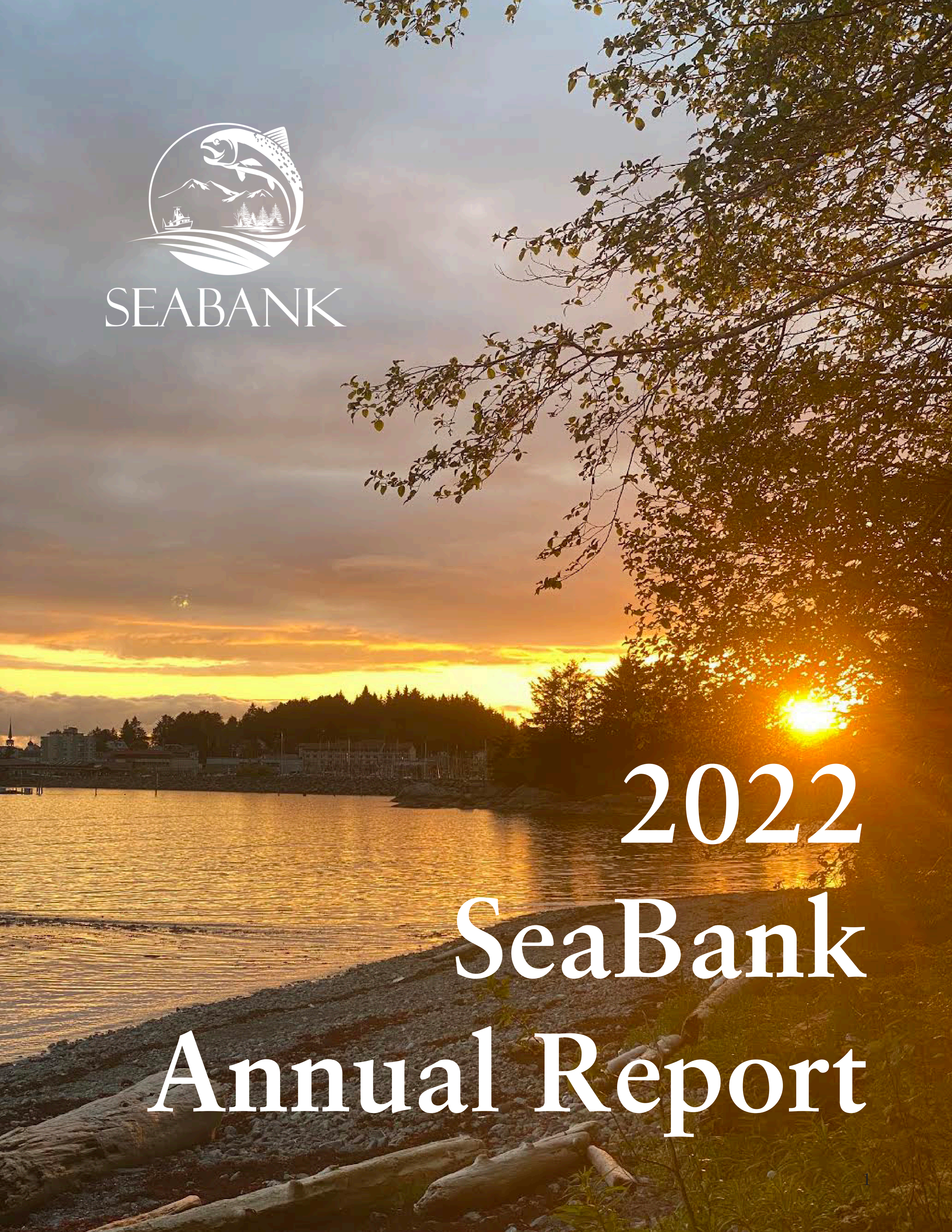

SEABANK

2022 SeaBank Annual Report

2022 Seabank Annual Report

Alaska Sustainable Fisheries Trust
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Larry T. Calvin Remembered
1934-2022

Long before the phrase "bootstrap" was popular, there was Larry T. Calvin actually doing it in Sitka, Alaska. From selling hotdogs and ice cream as a youth at the 4th of July parades to building his own house and raising his family of four children with his dear wife Maryann, Larry was all hustle. Only a couple of decades after SCUBA was invented by Cousteau, Larry pioneered the sport—and self-taught himself—into a business in chilly southeast Alaska waters. To describe Larry as the consummate entrepreneur would be the understatement of a lifetime of demonstrated business acumen and elbow-grease.

With his "can do" attitude, Larry Calvin established the role model for concerned and engaged citizens of the world and, more importantly, his own home waters. He was a true advocate. Whether he was trolling on the F/V Morning Mist, creating Sitka's first lumber store, cultivating his vast patch of raspberries, meeting with local non-profit leaders or speaking at assembly meetings downtown, Larry's keen eye (golly but they were blue!) for a great story and generous ear to listen made him memorable to all who had the joy to spend time at his knee or by his side.

As an elder well and truly beloved in his hometown of 80 years, Larry's generosity of spirit and philanthropy elevated his desire to do well and do good. Larry valued honesty and hard work and expected the same from everyone else. Fiercely in love with Southeast Alaska, he believed strongly in rigorous science to help make decisions and formulate public policy. He recognized the sound science in ASFT's SeaBank program and contributed generously to each annual report—an honor we never took for granted. He didn't tolerate BS and was not shy in sharing his knowledge or experience.

One of Sitka's great old growth spruces has fallen, but has left for us—like a nurse log nurturing future generations through its sacrifice—a legacy to build from. As Larry always said at the end of a VHF transmission or a voicemail, "I'm out." Well, you might be "out" of this world, Mr. Calvin, but your legacy lives on and you will never be forgotten.

Sam Skaggs

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Photo credit: Linda Behnken

2022 SeaBank Annual Report

Introduction: Southeast Alaska's Natural Capital – The SeaBank

SeaBank 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 SeaBank 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 – SeaBank.

SeaBank'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. SeaBank'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 SeaBank's natural capital, and any activities that reduce ecosystem services are likely to adversely impact these industries.

The economic value of SeaBank includes two ecosystems that are 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 other ecosystem services provided by coastal wetlands and temperate rainforests.

Purpose and Need: Quantify the Economic Values of SeaBank's Natural Capital

Coastal ecosystems such as the SeaBank combine estuaries, coral reefs, temperate rainforests and other high-value natural capital that provides multiple ecosystem services which contribute to human well-being and economies.[1,2] They are the most economically productive ecosystems in the world – not only for coastal communities but also for national economies and global trade.[2] The marine and terrestrial ecosystems provide highly desirable locations for living and are particularly notable for food provisioning services and opportunities for recreation and tourism.[3] The marine components of coastal systems like SeaBank comprise only eight percent of the planet's surface but generate 43 percent of the global ecosystem service economic values.[4] A major portion of the high-value of aquatic ecosystems is because of the high-value of ecosystem services attributable to estuaries.[5] When terrestrial ecosystems within 60 miles of coastlines are included in the accounting, the coastal proportion of global ecosystem values is even higher - over 75 percent.[6]

Coastal areas are vulnerable ecosystems subject to rapid environmental change through developments that degrade high-value habitats such as coastal forests, estuaries and coral reefs.[7] This threat heightens the need to maintain the SeaBank's natural capital, in the face of a decline in global capacity to provide ecosystem services due to habitat conversion for industrial uses. Global biodiversity is declining at an unprecedented rate.[8] Biodiversity loss and habitat degradation will lead to long-term interruptions in the supply of otherwise self-perpetuating natural capital vital to present and future generations.[9] Climate change and an increasing human population intensify this risk.[10]

Natural capital generates ecosystem services which in turn produce both goods and services which provide substantial benefits to people.[11] Indeed, the survival of people and their well-being depend on conserving ecosystems.[12] Ecosystem services fall in four main categories: provisioning, regulating, supporting, and cultural services.[13] Provisioning services are the material goods supplied from ecosystems and biodiversity, such as SeaBank's seafood, or water or raw materials.[14] Regulating services include carbon sequestration by trees and estuarine vegetation, and ecosystem services that moderate the impacts of extreme weather events and maintain soil, air and water quality.[15] Supporting services perpetuate basic ecosystem function, such as maintenance of genetic diversity and habitats (such as SeaBank's estuaries that serve as nurseries of the sea for juvenile fish).[16] Cultural services are the non-material benefits people receive from biodiversity and ecosystems – cultural identity, recreation and physical and mental well-being.[17]

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 SeaBank'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.

SeaBank's Natural Capital: Provisioning and Cultural Services

Provisioning services such as food and fresh water and cultural services such as recreation, tourism and scenery are the most obvious services because of the direct benefits to people.[18] Regulating services such as storm protection are receiving more attention because of climate change and associated natural disasters.[19] Carbon storage will be increasingly important as climate change accelerates.[20] This report provides an emphasis on the supporting services provided by the region's estuaries, which provide important habitat for all of SeaBank's fish and wildlife assets. Because these services generate substantial economic value, the belief that habitat conservation is bad for the economy is often wrong.[21] Natural capital yields dividends over an extended period of time, just like any other capital asset such as a fishing permit or commercial vessel.[22] 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.[23] Their research emphasizes the need to fully account for the value of long-term, lost economic benefits flowing from natural capital and reduce uses that degrade natural capital such as clearcut logging or developments that pollute or destroy estuarine habitats. 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 economic outputs flowing from SeaBank'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 SeaBank assets using estimated values per biome calculated by natural resource economists.

SeaBank's largest natural capital asset is the coastal rainforest biome, which provides asset values for multiple ecosystem services valued at over $1,200 per acre.[24] The value of SeaBank's 11 million acres of forested natural capital may be worth over $13 billion generated by ecosystem-provisioning services that support wildlife, fish, carbon sequestration, and outdoor recreation. River and lake biomes provide multiple ecosystem services valued at $5,065 per acre.[25] Their 201,000 acres are worth over a billion dollars annually, providing SeaBank fishery and recreation assets and other regulating services.

Coral reefs are the highest-valued ecosystems, yielding $143,000 per acre per year; there are 2,304 acres of coral habitat protected areas in the offshore SeaBank worth nearly $2 billion.[26] 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 lifecycle, particularly as juveniles, and sustain diverse flora and fauna.[27] These services amount to $78,500 per acre, or $22.3 billion annually for the 284,727 acres of SeaBank coastal wetlands.[28]

One of the main identified ecosystem services in coastal ecosystems is food provisioning services, mostly through fishing.[29] 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 SeaBank biomes. Eight of the top 100 seafood-producing ports (or NOAA Fisheries aggregated port groupings) in the U.S. rely on SeaBank's natural capital.[30]

The SeaBank annual reports have a significant focus on the cultural ecosystem services provided by SeaBank's natural capital such as spiritual, religious, educational, cultural and inspirational values, aesthetic values such as natural scenery, and recreation and tourism.[31] Recent research identifying health benefits associated with outdoor recreation and other types of nature-based tourism is spurring new studies seeking to quantify cultural services. [32] These cultural ecosystem services support Southeast Alaska's other top private sector economy - the visitor products industry, which can generate a $1 billion economic impact when including indirect and multiplier economic impacts.[33]

Table 1.1: Provisioning Services: Representative Commercial Fishery Harvests

Asset	Sales	Ex-vessel Income
2020 Halibut & Sablefish	14.4 million pounds	$40,000,000
2019/2020 Shellfish	8.4 million pounds	$27,100,000
2021 Salmon	58 million fish	$132,300,000

Table 1.2: Cultural Services: 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

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. SeaBank's natural capital provides significant competitive advantages that attract visitors such as 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.This report provides additional focus on one of SeaBank's most valuable ecosystem services - its scenic beauty and visual landscape alone are a primary reason to protect the region's forested ecosystems from industrial-scale logging. The value and protection of SeaBank's scenery, the strong bond between coastal communities and the sea, its fish, wildlife and habitats all warrant heightened protection from industrial developments.

Estuaries and Forests: Regulating and Supporting Ecosystem Services

Because of their high productivity, Southeast Alaska's estuaries provide multiple globally-significant ecosystem services. These include food-provisioning services, regulating services that include carbon sequestration (the process through which trees and other plants capture and convert carbon dioxide (CO2) into terrestrial organic carbon and store the CO2 as biomass, e.g., vegetation), coastal protection, erosion control and water purification, supporting services such as fish habitat, and cultural services that support tourism, recreation, education and research.

Chapter 2 focuses on these services - and estuaries, which 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 areas, refuge and forage for migratory birds, sea birds, marine mammals and terrestrial mammals.

Estuarine vegetation such as eelgrass 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.

Chapter 3 of this report focuses on carbon sequestration by coastal wetlands and SeaBank forests, which are globally significant and irreplaceable for their carbon stores and biodiversity.[34] In combination, the Tongass National Forest and adjacent forests in British Columbia comprise the largest, mostly- intact expanse of coastal temperate rainforest in the world, and nearly a third of all old-growth temperate rainforests remaining on the planet.[35] The Tongass National Forest is particularly invaluable, with over 9 million forested acres and the most remaining old-growth forest of any national forest with about 5 million acres left.[36] It stores 2.7 billion metric tons of carbon in aboveground biomass and soils - 20 percent of total carbon for the entire national forest system and more than any other U.S. national forest.[37]

The coastal old-growth forests store disproportionately high carbon stocks relative to other forests, making them individually and cumulatively critical to climate regulation.[38] These forests accumulate significant stocks of carbon, both above and below ground over time.[39] Scientific evidence shows that protecting mature and old-growth forests is a natural climate solution critical to reducing greenhouse gas emissions, for simple reasons: (1) forests absorb and store atmospheric CO2 in tree trunks, foliage and soils and (2) logging destroys that benefit by returning most stored carbon to the atmosphere.[40] It takes centuries for regrowing trees to recoup these losses.[41] It is thus essential to retain these forests to avoid adding their carbon to global greenhouse gas emissions, and so they can continue drawing down CO2 from the atmosphere.[42]

Land-use change accounts for nearly a quarter of anthropogenic greenhouse gas emissions, including from logging and other causes of forest loss.[43] Industrial logging is the leading cause of global forest loss, one of the major drivers of biodiversity loss and undermines the capacity of forests to function as one of the most effective climate change mitigation strategies – conservation of green carbon.[44] Globally, forest loss and degradation cause more emissions than the entire transportation network,[45] drawing down CO2 from the atmosphere.

FORESTS AND CLIMATE

...[i]t is clear that reducing greenhouse gas emissions alone is insufficient to avoid large global temperature increases. To avoid atmospheric concentrations of greenhouse gases that result in dangerous alternations of the climate, large reductions in carbon dioxide emissions from fossil fuel combustion and land use changes must be accompanied by an increase in atmospheric carbon dioxide sequestration. Natural Climate Solutions have become a major focus of climate policy. Land and ocean ecosystems remove and store atmospheric carbon, and forests play a major role.

Moomaw, W. R., Law, B. E., & Goetz, S. J. (2020). Focus on the role of forests and soils in meeting climate change mitigation goals: Summary. *Environmental Research Letters,*

There is a global need to maximize forest carbon stocks over the next few decades.[46] Because of the sequestration capacity of forests and the impacts of logging, reducing emissions from forest degradation is as urgent as halting fossil fuel use.[47] SeaBank forests are not reaching their full sequestration potential in large part because recent and ongoing logging of old-growth and maturing forests offsets sequestration by returning stored carbon to the atmosphere.[48] The overall amount of carbon sequestered by Alaska ecosystems could increase over the 21st century, primarily because of SeaBank's forests.[49] This potential can be maximized by making policies that maintain existing intact and maturing forests, allowing them to continue growing.[50]

Past logging in Southeast Alaska's public and private forestlands has created over 800,000 acres of previously clearcut forests that are now regenerating.[51] Many of these forests are "middle-aged," between 50 and 100 years old.[52] These forests sequester carbon quickly and are "carbon hotspots."[53] The large cohort of stands that are 30 to 50 years old make a large contribution to the net increases in live-tree carbon, too.[54] Allowing these forests to fully mature would compensate for a notable portion of U.S. CO2 emissions.[55]

The Tongass is the only national forest subjected to substantial amounts of old growth logging in recent decades.[56] The amount of future logging is uncertain. Federal policy for the Tongass has changed back and forth frequently – for example, over the past two decades there have been administrative processes exempting and reinstating the 2001 Roadless Rule.[57] In 2021, the U.S. Department of Agriculture announced it would stop selling old-growth timber sales on the Tongass National Forest and fully reinstate the Roadless Rule, in large part because of the importance of these forests to climate change mitigation and biodiversity.[58]

Although the Forest Service has been unable to attain planned logging levels in recent years, annual forest loss in Southeast Alaska continues and has ranged from 3,000 to 5,000 acres yearly over the past decade.[59] Alaska's Division of Forestry and other state entities and corporate forestland owners clearcut over 400,000 acres of old-growth forest during the 20th century, and have been responsible for most of the logging in the 21st century.[60] Nearly half that logging occurs on formerly public lands transferred from the Forest Service to state or private entities through Congressionally-approved land exchanges.[61] The Forest Service plans to increase industrial scale clearcutting of maturing second-growth forests on the Tongass National Forest.[62]

Conserving forests is one of the most robust and by far one of the most cost-effective options for climate mitigation because of the high value of ecosystem services that intact forests provide, including biodiversity, recreation, fisheries and enhanced resilience in a changing climate.[63] A no-loss forest policy would greatly benefit Southeast Alaska communities that depend on unlogged portions of the Tongass National Forest such as its roadless areas for fisheries, recreation, and subsistence.[64]

Ecosystem Services and the Changing Climate

Because of recent weather events and other documented changes, Chapter 5 of this report maintains a significant focus on the threat climate change poses to SeaBank's natural capital. It threatens to reduce biodiversity and the function of ecosystems, and hence the value of ecosystem services provided to people.[65] One of the major concerns is the impact of extreme weather events on ecosystem services, as climate change makes droughts, storms, floods and terrestrial and marine heat waves last longer and occur with more frequency and severity.[66] Chapter 5 explains how climate change is likely to cause sea level rise in most places worldwide – but that in Southeast Alaska sea level will lower as land rises underneath rapidly melting glaciers. The chapter also discusses the heating up of both freshwater and marine ecosystems, shifting precipitation patterns, and alterations to the distribution of plants and animals.[67] The region experienced record-setting temperatures and drought in 2019, followed by a year of record precipitation.[68] Alaska climate scientists expect that the frequency and intensity of severe weather events will accelerate in the future.[69]

Climate change may affect the cultural ecosystem services that are important to the region such as ocean and coastal recreation by altering ecosystems used for recreation, tourism and resident well-being.[70] Coastal communities are particularly vulnerable to impacts from storms and changes in sea level.[71] Climate-induced changes in provisioning services – the material goods people obtain from ecosystems and biodiversity such as seafood – may harm economies and people's well-being.[72]

Climate change is likely to have dramatic impacts on fishery resources by, among other impacts, redistributing fish stocks and reducing productivity.[73] One of the more notable effects in fish will be changes in body size. Future warming may reduce average fish body size by 14 to 24 percent by 2050, and changes in the availability, distribution and quality of commercial fish species are likely to reduce catch potential in all U.S. regions but the Arctic.[74]

Wildlife populations may change behaviors, locations, and migration patterns, and may have to adjust to changes in the food web, or perish.[75] Over half of the plant and animal species in North America are already changing locations because of transitions in the warmer and cooler edges of their ranges, with the fastest changes occurring for marine species – although those changes are highly variable.[76]

These changes will impact one of SeaBank's most valuable assets in terms of annual dividends, which are its salmon and salmon-producing ecosystems. Salmon use a combination of freshwater, estuarine and marine habitats at different stages of their lifecycle, 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.[77] Climate change affects salmon in many ways, including increased risk of events of pre-spawner, egg or embryo mortality for pink and chum, degradation of lake habitat for sockeye and rearing habitat for juvenile coho.[78] This report explains how these changes will challenge each salmon species in different ways.

Fish biodiversity is critical for the ability of salmon populations to weather the changing climate. Ongoing research regarding salmon populations demonstrates that maintaining salmon biodiversity is critical to the stability of multiple ecosystem services provided by salmon, including provisioning economies and livelihoods that depend on them.[79] The need to manage salmon-producing ecosystems in a way that maintains population diversity is heightened by the effects of a rapidly changing environment on the quality of marine and freshwater habitats and ultimately on fluctuations in salmon returns.[80] For maximizing the services salmon populations provide, the "portfolio effect" (biodiversity) is key. It relies on diverse assets (populations) from many watersheds, which reduce variances in productivity from year to year.[81] The portfolio effect depends on intact landscapes, which perform the best for consistently delivering salmon to ecosystems and people.[82]

Depletion of Marine Resources: The Problem of Trawling

Finally, this report adds new material on a long-term and increasing threat to SeaBank marine assets – industrial trawl fisheries in the Gulf of Alaska and Bering Sea. In 1996, Congress enacted The Sustainable Fisheries Act in order to address concerns about bycatch increases and impacts of bycatch on other fisheries, particularly by the North Pacific trawl industry.[83] The Sustainable Fisheries Act required that fishery management councils reduce the amount of bycatch in every fishery in order to stop the "inexcusable amount of waste" associated with bycatch and bycatch mortality in U.S. fisheries.[84]

However, the National Marine Fisheries Service (NMFS) and the North Pacific Fisheries Management Council (NPFMC) have failed to adequately address the impacts of industrial trawl bycatch on fishing communities in Southeast Alaska and throughout the state.[85] Federally-managed trawl fisheries in the Gulf of Alaska and Bering Sea are a major threat to SeaBank 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 to support numerous coastal communities. These impacts are even worse because many species taken by trawlers are declining in abundance.

Bycatch – particularly by non-selective trawl gear – is a national and global concern because of economic waste and harms to marine biodiversity.[86] In general, bycatch is the take of non-target species while fishing for other species.[87] Trawl gear is responsible for the largest proportion of the bycatch mortality of valuable commercial, sport and subsistence species in Alaska offshore waters.[88] The bycatch includes a high proportion of juvenile fish, which reduces future yields for Southeast Alaska's sport, subsistence and commercial fishermen who would otherwise harvest the bycaught species once mature.[89]

The Gulf of Alaska trawl fleet kills thousands of Chinook salmon as bycatch each year, including fish bound for Southeast Alaska and stocks from the Pacific Northwest and Canada.[90] NMFS' bycatch estimates show that Gulf of Alaska trawlers have killed nearly half a million Chinook salmon as bycatch since 2000.[91] In any given year, a significant percentage of these fish originate in Southeast Alaska.[92] The bycatch of these fish is troubling because of the small size and current stock status of those runs.[93]

NMFS estimates that bycatch by Bering Sea and Gulf of Alaska trawlers typically kills as much as 5 million pounds of halibut each year – more than the entire Southeast Alaska directed fishery. One of the problems with trawl halibut bycatch is the take of juvenile fish and the future lost yield for the resource and other fisheries.[94] Typically, over half the halibut taken in the Bering Sea and over a third of the halibut taken in the Gulf of Alaska are juvenile fish less than 26 inches in length that would otherwise mature, migrate southward and contribute to fisheries yields for Southeast Alaska fishing communities.[95]

Over the last five years an emerging problem is “unusually high levels" of bycatch by trawlers, causing "unprecedented increases" in the number of sablefish killed as bycatch.[96] The high level of juveniles in this bycatch is a concern because it later results in a smaller spawning population.[97] There are no bycatch limits or other requirements to avoid sablefish.[98] NMFS and the NPFMC have declined to take any action to address sablefish bycatch.[99]

Table 1.3: Trawl Halibut and Sablefish Bycatch 2017-2021

Year	Bering Sea and Gulf of Alaska Sablefish (round pounds)	Bering Sea and Gulf of Alaska Halibut (net pounds)
2021	1,937,843	2,799,291
2020	9,625,284	3,730,183
2019	5,943,602	5,259,624
2018	3,084,235	4,957,043
2017	769,405	4,718,946
Total	21,360,369	21,465,087

Conclusion

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

Tongass National Forest. Photo credit: Shutterstock

Chapter 2: Introduction and Key Habitats

Southeast Alaska is a single, vast, highly productive ecosystem that extends from mountaintop to open ocean. Everything is tightly interconnected: the land, water, vegetation, wildlife, resources, economies and culture. The Alaska Sustainable Fisheries Trust (ASFT) program SeaBank was created to tell the story of the contribution of ecosystem services to the economic and lifestyle needs of Southeast Alaska residents. This natural ecosystem functions as a richly-endowed bank that provides the 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, depletion or other degradation, 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.

The goal of ASFT's SeaBank program is to make people aware of Southeast Alaska's natural bank, to measure the huge annual capital it provides and its value to shareholders, and to inspire residents, visitors and policy makers to make sound long-term decisions that promote stewardship and sustainable economics. This fourth 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 annual SeaBank report captured in economic terms the ecological services and resource wealth of the Southeast Alaska ecosystem. The second report supplemented that focus with an emphasis on salmon and risks to that resource associated with the cumulative effects of climate change and timber and mineral extraction. The thirs report further updated the discussion of climate change impacts on fishery resources with a focus on the region's high-value estuaries. This forth report expands on the socio-economic importance of this unique coastal ecosystem for recreation and fishery values and expands on anthropogenic threats to SeaBank assets from industrial trawling and continued risks associated with industrial logging.

Ecology, Climate and Key Habitats – SeaBank's Value Creation Process

Southeast Alaska's coastline extends over 430 miles from Dixon Entrance to Yakutat with over 38,000 square miles of land and water.[100] Roughly 20,000 years ago, glaciers covered most of Southeast Alaska.[101] They receded in several phases between 13,000 and 17,000 years ago and carved out many of the fjords and inlets in Southeast Alaska's inside passage.[102] Glaciers and tectonic processes produced a marine environment of long, deep marine waterways, a deep, narrow continental shelf and a terrestrial environment dominated by steep coastal mountains and glacial valleys.[103]

Today, this 21.6-million-acre terrestrial environment includes hundreds of islands of all sizes (the Alexander Archipelago) and a coastal mountain range interspersed with glaciers and icefields, occasionally divided by large rivers.[104] It has over 18,000 miles – 20 percent of the U.S. coastline.[105] The largest thousand islands comprise 40 percent of the land area,[106] The U.S. Forest Service manages most of the land base – the 16.8-million-acre Tongass National Forest.[107] Although a rainforest, much of the landscape is wetlands and alpine tundra, recently glaciated, with ice covering 4.5 million acres.

The key habitats are coastal-temperate rainforests, rich estuaries, freshwater aquatic ecosystems fueled by run-off from glaciers and precipitation, and the near-shore and off-shore marine waters. Forests cover over half of the land area and the remainder is rock, ice, unforested alpine country and muskeg.[108] Aquatic ecosystems include large transboundary rivers on the mainland, and lakes and streams of all sizes are scattered throughout the region, including nearly 15,000 miles of anadromous or potentially anadromous salmon habitat.[109] The region has 350,000 acres of estuarine habitat utilized by most fish and wildlife species at some point in their life cycle.[110]

A highly scenic marine byway consisting of deep fjords, large straits, narrow channels and inlets provides the transportation infrastructure that allows access to 18,000 miles of marine shoreline.[231] The largest waterways are Chatham Strait, which reaches depths of over 1,600 feet, and Clarence Strait, each extending for roughly 150 miles.[232] These two main passages connect to smaller straits, channels, fjords, bays and the outer coastline.[233]

A whale using one of Southeast Alaska's numerous waterways. Photo credit: *F/V Patience.*

The marine highway network also includes Lynn Canal which has depths reaching 2,000 feet - the deepest fjord in North America.[111] 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.[112]

The Wet, Windy Climate

Southeast Alaska has a maritime climate with cool temperatures and abundant precipitation.[113] Skagway is the driest location, averaging 30 inches of precipitation per year, while over 200 inches typically falls on Port Walter at the south end of Baranof Island.[114] Land temperatures are within a narrow range, with only 24° Fahrenheit between the winter and summer averages.[115] Most low-elevation areas have an annual average temperature somewhere between 41 and 47 °F.[116]

The Alaska Coastal Current brings warmer water from the North Pacific current, flowing along the continental slope, and this combined with weather often encountering the high coastal mountains forms a cool, wet environment.[117] The current moderates the region's climate by providing warmer winter sea temperatures and cools the area in the summer.[118]Ocean storms interact with the coastal mountains to produce high winds and heavy coastal precipitation over the continental shelf and the archipelago year-round.[119] Numerous steep small watersheds quickly transfer rain to the ocean, or store it as snow. [120] The snow and ice act as freshwater reservoirs, storage that is seasonal or on longer time scales. [121]

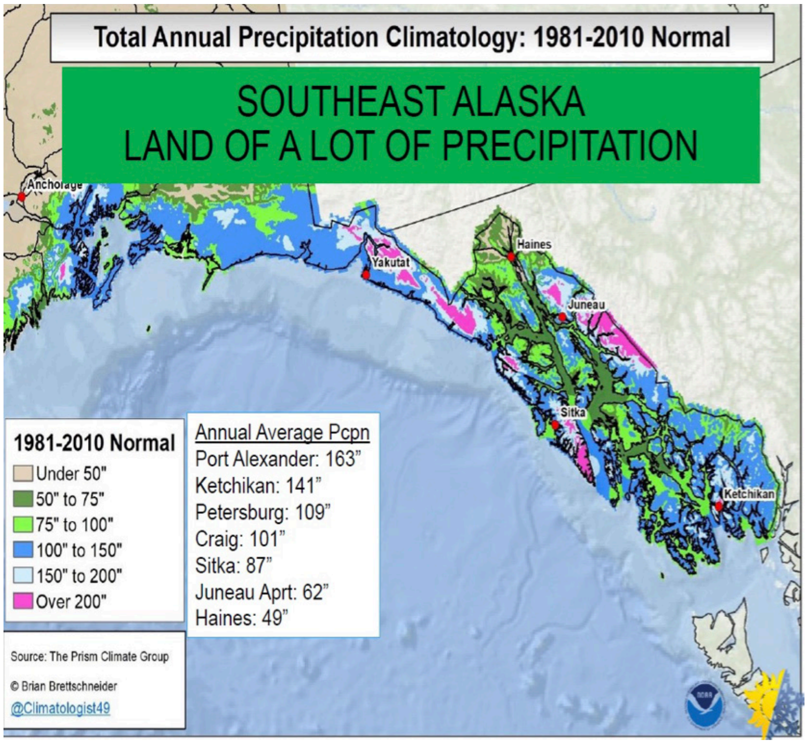


Figure 1: Southeast Alaska is one of the wettest areas in the world.
Graphics credit: Jacobs, A. & R. Thoman. 2020. Drought in a rainforest …
How can that be? Alaska Center for Climate Assessment and Policy.

The precipitation characteristics significantly influence the marine environment – runoff is minimal in the winter when most of the precipitation falls as snow, increases during the summer melt, and peaks during fall rains.[122] Runoff from all sources comprises 60 percent of the coastal discharge into the Gulf of Alaska, contributing to the Alaska Coastal Current and its northward flow along the coast. [123] Because of this massive freshwater discharge, oceanographers believe that the region's weather has a strong influence on downstream portions of the Gulf of Alaska.[124]

Coastal Temperate Rainforests

Coastal-temperate rainforests are globally-significant ecosystems and provide habitat for a large number and diversity of species.[125] Southeast Alaska and northern coastal British Columbia retain 30 percent of the remaining temperate old-growth rainforest on the planet and support healthy populations of fish and wildlife species that are no longer abundant in other parts of the Pacific Northwest.[126] Protecting this forest also protects a "basket of ecosystem co-benefits" such as biodiversity, conservation, air and water filtration, erosion control, hunting, fishing, recreation and Indigenous livelihoods.[127] This includes substantial sequestering of carbon in trees, soils and plants.[128] Of the region's 11 million acres of forest there are over 6 million acres of productive forest, generally meaning larger tree and higher values for forest diversity and wildlife habitat.

Freshwater Ecosystems and Glaciers

The region's abundant precipitation drains into 46,000 miles of streams and 3,200 lakes and ponds.[129] Major freshwater aquatic ecosystems include the five mainland transboundary rivers that originate in British Columbia and six coastal mainland rivers that are on the seaward slopes of the coastal mountains.[130] The transboundary rivers are the largest of these systems and bisect either the Alaska Coast Range or the St. Elias Mountains and are corridors between Southeast Alaska and the Canadian interior.[131] From north to south, these rivers are the Alsek (140 miles long), Chilkat (55 miles), Taku (80 miles), Stikine (404 miles), and Unuk (68 miles).[132] All except the Chilkat flow mostly through British Columbia.[133] The Stikine watershed encompasses 20,000 square miles.[134] On Southeast Alaska's islands, over 7,000 miles of streams are large enough to support salmon runs, led by Prince of Wales Island with over 2,000 miles, and the Chichagof Island and Kupreanof/Mitkof Islands subregions, each having over 1,000 miles of salmon streams.[135]

SeaBank's collection of temperate icefields and glaciers is the largest in North America and a primary capital asset. Glacial and icefield watersheds function differently than other watersheds, and contribute nearly half the water flowing into the Gulf of Alaska.[136] They significantly influence coastal marine ecosystems, as their runoff delivers a seasonal blast of cold water, nutrients and sediment to the region's fjords and bays.[137] This runoff contributes to high densities of phytoplankton – the very base of the aquatic food web – and other primary forage for fish, such as krill and copepods (small crustaceans).[138] As a result, bays and fjords affected by glacial runoff support large numbers of seabirds and productive pelagic communities by providing breeding, nursery and foraging areas.[139]

Coastal Marine Environment

Southeast Alaska's marine environment consists of diverse habitats in protected inside waters (channels, straits, bays and inlets within the archipelago and mainland) and offshore waters (the continental shelf and slope waters seaward of the outer coast).[140] It is also one of the great fjord regions in the world and one of the few places to observe tidewater glaciers.[141]

Much of the shoreline is a combination of rock and sediment such as sand and gravel flats or steep, rocky cliffs that lie within protected inlets, deep fjords and sandy bays.[142] Wave energy is the dominant influence for these areas, which have diverse intertidal and shallow subtidal zones with bare tideflats, algal beds with barnacles and mussels, estuaries, salt marshes and eelgrass meadows, kelp beds and beaches.[143] Roughly 12 percent of the shoreline consists of high-value estuarine habitat.[144]

Offshore waters include a narrow continental shelf with depths of less than 1,000 feet and a steep but equally narrow continental slope.[145] The shelf is 3 to 12 miles wide over much of the southern and central coastline and then increases to over 35 miles wide north and west of Cross Sound.[146] The near-shore continental shelf is rocky, but in most areas tapers to a broad flat plain before transitioning to the steep continental slope.[147] The shelf includes numerous submarine banks, troughs, channels and canyons that may be locations for enhanced biological production.[148] 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.[149] One of SeaBank's notable marine assets is a large no-trawl area encompassing 52,600 square nautical miles.[150]

Marine weather patterns are important to ocean productivity. [151] 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.[152] Winter storms mix the water column and distribute nutrients. [153] During spring, weather calms as the days lengthen, causing boundary layers to form in the water column. These create lenses of nutrient-rich water of suitable temperature for the plankton blooms that form the basis for overall marine biological productivity. Overlayed on that phenomenon is the Pacific Decadal Oscillation, which shifts oceanic circulation patterns, causing extended warm and cold phases that also affect productivity.[154]

Highest Valued Ecosystems: SeaBank Estuaries

Natural resource economists identify estuaries as the highest-valued ecosystems - Southeast Alaska's 350,000 acres of estuaries, 2 percent of Sea Bank's land area, provide $15,000 per acre in ecosystem services each year ($5.3 billion).[155] This value is second only to coral reef ecosystems, and higher than all terrestrial ecosystems combined.[156] This disproportionate ecological importance is because terrestrial, freshwater and marine ecosystems in these areas connect and provide numerous services.[157]

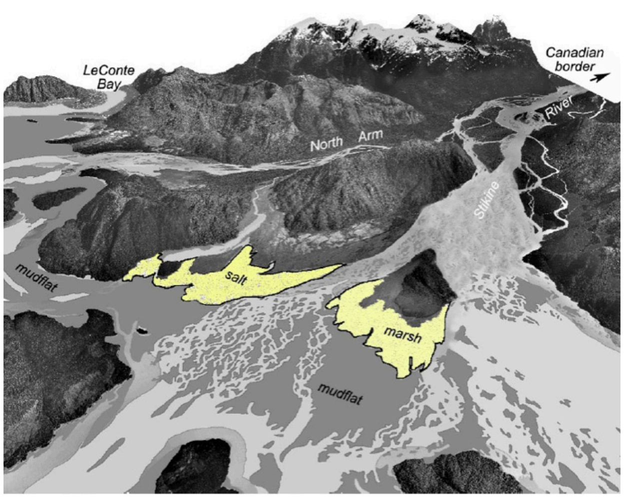


Figure 2: The Stikine River Delta is the region's largest estuary. Graphics credit: Carstensen, R. 2007. Coastal habitats of Southeast Alaska. Ch. 5.3 in Schoen, J. & E. Dovichin, eds. Audubon Alaska and The Nature Conservancy. 2007. Coastal Forests and Mountains of Southeastern Alaska and the Tongass National Forest: A Conservation Assessment and Resource Synthesis.

