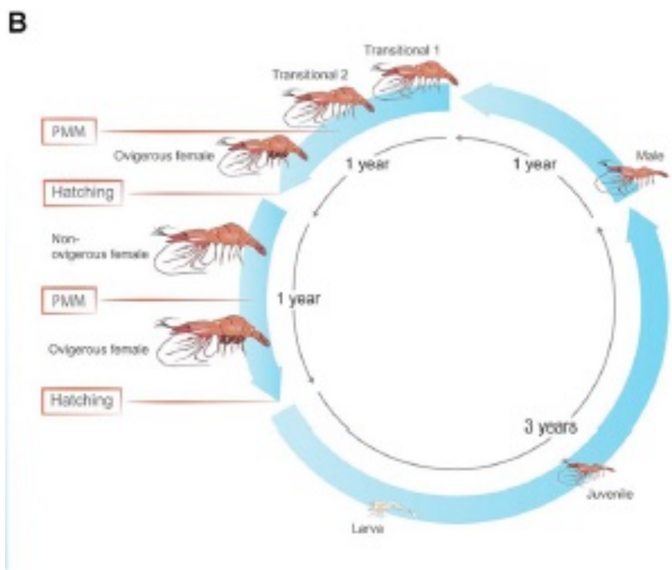
Southeast Alaska's Dungeness crab are more likely to remain in localized areas than southern Pacific Coast populations which inhabit the outer coast. Southeast Alaska Dungeness crabs tend to remain in local bays and move depending on bathymetry and locations of essential habitat. One studied population in Fritz Cove near Juneau showed that female crab remaining within 3 miles of the head of the cove. None of the tagged crabs moved close to the nearest population 6 miles away.

Fishery managers believe that Southeast Alaska's Dungeness crab stock is healthy, with steady and reliable amounts of crab recruiting into the fishery. The Stikine River flats are one of the most important habitats, supporting a stock that contributes substantially to overall harvests. Other high productivity areas include Duncan Canal near Petersburg, Ernest Sound near Wrangell, West Kuiu Island, and Stephens Passage.

These same areas support a Tanner crab biomass that has exhibited slow but steady growth over the past decade. The mature and legal tanner crab biomass are at the highest levels since the late 1990s. Fishery managers believe modest harvest rates in the fisheries will enable this trend to continue. Other crab species are at lower abundances, with commercial red king crab fishing closed in recent years.

Spot shrimp (*Pandalus platyceros*) occur throughout the North Pacific Ocean and utilize primarily hard-bottom marine habitats. Spot shrimp are the largest species in the family Pandilidae – in general, deep water prawns. Fishery managers hypothesize that Southeast Alaska's spot shrimp may live longer and grow larger because of the influence of colder waters. Juvenile shrimp use shallow water habitats and migrate as they grow to deeper rocky habitats or coral reefs. They prefer a narrow temperature range and are sensitive to increases in temperature.

A limited but growing amount of information exists regarding the species' life history. Spot shrimp are hermaphroditic, meaning that they begin adult life as males but eventually transform into females. Larvae hatch in spring, followed by a post-larval period of 40 days and a benthic juvenile phase that lasts two years and precedes development into a mature male. The time needed to transition to a female may differ across latitudes. In warmer waters, spot shrimp make the transition between age three to three and a half. Southeast Alaska spot shrimp spend more time as males and transform into females between ages four and five. The reproductive cycle takes a year, beginning with mating during late summer. Females extrude eggs in the fall and larvae hatch five to seven months later in the spring, between late March and late May.



Time scale of the spot shrimp life cycle. Graphics credit: Levy, T.L., S.L. Tamone, R. Manor, E.D. Bower & A. Sagi. 2020. The protandric life history of the Northern spot shrimp Pandalus platyceros: molecular insights and implications for fishery management. Scientific Reports. 2020.

The largest populations occur near Ketchikan (Behm Canal, Boca de Quadra), Cordova Bay, and Ernest Sound and northern Clarence Straits near Wrangell but there are smaller, harvestable populations throughout the region. In recent years, the Alaska Department of Fish and Game has reduced harvests in some areas in response to declines in abundance and catch efficiency. Overall, spot shrimp populations have declined since the 1990s and not recovered to their original numbers.

Geoduck clams (*Panopea generosa*) and sea cucumbers (*Holothuroidea*) are the two most important species for the region's dive fisheries. Both species are most abundant in protected bays and inlets on the outside coast. Geoduck habitat exists throughout southern Southeast Alaska and around Baranof Island, with the highest densities occurring around islands west of Craig. Southeast Alaska is the northernmost portion of geoduck's range. Sea cucumbers occur throughout southern Southeast Alaska and around Sitka and in Chatham Straits. Alaska's sea cucumbers are larger and have a high nutritional value. They use a range of habitats, most commonly shell debris and gravel substrates.

Marine Mammals

Breaching whales are a common sight throughout Southeast Alaska. Photo credit: Colin Arisman.

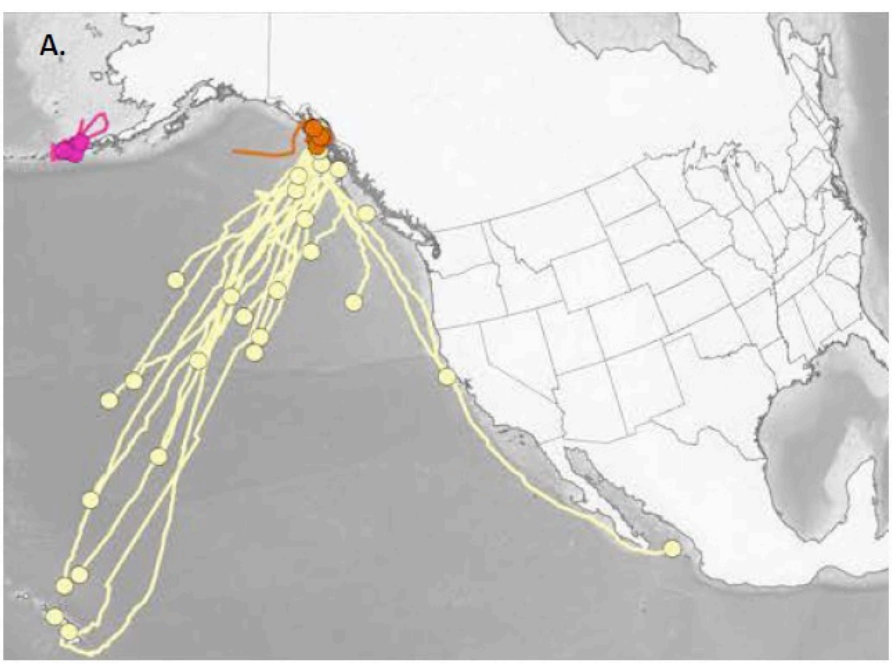
Whales and dolphins (*Cetacea*) are marine mammals that utilize Southeast Alaska's environment. Eight species of whales occur in Alaska's cold waters, with five species regularly or seasonally occurring in Southeast Alaska: humpback, gray, orca, minke, fin and sperm whales. Sightings of sperm whales, humpback whales and orcas are common and they are also some of the most widely distributed marine mammal species in terms of their range. Although scientists have produced estimates for several cetacean species, acquiring precise data on population status and trends for many cetaceans is challenging.

Humpback whales feed in Southeast Alaska waters throughout the year. The region is mostly a destination for humpback whales that breed and calve in Hawaii and may function as a secondary feeding ground for a small fraction of a population that breeds off the Mexico coast. The Hawaii population may exceed 10,000 whales and is the only population that uses Southeast Alaska as its primary feeding area. Recent estimates suggest that between roughly 2,900 and 6,400 humpback whales feed in Southeast Alaska and northern British Columbia and the population may be increasing.

Gray whales migrate through coastal Southeast Alaska en route from Baja California to primary feeding grounds in Arctic waters each spring and back in the fall. The average adult gray whale travels 400,000 miles over its lifetime. There is a subpopulation of eastern North Pacific gray whales that migrates through Southeast Alaska. 2015 estimates suggested significant growth of the gray whale population since 1967. Declining sea ice in arctic waters may have increased feed productivity, causing population growth over the past decade. However, there was a coast-wide gray whale mortality event in 2019 evidenced by emaciated whales found throughout their migratory path. There were 48 confirmed observations of stranded gray whales, including 3 in Southeast Alaska.

Sperm whales, one of the toothed whales found off Southeast Alaska, frequent the deep waters of the continental shelf and slope. The species occurs throughout the North Pacific, feeding primarily on squids but also eating large sharks, skates and fishes captured during deep dives that can last up to two hours. Sperm whales generally move to higher latitudes in summer and lower latitudes in winter. The species may be twice as common during the summer and some sperm whales may inhabit the Gulf of Alaska all year. Scientists estimate the population of sperm whales inhabiting the North Pacific at 102,000 but data limitations make estimates unreliable. The population is likely not declining but trends are unknown.

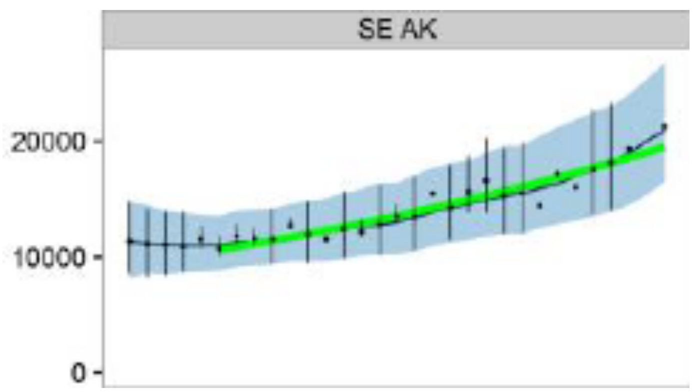
Orca whales are found on the continental shelf of Southeast Alaska through the Aleutian Islands and both Chukchi and Beaufort seas. The orca is actually the world's largest dolphin. Scientists have identified three ecotypes of killer whales in the North Pacific Ocean. Differences in the movement patterns among the three orca ecotypes found in Alaska have led, in part, to their names; i.e., "resident," "transient," and "offshore." Resident killer whales prey primarily on fish. Transients eat marine mammals and offshore orcas likely prey primarily on fish and even sharks. There are an estimated 109 resident orcas in Southeast Alaska, and roughly another 1,000 orcas from various stocks may be present in the Gulf of Alaska. Overall, the population of orcas between the Gulf of Alaska and Pacific Northwest had doubled over the past forty years.



Most humpback whales found in Southeast Alaska waters commute to Hawaii for the winter.
Graphics credit: Mate, B.R., et al. 2018. Humpback whale tagging in support of marine mammal monitoring across multiple Navy training areas in the Pacific Ocean: Final Report. 135 pp,

Steller Sealions (*Eumetopias jubatus*) are the largest member of the eared seal family. Steller sea lions are generalist marine predators with a diet of fishes and cephalopods that tends to be predictable by season and region, with the occasional meal of bird or true seal for variety. Populations plummeted during the 1980s for reasons that remain hotly disputed. NMFS identified two distinct populations of Steller sea lion stocks during the 1990s based on genetic and regional differences. The agency designated the Western Stock as endangered and the Eastern stock as threatened under the Endangered Species Act, but delisted the Eastern Stock in 2013. The Eastern stock inhabits Southeast Alaska and is a growing population.

Southeast Alaska's coast provides roughly 50 haul-out sites and breeding rookeries, including the largest Steller sea lion rookery in the world, Forrester Island. The estimated 21,000 adult and juvenile sea lions and 8,000 pups inhabiting Southeast Alaska rookeries comprise a little less than half of the eastern stock.



Estimated counts of adult and juvenile eastern Steller sea lions from 1989-2015. The population has been increasing throughout its range with the most significant growth observed in Southeast Alaska and British Columbia. Graphics credit: Muto, M.M., et al., 2019. Alaska Marine Mammal Stock Assessments 2018. NOAA Technical Memorandum NMFS-AFSC-393

Sea lions haulout off the Southeast Alaska coastline on a sunny day. Photo credit: Colin Arisman.

Seals and PorpoisesHarbor seals are the other most abundant pinniped and utilize the entire Southeast Alaska coast, with the greatest concentrations in Glacier Bay National Park, outer coast of Chichagof Island, and in glacier fed bays along the mainland. Harbor seals favor estuaries for fishing and tidewater glaciers for other habitat needs, particularly seal-pupping. There are five geographically distinct stocks of harbor seals and a total population of 60,000. The stocks are stable or increasing except in Glacier Bay. Black and white Dall porpoises look like miniature orcas and are abundant in the region, as are harbor porpoises. There are roughly 5,500 harbor porpoises in the region, concentrated primarily in Glacier Bay and near Wrangell. Population trends are unknown.

Sea Otters (*Enhydra lutris kenyoni*)—Sea otters forage in relatively shallow coastal waters for a variety of marine species, including mussels, clams, sea urchins, crabs, and occasionally fish. They rely on their high metabolism and incredibly dense fur for warmth (up to 1 million hairs per square inch). In order to maintain its body weight, a sea otter must eat 25 percent of that weight every day.

Commercial harvests of sea otters in the fur trade grew rapidly after Russian explorers arrived in Alaska in 1741. By the 1800s, hunters had nearly extirpated the species throughout its range, including Southeast Alaska. In 1965, sea otters were reintroduced to the outer coast. Sea otters have since reestablished themselves in Southeast Alaska. The population doubled between 2003 and 2013, and the Fish and Wildlife Service now estimates that are over 25,000 sea otters throughout the region. 8,500 sea otters inhabit Glacier Bay alone, and there are 12,200 sea otters inhabiting the southernmost portion of the region. The population is growing by 12 percent to 14 percent annually. Areas of expansion are Cordova Bay near Craig and northward through Chatham Straits and into Frederick Sound.

The population growth has created competition between fishery harvests and expanding sea otter predation on shellfish resources. Alaska Department of Fish and Game researchers and dive fishermen believe that this growing population is having a significant effect on commercial harvests of geoduck, crabs and other species.

Terrestrial Mammals

Southeast Alaska island ecosystems provide a wide range of habitat values for terrestrial wildlife species. North Prince of Wales Island and Admiralty Island have particularly high biological values for large-tree forests, bear, salmon and deer habitat. Southeast Alaska rainforests differ from most North American forests because they retain most of the wildlife species that have been here for centuries. Sitka black-tailed deer are an important ecological indicator species in Southeast Alaska because of their well-known relationship to the ecosystem, need for large home ranges, dependence on old-growth forests and multiple habitats and status as game and subsistence species. They are a subspecies of mule deer adapted to northern Pacific old-growth rainforests. They are present throughout Southeast Alaska and occur on nearly every island in the Alexander Archipelago but are less common along the mainland coast.

Sitka black-tailed deer have a particular dependence on old-growth forest because it functions as winter range and provides protection from predators. One of the most critical habitat features is the presence of large blocks of low-elevation, intact old growth forest in areas with more southerly exposure. These areas provide winter forage and intercept snowfall, making forage available to deer during periods of deep snow. Protecting these habitat assets is critical to maintaining annual deer dividends. Beach fringe forest is also one of the most important habitats as the final refuge for deer moving to low elevations in times of deep snow. Young clearcuts do provide abundant forage during snow free periods, but within several decades the newly growing forests shade out understory plants used by foraging deer, creating large areas that will be unsuitable, sterile habitat for over a century.

Black bear (*Ursus americanus*) are present along the entire mainland coast and inhabit most Alexander Archipelago islands south of Frederick Sound. Brown bears, ursus arctos, also occur on the entire mainland coast – especially along major river systems – and the "ABC" islands north of Frederick Sound – Admiralty, Baranof and Chichagof. These three islands support an estimated 4,300 brown bears, roughly 70 percent of the entire Southeast Alaska population. Southeast Alaska may support as many as 6,000 to 8,000 brown bears and 17,000 black bears. There are no precise population estimates for Southeast Alaska's black bears, although a study specific to north Kuiu Island estimated densities as high as 3.9 bears per square mile. Black bears and brown bears rarely overlap on island ecosystems.

Both bear species are umbrella species (a species with large habitat needs such that conservation of bear habitat benefits species across the landscape) with large area requirements and varied habitat uses, including riparian areas, estuaries and old-growth forests. The health of Southeast Alaska's bear populations is an indicator of overall ecosystem integrity. Hunters harvest both species which return dividends because of their values for hunting, recreation and tourism.

Riparian areas provide important habitat, especially during the late summer when bears concentrate along anadromous fish-bearing streams to harvest salmon. Forested buffers alongside these streams are critical, especially for females. Bears also utilize estuaries and beach fringe habitat for seasonal foraging needs. Bears are vegetarian and carnivorous at different times, eating vegetation during early spring, deer fawns in late May and June, and consuming large quantities of salmon when available during summer and fall. Salmon abundance in general results in larger, healthier bears and is critical to successful reproduction.

Wildlife managers believe that black bears select for large-tree old-growth forest habitat and expect black bear populations to decline with further losses of old-growth forest. The availability of adequate den sites to black bear survivability and reproductive success is critical. There is considerable re-use of existing den sites, which may indicate in part a lack of adequate alternative sites.

Photo credit: Eric Jordan

Assessing the value of the Southeast Alaska's SeaBank resources to the people and communities within and outside the region

There are nearly 72,400 people living in Southeast Alaska's 33 communities. Three-fourths of the population lives in the biggest communities – Juneau, Ketchikan and Sitka. Eleven of the communities are small and remote, with between ten and one hundred residents. The lowest population level this century was 70,219 people in 2007. A period of slow growth followed, peaking at 74,432 residents in 2014. Regional residents in general are aging and there are low birth rates and low new resident migration. Alaska demographers project small population declines over the next decade.

The public sector is the largest component of the region's economy and provides nearly a third of the jobs and wages. The two top private sector economies are the visitor industry and the commercial fishing/seafood industry. The two sectors rely on SeaBank assets – scenery, forests, shorelines, terrestrial and marine wildlife and especially salmon. In 2019, SeaBank assets used by the two sectors supported over 12,000 jobs (including self-employed workers) and generated over half a billion dollars in earnings. Three-fourths of the workers are Southeast Alaska residents.

Regional economists anticipated economic growth in 2020 based on 2019 economic indicators. In 2019 there were increases in jobs and wages in nearly every community. 1.3 million visitors arrived on cruise ships – a 14 percent increase in cruise passengers from 2018. Then an anticipated record 1.5 million cruise passengers stayed home in 2020 due to the COVID-19 pandemic. Southeast Alaska had a higher job loss rate – 17 percent – than other parts of Alaska. Impacts were highest in communities with the most dependence on expenditures by passengers of large cruise ships. There was also significant loss of seafood processing jobs, but communities with the largest fishery sectors such as Sitka and Petersburg were able to keep their job loss rate below ten percent.

32,000 people live in the state's capital and Southeast Alaska's largest city, Juneau. Juneau's diversified economy includes government, tourism, seafood, trades, education, and transportation. Ketchikan is the second largest community with roughly 13,800 residents and is as a hub for surrounding communities. As the southernmost gateway community, tourism has an important role in its diverse economy, which also includes government, fishing and trade. With 8,500 residents, Sitka is the third most populous community. Its location on Baranof Island's outer coast affords access to the Gulf of Alaska's marine resources, which contribute to an economy largely reliant on the visitor services and fishing. Other economic drivers include health care and education.

Southeast Alaska's northernmost community is Yakutat, a community of over 500 residents that relies on commercial fishing. Haines, Klukwan, and Skagway along Lynn Canal are the other northernmost communities. Haines and Skagway each have roads that connect Alaska with British Columbia, though not each other. Tourism dominates Skagway's economy. Haines also depends on a mix of commercial fishing and a growing visitor products industry. Roughly 3,700 people reside in these communities. Hoonah and Gustavus along Icy Strait are gateway communities to Glacier Bay National Park. Hoonah is a major cruise ship destination and has a strong commercial fishing economy. More than two thousand people live in the Hoonah-Angoon Census Area including residents of Pelican and Elfin Cove which, though small and remote, are important ports for both sport and commercial fishermen. Hoonah is the largest community, with 780 residents.

The largest central Southeast Alaska communities are Petersburg and Wrangell. The Petersburg Borough has over 3,200 residents. Petersburg is a commercial fishing town, but tourism has increased recently with charter fishing businesses and increased port calls by smaller cruise vessels. Wrangell is an attraction to visitors as the gateway community to the Stikine River and has a diverse fishery economy. Its population is roughly 2,400 residents. The native village of Kake, with 570 residents, is the third largest community in the area. Kake's economy has traditionally relied on a mix of fishing and subsistence, but the community is becoming an increasing attraction for visitors as a gateway community to recreation opportunities in Frederick Sound, Chatham Strait and the adjacent coastlines.

The Prince of Wales-Hyder Census Area is the southernmost portion of the region and extends from Prince of Wales Island to the community of Hyder at the British Columbia border. Most residents live in the larger communities of Craig, Klawock, Metlakatla and Thorne Bay. Prince of Wales Island is the third largest island in the United States with 4,200 residents living in 12 communities – mostly smaller fishing villages or former logging communities dispersed along the coastline. Commercial fishing, sport fishing and nature-based tourism are economic drivers for most of these communities.