Southeast Alaska's estuaries are globally-significant because of their high productivity. There are 12,000 estuaries in Southeast Alaska.[158]

Nearly 3,000 of the estuaries are roughly 250 acres in size.[159] The largest estuaries are on the mainland, including the 21,000-acre Stikine River Delta.[160] The Yakutat Forelands area includes the 13,859-acre Dangerous River estuary and the 6,811-acre Dry Bay estuary.[161] 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).[162] Those estuaries drain freshwater systems that are much smaller than transboundary rivers.[163] The Chilkat River and Gustavus and Taku estuaries are all larger than 4,000 acres. [164]

Estuaries provide important resource values for nearly all Southeast Alaska's fish and wildlife assets.[165] This includes spawning and nursery areas for diverse species of finfish, forage fish, shellfish and other invertebrates.[166] For migratory birds, sea birds, marine mammals and terrestrial mammals, estuaries provide areas for breeding, refuge and forage.[167] They also support ocean health and water quality, as a buffer between ocean and land that filters sediment and pollutants from freshwater before they enter the ocean.[168]

Estuaries provide protection, nutrient exchanges and abundant food sources for fish and shellfish, including numerous forage fish such as herring, eulachon, Pacific sand lance and capelin that support other species.[169] Three-fourths of all fish caught in Alaska utilize estuaries and estuarine vegetation during some part of the life history, including major groundfish species such as halibut, sablefish, pacific cod and rockfish.[170] Juvenile sablefish occur only in a few estuaries, heightening the value of those locations.[171]

Salmon fishery production often corresponds to productive estuaries.[172] Estuaries are transitional habitats between the marine and freshwater environments for salmon. Critically, salmon pass through estuaries twice, during outmigration as smolts (rearing there extensively as juveniles) and when returning to spawn.[173] Multiple studies of juvenile salmon show that their initial growth and survival depend on the capacity of these systems to produce forage and protection from predators.[174]

Estuarine Vegetation: Eelgrass, Salt Marsh and Kelp Forests

Estuarine vegetation such as salt marsh grasses, seagrass meadows and kelp forests provide critical ecological functions for numerous SeaBank assets. Seagrasses such as eelgrass are flowering plants that form underwater meadows along coastal shorelines and provide some of the most biodiverse and productive coastal habitats.[175] They grow below salt marshes in wave-sheltered shallow marine habitats such as the lower intertidal and nearshore subtidal portions of estuaries.[176]

Seagrass meadows, one of the planet's most productive ecosystems, provide critical services for coastal communities, economies and lifestyles.[177] The multiple ecosystem services they provide include food sources, coastal protection and erosion control, water purification, maintenance of fisheries and carbon sequestration. [178] They also support important forms of tourism, recreation, education and research.[179]

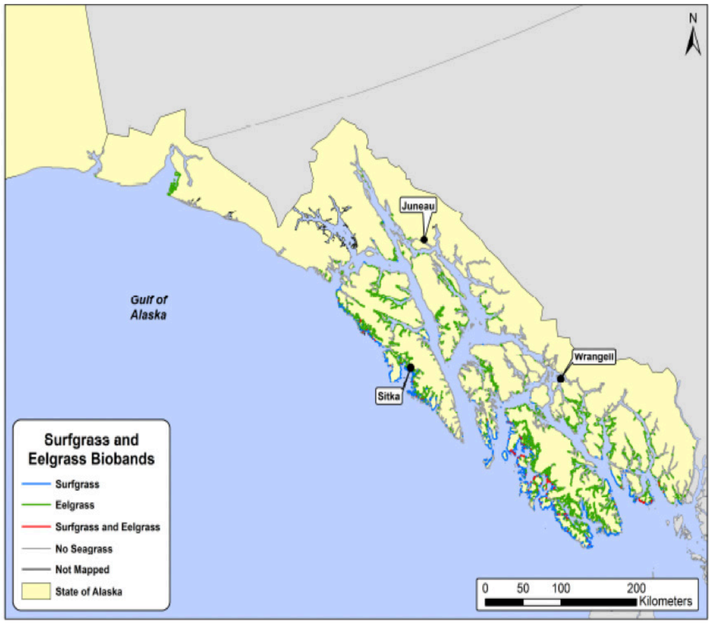


Figure 3: Eelgrass meadows are prevalent along the Southeast Alaska shoreline. Graphic: Coastal & Ocean Resources Inc. & Archipelago Marine Research Ltd. 2011. Coastal Habitat Mapping Program. Southeast Alaska Data Summary Report 2011.

Eelgrass is the most widespread seagrass species in the northern hemisphere and most common seagrass along the North American Pacific Coast.[180] Most of Southeast Alaska's eelgrass meadows grow in soft sand and mud substrates in protected bays and inlets that have freshwater influence.[181] Peak growth occurs in the late spring.[182] The 3,500 shoreline miles of continuous or patchy eelgrass meadows in Southeast Alaska likely exceed that of the combined shorelines in Oregon and Washington.[183] The outer coast also contains surfgrass meadows which have higher wave tolerances.[184]

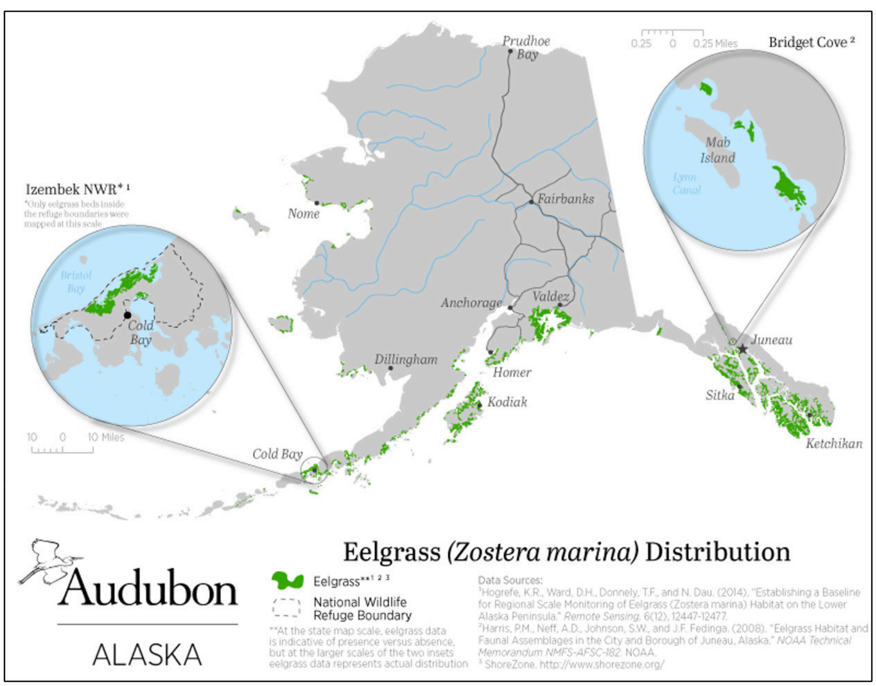


Figure 4: Eelgrass Distribution. Credit: Audubon Alaska

Eelgrass is one of the most important habitats of Southeast Alaska's estuarine ecosystems. Dozens of marine finfish, commercially-utilized invertebrates such as crab and shellfish and numerous other invertebrates occupy eelgrass habitats.[185] Southeast Alaska eelgrass meadows are the top estuarine habitat for species diversity (relative to kelp and salt marshes).[186] 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.[187]

Eelgrass is a productive habitat that supports a high abundance and diversity of Southeast Alaska's marine species, including dozens of forage fish and commercially-important species.[188] 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.[189]

Eelgrass meadows are common in Southeast Alaska's bays. Photo credit: Shorezone. Source: Johnson, A.C., Noel, J., Gregovich, D.P., Kruger, L.E., and Buma, B. 2019. Impacts of submerging and emerging shorelines on various biota and indigenous Alaskan harvesting patterns. *Journal of Coastal Research, 35*(4) pp. 765-775.

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.[190] 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.[191] Juvenile salmon grow rapidly during this critical life cycle phase, which is critical because larger fish are more likely to survive early marine residence.[192] Studies have shown that large-scale eelgrass loss in many estuaries can decrease invertebrate densities, reduce salmon survival rates and drastically diminish salmon returns. [193]

Eelgrass supports other marine species such as juvenile shellfish. There is a rich invertebrate community of 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.[194]

Eelgrass is susceptible to coastal development and environmental changes both in nearshore waters and on adjacent uplands. Direct disturbances such as dredging and marine construction or scouring from motorized boat propellers and excess sediment or other pollution from mining, agriculture and other industrial activity are a major cause of seagrass declines.[195] Excessive runoff from timber roads and deposition of logging waste has been known to destroy eelgrass habitats.[196]

Marine log transfer facilities are one of the more significant threats to eelgrass in Southeast Alaska. Photo credit: Colin Arisman.

Salt marshes are a diverse grassland plant community that occupies the upper intertidal zone at the border of an estuary.[197] The marshes utilize wave-protected shorelines and grow behind barrier island systems and in bays and estuaries.[198] In Southeast Alaska they are common at river deltas and the heads of inlets.[199] There are nearly 34,000 acres of salt marshes in Southeast Alaska, making them the most common shoreline plant community.[200] Salt marshes occur continuously or in patches along at least 8,000 miles of the Southeast Alaska shoreline.[201]

Ecosystem services provided by salt marshes include coastal protection from waves and storm surges because they attenuate waves by as much as 40 percent, controlling erosion, flood defense and protecting coastal areas.[202] Salt marshes have significant habitat values for economically and ecologically important fish species, including protection from larger fish predators and plant material for forage.[203] They also take on excess nutrients from rivers and terrestrial runoff, purifying and improving water quality entering the estuary and benefitting adjacent ecosystems such as seagrass meadows.[204]

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 [Nereocystis luetkeana], giant kelp [Macrocystis integrifolia] and dragon kelp [Alaria fistulosa]) grow on rocky substrates and are the primary vegetation on over one-third of the shoreline, covering 6,200 miles.[205] Most kelp sites are more oceanic and located in exposed locations at the mouths of bays.[206]

Threats to Estuaries and Estuarine Vegetation

Estuarine and coastal ecosystems are heavily used and threatened on a global and regional scale.[207] There is rapid global loss of coastal wetlands, including one-half of the salt marshes and nearly one-third of the seagrasses.[208] Global loss of seagrasses continues at a rate of 5 to 7 percent annually.[209]

Climate change is a major threat to the geography and vegetation of estuarine systems.[210] Seagrass meadows and kelp forests are some of the world's most highly vulnerable ecosystems.[211] The two ecosystems have low or moderate adaptive capacity and high sensitivity to ocean warming, marine heat waves and acidification.[212] The Intergovernmental Panel on Climate Change (IPCC) concludes that low-latitude kelp forests and temperate seagrasses such as eelgrass will diminish with more frequent temperature extremes.[213] Impacts to these systems will increase biodiversity loss and alter ecosystem structure and functioning.[214]

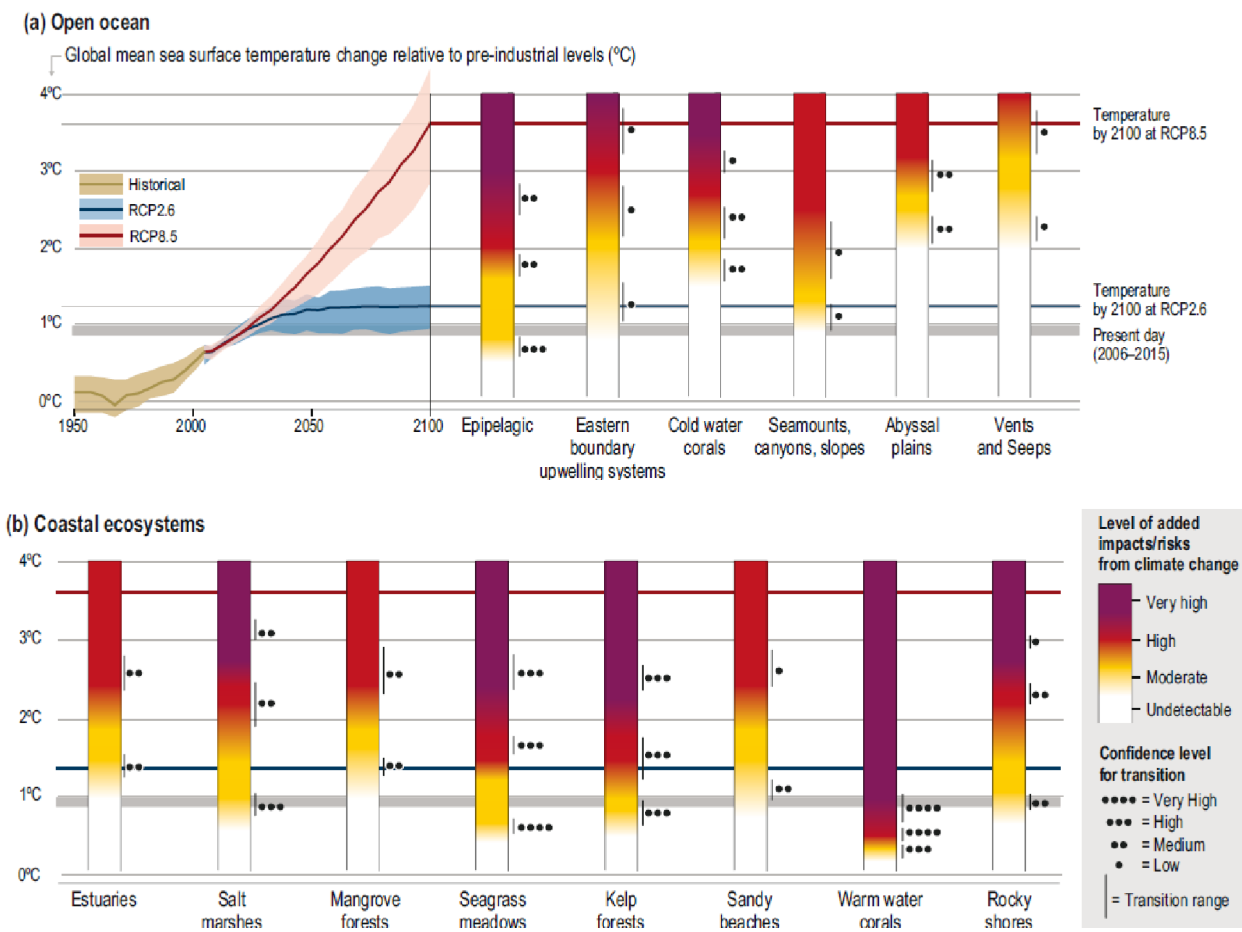


Figure 5: Oceans are likely to warm considerably over the next 80 years, threatening kelp forests, seagrass meadows and salt marshes. Graphics credit: Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. Purca 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.)].

Recent IPCC studies suggest kelp forests are already experiencing large-scale changes.[215] They have low capacity to relocate and high temperature sensitivity.[216] Abundance of kelp forests has decreased by roughly 2 percent per year over the past half century, mostly from mass mortality events caused by ocean warming in general or extreme temperatures in marine heatwaves.[217]

The main risks to tidal salt marshes include changes in sea level, habitat conversion, reduced water quality and increasing storm activity.[218] The U.S. Pacific Coast alone lost 90 percent of its salt marshes over the past century.[219]

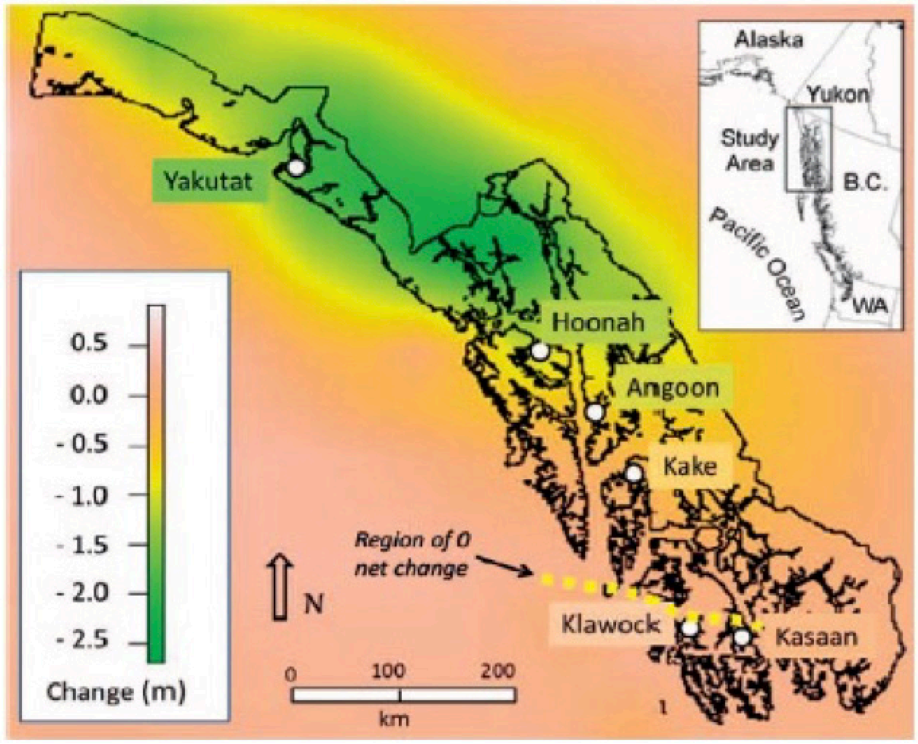


Figure 6: This map projects changes in sea level, which will be lower in much of northern Southeast Alaska, decreasing the amount estuarine habitat. Graphics credit: Johnson, A.C., Noel, J., Gregovich, D.P., Kruger, L.E., and Buma, B. 2019. Impacts of submerging and emerging shorelines on various biota and indigenous Alaskan harvesting patterns. *Journal of Coastal Research, 35*(4) pp. 765-775.

Changes in sea level also are a main threat to seagrasses.[220] In northern Southeast Alaska, the rate of sea level fall (e.g, northern Southeast Alaska is rising from the sea) 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 uplift rates in the world.[221]

The expected sea level lowering of between 2 to 8 feet throughout much of the region is likely to be a major cause of a projected 30 percent decrease in estuary shoreline lengths over the next century.[222] The greatest projected change in shoreline lengths will occur in low-slope gradient shorelines within protected bays and estuaries – particularly those dominated by eelgrass.[223] Researchers project a cumulative eelgrass loss of 14 percent over the next century with the greatest loss – roughly one-third - around Kake.[224] Some of the southern portions of the region may receive increases in shore eelgrass length in Kasaan and Klawock.[225]

This land emergence has significant consequences for protected-bay coastlines.[226] Naturalists project a rapid loss of coastal marshes, which will transition to meadows.[227] The "uplift meadows" will replace salt-tolerant grasses in the salt marsh zone and the areas will eventually transition to spruce forests.[228] Uplift meadows are emerging near Gustavus, The Chilkat estuary and in Port Frederic near Hoonah.[229] The largest uplift meadows are emerging in estuaries in the vicinity of Icy Strait and Lynn Canal.[230]

Photo credit: Eric Jordan

Chapter 3: Key Resources Produced by the Southeast Alaska Seabank

Southeast Alaska has a global reputation for its beauty and wildness, but its economic value is often overlooked. 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. Commercial fishermen typically harvest over 160 million pounds of seafood in Southeast Alaska, supporting more than 10,000 jobs with $600 million to $800 million in economic outputs.[234] Nearly 1.8 million air and cruise ship passengers visited Southeast Alaska in 2019, supporting nearly 8,000 jobs.[235] In peak years, the seafood and visitor products industries can each generate over $1 billion in economic outputs.[236] Salmon are critical to both industries, and the spending and earnings of commercial, sport and subsistence fishermen contribute nearly $1 billion to the Southeast Alaska economy.[237] 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 $400 million (in 2021 dollars) on hunting and wildlife viewing in the region.[238]

Southeast Alaska's marine environment and productive 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 sequestration capacity and stored carbon stocks, biodiversity and other ecosystem benefits.

Climate Mitigation Resources: Blue Carbon and Green Carbon

The global carbon cycle is the process by which the element carbon moves between air, land and the ocean.[239] This "carbon flux" is constantly ongoing.[240] Sequestration is the process of forests and coastal wetlands capturing and converting atmospheric carbon (CO2) through photosynthesis into terrestrial organic carbon, storing its carbon content as biomass (e.g., vegetation and soil carbon compounds).[241]

The numerous ecosystem services provided by tidewater vegetated ecosystems include significant CO2 uptake and long-term carbon storage.[242] Blue carbon is the organic carbon sequestered and stored by or released from coastal tidewater wetlands – most of it stored in sediments.[243] Three blue-carbon ecosystems – salt marshes, sea grasses and mangroves – cover two-tenths of a percent of the ocean floor but account for one-third of oceanic carbon uptake.[244] Seagrasses and salt marsh vegetation found in Southeast Alaska estuaries remove CO2 from the atmosphere and store it as organic carbon.[245] Dead plant material then eventually accumulates in oxygen-free sediments, accumulating considerable carbon over time.[246] Carbon transported into sediments or deep waters can remain there indefinitely if undisturbed.[247] Green carbon is carbon that is captured and stored in terrestrial plant biomass and soils.[248] Terrestrial ecosystems are much more extensive, but per amount of area, coastal blue-carbon ecosystems capture and store atmospheric carbon at greater rates than mature forests.[249]

SeaBank's forests and estuaries are carbon sinks – ecosystems of sufficient size to absorb substantial amounts of atmospheric carbon at a rate of sequestration that exceeds the rate of carbon lost through respiration and other export. Scientists have just started to sample blue carbon stocks in SeaBank's eelgrass, and are finding considerable variability among the few sampled stocks with areas that may be blue-carbon hotspots and areas that store relatively little carbon compared to other seagrass systems. There have been multiple studies of the region's forests showing that its sequestration and storage capacity is globally significant.[250]

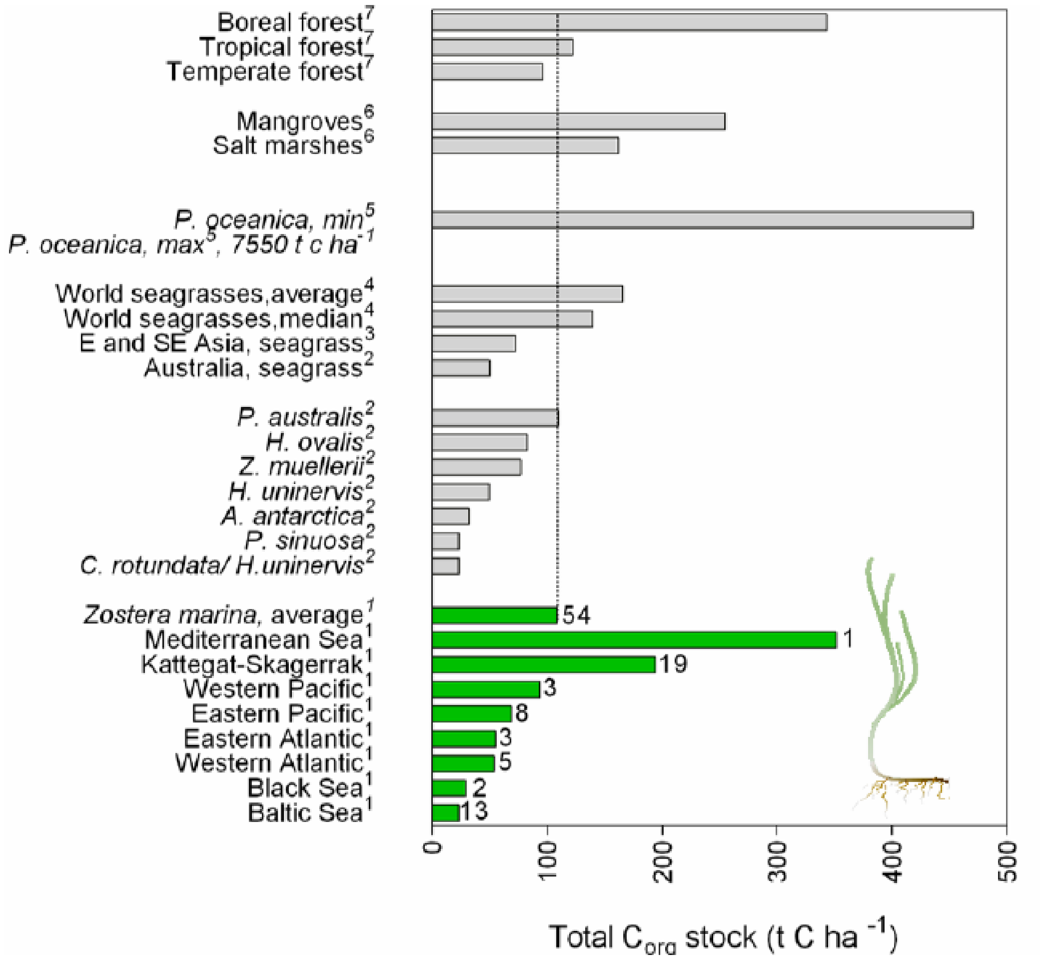


Figure 1: Blue and Green carbon stocks per hectare. Zostera marina is eelgrass. Credit: Röhr, M.E., Holmer, M., Baum, J.K., Björk, M., Boyer, K., Chin, D., Chalifour, L., Cimon, S., Cusson, M., Dahl, M. and Deyanova, D., 2018. Blue carbon storage capacity of temperate eelgrass (Zostera marina) meadows. *Global Biogeochemical Cycles, 32*(10), pp. 1457-1475.

Blue Carbon

There are significant questions about the permanence of blue-carbon ecosystems under future temperature regimes. Rising sea levels are a significant hurdle because in many landscapes there are few suitable sites for seagrass or salt marsh migration due to developed shorelines or steep coastal landscapes.[251] Less than one-half of restoration efforts are successful, in large part because of environmental changes caused by loss or degradation of the original meadow.[252] Even when successful, it may take several decades before the ecosystem again becomes a carbon sink.[253]

These challenges have led researchers to suggest that conservation is far preferable to restoration as a climate change mitigation strategy.[254] Coastal wetlands, like forests, become sources of CO2 emissions when degraded by industrial development or other causes.[255] Seagrasses and salt marshes store most of the blue carbon in sediments so that conversion or degradation of these ecosystems causes the release of blue carbon accumulated over centuries or even millennia to the atmosphere.[256] The estimated amount of CO2 released each year may be between 150 million metric tons and 1 billion metric tons – equivalent to 3 percent to 19 percent of that from deforestation globally, and resulting in economic damages of $6 billion to $42 billion annually.[257]

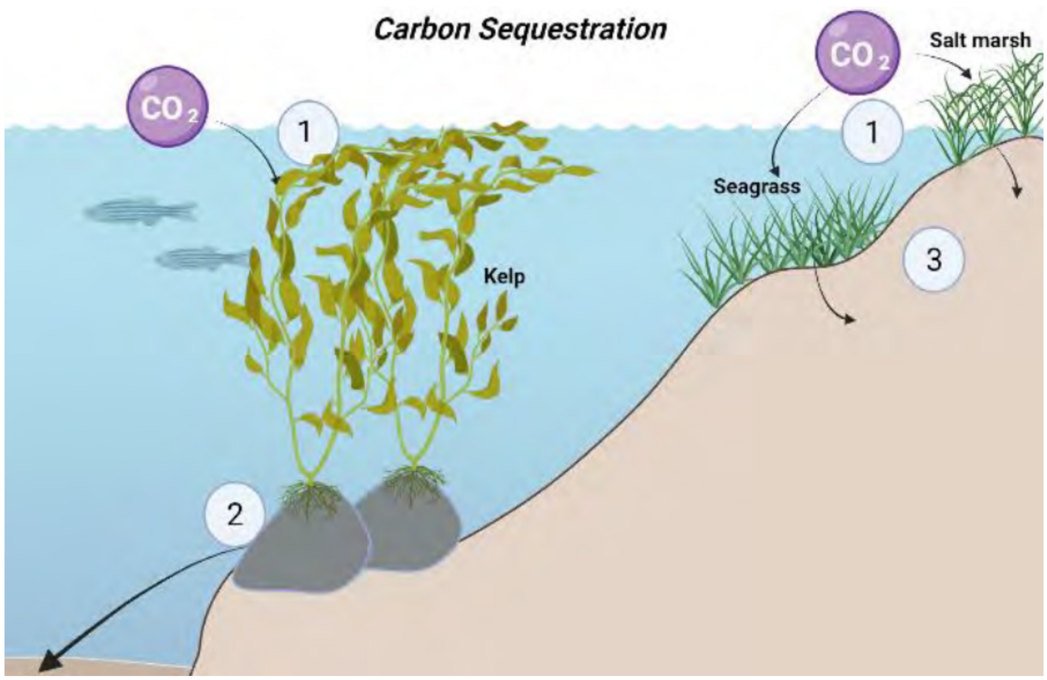


Figure 2: Diagram indicating pathways for carbon sequestration by kelp, seagrass and salt marsh. Credit: Hutto, S.H., Brown, M., & Francis, E. 2021. Blue carbon in marine protected areas: Part 1: A guide to understanding and increasing protection of blue carbon. National Marine Sanctuaries Conservation Science Series ONMS-21-07. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries.

The identification of coastal wetlands as efficient carbon sinks is a relatively recent development.[258] The sequestration process in vegetated habitats constitutes about one-half of the total carbon burial in the ocean. The living plant biomass sequesters carbon for shorter periods of time, but once captured, carbon stored in coastal soils can remain in place for millennia, resulting in large carbon stocks.[259] This advantage offered by coastal systems is because anaerobic conditions (low or no oxygen) help to maintain the long-term storage.[260] The high effectiveness of blue-carbon ecosystems at carbon sequestration has spurred ongoing evaluation of how these systems can contribute to climate change mitigation.[261]

Salt marshes have a high sequestration rate – globally they may store as much as 6.5 billion metric tons of blue carbon in sediments.[262] They comprise 1 percent to 2 percent of the annual carbon sinks in the U.S.[263] They are most valuable for climate mitigation in areas with large coastlines.[264] Tidal fluctuations mix fresh and saltwater in tidal salt marshes and help trap carbon in the sediments which accrue 95 percent of the stored carbon.[265]

While there is high variability, the averaged estimate of global salt marsh carbon storage is 250 metric tons of carbon per hectare (2.5 acres), exceeding the storage capacity of tropical and temperate forests.[266] Scientists studying salt marshes in British Columbia found that salt marshes in that area sequestered carbon at high rates of roughly 1 metric ton per hectare per year but their storage capacity was less than one-half of the global average.[267] Assuming similar sequestration and storage capacity, SeaBank's 17,000 hectares (42,000 acres) of salt marshes may sequester enough CO2 to offset emissions from 85,000 vehicles per year and store between 1.4 million and 2.1 million metric tons of carbon.[268]

A study of sequestration in New England salt marshes showed that a slightly smaller salt marsh area of over 14,000 hectares (35,000 acres) sequestered over 15,000 tons of carbon in a year – an amount equivalent to 1.7 million gallons of gasoline emissions which would power an average car around the equator more than 1,600 times. [269] The loss of tidal salt marshes to sea level rise or development releases stored carbon into the estuary where each metric ton of carbon lost becomes 3.67 metric tons of atmospheric CO2 .[270] Some research estimates the global cost of lost tidal marshes due to climate change in the billions of U.S. dollars per year.[271]

Seagrasses are carbon sinks and use CO2 dissolved in seawater to grow, and once the plant completes its lifecycle, carbon accumulates in the sediment.[272] Seagrass carbon sequestration capacity varies among species and even within meadows of the same stock.[273] There are between 70,000 and 230,000 square miles of seagrass meadows globally.[274] These meadows sequester nearly 20 billion metric tons of blue carbon per year globally and account for 15 percent of global blue carbon storage.[275]

Eelgrass is the most prevalent SeaBank seagrass. There are data gaps for U.S. eelgrass carbon sequestration relative to other studied seagrasses so that data collection is an emerging research priority.[276] Seagrass carbon burial rates are highly variable, making it difficult to use extrapolated rates from other areas.[277] Numerous environmental factors influence the high variability in eelgrass sequestration capacity, including plant and sediment characteristics, meadow density, salinity, temperature, wave height, water depth and ocean exposure.[278] Recent research suggests that meadow size, particularly the presence of large and continuous meadows, may elevate carbon sequestration capacity.[279]

A 2018 study of multiple sites in the Pacific and Atlantic Oceans and adjacent seas confirmed huge variability in eelgrass carbon stocks, including the identification of some blue-carbon hotspots and overall values comparable to many other blue-carbon ecosystems and terrestrial forests.[280] The largest eelgrass meadow carbon stock in the Mediterranean Sea stored nearly 352 metric tons of blue carbon per hectare (per 2.5 acres) – 15 times as much carbon per hectare as some other sampled stocks.[281] The Kattegat-Skaggerak region, a sea and strait that connect Scandinavia's North Sea with the Baltic Sea, another hotspot, had characteristics with some similarities to Southeast Alaska in latitude and ocean exposure.[282]

Pacific Northwest researchers similarly identified significant variability and found that eelgrass does not sequester carbon to the same degree as other global seagrasses, likely because of types of sediment occupied, patchy distribution, shallower root systems and subspecies or population physical characteristics.[283] At some Pacific Northwest sites, recent studies of eelgrass carbon stocks found much lower values relative to tropical and subtropical seagrasses.[284] In a subsequent and more expansive study of eelgrass meadows from Oregon to Prince of Wales Island in Southeast Alaska, sampled sites showed similarities to other studied eelgrass systems in the North Pacific and North Atlantic Oceans with lower carbon stocks and accumulation rates compared to other blue carbon and seagrass habitats.[285] Some of the SeaBank sites studied had high organic carbon content values that were close to the global average for all types of seagrass meadows, while others had low values.[286] In general, the Prince of Wales Island sites had higher organic carbon content than Pacific Northwest eelgrass meadows.[287]

Eelgrass meadows.
Photo credit: www.seaweedsofalaska.com.

Green Carbon

Land-use change, including logging and other causes of forest loss, accounts for nearly one-quarter of anthropogenic greenhouse gas emissions.[288] Industrial logging is one of the major drivers of global forest and biodiversity loss, and undermines one of the most cost-effective climate change mitigation strategies – the conservation of green carbon.[289] Globally, forest loss and degradation cause more emissions than the entire transportation network.[290]

Forests contain the largest store of terrestrial carbon, and through their vegetation and soils continuously transfer it to and from the atmosphere. Some of the stored carbon returns to the atmosphere through soil respiration, fires and decomposition.[291] Forests store accumulated carbon in five different pools: aboveground biomass (leaves, trunks, limbs and brush), belowground biomass (roots), deadwood, detritus (fallen leaves and stems) and soils.[292] In general, forests store over 50 percent of the carbon in soils and over 25 percent in aboveground biomass.[293]

U.S. forests are a net carbon sink that offsets 12 percent of the greenhouse gas emissions released from the U.S. into the atmosphere each year.[294] Whether a forest is a sink or a source depends on the degree of disturbances such as logging or wildfires.[295] Cutting down old-growth forests releases one-half of the forest carbon as CO2 into the atmosphere, and losses can continue for years as logs and snags left after harvest decompose.[296] It takes centuries for regrowing trees to compensate for these losses.[297] Logging is the primary cause of CO2 emissions from U.S. forests, releasing over 700 million tons of CO2 into the atmosphere – equivalent to burning more than 3.7 billion pounds of coal.[298] Because of the sequestration capacity of forests and the impacts of logging, reducing emissions from forest degradation is as urgent as halting fossil fuel use.[299]

SeaBank forests are the northernmost part of the Pacific Coastal Temperate Rainforest, which extends north from the coastal Redwoods in California and comprises one-third of the world's entire temperate rainforest biome.[300] The Pacific Coast Temperate Rainforest is one of the planet's top forests for carbon storage.[301] The SeaBank forest and adjacent Great Bear Rainforest in British Columbia are two of just four remaining relatively intact temperate rainforests in the world and are globally significant and irreplaceable for their carbon stores and biodiversity.[302] The carbon sequestration potential of these forests is less than optimal because ongoing logging of old-growth and maturing forests offsets sequestration by returning stored carbon to the atmosphere.[303]

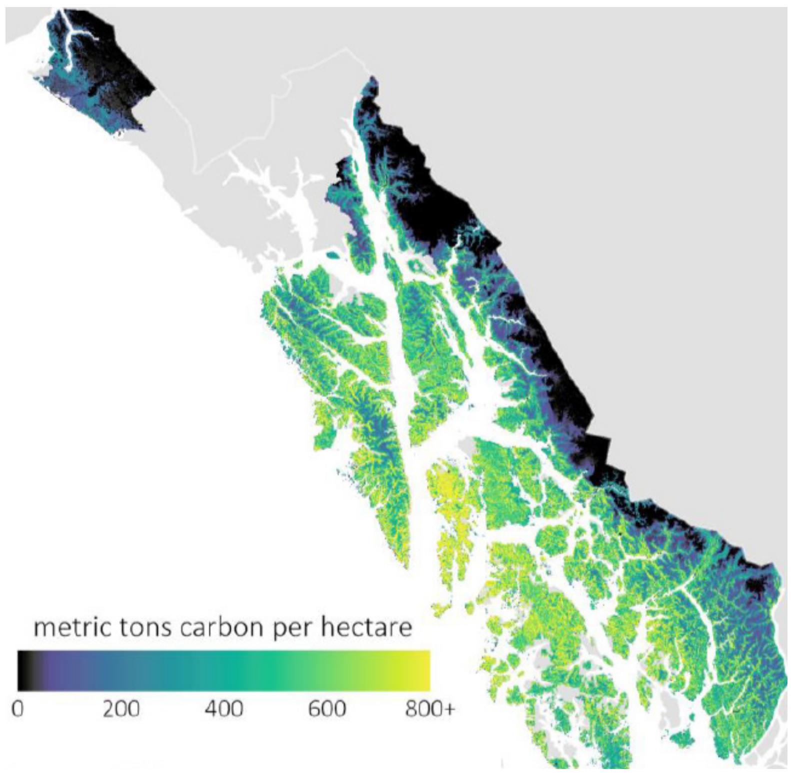


Figure 3: Some of Southeast Alaska's forests store over 800 metric tons of carbon per hectare (2.5 acres). Credit: DellaSala, D.A., Gorelik, S.R. and Walker, W.S., 2022. The Tongass National Forest, Southeast Alaska, USA: A Natural Climate Solution of Global Significance. *Land, 11*(5), p. 717.

SeaBank's Tongass National Forest is particularly invaluable, with over 9 million forested acres and the most remaining old-growth forest of any national forest with about 5 million acres left.[304] Its live trees remove 2,800 pounds of atmospheric CO2 per acre per year.[305] Its carbon stores 20 percent of total carbon for the entire national forest system and more than any other U.S. national forest, are irreplaceable as a carbon sink.[306] Total live and dead tree carbon-storage capacity is roughly twice as high as other U.S. forests.[307] The aboveground carbon mass alone of more than 70 tons per acre stored in trees, snags and logs in the Tongass National Forest is "huge" – an estimated 650 million tons in aboveground biomass (live trees, snags and logs) – equivalent to 2.4 billion tons of CO2.[308] The total forest carbon stock in aboveground biomass and soils in the Tongass National Forest alone is 2.7 billion metric tons.[309]

SeaBank's old-growth forests are a primary driver of the carbon storage capacity, continuing to accrue biomass and carbon at high rates. [310] Trees accumulate carbon continuously so that the largest, oldest trees and oldest forests store a disproportionate amount of carbon over time. [311] The largest 1 percent of trees may store up to one-half of the stand-level carbon. [312] Intact SeaBank forests store the most carbon because of a high percentage of old-growth and stable-carbon storage in soils, and annually accrue 1 million metric tons of biomass.[313] The high biodiversity of SeaBank old-growth forests also increases carbon sequestration capacity.[314]

The Tongass National Forest is the only national forest with substantial amounts of old-growth logging in recent decades.[315] In areas managed for timber, logging along with some natural mortality has reduced net sequestration gains to near zero in aboveground biomass because of the substantial amount of CO2 returned to the atmosphere.[316] Researchers estimate that logging in the Tongass National Forest from 1909 through 2021 caused over 69 million metric tons of CO2 emissions.[317] The social cost of this carbon loss could exceed $5 billion using the recent U.S. estimated social cost at the recommended discount rate of $76 per ton.[318] Recent research indicates the social cost of carbon emissions may be much higher, with median costs exceeding $400 per ton.[319]

Past logging has created roughly 450,000 acres of previously clearcut forests that are now regenerating.[320] The Forest Service plans to clearcut significant portions of these recovering forests.[321] Many of these forests are "middle-aged" – between 50 and 100 years old.[322] These forests sequester carbon quickly and are "carbon hotspots."[323] There is also a significant number of stands that are 30 to 50 years old and approaching ages where they could similarly contribute to net increases in live tree carbon.[324]


Tongass National Forest old-growth trees are champions of carbon sequestration. Photo credit: Colin Arisman.

There is wide recognition that preserving these forests would increase sequestration rates by avoiding the simultaneous CO2 emissions caused by logging and loss of the future carbon storage capacity.[325] Emphasis on proforestation is increasing, as a cost-effective strategy for mitigating climate change.[326] Proforestation allows maturing trees that are already rapidly sequestering carbon to fully mature into natural forests of diverse species, maximizing their potential as carbon sinks.[327]

Proforestation would generate rapid, additional carbon sequestration and significantly help offset CO2 emissions in the U.S.[328]

The amount of carbon sequestered by Alaska ecosystems could increase over the 21st century, primarily because of SeaBank forests.[329] The amount of future logging will determine the extent to which the Tongass National Forest and privately owned forests in the region will continue to sequester carbon – or become a potentially large source of emissions.[330]

The amount of future logging is uncertain, and federal forest policies frequently flip-flop.[331] In 2021, the U.S. Department of Agriculture reversed a decision by a previous administration and initiated a process to reinstate protections for roadless areas and add new protections for old-growth forests, in large part because of the importance of these forests to climate change mitigation and biodiversity.[332] Although the Forest Service has been unable to attain planned logging levels in recent years, annual forest loss continues, ranging from 3,000 to 5,000 acres over the past decade.[333] Alaska's Division of Forestry and other state entities and corporate landowners removed large amounts of old-growth forest during the 20th century – over 400,000 acres in Southeast Alaska – and have been responsible for most of the logging in the 21st century.[334] Nearly one-half of that logging occurs on formerly public lands transferred from the Forest Service to state or private entities through Congressionally-approved land exchanges.[335]

There is potential to double the volume and increase the speed of forest carbon sequestration by allowing maturing forests such as SeaBank's second-growth forests to continue growing over the next few decades, a period in which the worldwide need to maximize carbon storage is crucial.[336] The amount of accumulated forest carbon in Alaska coastal forests would be much higher under policies that maintain existing intact forests and allow maturing forests to grow.[337] Under a no-logging scenario, forest carbon stock would increase by 27 percent – from just over 1 billion metric tons to 1.3 billion metric tons.[338] The no-logging scenario would help meet national climate mitigation goals – U.S. forests currently remove enough atmospheric CO2 each year to reduce national annual net emissions by 11 percent.[339] Existing older and maturing second growth forests in the U.S. – most of them publicly-owned – could sequester 120 gigatons of carbon by 2100, or offset 12 years of global fossil carbon emissions.[340]

Conserving Carbon Sinks is "No Regrets" Climate Mitigation

Conserving coastal blue-carbon and terrestrial green-carbon ecosystems is a "no regrets" mitigation policy.[341] Tidewater wetlands provide numerous ancillary ecosystem services – benefits to biodiversity, storm protection and water purification in coastal areas and fisheries.[342] Fishery production value alone is roughly $1,000 per hectare (2.5 acres).[343] Because of the multiple ecosystem services provided by SeaBank's tidewater wetlands, the potential for climate mitigation by seagrass meadows and salt marshes that may be blue-carbon hotspots and avoiding the CO2 emissions resulting from degradation, it is important to maintain SeaBank estuaries.[344]

Conserving high-biodiversity forests – both abundant, large old-growth trees and trees that can soon reach large diameters – for their value as carbon reservoirs is by far one of the most cost-effective options for climate mitigation in part because of the high value of intact forests for the other ecosystem services they provide. These services include biodiversity, recreation, fisheries and enhanced resilience in a changing climate.[345] Studies of the Pacific Northwest's old-growth forests have found that maximum air temperatures in old-growth stands (compared to logged areas) were as much as 2.5° C lower in spring and summer.[346] Intact forests protect against extreme weather impacts by reducing flood and landslide risks.[347] Forests also regulate and purify water and the air, and as "natural air conditioners" act as a climate buffer that stabilizes microclimates and can mitigate the damage of heatwaves to aquatic life.[348] Other benefits include sustaining biodiversity, opportunities for low-impact recreation and scenic beauty.[349]

Fisheries Resources

Salmon

Photo credit: nfwf.org

Among SeaBank's most important annual dividends are productive commercial, sport and subsistence salmon fisheries. Salmon also feed multiple mammal and avian species and are ecosystem engineers, bringing energy and nutrients to freshwater and riparian ecosystems.[350] These dividends depend on the quality and abundance of physical assets: nearly 15,000 miles of anadromous or potentially anadromous salmon streams and rivers and 123,000 acres of lakes.[351] Approximately 5,500 individual streams and tributaries support salmon with varying levels of productivity.[352] Transboundary rivers, the Alexander Archipelago island ecosystem, and the northern outer coast from Cape Spencer to Cape Suckling are the three broad and distinct areas that produce salmon. Their range of habitats normally buffers against variability in marine and freshwater conditions.[353]

Salmon rely on both marine and freshwater environments.[354] Spawning and incubation occur in freshwater streams.[355] Juvenile fish then grow in the estuaries before migrating to the ocean to feed and mature before returning to natal streams to reproduce. Salmon in the ocean follow a general migratory pattern, seeking large areas with favorable environmental and food conditions, and remaining there as long as favorable conditions persist.[356] Returning salmon use the planet's magnetic field and characteristics of river runoff water to navigate back to the mouth of their natal stream.[357]

Most SeaBank watersheds produce multiple salmon species. Each species utilizes available habitat in different ways and at different times. Pink and chum rear in the marine environment while coho, Chinook and sockeye rear in lakes or rivers.[358] Pink and chum salmon spawn first, beginning in early July.[359] Adult coho return to the outer coast during the summer and spawn throughout the fall.[360] Sockeye and Chinook return to spawn in late spring or early summer.[361]

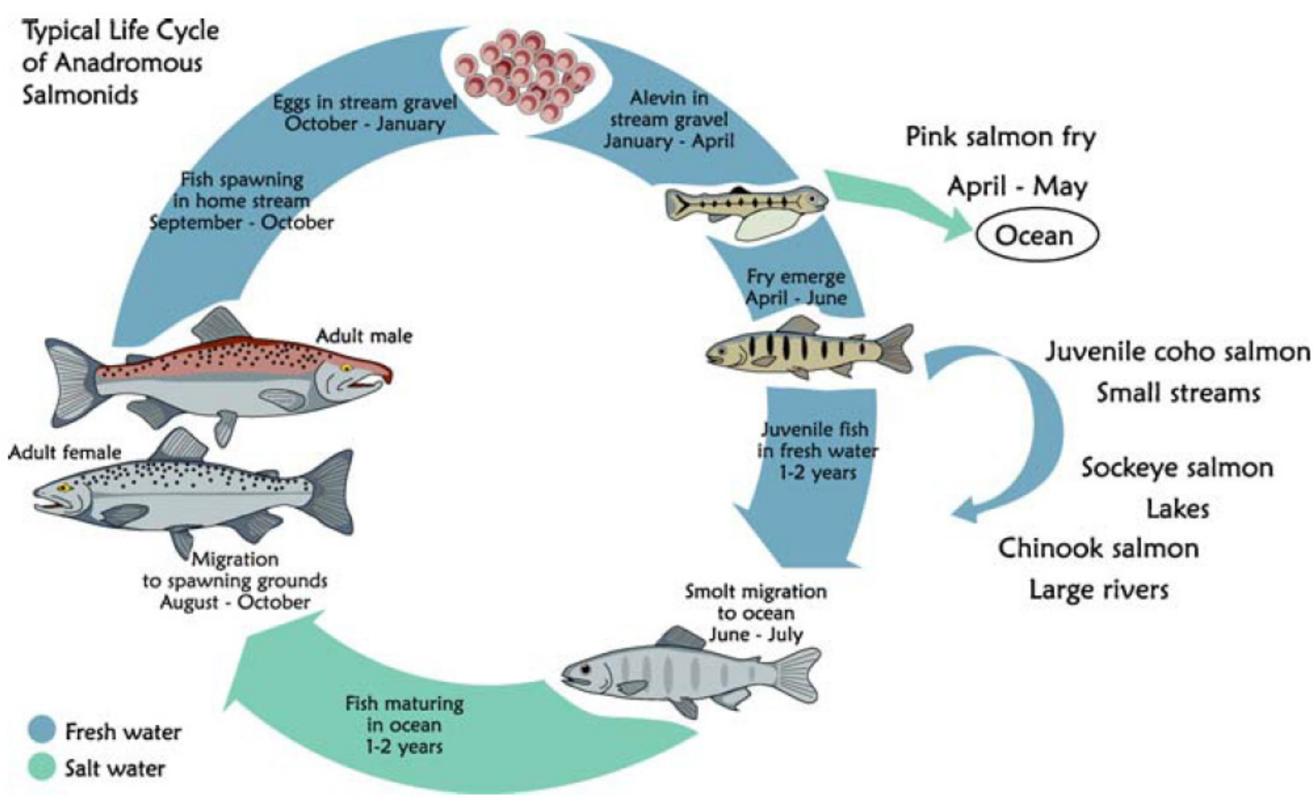


Figure 4: Credit: Bryant, M.D., 2009. Global climate change and potential effects on Pacific salmonids in freshwater ecosystems of Alaska. *Climate Change, 95*, p. 171.

The region's major mainland rivers – the Alsek, Chilkat, Stikine, Taku and Unuk – produce all five salmon species, and run sizes (including escapement and harvests) can exceed over 1 million fish per year.[362] Some of the most economically-valuable salmon species – coho and sockeye salmon – comprise the largest numbers of fish spawning in these rivers.[363] The two most prevalent species spawning in Tongass National Forest island ecosystem are coho and pink salmon.[364] Overall, the Tongass National Forest is the breeding source of 95 percent or more of Southeast Alaska's pink salmon harvest and roughly two-thirds of the coho harvest.[365] Alaska salmon fishery managers use escapement goals to maintain salmon productivity.[366] Escapement is the estimated number of salmon that return to spawn; escapement goals set the number of spawners needed to maintain long-term productivity.

<u>Chinook salmon</u> *(Oncorhynchus tshawytscha)* – Chinook salmon, Alaska's state fish, is 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 coastwide mixed stocks that spawn in Pacific Northwest rivers, mainland transboundary rivers shared by Alaska and British Columbia or are hatchery-origin fish produced in Southeast Alaska or elsewhere in the Pacific Northwest.[367]

Pacific coast Chinooks historically lived between 3 and 7 years, but now there are fewer older fish.[368] Juveniles spend one to two years in fresh water before entering the marine environment and migrating north along the Pacific Coast where the fish spend between one and five years feeding and growing in the marine environment.[369] There has been a long-term and consistent decline in the average size of mature, wild Chinook over the past four decades.[370] The changes are most notable in Alaska, with recent studies estimating size declines of roughly 10 percent.[371] Environmental changes caused by a warming climate and high grading of large fish by a rapidly growing orca population are common hypotheses.[372] Scientific studies show that interactions with hatcheries are not a likely cause of the decline.[373]

One known cause of the size decline is a major change in age composition over the 21st century.[374] There are fewer older and larger fish in the mix, particularly fish that spend four or five years at sea.[375] Overall, Chinook are spending less time in the marine environment, and returning to spawn at younger ages.[376] The loss of older and larger fish is a population viability concern due to the higher fitness – and hence spawning success – of older, larger fish.[377]

Mainland transboundary river systems and their tributaries provide habitat for most Chinook stocks that spawn and rear in the region.[378] Most juvenile Chinook in the region rear in fresh water for at least a year before spending three or four years maturing in the marine environment, and then return to spawn in the late spring.[379] Some stocks are "outside"-rearing (spending most of their marine

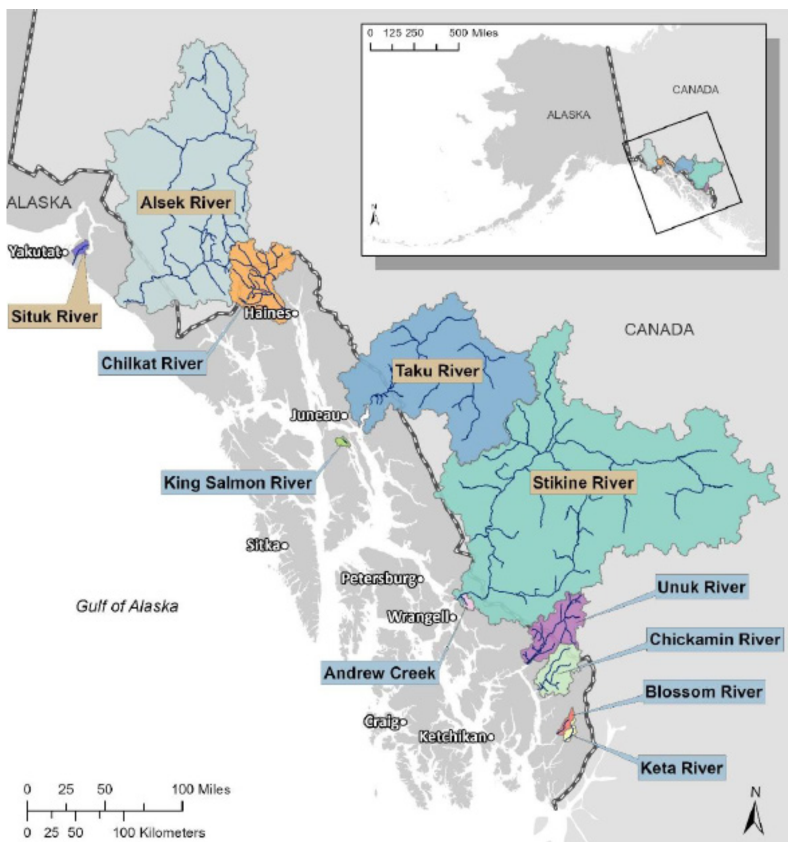


Figure 5: Southeast Alaska wild Chinook stocks. Credit: Nichols, J., S. Heinl & A. Piston, 2022. Salmon stock status and escapement goals in Southeast and Yakutat. PowerPoint prepared for the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Sport Fish and Commercial Fisheries.

lifecycle in the Gulf of Alaska and Bering Sea) while other stocks rear in nearshore marine waters.[380]

Eleven stocks account for 90 percent of Southeast Alaska's wild Chinook populations.[381] The Taku and Stikine Rivers support by far the largest stocks overall.[382] The Chilkat river near Haines, Alsek and Situk rivers near Yakutat and Chikamin and Unuk rivers near Ketchikan support other major stocks.[383] A deep concern is recent low escapements (the numbers of salmon returning to freshwater habitat to spawn) across these 11 systems. Chinook runs have failed to meet escapement goals roughly one-half the time over the last decade, causing the designation of seven stocks as "stocks of management concern" over the past four years: the Chilkat, King Salmon, Unuk, Taku, Stikine, Andrews Creek and Chickamin.[384]

Stikine and Taku Chinooks spawn mostly in Canada and historically supported multiple fisheries in Alaska and British Columbia.[385] Both stocks failed to meet escapement goals from 2016 to 2021, and in 2020 record-low returns were projected for 2022 (with outcomes unknown at the time of this report).[386] Chilkat River and Unuk River returns remain listed as stocks of concern but have achieved the lower end of escapement goals multiple times between 2018 and 2021.[387] The Alaska Department of Fish and Game has closed most inside waters to all spring salmon fishing in order to protect Chinook migrating to their Southeast Alaska freshwater systems.[388]

<u>Sockeye salmon</u> *(Oncorhynchus nerka)* can utilize various freshwater habitat types but most of Southeast Alaska's roughly 200 stocks spawn in systems that include lakes.[389] Juveniles typically spend one year rearing in lakes.[390] Juveniles typically leave freshwater systems in the late spring and spend two to three years in the marine environment before returning to spawn.[391] Sockeye salmon are spending less time in the marine environment, resulting in shrinking sizes. [392]

There are 200 different systems that produce sockeye in Southeast Alaska.[393] The largest sockeye systems are mostly on the mainland – in the Alsek and Situk Rivers near Yakutat, the Chilkat River and Chilkoot Lake near Haines and the Taku and Stikine Rivers near Wrangell.[394] These larger systems support major drift gillnet fisheries and significant subsistence harvests.[395] Taku River sockeye populations also fluctuate considerably from year to year, with recent run sizes ranging from 120,000 to 280,000 fish.[396] Total run sizes (including harvest and escapement) of the Taku and Stikine Rivers can range between 300,000 and 400,000 fish.[397] Prince of

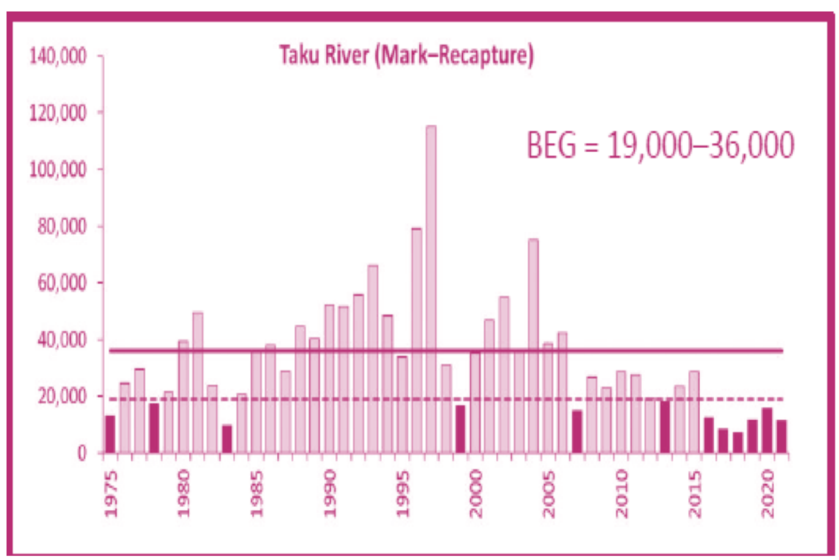


Figure 6: Taku River chinook returns failed to meet the biological escapement goal range of 19-36,000 fish since 2016. Nichols, J., S. Heinl & A. Piston, 2022. Salmon stock status and escapement goals in Southeast and Yakutat. PowerPoint prepared for the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Sport Fish and Commercial Fisheries.

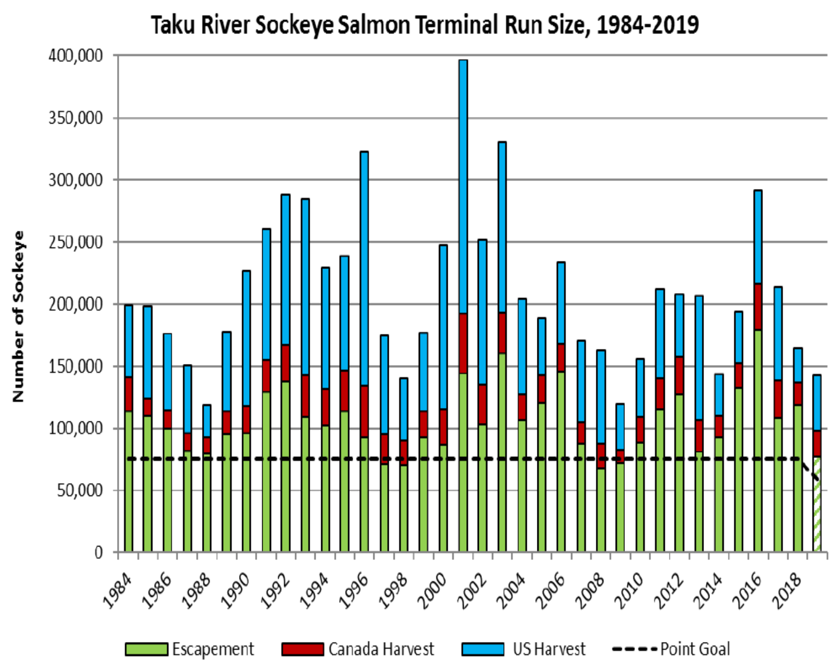


Figure 7: Kowalske, T., 2019. District 6 and 8 Gillnet Fisheries 2019 post-season report. Alaska Department of Fish and Game Gillnet Task Force Meeting, December 2019.

Wales Island provides the most sockeye habitat of any island ecosystem.[398]

There are two sockeye populations designated as stocks of concern. Returns to McDonald Lake near Ketchikan have been below escapement goals for six of the last seven years.[399] McDonald Lake was the only exceptionally large system remaining in southern Southeast Alaska.[400] In 2020, the Alaska Department of Fish and Game designated Klusksu River (a tributary of the Alsek near Yakutat) as a stock of concern.[401]

Average harvests by gillnetters targeting SeaBank salmon typically exceeded 400,000 fish over the past decade.[402] Through 2019, most northern Southeast Alaska sockeye systems were productive, particularly the Chilkat system.[403] In contrast, since 2018, southern Southeast Alaska sockeye production has been poor.[404] Returns were poor in 2020, with gillnetters who target SeaBank salmon harvesting just over 100,000 sockeye.[405] Over one-half of the systems failed escapement goals.[406]

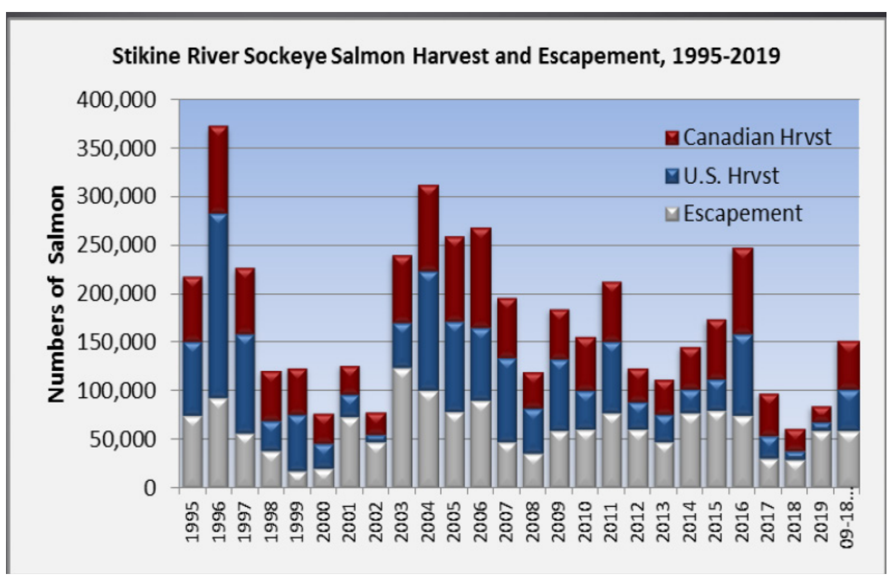


Figure 8: Credit: Forbes, S. 2019. District 11 Gillnet Fishery Taku Inlet, Stephens Passage and Port Snettisham 2019 management summary. Alaska Department of Fish and Game Gillnet Task Force Meeting, December 2019.

Pink salmon *(Oncorhynchus gorbuscha)* are the most abundant of the five salmon species and also the smallest in size.[407] They are also the least reliant on freshwater habitat and migrate to sea almost immediately after emergence.[408] Nearly all the pink salmon in Southeast Alaska are wild. There are over 6,000 pink salmon populations that utilize the lower reaches of over 3,000 streams for spawning.[409] Because pink salmon have a fixed, 2-year lifecycle they also comprise reproductively-isolated and distinct odd- and even-year runs.[410] Even-year cycles of pink salmon runs have historically been much lower than odd-year cycles, and odd-year productivity is spread more uniformly across the region.[411] Pink salmon marine survival estimates are based on long-term data from Auke Creek near Juneau.[412] On average just over 11 percent survive to return, but this can range from just over 1 percent to nearly 50 percent.[413] Factors that influence marine survival include migration timing, fishery effort and timing, predation, growth rates, genetic variation and stream conditions.[414] Significant warming trends in Auke Creek are causing earlier out-migrations, with juveniles entering the marine environment earlier and adults returning earlier to spawn.[415]

Table 3.1 Gillnet Sockeye Declines: Average 2010-2019 vs. 2018-2020

	Tree Point	Stikine	Prince of Wales	Taku Snettisham	Lynn Canal
2010-19	46,780	73,719	26,648	132,559	142,995
2018	20,800	25,203	5,731	92,889	81,688
2019	16,209	23,844	6,591	105,026	241,533
2020	9,596	11,314	2,781	28,233	50,220

Northern Southeast Alaska runs declined the most from 2016 to 2020.[416]

Pink salmon returns have declined significantly throughout the region over the past decade. For example, the 2016 return of 18 million fish (a federally-declared fishery disaster) parented a 2018 run in which only 8 million fish were harvested – the lowest since 1976.[417] The poor 2018 parent year and the resulting near record-low juvenile pink salmon abundance estimates in 2019 led to expectations of another poor return in 2020, confirmed with another harvest of only 8 million fish.[418] Drought conditions and marine heatwaves are likely causes of the population decline.[419] Further, the 2019 pink salmon harvest of 21.1 million fish was the lowest odd-year harvest in over three decades.[420]

Northern and southern Southeast Alaska pink salmon populations have distinctly different life histories, using different migratory pathways, and they do not intermingle.[421] For the even-year runs, the southern Southeast Alaska area provides most of the region's pink salmon harvest – in some years as much as 90 percent of the harvest, with regulatory districts near Prince of Wales Island and Ketchikan being top producers.[422] Prince of Wales Island has the most pink salmon spawning habitat in the region.[423]

In this subregion's inside waters, the 2020 harvest of just 1.1 million fish was only 10 percent of the recent average.[424] Except in 2017, escapements to these inside waters have been well below targets for roughly three-fourths of the 21 pink salmon stocks surveyed each year.[425] Harvests fluctuated wildly, as shown in the table below.