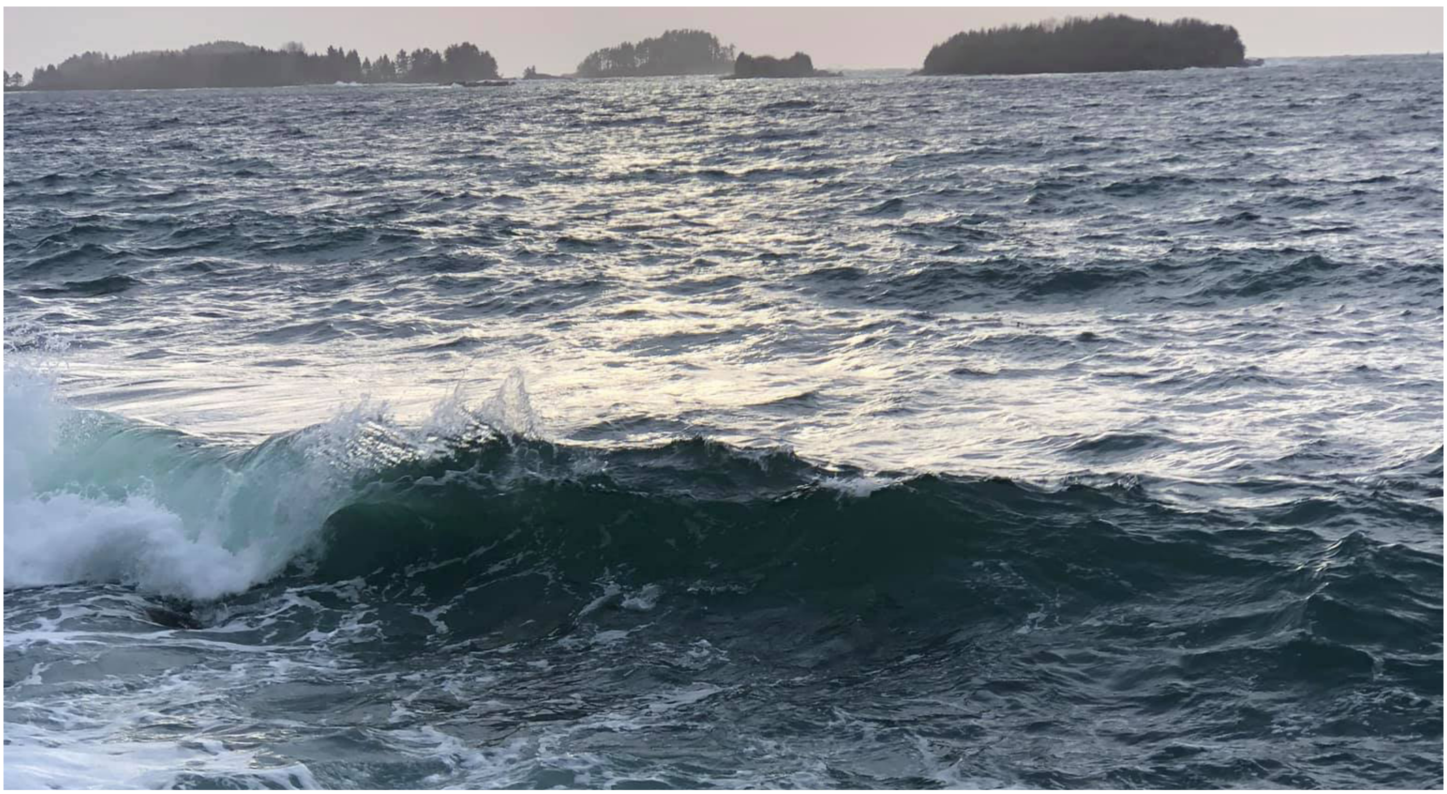


Photo credit: Eric Jordan

The Commercial Fisheries Economy

The productivity of Alaska's fisheries statewide is massive, generating an economic impact estimated at $13.9 billion that extends across the nation. Southeast Alaska is one of the most important fishing regions in the state, with more fishery workers than any region other than the Bering Sea. Seven of the top 100 fishing ports by value in the entire country are Southeast Alaskan ports. It produces ten percent of the state's seafood wholesale value.

The top strength is the high quality of Southeast Alaska seafood products, which include most of the

Alaska harvest of high value chinook and coho salmon, Dungeness crab, spot shrimp, geoducks and sea cucumbers. Over the past decade (2010-2019), the region's average inflation adjusted ex-vessel value (price paid to fishermen) was $308 million, with highs of $405 million in 2011 and $387 million in 2013.

A changing ocean environment and reduced salmon harvests are major concerns. The 2019 ex-vessel value dropped to $218 million. A lower than expected 2019 pink return combined with the trade war with China were major drivers of the reduced catch value. In 2020, restaurant shutdowns, tariffs, increased expenditures on pandemic-related costs and one of the worst salmon catches on record made it one of the worst seafood seasons in Southeast Alaska history. Fishermen and processors hope for relief in 2021 as fresh seafood sales in fish markets, frozen salmon sales and online ordering are all showing positive trends.

Southeast Alaska has a high level of resident participation in the fisheries. Residents own 2,462 fishing vessels – nearly a quarter of Alaska's fishing fleet and more than any other region in the state. Most fishing vessel owners participate in multiple fisheries. The number of resident commercial fishermen peaked at 5,000 in 2014 and has since declined to roughly 4,400 resident fishermen. Another thousand out-of-state residents, mostly from Washington and Oregon, also fish commercially in Southeast Alaska.

The fishermen's harvests support 42 shore-based processing facilities and over 4,300 processing jobs, generating $66 million in wages. Annual wholesale values have typically exceeded half a billion dollars but were lower in 2018 and 2019 – $439 million and $422 million, respectively. The fisheries also support 1,100 management jobs and significant employment in the transportation, marine and academic sectors. Economists estimate recent economic outputs from SeaBank seafood, including multiplier impacts, to exceed $800 million annually and account for 15 percent of regional employment.

Commercial fishermen and processors also provide substantial direct support to regional communities through landings and fisheries business taxes. Alaska deposits fishery business tax revenues from processors in its general fund and the legislature then appropriates up to fifty percent of the revenue back into the community where the processing occurred. Alaska's state fisheries resource landing tax also returns half the revenue to municipalities based on landings.

SeaBank annual dividends from the fisheries are critical to nearly all of Southeast Alaska's 33 communities. Many of the more remote communities, such as Port Protection, Port Alexander and Pelican, are historical fishing villages that rely almost exclusively on commercial fishing and new economic activity associated with sport fishing lodges. Prince of Wales Island has 300 fishing permit holders and 275 crew - roughly eight percent of the population – earning $16.8 million in ex-vessel revenue.

Photo credit: Eric Jordan

Alaska Native villages Hoonah, Klawock, Metlakatla and Yakutat also heavily rely on commercial fishing. Nearly ten percent of the Hoonah/Angoon Census Area population is active in commercial fishing. The 200 active fishermen own 160 boats and 170 permits, earning $4.3 million and generate jobs for a mostly local seafood processing work force. Yakutat is among the top 80 ports in the U.S. based on the value of landed seafood and is the most fishing-dependent community in Southeast Alaska. It has a fleet of over 100 boats and over a third of its residents are active in commercial fishing or seafood processing.

The region's three largest communities – Juneau, Ketchikan and Sitka – rely on commercial fishing as a primary private sector small business generator and employer. There are over 2,000 permit holders and crew in the three communities – and 1,568 fishing boats. Each community has multiple processing facilities which collectively employ over 2,200 workers earning over $32 million in wages. Sitka is Southeast Alaska's top seafood port and ranks 21st in the U.S by seafood volume and 16th by value, producing 45.5 million pounds of seafood worth $61 million in 2018. Roughly ten percent of Sitka residents are active fishermen and average resident permit holder earnings of $41 million are the fourth highest in Alaska. Sitka has the most active troll fleet, with its power trollers earning roughly $10 million each year in ex-vessel values, more than twice as much as any other community. Both Ketchikan and Juneau are among the country's top 50 fishing ports and the top ten Alaska ports for resident permit holder earnings.

“Mid-sized” Southeast Alaska communities of Haines, Petersburg and Wrangell are heavily dependent on SeaBank fishery resources. More than one in every ten residents owns a fishing permit. In 2018, Petersburg was the 25th ranked port by seafood volume and 24th by value in the U.S. with local landings of 35.3 million pounds of seafood worth $44.7 million. Petersburg’s active resident permit holders averaged nearly $50 million in earnings in local and Gulf of Alaska fisheries in 2017/2018, the third highest among Alaska communities and highest in Southeast Alaska. Nearly a quarter of Petersburg residents are active fishermen. Wrangell and Haines also both rank among the nation’s top 100 fishing ports. The gillnet fishery – mostly in Lynn Canal – is the most important fishery for the Haines fleet, producing over half the community’s ex-vessel value. Including crew, over 1,300 individual fishermen live in the three communities with a fleet of 900 vessels generating nearly $70 million in fishing income in 2018. Seafood harvested by these fishermen supported over 1,100 processing jobs generating roughly $15 million in wages.

The Salmon Economy

Salmon supports 1 in 10 jobs in Southeast Alaska and is the most abundant and valuable seafood species, comprising over 80 percent of the total seafood harvest and 50 to 60 percent of regional seafood value from 2017-2019. Over the past decade, SeaBank produced an annual harvest of 52 million salmon worth over $134.2 million in ex-vessel value. 2013 was a record year for salmon catches by all gear types, with a regional record harvest of 112 million fish worth $228 million in ex-vessel value. Chum and pink salmon are the most prevalent species and a major component of the region’s total seafood volume, including nearly ¾ of the volume in 2019. An average of 1,855 gillnet, seine and troll salmon permit holders each year were active over the past decade. Effort has gradually decreased since 2016. 1,604 permit holders fished in 2019.

2017 was the last "normal" year with a catch of 50.1 million salmon and ex-vessel value of $133 million. Harvests and values were much lower in 2018, 2019 and 2020:

Year	Millions of fish	Ex-vessel Value (millions)
2018	21.9	$108
2019	33.0	$88
2020	14.3	$40

Because of a disastrously low even-year pink salmon return, the 2018 harvest was the lowest this century. High prices paid for a large hatchery chum return helped to generate a $108 million ex-vessel value. Prices were lower in 2019 resulting in the lowest ex-vessel value of the decade. The 21.2 million pink salmon harvest in 2019 was the lowest odd year harvest since 1987. 2020 catches of most salmon species were half the amount caught in 2019 or less for all species expect Chinook. Chinook accounted for a third of the entire salmon ex-vessel value in 2020 by all gear types.

Seine Salmon. Seining is typically the highest value fishery overall, averaging over $73 million in annual ex-vessel value over the past decade and peaking at $154 million in 2013. Seiners mostly harvest pink and chum and catch over 70 percent of the fishery volume each year. In 2019, 236 seiners caught 18.6 million pinks, 4.4 million chum and 445,000 sockeye worth $47.3 million. The 2020 season failed to reach $10 million in ex-vessel value.

Gillnet Salmon. Gillnetters' ex-vessel catch value dropped from $18.8 million in 2019 (for 3.8 million fish) down to $7 million in 2020, a fraction of the annual average of $27 million over the 2010s decade. Over 400 gillnetters actively fish each year and obtain the most value from chum, but catch a mix of all five salmon species.

Troll Salmon. Annual ex-vessel values generated by trollers averaged $33 million over the past decade with a peak value of $44.1 million. The 2019 ex-vessel value was $23 million and is likely to exceed $20 million in 2020. There are roughly 1,000 salmon power and hand troll permit holders active each year, making the troll fishery the second largest fleet in the state, next to Bristol Bay. Alaska residents comprise 86 percent of active permit holders. Trollers typically harvest sixty percent of the coho catch each year, most of the Chinook, and also target chum. For coho, the average troll catch over the past decade has been 1.5 million coho, peaking at 2.4 million fish in 2013 but failing to reach a million fish in 2018 and 2019. The 2020 troll harvest of 700,000 cohos was the second lowest harvest since 1988.

Chinook account for 44 percent of the troll fleet's ex-vessel value, averaging $14.8 million from 2014-2018, with a peak at over $20 million in 2014. The average total Chinook harvest from 2007-2016 was nearly 311,000 fish, most of them taken by troll gear. 2017-2019 harvests declined to fewer than 180,000 fish each of the past three years – the lowest three harvests since 1911.

Variance in Salmon Prices. Prices vary by species and type of fishing gear. Pink salmon are the lowest valued species, with prices varying between 22 and 47 cents/lb. over the past five years. Troll-caught Chinook are by far the highest valued species. Summer prices reached a recent peak in 2017 of $7.45/lb. and were $5.65/lb. in 2020. Chinook caught during the winter have the highest value with prices often exceeding $10/lb. The 2020 ex-vessel price for sockeye caught in the net fisheries was $1.29/lb., down from a recent peak of $1.90/lb. in 2019. Coho ex-vessel values exceeded $2.00/lb. for troll-caught fish dressed at sea. Peak chum prices in 2018 were over a dollar a pound and dropped to roughly 60 cents/lb. in 2019 and to 45 cents/lb. in 2020.

Trollers target coho salmon with hook and line gear. Photo Credit: Colin Arisman.

Salmon Hatcheries. There are four hatchery associations – the Northern and Southern Southeast Regional Aquaculture Associations (NSRAA and SSRAA), Douglas Island Pink and Chum (DIPAC) and Armstrong Keta, Inc. -– operating 15 hatcheries in Southeast Alaska. The hatcheries release salmon smolt in numerous locations which then grow to adult size during a migration around the Gulf of Alaska. The hatcheries produce most of the region's chum harvest and between ten and thirty percent of the Chinook and coho catches. Over the past decade, the hatcheries produced on average, over 22,000 chinook, 236,000 coho and 2.8 million chum for common property fisheries. On average, hatchery fish generated $43.8 million in ex-vessel values from 2012 through 2017. Cost recovery by hatchery organizations is also a major component of regional salmon production, comprising 9 percent of average harvests, including $12 million in 2019.

Up until 2020, hatchery production had a buffering effect on the decline in naturally spawning salmon catches. In both 2018 and 2019, exceptional hatchery chum runs partially offset the low overall salmon harvest. In 2018 ex-vessel chum fishery value, including cost-recovery harvests by hatcheries, was $81.1 million, exceeding the value of all other species combined. Chum produced by NSRAA near Sitka alone accounted for a quarter of the total salmon fishery value. Most of the catch occurred at Crawfish Inlet, a new release site for the hatchery smolt. Seiners caught over a million chum there in a single day, a state record for a chum opening. Even with a considerable price decrease from 2018, the chum salmon harvest in 2019 again generated the highest ex-vessel value of the five species of $37.6 million. NSRAA alone produced nearly 3.5 million chum. The Crawfish Inlet release site was the most productive in 2019, generating more than half of the $15 million ex-vessel value from NSRAA fish caught in common property fisheries. 2020 had the poorest chum return since the early 1990s. DIPAC's chum return came in 48 percent below projections. Crawfish Inlet was the only productive area and accounted for most of the 1.9 million chum produced by NSRAA. The hatcheries project higher returns in 2021.

The Groundfish Economy

Halibut and sablefish longline fisheries produce less than ten percent of the Southeast Alaska seafood catch by weight but typically generate a third of the value. Fishermen deliver halibut to processors in most of the region's larger communities and deliver almost 90 percent of the sablefish to Petersburg and Sitka. Petersburg and Sitka fishermen have the most engagement in the longline fisheries, combining to harvest nearly 10 million pounds of both halibut and sablefish in 2019 worth $33 million.

Most Southeast Alaska fishermen harvest halibut in Southeast Alaska (Area 2C) and the Eastern Gulf of Alaska (Area 3A). In recent years, the combined halibut landings from the two areas have been between 10.1 and 11.1 million pounds, with catches of 11.3 million pounds in 2019 and 10 million pounds in 2020. The 2021 commercial quota for the areas is up slightly to 3.53 million pounds in Area 2C and to 8.95 million pounds in Area 3A. Halibut from Areas 2C and 3A generally commanded the highest ex-vessel prices in the state. Largely because of pandemic impacts, 2020 prices were much lower.

Halibut Area 2C & 3A Harvests by Southeast Alaska Residents

	2017	2019	2020
Pounds	6.7 million	6.4 million	(awaiting data)
Price per pound	$6.62	$5.62	$3.96 to $4.44
Total ex-vessel value	$32.6 million	$25 million	(awaiting data)

Sablefish are a premium, high-priced whitefish with export markets in Japan and China and growing markets in the United States and Europe. Alaska typically produces between 60 and 65 percent of the global sablefish production. Southeast Alaska sablefish harvests steadily declined over the past decade due to reduced abundance. Ex-vessel price increases initially helped to offset lower production through most of the decade.

However, there is a declining price trend caused by increasing numbers of smaller size fish and trade wars. Four- and six-year old fish from the large 2014 and 2016 year classes have created a population consisting mostly of smaller fish six years old or younger that yield lower market values. The 2014- year class will not approach maximum value for several more years. The pandemic added to the downward price trend in 2020, with standardized ex-vessel prices (averaged across the season) dropping to $2.32 per pound.

Sablefish Harvests by Southeast Alaska Residents			
	2017	2018	2019
Pounds	6.7 million	7 million	6.4 million
Price per pound (average)	$5.08	$4.22	$3.55
Total ex-vessel value	$32.6 million	$24.7 million	$20 million

The Shellfish Economy

Crab and shellfish species harvested in pots or by divers comprise the other major fisheries. Central Southeast Alaska is the primary crab producer. Southern Southeast Alaska communities and Sitka are leading ports for harvests of shrimp, sea cucumbers and geoduck clams. The combined 2019 economic output from crab and other shellfish was roughly $27 million, boosted by recent record harvests of Dungeness crab, which accounts for nine percent of the region's ex-vessel seafood value.

Roughly 200 permit holders – mostly from Juneau, Petersburg, Sitka and Wrangell – participate in the Dungeness crab fishery each year. The Dungeness crab fishery has been a regional fishery bright spot after poor harvests in 2017 caused an early season closure. The 2018 harvest was the second highest in the past decade at the time. The 2019 and 2020 harvests were the third and second highest harvests on record. The 2019 harvest was also the most valuable on record. Shellfish fishery managers believe these high harvests are indicative of a healthy population.

SeaBank Dungeness Crab Harvests: Resource on the Rise			
	2018	2019	2020
Pounds	4.0 million	5.3 million	6.7 million
Price per pound	$3.01	$3.07	$1.67
Ex-vessel value	$13.6 million	$ 16.3 million	$11.6 million

Most of the Dungeness crab harvest occurs in central Southeast Alaska near Petersburg and Wrangell which account for three-fourths of Southeast Alaska Dungeness crab and tanner crab fishery value and volume. Recent tanner crab prices have exceeded $3.00/lb. Between 70 and 80 tanner crab permit holders typically harvest slightly more than a million pounds each year. Recent harvests of 1.2 million pounds and 1.3 million pounds generated 3.9 million dollars and 4.2 million dollars, respectively Geoducks and sea cucumbers are the primary targets in Southeast Alaska's dive fisheries. The sea cucumber dive fishery is the highest volume and value dive fishery. Roughly 200 divers harvest 1.5 million pounds each year. In 2019, divers harvested nearly two million pounds worth over $10 million. Divers harvested 1.6 million pounds during the 2020-2021 season, but lower prices reduced the harvest value to $5.7 million. Geoducks are the most valuable of the dive fishery species on per pound basis, with prices exceeding $6.00/lb. and recent fishery values ranging between $2.9 and $4.3 million.

Spot shrimp are another significant Southeast Alaska shellfish species. There are slightly over 100 active pot shrimp permit holders. The most productive areas for spot shrimp fisheries are Cordova Bay at the south end of Prince of Wales Island and Ernest Sound and adjacent bays and inlets south of Wrangell. There are fewer spot shrimp in northern Southeast Alaska inside waters and a declining stock so that fisheries are either closed or have decreasing quotas. The pot shrimp fisheries expanded significantly during the 1990s and early 2000s, with harvest typically exceeding 1 million pounds. Recent harvests during the late 2010s typically exceeded a half million pounds. Many pot shrimp fishermen are doing direct sales or marketing frozen-at-sea shrimp at prices ranging between $14 and $16 per pound.

Herring Sac Roe Fisheries

Southeast Alaska has also had active herring sac roe fisheries during the 21st century. The largest fishery – herring seining in Sitka Sound – generated ex-vessel values exceeding $12 million in 2009 and 2010. There was no fishery in 2019 and 2020 and a short fishery in 2018 that harvested 2,926 tons – the lowest harvest 2006. The last four years the fishery was fully active ex-vessel values ranged from $2 million to $4.3 million. A spawn on kelp fishery near Craig has been more successful. From 2018-2020, the fishery generated ex-vessel values ranging between $3.2 and $3.3 million for 130 to 147 permit holders. State of Alaska budget cuts have ended surveys of other areas that were necessary to open the fisheries.

The Recreation Economy

According to the Tongass National Forest's 2016 Forest Plan Final Environmental Impact Statement, Southeast Alaska's comparative advantage in the national and global economy is its "remarkable and unique combination of features including inland waterways with over 11,000 miles of shoreline, mountains, fiords, glaciers and large or unusual fish and wildlife populations that provide opportunities for a wide range of outdoor recreation experiences." The availability of scenic and undeveloped areas creates economic "gateway" communities that benefit from adjacency to outdoor recreation opportunities. Recreation use generates considerable economic benefits for small businesses in gateway communities – particularly through non-resident visitors who bring in "outside" dollars. Alaska's pristine landscapes are an attraction for all visitors - whether cruise ship passengers, wilderness kayakers, or sport fishermen staying at remote lodges.

University of Alaska research has identified features such as undeveloped, unlogged areas as providing the recreation experiences desired by 21st century visitors that influences decisions to visit the region. Southeast Alaska's significant competitive advantages include intact ecosystems, dramatic attractions such as glaciers or salmon streams, and a decreasing global supply of high-quality outdoor recreation opportunities. These competitive advantages were stimulants for rapid growth in nature-based tourism in Southeast Alaska over the past decade. Important growth areas include opportunities for shore-based day excursions from cruise passengers, development of new and creative visitor products, and increasing markets for wildlife viewing, sightseeing, and active visitor experiences such as hiking and kayaking.

Recreation depends primarily on marine transportation for shoreline-based activities. The terrain and topography of Southeast Alaska makes much of rest of the land base unsuitable for outdoor recreation. Primary recreation resources include the region's estuaries and beaches used by residents and visitors for shore-based or water-based viewing of brown bears, black bears, seabirds and waterfowl and marine mammals - the top ranked wildlife viewing species in the state. There are nearly 1,000 miles of trails on National Forest lands, 80,000 acres of state parks, including 16 marine parks – all offering unique recreation settings not found in other areas of the United States.

Marine mammal viewing is popular for visitors on water-based excursions from nearly every community. Sport fishermen utilize the same SeaBank resources as their commercial counterparts – particularly all five species of salmon and halibut. Chinook salmon and halibut are highly prized sport fish pursued extensively by anglers in Southeast Alaska. Yakutat boasts the region's largest steelhead run.

Photo credit: Eric Jordan

Cruise ship visitors and independent boaters travel to Alaska to view scenery such as rugged mountains and coastal forests from Southeast Alaska's thousands of miles of inland waterways. Photo credit: Colin Arisman

The Visitor Economy

Nearly two decades ago, federal land managers projected that undeveloped lands in Southeast Alaska could become valuable assets as the regional economy shifted towards recreation and passive use values by maintaining natural capital – "wild and unspoiled" areas and "sustainable fish and wildlife populations, natural scenery, and feeling of remoteness." There already was an economic shift in response to increased demand – recreation and tourism levels more than doubled between the mid-1980s and mid-1990s. At a national level, demand increased for remote recreation opportunities even as the supply of lands available for outdoor adventure experiences was diminishing. The increasing global scarcity of large areas of intact forest lands has increased their value to visitors. Preserving Southeast Alaskan resources for dispersed recreation opportunities provides stability for gateway communities to maximize benefits from this economic sector as it recovers from losses caused by the COVID-19 pandemic.

Demand for Southeast Alaska's visitor products grew rapidly from 2010-2019. 21st century economic activity in Alaska relies on ecosystem values, particularly values associated with fish, wildlife, scenery and adventure outdoor recreation. Communities throughout the region have developed marketing strategies and small businesses aimed at capitalizing on Southeast Alaska's wild infrastructure. The visitor products industry is thriving because of the supply of scenery, gateway communities and outdoor adventure opportunities, with consistent annual increases in industry employment and earnings. Visitor spending directly contributes to the development of other economic activity such as the growing arts economy. There are over 2,340 artists residing in Southeast Alaska who earn $29.9 million and produce a total economic impact of $57.8 million through retail sales and events that rely to a substantial extent on visitor spending. The regional arts sector is nearly twice the size of the timber industry.

Alaska's popularity is growing – particularly Southeast Alaska, which typically hosts two-thirds of all state visitors, making it the most visited region of the state. Overall, the annual recreation dividend to gateway communities in Southeast Alaska has been massive, providing between 10,200 and 10,900 direct and indirect jobs, with total labor income impacts ranging from $370 million to $407 million. The growth in tourism prior to 2020, particularly small and large cruise ship tourism, increased regional employment and offset downturns in state sector employment and fluctuations in seafood industry production.

In 2017, 1.5 million people visited Southeast Alaska by air and cruise. The number of visitors increased to 1.6 million in 2018, and increased another 10 percent in 2019, to 1.8 million visitors. Growing numbers of cruise ship passengers were a major driver, topping 1 million in 2017 and increasing each year to 1.3 million in 2019. Ketchikan, Juneau, Skagway, and Glacier Bay are four of the top destinations in Alaska. Ninety percent of the visitors to those destinations, and Hoonah, are cruise ship passengers.

Regional economists projected that Southeast Alaska visitor expenditures would reach $800 million in 2020 based on growth indicators from the record breaking 2019 season and an anticipated 1.5 million cruise passengers in 2020. The COVID-19 pandemic halted the cruise season and air passenger arrivals dropped by more than half. Visitor products industry revenue declined by more than eighty percent. Three communities with significant dependence on large cruise ship passengers – Haines, Hoonah and Skagway experienced the biggest job losses. Unemployment levels reached 19 percent in Skagway. Cancelled tours caused the transportation sector to shed half of the jobs held in 2019 – 2,000 – due to the loss of sightseeing clients. The leisure and hospitality sectors also lost 2,000 jobs – over a third of total employment compared to 2019.

Regional business leaders hope for recovery. The top attractions for visitors – the region's natural beauty and recreation opportunities - are intact. For this reason, and industry growth opportunities related to Alaska Native culture and heritage, the visitor products industry should remain a top economic sector as travel opportunities rebound.

Glacier Bay National Park exemplifies the potential for dividends returned from pristine environments.

Glacier Bay is a major capital asset and the top cruise destination in the world. Half a million visitors each year cruise, boat or otherwise experience the park, resulting in $96 million in visitor spending. Visitors who stop in nearby Gustavus for sport fishing or as part of their Glacier Bay experience spend nearly $3,000 each in Alaska - the highest per visitor expenditures in the region.

Across Icy Strait from Gustavus is a tourism complex near Hoonah, Icy Strait Point, that has facilitated access for larger cruise ships. Icy Strait Point normally receives over 160,000 visitors annually and captures 13 percent of all Alaska visitors. The development now provides 130 seasonal and permanent jobs each year, mostly to Hoonah residents. It injects $3.6 million of taxes, wages and visitor spending into the local economy. The development of Icy Strait Point has helped make Hoonah the 9th most visited destination in Alaska.

Nearby Juneau receives over one million visitors each year, making it the most visited community in the region. Passengers visiting Juneau often select shore excursions, particularly glacier tours. Glaciers are a primary local asset, with Mendenhall Glacier being the most visited summer attraction in Alaska, hosting over 700,000 people in 2017. Visitors and businesses use the Taku River and its glacier for camping, sightseeing and helicopter tours. 11,000 visitors land on the Taku and Norris glaciers each year, with revenue to tour companies estimated at $6.6 million. 40,000 visitors use the Taku River watershed each year, spending $15 million and adding $800,000 to Juneau's sales tax revenue.

Photo credit: Colin Arisman

Ketchikan receives the second largest number of visitors – nearly 1 million per year and mostly cruise ship passengers. Local businesses provide roughly 50 unique shore-based excursions for cruise passengers, flightseeing, marine charters, outdoor adventure, and general sightseeing. Sitka's cruise passenger visitor numbers – roughly 150,000 in recent years - are much smaller than Ketchikan and Juneau, but the city has a proportionally larger number of independent travelers who visit for fishing, kayaking, hunting, marine charters and other nature-based tourism. Haines is the other Southeast

Alaska community that hosts over 50,000 passengers arriving via large cruise ships.

The central Southeast Alaska communities of Kake, Petersburg and Wrangell have experienced recent increases in port calls from smaller cruise vessels and increased small business activity in the visitor products sector. The reconstruction of the Kake's historic cannery is in progress and will provide space for artisans, vendors and other activities. The effort to increase the community's attraction to the visitor industry reflects recognition that the community's location near the intersection of Frederick Sound and Chatham Strait enables it to take advantage of easy marine access and natural surroundings and market a variety of tourist attractions.

The number of small cruise vessel visits to Wrangell has nearly tripled over the past decade to 22,000 in 2019, helping to support 37 visitor industry businesses that offer excursions, lodging and meals. Wrangell also is the gateway community for the Stikine River, with six companies that offer river tours. Small cruise vessels also make roughly 150 port calls to Petersburg. Although Wrangell and Petersburg receive significantly fewer visitors than ports that host large cruise ships, visitors to those two communities stay the longest – often two weeks – and spend roughly three times as much on their Alaska trip as visitors to the large cruise ship ports.

Hunting, Wildlife Viewing and Sport Fishing Economy

Southeast Alaska's wildlife and fishery resources are valuable assets for nearly every Southeast Alaska community because of their value for viewing, hunting or sport fishing. In 2011, wildlife hunting and viewing alone generated 2,463 jobs in Southeast Alaska and $138 million in labor income. Residents and visitors spent $363 million on hunting and wildlife viewing. Alaska residents accounted for 81 percent of the hunting expenditures and visitors were responsible for 81percent of expenditures on wildlife viewing trips. These activities also generated $29 million in government revenue. Fishing related tourism creates almost $350 million per year in statewide revenue for Alaska.

Marine mammals are also popular with visitors, particularly in areas like Glacier Bay and Frederick Sound which provide abundant opportunities to view whales, porpoises and seals. Bears are a top species for wildlife viewing visitors in Alaska and generate millions of dollars in regional economic impacts. 2014 and 2019 studies show that bear viewing alone generated $36 million in economic impacts in southcentral Alaska and with similar impacts in British Columbia's Great Bear Rainforest. Both studies identified growth in businesses and jobs related to bear viewing, and indicated that visitors identified bear viewing as a primary reason for their visits.

Bear viewing is likely of similar or even more economic importance in Southeast Alaska. In addition to growing demand for remote wildlife viewing tours on small cruise vessels, there are several popular

Southeast Alaska's bears are a major capital asset that attract thousands of visitors each year for the opportunity to view bears from a small tour boat or at established bear viewing sites at Pack Creek on Admiralty Island and Anan Creek near Wrangell. Photo credit: Colin Arisman.

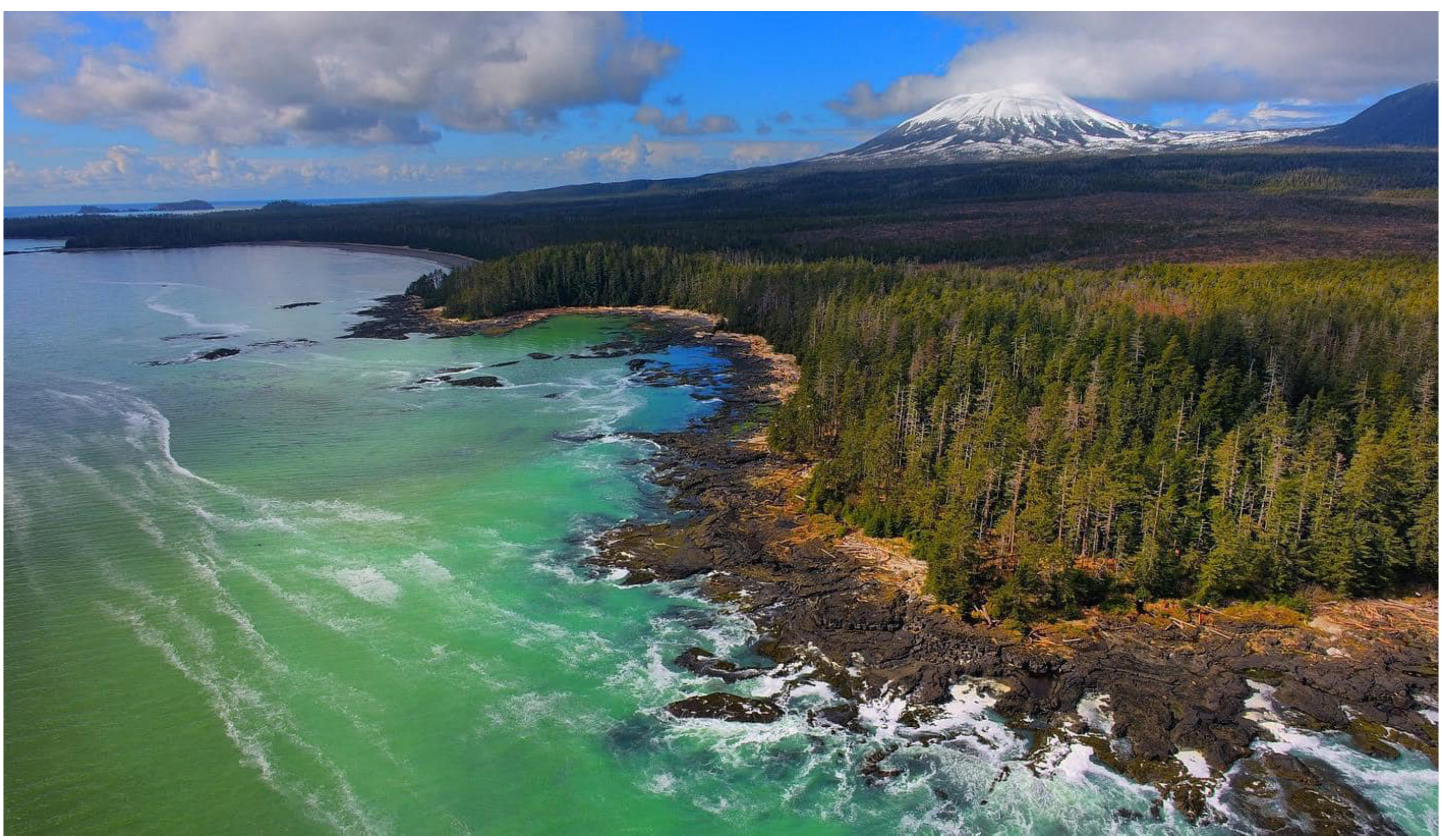
areas used for bear viewing opportunities, including the Stan Price Wildlife Sanctuary and Salt Lake on Admiralty Island, Port Althorp near Elfin Cove and Anan Creek near Wrangell. Hoonah now offers a bear viewing tour to visitors and Sitka's Fortress of the Bear rescues and rehabilitates orphaned cubs and is highly popular with visitors.

Guided hunting – mostly for black and brown bears - provides significant revenue for wildlife management by the Department of Fish and Game, with most of the funding going to wildlife conservation programs. Recent brown bear harvests have ranged between 110-120 bears per year, mostly from Admiralty, Baranof and Chichagof Islands. Hunting guides also pursue black bears – mostly on the mainland and Kuiu, Kupreanof and Prince of Wales Islands. 90 percent of hunting guides are Alaska residents and a significant portion of statewide hunting guide spending and income ($25 million) benefits rural communities.

Charter fishing businesses operate throughout Southeast Alaska. Sitka and Prince of Wales Island are two of the top three sport fishing destinations in the state because of their proximity to the outer coast and its exceptional fishing opportunities for salmon and halibut. Smaller and remote fishing villages such as Pelican, Port Alexander and Elfin Cove are also sport fishing destinations; summer revenues generated by over 1,500 visitors to Elfin Cove alone amount to $5 million annually. Transboundary river Chinook and coho salmon assets support 32 sport fishing businesses in Petersburg and Wrangell.

Formerly timber-dependent regions such as Prince of Wales Island have new, redefined economies based primarily on fishery and wildlife resources. The decline of the timber industry was an opportunity to shift into the maritime economy and visitor products industry for long term community viability. Prince of Wales Island community planners now pursue a market-based transition featuring hiking, hunting and fishing lodges that support small local businesses. Nature-based tourism generates more money each year than the Forest Service has generated selling timber from the island over the past 25 years. Most of the revenues derive from marketing sport fishing on the island as a "dream destination for sport fishers." Over two-thirds of island visitors participate in fishing – the highest rate among SE communities. Waterfall Cannery is the island's largest lodge and its fifth largest employer, with over a hundred seasonal employees. Sport fishing lodges near the small communities of Coffman Cove and Whale Pass attract sport fishers for saltwater fishing in Clarence Strait or steelhead fishing in freshwater streams.

The island's road system connects most of the island's towns and villages and is a major competitive advantage relative to other Southeast Alaska communities by attracting visitors for road-based recreation. The inter-island ferry system is a key part of the transportation system, bringing 3,000 visitors to the island – half hunters and sport fishermen and half hikers and campers. Others arrive by float plane. Data compiled in a 2016 Alaska visitor study indicated that campers, fishermen, hunters and hikers stayed for multi-day trips, spending $10.2 million, generating 213 seasonal jobs and generating a total economic impact of $14 million. The island hosts between 14,000 and 18,000 visitors each year, and has the region's highest proportion of return visitors.



The Eco-Tour Economy

There is strong demand for outdoor adventure and eco-tour services provided by outfitters and guide businesses. Forest Service lands, particularly inventoried roadless areas, host roughly half of regional visitor activity, accommodating 2,874,000 visits which generate $382 million in spending and support 3,947 direct jobs and 1,110 indirect jobs. The number of guided clients on the Tongass National Forest is increasing at a high rate – from 533,388 clients during the recession in 2011 to 641,149 clients in 2017 – a 17 percent increase. The primary activities sought by guided visitors are dispersed, active and remote outdoor recreation experiences such as hiking, kayaking and wildlife viewing which comprise over sixty percent of all guided visitor activity.

The small cruise vessel fleet is a major regional growth sector consisting of a diverse group of overnight commercial passenger vessels including yachts and smaller motor vessels that carry between 6 and 250 passengers. Many of the small cruise companies have Forest Service special use permits and specialize in providing visitors with remote recreation opportunities. Passenger capacity of this fleet doubled over the past decade. There were roughly 30 small cruise vessels carrying more than 20 passengers operating in Southeast Alaska during the late 2010s.

Small cruise vessel companies increase the number of multi-day visitors to the region and bring visitors to wider range of Southeast Alaska communities, including mid-sized communities such as Haines, Hoonah, Petersburg and Wrangell and even to smaller communities such as Kake, Kasaan, Skagway and Tenakee Springs. Passengers typically will pay premium prices for remote recreation experiences in more pristine environments.

Southeast Alaska's gateway communities have developed marketing strategies aimed at small cruise companies and adventure-oriented multi-day visitors. Multiple small cruise itineraries describe Haines as "the center of adventure" and offer weekly visits or rotating visits that bring hundreds of visitors to the community between April and September. Haines' website describes the community as "The Adventure Capital of Alaska."

Regulations preventing large cruise ships from operating in 2021 do not affect the U.S. flagged fleet of small cruise vessels. As of the early spring 2021, several small cruise vessel companies intend to operate in 2021.

Haines boasts year-round fun for the entire family, located along the edge of North America's longest and deepest fjord, just 68 nautical miles north of Juneau in Southeast Alaska. Craggy mountain peaks tower above a lush coastal rainforest with temperate seasons that call to the adventurer in all of us. Fill the long daylight hours of summer with a rafting trip, a deep-sea halibut fishing charter, or a hike through an ancient spruce forest. Visit museums dedicated to our earliest residents, the Native Tlingit people, and a national favorite, the American Bald Eagle. And if you're still up for more, explore gold rush era Fort William H. Seward, or find yourself alone at the end of a rocky beach trail.

Risk factors:
Threats to SeaBank Natural Resources

The natural systems and myriad resources that comprise Southeast Alaska's ecosystems are subject to trends, variations and cyclical fluctuations in larger-scale systems. The vectors of change may be global, such as climate change, or local, such as timber harvest, transboundary river pollution and biological population dynamics. Some changes are irreversible. Many kinds of shifts can affect SeaBank capital and dividends, highlighting the importance of enumerating assets, identifying possible risks to them, and carefully managing the natural capital. Specific risk factors considered here are:

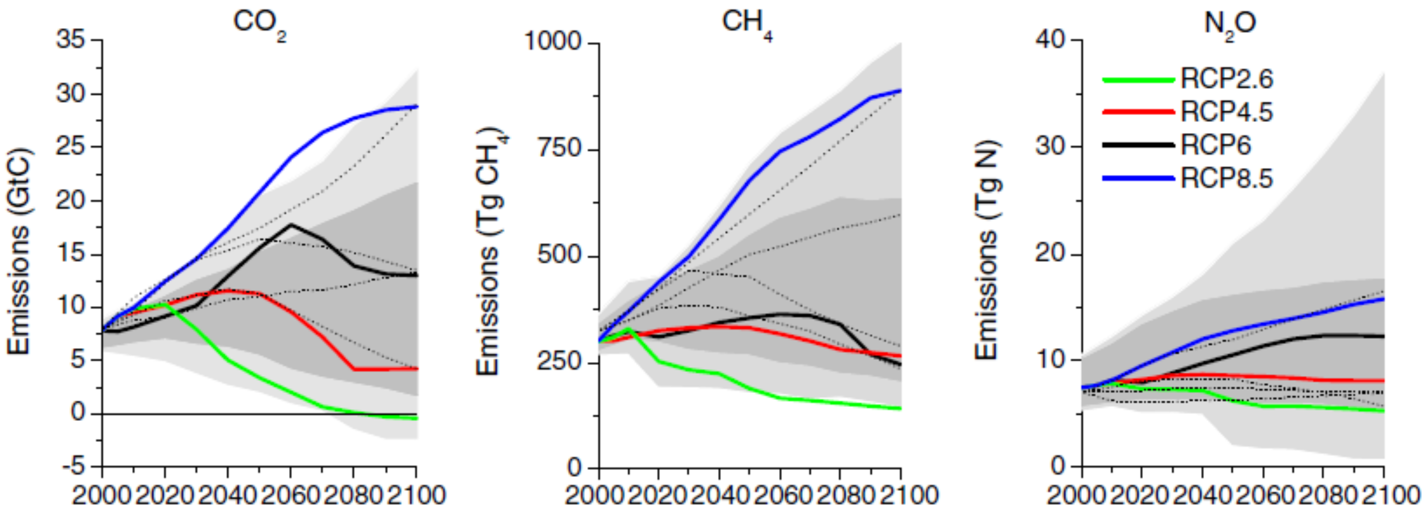
Climate
Trawling
Industrial Logging
Transboundary River Pollution

Climate Change and Effects on Southeast Alaska Resources

Climate change effects are already apparent in Southeast Alaska, and notable impacts are likely on Southeast Alaska's natural capital, from sea level rise, melting glaciers, changing thermal regimes for freshwater and marine ecosystems, shifting precipitation patterns, and alterations in distributions of plants and animals.