The 2020 juvenile pink salmon abundance estimates improved over recent years, implying better freshwater and early marine survival.[426] Out-migrating juvenile pinks encountered more moderate sea surface temperatures than the much warmer conditions of 2014 through 2019 (except 2017) in the Gulf of Alaska.[427] The 2021 regionwide harvest of 48.5 million pink salmon, from 2019 juveniles, vastly exceeded recent harvests.[428]

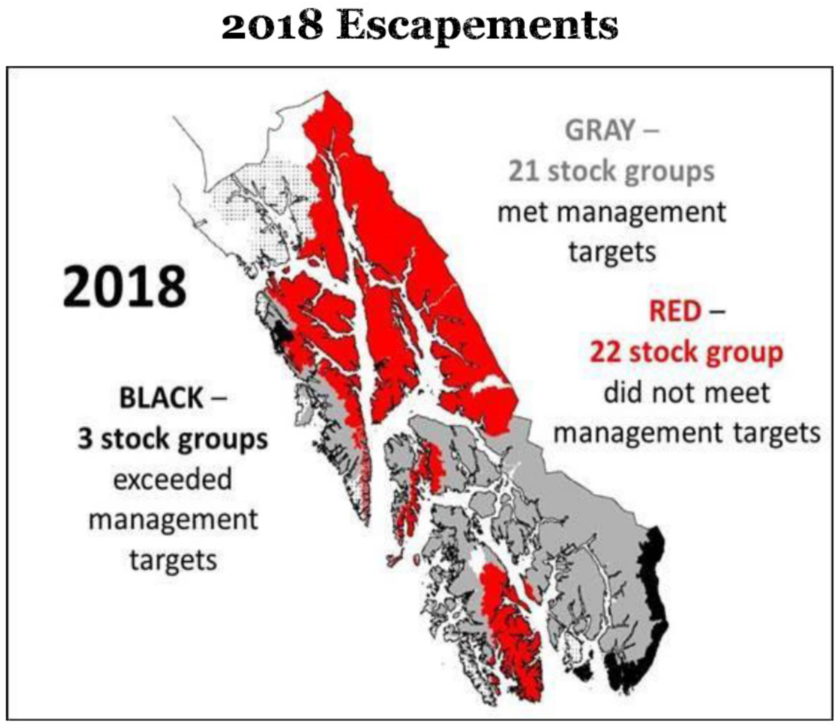


Figure 9: Credit: Salomone, P., 2019. Petersburg-Wrangell management area 2019 season summary and 2020 outlook. Alaska Department of Fish and Game Purse Seine Task Force Meeting, December 2019.

<u>Coho salmon</u> *(Oncorhynchus kisutch)* spawn and rear in a variety of freshwater ecosystems for at least a year before migrating to the marine environment.[429] The availability of rearing habitat in small streams, ponds, lakes and off-channel areas is a key factor in the viability of coho populations, which are highly vulnerable to changes in freshwater habitat.[430] 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.[431] Like many Alaska salmon species, coho sizes are diminishing and they are shortening their marine lifecycle to spawn at younger ages. [432]

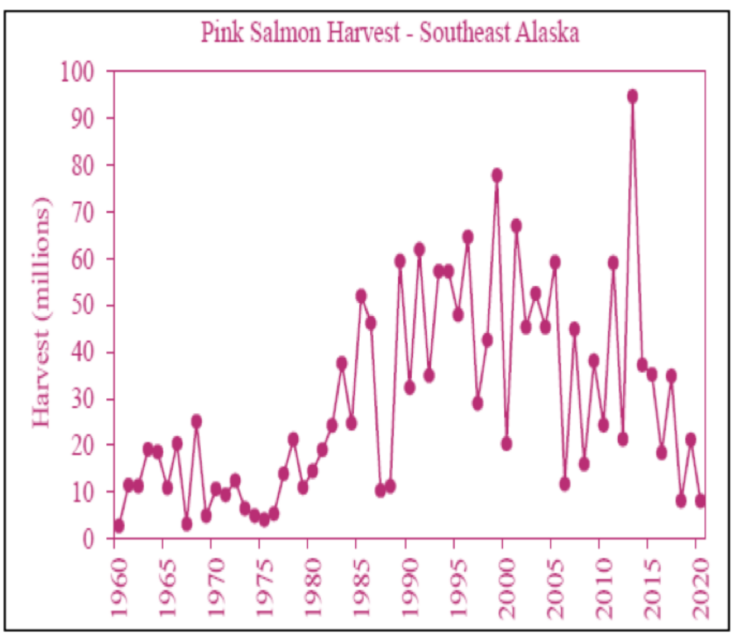


Figure 10. Credit: Thynes, T., J.A. Bednarski, S.K. Conrad, A.W. Dupuis, D.K. Harris, B.L. Meredith, A.W. Piston, P.G. Salomone & N.L. Zeiser, 2021. Annual management report of the 2020 Southeast Alaska commercial purse seine and drift gillnet fisheries. Alaska Department of Fish and Game, Fishery Management Report No. 21-30.

Southeast Alaska coho emanate from 4,000 streams, large transboundary mainland rivers, and 13 hatcheries. [433] Mainland rivers provide over 3,000 miles of coho freshwater habitat.[434] Most of the 2,300 stocks are small populations of less than 1,000 spawners that utilize small- to medium- stream systems; they support 60 percent of the annual return.[435] The region's most abundant stocks are from larger mainland systems such as the Chilkat, Stikine and Taku Rivers and the Tsiu-Tsivat system, which provide over 3,000 miles of coho freshwater habitat.[436] The Taku River, for example, had a peak run of 250,000 coho in 2002.[437] North Prince of Wales Island has 1,904 stream miles of coho habitat, making it the most important island ecosystem for coho, followed by eastern Chichagof Island and Mitkof and Kupreanof Islands.[438]

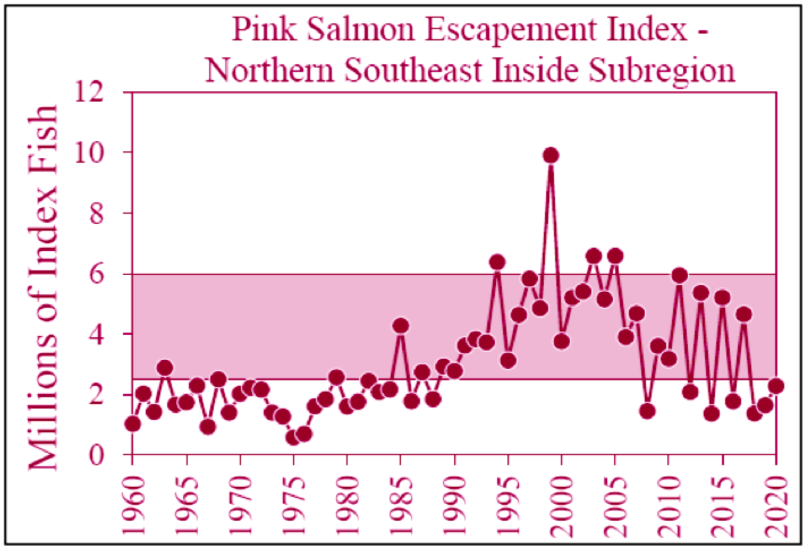


Figure 11: Pink salmon escapement from 1960 to 2020. Credit: Thynes, T., J.A. Bednarski, S.K. Conrad, A.W. Dupuis, D.K. Harris, B.L. Meredith, A.W. Piston, P.G. Salomone & N.L. Zeiser, 2021. Annual management report of the 2020 Southeast Alaska commercial purse seine and drift gillnet fisheries. Alaska Department of Fish and Game, Fishery Management Report No. 21-30.

Harvests declined considerably in recent years. In 2020, four of the eight Southeast Alaska indicator coho salmon systems failed to meet escapement goals – the first time that more than three systems failed.[439] Other stocks were at the lower end of escapement goal ranges.[440]

Alaska salmon fishery researchers have collected data on marine survival of Auke Creek coho since 1980.[441] Survival rates vary from 5 percent to nearly 50 percent, with an average survival rate of 21.7 percent.[442] Key factors include migration timing, juvenile growth rates and marine environmental productivity – both in nearshore areas and in the ocean.[443] The 2020 marine survival rate of just over 8 percent was the fourth lowest on record, compounding an overall survival rate of under 10 percent over the last five years.[444] Juvenile coho leave coastal areas in late fall and spend winter in offshore areas of the Pacific. Many different populations join to form large schools.[445] There is limited information about their winter ecology, although they do not begin to grow rapidly until the end of March.[446]

Wild coho harvested in the troll fishery.
Photo credit: Alaska Sustainable Fisheries Trust.

Coho gain most their weight during their final summer at sea – rapid growth depends on the abundance of energy-rich prey, particularly epipelagic (upper open-ocean) squid.[447] Year-to-year variation in coho salmon weights is normally driven by competition with pink salmon and water temperatures, with coho growing the largest during warmer years that are favorable for cephalopod (squid and cuttlefish) productivity combined with lower pink salmon abundance.[448]

Because of the influence of pink salmon on coho salmon prey, coho runs in even years are typically much larger, due to lower even-year pink salmon abundance, with dressed weight averaging 6.5 pounds in odd years and 7 pounds in even years.[449] But for 2020, although the Alaska Department of Fish and Game expected a very large 7.8-pound average weight (based on warm conditions and poor pink abundance), the average weight fell to a new record-low weight of 5.8 pounds. That is 1.2 pounds below the long-term, even-year average.[450] The 2021 average weight of 5.3 pounds was also 1.2 pounds below the long-term, odd-year average.[451] This dramatic loss suggests a decline in availability of prey (offshore populations of epipelagic squid) caused either by changes in Gulf of Alaska conditions, or heightened competition for prey by highly abundant Asian pink salmon stocks.[452]

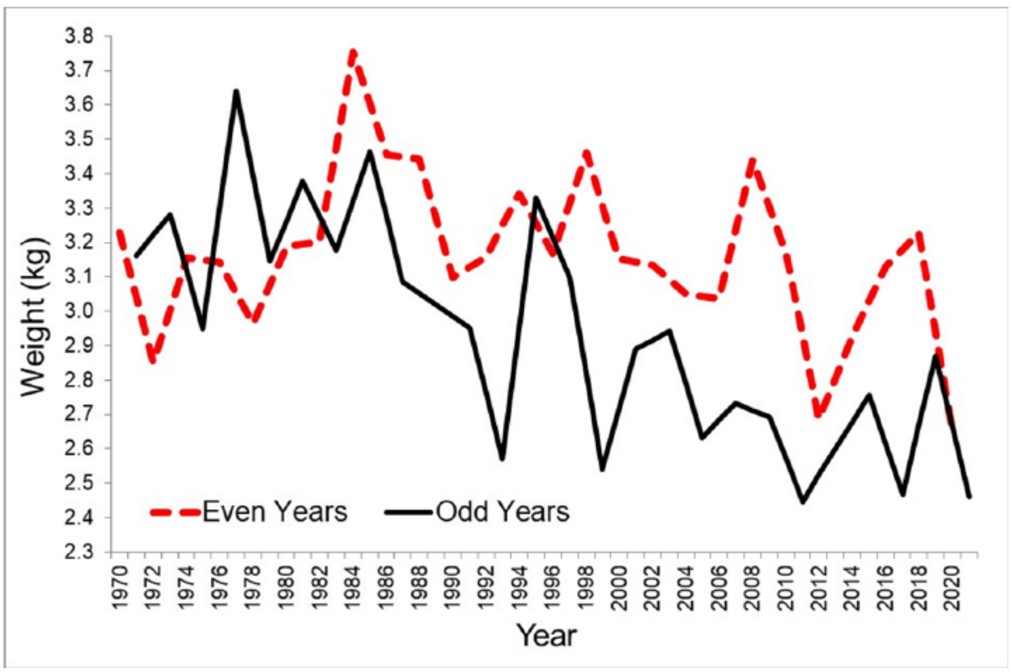


Figure 12: Credit: Shaul, L.D., G.T. Ruggerone & J.T. Priest, 2021. Dressed weight of troll caught salmon in Southeast Alaska in even and odd years. Maturing coho salmon weight as an indicator of offshore prey status in the Gulf of Alaska. Ferriss, B.E. and Zador, S. [Eds.], Ecosystem Status Report 2021: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Chum Salmon *(Oncorhynchus keta)* – also known as dog salmon, are the second largest salmon in Alaska, averaging over 6.5 pounds in 2021.[453] Chum are also the most widely-distributed of all the Pacific salmon.[454] Chum leave fresh water shortly after emergence and then spend three to three and a half years in the ocean.[455] They rely heavily on estuaries for growth and protection during their first two months in the marine environment.[456] Wild chum utilize over 1,000 streams and rivers in Southeast Alaska and are generally divided into two runs based on migration timing – summer-run fish spawn between mid-July and mid-August while fall-run fish spawn in September or later.[457]

Over the past several decades, hatcheries have produced over 80 percent of the chum harvested in Southeast Alaska – on average 8.4 million out of the 10.2 million.[458] In 2020, chum returns throughout Alaska were the poorest in three decades.[459] Most of those chum entered the ocean during the end of the 2014-2016 marine heatwave.[460] Southeast Alaska hatchery managers believe warmer temperatures caused very low marine survival rates that reduced returns.[461]

Herring

Herring *(Clupea pallasii)* – Pacific herring are a major schooling forage fish. Herring reach sexual maturity at three to five years of age and then spawn every year.[462] Southeast Alaska herring typically live for eight years.[463] Spawning occurs in the spring in shallow, vegetated areas in intertidal and subtidal zones.[464] The eggs are adhesive and attach to vegetation or the bottom substrate.[465] Eggs hatch about two weeks after fertilization and the young larvae drift and swim in the ocean currents.[466] Once the larvae undergo metamorphosis into their juvenile stage, they rear in sheltered bays and inlets.[467] In the fall, the schools of juveniles move to deeper water, where they spend the next two to three years.[468] Herring are an important part of the marine food web, gaining nutrients from plankton and serving as prey for other fish, sea birds and marine mammals.[469]

Herring populations have fluctuated significantly over time, driven both by larger-scale environmental conditions and overharvest.[470] One threat to Pacific herring is the loss of spawning grounds.[471] Dredging, construction activities, log storage facilities, oil spills and reduced water quality have degraded or destroyed spawning habitat.[472] Climate change may also pose a threat to herring by reducing the availability of their prey: zooplankton and phytoplankton.[473] In addition, the recovery of populations of predator species, such as humpback whales, may impact herring stocks.[474]

There are nine major herring spawning areas historically surveyed by the Alaska Department of Fish and Game.[475] Sitka Sound, Craig and Kah Shakes/Cat Island produce "outside stocks" with greater ocean exposure.[476] Seymour Canal, Hoonah Sound, Hobart Bay/Port Houghton, Tenakee Inlet, Ernest Sound and West Behm Canal produce "inside stocks."[477]

The outer coast herring stocks are larger and more stable than those spawning in inside waters.[478] The herring biomass is now at very high levels for Sitka Sound and Craig stocks but at relatively low or moderate levels for the inside stocks.[479] These herring populations grew from the late 1990s and increased to high levels from 2008 to 2011, then declined until 2019 when a dramatic increase in the Sitka Sound and Craig herring biomasses began.[480] Limited aerial surveys suggest other stocks declined to lower levels after 2011, with some – Hoonah Sound, Seymour Canal and Ernest Sound – at fractions of historical abundance.[481] Inside stocks did not rebound to high levels in 2019, suggesting a significant difference between outside and inside stocks.[482]

The outer coastal stocks around Sitka Sound and Craig typically account for 80 percent of the spawning herring biomass in Southeast Alaska and both populations are growing.[483] The observed spawning biomass in Sitka Sound and Craig doubled between 2018 and 2019.[484]

The growth in the Sitka and Craig herring biomasses coincided with an exceptionally large recruitment event for herring stocks across the Gulf of Alaska that hatched during the tail end of the 2014-2016 marine heatwave.[485] Fishery managers suspect that elevated sea temperatures may have produced marine conditions favorable for increased larval or juvenile survival.[486]

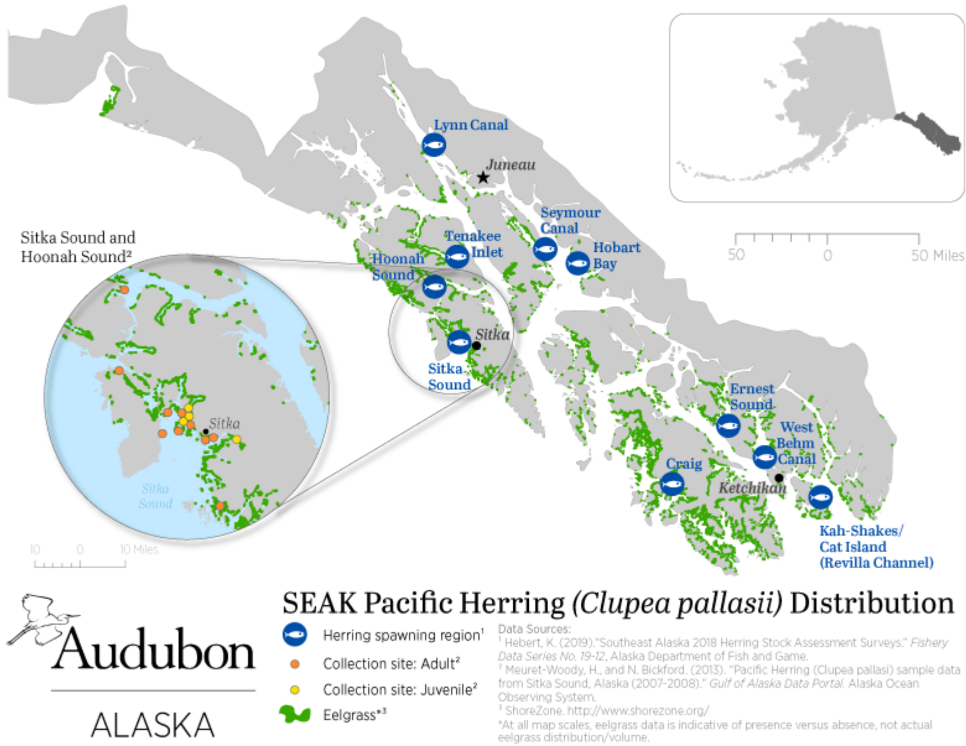


Figure 13: Dawson, N., 2020. Forage Fish and Seabirds Are Critical to Alaska's Future, https://ak.audubon.org/news/forage-fish-and-seabirds-are-critical-alaska%E2%80%99s-future. Audubon Alaska, Anchorage, AK.

As the large 2016 year class continues to mature, there are even larger Sitka Sound and Craig spawning biomasses.[487] In 2019, the estimated Southeast Alaska biomass reached 169,514 tons – 167 percent of mean regional spawning biomass over the past 40 years.[488] The 2020 and 2021 estimated Sitka Sound mature herring biomass peaked at 250,446 tons and fell back to 210,453 tons, respectively.[489] The 2020 estimated egg deposition in Sitka Sound was the highest on record since 1976.[490] The five-year-old cohort now comprises 60 percent of the spawning herring biomass.[491] Twelve percent of the remaining mature herring are older (six to eight years old) and there is a much smaller population of 3- and 4-year-old fish.[492] Fishery managers expect that the 2016 cohort's high outer coast biomass should support marine predators and fisheries for several more years.[493]

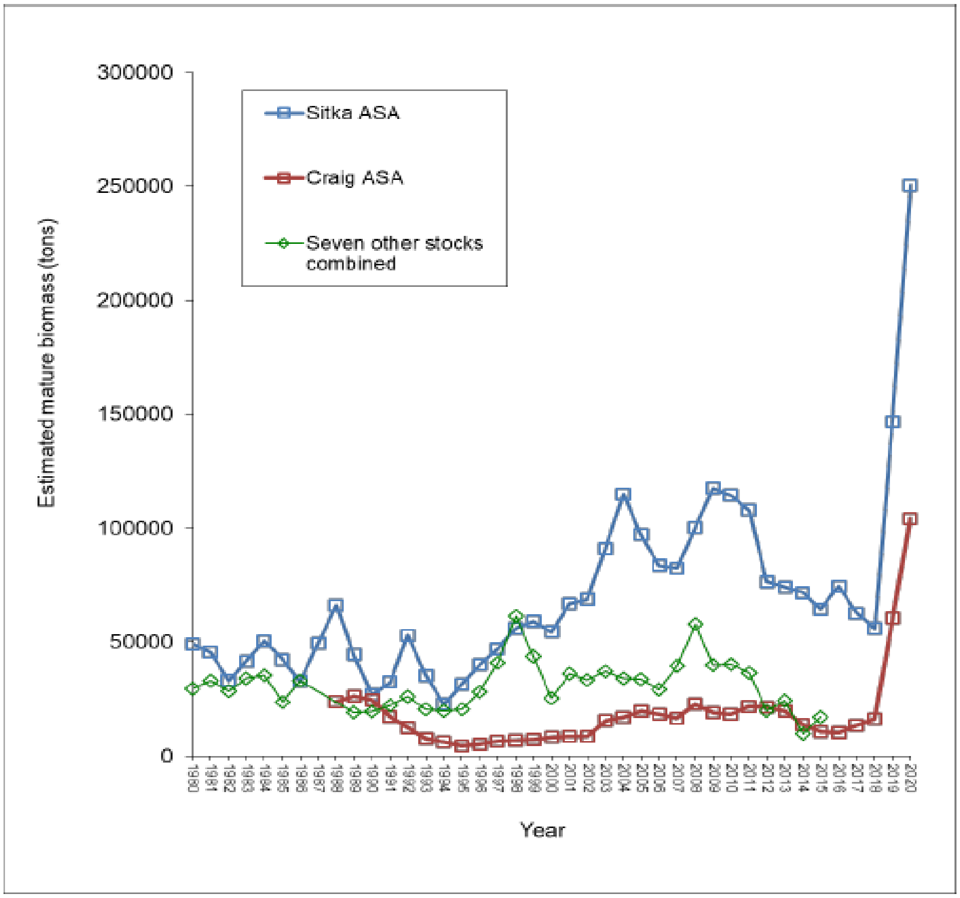


Figure 14: Credit: Hebert, K. & S. Dressel. Southeastern Alaska Herring biomass. Credit: Ferriss, B.E. and Zador, S. 2021. Ecosystem Status Report 2021: Gulf of Alaska, Stock Assessment and Fishery Evaluation Report, North Pacific Fishery Management Council, Anchorage, AK.

Halibut

Pacific halibut *(Hippoglossus stenolepis)* – Halibut are the largest flatfish and live on or near the continental shelf throughout much of the northern Pacific Ocean.[494] Halibut typically live near the bottom over a variety of benthic habitats and sometimes swim up in the water column to feed.[495] They usually inhabit waters between 90 and 900 feet deep, but will occupy depths up to 4,000 feet.[496] Halibut are laterally flat, and swim sideways, with one side facing down and the other facing up.[497] 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.[498]

Halibut are a long-lived species, living up to 55 years.[499] Female halibut grow faster and reach larger sizes than male halibut.[500] The maximum reported size is over 8 feet in length and over 500 pounds. [501] Large females are highly fecund, meaning that they can produce abundant offspring. A 50-pound halibut can produce one-half million eggs and a 250-pound halibut can produce 4 million eggs.[502] Most male halibut are sexually mature by about eight years of age, while one-half of the females are mature by about age 12.[503]

Most halibut spawn between November and March at depths of 300 to 1,500 feet.[504] 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.[505] 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.[506] Halibut tagged in the Bering Sea have migrated as far south as the Oregon coast – a trip of over 2,000 miles.[507] 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.[508] The Gulf of Alaska (International Pacific Halibut Commission [IPHC] Area 3) hosts the largest proportion of the halibut stock.[509] Roughly 55 percent of the population is now in the Gulf of Alaska, with Area 2 (Southeast Alaska to California) and Area 4 (Bering Sea) each hosting roughly 22 percent of the population.[510]

Halibut size-at-age has changed over time.[511] From the 1920s to the 1970s, the average length and weight of halibut of each age increased, and has decreased since then.[512] By the 2000s, 12-year-old halibut were about three-quarters the length and about one-half the weight than in the 1980s.[513] Reasons for the decline are unknown. [514] Currently, individual size-at-age is increasing for young halibut in most areas.[515] Size-at-age changes slowly and likely affects long-term overall yield significantly.[516]

Over the past century, halibut harvests ranged from 34 million to 100 million pounds, averaging 63 million pounds.[517] Over the past five years, average removals, including trawl bycatch, have been 38.5 million pounds.[518] For 2021, total estimated mortality from directed harvests, bycatch and other uses is 37.7 million pounds.[519] 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. [520] Recruitment strengths were also weaker. [521]

The estimated spawning biomass at the end of 2021 was 191 million pounds.[522] The 2005 year class is currently the largest coastwide contributor in numbers of fish.[523] The 2006 to 2010 classes, which comprise much of the harvestable and spawning biomass, were small.[524] The 2012 year class is likely the strongest class since 2005 and its maturity, along with higher catch rates in 2021, has resulted in more optimistic projections for the halibut stock.[525] The size of subsequent year classes is uncertain.[526]

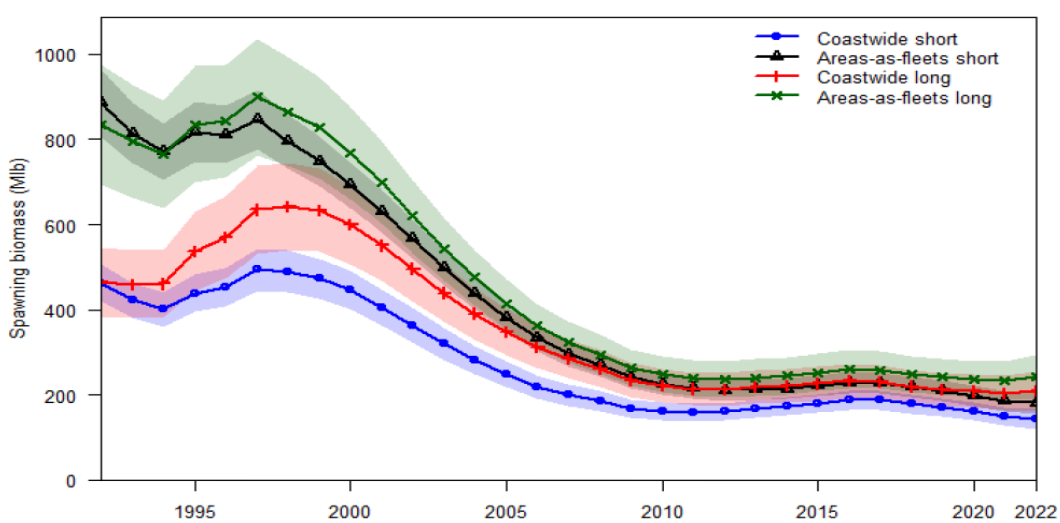


Figure 15: The halibut spawning biomass has steadily declined since the late 1990s but has stabilized at lower levels in recent years. Credit: Stewart, I. & A. Hicks. 2021. Assessment of the Pacific halibut (Hippoglossus stenolepis) stock at the end of 2021. International Pacific Halibut Commission, IPHC-2022-SA-01.

Linkages between environmental conditions and halibut productivity are unclear. Overall halibut abundance 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.[527] IPHC scientists now caution that attempting to correlate PDO with high recruitment may be less useful in future environmental conditions.[528]

Sablefish

Sablefish *(Anoplopoma fimbria)* – Sablefish, also known as black cod, are a groundfish species with a range that spans the North Pacific Coast from California to Alaska.[529] Sablefish are a highly mobile, long-lived fish and one of the deepest-dwelling commercial fish species.[530] Like halibut, sablefish are highly fecund.[531] Sablefish are fast-growing and reach reproductive maturity between five and 10 years old; roughly one-half are mature by age seven.[532] The oldest known sablefish reached 94 years in age.[533] Adults show considerable movement throughout the Bering Sea and Gulf of Alaska, with highest abundance centered in the Gulf of Alaska.[534] Adult sablefish utilize a variety of deep-water benthic habitats, ranging from 600 to 4,800 feet, along the continental slope, in shelf gullies or in fjords.[535] Adults spend most of their lives in depths between 1,000 and 3,000 feet but can go as deep as 6,000 feet.[536]

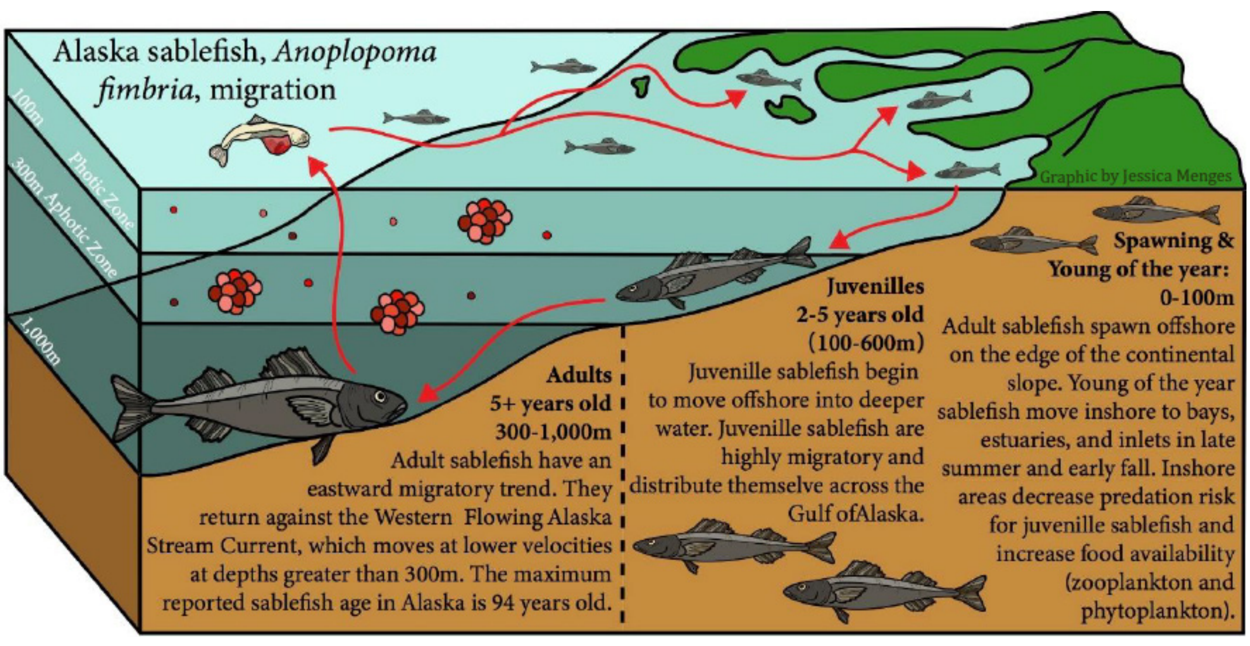


Figure 16: Sablefish lifecycle. Credit: Jessica Menges, Alaska Sustainable Fisheries Trust.

Gulf of Alaska bathymetry and current patterns drive sablefish migration. Spawning occurs in deep water (900 to 1,800 feet) in winter or spring in Alaska.[537] The fertilized eggs develop at depth to larvae and drift in surface waters.[538] 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.[539] These young of the year sablefish feed mostly on small crustaceans like krill and copepods, a type of zooplankton.[540] 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 sablefish during early developmental phases as they grow rapidly in nearshore pelagic habitats, including estuaries such as St. John Baptist Bay near Sitka – the only specific location that juveniles are known to occupy on a regular basis.[541] The young of the year remain in nearshore habitats and shallower waters (less than 300 feet) as prevailing northwest currents carry them along the Gulf of Alaska, eventually depositing them as far west as the Bering Sea.[542] As juveniles grow during this phase they migrate at around age two to deeper waters that are 300 to 1,800 feet in depth.[543] They 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.[544] Older juveniles and adult sablefish feed opportunistically.[545]

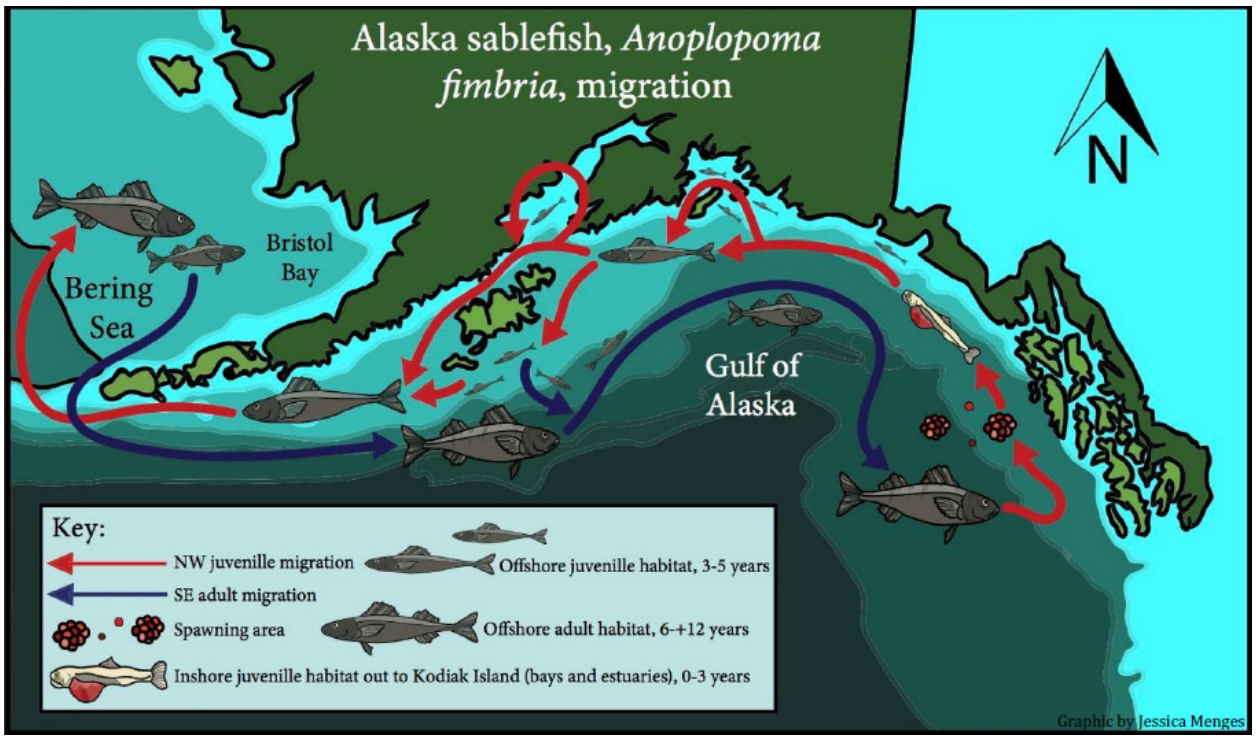


Figure 17: Sablefish migration. Credit: Jessica Menges, Alaska Sustainable Fisheries Trust.

Sablefish abundance has fluctuated over the past half century, with increases and decreases tied to the presence or absence of strong year classes.[546] The 2014, 2016 and 2017 year classes were the largest since 1977.[547] Climate and environmental conditions appear to have the greatest effect on sablefish abundance and recruitment.[548] Some of the largest year classes followed near historic low abundances. Changes in the Pacific Decadal Oscillation, particularly a switch in ocean conditions from cooler sea surface temperatures to above-average temperatures, have triggered large recruitments.[549] The 2014-2016 marine heatwave may have contributed to two recent large year classes by creating over-winter and nearshore conditions favorable for juvenile sablefish.[550] Fisheries scientists initially estimated that the 2014 and 2016 year classes were as much as four to 10 times larger than average. [551]

There is now considerable uncertainty about those estimates. The most recent stock assessment downgraded the original estimates of the 2014 year class population size by 68 percent.[552] It is likely that estimates of the 2016 year class size were also too high.[553] It is unknown whether estimation errors or higher than normal natural mortality caused the later, lower class size estimates. Even so, the 2014 and 2016 year classes respectively comprised an estimated 27 percent and 22 percent of the 2020 spawning biomass.[554] That year, the 2014 year class was about 60 percent mature while the 2016 class was less than 20 percent mature.[555]

The future effect of changing environmental conditions on those year classes is uncertain, particularly the impact of warmer waters on maturing sablefish.[556] Indicators have been poor for ecosystem conditions experienced by adults and juveniles migrating to adult habitat.[557] The body condition of juveniles arriving in adult habitat has been below average since 2014, and poor for the 2014 and 2016 year classes in particular.[558]

Stock assessment scientists project rapid increases in the biomass of spawners, based on maturation of the 2014 and 2016 year classes.[559] The stock may then stabilize, assuming average recruitments after the 2016 year class. One major concern for the stock is a lack of older fish.[560] The mean age of spawners has decreased dramatically since 2017, worsening a preexisting downward trend.[561] Stock assessment scientists recommend caution in harvest rates in order to allow the younger subpopulation to further mature and more fully contribute to the spawning biomass. [562]

Two related populations inhabit Southeast Alaska's inside waters, in Clarence Strait and Chatham Strait, and support state-managed fisheries.[563] Chatham Strait may be a local population, with 90 percent of tagged fish remaining after a year of occupancy, while Clarence Strait fish are more mobile, with 30 percent leaving after a year of occupancy.[564] Both stock abundances have been lower but stable over the past decade.[565]

Rockfish

Rockfish *(Sebastes sp.)* and **lingcod** *(Ophiodon elongatus)* – Rockfish are among the longest-living vertebrates on earth. Many of the oldest fish recorded were caught in Southeast Alaska, including a 205-year-old rougheye, a 157-year-old shortraker, an 118-year-old yelloweye and a 90-year-old quillback.[566] Most rockfish do not start reproducing until they are at least five to seven years old, and some may not reproduce until they are 15 to 20 years old. In general, rockfish associate with complex habitat such as rockpiles and pinnacles, and avoid soft, flat seabed habitats.[567] There is a greater diversity of rockfish species on the outer coast.[568] As juvenile fish grow and mature, they move to adult habitats in deeper water (250 to 900 feet).[569] 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.[570]

Oceanographic factors such as temperature, currents and food availability affect the survival of larval rockfish.[571] 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.[572] Because they are slow-growing, long-lived and mature late, rockfish populations are vulnerable to excessive harvest.[573]

There are 30 species of rockfish landed in Southeast Alaska, divided into three main groups.[574] The demersal shelf rockfish group is a nearshore, bottom-dwelling rockfish species.[575] Demersal shelf rockfish grow slowly, mature late, live long and do not produce large quantities of offspring.[576] They are susceptible to over-exploitation and localized depletions are slow to recover.[577] Yelloweye rockfish and quillbacks are the dominant demersal shelf rockfish species harvested in Southeast Alaska.[578] Both species associate with rocky habitat and have high site fidelity.[579] Yelloweye are one of the larger rockfish and can grow up to three feet in length, and their size increases with depth.[580] Yelloweye rockfish reach reproductive maturity in 18 to 22 years, and are known to live as long as 121 years.[581] Surveys indicate an ongoing 60 percent decrease in the yelloweye biomass since 1994, even with stricter harvest controls and tighter limits for all fisheries.[582] Fishery managers have closed directed sport and commercial fisheries in recent years, and 2021 surveys did show an increase in the yelloweye biomass.[583]

The other rockfish groups are pelagic rockfish (nearshore schooling species, including black rock fish) and slope rockfish (found along continental shelf edges and downslope in deeper water) that include rougheye, shortraker and redbanded and thornyhead rockfish).[584] Rougheye and shortraker are the longest-living rockfish and have a wide distribution, from California to the Bering Sea.[585] They are most abundant on the continental shelf in waters over 1,000 feet in depth.[586]

Lingcod are the largest member of the greenling family and can grow up to five feet long.[587] Females are larger than males.[588] Lingcod mature between three and five years old and have lived up to 36 years in Southeast Alaska.[589] Males establish nest territories in the fall and females move in to spawn during the winter, then leave the males to guard the eggs until hatching.[590] Lingcod inhabit a wide range of depths, including below 1,000 feet.[591] Multiple tagging studies indicate that while some lingcod may travel great distances, most have high fidelity to specific locations and remain within two to 20 miles of their release site.[592] Studies of tagged lingcod in Southeast Alaska have led scientists to suspect that lingcod establish a home range and make frequent trips outside that range to feed, but return quickly to their home range.[593]

Lingcod populations in British Columbia and the Pacific Northwest have declined to roughly 10 percent of their historical biomass; the Alaska population status is unknown but appears stable with some evidence of localized depletions.[594] Because lingcod appear to have home ranges, small marine reserves may provide opportunities to protect spawning habitat, increase recruitment and replenish adjacent areas, supporting increased fishery yields.[595] Southeast Alaska has a 3-square-mile marine reserve – the Edgecumbe Pinnacles Marine Reserve – consisting of two underwater volcanoes off Cape Edgecumbe near Sitka that support high densities of lingcod.[596] This area was the first no-take groundfish marine reserve in Alaska and has been closed to fishing since 1999.[597]

Dungeness crab *(Cancer magister)* – Dungeness crab range widely throughout the coastal eastern Pacific Ocean from the Pribilof Islands to Magdalena Bay in Mexico. [598] They are important for both commercial and recreational fisheries, and SeaBank can provide up to 50 percent of the total U.S. harvest in some years.[599] Shallow (12 to 300 feet) mud and sand substrate habitats and estuaries are the most important areas, and support the highest densities of juvenile Dungeness crab.[600] Estuarine habitats contain higher prey densities for juveniles and intertidal vegetation that provides protection from predators.[601]

Egg-bearing females use nearshore substrates when incubating eggs. Peak mating timing occurs in late summer through early fall, and females begin to extrude eggs soon thereafter, from October to December.[602] The largest females can carry up to 2.5 million eggs but also mate less frequently.[603] Southeast Alaska's Dungeness crabs mostly inhabit bays and deep fjords.[604] Studies suggest they are likely to remain in local bays, make limited movements and have small home ranges due to the discontinuity of appropriate habitats.[605] One studied population in Fritz Cove near Juneau showed that female crab remaining within three miles of the head of the cove. [606] None of the tagged crabs moved close to the nearest population six miles away.[607] Ovigerous (egg- carrying) females used the most limited range of habitats, suggesting that some specific habitats are more optimal for brooding eggs.[608] The reliance on specific habitat qualities may make them more vulnerable to sea otter predation or other changes.[609]

Fishery managers believe that Southeast Alaska's Dungeness crab stock is healthy, with steady and reliable amounts of crab recruiting into the fishery.[610] Crab are most prevalent in SeaBank inside waters, with the Stikine River flats providing one of the most important habitats, supporting a stock that contributes substantially to overall harvests.[611] Other high-productivity areas include Frederick Sound, Chatham Strait and Peril Strait.[612]

Tanner crab *(Chionoecetes bairdi)* – Tanner crab biomass has exhibited slow but steady growth over the past decade in northern and central Southeast Alaska inside waters.[613] The biomasses of mature and legal tanner crab are at the highest levels since the late 1990s.[614] Fishery managers believe modest harvest rates in the fisheries will enable this trend to continue.[615] Other crab species are at lower abundances, with small fisheries for golden king crab and commercial red king crab fishing closed in recent years due to a declining biomass.[616]

Spot shrimp *(Pandalus platyceros)* – Spot shrimp occur throughout the North Pacific Ocean and utilize primarily hard-bottom marine habitats as adults.[617] Spot shrimp are the largest species in the family Pandilidae – in general, deep-water prawns.[618] 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 intertidal habitats, including eelgrass and kelp forests, and migrate as they grow to deeper rocky habitats or coral reefs at depths of up to 1,500 feet.[619] Adults are benthic scavengers and predators.[620]

A limited but growing amount of information exists regarding the life history of this species.[621] Spot shrimp are hermaphroditic, meaning they begin adult life as males and may spawn several times as males before eventually transforming into females.[622] The time needed to transition to a female may differ across latitudes.[623] In warmer waters, spot shrimp make the transition between age three to three and a half.[624] Southeast Alaska spot shrimp spend more time as males and transform into females between ages four and five.[625] Females produce a single egg clutch each year, beginning with mating during late summer.[626] After mating, females extrude in the fall and larvae hatch five to seven months later in spring, followed by a post-larval period of 40 days and five benthic juvenile stages that last two years and precede development into a mature male.[627] It is unknown how long spot shrimp live; studies from British Columbia suggest they live up to five years while Prince William Sound studies indicate they live between eight and 10 years.[628]

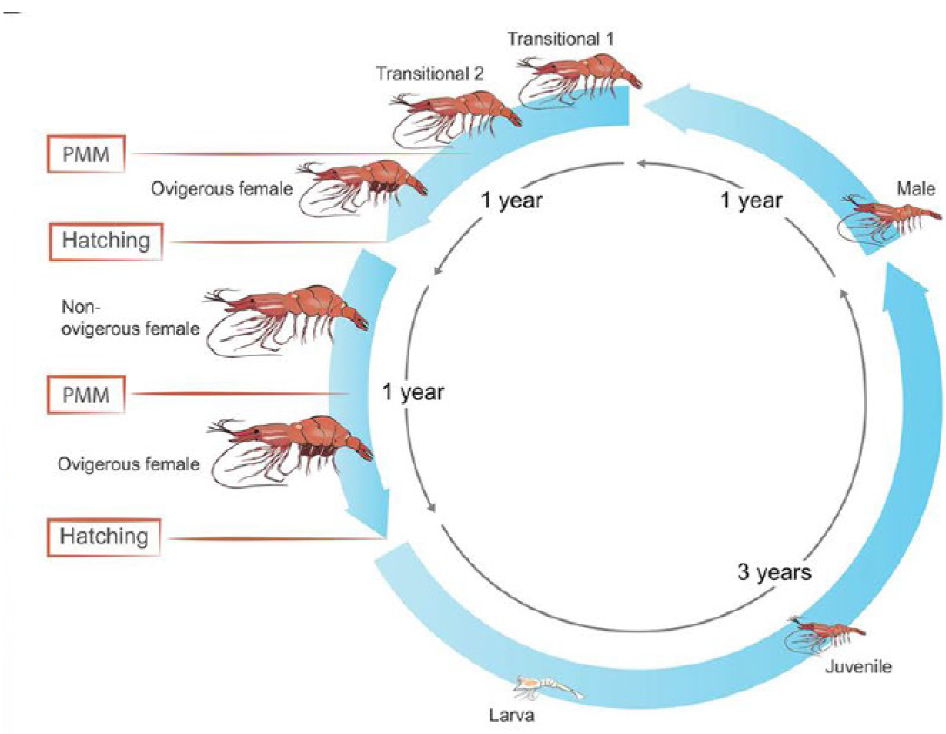


Figure 18: Time scale of the spot shrimp lifecycle. Credit: Levy, T., Tamone, S.L., Manor, R., Bower, E.D. and Sagi, A., 2020. The protandric life history of the Northern spot shrimp Pandalus platyceros: molecular insights and implications for fishery management. *Scientific Reports, 10*(1), pp. 1-11.

The largest populations of spot shrimp occur in Behm Canal and Boca de Quadra near Ketchikan, Cordova Bay, Ernest Sound and northern Clarence Strait near Wrangell, but there are smaller, harvestable populations throughout the region.[629] 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.[630] Overall, spot shrimp populations have declined since the 1990s and have not recovered to their original numbers.[631]

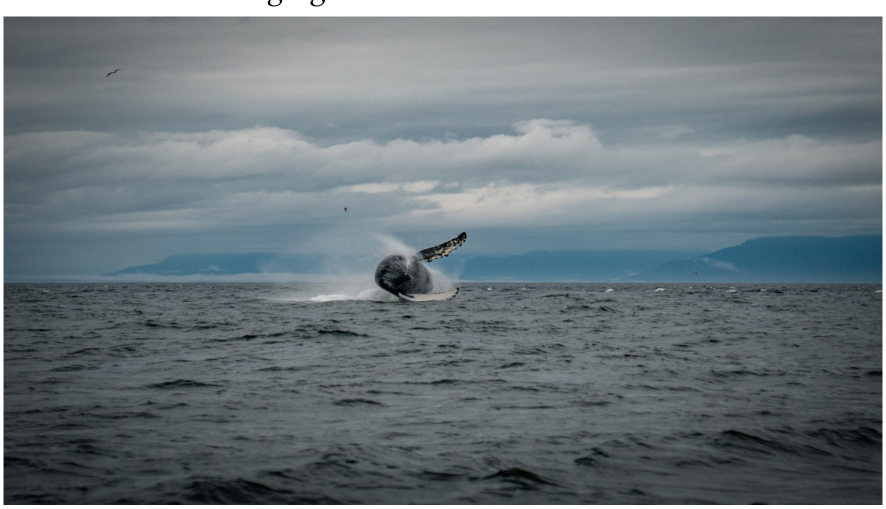
Geoduck clams *(Panopea generosa)* and **sea cucumbers** *(Holothuroidea)* – Geoduck clams and sea cucumbers are the two most important species for the region's dive fisheries. [632] Both species are most abundant in protected bays and inlets on the outer coast.[633] Southeast Alaska is the northernmost portion of geoduck's range. [634] Geoducks can live up to 100 years and occupy habitat throughout southern Southeast Alaska and around Baranof Island, with the highest densities occurring around islands west of Craig. [635] Because of their long life expectancy, low growth rate and variable recruitments, geoducks can be vulnerable to overharvest.[636] Sea cucumbers are common species that range from Mexico to southern Southeast Alaska, near Sitka and in Chatham Strait. [637] 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 in less than 60 feet of water.[638] Abundance of both species declines to very low levels in areas recolonized by sea otters.[639]

Wildlife

SeaBank assets include a wealth of wildlife – 82 species and 116 subspecies of marine and terrestrial mammals.[640] A significant proportion of terrestrial wildlife species are "endemic," meaning they are unique to their particular location, such as Alexander Archipelago islands, and found nowhere else.[641] Many of the terrestrial wildlife species depend on old-growth forests.[642]

Marine Mammals

Whales, dolphins and porpoises *(Cetacea)* – Whales, dolphins and porpoises are marine mammals that utilize Southeast Alaska's environment. Five whale species regularly or seasonally occur in Southeast Alaska: humpback, gray, orca, minke, fin and sperm. Sightings of sperm whales, humpback whales and orcas are the most common and they are also some of the most widely-distributed marine mammal species in terms of range.[643] Although scientists have produced estimates for several cetacean species, acquiring precise data on population status and trends for many cetaceans is challenging.[644]



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

Most humpback whales observed in Southeast Alaska are from the Central North Pacific stock and migrate from their Hawaii winter home where they breed and calve, to feed in Southeast Alaska from spring through the fall.[645] Many whales return each year to the same areas, such as Glacier Bay and Icy Straits.[646] The productivity of these higher-latitude feeding grounds is critical to humpback whale survival and reproductive success.[647] Humpbacks mostly feed on krill and forage fish such as juvenile pollock, sand lance or herring.[648] Recent estimates suggest that roughly 3,000 to 6,000 humpback whales feed in Southeast Alaska and northern British Columbia, and the population in general has been increasing.[649]

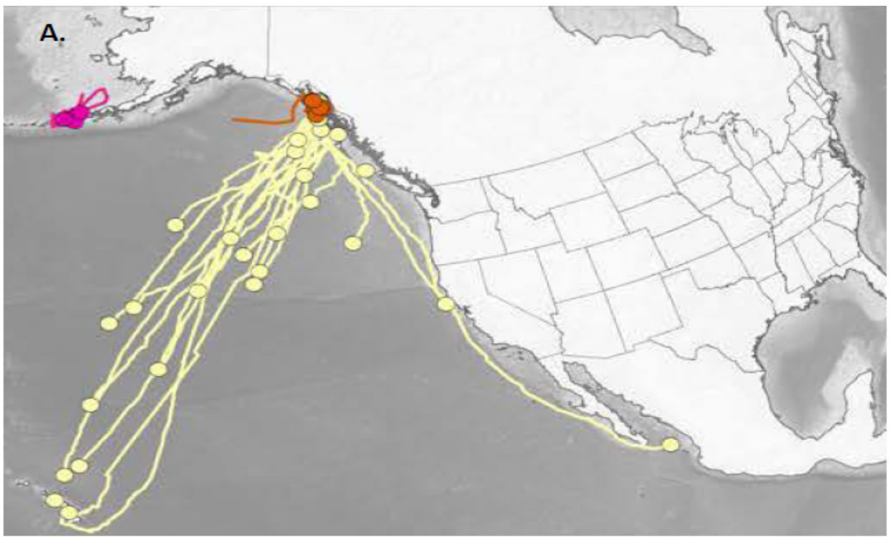


Figure 19: Most humpback whales found in Southeast Alaska waters commute to Hawaii for the winter. Credit: Mate, B.R., et al., 2018. Humpback whale tagging in support of marine mammal monitoring across multiple Navy training areas in the Pacific Ocean: Final Report. 135 pp. Prepared for U.S. Navy Commander, U.S. Pacific Fleet and Commander, Naval Sea Systems Command.

The marine heatwave of 2014-2016 interrupted population growth and was a likely cause of observed higher mortality of humpback whales.[650] There was a sharp decline in the growth of a studied population in Glacier Bay and Icy Straits that had been steadily increasing in numbers.[651] Researchers believe that a significant decrease in prey caused by warmer ocean conditions during and after the heatwave adversely impacted the population.[652] Female humpbacks produced very few calves and calf survival rates were extremely low.[653] Concurrent observations of humpback whale abundance in Hawaii also indicated a likely population decline linked to the North Pacific heatwave.[654] Calving rates and juvenile abundance returned to normal levels in 2020 and 2021, suggesting better prey availability.[655]

Sperm whales, one of the toothed whales found off Southeast Alaska, frequent the deep waters off the continental shelf and slope.[656] The species occurs throughout the North Pacific, feeding primarily on squid but also eating large sharks, skates and fish captured during deep dives that can last up to two hours.[657] Many male sperm whales move north to feed in the Gulf of Alaska during the summer while most females remain in lower latitudes.[658] Scientists estimate the population inhabiting the North Pacific at 102,000 individuals but data limitations and the far-ranging, nomadic nature of these whales make estimates unreliable.[659] The population is likely not declining, but trends are unknown.[660]

Orca whales are found on the continental shelf of Southeast Alaska through the Aleutian Islands and in both the Chukchi and Beaufort Seas. The orca is actually the world's largest dolphin.[661] Scientists have identified three ecotypes of killer whales in the North Pacific Ocean. Differences in the movement patterns among the three distinct orca ecotypes found in Alaska have led, in part, to their designations; i.e., "resident," "transient" and "offshore."[662] Resident killer whales prey primarily on fish.[663] Transients eat marine mammals, and offshore orcas likely prey primarily on fish and even sharks.[664] There are an estimated 109 resident orcas in three pods in Southeast Alaska.[665]

Harbor porpoises and Dall porpoises are abundant in the region.[666] There are roughly 5,500 harbor porpoises, including larger, distinct subpopulations concentrated primarily in Glacier Bay and near Wrangell.[667] Population trends are unknown.

<u>Steller sea lions</u> *(Eumetopias jubatus)* – Steller sea lions are the largest pinniped (fin-footed sea mammal) and a member of the eared seal family. Steller sea lions are generalist marine predators with a diet of fish and cephalopods that tends to be predictable by season and location in Southeast Alaska.[668] Populations plummeted during the 1980s in some areas for reasons that remain uncertain.[669] The National Marine Fisheries Service (NMFS) identified two distinct populations of Steller sea lion stocks during the 1990s based on genetic and regional differences.[670] The agency designated the Western Stock west of Cape Suckling near Prince William Sound as endangered and the Eastern Stock, which lives in Southeast Alaska and the Pacific Northwest, as threatened under the Endangered Species Act but delisted the Eastern Stock in 2013.[671] The Eastern Stock is a growing population.[672] A more diverse diet may explain why Southeast Alaska Steller sea lion populations increased while other Alaska populations were declining.[673]

Steller sea lions on a Southeast Alaska haul-out. Photo credit: Hans Weinberg.

Steller sea lions are polygamous and congregate at rookeries during breeding season and usually return to their natal rookery to breed.[674] During summer, non-breeding sea lions occupy numerous haul-out sites.[675] Southeast Alaska's coast has roughly 50 haul-out sites and breeding rookeries, including the world's largest Steller sea lion rookery, Forrester Island.[676] Other major breeding areas are the White Sisters Islands near Pelican and the Hazy Islands south of Port Alexander.[677] The estimated 21,000 adult and juvenile sea lions and 8,000 pups inhabiting Southeast Alaska rookeries comprise a little less than one-half of the Eastern Stock.[678]

<u>Harbor seals</u> *(Phoca vitulina)* – Harbor seals are the other most abundant pinniped and utilize the entire Southeast Alaska coast. Harbor seals favor estuaries for fishing and tidewater glaciers

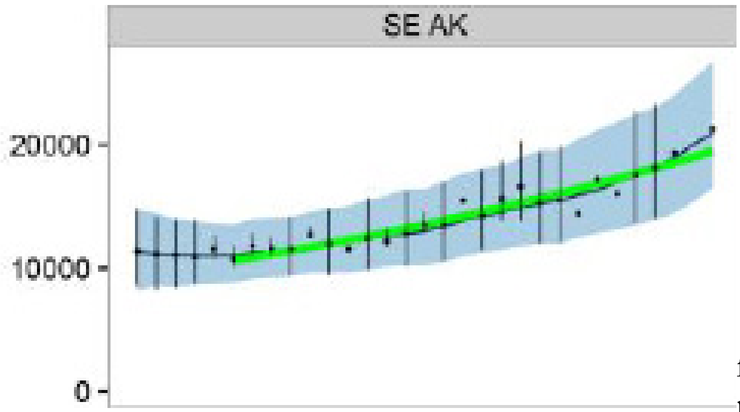


Figure 20: Estimated counts of adult and juvenile eastern Steller sea lions from 1989-2015. The population has been increasing throughout its range with the most significant growth observed in Southeast Alaska and British Columbia. Graphics credit: Muto, M.M., et al., 2019. Alaska Marine Mammal Stock Assessments 2018. NOAA Technical Memorandum NMFS-AFSC-393.

for other habitat needs, particularly seal-pupping. Glacial fjords are some of the most important habitats, especially for pupping.[679] There are five geographically distinct stocks of harbor seals and a total estimated population of over 80,000 individuals.[680] The stocks are stable or increasing except in Glacier Bay.[681] Glacier Bay once hosted the largest breeding aggregation of harbor seals in Alaska, but much haul-out habitat disappeared due to glacial retreat.[682]

Sea otters *(Enhydra lutris kenyoni)* – Sea otters forage in relatively shallow coastal waters for a variety of marine species, including mussels, clams, sea urchins, crab and occasionally fish.[683] They rely on their high metabolism and incredibly dense fur (up to 1 million hairs per square inch) for warmth.[684] In order to maintain body weight, a sea otter must eat 25 percent of its weight every day.[685]

Commercial harvests of sea otters in the fur trade grew rapidly after Russian explorers arrived in Alaska in 1741.[686] By the 1800s, hunters had nearly extirpated the species throughout its range, including Southeast Alaska.[687] In 1965, roughly 500 sea otters were reintroduced to the outer coast.[688] A period of rapid population growth began in the late 1980s. [689] The population doubled between 2003 and 2011 (from 13,221 individuals to 25,584 individuals).[690] That 2011 estimate, from the U.S. Fish and Wildlife Service's 2014 stock assessment, is the latest available.[691]

It is estimated that 8,000 to 8,500 sea otters inhabit Glacier Bay alone. They constitute most of the northern Southeast Alaska population, and at nearly four sea otters per square mile, their density is over three times as high as the rest of the region.[692] Over 12,000 sea otters inhabit southern Southeast Alaska, in areas south of Frederick Sound.[693] Estimated population growth rates across Southeast Alaska for recent years range from 8.6 percent to 14 percent annually.[694] Areas of expansion are Cordova Bay near Craig and northward through Chatham Strait and into Frederick Sound.[695] Large groups of sea otters are still expanding into unoccupied areas with potential for the Southeast Alaska population to triple in size if current patterns continue.[696]

Alaska Department of Fish and Game shellfish managers believe that the growing population is significantly affecting commercial harvests of geoduck, crab and other species.[697] For example, sea otters consumed an estimated 16,000,000 urchins – most of the stock – after moving into southern Sitka Sound in 1992.[698] Multiple areas, particularly on the outer coast, no longer support sea cucumber or geoduck harvests after large sea otter populations moved in. [699]
As shown below, sea otter densities are highest on the outer coast and are at or approaching carrying capacity (K) around north Chichagof Island and areas near Craig.

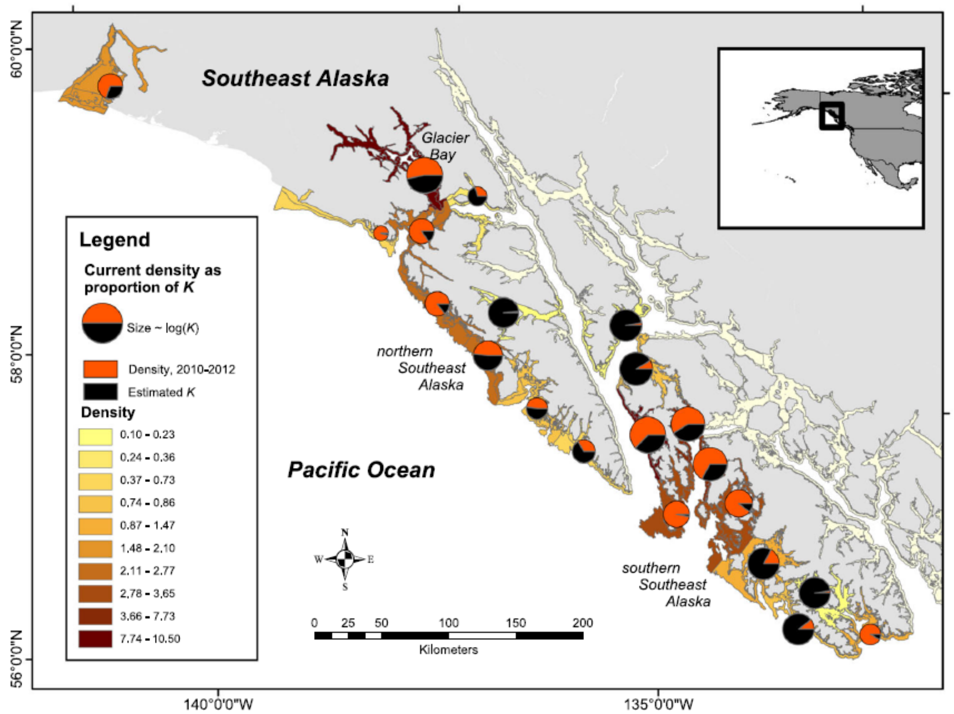


Figure 21: Sea otter population density is highest in outer coastal areas. Credit: Tinker, M.T., Gill, V.A., Esslinger, G.G., Bodkin, J., Monk, M., Mangel, M., Monson, D.H., Raymond, W.W. and Kissling, M.L., 2019. Trends and carrying capacity of sea otters in Southeast Alaska. *The Journal of Wildlife Management, 83*(5), pp. 1073-1089.

Terrestrial Mammals

Southeast Alaska rainforests differ from most regions in North America because they retain most of the wildlife species that have been here for centuries. The wide range of habitat values in the region's island ecosystem, and the forage and prey they produce support important large land-mammal species.

Sitka black-tailed deer. Photo credit: Alaska Department of Fish and Game.

Sitka black-tailed deer *(Odocoileus hemionus sitkensis)* are an important species because of their well-studied need for large home ranges, dependence on old-growth forests and multiple habitats and status as game and subsistence species.[700] They are a subspecies of mule deer adapted to northern Pacific old-growth rainforests.[701] They are present throughout Southeast Alaska and occur on nearly every island in the Alexander Archipelago but are less common along the mainland coast.[702] Population densities are currently highest on islands north of Frederick Sound.[703]

Deer are one of the most important Tongass wildlife species in terms of cultural and recreational value and as a primary food source for many resident subsistence and sport hunters.[704] Average annual harvests exceed 12,000 deer and provide nearly one-quarter of the region's subsistence food harvests.[705] Severe winter weather is a primary cause of deer mortality, causing malnutrition, disease and higher predation.[706] They depend highly on old-growth forests that have over-winter forage and intercept snowfall, making food available during periods of deep snow.[707] Because of this ecological function, large blocks of intact, low-elevation, old-growth forest are essential to maintaining healthy populations.[708]

Protecting low-elevation, old-growth forest is critical to maintaining annual deer dividends. Young clearcuts do provide abundant forage during snow-free periods, but within several decades the growing forests shade out understory plants used by foraging deer. This creates large areas of unsuitable, sterile habitat causing long-term decline in a deer population's density.[709] Declines are periodically caused by a winter of severe weather or several in succession, particularly in central Southeast Alaska. These losses are intensified when logging has reduced winter habitat capability or has disrupted predator-prey dynamics, giving wolves and bears a heightened advantage.[710] Population recovery has been slower than anticipated in that central area – taking several decades, likely because of predator advantage.[711]

Southeast Alaska in general provides excellent habitat for bears, with the availability of salmon contributing to high bear densities.[712] Black bear, Ursus americanus, are present along the entire mainland coast and inhabit most Alexander Archipelago islands south of Frederick Sound.[713] Southeast Alaska may support as many as 16,000 black bears.[714] A study specific to north Kuiu Island estimated densities as high as 3.9 bears per square mile.[715]

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.[716] The ABC island populations' ancestors were polar bears stranded during the last glacial period who eventually interbred with mainland brown bears.[717] The three islands support some of the highest brown bear densities on the planet – over 4,500 bears, roughly 70 percent of the entire Southeast Alaska population.[718]

Black bears and brown bears rarely overlap on island ecosystems.[719] Both have large area requirements and use habitats such as riparian areas, estuaries and old-growth forests in differing ways.[720] Hunters harvest both species, which return dividends because of their values for hunting, recreation and tourism.

Riparian forests are some of the most important habitat, especially during late summer when bears concentrate along anadromous fish-bearing streams to harvest salmon.[721] Forested buffers alongside these streams are critical, especially for females.[722] 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 and deer fawns in late May and June, then consuming large quantities of salmon when available during summer and fall.[723] Salmon abundance in general results in larger, healthier bears and is critical to successful reproduction.[724]

Southeast Alaska brown bear. Photo credit: Hans Weinberg.

Roadless areas have high value for bears, serving as strongholds that satisfy their diverse habitat needs, sensitivity to disturbance by humans, and dependence on large, undisturbed and unroaded areas of land.[725]

Because black bears depend on large-tree, old-growth forest habitat, wildlife managers expect black bear populations to decline with further losses of old-growth forest.[726] Logging and timber road construction reduce old-growth forest habitat, denning habitat and foraging habitat, increase disturbances during summer and increase vulnerability to human harvest.[727] The availability of numerous, adequate den sites is critical to black bear survivability and reproductive success.[728] Existing den sites are commonly reused, which may indicate in part a lack of adequate alternative sites.[729] Bears, like deer, are also susceptible to the long-term loss of foraging opportunities, which occurs as clearcuts regenerate into unsuitable habitat.[730]

Southeast Alaska troller. Photo credit: Hans Weinberg

The Scenery Resource

The SeaBank provides a combination of assets with high value for scenery and landscape character that is hard to find anywhere else – steep snowcapped mountains, coastal islands facing the open ocean, long inland saltwater beaches, old-growth temperate rain forests, icefields and glaciers.[731] There is high demand for scenic values, shown by increases in both tourism and local resident values.[732]

Scenery – particularly more natural-appearing forest scenery in coastal settings – is a major driver of destination choices, the increasing popularity of Southeast Alaska being a prime example.[733] Visitors arrive seeking natural-appearing landscapes to meet their expectations of a wild and unspoiled Alaska.[734] Indeed, natural beauty and outdoor adventure opportunities are recognized as the top strength of the region's visitor industry, conferring a competitive advantage on which the industry thrived over the past decade.[735]

Snow-capped mountain in Southeast Alaska. Photo credit: Hans Weinberg.

Extensive research inspects forest aesthetic values for visitors and local residents.[736] In general, it shows that the highest-rated scenes for aesthetic quality are diverse, mature forests in their natural state with little trace of human activity.[737] Forest visitors also prefer remote, undeveloped sites.[738] They generally avoid the visual disturbance of industrial logging (such as logging trucks, bare ground or fallen trees), the opposite of scenic beauty.[739]

Fishermen often refer the working decks of their boats as "an office with a view."
Photo credit: Hans Weinberg.