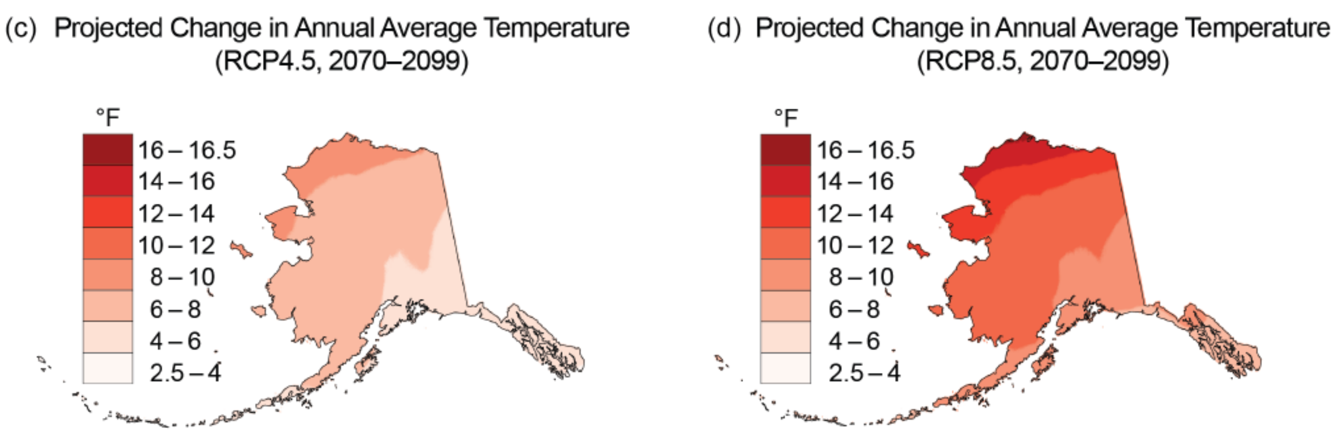
USA, pp. 1185-1241.

Climate scientists use four greenhouse gas emissions scenarios, known as Representative Concentration Pathways (RCP 2.6 – RCP 8.5) to forecast future temperature trends and other changes. The RCPs reflect potential levels of actions to reduce greenhouse gas emissions. RCP 2.6 assumes major and immediate initiatives to reduce emissions while RCP 4.5 and 6 are "stabilization" scenarios assuming that emissions peak over the next thirty years. RCP 8.5 is the "nightmare scenario" which assumes continued increases in greenhouse gas emissions through 2050.

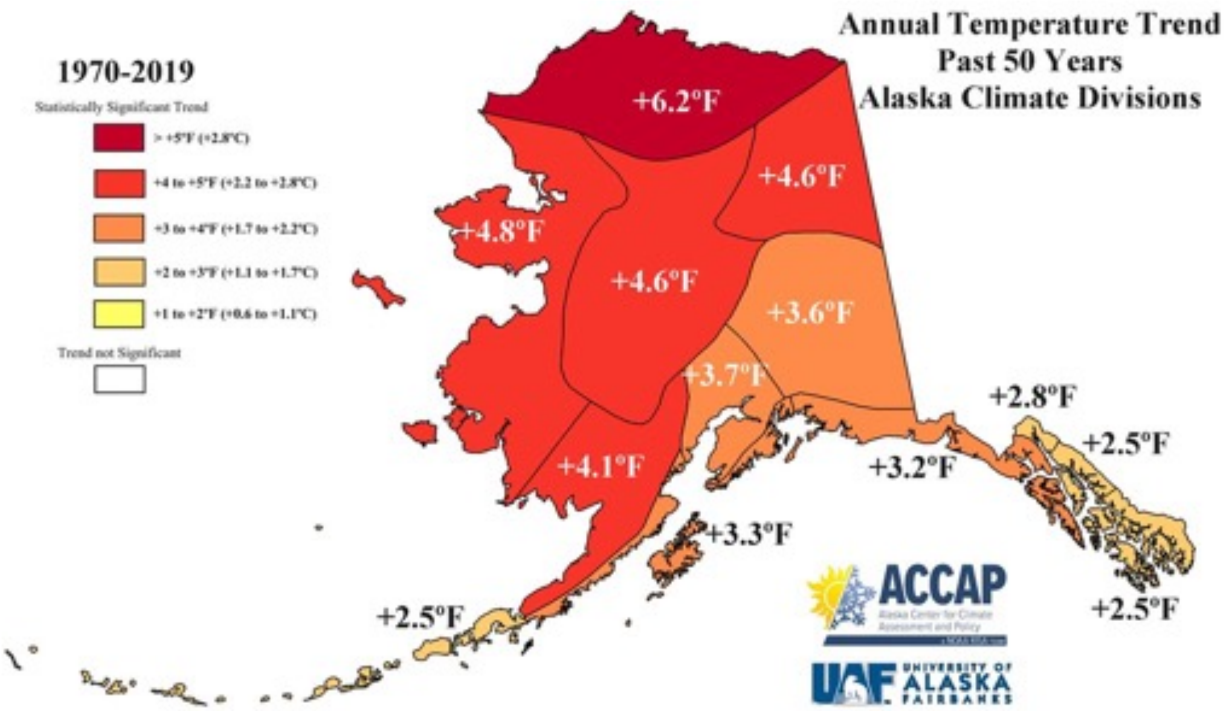


Graphics credit: Van Vuuren, D.P. et al. 2011. The representative concentration pathways: an overview. Climate change (2011) 109:5-31.

As shown in the figure below, the 2018 National Climate Assessment Chapter for Alaska also projects significant ongoing temperature increases for Alaska exceeding 10° Fahrenheit through most of the state under RCP 8.5. Specific projections under RCP 8.5 for Southeast Alaska are for average annual increases of 3 – 5° F by the 2040s, and 5 to 9° F by the 2080s. Warming temperatures will increase the frequency and intensity of extreme weather such as record heat, intense precipitation events associated with atmospheric rivers, marine heat waves and other anomalous weather events.

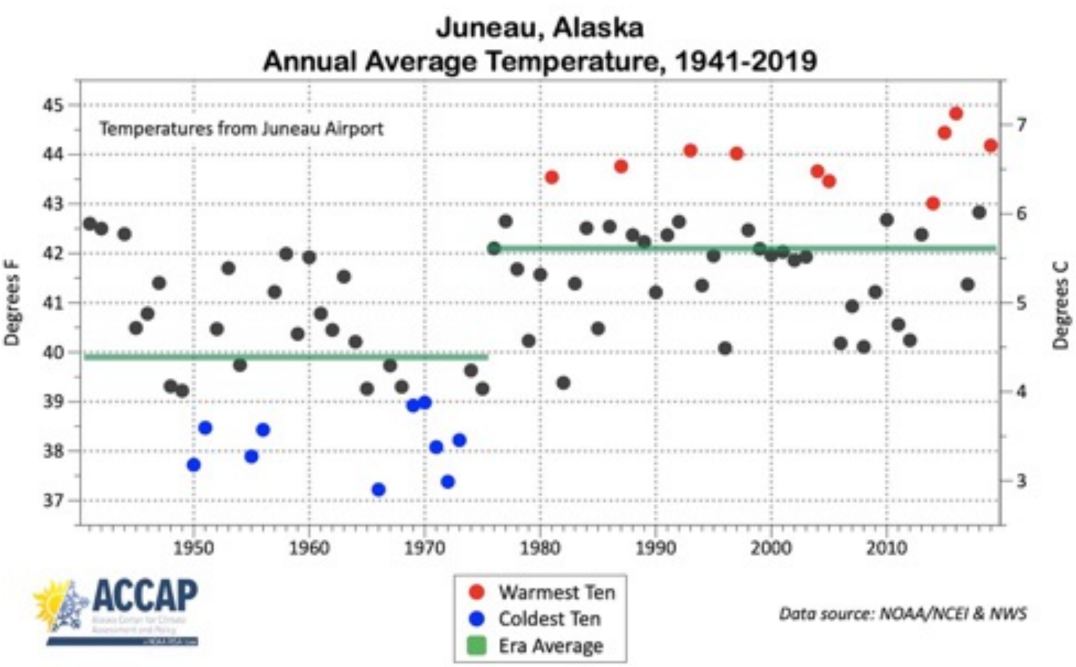


Scientists project that Southeast Alaska will experience considerable warming over the next half century. Graphics credit: Markon, C., S. Gray, M. Berman, L. Eerkes-Medrano, T. Hennessy, H. Huntington, J. Littell, M. McCammon, R. Thoman and S. Trainor, 2018: Alaska. In: Impacts, risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington DC,



Alaska has already warmed considerably over the past half century. Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

Alaska overall has experienced significant temperature increases, warming twice as fast as the rest of United States, with fewer extremely cold days and increasing numbers of record high temperature events. While the most rapid warming is occurring in Alaska's Arctic regions, Southeast Alaska has also warmed – by roughly 2.5° to 3.2° Fahrenheit over the past half century, most of that recently. Beginning in the 1990s, high temperature records in Alaska began occurring three times as frequently as record low temperatures. In 2015, high temperature records occurred nine times as often as record lows. 2014-2016 and 2018 were four of the five warmest years on record.



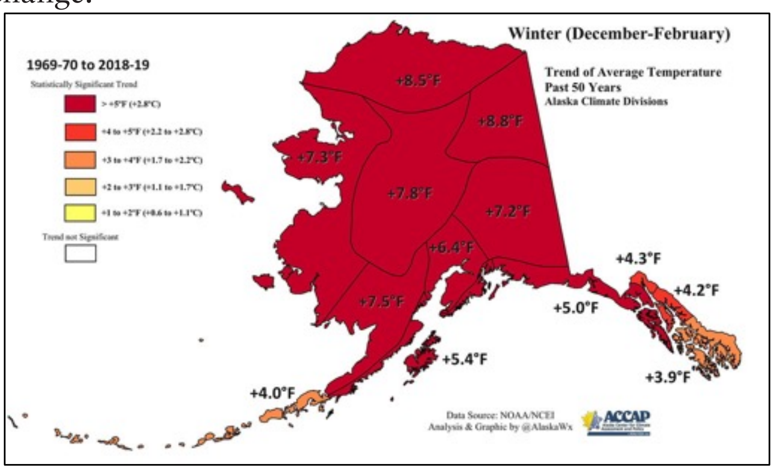
Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, Funded by The NOAA Climate Program Office.

Alaska's record heat wave in 2019 was globally significant, and set records in Southeast Alaska in both the spring and summer. March temperatures were 3 to 4° F higher than the 1981-2010 average and July temperatures were 3 to 5° F higher than everage.

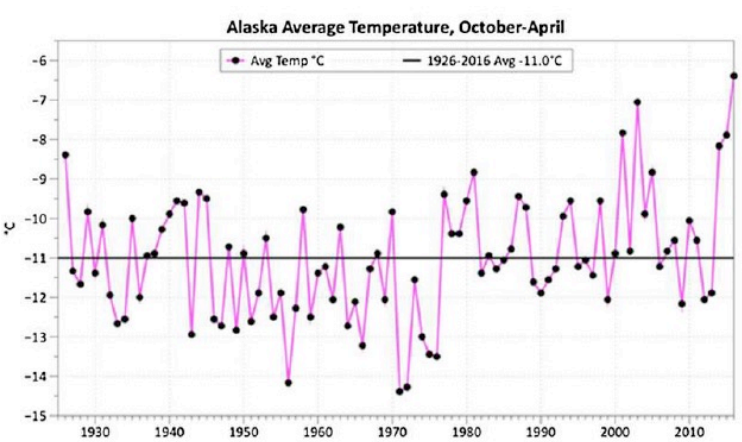
Warmer Winters, Snow Droughts and Melting Glaciers

The highest temperature anomalies are occurring in the winter. November 2019 temperatures were over 5° F higher than average in Ketchikan and Juneau, 6.4° F higher in Skagway, and 7.4° F higher in Yakutat. Alaska's winter temperatures are rising more than temperatures of any other season – a trend described by Alaska climate scientists as "extreme cold season anomalies." Scientists expect that the greatest temperature increases will continue to occur during winter. Warm winters will likely become normal by 2050 under current greenhouse gas emission scenarios. Lowest daily minimum temperatures (coldest nights of the year) may increase by 12° F. The number of nights below freezing may decrease by as much as 45 nights per year in coastal areas.

The 2019 warm winter occurred just four years after the winter of 2015-2016 when statewide temperatures exceeded historical averages (1925-2016) by 8.4° F for the whole winter and by 10.9° F from January to April of 2016. There were multiple causes: warmer than normal ocean temperatures, diminished sea ice coverage, the albedo effect (reduced snowpack) and warming caused by climate change.



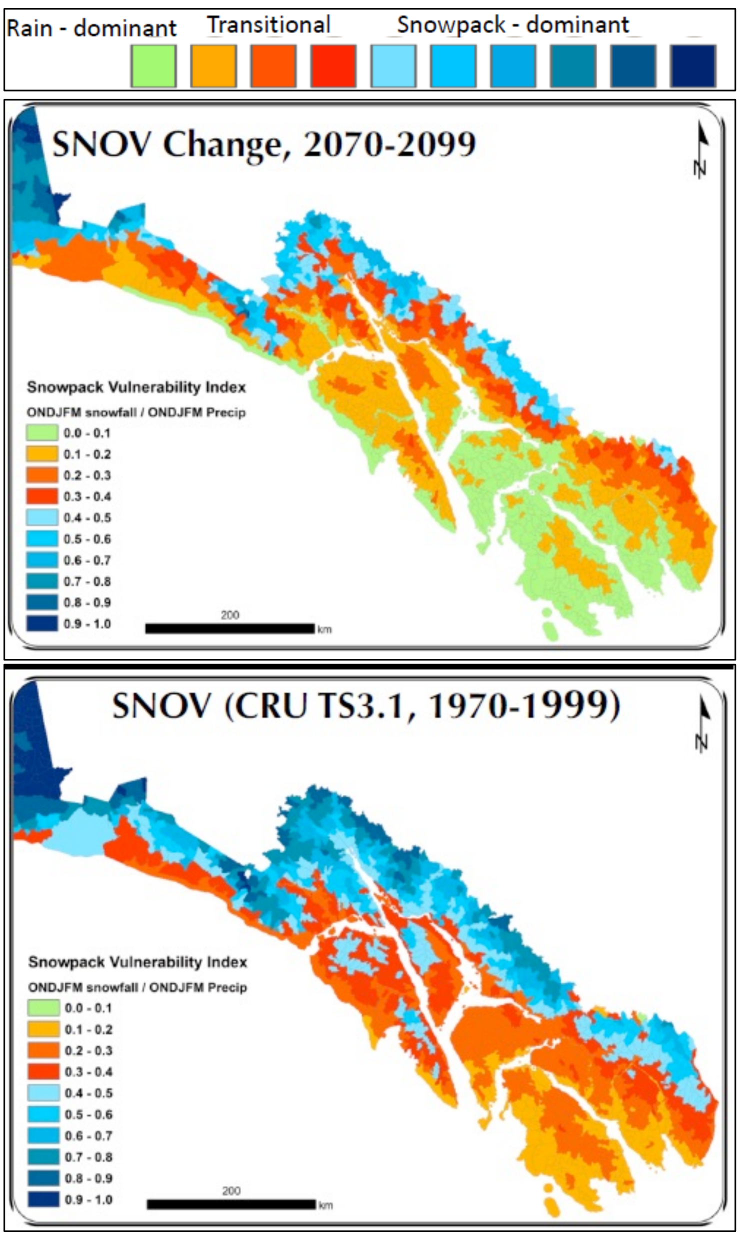
Graphics credit: Alaska Center For Climate Assessment & Policy, University of Alaska Fairbanks, Funded By The NOAA Climate Program Office.



Graphics credit: Walsh, J.E., P.A. Bienek, b. Brettschneider, E.S.. Euskirchen, R. Lader & R.L. Thoman. 2017. The exceptionally warm winter of 2015/16 in Alaska. In Journal of Climate 30 (6) 2069-2088.

Warmer winter projections are highly relevant to Southeast Alaska which may experience the largest change in number of winter days above freezing in all North America. These changes cause "snow droughts" which occur when there is near normal precipitation but less than average snow accumulation caused.

Watersheds currently fed by snowpack will change into rain-fed systems. As glaciers disappear, presently glacial-fed watersheds will shift to relying on snow melt and eventually also become dependent on rainfall. These changes will increase winter stream flows, reduce summer stream flows and cause year-round increases in stream temperatures. The rain-snow transition zone will rise in elevation, resulting in less precipitation stored as snowpack. Evidence of this changing water balance is already appearing with quantifiable decreases in the number and area of some Southeast Alaska waterbodies. By 2050, most of coastal Southeast Alaska will lose twenty to thirty percent – or more – of historical snowpack levels.



One of the major impacts of these temperature changes will be continued rapid thinning and recession of most of Alaska's glaciers. Normally, winter snowfall grows glaciers which then shrink during the summer. Rising temperatures have caused summer melt to exceed winter gain. According to the International Arctic Research Center, glaciers thinned by several feet a year between 2002 and 2017 - an overall annual mass loss of nearly 60 billion tons of ice. 95 percent of Southeast Alaska's glaciers are losing volume, some at the highest rates in the world.

Glacial melt in Alaska and neighboring British Columbia transfers more freshwater to the ocean than the melting Greenland ice sheet. scientists project losses of between 18 and 45 percent of

As shown to the left in the Snowback Vulnerability Index map, areas covered by snowpack in Southeast Alaska will likely change considerably over the next century. Graphics credit: Littell, J. 2019. Powerpoint: Climate model uncertainty. U.S. Geological Survey, Alaska Climate Adaptation Science Center.

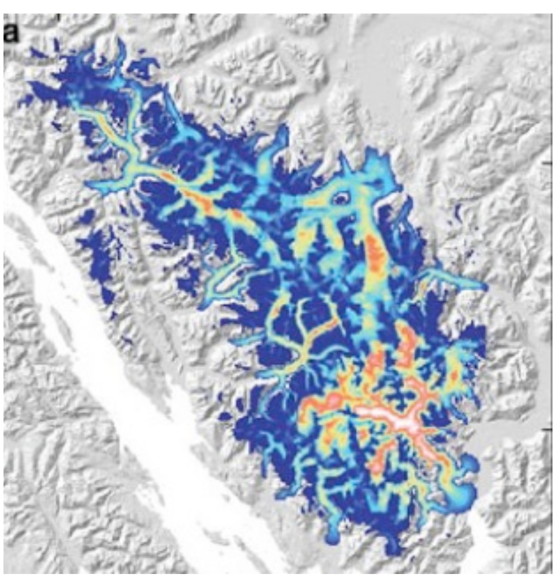
Alaska's glaciers by the end of this century. The largest mass loss of glacial ice occurs in maritime climates such as those adjacent to the Gulf of Alaska, meaning that glacier volume loss in Southeast Alaska will increase over the next century. These losses are globally significant as North American glacial ice loss accounts for roughly 20 percent of global loss (excluding ice sheets).

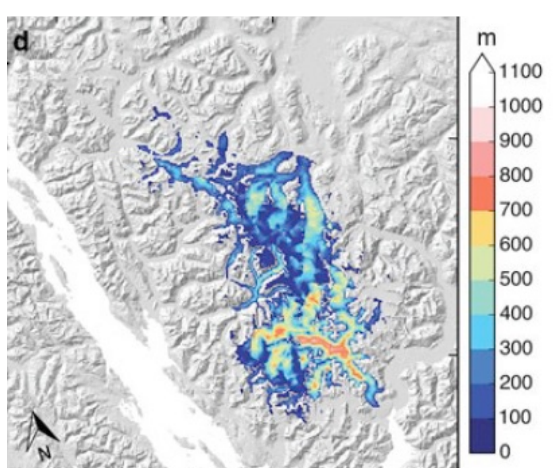
A study specific to Southeast Alaska's glaciers found that the low elevation Yakutat glacier is likely to retreat at an accelerating rate and could disappear over the next half century. The Juneau Icefield, one of the largest icefields in North America, has a mountain topography that makes it less vulnerable to climate change than other glaciers. Even so, as shown here, the Juneau Icefield, may lose nearly two-thirds of its volume and area by the end of the century.

The loss of glacial and ice sheet volume will be one of the more significant causes of rising sea levels this century. Half or more of the world's tidal wetlands could disappear due to sea level rise. Sea level rise and increased frequency and severity of storm surges will change the hydrology of remaining coastal wetlands and deltas. These effects would occur primarily in the southern portion of Southeast Alaska. In northern Southeast Alaska, the sea level is actually decreasing, at least so far, due to glacial rebound.

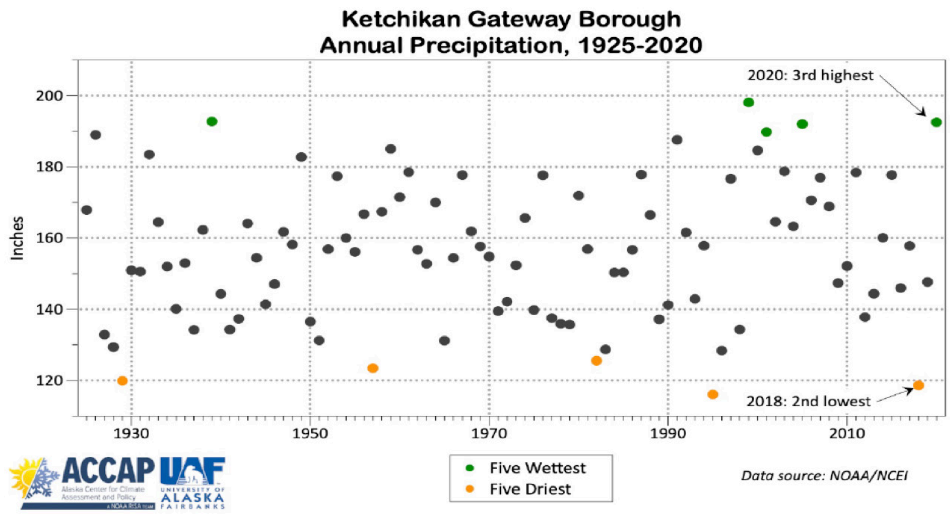
Glacial runoff influences downstream freshwater and near shore marine ecosystems. Changes in flow, temperature and nutrient dynamics in freshwater ecosystems in turn influence fish abundance across multiple life history stages. In the long term, loss of glacial ice will result in lower water yields. These changes have significant implications for coastal ecosystems because of effects on the marine food web – the altered distribution of forage fish species will force adaptation by the numerous avian, fish and wildlife species that utilize glacial tidewaters and estuaries during portions of their life cycle. Species such as harbor seals and Kittlitz's murrelets that depend on glacial habitats for breeding are likely to decline due to habitat loss.

The first graphic shows the extent of the Juneau icefield and ice thickness in 2011. The second graphic illustrates projected shrinkage by 2099. Graphics credit: Ziemen, F.A., R. Hock, A. Achwanden, C. Khroulev, c. Kienholz, A. Melkonian & J. Zhang.





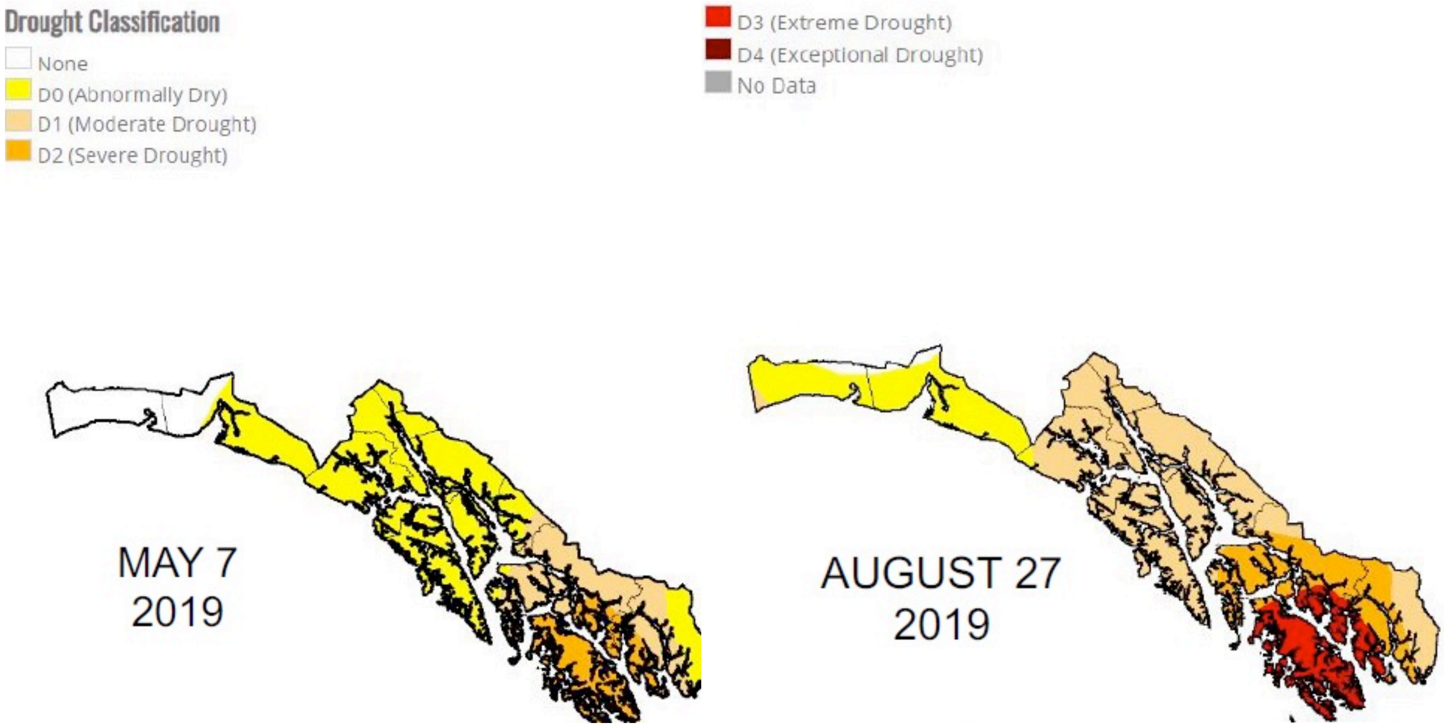
Alaska climate scientists anticipate continued changes in the frequency and intensity of extreme weather such as record heat and rainfall events. The frequency of extreme weather events will double under a 2° Fahrenheit increase associated with RCP 2.6, the reduced greenhouse gas emissions scenario. RCP 8.5 would raise temperatures by 7. 2° F and cause extreme weather events to occur as often as 1 in every 5 years. Another concern raised by recent extreme precipitation events is that storms once thought of as impossible or extremely unlikely could become real concerns, and perhaps not infrequent.



Ketchikan had its second driest year over the past century in 2018, followed by the 3rd wettest year two years later, in 2020. Graphics Credit: Thoman, R., R. Lader & J. Littell. 2021. Are we living in the future? The climate extremes of recent and future Southeast Alaska droughts and floods.

Southeast Alaska is normally one of the wettest locations in the world. Haines is one of the driest communities in the region, receiving an average of 49 inches of precipitation a year – more than either Portland or Seattle. Craig, Petersburg and Ketchikan all average over 100 inches a year. The two wettest large cities in the continental U.S, New Orleans and Miami, receive just over 60 inches a year. One of wettest locations, Port Alexander at the tip of southern Baranof Island, receives 163 inches a year with a nearby inlet, Port Walter, receiving 237 inches a year – 100 inches more than any other location in the continental U.S. Scientists project significant increases in precipitation to occur in all seasons in communities adjacent to the Gulf Alaska. 2020, for example, was one of the wettest years on record. The one exception is that most climate models project lower precipitation in the summer, particularly in central and southern Southeast Alaska.

Indeed, from 2017- 2019, the region experienced its lowest rainfall on record accompanied by record high temperatures, with moderate drought conditions in the northern part of the region and severe to extreme drought conditions in central and southern Southeast Alaska. There were bans on fireworks, fires, increased fire risks, and below normal stream flows, including record low stream flows affecting upstream fish migration timing. There were long term precipitation deficits in southern southeast Alaska, with water restrictions in Wrangell and increased need to use diesel power rather than hydropower in multiple southern Southeast Alaska communities.

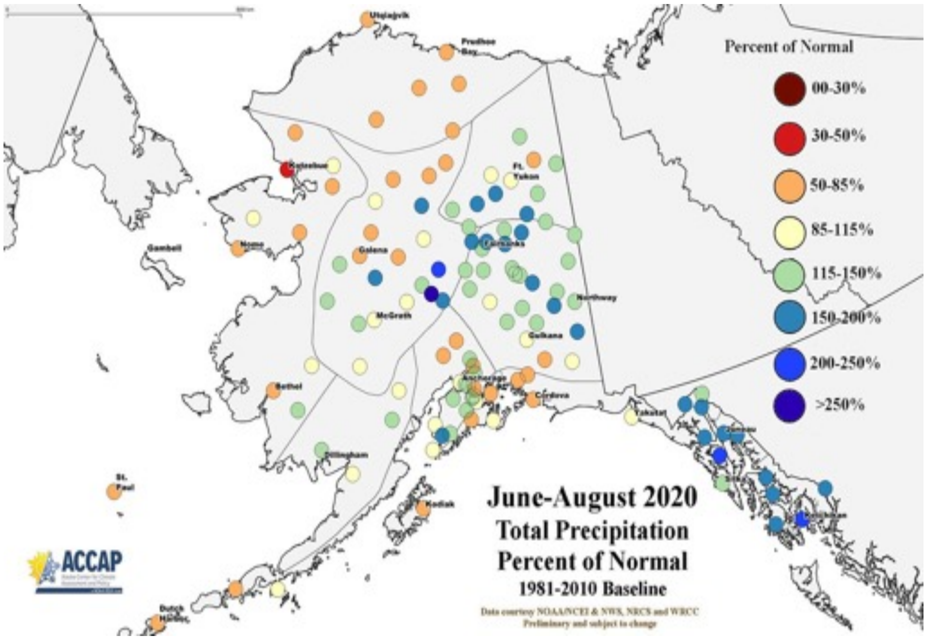


Graphics credit: Jacobs, A., R. Thoman & H. Prendeville. 2020. SEAK Drought-Better or Worse

Precipitation deficits from June 2018 to May 2019 were the largest for a 12 month period dating back to 1925. The deficit caused the state's first extreme drought classification by the U.S. Drought Monitor. Most Southeast Alaska communities had a 20-30 percent precipitation deficits over the three year period. The drought eased by summer of 2019, with normal rainfall developing around southern and central Southeast Alaska and deficits continuing around Juneau, Hoonah and Sitka.

An extremely wet year followed the drought, with most of the region experiencing two to three times as much precipitation as normal. The wet summer and fall culminated in an atmospheric river hitting the region in early December. Atmospheric rivers are streams of water vapor in the lower atmosphere that can be 300 miles wide and hundreds of miles long, at times extending across the entire ocean. If condensed into liquid water, the vapor would create a water layer 2 centimeters thick, over that whole span. High winds accompany atmospheric rivers. Extreme precipitation, flooding, increased landslide and avalanche risks and record high stream flows can occur when they make landfall and collide with coastal mountain ranges.

The impacts were most notable in northern Southeast Alaska, setting rainfall records in Pelican, Haines, Hoonah, Juneau, and Skagway. Haines received over seven inches of rain in one day, eclipsing its previous one day record, and ten and a half inches in two days. The event was a 200 to 500 year storm. Skagway, the driest city in Southeast Alaska, with an average of 30-35 inches of rain per year, received nearly 9 inches in 3 days – a one in one thousand year event. Pelican received over 18 inches between November 30 and December 3, surpassed by Port Walter on southeastern Baranof Island, which received nearly 20 inches. Seven of the fifty largest cities in the United States average less precipitation for the entire year. Impacts included widespread flooding, landslides and power outages. Several days later, Ketchikan recorded its wettest week in 100 years, with 20 inches in seven days (a 20 year event).



2020 summer precipitation was 2-3 times as high as average, followed by record-setting precipitation events in December. Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

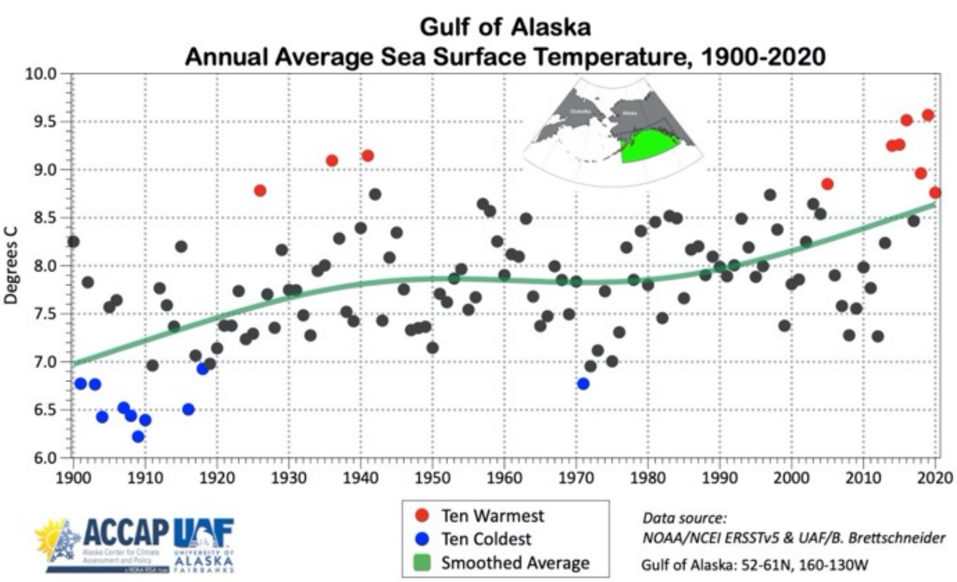
> "Imagine a stream of water thousands of kilometers long and as wide as the distance between New York City and Washington D.C. flowing toward you at 30 miles per hour. No, this is not some hypothetical physics problem – it is a real river, carrying more than 7 – 15 Mississippi Rivers combined. But it is not on land. It's a river of water vapor in the atmosphere."
> Ralph, F.M. & M.D. Dettinger. 2011. Storms, Floods, and the Science of Atmospheric Rivers. Eos, Vol. 92, No. 32, 9 August 2011.

The U.S. 4th National Climate Assessment projects that both the frequency and severity of atmospheric rivers making landfall will increase due to increasing evaporation and resulting higher atmospheric water vapor caused by increasing temperatures. Arctic warming is shifting storm tracks toward higher latitude areas, increasing the risk that atmospheric rivers will make landfall along the Southeast Alaska coast and increase the number of intense multi-day precipitation events.

One of the implications of intense precipitation events – and precipitation falling as rain instead of snow – is a corresponding increase in landslide risks and frequency because precipitation causes most landslides. A recent study by British Columbia scientists indicates that most of the increased landslide risks will occur during winter and fall seasons when the largest projected increases in single- and multi-day precipitation will occur. Some areas – large coastal islands and the northern mainland closest to Southeast Alaska – will see the frequency of days with an elevated landslide hazard increase by as much as sixty percent over the next three decades, by 8 to 11 additional days per year.

The Warming Ocean

Changes in ocean chemistry and warming temperatures will also impact Southeast Alaskan marine resources. Warming oceans will redistribute marine fish species, opening new habitat for some species but also causing viability risks for others. Over the past five years, market squid have moved north from British Columbia and started spawning in Southeast Alaska waters that previously were too cold for them to spawn. But among marine species there will be more losers than winners. Consecutive years of warm water patterns and associated food web changes are likely to reduce overall marine ecosystem productivity, particularly for ectothermic marine species(cold-blooded species, such as fish, that rely on external factors, such as water temperature, to regulate body temperature).



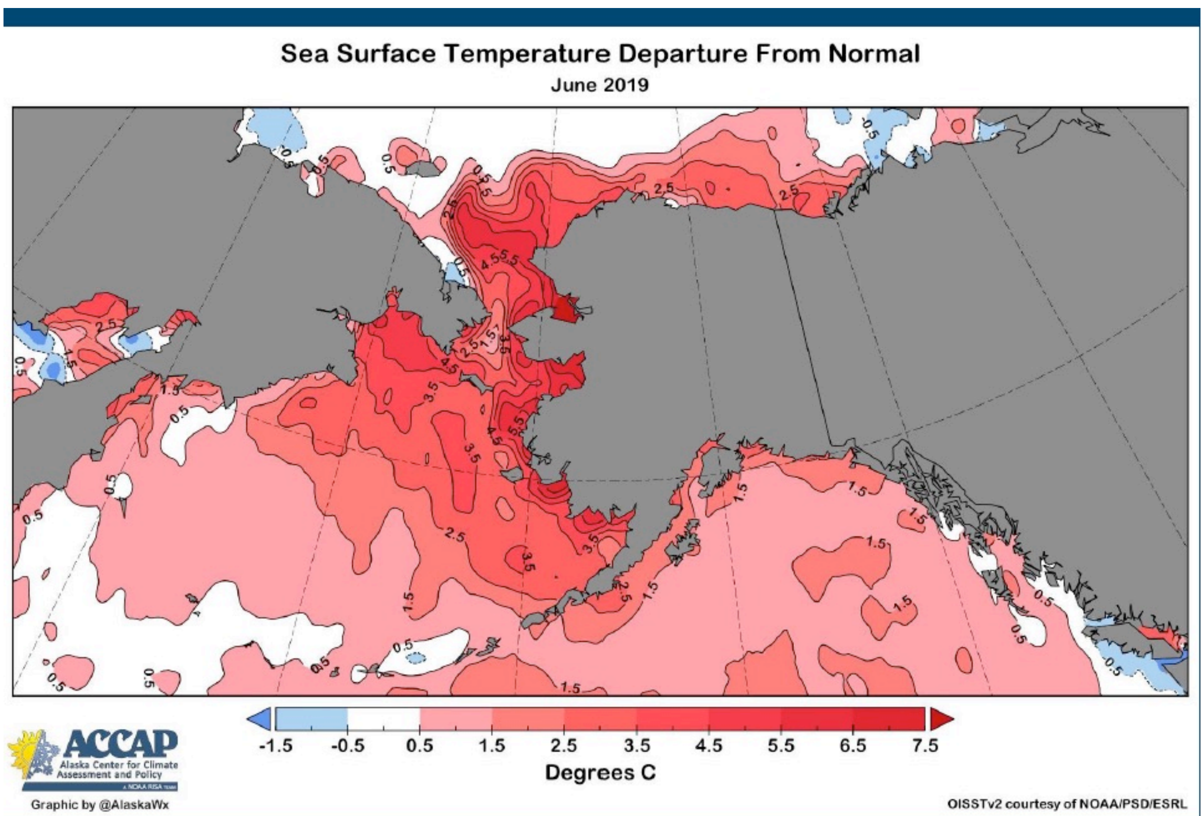
Gulf of Alaska sea temperatures have steadily warmed over the past thirty years, with six of the warmest years on record occurring this decade. Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

Across the North Pacific, there was an extreme marine heat wave from 2014 through 2016. Surveys measuring the abundance of juvenile cod, pollock and salmon in the eastern Gulf of Alaska showed precipitous declines following the heat wave. The heat wave also contributed to record high winter-spring temperatures onshore in 2016. Both the Bering Sea and Gulf of Alaska were anomalously warm during this heat wave with record sea surface temperatures and ocean heat content (the thermal energy stored in the ocean). Gulf of Alaska sea surface temperatures were 3.6° F above normal. The heat wave had multiple causes, including warming caused by climate change, a strong El Nino and a possible warm phase of the Pacific Decadal Oscillation. Climate change increases the risk of more marine heat waves in the future. Current climate trends suggest that what are now extreme sea surface temperature anomalies will become common in the coming decades.

NOAA fishery scientists identified the heat wave as unusual based on the amount of temperature increase, winter ocean warmth and ocean depths reached by the warmer temperatures. The 2014-2016 marine heat wave changed the ecology of the Gulf of Alaska, including a shift to lower quality prey species, overall reductions in forage fish populations and associated effects on other species at the top of the food chain. The extended and anomalously warm period from the surface waters to ocean depths likely caused high mortality among juvenile and adult Pacific cod. Ectothermic species (cold-water fish) must consume more food in warmer waters, and often expend excess energy in times of prey depletion.

The Alaska Department of Fish and Game identified the warming temperatures as a probable cause for low returns of pink salmon that went to sea from 2014 through 2016. Those returns were below recent averages, and harvests were below projections. Pacific Northwest salmon scientists have noted that the general non-linearity of marine ecosystem dynamics makes consequences of ocean regime change hard to predict, but warmer decades have often occurred in tandem with prolonged periods of poor marine survival. There is evidence of lower fish foraging success during the recent warm years.

After the heat wave, the Gulf of Alaska ecosystem returned to typical temperatures in 2017 and 2018. Then, the region experienced another marine heat wave as summer temperatures rapidly exceeded normal temperatures in 2019:



A 1.5° C increase is equal to a 2.7° F increase. Graphics credit: Zador, S., E. Siddon & E. Yasumiishi. 2019. Ecosystem Status Reports; Early warnings: Bering Sea and Gulf of Alaska. Powerpoint presentation, North Pacific Fisheries Management Council. Homer, Alaska. October 2019.

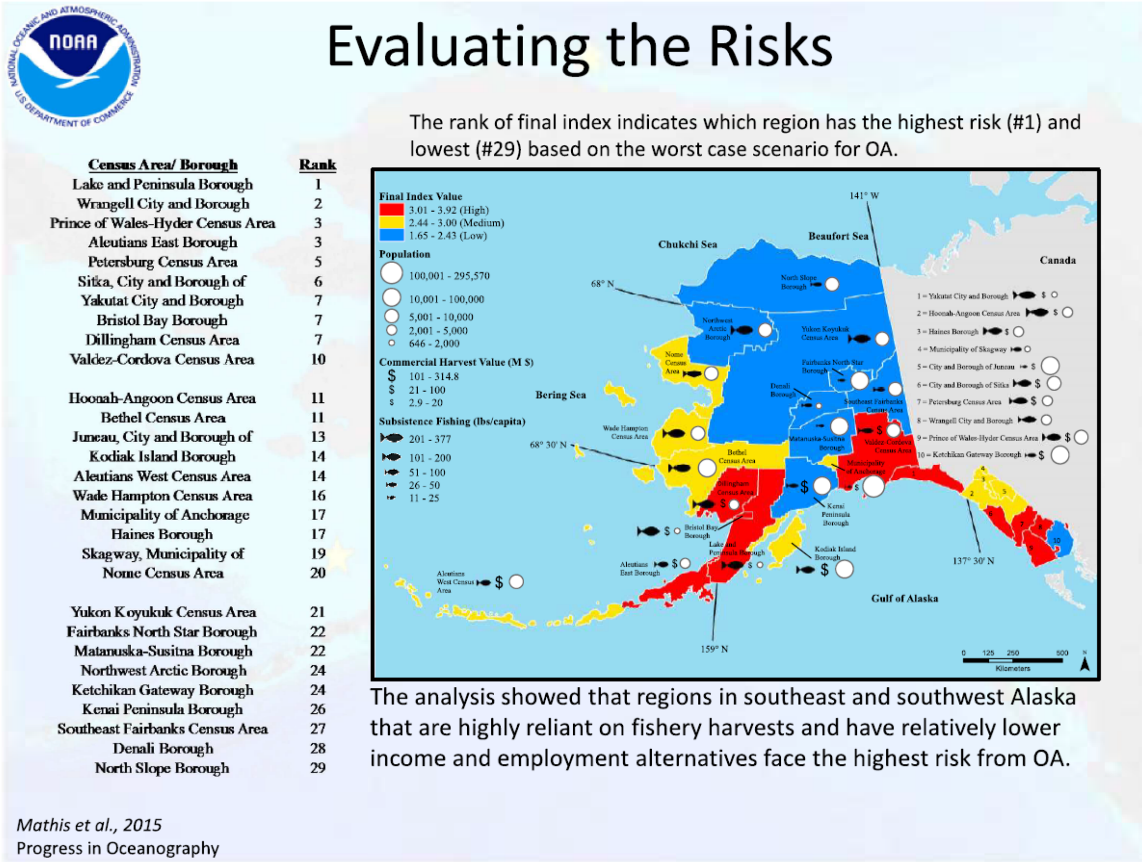
In December 2019, scientists projected continued but somewhat moderated ocean warming into 2020 over most of the Gulf of Alaska but a lengthy cold snap in early 2020 resulted in a return to more typical temperatures. Coastal areas around Southeast Alaska were within the range of historical averages during the spring and summer of 2020 while offshore ocean areas were 1 – 2 ° F warmer than average.