The scenic environment also has high local value for resident recreation, and other amenity values that extend well beyond revenues from tourism.[740] Many remote, unroaded areas are the 'backyard' for Southeast Alaska communities. They are where people work, walk, camp, ski and hunt amidst the region's scenic beauty.[741] Whether using the forest for subsistence, sport fishing, hunting or recreation, Southeast Alaskans have long held a deep commitment to protecting the forest for its scenic value.[742]

St. Lazaria Island and Mt. Edgecumbe near Sitka are popular viewing and hiking sites for visitors and residents. Photo credit: Hans Weinberg.

As with protecting areas for climate mitigation, managing areas for scenic values also protects other ecosystem services.[743] For example, Southeast Alaska residents and visitors gain numerous health benefits while viewing and using the forest, including improvements in physical health and emotional and psychological well-being.[744]

Southeast Alaska troller at sunset. Photo credit: Hans Weinberg.

Chapter 4: Seabank Economy

Assessing the Value of the Southeast Alaska's SeaBank Resources to the People and Communities Within and Outside the Region

There are nearly 72,500 people living in Southeast Alaska's 33 communities.[745] Three-fourths of the population lives in the biggest communities – Juneau, Ketchikan and Sitka.[746] Eleven of the communities are small and remote, with between 10 and 100 residents.[747] Most of these smaller communities are commercial fishing ports that feature sportfishing and other nature-based tourism activities.[748] Over 3,000 people live in eight Alaska Native villages – Angoon, Hoonah, Hydaburg, Kake, Kasaan, Metlakatla, Saxman, and Yakutat – where commercial fishing, subsistence food harvests and, in some cases, tourism comprise the main economies.[749]

Figure 1: Map of Southeast Alaska communities. Credit: http://alaskaweb.org/region-insidepass.html.

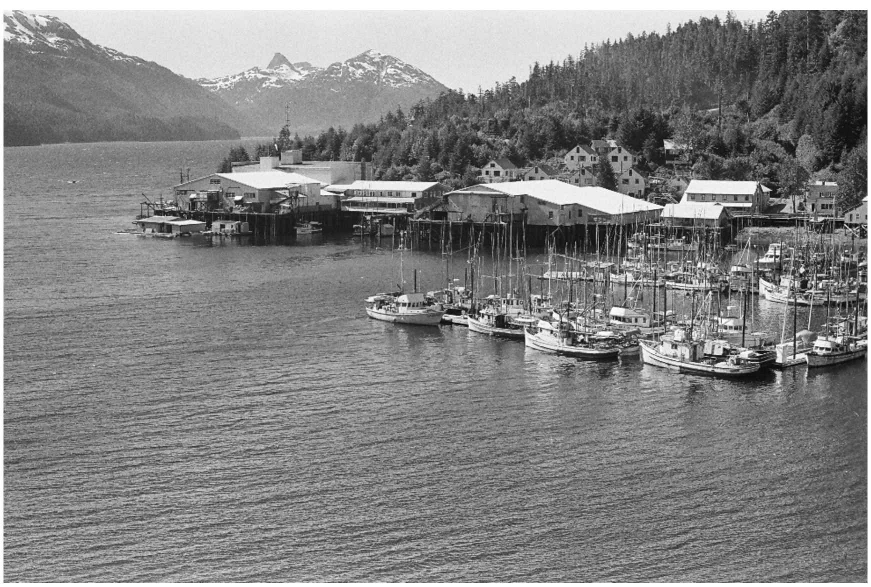
The lowest population level this century was 70,219 people in 2007.[750] A period of slow growth followed, peaking at 74,432 residents in 2014.[751] Across the state, residents in general are aging and there are low birth rates and low new-resident migration.[752] Alaska demographers project small population declines in most Southeast Alaska communities over the next decade.[753]

The public sector and health care industry are the largest component of the region's economy.[754] The two top private sector economies are the visitor industry and the commercial fishing/

seafood industry.[755] Both economic sectors depend on ecosystem services provided by public lands, particularly the Tongass National Forest and its accessible, undeveloped areas such as roadless areas and assets such as scenery, forests, shorelines, terrestrial and marine wildlife and especially salmon.[756] 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.[757] The visitor products industry experienced significant declines in 2020 and 2021 because large numbers of visitors stayed home due to the COVID-19 pandemic.[758] Seafood industry production improved considerably in 2021 after a poor year in 2020, with higher prices and stronger salmon returns.[759]

Over 32,000 people live in the state's capital and Southeast Alaska's largest city, Juneau.[760] Juneau's diversified economy includes government, tourism, seafood, trades, education and transportation.[761] Ketchikan is the second largest community with roughly 13,900 residents and is a hub for surrounding communities.[762] As the southernmost gateway community, Ketchikan relies on tourism for its important role in a diverse economy, which also includes government, fishing and trade.[763] With 8,400 residents, Sitka is the third most populous community.[764] 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 industry and fishing.[765] Other economic drivers include health care and education.[766]

Southeast Alaska's northernmost community is Yakutat, a community of 540 residents that relies on commercial fishing.[767] 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.[768] Tourism dominates Skagway's economy.[769] Haines also depends on a mix of commercial fishing and a growing visitor products industry.[770] Roughly 3,700 people total reside in these communities.[771]



Pelican, a fishing town near the outer coast. Photo Credit: *F/V Patience.*

Hoonah and Gustavus along Icy Strait are gateway communities to Glacier Bay National Park.[772] Hoonah is a major cruise ship destination and has a strong commercial fishing economy.[773] The Hoonah-Angoon Census Area has a population of 2,350 people, including residents of Pelican and Elfin Cove which, though small and remote communities, are important ports for both sport and commercial fishermen.[774] Hoonah is the largest community, with 780 residents.[775]

The largest central Southeast Alaska communities are Petersburg and Wrangell.[776] The Petersburg Borough has nearly 3,400 residents.[777] Petersburg is a commercial fishing town, but tourism has increased recently with charter fishing businesses and increased port calls by smaller cruise vessels.[778] Wrangell is an attraction to visitors as the gateway community to the Stikine River and has a diverse fisheries economy.[779] Its population is roughly 2,100 residents.[780] The Alaska Native village of Kake, with 570 residents, is the third largest community in the area.[781] Kake's economy has traditionally relied on a mix of fishing and subsistence, but the community is increasingly an attraction for visitors as a gateway community to recreation opportunities in Frederick Sound, Chatham Strait and the adjacent coastlines.[782]

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. Prince of Wales Island is the third largest island in the United States with 3,600 residents living in 12 communities – mostly smaller fishing villages or former logging communities dispersed along the coastline.[783] Most residents live in the larger communities of Craig, Klawock, Metlakatla and Thorne Bay.[784] Commercial fishing, sportfishing and nature-based tourism are economic drivers for most of these communities.[785]

The Commercial Fisheries Economy

Southeast Alaska is one of the most important fishing regions in Alaska, with more full-time fishery workers than any region other than the Bering Sea.[786] In any given year, seven of the top 100 fishing ports by value in the entire country are likely to be Southeast Alaska ports.[787] There is a high level of resident earnings in these communities – Petersburg (in third place with $49 million in earnings), Sitka (in fourth place with $41 million), Juneau (in eighth place with $20 million) and Ketchikan (in tenth place with $16 million) are among the top 10 fishing communities in Alaska.[788]

The top competitive 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.[789] Over the past decade (from 2010 to 2019), the region's average inflation-adjusted ex-vessel value (price paid to fishermen) was $308 million.[790] A changing ocean environment and reduced salmon harvests are major concerns affecting lower values in recent years.[791] In 2020, restaurant shutdowns, tariffs, increased processor 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.[792] A strong salmon season, combined with higher halibut prices and high Dungeness crab harvests yielded a considerably better season in 2021.

Southeast Alaska has a high level of resident participation in the fisheries. Residents own 2,655 fishing vessels – one-third of Alaska's fishing fleet and more than any other region in the state.[793] 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.[794] Another 1,000 fishermen from out of state also work in Southeast Alaska fisheries.[795]

Commercial fishing harvests support 41 shore-based processing facilities and 2,900 full-time-equivalent processing jobs.[796] Annual wholesale values have typically ranged between $400 million and $600 million dollars.[797] The fisheries also support 1,100 management jobs and significant employment in the transportation, marine and academic sectors.[798] Economists estimate the economic output from Southeast Alaska seafood, including multiplier impacts, to exceed $800 million annually and account for 15 percent of regional employment.[799]

Commercial fishermen and processors also provide substantial direct economic benefits to local communities through landing taxes and fisheries business taxes.[800] Fisheries business tax revenues from processors go into Alaska's general fund, and the legislature then appropriates up to 50 percent of the revenue back into the community where the processing occurred.[801] Also, 50 percent of the landing tax revenue is returned to municipalities based on landings there.[802]

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 Edna Bay, Meyers Chuck, Point Baker, Port Protection, Port Alexander and Pelican, are historical fishing villages that rely almost exclusively on commercial fishing, with some of these communities developing new economic activity associated with sportfishing lodges.[803] Prince of Wales Island has 300 fishing permit holders and 275 crew – roughly 8 percent of the population – earning $16.8 million in ex-vessel revenue.[804]

The Alaska Native villages of Hoonah, Klawock, Metlakatla and Yakutat also rely heavily on commercial fishing.[805] Nearly 10 percent of the Hoonah/Angoon Census Area population is active in commercial fishing.[806] The 200 active fishermen own 154 boats and 244 permits, earning $4.3 million per year and generating jobs for a mostly local seafood processing work force.[807] Yakutat is among the top 80 ports in the U.S. for value of landed seafood and is the most fishing-dependent community in Southeast Alaska, with one fishing permit for every four residents.[808] It has a fleet of over 100 boats and over one-third of its residents work in commercial fishing or seafood processing.[809]

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.[810] Each community has multiple processing facilities, which collectively employ over 2,200 workers earning over $32 million in wages.[811] Sitka is Southeast Alaska's top seafood port and ranks twenty-first in the U.S by seafood volume and sixteenth by value, producing 45.5 million pounds of seafood worth $61 million in 2018. [812] Roughly 10 percent of Sitka residents are active fishermen and average resident permit holder earnings of $41 million are the fourth highest in Alaska.[813] Sitka has the most active troll fleet, with its power troll fleet 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 top 10 Alaska ports for resident permit holder earnings.[814]

The "mid-sized" Southeast Alaska communities of Haines, Petersburg and Wrangell are heavily dependent on SeaBank fisheries resources. More than one in every 10 residents owns a fishing permit.[815] In 2018, Petersburg was the 25th-ranked port by seafood volume and 24th-ranked by value in the U.S., with local landings of 35.3 million pounds of seafood worth $50.5 million.[816] Petersburg's active resident permit holders averaged nearly $50 million in earnings in local and Gulf of Alaska fisheries from 2017 to 2018, the third highest among Alaska communities and highest in Southeast Alaska. Nearly one-quarter of Petersburg residents are active fishermen.[817] Wrangell and Haines also both rank among the nation's top 100 fishing ports.[818] 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.[819] Including crew, over 1,300 individual fishermen live in the three communities, relying on a fleet of 900 vessels that generated nearly $70 million in fishing income in 2018.[820] Seafood harvested by these fishermen supported over 1,100 processing jobs that generated roughly $15 million in wages.[821]

The Salmon Economy

Salmon support one in 10 jobs in Southeast Alaska, and its commercial, sport and subsistence fisheries can produce $1 billion in economic outputs.[822] It is the region's most abundant and valuable harvested seafood species and comprises between 60 percent and 70 percent of the total seafood productivity in any year.[823] There are five commercial salmon fisheries in the region: purse seine, drift gillnet, set gillnet, hand troll and power troll.[824] They harvest all five Pacific salmon species. Since 1975, pink salmon have generated one-third of the harvest value; chum salmon and coho salmon have each generated over 20 percent; and Chinook and sockeye salmon each generate 13 percent.[825]

From 2009 to 2018, SeaBank produced an annual harvest of 52 million salmon worth over $134.2 million in ex-vessel value.[826] The 2013 fishing year saw record salmon catches by all gear types, with decadal-peak harvests of 95 million pinks, 12.3 million chum and 4 million coho.[827] The catch of 112 million fish was a regional record and worth $228 million in ex-vessel value.[828]

Table 4.1.1: Seabank Salmon Harvests (Numbers of Fish in Millions) and Value (Millions of Dollars) 2017-2021

	Chinook	Sockeye	Coho	Pink	Chum	Total
2017 Catch	.16	.66	2.75	34.61	11.33	49.52
Value	$14.6	$6.9	$22.9	$40.8	$75.5	$160.5
2018 Catch	.16	.60	1.565	7.76	11.16	21.24
Value	$14.3	$6.3	$20.5	$11.4	$81.1	$133.6
2019 Catch	.18	.88	1.65	21.11	8.41	32.23
Value	$10.7	$10.6	$19.3	$23.7	$37.6	$101.8
2020 Catch	.20	.37	1.1	8.0	4.66	14.30
Value	$13.5	$2.6	$12.2	$6.2	$15.7	$50.1
2021 Catch	.22	1.11	1.50	48.21	7.0	58.04
Value	$15.2	$11.4	$17.9	$48.1	$39.6	$132.3

Prices vary by salmon species and type of fishing gear. Pink salmon are the lowest-valued species, with prices varying between 22 cents and 38 cents per pound over the past five years.[829] Troll-caught Chinook are by far the highest-valued species, for which summer prices reached a recent peak in 2017 of $7.75 per pound, with a price of $6.17 per pound in 2021.[830] The 2021 ex-vessel price for sockeye caught in the net fisheries was $1.80 per pound, down from a recent peak of $2.13 per pound in 2019.[831] Coho ex-vessel values have typically exceeded $1.70 per pound in recent years, and reached $2.11 per pound in 2021.[832] Chum prices have varied the most, from 45 cents per pound in 2020 to 87 cents per pound in 2018.[833]

Southeast Alaska's salmon landings rebounded in 2021 after a disastrous year in 2020. The pink salmon harvest of 48.5 million fish was close to the average odd-year harvest of 49 million fish from 2010 to 2019.[834] The total 2021 harvest including hatchery recovery was 58.9 million fish – four times as high as in 2020, when the overall harvest was just over 14.6 million fish.[835]

Southeast Alaska's troll fishery has the highest level of local ownership of any major Alaska fishery. Southeast Alaska resident harvests, as well as harvests by non-resident fishermen who function as locals during the extended troll season, significantly benefit local economies through higher local expenditures on fuel, groceries, vessel repair and maintenance sectors and gear suppliers, generating induced economic effects that include more indirect employment and wage income circulating in the economy.[836] These economic multiplier effects (leading to additional income for businesses due to industry-related revenues) on local economies are indispensable to a diverse range of businesses – each dollar in resident fisheries earnings generates $1.54 in total community revenue and over 7 jobs per $ 1 million dollars in fishery earnings. [837] In other words, average annual local troll earnings of over $30 million the past decade generated $45 million in Southeast Alaska community revenues and 2,100 jobs each year.

Also, when quantified from a multi-regional perspective such as the Pacific Northwest, studies show that the value of high-quality seafood such as salmon multiplies by a factor of four as the harvested fish transit the economy from hook to plate.[838] The total troll fishery value of $37 million per year generates $148 million annually in economic outputs when adding in restaurant sales, consumer purchases, transportation jobs and other benefits accruing throughout the west coast of the U.S. and beyond.[839]

Table 4.1.2: Southeast Alaska Troll Economy

Year	Ex-vessel value	Southeast Alaska resident ex-vessel value	Active permits	Southeast Alaska resident active permits
2011	$38.3	$31.5	1,150	954
2012	$34.6	$29.2	1,112	947
2013	$47.3	$39.9	1,100	936
2014	$52.4	$43.4	1,114	944
2015	$29.0	$24.9	1,070	903
2016	$38.3	$32.4	1,022	871
2017	$39.1	$33.3	987	833
2018	$34.5	$28.9	910	777
2019	$34.4	$19.7	895	761
2020	$22.0	$19.0	853	737

Trollers are diverse in size and use hook and line gear. Photo credits: *F/V Patience*

The troll fleet, which sells fish to shore-based processing plants, is diverse and includes hand trollers (who use hand-powered downriggers or fishing rods), power trollers, and catcher-processors (boats that freeze fish at sea).[840] As shown in the table above, over the past decade between 850 and 1,150 power and hand troll permit holders participated in the fishery each year, making this fleet the second largest in the state, surpassed only by that in Bristol Bay.

The troll fleet harvests mostly Chinook and coho salmon – roughly two-thirds of the regional harvest of both species over the past decade.[841] Since 1975, coho and Chinook salmon have comprised 51.4 percent and 43 percent of troll harvest value, respectively.[842] In recent years, trollers have devoted significant effort to harvesting chum.[843] Average chum harvests from 2009 to 2019 rose to 450,000 fish, including over one million fish in 2013.[844] The outer coast areas offshore from Sitka and Craig typically comprise roughly two-thirds of the troll fishery value each year.[845]

Dressed troll coho salmon ready for chilling and delivery to Sitka. Photo credit: *F/V Pacific Flyer*

In general, troll Chinook harvests averaged 193,000 fish per year over the past decade and have been much lower than historical catches. The main reasons are declines in Alaska stocks and new restrictions under the Pacific Salmon Treaty, which regulates Pacific Northwest stocks that transit Southeast Alaska waters.[846] The 2020 Chinook harvest was the sixth lowest since 1959.[847] Alaska Department of Fish and Game regulations intended to protect Southeast Alaska transboundary river stocks have limited both areas for spring and winter troll fisheries, reducing harvests and effort.[848]

Most troll-caught coho originate in Southeast Alaska watersheds.[849] The troll coho harvest from 1989 to 2019 averaged 1.7 million fish per year.[850] The 1990s had high harvests averaging 3.2 million coho, including a record of 5.5 million in 1994.[851] The highest recent harvest was 2.1 million in 2017, then trollers harvested less than 1 million coho from 2018 to 2020, with a catch of 750,000 fish in 2020 being the lowest since 1988.[852]

Power trollers now account for nearly all of the troll harvest.[853] Southeast Alaska residents own 741 of the 960 power troll permits.[854] Roughly 85 percent of the vessels are local to Southeast Alaska.[855] Troll earnings per permit peaked in 2014 and, like gillnet and seine earnings, have also declined but not to the same degree.[856] The number of actively-fished power troll permits has declined 27 percent from a peak of 852 in 1991 to 628 in 2020.[857] Between 550 and 630 power trollers have actively fished each year since 2014, with average earnings per vessel ranging from $33,000 to $65,000.[858] The fishery reached its peak value of $52.4 million in 2014 and a low value of $22 million in 2020.[859]

Of the 910 hand troll permits, Southeast Alaska residents own 775 (85 percent), and over 90 percent of the active permit holders are local fishermen.[860] Hand trollers historically harvested a significant portion of the troll catch but now catch roughly 3 percent of the total troll harvest.[861] From 2007 to 2015 roughly one-third of the hand troll permits were active.[862] From 2016 to 2020, the number of active hand trollers declined each year, reaching a low of 218 active fishermen (roughly one-quarter of the permit holders) in 2020.[863] Hand trollers currently comprise roughly one-fourth of the currently active troll fleet.[864]. The hand troll fleet's ex-vessel values bottomed out at $800,000 in 2020 and peaked at $3.4 million in 2013.[865] For most of the past decade, annual harvests exceeded 100,000 fish, mostly coho, but harvests from 2018 to 2020 were less than one-half the decadal average.[866]

Seining is usually the highest-value fishery overall. It averaged over $73 million in ex-vessel value in the past decade, peaking at $154 million in 2013. [867] Seiners mostly harvest pink and chum, and catch over 70 percent of the total salmon fishery volume each year: roughly 90 percent of the pinks and 50 percent the chum caught in Southeast Alaska.[868] Varying by year, Southeast Alaskans own just over one-half of the 200 to 240 active seine vessels.[869] From 1975 to 2020, the purse seine fishery's harvest value was roughly 61 percent from pinks and 24 percent from chums.[870] In 2013, a record year, the ex-vessel value was $176 million.[871] The 2020 value, the lowest since 1975, was $82 million. [872] In general, fishing districts near Ketchikan and Prince of Wales Island garner between one-half to two-thirds of the fishery value each year.[873] In 2021, pink runs rebounded – seiners caught 44.5 million pinks of the total 48.5-million-fish harvest.[874]

Table 4.1.3: Southeast Alaska Seine Economy

	Ex-vessel value (million dollars)	# of vessels	Earning per vessel (100 thousand dollars)	# of Southeast Alaska vessels
2011-2020 average	**$75.9**	**266**	**$543.7**	**132**
2017	$82.2	259	$317.4	140
2018	$60.6	240	$252.6	134
2019	$53.7	236	$227.6	134
2020	$18.3	201	$91.2	124

Among gillnetters, Southeast Alaskans own 330 of the active vessels and permits – over three-fourths of the fleet.[875] Gillnetters harvest a mix of all five salmon species and averaged nearly 5 million fish per year from 2010 to 2019.[876] Since 1975, sockeye salmon and chum salmon have comprised 32.7 percent and 41.7 of the gillnet fishery harvest value, respectively.[877] The state issues typically 474 permits each year and 80 to 90 percent of permit holders actively fish.[878] Earnings per permit peaked in 2013 and have declined since then, reaching a low of $20,000 in 2020.[879]

There are five traditional drift gillnet fishing areas: Tree Point south of Ketchikan near the British Columbia border, the north Prince of Wales Island fishery in Sumner Strait and Clarence Strait, the Stikine River gillnet fishery near Petersburg and Wrangell, the Taku River/Port Snettisham gillnet fishery south of Juneau and the Lynn Canal gillnet fishery near Haines.[880]

The Lynn Canal and Taku River/Port Snettisham areas have been the most productive over the past decade, particularly for sockeye and chum. There, gillnetters usually harvest over 270,000 sockeye and over 1.7 million chum each year,[881] comprising over half the gillnet fishery value each year.[882] The lowest harvest of the 2011-2020 decade by far was 2020, when the two areas produced less than 80,000 sockeye and 430,000 chum.[883]

The Tree Point fishery produced roughly 1 million fish per year, mostly pink and chum, from 2010 to 2019 – but in 2020 dropped to less than 500,000 fish.[884] The Sumner Strait fisheries produce over 900,000 salmon each year and the most diverse mix of sockeye, coho, pinks and chum.[885] The 2020 Summer Strait harvest, as in other fisheries, dropped to less than one-half – to 418,000 fish.[886] Deep Inlet near Sitka and Boat Harbor near Juneau drive gillnet hatchery chum harvests, from 2010 to 2019 providing an average of 1.7 million hatchery chum in traditional areas and another 1 million fish in hatchery terminal harvest areas.[887] Together, the gillnet fleet generated an average of $28 million in ex-vessel value from 2010 to 2019.[888]

Table 4.1.4: Seabank Gillnet Harvests and Value

	Fleet real value	Vessels	Earning per vessel	Local value	Local vessels	Earning per local
2017	$33.4	424	$78.8	$26.8	333	$80.3
2018	$31.3	428	$73.2	$25.2	330	$76.2
2019	$21.0	431	$48.7	$16.5	331	$49.9
2020	$7.8	370	$21.1	$6.2	296	$20.9

There is also a Yakutat set gillnet fishery, which targets sockeye and coho salmon, mostly bound for the Situk River and comprising nearly all of the fishery's value.[889] Between 90 and 120 permit holders participate each year, and roughly 70 percent of the permit holders live in Southeast Alaska.[890] The peak fishery value was $3 million in 2013, and 2018 and 2020 were two of the lowest-producing years of the past decade – barely exceeding $1 million, about one-half the 10-year average of $2 million.[891]

Figure 2: Locations of hatchery release sites in Southeast Alaska. Graphics credit: Thynes, T., J.A. Bednarski, S.K. Conrad, A.W. Dupuis, D.K. Harris, B.L. Meredith, A.W. Piston, P.G. Salomone & N.L. Zeiser. 2021. Annual management report of the 2020 Southeast Alaska commercial purse seine and drift gillnet fisheries. Alaska Department of Fish and Game, Fishery Management Report No. 21-30, Anchorage, AK.

Five major organizations operate 15 hatcheries in Southeast Alaska – the Northern Southeast Regional Aquaculture Association (NSRAA), the Southern Southeast Regional Aquaculture Association (SSRAA), Douglas Island Pink and Chum (DIPAC), Armstrong Keta, Inc. and Sitka Sound Science Center.[892] As shown in the adjacent graphics, these hatcheries release salmon smolt in numerous locations. The fish then grow to adult size during their migrations around the Gulf of Alaska. In recent years, hatcheries produced 85 to 95 percent of the region's chum harvest, 14 to 25 percent of the Chinook harvest, and 28 to 58 percent of the coho harvest.[893] In 2020, hatcheries accounted for 22 percent of overall harvests and 37 percent of the ex-vessel value.[894] The hatcheries make their own substantial harvests for cost recovery, mostly of chum.[895] Hatchery production had a buffering effect on the recent decline in catches of naturally-spawned salmon. For example, in both 2018 and 2019, exceptional hatchery chum runs partially offset the low overall salmon harvest.[896] Hatchery chum production has increased the overall harvest of the species by over 80 percent, leading to a yearly harvest over the past decade that averaged 10 million fish.[897]

Herring Sac Roe Fisheries

Alaska Natives have harvested herring and herring eggs for subsistence uses for thousands of years.[898] 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.[899] Reduction plants then proliferated throughout the region with commercial catches peaking during the 1920s and 1930s when annual harvests frequently exceeded 50,000 tons.[900] In 1929 seiners harvested a record 78,745 tons of herring for all uses, including bait. [901] Intensive harvests continued for three decades, and herring populations plummeted. By the mid-1960s, the fishery had crashed.[902]

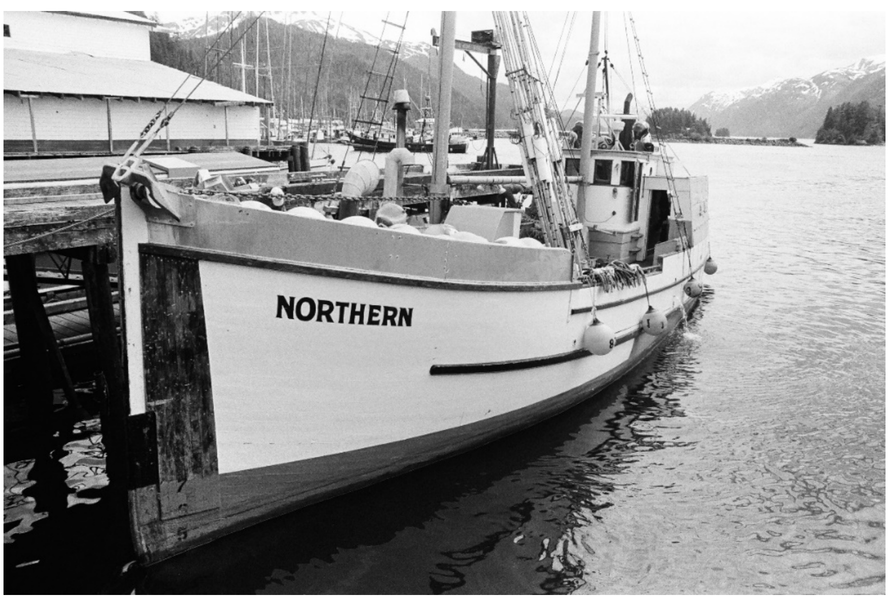
Commercial fisheries targeting sac roe (herring eggs) began in Southeast Alaska in 1971.[903] The largest sac roe fishery – seining in Sitka Sound – generated recent peak ex-vessel values exceeding $12 million in 2009 and 2010.[904] Southeast Alaska commercial herring fisheries have since been in flux, with no Sitka seine fishery in 2019 or 2020 due to weak markets and small fish.[905] Over 100 herring spawn-on-kelp commercial fishery permit holders have provided an increasing proportion of the commercial herring fishery harvest near Craig in recent years.[906] The Sitka seine fishery and Craig spawn-on-kelp fishery harvest values respectively averaged $3 million and $2.7 between 2011 and 2020.[907]

Most of the herring egg subsistence harvest occurs in Sitka Sound.[908] Commercial harvests of Southeast Alaska herring have caused controversy because of concerns about impacts to subsistence and personal use harvests that are important for local food and cultural values.[909] There is also concern about the impact of commercial herring harvests because they are a forage fish that conributes to healthy populations of other species.[910]

The Groundfish Fisheries Economy

Halibut and sablefish longline fisheries produce less than 10 percent of the Southeast Alaska seafood catch but typically generate one-third of the value.[911] Fishermen deliver halibut to processors in most of the region's larger communities.[912] Over 80 percent of the sablefish catch is delivered to Petersburg and Sitka.[913] Petersburg and Sitka fishermen have the most engagement in the longline fisheries, combining to harvest over 10 million pounds of both halibut and sablefish in 2020 worth $29 million.[914] Sablefish fishermen have rapidly shifted from longline to pot gear over the past three years in order to reduce sperm whale depredation.[915]

Halibut is one the highest-value groundfish species.[916] Fillets routinely retail for over $27 per pound.[917] Most halibut is consumed at restaurants, which commonly serve portions as part of a $37- to $43-entrée.[918] As harvested halibut migrate from hook to plate, the trade supports wholesalers, retailers and services.[919] Each dollar in commercial landing value generates over $4 in economic activity: the 2019 coastwide value of $134.1 million was worth over $550 million in total economic activity, generating over 5,000 jobs.[920]



The halibut schooner *Northern* at the Pelican Seafoods plant. Photo credit: *F/V Patience*

The economic benefits accrue mostly in Alaska – where residents driving the fishery own 572 vessels and 903 permits, generating two-thirds of the revenue that flows from sport and commercial harvest locations to adjacent coastal communities.[921] Seventy-eight percent of participants in the fishery are Alaska residents.

Statewide, Southeast Alaska communities have the highest dependence on halibut fisheries and the highest proportion of direct earnings per dollar in landed value in the state.[922] Residents of other states, principally Washington, own over one-third of the Alaska halibut quota but generally deliver their fish to Alaska shore-based processors that purchase almost all the halibut harvested in Alaska.[923]

The overall Alaska commercial halibut catch has declined over the past decade from 56.4 million pounds in 2010 to 21.2 million pounds in 2020, with total catches since 2014 ranging between 21.2 million and 24.7 million pounds.[924] The reduced catch has also reduced fishery values, which exceeded $100 million per year between 2014 and 2017, but dropped to $88 million and $94 million in 2018 and 2019, respectively.[925]

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 stable – between 10.1 million and 11.1 million pounds. Halibut harvested in Southeast Alaska generally command the highest ex-vessel prices in the state.[926] During the COVID-19 pandemic in 2020, prices dropped below $4 per pound at points but are now recovering to high levels, reaching $6.73 per pound in Southeast Alaska ports by the end of the 2021 season.[927] With higher quotas set for 2022, the Southeast Alaska and Gulf of Alaska halibut fisheries could approach $100 million in ex-vessel values, generating $400 million in economic activity that accrues substantially in local communities.

Table 4.1.5: Halibut Harvests and Value

	2019	2020	2021	2022 (quota)
2C Pounds	3.4	3.2	3.3	3.6
3A Pounds	7.9	6.8	8.7	9.2
Southeast Alaska Pounds	$5.55	$4.36	$6.73	$7.50

Although data for 2021 halibut harvests by community is not yet available, halibut harvests were a critical component of SeaBank fisheries values during the pandemic years, even with lower prices.

Table 4.1.6: 2020 Halibut Landed by Southeast Alaska Residents

Borough	Active Permits	Pounds	Ex-vessel value
Haines	18	274,000	$916,000
Hoonah	25	151,000	$524,000
Juneau	69	836,000	$2,740,000
Ketchikan	28	292,000	$926,000
Petersburg	147	2,169,000	$7,159,000
Prince of Wales	37	198,000	$606,000
Sitka	123	1,521,000	$4,973,000
Wrangell	45	405,000	$1,261,000
Yakutat	24	514,000	$1,628,000
Southeast Alaska	**516**	**6,366,000**	**$20,733,000**

Sablefish are a premium, high-priced whitefish marketed in Asia, the United States and Europe, and are among the most valuable species harvested in Alaska.[928] Alaska typically produces 60 to 65 percent of the global sablefish catch.[929] Ninety percent of the Alaska harvest is by Gulf of Alaska catcher vessels, typically accounting for over 90 percent of the annual fishery value.[930] A fleet of 260 to 290 smaller- to medium-size vessels participate in the fishery using fixed longline and pot gears.[931] Presently, a shift in the sablefish population to mostly smaller, younger fish has lowered market values.[932] The statewide fishery value dropped from $110.1 million in 2017 to $73.6 million in 2019 despite a 9 percent increase in the harvest volume.[933] The 2014 year class is approaching fish sizes in a proportion of the population that will generate higher prices.[934]

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. The average price dropped from $4.99 per pound in 2017 to $2.19 per pound in 2021, reducing the total Alaska fishery value from $110 million in 2017 to $73.6 million in 2021, even though harvests increased each year.[935] Small fish fetch low per–pound prices; prices progress upward with size.[936] Younger fish from the large 2014 and 2016 year classes have created a population that is mostly smaller fish, at most six years old, that have low market values. Regional 2021 harvest data are not yet available, but even at the lower 2020 pandemic-year average price of $2.07 per pound, the 2021 sablefish harvests would be worth nearly $20 million to Southeast Alaska communities, mainly in Petersburg and Sitka.

Table 4.1.7: Sablefish Landed by Southeast Alaska Residents

Borough	Active Permits	Pounds	Ex-vessel value
Haines	4	43,000	$80,000
Hoonah	6	90,000	$180,000
Juneau	10	388,000	$788,000
Ketchikan	17	575,000	$972,000
Petersburg	73	2,572,000	$6,256,000
Prince of Wales	5	100,000	$237,000
Sitka	12	4,201,000	$10,540,000
Wrangell	5	75,000	$164,000
Total	**132**	**8,044,000**	**$19,217,000**

Overall Southeast Alaska groundfish fisheries. Other SeaBank groundfish fishery resources include state-managed fisheries for rockfish and lingcod.[937] Overall, for all species, State of Alaska groundfish fisheries have generated between $2.3 million and $9 million per year over the past decade, with sablefish fisheries in Chatham and Clarence Straits comprising at least one-half and sometimes three-fourths of the value.[938] Southeast Alaska fishermen harvested an average of 2.5 million round pounds from 2017 to 2020, with an average value of $5.6 million.[939] Lingcod fisheries are the other main state-directed groundfish fishery, generating up to $500,000 in ex-vessel values.[940] Between 40 and 50 permit holders participate in the directed lingcod fishery each year, harvesting 240,000 to 300,000 pounds, with prices reaching $2.71 per pound in 2020.[941] Fishery managers closed directed fisheries for another high-value species, yelloweye rockfish, due to reduced abundance after limited openings in some areas between 2017 and 2019.[942]

The Shellfish and Dive Fisheries Economy

Other major Southeast Alaska fisheries are crab and and other shellfish harvested in pots or by divers. Central Southeast Alaska is the region's primary crab-producing area.[943] Leading ports for the shrimp, sea cucumber and geoduck clam fisheries are southern Southeast Alaska communities and Sitka.[944] As shown in Table 4.1.8, the combined ex-vessel value for the 2019/2020 shellfish season from the three most productive fisheries – pot fisheries for Dungeness crab and dive fisheries for sea cucumber and geoducks – was roughly $27 million.