Ocean Acidification Risks to SeaBank Natural Capital

Marine waters have absorbed roughly 550 billion tons of carbon dioxide (CO_2) over the last 250 years – 28 percent of the anthropogenic CO_2 emitted into the atmosphere since the beginning of the industrial era. CO_2 uptake has caused oceans to become nearly a third more acidic since the 1850s through a process known as ocean acidification. As CO_2 dissolves in the ocean, it reduces ocean pH, changing water chemistry. These chemical changes reduce the seawater saturation level of carbonate minerals naturally found in the ocean such as calcite and aragonite, two of the most common forms of calcium carbonate formed by shelled species. The effects have occurred to a greater and more severe extent in Alaska marine waters and other high latitude areas of the open ocean because of the high solubility of CO_2 in cold waters. Ocean acidification in Alaska is accelerating.

The effects of ocean acidification on marine species are mostly negative. The most significant impacts will be on shelled species such as crab and planktonic species that form a key component of the marine food web because the depletion of calcium carbonates makes it more difficult for shelled organisms to build and maintain shells. Alaska's oceans, marine species and coastal communities have a high degree of vulnerability to ocean acidification because of its combined effect with on-going rapid transitions in ocean temperature and chemistry on the marine food web and particularly fishery resources. Southeast Alaska is one the state's two most economically vulnerable regions because of that combined effect and the region's high dependence on crab, salmon and shellfish fisheries.

The Southeast Alaskan species most directly vulnerable to ocean acidification are Tanner and king crabs. Studies of salmon susceptibility suggest "low to moderate sensitivity" and species-specific differences. The greatest concern is change near the base of the food web – potential declines in important invertebrate prey species such as pteropods, crustaceans and krill. Sockeye, chum and pink salmon will be more vulnerable due their reliance on these species while risks to more piscivorous fish such as chinook, coho and steelhead may be lower. Pink salmon are the most vulnerable salmon species because of their heavy forage reliance on pteropods. Ocean acidification causes severe shell dissolution and reduced survival of pteropods which have a "critically important role" in the Alaska water food web. Pteropods are also prey for chum and sockeye and other pelagic and demersal fish such as cod and herring.



Graphic credit: Jeremy Mathis

There is considerable evidence that shell dissolution is occurring. A study of pteropod populations found in the California Current Ecosystem showed that they may be at the limit of their capacity to adapt to corrosive conditions. The California Current Ecosystem is experiencing CO_2 concentrations similar to levels projected for Alaska marine waters. Scientists concluded that ocean acidification was responsible for a doubling of incidences of severe pteropod shell dissolution in nearshore habitats over the past century and a half, and expect increased severe shell dissolution in the near future. The study concluded that some pteropod populations are already at risk of extinction under projected acceleration of ocean acidification over next 30 years.

Pteropods (are) one of the most susceptible indicators for ocean acidification. The effects observed in pteropods can be interpreted as the early-warning signal of the impacts of ocean acidification on the ecosystem integrity, linking pteropod effects to higher trophic levels, in particular fish (such as pink salmon, sole, and herring) that are feeding on pteropods.

USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

Climate Change Effects on Salmon and Fisheries

Salmon use a combination of freshwater, estuarine and marine habitats at different stages of their life cycle, resulting in exposure to multiple climate change related threats. Climate change is already stressing salmon stocks by changing summer and winter stream flows and increasing both marine and freshwater temperatures. Water temperature is a major driver of salmon system productivity, influencing spawn timing, incubation, growth, distribution, and abundance. Each salmon stock adapts to local conditions in a particular watershed, including chemistry, temperature and stream flow patterns. Stream warming and changes in summer stream flow can reduce habitat values for growth, spawning and survival. The greatest increase in marine temperatures is likely to occur in the epipelagic zone – the upper pelagic area occupied by salmon and where most of the ocean's productivity occurs.

Projected increases in Southeast Alaska's regional air temperature and changing precipitation patterns will continue to affect watersheds and salmon. Major freshwater habitat vulnerabilities include increased summer stream temperature and summer water deficits, extreme precipitation or flooding events and a changing balance between rain and snow in winter.

Warmer winter air temperatures and snow droughts (a lower proportion of precipitation falling as snow) will also be a major concern for many Southeast Alaska watersheds. Systems influenced by snow run-off and glacier melt are less vulnerable to increased air temperatures but will lose the buffering effect of snowmelt in the summer that historically maintained cooler summer stream temperatures. These watersheds will also have lower stream flows. These changes may also alter salmon spawn timing as the population seeks to avoid peak stream temperatures or adapt to the warmer thermal regime. Recent studies of southcentral Alaska salmon systems revealed that summer stream temperatures were up to

7.2° F higher in low snow years compared to high snow years. Warmer winter months accompanied by even modest increases in stream temperature may alter salmon egg incubation rates and emergence timing.

Climate change models for Southeast Alaska do project overall precipitation increases. But both winter snowfall and summer rainfall are likely to decrease, with a potential 40 percent decline in regional snowfall by 2100. This means reduced summer flows in both rain and snow fed streams. Summer low flows and warmer temperatures often work together to sever connections between habitats, and reduce water quality. This combination can be lethal, causing pre-spawning mortalities. In many cases higher stream temperatures can function as dams and block migratory corridors.

Stream warming will affect each salmon species and stock differently. Stocks that have the longest migrations (Chinook) and species with the longer freshwater phases of their life cycles (coho) have high vulnerability to stream warming and other hydrologic regime changes. Low flows and accompanying high temperatures in late summer, which periodically occur in southern Southeast Alaska streams, are likely to become more common throughout the region. s This will increase pre-spawning mortality for pink and chum salmon returning to spawn during summer months.

Alaska Department of Fish and Game aerial photos showed low flow conditions during the summer of 2019. Warm ocean temperatures in 2019 also likely had a significant effect on the 2020 pink return. Photo credit: Harris, D. (Alaska Department of Fish and Game) 2019. 2019 Juneau Management Area Purse Seine. Juneau AMB Purse Seine Task Force. December 3, 2019

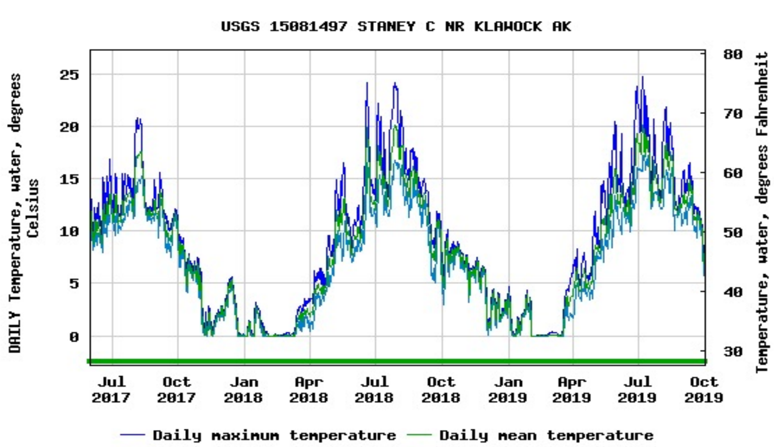
There is some variability in how Southeast Alaska salmon systems will respond to warming because of differences in elevation, terrain, lake coverage and the proportion of stream flow derived rainfall run off or snow melt. Scientists starting to study regional streams and other Alaskan watersheds are identifying watershed-specific factors that may help to predict stream susceptibility to increasing air temperatures. Some streams in southcentral and Southeast Alaska have warmed by nearly 2° F since the 1970s or 1980s. In general, warmer air temperatures will be harmful and reduce productivity in some systems, particularly low-elevation, wetland or lake dominated systems. There are some colder streams in the state where warming may benefit juvenile fish productivity.

In Southeast Alaska, lower elevation watersheds with higher lake coverage will be most vulnerable to warmer air temperatures. Warmer summer stream temperatures are likely because lakes have increased exposure to solar radiation and temperature. Watersheds fed by high elevation streams will benefit from the cooling influences of shade and the increased proportion of snow at high elevations. These normally colder streams may provide increased fish productivity because of enhanced juvenile growth potential.

At particular risk for warming temperature conditions are the prevalent small streams that provide habitat for salmon and regulate water quality in larger systems. Even prior to the recent onset of warming temperatures, there was a long history of pre-spawning mortality events in smaller watersheds, usually caused by a combination of warm temperatures, a high density of returning salmon and low summer water discharge. Smaller watersheds are most vulnerable to these occurrences.

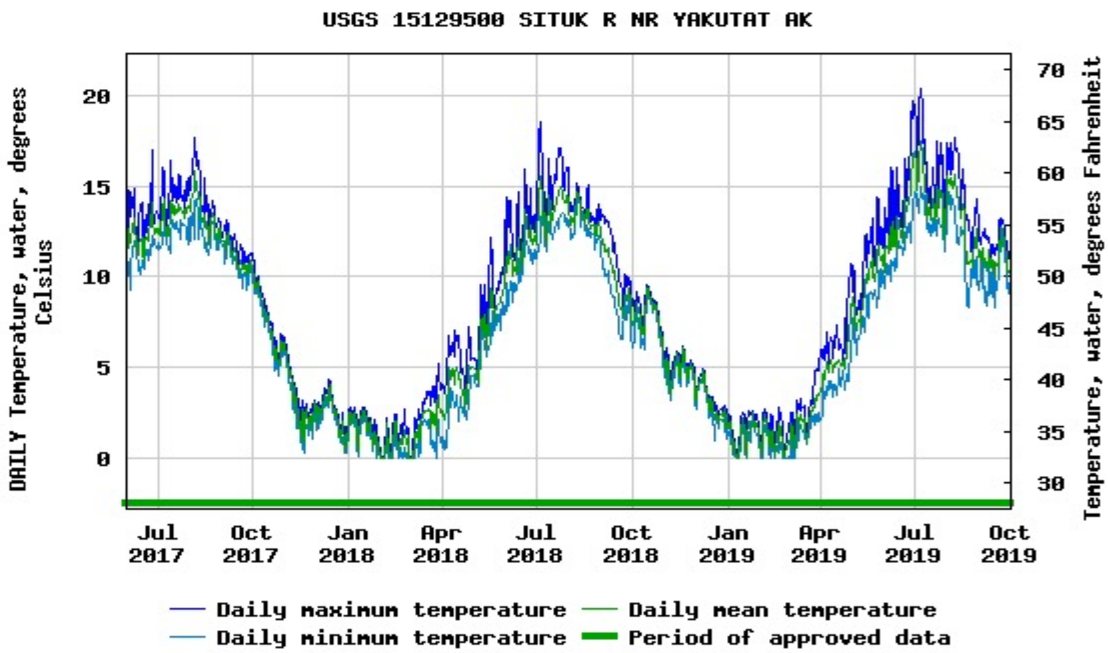
Alaska's water quality standards for temperature are 15° C (59° F) for migration routes and rearing areas and 13° C (56° F) for spawning areas and egg and fry incubation. Temperatures above 20° C (68° F) are generally deemed lethal for salmon. 2019 stream temperatures in many parts of Alaska far exceeded the 59° F threshold for migrating and rearing fish and 56° F threshold for spawning fish, in some cases reaching 80° F.   Surveys of western Alaska systems in June and July 2019 identified thousands of summer chum salmon killed while migrating upstream to spawning grounds as stream temperatures reached 64° F, exceeding typical temperatures for that tributary by 3-5° F.

These concerns are present in Southeast Alaska. Low stream flows and/or high temperatures in recent decades may have played a significant role in low juvenile pink salmon abundance indices in Southeast Alaska. The Alaska Department of Fish and Game suspects that declining pink salmon runs may reflect poor freshwater survival. Recent drought conditions may have reduced spawning success or reduced overwinter egg survival or development of alevins. But even today, the primary landowner in Southeast Alaska – the Forest Service – insists studies that increased summer temperatures in Southeast Alaska are of little concern "due to the normal cool climate conditions," on the basis of outdated 1990s studies. However, in Staney Creek summer stream temperatures exceeded lethal levels each of the past three



Temperatures for spawning and rearing fish should be below 59° F and temperatures above 68° F are lethal for salmon. Some climate models for Southeast Alaska project mean annual air temperature increases of almost 7° F which would increase high stream temperature events. There is an active stream temperature monitoring network throughout the state operated by the Alaska Center for Conservation Science at the University of Alaska Anchorage. Graphics credit: Alaska Center for Conservation Science.

years. It is a heavily logged watershed near Klawock on Prince of Wales Island. Even the glacially fed Situk River near Yakutat exceeded temperature thresholds in 2019.



Climate change research on Chinook populations in southcentral Alaska showed that warmer streams exceeding Alaska's temperature standards reduced population productivity at multiple life stages. There was increased mortality of migrating adults and eggs and lower survival for rearing juvenile fish. The study confirmed 68° F as a lethal threshold. Observed productivity declines occurred when temperatures ranged between 64.4°and 71.6° F during spawning. Other adverse conditions, such as heavy fall rains, were concurrent across many different spawning and rearing streams in the study area.

These findings and other climate change effects in Alaska are increasingly indicating that changes in freshwater habitat conditions caused by formerly unusual or unexperienced climatic occurrences of several kinds are playing an increasingly significant role in salmon population declines in Alaska. These include worsening and more frequent droughts and fall and winter storms, as well as higher stream temperatures during much of the year. One particular concern is that winter precipitation falling as rain instead of snow may worsen flooding. Though higher winter flows can benefit smolts, excessive flow increases embryo mortality by scouring stream beds, and high runoffs increase fine sediment levels. Recent research from southcentral Alaska concluded that extreme precipitation events during the fall spawning and early winter incubation periods had an even greater negative impact on salmon productivity across multiple populations than summer stream warming.

In Southeast Alaska there is potential for significant loss of coho spawning habitat in steeper, confined stream reaches that are more susceptible to streambed scour during high flows. High flow events may eliminate as much as ten percent of coho spawning habitat over the next two decades. Changes in sea level – both up and down - will also reduce the amount of estuarine habitat available to all salmon species for spawning and rearing.

Watersheds with identified warming trends are already demonstrating adverse fish responses. Bristol Bay sockeye are leaving warmer freshwater lakes earlier. The proportion of sockeye spending 1 year instead of 2 years in freshwater is increasing because climate change related growth opportunities enabled earlier migration to the ocean. Auke Creek near Juneau is a low elevation watershed identified as vulnerable to rising air temperatures. Long-term temperature increases have resulted in observed shifts in spawning timing. As average long-term water temperatures during the incubation period increased, pink salmon fry began to migrate earlier to the marine environment. The earlier fry migration in turn caused earlier migration by pink salmon adults. Researchers suspect that Auke Creek could become unsuitable habitat for pink salmon in the long-term because early migrations have caused a mismatch between spawning timing and optimum environmental conditions spawning – adults returning earlier during high summer stream temperatures may experience increased pre-spawning mortality.

"Insidious Costs" of Climate Change: Declining Fish Body Sizes

There is an increasing amount of research that evaluates the effects of warming oceans on many marine fish species, the most common effects being shifts in range, shifts in timing of life cycle events, and changes in body size. The warming induced reductions in body size are pervasive. Many fish species are growing more rapidly as juveniles due to warming waters but then mature at smaller sizes as adult fish, a phenomenon known as the "temperature size rule."

The temperature size rule applies to roughly eighty percent of ectothermic, or "cold-blooded" species such as most fish, reptiles and amphibians that use the external environment to regulate body temperature. Warmer water limits adult fish body size because it usually contains less oxygen while simultaneously increasing oxygen demand through higher metabolic rates. Fish in warming waters grow quickly, but can no longer acquire sufficient oxygen to meet the increased metabolic demand. In other words, oxygen is a limiting factor shaping the temperature-size rule in fishes. Recent findings indicate that the size loss is most dramatic for more active fish species, which often are the main species targeted in commercial fisheries.

These findings have significant implications for fisheries, as decreases in adult body sizes may reduce fishery yields. Some researchers suggest that the possibility that faster growing, larger and more numerous juveniles may offset the yield loss caused by smaller adult body sizes. Many other researchers project that warmer oceans will result in both smaller and fewer commercial fish species. Recent studies of Atlantic commercial groundfish species showed that adults were smaller, both in high latitude oceans that have warmed rapidly and in lower latitudes which experienced moderate warming.

Larger fish have several competitive advantages, including fecundity (ability to produce more offspring), longer life spans and likely being better predators, and are better at avoiding predators. One of the primary ecological concerns is that smaller fish have lower reproductive outputs. Many fishery scientists believe that "BOFFFFs" (Big Old Fat Fecund (or Fertile) Female Fish) have a disproportionately large role in fish population productivity and replenishment. BOFFFFs produce larger eggs, more eggs, and larger offspring. Egg size can often correlate with a population's recruitment success, so that declining size may reduce the capacity of marine fish population to replenish itself.

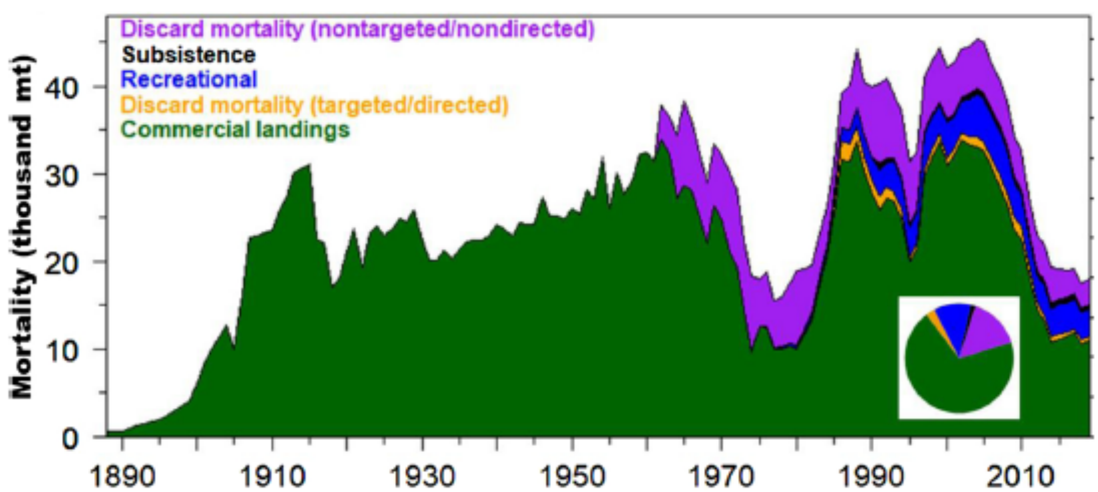
Industrial Trawling Threats to Sea Bank Resources

Deckhands on a trawler sort out large numbers of halibut. The 2019 estimated halibut bycatch in the Gulf of Alaska and Bering Sea, mostly caused by trawlers, was 5.8 million pounds of adult and juvenile halibut. Photo credit: Tholepin (http://tholepin.blogspot.com/).

Bottom trawling is the most destructive industrial fishery, producing the highest volumes of bycatch (the taking of non-targeted fish species) of any fishing gear. Bottom trawling in Alaska kills many non-target fish that are marketable high value species such as sablefish, halibut and Chinook salmon. These are species that migrate to Southeast Alaska waters and support numerous Southeast Alaska communities. Bottom trawlers are responsible for the majority of the Gulf of Alaska and Bering Sea halibut bycatch mortality, typically over 80 percent in each area. "Midwater" trawl fisheries such as the Gulf of Alaska trawl pollock fishery kill thousands of Chinook salmon each year, including unknown numbers of fish bound for Southeast Alaska's troubled transboundary rivers. Over the last four years, midwater and bottom trawlers have been killing alarming numbers of juvenile sablefish. Trawlers also kill and waste forage fish such as herring, millions of juveniles that are commercial fish species, and adults of numerous other fish species because of small size or low economic value.

The amount and proportion of bycatch declined over the last two decades in federally managed industrial trawl fisheries in Alaska, after peaking near the end of the 20th century. This decline in bycatch does not, however, mean that these fisheries are "cleaner." A major problem in Alaska is that many fish species vulnerable to the bycatch fisheries are declining in abundance at a higher rate than the species trawlers are targeting. The exploitation rates (i.e. percentage of population biomass caught each year) on Chinook and halibut remain high. Additionally, Alaska trawlers' bycatch of juvenile fish is disproportionatly high, reducing future stock growth and fisheries yields. This is a substantial harm to Alaska's coastal community fisheries that would otherwise harvest many of those fish as mature adults.

Poor management of industrial trawl fisheries combined with poor fishing practices by trawlers heighten the waste. Enforcement of bycatch regulations is inconsistent and lax, a problem aided and abetted by poor estimation of trawl bycatch due to low observer coverage in the Gulf of Alaska. NOAA Fisheries and the North Pacific Fishery Management Council avoid comprehensive regulation of bycatch and instead adopt species-specific piecemeal approaches. Regulations designed to reduce bycatch of one species often increase bycatch of another species.



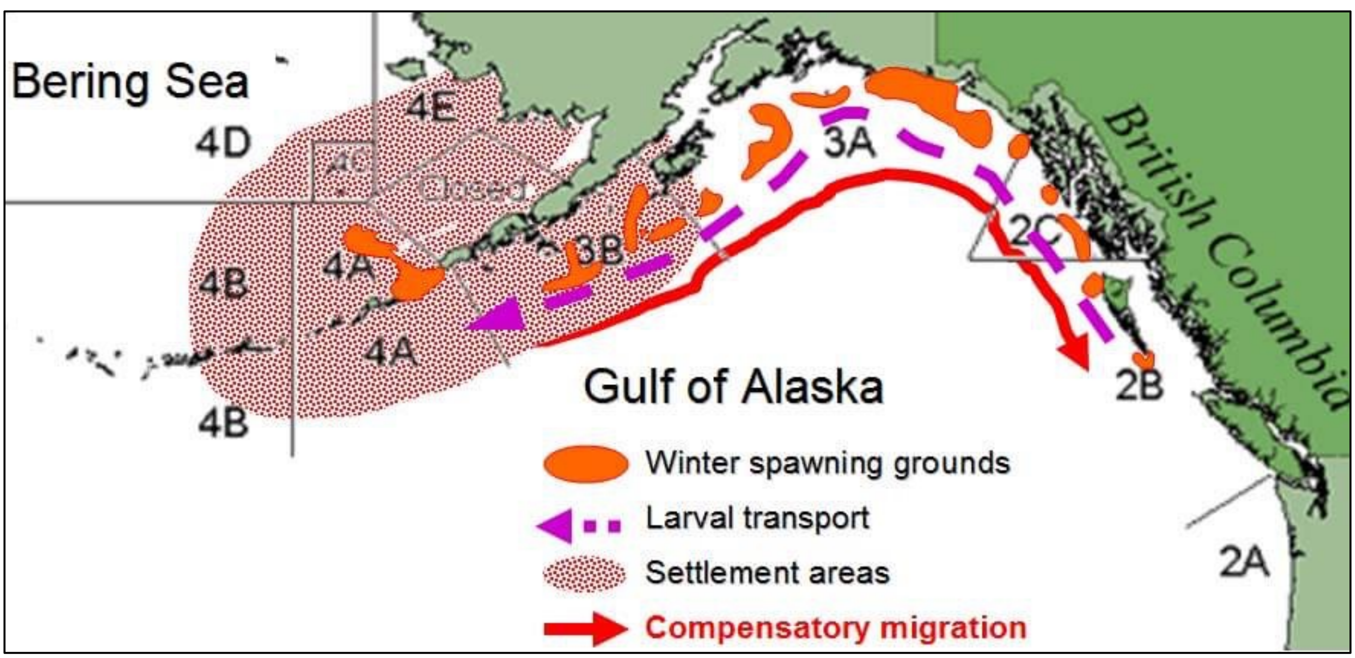
Inset shows the amount of halibut taken as bycatch between 1992 and 2018. 10,000 metric tons is equivalent to roughly 16 million net pounds. Fig. 2, reconstructed historical mortality from all fisheries, 1880-2019, in Stewart, I.J., A.C. Hicks & P. Carpi. 2021. Fully subscribed: Evaluating yield trade-offs among fishery sectors utilizing the Pacific halibut resource. Fisheries Research 234 (2021) 105800.

The history of halibut bycatch illustrates the consequences of industrial trawl fisheries on coastal communities and fisheries. Over the past century, hook and line fisheries targeted and harvested most of the halibut. During the 1960s, rapidly developing foreign trawl fisheries began operating in the Bering Sea, killing large numbers of juvenile halibut between 1964 and 1974. Halibut bycatch mortality reached about 20 million pounds. From 1973-1982, landings in the directed fishery fell to the lowest levels since the early development of the Pacific halibut fishery. The International Pacific Halibut Commission (IPHC) IPHC responded to the emerging crisis by closing a portion of the Bering Sea in 1967 to protect a large population of juvenile halibut from the foreign trawlers. The "Bering Sea Closed Area" helped to reduce halibut bycatch to 4.2 million pounds by 1985. Halibut abundance then improved dramatically.

In 1976, Congress responded to rising bycatch by foreign fleets and enacted the Magnuson-Stevens Act to conserve U.S. fishery resources and particularly protect them from foreign trawlers. Congress anticipated that Americanizing the fisheries would conserve U.S. fishery resources. For a brief period during the 1980s, the curtailment of foreign fisheries reduced halibut bycatch mortality to the lowest level since 1960. By 1984, commercial halibut landings had begun to recover, increasing to 45 million pounds. Commercial and sport landings subsequently averaged over 67 million pounds annually for the next decade.

However, American trawlers replaced the foreign vessels, and coastwide halibut bycatch increased again rapidly, peaking at 20.3 million pounds in 1992. The North Pacific Fishery Management Council opened the Bering Sea Closed Area to bottom trawling shortly after the Americanization of the trawl fisheries, exposing large numbers of juvenile halibut to the emerging domestic trawl industry. Over three-fourths of Bering Sea halibut bycatch, by weight, consisted of juvenile halibut. After the Closed Area reopened, Bering Sea halibut bycatch mortality again increased substantially, to 10.7 million pounds in 1992.

Juvenile halibut migrate extensively across the North Pacific, so that most of the juvenile halibut bycatch in the Bering Sea affects all other downstream areas – including Areas 2C and 3A in the Gulf of Alaska where most Southeast Alaska fishermen harvest halibut. Juvenile halibut taken as bycatch would otherwise grow over a period of years and recruit to the resource and fishery, supporting resource productivity and future fishery yield for Alaska fishing communities.



Juvenile halibut rear in the Btering Sea and portions of the Gulf of Alaska where they are vulnerable to trawl bycatch fisheries before migrating to Southeast Alaska and beyond as adults. Graphics credit: International Pacific Halibut Commission; available at https://iphc.int/management/science-and-research/biological-and-ecosystem-science-research-program-bandesrp/bandesrp-migration/juvenile-migration

In 1996, Congress countered these bycatch increases by amending the Magnuson-Stevens Act through the Sustainable Fisheries Act. The Sustainable Fisheries Act added National Standard 9, which requires regional fishery councils to reduce the amount of bycatch in every fishery. The bycatch minimization requirements explicitly targeted worsening bycatch problems in many areas and particularly the Bering Sea trawl fisheries.

The North Pacific Fishery Management Council has failed to adequately minimize trawl bycatch. Since 1996, Bering Sea trawlers have killed over 900,000 Chinook salmon as bycatch, including over 100,000 in 2007. Most of these fish spawn in the Yukon, Kuskokwim or other western Alaska systems where Native Alaskans have lost both commercial and subsistence fisheries even as annual bycatch of salmon from those runs is typically in the tens of thousands. In the Gulf of Alaska alone, trawlers have killed an estimated half a million Chinook salmon.

Trawlers have killed at least 181 million pounds of halibut as bycatch since 1996 – an estimated 65 million pounds in the Gulf of Alaska and over 116 million pounds in the Bering Sea. Those Gulf of Alaska halibut and Chinook bycatch numbers may be substantial underestimates. There have been longstanding concerns about inaccurate and imprecise bycatch estimates from the Gulf of Alaska trawl fisheries because of the poor quality of data obtained from the NOAA Fisheries' observer program. After killing large numbers of these two species which sustain Southeast Alaska communities, trawlers are now killing large numbers of juvenile sablefish – another high value SeaBank resource. The large sablefish classes of 2014 and 2016 are occupying habitat shared by lower value species targeted by trawlers, causing a new and concerning bycatch problem for Southeast Alaska fishermen.

Preceding the 1996 enactment of the Sustainable Fisheries Act, the North Pacific Fishery Management Council (NPFMC) had established trawl halibut bycatch limits of 6.2 million pounds (net weight) in the Bering Sea in 1993 and 3.3 million pounds in the Gulf of Alaska in 1995. Between 1996 and 2012, small incremental cuts dropped the Bering Sea bycatch limit to 5.8 million pounds – an 8 percent overall reduction. There were no changes to Gulf of Alaska trawl bycatch limits until 2013 when there was a small stagger step reduction down to 2.9 million pounds in 2015. In 2015, the NPFMC finally reduced the Bering Sea trawl bycatch limit to roughly 4.1 million pounds as high bycatch levels threatened to close small boat halibut fisheries.

The bycatch limit reductions failed to keep pace with much larger declines in halibut abundance. Since 1992, directed commercial fisheries have taken roughly 70 percent of the halibut catch and the bycatch fisheries have taken just over fifteen percent. That fifteen percent is more than the total catch by recreational, guided sport and subsistence fisheries. But as halibut abundance declined during the 2000s, trawlers took increasingly larger proportions of the resource. Between 2010 and 2014, for example, commercial landings in the directed fisheries declined by more than half, from nearly 50 million pounds to less than 24 million pounds. But trawl bycatch declined only 13 percent, from 10.3 to 9.0 million pounds over that period. These shifts mean that trawlers are taking an ever-increasing share of the resource. In 2014, commercial and guided sport fishermen caught a bit over three-quarters of the quota while trawler bycatch took 22 percent.

Sustainable Fisheries Act of 1996

The bycatch problem is of great concern in my State of Alaska, where over half of the Nation's fish are harvested each year off our shores.

In 1995, 60 factory trawlers discarded nearly as much fish in the Bering Sea as was kept in the New England lobster fishery, the Gulf of Mexico shrimp fishery, the Pacific sablefish fishery, and the North Pacific halibut fishery combined. The waste in that area was as great as the total catch of all the major fisheries off our shores. These 60 factory trawlers threw overboard-dead and unused-about one out of every four fish they caught. I have a chart here to call to the attention of the Senate. Last year, the Bering Sea trawl vessels – this all the trawl vessels and not just the factory trawlers that are committing waste – threw 17 percent of their catch overboard, dead and not used. That total catch, as you can see by the chart, exceeds by almost 500 million pounds the total catch of all five of the major fisheries of the United States.

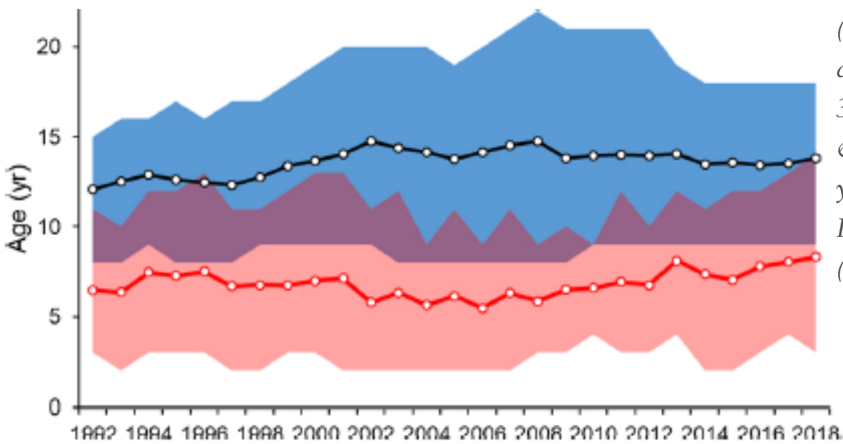
…

I hope this bill will bring a stop to this inexcusable amount of waste.

Senator Ted Stevens, September 18, 1996 (142 Cong. Rec. S10810).

Because trawlers catch small, mostly juvenile fish, half the numbers of individual halibut caught that year were killed by trawlers. Trawl halibut bycatch did drop from 5.6 million pounds in 2019 to 3.9 million pounds in 2020. However, that 3.9 million pound magnitude exceeds the Southeast Alaska directed longline fishery quota for 2021 and is just slightly lower than the entire U.S. recreational and subsistence halibut harvest. Trawl halibut bycatch has increased significance because of the large numbers of smaller, juvenile fish killed by trawlers. Roughly half the bycatch by weight is small juvenile halibut. The average age of bycaught halibut is slightly less than seven years. In comparison, in the hook and line directed halibut fishery, ninety percent of harvested halibut are between 8 and 21 years old, and average age is 13.6 years.

Some research has identified halibut bycatch impacts on directed fisheries. Generally, each pound of trawl halibut bycatch would instead yield more than a pound to commercial halibut fisheries, but the actual rate varies over time depending on where the bycatch occurs and particularly the size and age composition of the bycaught fish. Recent IPHC estimates suggest that every 2.2 pounds (a kilogram) of eliminated bycatch in the immediate short-term (2019-2021) would instead yield up to an additional 2.8 pounds to directed fisheries.

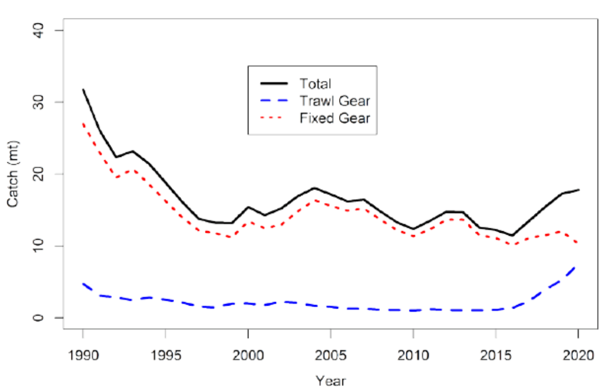


Average halibut age in directed commercial fishery (upper line) and in the discards from non-directed commercial fisheries (lower line), 1992-2018. Fig. 3 in "Fully subscribed" Stewart, I.J., A.C. Hicks & P. Carpi. 2021. Fully subscribed: Evaluating yield trade-offs among fishery sectors utilizing the Pacific halibut resource. Fisheries Research 234 (2021) 105800.

Emerging Problems: Sablefish Bycatch by Trawlers

Trawlers are now taking massive amounts of sablefish as bycatch. Regulations assign a portion of the sablefish quota to trawlers, an amount they are currently exceeding by millions of pounds. In 2018 trawl sablefish bycatch spiked significantly, particularly in the Bering Sea, which is the northern edge of sablefish population distribution. Most of the bycatch has consisted of small sablefish averaging 3 pounds apiece who are two to four years old. From 2018-2020, Bering Sea trawlers took 12.5 million pounds, over their quota for the three-year period. In 2019, they took 5.4 million pounds, which is over three times what the regulation allows. The resulting waste was 3.9 million pounds of sablefish as bycatch. In 2020, they exceeded the quota by nearly 8 million pounds – five times what the regulation allows.

These young sablefish taken by trawlers would otherwise help build the future of the resource. Oceana estimates that the 2020 Bering Sea take of over 9.7 million pounds amounted to a total of 3.25 million individual fish. There is a similar trend in the Central Gulf of Alaska regulatory area. From 2018-2020, Central Gulf of Alaska trawlers took 6.1 million pounds over their quota for the four year period or nearly twice as many as authorized.



Graphics credit: Figure 3.17 in Goethel et al. 2020. Assessment of the sablefish stock in Alaska. Available at: https://archive.fisheries.noaa.gov/afsc/refm/stocks/plan_team/2020/sablefish.pdf

Chinook Bycatch by Trawlers

The Gulf of Alaska provides foraging habitat for Chinook salmon migrating from and back to coastal rivers draining into Gulf of Alaska and throughout the Pacific Northwest, including Southeast Alaska, British Columbia, Washington and Oregon. Gulf of Alaska trawlers have taken nearly half a million Chinook salmon since 1996. Their average take was 21,646 Chinook from 1991-2017, peaking at 54,678 in 2010. These numbers are likely gross underestimates, since they rely on the belief of NOAA Fisheries scientists that there is no level of observer coverage too low to result in incorrect bycatch estimates. Recent Gulf of Alaska observer coverage levels are generally well below 20 percent. Most of the Chinook killed as bycatch by trawlers spawn in British Columbia or the Pacific Northwest. Between twelve and twenty percent of Chinook bycaught each year are from Southeast Alaska stocks. The bycatch of these fish is significant because of the small size and currently impaired stock status of those runs.

Conclusion: Trawl bycatch harms Southeast Alaska fisheries

The bycatch of Chinook, halibut and sablefish is significantly detrimental to coastal Alaska community economies because most of the value generated by destructive trawling accrues to large out of state fishing companies based in Seattle. In contrast, most Alaska fishing business owners are smaller catcher-seller operations. Recent studies of Alaska coastal community economies show major employment spillover effects from commercial fishing to other community sectors. Every additional million dollars of local fishery earnings generates between 1 and 3 local crew jobs, 9 processing jobs, another 7 non-fishing jobs, and an increase of local processing value. This disparity between the industrial bycatch fisheries and small, community-based Alaska fishing businesses means that a large portion of that fishery's value – particularly the millions of pounds of halibut and sablefish killed each year - never enters local economies.

THE TONGASS AND CHUGACH NATIONAL FORESTS WERE MAJOR CONTRIBUTORS TO THE OVERALL NUMBER AND VALUE OF COMMERCIALLY CAUGHT SALMON IN SOUTHEASTERN AND SOUTHCENTRAL ALASKA. FROM 2007 TO 2016 THESE NATIONAL FORESTS CONTRIBUTED AN AVERAGE OF 48 MILLION PACIFIC SALMON ANNUALLY TO COMMERCIAL FISHERIES, WITH A DOCKSIDE VALUE AVERAGING US$88 MILLION (INFLATION ADJUSTED TO THE BASE YEAR 2017). THESE "FOREST FISH" REPRESENTED 25% OF ALASKA'S COMMERCIAL PACIFIC SALMON CATCH FOR THIS TIME PERIOD AND 16% OF THE TOTAL COMMERCIAL VALUE. THESE FINDINGS EMPHASIZE THE IMPORTANCE OF ALASKA'S FOREST RIVERS AND LAKES FOR SUSTAINING PACIFIC SALMON AND CAN CONTRIBUTE TO DISCUSSIONS ABOUT ALTERNATIVE LAND MANAGEMENT STRATEGIES THAT MIGHT IMPACT PACIFIC SALMON POPULATIONS AND ASSOCIATED COMMERCIAL FISHERIES.

Johnson, A.C., J.R. Bellmore, S. Haught, and R. Medel. 2019. Quantifying the monetary value of Alaskan National Forests to commercial Pacific salmon fisheries at 2. North American Journal of Fisheries Management.

USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)].

At one time, the Pacific Northwest supported the largest salmon runs and fisheries in the world. But habitat loss has been a major factor in the decline of Pacific salmon populations at the southern end of their range, extirpating 29 percent of 1,400 salmon populations in the Pacific Northwest and California. Many remaining runs are in peril. Degradations of freshwater spawning and rearing habitat by industrial logging and timber road construction, past and present, are significant contributors to these run failures and reduced salmon abundance and diversity. The habitat destruction necessitated billions of dollars of expenditures on hatcheries and restoration actions in order to maintain salmon and salmon fisheries. Intact, functioning forested ecosystems previously provided ecosystem services needed for fish, such as clean water, at no cost.

Southeast Alaska possesses one of the largest remaining productive salmon systems in the world, even though impaired, in large part because of natural capital assets that include the planet's largest tract of mostly undisturbed coastal temperate rainforest. Clearcutting and timber road construction have harmed salmon habitat in some Southeast Alaska watersheds, but the Tongass National Forest is still by far the leading producer of wild salmon of any national forest. Alaska fisheries scientist Dr. Mason D.

Bryant describes the physical and biological diversities of Southeast Alaska's salmon producing watersheds as globally unique. The diverse set of physical and climatic features contribute to the abundant salmon populations. Other fishery scientists attribute the region's "globally impressive productivity" for salmon to extensive areas of unlogged, roadless watersheds that maintain the productive capacity of freshwater habitat.

Although many of Southeast Alaska's salmon populations still support viable fisheries, researchers from the Forest Service's Pacific Northwest Research Station acknowledge that the same threats to forests that reduced salmon populations in the Pacific Northwest are present in Southeast Alaska. These other anthropogenic stressors such as mining and logging and road construction will exacerbate climate change vulnerabilities. Numerous studies of Pacific Northwest salmon habitat show that stream temperatures increase substantially in heavily logged areas. Removing riparian forests increases summer temperatures in several ways – by directly removing vegetation, exposing the landscape to increased insolation and increasing erosion and debris flows. Riparian buffers do not adequately protect against these increases both because the buffers are susceptible to windthrow and because numerous factors affect stream temperatures. Studies of headwater streams in salmon producing watersheds logged with a range of buffer widths still showed stream temperature increases of between roughly 7° and 11° Fahrenheit compared to unlogged watersheds. Timber roads introduce other problems, including increases in erosion, risk of landslides, and stream flow volatility – all additive to climatic stresses like flood and drought.

This logging road on Prince of Wales Island will increase sediment input into Southeast Alaska's salmon habitat and reduce fishery outputs. Photo credit: Colin Arisman

Scientists have identified habitat conservation – particularly maintaining regulatory prohibitions on logging and timber road construction in remaining intact watersheds in Southeast Alaska – as critical to buffering salmon populations against climate impacts. There is a particular need to maintain intact habitats as thermal refugia. Forest cover has a significant role in moderating air temperature and areas with high forest cover common throughout the region may help to mitigate low snow accumulation by providing shade in summer.

A major concern is that high levels of habitat degradation caused by industrial logging is long-term and will at times coincide with periods of low marine productivity, which climate change is making more frequent and severe. Intensively logged watersheds still have some habitat value during periods of high marine productivity. But during periods of environmental stress the combined impacts of low marine productivity and freshwater habitat degradation may result in long-term harm, and the more watersheds with degraded habitat the lower the resilience of SeaBank. The current management plan for the Tongass National Forest continues and even accelerates intensive logging of old growth and immature recovering forests at a time when the region's salmon productivity is lower due to multiple environmental factors.

Clearcutting and timber road construction in salmon habitat harm habitat productivity for salmon in numerous ways. For example, timber roads and clearcutting increase sedimentation in streams, generally degrade water quality, fragment habitat and increase the frequency and extent (in both time and area) of high temperature regimes. These habitat impacts lower stock productivity by causing reproductive failures and egg and embryo mortality, increasing subpopulation vulnerability to catastrophic events and reducing genetic fitness. Fishery managers identify sediment delivery to streams as a principal and widespread cause of declining salmon runs. Studies have shown that sedimentation by itself has significantly reduced salmon productivity in numerous watersheds. In many cases, frequent maintenance is necessary to reduce sediment impacts from roads, and it is impossible to mitigate sedimentation caused by logging, post-logging blowdown, landslides and stream channel destabilization.