Dungeness Crab. Roughly 200 permit holders – mostly from Juneau, Petersburg, Sitka and Wrangell – participate in the Dungeness crab fishery each year. [945] It is a diverse fleet with most vessels less than 58 feet in length.[946] Areas near Petersburg and Wrangell are typically the most productive, but there is regional variability from year to year with occasional high harvests in Chatham, Peril and Icy Straits.[947] The sea otter population has caused drastic declines in three areas and this decline continues to expand into some of the most productive areas between Sumner Strait and Frederick Sound.[948]

The Dungeness crab fishery has been a regional fishery bright spot, with recent harvests exceeding the 10-year average of 3.28 million pounds.[949] The 2019/20 harvest was the third highest on record and most lucrative season in the fishery's history.[950] The 2020/2021 season was the second largest on record, reaching 6.7 million pounds by the end of November 2021.[951]

Table 4.1.8: Seabank Shellfish Harvests (Millions of Pounds), Prices (Average Price Per Pound) and Ex-Vessel Values (Millions of Dollars)

	2017/2018	2018/19	2019/2020
Dungeness Crab M-lb	1.9	4.1	5.3
Price/lb	$3.07	$3.08	$3.01
Ex-Vessel Value	$5.8	$12.2	$15.8
Sea Cucumber M-lb	1.3	1.8	2.0
Price/lb	$3.37	$4.41	$4.27
Ex-Vessel Value	$4.4	$7.8	$8.5
Geoduck M-lb	.54	.53	.50
Price/lb	$6.94	$6.07	$5.69
Ex-Vessel Value	$3.7	$3.2	$2.8

Dive fisheries have grown since the 1990s, when divers developed a fishery through fees on their landings. These fees fund the Southeast Regional Dive Fisheries Association and the surveys needed to develop the fishery and increase open areas for harvesting sea cucumbers, geoducks and red sea urchins.[952] Red sea urchin harvests and values have diminished considerably over the past two decades largely because of sea otter predation.[953] During the early 2000s, over 30 divers typically generated between $800,000 and $1.1 million in ex-vessel values.[954]

Since 2010, between three and 17 divers harvested sea urchins each year, with harvest values typically lower than $200,000.

The sea cucumber dive fishery is the highest-volume dive fishery. Between 170 and 200 divers typically harvest sea cucumbers each year. [955] The fishery's value has nearly doubled over the past two decades in price per pound, overall ex-vessel value and earnings per diver. [956] The 2019/2020 season hit a recent peak for catch value.[957] Per pound, Geoducks are the most valuable dive species, and 60 to 70 active divers harvest them each year.[958] The overall fishery value has been trending upward, mostly because of higher prices over the past decade.[959]

Spot shrimp are another significant Southeast Alaska shellfish species. There are just over 100 active pot shrimp permit holders.[960] 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.[961] There are fewer spot shrimp in northern Southeast Alaska inside waters and they are a declining stock, so those fisheries are either closed or have decreasing quotas.[962] The pot shrimp fishery expanded significantly during the 1990s and early 2000s, with harvests often exceeding 1 million pounds.[963] Harvests over the past decade averaged just over 500,000 pounds, with harvest values ranging between $1.7 and $2.6 million.[964] There are just over 100 active permit holders each year.[965] Actual revenues may be higher as an increased number of fishermen are doing direct sales or marketing frozen-at-sea shrimp at prices ranging between $14 and $16 per pound.

The Visitor 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."[966] These scenic and undeveloped areas make communities in the region economic "gateways" that benefit from adjacency to outdoor recreation opportunities.[967] Recreation use generates much economic benefit for small businesses in gateway communities – particularly through non-resident visitor expenditures.[968]

Similarly, University of Alaska research identified the availability of nature-based tourism experiences in the region's intact ecosystems coincident with a decreasing global supply of high-quality outdoor recreation opportunities, which has a significant influence on visitor preferences.[969] For over two decades, this competitive advantage has been stimulating rapid growth in nature-based tourism here.[970] Important growth is occurring in shore-based day excursions for cruise passengers and in businesses that offer wildlife viewing, sightseeing, the creation and sale of local artwork, Alaska Native cultural performances and active visitor experiences such as hiking and kayaking.[971]

Shore-based recreation depends largely on marine transportation.[972] The region's terrain and topography make much of the land base difficult for commercial outdoor recreation.[973] Some of the most valuable resources are the region's estuaries and beaches used by residents and visitors for shore-based or water-based viewing of seabirds and waterfowl, bears, moose and marine mammals – the five top-ranked kinds of wildlife for viewing in the state.[974] There are nearly 1,000 miles of trails on national forest lands and 80,000 acres of state parks, including 16 marine parks – all offering unique recreation settings not found in other areas of the United States.[975]

Nearly two decades ago, federal land managers projected that an inventory of undeveloped lands in Southeast Alaska could become a valuable asset 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." [976] This followed an earlier economic shift based on increased demand for such places – more than doubling recreation and tourism activity between the mid-1980s and mid-1990s.[977] At a national level, too, demand increased for remote recreation opportunities even as the supply of lands available for outdoor adventure experiences was diminishing.[978] The diminishing global supply of wilderness has made Southeast Alaska's Glacier Bay National Park and protected wilderness areas such as the Misty Fjords and Admiralty Island National Monuments increasingly valuable assets.[979] The Roadless Rule, which prohibits developments such as logging in Tongass National Forest roadless areas, similarly benefits Southeast Alaska by securing economic opportunity associated with remote recreation and adventure tourism – thereby preserving the region's main visitor attractions: sustainable fish and wildlife populations, natural scenery and remote places.[980]

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.

Demand for Southeast Alaska's visitor products grew rapidly over the past two decades.[981] Twenty-first 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.[982] The visitor products industry – comprising retail, tour, hospitality and transportation businesses – is thriving because of the supply of scenery, fish and wildlife and outdoor adventure opportunities, with consistent annual increases in industry employment and earnings.[983]

Southeast Alaska typically hosts two-thirds of all state visitors, making it the most visited region of the state.[984] Overall, the annual recreation dividend has been massive, providing nearly 12,000 direct and indirect jobs, with total labor income impacts reaching $445 million per year.[985] The growth in tourism prior to 2020, particularly small and large cruise ship tourism, increased regional employment and offset downturns in state government employment and fluctuations in seafood industry production.[986]

In 2017, 1.5 million people visited Southeast Alaska by air and cruise ship. The number of visitors increased to 1.6 million in 2018 and another 10 percent in 2019, to 1.8 million.[987] Growing numbers of cruise ship passengers were a major driver, topping 1 million in 2017 and increasing year by year to 1.3 million in 2019.[988] Ketchikan, Juneau, Skagway and Glacier Bay are four of the top destinations in Alaska.[989] The overwhelming majority of visitors to those destinations, and to the town of Hoonah, are cruise ship passengers.[990]

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.[991] The COVID-19 pandemic halted the 2020 cruise season, and air passenger arrivals dropped by more than one-half.[992] Visitor products industry revenue declined by more than 80 percent.[993] Three communities with significant dependence on large cruise ship passengers – Haines, Hoonah and Skagway – experienced the biggest job losses.[994] Unemployment levels reached 19 percent in Skagway.[995] Cancelled tours caused the transportation sector to shed half of the jobs held in 2019 to 2,000 – due to the loss of sightseeing clients.[996] The leisure and hospitality sectors also lost 2,000 jobs – over one-third of their total employment compared to 2019.[997] These effects endured into 2021, although there was a small amount of cruise ship tourism, at 10 percent of normal capacity.[998]

Regional business leaders hope for recovery. The top attractions for visitors – the region's natural beauty and recreation opportunities – are intact.[999] For this reason, and industry growth related to Alaska Native culture and heritage, the visitor products industry should remain a top economic sector as travel opportunities rebound.[1000]

Visitor spending directly contributes to the development of other economic activity such as the growing arts economy.[1001] There are over 2,340 artists residing in Southeast Alaska who earn $29.9 million per year and produce a total economic impact of $57.8 million per year through retail sales and events that rely to a substantial extent on visitor spending.[1002]

Glacier Bay National Park exemplifies the potential for dividends returned from pristine environments.[1003] It is the top-rated cruise destination in the world.[1004] The park received 672,000 recreation visits in 2019, with visitors spending $250 million in the region and supporting 3,000 jobs for a total economic output exceeding $400 million.[1005] The rapidly-receding glaciers are increasing demand for glacier viewing – a phenomenon known as "last chance tourism."[1006] Visitors who stop in nearby Gustavus for sportfishing or as part of their Glacier Bay experience spend nearly $3,000 per person in Alaska – the highest per-visitor expenditure in the region.[1007]

In Hoonah, across Icy Strait from Gustavus, the tourism complex Icy Strait Point has built docks for larger cruise ships.[1008] Icy Strait Point received international recognition as the 2020 Port of the Year in part because of local ownership of the facility and requirements for local ownership of retail and tour guide businesses.[1009] Over 267,000 cruise ship passengers visited Icy Strait Point in 2019, making it the fourth most popular port in Southeast Alaska.[1010] The development now provides 100 jobs, mostly to Hoonah residents, with taxes, wages and visitor spending injecting $6.8 million into the local economy.[1011] Visitors to Icy Strait Point spend more per person in Alaska than in other Southeast Alaska large-cruise-ship destinations.[1012] The development of Icy Strait Point has helped make Hoonah the ninth most visited destination in Alaska.[1013]

Nearby Juneau received over 1.3 million visitors in 2019 – mostly cruise ship passengers – making it the most visited community in the region.[1014] Glaciers such as Juneau's Mendenhall Glacier are a primary local asset as large-cruise-ship passengers often select shore excursions, particularly glacier tours. Visitors and businesses use the Taku River and its glacier for camping, sightseeing and helicopter tours.[1015] Eleven thousand visitors land on the Taku and Norris Glaciers each year, with revenue to tour companies estimated at $6.6 million.[1016] On the Taku River watershed each year, 40,000 visitors spend $15 million and add $800,000 to Juneau's sales tax revenue.[1017]

Ketchikan received over 1.2 million visitors in 2019, with 90 percent of them cruise ship passengers.[1018] Local businesses provide roughly 50 unique shore-based excursions for cruise passengers, flightseeing, marine charters, outdoor adventure and general sightseeing. Numerous flightseeing tours offer access to the Misty Fjords National Monument.[1019]

Sitka's cruise ship passenger numbers were smaller than Ketchikan and Juneau, but the city had a proportionally larger number of independent travelers who visited for fishing, kayaking, hunting, marine charters and other nature-based tourism.[1020] Sitka is likely to receive a much larger number of cruise ship passengers in the future due to the increasing size of cruise ships and the development of the new Sitka Sound Cruise Terminal, a private dock that can accommodate larger vessels.[1021] The city anticipates 478,000 passengers arriving in 2022 – nearly twice as many as the previous record set in 2008.[1022] The high number of cruise ship passengers has challenged local planners to find ways to disperse large crowds, including closing sections of downtown to vehicle traffic, so that the town is not overrun on high-volume days.[1023] The large-scale cruise visitations will also create numerous infrastructure challenges.[1024] Other Southeast Alaska communities have raised concerns about air and water impacts caused by exhaust emissions and sludge and graywater discharges.[1025]

The central Southeast Alaska communities of Petersburg and Wrangell have experienced recent increases in port calls from smaller cruise vessels and increased small business activity in the visitor products sector.[1026] The number of small- and mid-sized cruise vessel passengers visiting Wrangell nearly tripled between 2010 and 2019, to 22,000 visitors.[1027] Wrangell is also the gateway community for the Stikine River, with local businesses that offer jet boat and river-float tours and flightseeing tours to the LeConte Glacier.[1028] 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.[1029]

The Hunting, Wildlife Viewing and Sport Fishing Economy

SeaBank fish and wildlife species are valuable assets for nearly every Southeast Alaska community because of their value for wildlife viewing, hunting or sportfishing.[1030] 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. [1031] Alaska residents accounted for 82 percent of the hunting expenditures and visitors accounted for 81 percent of expenditures on wildlife viewing trips.[1032] These activities also generated $29 million in government revenue.[1033]

Businesses in nearly every community provide water-based excursions for marine mammal viewing.[1034] 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.[1035] Juneau and Icy Strait are the most popular whale watching areas in the state.[1036]

Bears are a top species for wildlife-viewing visitors in Alaska and generate millions of dollars in regional economic impacts. Visitors to Alaska and coastal rainforests in British Columbia identify bear-viewing opportunities as a primary reason for their visits – indeed, bears are the top attraction in the adjacent Great Bear Rainforest in British Columbia.[1037] Ecotour companies provide viewing opportunities throughout the region accompanied by ecological-education presentations about bears.[1038] Recent studies show that bear viewing generates massive economic impacts in similar forested areas in Southcentral Alaska and British Columbia. Bear viewing in Southcentral Alaska generates over $17 million annually in labor income and has a total economic output exceeding $36 million.[1039] Bear viewing in British Columbia's Great Bear Rainforest similarly generates over $15 million in direct visitor spending, 500 jobs and $17.7

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.

million in tour company revenues.[1040] These values are consistent with other research showing that opportunities to view unique or rare animals are critical to destination choices.[1041]

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 numerous popular areas used for bear-viewing opportunities, including developed viewing areas such as Pack Creek on Admiralty Island and Anan Creek near Wrangell.[1042] Hoonah now offers bear-viewing tours to visitors and Sitka's Fortress of the Bear, which rescues and rehabilitates orphaned cubs, is highly popular with visitors.[1043]

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.[1044] Recent brown bear harvests have ranged between 110 and 120 bears per year, mostly from Admiralty, Baranof and Chichagof Islands.[1045] Hunting guides also pursue black bears – mostly on the mainland and on Kuiu, Kupreanof and Prince of Wales Islands.[1046] Nearly all Southeast Alaska hunting guides are local residents and a significant portion of hunting guide spending, income and other economic outputs benefit rural communities.[1047]

Healthy fish populations are an attraction to many visitors and especially vital to Southeast Alaska's freshwater and marine sportfishing businesses. Resident and non-resident anglers pursue all five species of salmon along with steelhead and halibut.[1048] The Alaska Department of Fish and Game has estimated that resident and non-resident anglers spend up to $274 million on gear, transportation, lodging and guide services in Southeast Alaska in a single year.[1049] Charter fishing businesses operate throughout Southeast Alaska.[1050] [1051] Sitka and Prince of Wales Island are two of the top three sportfishing destinations in the state because of their proximity to the outer coast and its exceptional fishing opportunities for salmon and halibut. Smaller and more remote fishing villages such as Pelican, Port Alexander and Elfin Cove are also sportfishing destinations; summer revenues generated by over 1,500 visitors to Elfin Cove alone amount to $5 million annually.[1052] Transboundary river and other local salmon assets support 32 sportfishing businesses in Petersburg and Wrangell.[1053]

Formerly timber-dependent regions such as Prince of Wales Island have new, redefined economies based primarily on fishery and wildlife resources.[1054] The decline of the timber industry was an opportunity to shift into the maritime economy and visitor products industry for long-term community viability.[1055] Prince of Wales Island community planners now pursue a market-based transition featuring hiking, hunting and fishing lodges that support local businesses. Nature-based tourism generated more than $30 million in gross revenues to Prince of Wales Island in 2007, mostly from sportfishing.[1056] Over two-thirds of island visitors participate in fishing – the highest rate among Southeast Alaska communities. Waterfall Cannery is the largest lodge on the island and is the fifth largest employer, with over 100 seasonal employees. Sportfishing lodges near small communities along Clarence Strait (Coffman Cove, Whale Pass and Thorne Bay) attract sport fishers for saltwater fishing in Clarence Strait or steelhead fishing in freshwater streams.[1057]

The island's 2,000-mile road system connects most of the island's towns and villages and is a major competitive advantage relative to other Southeast Alaska communities in terms of attracting visitors for road-based recreational opportunities.[1058] The inter-island ferry system is also a key part of the transportation system, bringing 3,000 visitors to the island – one-half of them hunters and sport fishermen, and one-half hikers and campers.[1059] Campers, fishermen, hunters and hikers stayed for multi-day trips, spending $10.2 million annually, generating 213 seasonal jobs and a total economic impact of $14 million.[1060] The island hosts between 14,000 and 18,000 visitors each year, including the region's highest proportion of return visitors.[1061]

The Eco-Tour Economy

Small cruise vessel ecotour operators provide visitors with scenic views of Southeast Alaska coastlines, fjords and forests, hiking, beach combing, wildlife viewing and other remote recreation experiences throughout the Tongass. Ecotourism relies on remote, undeveloped areas; this is their stock in trade, generating substantial revenues in the region and helping support the well-being of local communities.[1062] Resource economists define ecotourism as "travel to natural areas to admire, study or enjoy wild nature in a way that contributes to its conservation and to the well-being of local people."[1063] It is widely recognized that ecotourism supports both conservation and local economic development.[1064]

There is strong demand for outdoor adventure and ecotour services provided by outfitters and guide businesses. Forest Service lands, particularly inventoried roadless areas, account for roughly one-half of regional visitor activity, accommodating 2,874,000 visits that generate $382 million in spending and support 3,947 direct jobs and 1,110 indirect jobs.[1065] The number of guided clients on the Tongass National Forest increased by 17 percent after the 2011 recession year, to 641,149 clients in 2017.[1066] Primary activities sought by guided visitors are dispersed, active and remote outdoor recreation experiences such as hiking, kayaking and wildlife viewing, which comprise over 60 percent of all guided visitor activity. [1067]

The *M/V Mist Cove* takes 24 people each week for hiking, kayaking and other adventures while cruising between Sitka and Juneau. Photo credit: The Boat Company.

The small cruise vessel fleet is a major regional growth sector consisting of a diverse group of overnight commercial passenger vessels such as yachts and smaller motor vessels that carry between six and 250 passengers.[1068] Many of the small cruise companies have Forest Service special- use permits and specialize in providing visitors with remote recreation opportunities. Passengr capacity in Southeast Alaska doubled over the past decade. Twenty-four small cruise vessels carrying more than 20 passengers each operated in Southeast Alaska in 2015. [1069] Since then, three companies have added four more vessels and considerable additional passenger capacity to the fleet.[1070] Passengers typically pay premium prices for remote recreation experiences in such pristine environments.[1071]

Small cruise companies rely heavily on forest recreation opportunities. The 2001 Roadless Rule FEIS projected an increase in market demand for forest recreation – particularly the most undeveloped settings that feature scenery, remote hiking and related activities and fish and wildlife.[1072] Forests are massive value generators for recreation and there is ample evidence that no-loss forest policies aimed at preserving ecotourism opportunities provide economic benefits that outweigh other resource uses. [1073] Managing roadless areas for recreational values also preserves myriad other ecosystem service values.[1074]

Chapter 5: Climate Change Threats to Seabank Natural Resources

Climate Change Effects on Southeast Alaska Weather

Climate change is likely to impact SeaBank natural capital by causing sea level rise and lowering, glacier melt, rises in air, ocean and freshwater temperatures, changes in precipitation patterns, and alteration of plant and animal distribution. Coastal ecosystems are particularly vulnerable to these climate change impacts.[1075]

Climate scientists use four greenhouse gas emissions scenarios, called Representative Concentration Pathways (RCP2.6, RCP4.5, RCP6, and RCP8.5), to forecast future temperature trends and other changes.[1076] RCPs in part incorporate assumed actions for reducing greenhouse gas emissions.[1077] RCP2.6 assumes major immediate initiatives to reduce emissions while RCP4.5 and RCP6 are "stabilization" scenarios that assume emissions peak over the next 30 years.[1078] RCP8.5 is the "business as usual" scenario and assumes continual emissions from high use of fossil fuels and emissions from land-use changes such as forest loss.[1079]

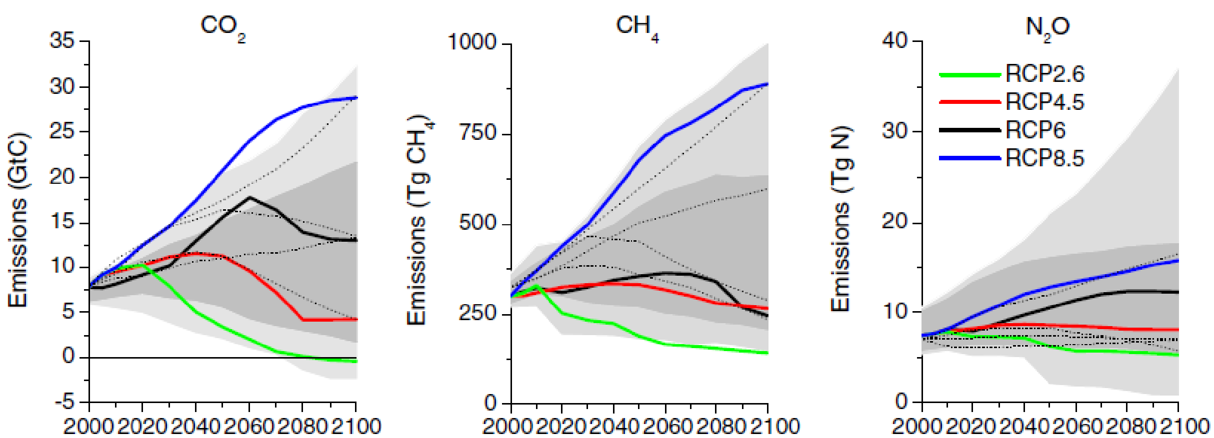


Figure 1: Graphics credit: Van Vuuren, D.P. et al. 2011. The representative concentration pathways: an overview. *Climate Change, 109*, pp. 5-31.

The graphics on page 87 show that Alaska has warmed considerably over the past 50 years, and scientists project significant ongoing temperature increases exceeding 10° Fahrenheit through most of the state under RCP8.5.[1080] Specific projections under RCP8.5 for Southeast Alaska are for average annual increases of 3° to 5° F by the 2040s and 5° to 9° F by the 2080s.[1081] Overall, Alaska has warmed twice as fast as the rest of United States, with increasing numbers of record-high temperature events.[1082] The most rapid warming is occurring in the Arctic, but Southeast Alaska has also warmed – by roughly 2.5° to 3.2 ° F over the past one-half century.

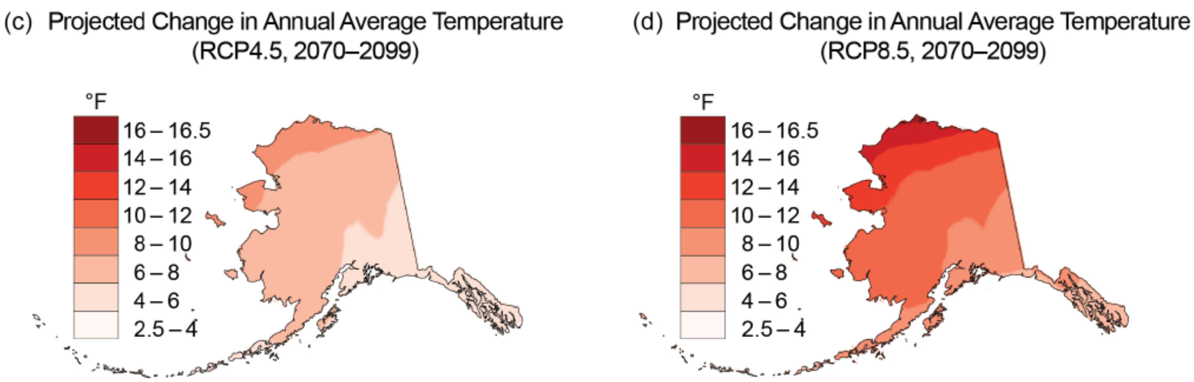


Figure 2: Scientists project that Southeast Alaska will experience considerable warming over the next half century. Graphics credit: Impacts, risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. https://nca2018.globalchange.gov/chapter/26.

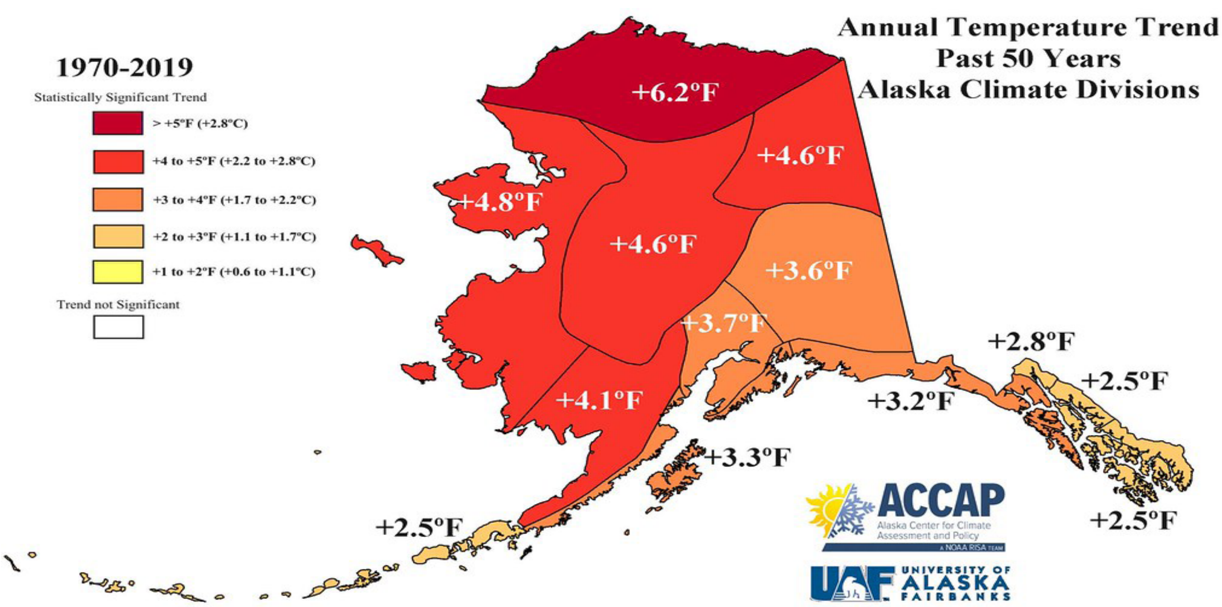


Figure 3: Graphics Credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

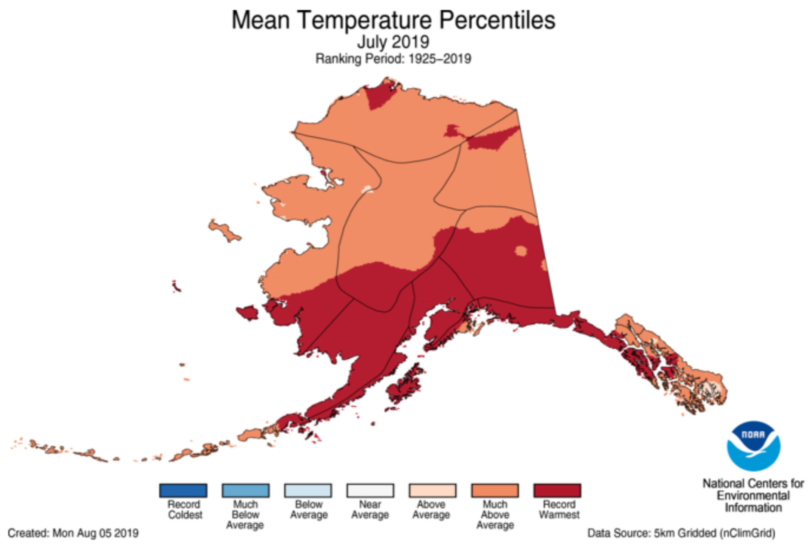


Figure 4: Graphics Credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

Beginning in the 1990s, high temperature records in Alaska began occurring three times more often than record lows.[1083] In 2015, high temperature records occurred nine times as often as record lows.[1084] The warmest years on record are 2016, 2018 and 2019, with 2019 being the first year with an annual average state temperature above freezing.[1085] The 2019 Alaska heatwave was globally significant.[1086] There were record high temperatures set in Southeast Alaska in both the spring and summer.[1087]

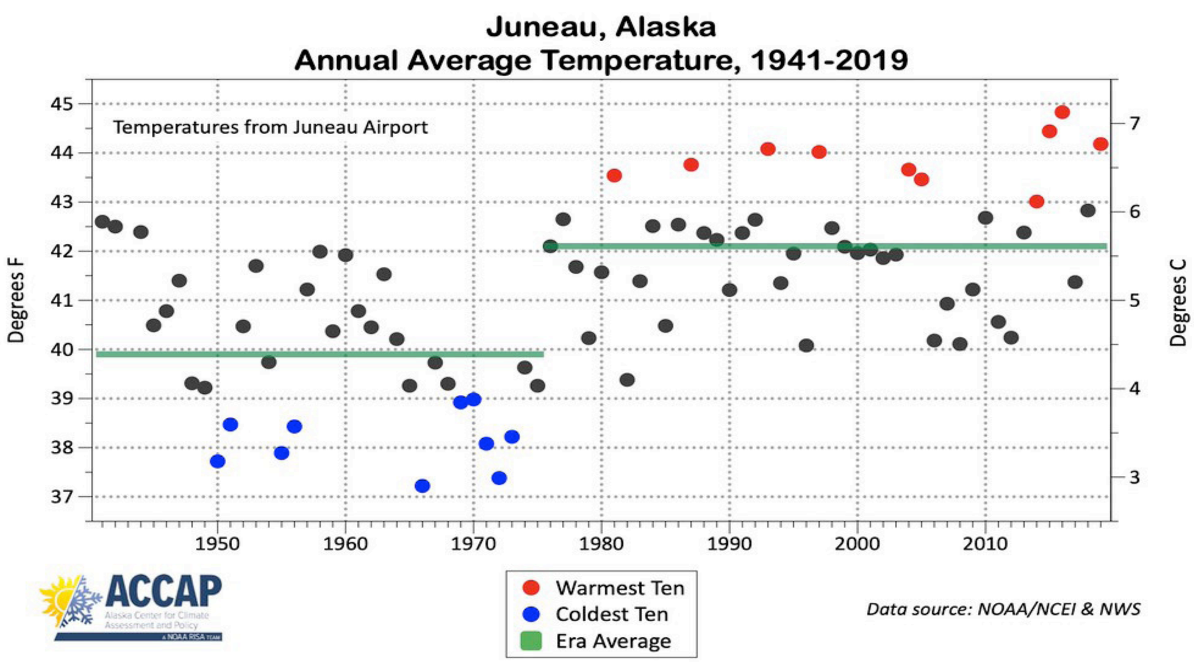


Figure 5: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

Warmer Winters and Snow Droughts

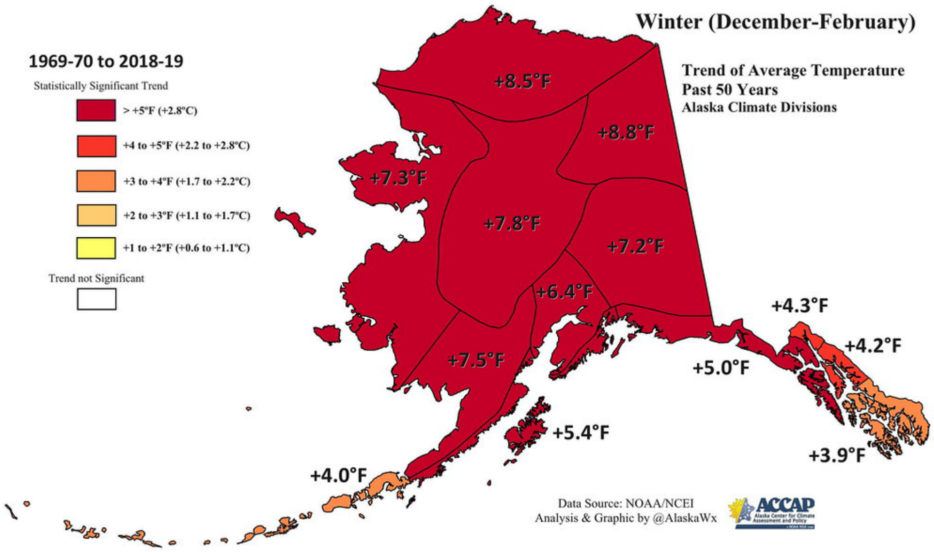


Figure 6: Graphics Credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate Program Office.