Windstorms will blow down many of the trees left in this non-federal clearcut on Prince of Wales. Federal clearcuts have wider buffers along some streams but also have a high unraveling rate. Photo credit: Colin Arisman.

Forest Service scientists and state fishery managers have suspected that this habitat degradation has already caused an undocumented level of loss to Southeast Alaska salmon populations due to heavily logged watersheds coinciding with highly productive streams. Forest Service leadership ignored recommendations to conduct the watershed analyses needed to determine whether and to what extent logging in the region has reduced salmon productivity. Lack of these determinations restricts our ability to assess the long-term sustainability of SeaBank's fish populations.

Adverse impacts to salmon are likely even if measures are put in place to mitigate and, to the degree possible, repair habitat harms. Significant habitat degradation of riparian areas occurs even when forested buffers are required on known anadromous streams. Tree buffers in Southeast Alaska are narrow and tend to blow down, losing their effectiveness over time. And buffer requirements are minimal and inadequate for most landowners and most stream sizes. Unbuffered, smaller streams comprise the bulk of the stream mileage in developed Southeast Alaska watersheds.

The Forest Plan Disaster

Much of the most highly productive fish habitat in Southeast Alaska coincides with areas managed mostly for the benefit of timber companies, as either private or public forestland. The Forest Service has recently planned massive timber projects on central and southern Southeast Alaska islands. The agency designed these projects to meet timber targets established in 2015 and 2016 by an advisory committee comprised primarily of timber industry stakeholders. The Forest Service and other landowners have already disproportionately clearcut the larger-tree old-growth forests on these major islands: Etolin, Kupreanof, Kuiu, Mitkof, Prince of Wales, Revillagigedo, Wrangell and Zarembo. These areas – particularly Prince of Wales Island – have suffered habitat loss at a much greater rate than other portions of Southeast Alaska. Timber companies have already removed nearly 400,000 acres of old-growth forest from Prince of Wales Island.

Prince of Wales Island is the largest island in Southeast Alaska and the 3rd largest island in the United States. It is the most important island ecosystem in Southeast Alaska for commercial fish production, on the basis of identified sockeye habitat, numbers of stream miles for coho and pink salmon and number and area of Alaska Department of Fish and Game "Primary Salmon Producer" watersheds. Remaining watersheds on the island are the most important part of the Southeast Alaska's salmon system and a primary producer of wild salmon stocks that support salmon sport, subsistence, seine, gillnet and troll fisheries. Forest Service disclosures show that there is substantial deferred road maintenance and chronic sedimentation throughout the island caused by the system of several thousand miles of logging roads which impair and reduce salmon production capacity.

Further, the Forest Service's timber advisory committee has set second growth timber targets that will

Recent clearcuts by non-federal landowners are present throughout the Prince of Wales Island landscape. State of Alaska regulations allow for large clearcuts with few buffers. Photo credit: Colin Arisman.

negatively affect southern Southeast Alaska watersheds that are currently in recovery from past clearcutting. The recovery can take over a century. The Forest Service's second-growth logging program would permanently degrade previously logged watersheds with a succession of short timber rotation cycles. Scientists explain that "[f]ew refuges remain in a watershed that fish can use during such widespread, intense, and recurrent disturbances."

Making the Forest Plan Worse: The Roadless Rule Repeal

In 2001, the Forest Service issued the Roadless Area Conservation Rule ("Roadless Rule"), which provided regulatory protections for inventoried roadless areas in part because roadless characteristics have unique values for salmon and other fish species. The inability to mitigate harms to fish from road-related sediment, and not making matters worse, was also a major rationale. The Forest Service also identified clearcutting and timber road construction as threats to commercial fishing c ommunities because those activities caused declines in salmon runs.

The Roadless Rule thus prohibited industrial logging and timber road construction in inventoried roadless areas. Roadless watersheds or watersheds with low road densities are two to three times as likely to support healthier, more abundant salmon populations than watersheds with high road densities. Because of reduced road impacts, scientists describe these areas as often providing "the highest quality fish habitat." The Roadless Rule also protects smaller headwaters streams that significantly influence water quality throughout a watershed and provide habitat for many fish species, including juvenile coho salmon.

ROADLESS = RESILIENCE

Watersheds with a large proportion of primary forest and roadless area are likely to be the most resilient salmon habitats to the stresses imposed by ongoing and future climate change.

…Once these watersheds are opened to road construction and other development, they will be lost forever. In this context they should (be) placed as world heritage sites.

Dr. Mason D. Bryant, fisheries scientist, Douglas, Alaska. Comments on the Alaska Roadless Rulemaking

Watersheds with a high proportion of roadless area tend to be high in fish abundance, salmon diversity and production, and roadless areas thus are of extreme value in the long-term conservation of salmon and trout populations throughout their ranges.

Dr. Christopher Frissell, Comments on the Alaska Roadless Rulemaking

On October 29, 2020, the U.S. Department of Agriculture reversed course on these findings and published its final rule exempting the Tongass National Forest from the Roadless Rule. The primary purpose of the repeal is to massively increase the scale of clearcutting and road construction in fish habitat on Prince of Wales Island and central Southeast Alaska islands.

The Department of Agriculture's decision removes Roadless Rule protections for over 9 million inventoried roadless acres on the Tongass National Forest, of which about 2.5 million acres have productive old-growth forest. The exemption will be a disaster for Southeast Alaska unless it is reversed, because the Roadless Rule currently protects many salmon producing watersheds from roadbuilding and industrial scale clearcutting. The exemption could lead to building roads that impact fish habitat and to more industrial logging of old growth, at a time when the region's salmon production capacity is vulnerable due to the multiple climatic, terrestrial, aquatic and marine factors discussed in this report.

Thousands of fishermen, Southeast Alaska residents and other Americans provided individual comments on the Roadless Rule. Nearly all commenters requested that the Forest Service take no action on the rulemaking and leave the Roadless Rule in place in the region.

Southeast Alaska's inventoried roadless areas currently provide essential and intact spawning, rearing and migratory habitat for salmon – Southeast Alaska's most valuable crop. Prohibitions on logging and road construction in these areas are even more important now with declining abundance trends for several salmon species. Aquatic systems within inventoried roadless areas may thus be critical to the recovery of these diminished Southeast Alaska salmon populations because intact habitats function as biological strongholds and refuges for many fish species.

For these reasons, Pacific Northwest and Alaska salmon scientists voiced significant concerns about the Alaska Roadless Rulemaking – particularly over considerable risks of widespread watershed degradation and reductions in salmon system productivity. Their major concerns are the value of roadless watersheds as both a buffer and reservoir for salmon against the adverse impacts of past, present and future logging and as intact habitat that better enables salmon population resiliency to climate change.

The rivers, streams and lakes in inventoried roadless areas are also increasingly important because they support the resilience and biodiversity of fish species against long-term impacts of cumulative degradation that has occurred in other nearby watersheds that had more biologically rich habitat. These concerns are particularly pertinent in large, heavily degraded portions of central and southern Southeast Alaska, and especially on Prince of Wales Island.

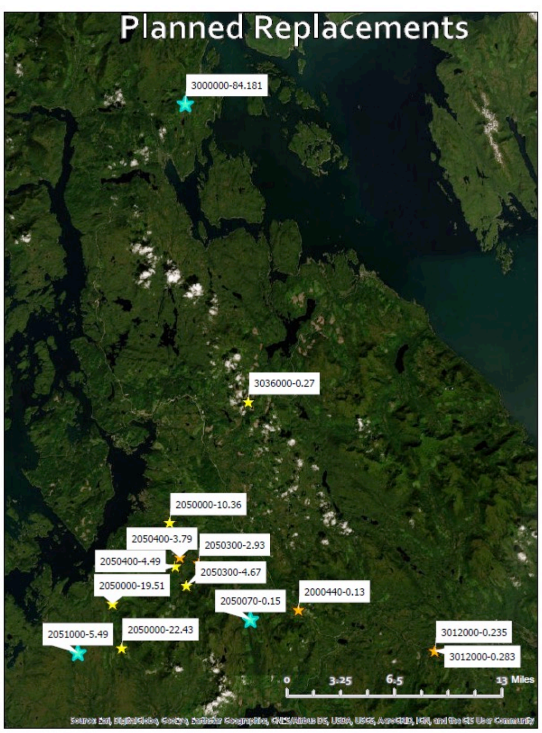
Stealing Fish From Fishermen: "Red Culverts" Cost Coastal Communities

Another primary purpose of the Roadless Area Conservation Rule was to address federal cost concerns – particularly the costs of building new roads in inventoried roadless areas. When the Forest Service developed the Roadless Rule in 2001, conservative estimates showed an $8.4 billion backlog on deferred logging road maintenance nationwide, including culvert replacement. At that time, Congress had been funding repair of only 20 percent of the growing backlog. By 2003, the Tongass National Forest was the second worst offender on a national basis (next to the entire state of California's Forest Service road system), with a deferred maintenance backlog of nearly $1 billion. The deferred road maintenance caused harms to fish and fishing communities, and continues to reduce fish productivity on Forest Service managed lands. In 2019 the estimated total maintenance backlog was $5.2 billion, more than ten times the $450 million road maintenance budget for the national forests.

A major habitat problem for Southeast Alaska salmon is the number of stream miles blocked off to salmon by failed culverts ("red culverts"). A big reason inventoried roadless areas function as biological strongholds and refuges for salmon is the absence road crossings of any kind over streams, and particularly culverts that over time can begin to impede fish passage or become complete barriers. When less habitat is accessible for salmon returning to spawn there will be fewer fish for fishermen later. Barrier culverts throughout a watershed cumulatively reduce salmon stream productivity by impairing in-stream migration and foraging by juveniles, slowing their growth and development. For several reasons, the Roadless Rule thus helps reduce vulnerability to local extirpations, under the growing threats that salmon populations face during their life cycles.

During the 1990s, the Alaska Department of Fish and Game surveyed 60 percent of the Forest Service's roads to assess fish passage problems in the region. This survey showed that two-thirds of the culverts (179) on Class I streams (streams and lakes with anadromous fish habitat or high quality resident fish waters or habitat) and 85 percent of the culverts (531) on Class II streams (streams and lakes with resident fish or fish habitat where no anadromous fish occur, and otherwise do not meet Class I criteria) failed fish passage standards. The Forest Service addressed some of these problems between 1998 and 2006, spending between $1.5 million and $2 million annually to fix roughly 50 sites per year, and not keeping ahead of the growing problem. The culvert repair program ended in 2006 due to funding cuts.

Now there are 1,100 red culverts blocking 270 stream miles of fish habitat in Southeast Alaska. Most of them are concentrated in the Petersburg and Prince of Wales (Thorne Bay and Craig) Ranger Districts, where the Forest Service focuses its timber sale program. They are areas with high levels of past logging and road density. In central Southeast Alaska islands, there are 432 red culverts. The Forest Service expected to repair three of them in 2020. On Prince of Wales Island, the Forest Service said it would consider fixing fourteen of the 447 red culverts in 2020, but only wanted to fund three replacements.



Blue stars show where the Forest Service has funded culvert replacement; yellow stars show where the agency and timber companies would like someone to pay to clean up their mess. These culverts and the hundreds of other fish passage obstructions in Southeast Alaska cost commercial fishermen in Southeast Alaska millions of dollars a decade. Graphics credit: U.S. Forest Service, September 2019.

Habitat loss has a substantial economic impact on salmon fisheries. Canadian researchers developed methods to estimate the loss of salmon related economic values caused by logging and related road construction. Conservative estimates are that each salmon spawning stream mile is worth $10,000 in annual fishery production value, a recurring benefit. By blocking off spawning and rearing habitat, red culverts cost commercial fishermen $2.7 million annually; that is, $27 million over the past decade, $27 million this decade, and $27 million the next. The Forest Service's failure to fund and fix fish passage problems reduces salmon system productivity with real costs to commercial fishermen and their communities even while the agency wastes millions of dollars on other less effective or even harmful projects purportedly intended to ameliorate degraded fish habitat. Removing or replacing red culverts is the most important and effective salmon recovery measure because they completely block access to habitat.

Timber Harvest Effects on Deer and Bears

A major challenge for preserving Southeast Alaska's wildlife is the nature of island ecosystems, which make wildlife populations highly vulnerable to climatic events and habitat alteration and fragmentation. The many values of Southeast Alaska's most productive ecosystems – for subsistence, sport, visitor products and intrinsic existence purposes – are highly vulnerable to future habitat loss caused by industrial scale clearcut logging. Industrial logging has reduced habitat values for deer and bears, particularly on Southeast Alaska's southernmost island ecosystems that provided the largest numbers of salmon streams and high value old-growth wildlife habitat. These losses include nearly one third of the crucial, most valuable large-tree old-growth forest stands.

Severe winter weather, habitat changes caused by clearcut logging, and predation by wolves and bears are primary factors governing fluctuations in deer populations. The effect of coming climate change on deer and deer habitat is an unknown. However, warming temperatures and associated average milder winters will not necessarily diminish the importance of winter habitat. An expected increase in precipitation and the probability of extreme storms may increase and even increase the risk of record-setting deep snow. Such events occurred during the winters of 2006/2007 and 2007/2008 and reduced deer numbers throughout the region. Areas where the presence of predators is combined with a legacy of logging and road construction have experienced rapid deer population declines during snowy winters, requiring prolonged periods with little or no hunting, for recovery, for decades in one case described later. Alaska Department of Fish and Game biologists estimate that eighty percent of the deer population on Chichagof Island perished during the record snowfall years between 2006 and 2008. But there are no wolves on the northern islands (Admiralty, Baranof and Chichagof) and deer populations there recovered following a series of mild winters. These three islands produce more than half of the annual deer harvest in Southeast Alaska.

Deer numbers are extremely low in three island ecosystems – Kuiu, Kupreanof and Mitkof – and have been since a heavy winter in the 1960s. Record-setting snowfalls in 2006/2007 and 2007/2008 resulted in further declines. Other heavily logged areas such as Wrangell Island have lost more than a third of their lower elevation deer winter habitat. That island has fewer deer than surrounding ones. In the Ketchikan area there are not enough deer to meet hunter demand. Ketchikan area wildlife managers fault clearcutting and loss of winter habitat for poor deer production. They anticipate that Ketchikan hunters will increasingly utilize Prince of Wales Island for deer hunting. However, biologists expect the Prince of Wales deer population to decline because of habitat loss. Clearcutting removed a third of the most important deer winter range on the island by 2005. The loss has continued at a high pace ever since. The Forest Service and other owners of large tracts of the island's forestland are targeting the last remaining stands of high-quality winter deer habitat and deer travel corridors in the north and central parts of the island.

Stability of Prince of Wales Island's deer populations is threatened by the combination of habitat loss, displacement of deer hunters to the island from other communities where deer numbers are low, and increasing guided hunting by non-Alaskans. Subsistence hunters protested a harder time harvesting deer during the 2016 season. Then, the 2017 deer season "was the worst in recent memory for a lot of hunters." The Alaska Department of Fish and Game has concerns about the cumulative adverse effects of past, ongoing and future industrial scale clearcutting on future deer dividends. Area biologists believe that the public has not received adequate information on the effects of logging and the tradeoffs between clearcutting and wildlife – particularly long-term loss of hunting opportunity and unmet subsistence needs.

Alaska Department of Fish and Game wildlife managers consider the region's brown bear population to be stable. However, wildlife managers have observed recent indications of declines in black bear populations, particularly in the more heavily logged island ecosystems in central Southeast Alaska and on Prince of Wales Island. Hunter harvests and the skull sizes of harvested black bears have declined considerably over the past decade. State biologists speculate that the population decline may be evidence of reduced carrying capacity due to habitat loss, and consider logging to be the most serious long-term threat to black bear habitat.

Past logging has also reduced habitat carrying capacity for brown bears. There is significant bear habitat degradation on eastern Chichagof Island and part of eastern Baranof Island. However, federal wilderness areas on Admiralty, south Baranof and west Chichagof islands provide brown bears with large areas of intact habitat. The population is stable and the most serious current risk to the species likely results from declining numbers of pink salmon during even year spawning cycles.

Inventoried roadless areas provide important habitat for black bears and other species of large mammals that are sensitive to disturbance or avoid roads. They function as biological strongholds and places of refuge. Black bears populations decline as road density increases, and they need habitat remote from human activity. Protections provided by Roadless Rule prohibitions on industrial logging and timber road construction are highly important due to the cumulative degradation and loss of bear habitat in many places throughout the region. Ongoing implementation of the 2016 Forest Plan intends to convert much of the remaining old-growth habitat in the Tongass National Forest timber base to second growth forest that is low quality or even inhospitable habitat for wildlife. Maintaining inventoried roadless areas is critical to maintaining wildlife for viewing, consumptive uses, and ecosystem integrity. According to ADF&G Division of Wildlife Conservation researcher Lavern Beier, who has studied the region's bears for decades, Roadless Rule exemption alternatives present significant cumulative risks to bears, particularly female bears foraging in an altered landscape.

Transboundary River Pollution

At least ten large-scale mines are in some stage of advanced exploration, environmental review, permitting or operation in an area known as the "Golden Triangle" in Northwest British Columbia, adjacent to Southeast Alaska and the headwaters of several major rivers flowing to us. The mines will extract minerals such as gold, copper, silver, lead and zinc. They will produce watershed-scale pollution – acid drainage and toxic heavy metals – known to have severe, even population-level, impacts on salmon. These mining projects are in watersheds of key transboundary rivers—the Taku, Stikine and Unuk—that originate in B.C. and flow into Southeast Alaska. These are three of the longest undammed rivers in North America, and have watersheds encompassing almost 30,000 square miles. They provide significant natural capital in support of Southeast Alaska culture and economy.

The existing and proposed mines can harm British Columbia's and Southeast Alaska's lucrative fishing and tourism industries, the traditional practices of indigenous peoples, and the way of life of all the residents of the region. Mining processes release toxic heavy metals from waste rock and mine tailings into the environment. British Columbia mines that drain into the transboundary rivers will generate levels of aluminum, cadmium, copper, lead, silver, zinc and selenium in concentrations that will be at best harmful, and perhaps lethal, to salmon. The mines will cumulatively produce well over a billion metric tons of mine tailings and several billion metric tons of waste rock, leading to long-term acid mine drainage which releases the toxins. Concentration levels of aluminum are likely to exceed known thresholds for fish by an order of magnitude. Cadmium and copper concentrations will be just below or at times above lethal levels.

Toxic Tailings are Forever

Every decision to allow a mine to proceed with a tailings storage facility indelibly transforms rivers and their ecosystems for hundreds of years.

Christopher Sergeant, research scientist. Flathead Lake Biological Station, University of Montana.

Julian D. Olden, Professor of Aquatic and Fishery Sciences, University of Washington

Some heavy metals impair fish reproductivity, survival, growth and development for decades. The elevated presence of these metals may cause fish to avoid impacted habitat entirely, thus functioning as a toxic dam permanently obstructing salmon migration and eliminating upstream habitat. Finally, the combination of these toxic pollutants may create multiple toxic "cocktails" that combined are more destructive than any single element.

Mining companies promise mitigation measures, but have failed to correct acid drainage from existing mines. There is a long history of mines failing to meet predictions of low impacts. In particular, tailings dam failures, which occur annually somewhere around the world, would be catastrophic. Over 300 tailings dams have failed over the past century. Tailings dams in the transboundary watersheds will be massive – larger than recent notable failures at the Mt. Polley tailings dam in British Columbia and the Burmadinho tailings dam in Brazil. Tailing dams and their toxic contents require maintenance forever. If water treatment plants fail to operate as speculated, chronic, long-term leakage of acid mine drainage and heavy metals is likely. Bankruptcies of mining companies have commonly orphaned toxic waste sites, leaving them out of control with no one to maintain them. Significant long-term loss or degradation of fish production from transboundary watersheds could cost Southeast Alaskan commercial and sportfishing businesses over $1.6 billion over the next century.

A Canadian company is working to develop a copper-zinc mine, the Palmer Project, in the Chilkat River watershed near Haines. The mine is adjacent to the Klehini River and just outside the Chilkat River Bald Eagle Preserve and Tlingit Village of Klukwan. Mineral extraction will likely result in increased toxicity in this highly productive salmon system, risking long-term damage to the salmon runs and the entire Chilkat Valley ecosystem.

Conclusion

Coastal ecosystems such as SeaBank are the most productive economic systems in the world. SeaBank's natural capital provides goods and services that include the highest quality and most valuable seafood on the planet, scenic and remote recreation experiences for hundreds of thousands of visitors each year, plus 11 million acres of forests that sequester carbon and host abundant wildlife. This combination of assets is globally rare, if not unique. If not overdrawn, the future economic value of this natural capital to the region's fishery and visitor product's industries could amount to $200 billion over the next century.

Asset values are also vulnerable to rapid environmental change caused by the cumulative effects of a warming planet and industrial developments that degrade natural capital assets. The SeaBank economic system works best through a fully capitalized business model. Actions that degrade key assets such as adding toxic mine pollution to watersheds, removing forested habitat, or disrupting streams through industrial logging and timber road construction will diminish the capital and reduce dividends. Climate change and the attendant ocean acidification are likely to alter the distribution, quantity and productivity of water, wildlife, forests and fish, heightening the need to aggressively safeguard existing assets.

The Alaska Sustainable Fisheries Trust will monitor changes in SeaBank's natural capital assets such as habitat changes, trends in fish and wildlife abundance and natural capital dividends-seafood sales, visitor numbers and spending. Subsequent annual reports will update the status of SeaBank's natural capital, annual sales, and evolving asset risks in order to better inform the public as well as local, regional and national decisionmakers.

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