Alaska's winter temperatures are rising more than in any other season.[1088] During the winter of 2015-2016, statewide temperatures exceeded historical averages (1925 to 2016) by 8.4° F for the whole winter and by 10.9° F from January to April of 2016.[1089] There were multiple causes: warmer than normal ocean temperatures, diminished sea ice coverage, reduced snowpack and warming caused by climate change.[1090]

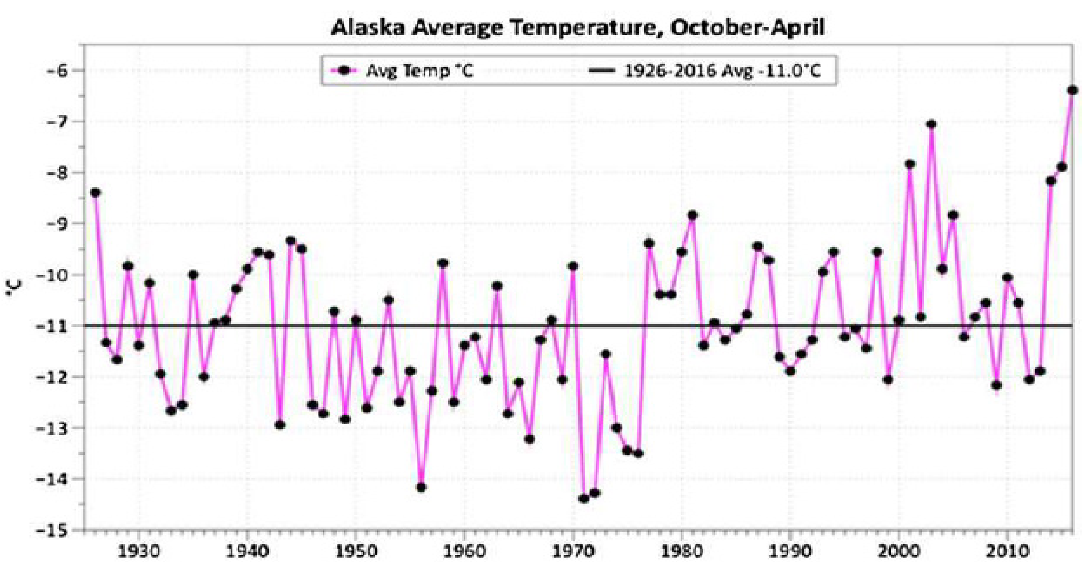
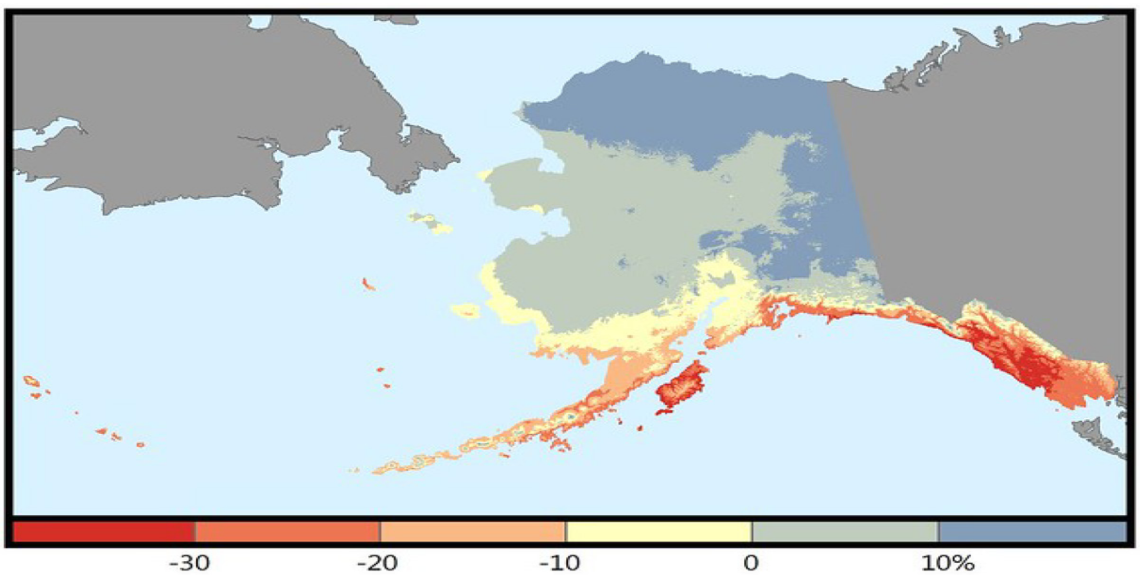


Figure 7: Graphics credit: Walsh, J.E., P.A. Bienek, B. Brettschneider, E.S. Euskirchen, R. Lader & R.L. Thoman. 2017. The exceptionally warm winter of 2015/16 in Alaska. *Journal of Climate 30*(6), pp. 2069-2088.

Southeast Alaska may experience the largest change in number of winter days above freezing in all of North America.[1091] Some climate models project there will be 30 to 40 more days per year without freezing temperatures between 2031 and 2060.[1092] Researchers project substantial decreases in Southeast Alaska snowfall over the next 40 years, mostly at lower elevations.[1093] Warmer winter temperatures will shorten the snow season by roughly one month, with autumns experiencing roughly one-half the historical snowfall and between 8 and 20 percent less snow during winter months.[1094] At the same time, total precipitation is likely to increase during autumn and winter.[1095] These changes cause "snow droughts," which occur when there is near- normal precipitation but less-than-average snow accumulation, causing affected areas to lose ecosystem services provided by snow, which range from water supply, cooling of the earth's surface and recreation.[1096]

Reduced snowfall and duration of snow cover will cause a fundamental shift in the hydrology of Southeast Alaska watersheds.[1097] Watersheds currently fed by snowpack will change into rain-fed systems.[1098] As glaciers disappear, presently glacial-fed watersheds will shift to relying on snowmelt and eventually become dependent on rainfall.[1099] These changes will increase winter stream flows, reduce summer stream flows and cause year-round increases in stream temperatures in most systems.[1100]



As warming in Alaska continues, the amount of snowpack remaining at the end of winter will change. The snow-water equivalent, or the amount of water held in the snowpack, on April 1, is predicted to increase in some parts of Alaska, and decrease in others. In the map above, you can see the changes predicted by 2050. (USDA Forest Service)

Figure 8

Warming and drought have already shifted forest communities and/or caused forest declines around the world, including yellow-cedar decline.[1101] Yellow-cedar decline is the most severe tree die-off in North America, with nearly 1 million acres of decline mapped in Southeast Alaska and British Columbia, with one-half of the loss occurring in Southeast Alaska.[1102] Snow droughts are the primary environmental driver of yellow-cedar decline.[1103] Warmer winters shifted the frequency of freezing and thawing events in late winter, and the lack of snow cover exposed yellow-cedar trees to root injuries.[1104]

There is increasing evidence that forest biodiversity and particularly mixed-species forests such as those found in Southeast Alaska are important to maximizing carbon sequestration and thus to climate change mitigation.[1105] Forest diversity also buffers ecosystems against environmental change, including drought, invasive species and other disturbances.[1106] Yellow-cedar is an important component of SeaBank forest diversity – the trees live for over 500 years on average and provide richer habitat values for wildlife.[1107] Losses of forest biodiversity such as yellow-cedar decline has altered soil and stream chemistry, changed understory plant communities and impaired ecosystem functioning, including potential reduction in carbon stocks, thereby accelerating climate change.[1108]

Extreme Weather Events: Drought and Atmospheric Rivers

Climate change will increase the frequency and intensity of extreme weather such as record heat, intense precipitation events associated with atmospheric rivers, marine heatwaves and other anomalous weather events.[1109] Alaska climate scientists project that the frequency of extreme weather events may double under a 2° F increase associated with RCP2.6, the reduced greenhouse gas emissions scenario, and if greenhouse gas emissions remain high under RCP8.5, temperatures could increase by 7. 2° F and cause extreme weather events to occur as often as one in every five years.[1110] Another concern raised by recent extreme precipitation events is that storms once thought of as impossible or extremely unlikely could become real concerns.

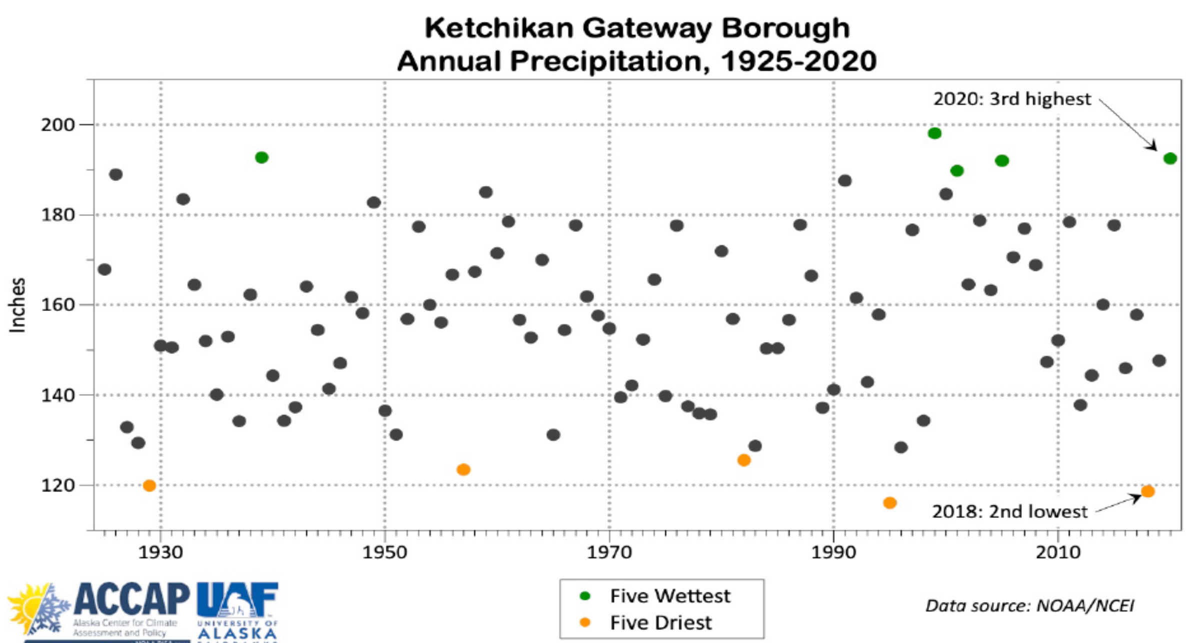


Figure 9: Ketchikan had its second driest year over the past century in 2018, followed by the 3rd wettest year two years later, in 2020. Graphics Credit: Thoman, R., R. Lader & J. Littell, 2021. Are we living in the future? The climate extremes of recent and future Southeast Alaska droughts and floods. Webinar by Arctic Research Consortium of the United States, Fairbanks, AK.

Southeast Alaska is normally one of the wettest areas 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.[1111] Yakutat, Pelican and Ketchikan all average over 140 inches a year. [1112] The two wettest cities in the continental U.S, New Orleans and Miami, receive just over 60 inches a year.[1113] One of wettest locations in Southeast Alaska, Port Alexander at the tip of southern Baranof Island, receives over 160 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.[1114] Scientists project significant increases in precipitation in Southeast Alaska, mostly during fall and winter.[1115]

From 2017 to 2019, Southeast Alaska had its lowest rainfall on record combined with record-high temperatures, with moderate drought conditions in the northern part of the region and severe to extreme drought conditions in central and southern regions.[1116] The drought was likely the most impactful ever in southern Southeast Alaska.[1117] Impacts included record-low streamflow and high stream temperatures that affected salmon migrations, water restrictions, increased power costs, sawfly infestations and even fire risks, with the 2nd highest acreage burned in the central Alaska Panhandle since 1950.[1118]

An extremely wet year followed the drought, with most of the region experiencing two to three times as much precipitation as normal in 2020.[1119] The wet summer and fall culminated in an atmosphe andric 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.[1120] If condensed into liquid water, the vapor creates a water layer as much as two centimeters thick. High winds accompany atmospheric rivers.

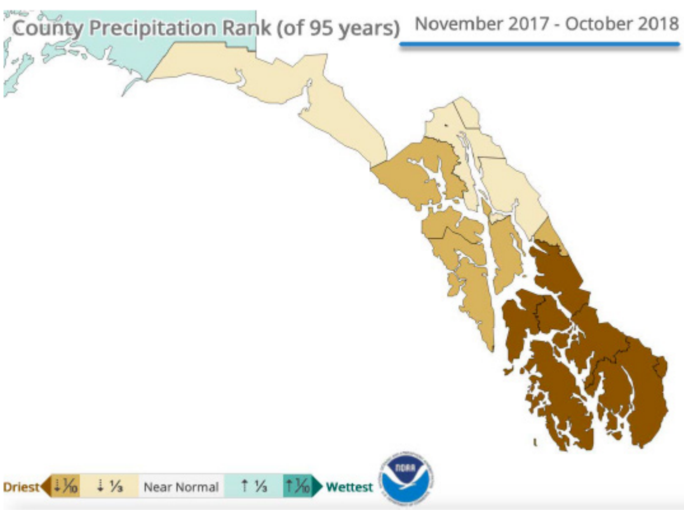


Figure 10: Graphics Credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks. Funded by the NOAA Climate Program Office, Silver Spring, MD.

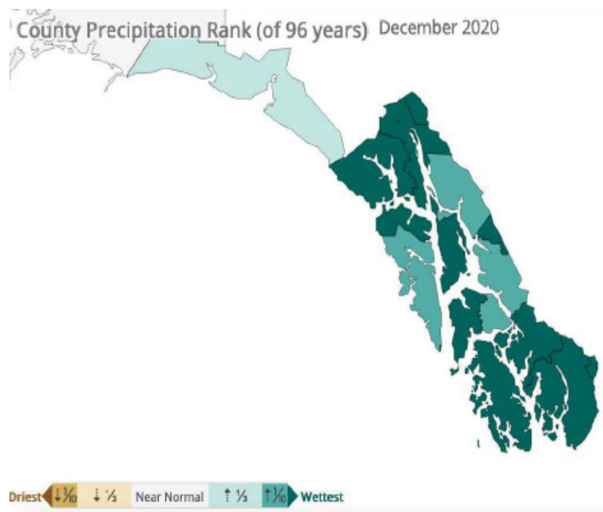


Figure 11: This graphic showss the extent of the Juneau Icefield and ice thickness in 2011. The right graphic illustrates projected shrinkage by 2099. Graphics credit: Ziemen, F.A., Hock, R., Aschwanden, A., Khroulev, C., Kienholz, C., Melkonian, A. and Zhang, J., 2016. Modeling the evolution of the Juneau Icefield between 1971 and 2100 using the Parallel Ice Sheet Model (PISM). Journal of Glaciology, 62(231), pp. 199-214.

Extreme precipitation, flooding, increased landslide and avalanche risks and record high stream flows can occur when atmospheric rivers make landfall and collide with coastal mountain ranges.[1121]

The impacts of the 2020 rainfall event were most notable in northern Southeast Alaska, setting rainfall records in Pelican, Haines, Hoonah, Juneau and Skagway.[1122] Haines received over seven inches of rain in one day, eclipsing its previous 1-day record, and 10.5 inches in two days.[1123] The event was a 200- to 500-year storm.[1124] Skagway, the driest city in Southeast Alaska, with an average of 30 to 35 inches of rain per year, received nearly nine inches in three days – a 1,000-year event.[1125] Pelican received over 18 inches of rain between November 30 and December 3, surpassed by Port Walter on southeastern Baranof Island, which received nearly 20 inches.[1126] Seven of the 50 largest cities in the United States average less precipitation for the entire year.[1127] Impacts included widespread flooding, landslides and power outages.[1128] Several days later, Ketchikan recorded its wettest week in 100 years, with 20 inches of rain in seven days.[1129]

> **"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, 92*(32).**

The frequency and severity of atmospheric rivers making landfall is likely to increase because warmer temperatures are increasing ocean evaporation, which generates more atmospheric water vapor.[1130] 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.[1131]

One of the implications of intense precipitation events – and precipitation falling as rain instead of snow – is a corresponding increase in landslide risk and frequency, because precipitation causes most landslides. [1132] Increased landslide frequency creates serious risks for public infrastructure, private property and public safety.[1133] 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.[1134] Some areas – large coastal islands and the northern mainland closest to Southeast Alaska – will see the frequency of landslide hazard days increase by as much as 60 percent over the next three decades, with 8 to 11 additional days of higher landslide hazards per year. [1135]

Climate Change and the Disappearing Glaciers

One of the major impacts of warming temperatures will be continued rapid thinning and recession of most of Alaska's glaciers.[1136] Normally, winter snowfall grows glaciers, which then shrink during the summer.[1137] Rising temperatures are causing summer melt to exceed winter gain.[1138] According to the International Arctic Research Center, Alaska glaciers thinned by several feet a year between 2002 and 2017 – an overall annual mass loss of nearly 60 billion tons of ice.[1139] Southeast Alaska and the adjacent Gulf of Alaska coast is the largest system of icefields

Scientists project a loss of between 18 and 45 percent of glacial mass in Alaska by the end of this century.[1140] The largest loss of glacial ice occurs in maritime climates such as those adjacent to the Gulf of Alaska..[1141] Alaska's current annual loss of glacial mass is 25 percent of the global loss (excluding ice sheets), and is rapidly accelerating.[1142] The loss of glacial and ice sheet volume will be one of the more significant causes of rising global sea levels this century.[1143] Glaciers draining into the Gulf of Alaska alone account for 7.5 percent of recent sea level rise.[1144]

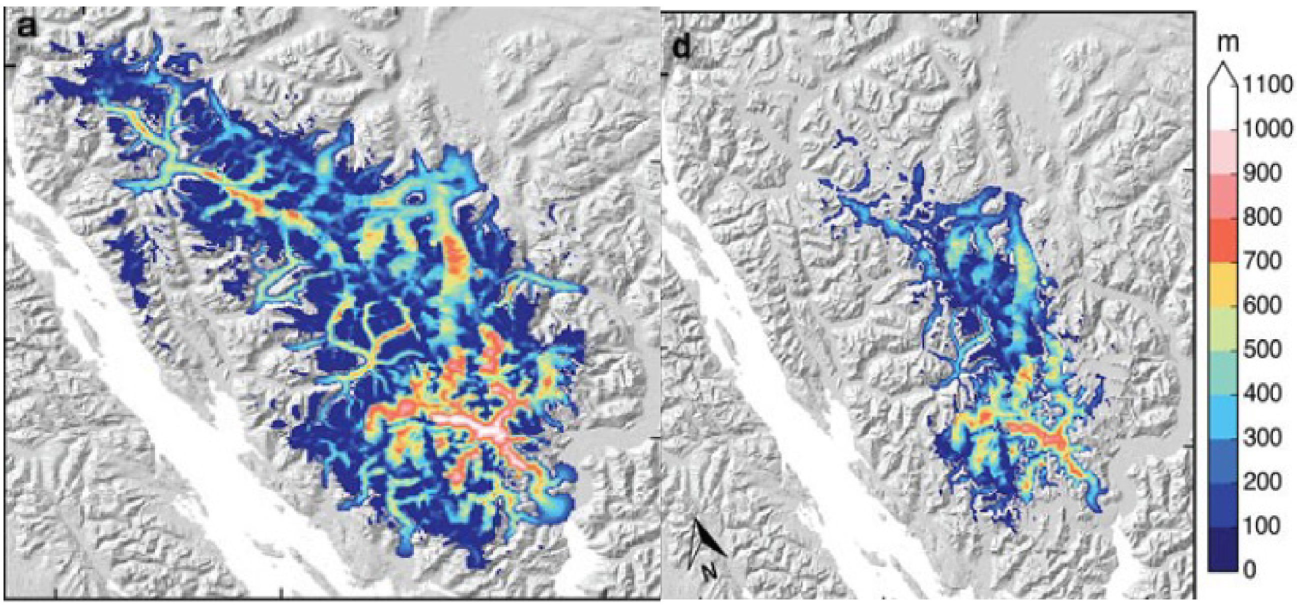


Figure 12: Gulf of Alaska sea temperatures have steadily warmed over the past thirty years, with six of the warmest years on record occurring this decade. Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate program office.

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.[1145] 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.[1146] Even so, the Juneau Icefield may lose nearly two-thirds of its volume and area by the end of the century.[1147]

Glacial runoff influences downstream freshwater and near-shore marine ecosystems.[1148] Changes in flow, temperature and mineral nutrient dynamics in freshwater ecosystems in turn influence fish abundance across multiple lifecycle stages.[1149] 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 lifecycle.[1150] Species such as harbor seals and Kittlitz's murrelets that depend on glacial habitats for breeding are likely to decline due to habitat loss.[1151] The retreating glaciers may also open up new habitat for salmon, particularly in northern Southeast Alaska where glaciers cover 25 percent of the watersheds.[1152]

Climate Change Effects on Salmon Fisheries

The Warming Ocean

Changes in ocean chemistry and warmth will also impact SeaBank marine resources. The most rapidly-occurring effects on ecosystem services provided by oceans are changes to ecosystems that support fisheries.[1153] There are ongoing reductions in ecosystem service values for some fisheries and potential long-term marine productivity losses of up to 20 percent.[1154] Consecutive years of warmer water and associated food web changes are particularly challenging for ectothermic marine species (i.e., cold-blooded species, such as fish, that rely on external factors, such as water temperature, to regulate body temperature).[1155] Temperature drives metabolic and growth rates, distribution, intensity of foraging and prey qualities.[1156] Because fish species are highly sensitive to rising ocean temperatures, changes in species productivity are occurring much more rapidly than for terrestrial animals.[1157] Three common responses include shifts in range, shifts in timing of lifecycle events, and changes in body size.[1158]

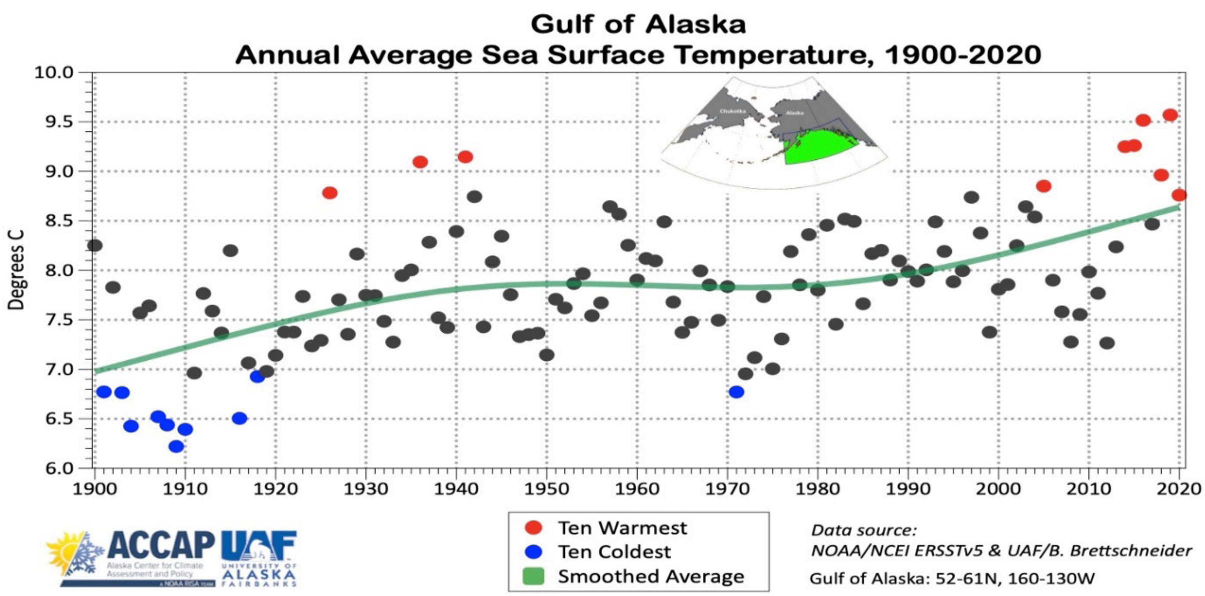


Figure 13: Gulf of Alaska sea temperatures have steadily warmed over the past thirty years, with six of the warmest years on record occurring this decade. Graphics credit: Alaska Center for Climate Assessment & Policy, University of Alaska Fairbanks, funded by the NOAA Climate program office.

A major risk to Alaska's fisheries is the increased frequency and intensity of marine heatwaves, which cause major disturbances to marine ecosystems, biodiversity and fishery productivity.[1159] The northeast Pacific marine heatwave from 2014 to 2016 was the longest-lasting marine heatwave on the planet over the past decade.[1160] Both the Bering Sea and Gulf of Alaska were anomalously warm during this heatwave, with record sea surface temperatures and ocean heat content. [1161] The heatwave had multiple causes, including warming caused by climate change, a strong El Niño pattern and a possible warm phase of the Pacific Decadal Oscillation.[1162] Gulf of Alaska sea surface temperatures and heat content were both 3.6° F above normal.[1163] The heatwave also contributed to record-high winter-spring temperatures onshore.[1164] The warm phase changed the marine ecosystem in the Gulf of Alaska.[1165]

Another marine heatwave developed in late 2018 and persisted until the fall of 2019.[1166] The eastern Gulf of Alaska had a brief heatwave in 2020 but ocean temperatures have shifted to pre-heatwave environmental conditions.[1167] Climate change increases the risk of more marine heatwaves in the future, and extreme heatwaves may become common.[1168]

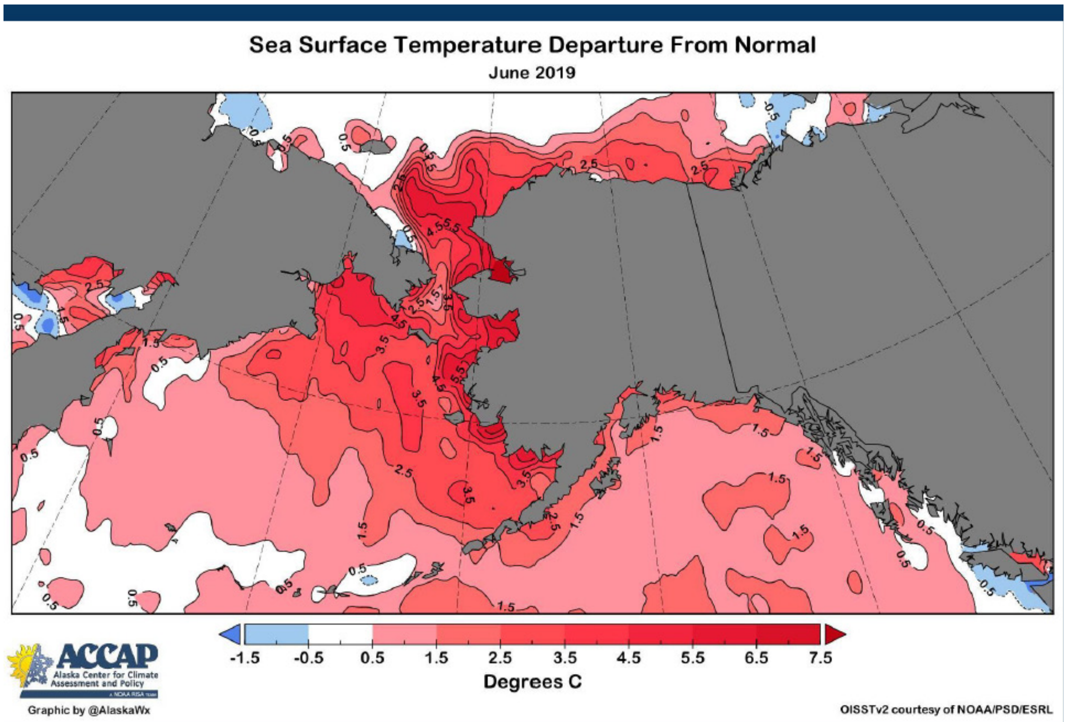


Figure 14: Mathis, J.T., Cooley, S.R., Lucey, N., Colt, S., Ekstrom, J., Hurst, T., Hauri, C., Evans, W., Cross, J.N. and Feely, R.A., 2015. Ocean acidification risk assessment for Alaska's fishery sector. *Progress in Oceanography, 136*, pp.71-91.

In the Gulf of Alaska, the 2014-2016 heatwave caused shifts in the ranges of commercial fish species and declines in their abundance and condition and in that of their forage.[1169] Reduced productivity from the base of the food web upward depressed growth and survival of prey species and many commercial fish species.[1170] Cold-water fish must consume more food in warmer waters, and often expend excess energy in times of prey depletion. Some species declined precipitously.[1171] Pacific cod, for example, had difficulty finding food needed to meet increased energetic demand during the extended heatwave.[1172] With high adult and juvenile mortality rates, the population declined over 70 percent between 2015 and 2017.[1173] In general, commercial species depressed by heatwaves are ones relied upon by high-revenue fisheries that provide a substantial portion of regional ex-vessel values.[1174] The warming temperatures are a probable cause for the low returns of pink salmon that went to sea from 2014 through 2016.[1175] Those returns were below recent averages, and harvests were below projections.[1176]

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

An increasing amount of research describes the effects of warming oceans on the decreased adult size of many marine fish species.[1177] Warming-induced reductions in body size are pervasive.[1178] Many fish species grow more rapidly as juveniles in warmer water, but then mature at smaller sizes as adult fish, a phenomenon known as the "temperature-size rule" and a cause of significant harm to commercial fisheries productivity.[1179] In warmer waters, the metabolism of fish increase along with their need for forage, yet this warmth also often decreases the energy and nutritional contents of prey. This causes predatory fish to be smaller, and also adversely affects their reproduction and activity.[1180]

The temperature-size rule applies to roughly 80 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. In other words, oxygen is a limiting factor, shaping the temperature-size rule in fishes. The size loss is most dramatic in more active fish species, which are often the main species targeted in commercial fisheries. Significantly for fisheries, the temperature-size rule decreases in adult body sizes may reduce fisheries yields by 23 percent or more for some species. Recent studies of Atlantic fish species showed that adults were smaller, both in much-warmed high latitude oceans and in lower-latitudes oceans that warmed moderately.

Larger fish have several survival and population advantages, including fecundity (ability to produce more offspring), longer life spans, greater resiliency, enhanced predatory ability and the ability to avoid other predators. One primary ecological concern is that smaller fish sizes cause lower reproductive outputs. Many fisheries 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 recruitment success, so that size declines may reduce the capacity of marine fish to replenish.

Ocean Acification Risks to SeaBank Natural Capital

Oceans have absorbed over 600 billion tons of CO_2 since the early 1800s.[1181] This uptake equals nearly one-third of the anthropogenic CO_2 emissions since that time, and has helped prevent an even more rapid rise in atmospheric CO_2 and climate change impacts.[1182] CO_2 uptake has caused oceans to become nearly one-third more acidic since the 1850s through a process known as ocean acidification. [1183] This fundamental chemical change in the ocean is known as "the other CO_2 problem," the first being increased atmospheric CO_2. [1184] As CO_2 dissolves in the ocean, it reduces ocean pH, changing water chemistry.[1185] 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.[1186] Population-level effects are uncertain but numerous laboratory studies have shown that ocean acidification reduces the rate of both growth and calcification (the biological process of shell-building) for these species.[1187]

Unlike many climate projections, the process of ocean acidification is predictable with few uncertainties, as are the increasing levels of acidification.[1188] The rate of acidification will accelerate this century unless there are dramatic cuts in CO2 emissions.[1189] Its 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 higher CO2 capacity of cold waters.[1190] Also, ocean acidification is occurring concurrently with other climate change stressors affecting fish at an unprecedented pace.[1191]

The effects of ocean acidification on marine species are mostly negative.[1192] Highest impacts are on shelled species such as crab, and on planktonic species at the base of the marine food web. As acidification depletes calcium carbonates, shelled organisms have greater difficulty building and maintaining shells.[1193] Alaska's oceans, marine species and coastal communities are highly vulnerable to ocean acidification because rapid transitions in ocean temperature and chemistry, which commenced earlier this decade, are likely to increase significantly in the future, harming the marine food web and fisheries resources.[1194] Projections of more rapid acidification make Southeast Alaska one of the state's two most vulnerable regions, due to its economic dependence on crab, salmon and shellfish.[1195] The most vulnerable Southeast Alaska shellfish species are Tanner crab and king crab.[1196]

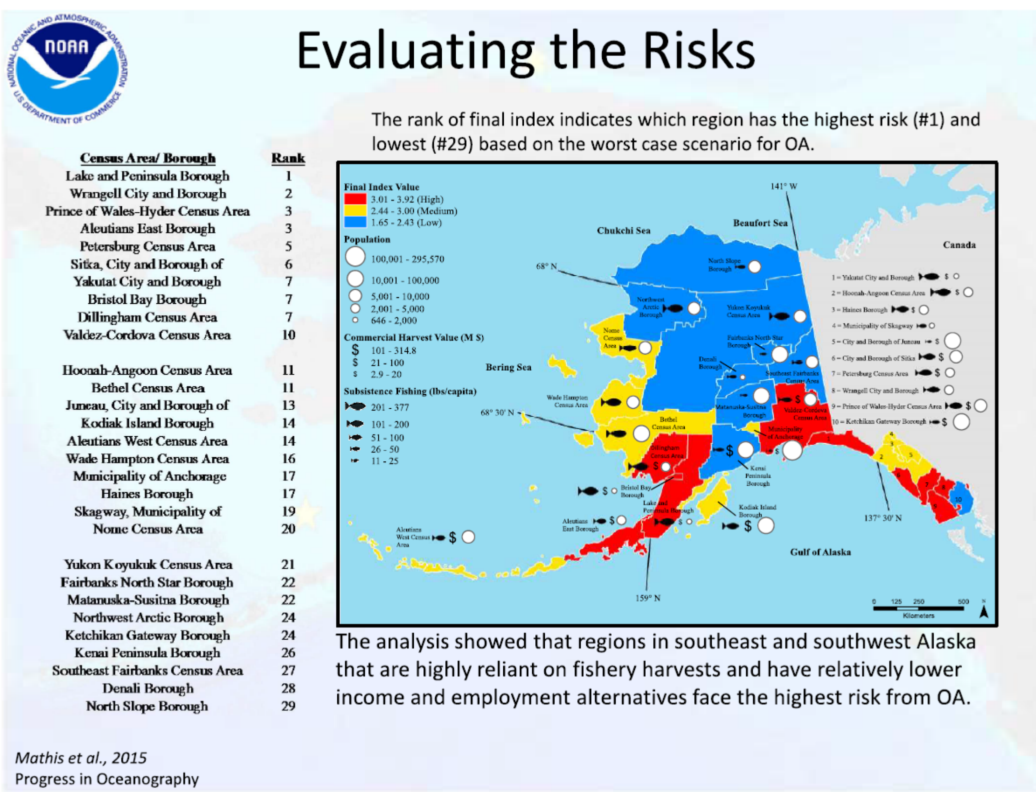


Figure 15: Mathis, J.T., Cooley, S.R., Lucey, N., Colt, S., Ekstrom, J., Hurst, T., Hauri, C., Evans, W., Cross, J.N. and Feely, R.A., 2015. Ocean acidification risk assessment for Alaska's fishery sector. *Progress in Oceanography, 136, pp.* 71-91.

While the effects on shelled marine species are well-known, concern is increasing about impacts to behavioral responses for salmon and other finfish.[1197] The earliest studies of salmon susceptibility to ocean acidification suggest changes in the food web are related to potential major declines of important invertebrate prey species such as pteropods, crustaceans and krill.[1198] Evidence shows that increased ocean acidification is harming olfactory sensitivity of coho salmon, which plays a key role in helping fish find food, avoid predators and migrate to natal streams.[1199] Because of this impact, some researchers have concluded the projected increases in ocean CO2 may profoundly affect salmon.[1200]

Although studies of pink salmon indicate better behavioral resilience than coho salmon to ocean acidification, pink salmon may be the most vulnerable species because of their heavy forage reliance on pteropods.[1201] Pteropods are one of the species most susceptible to acidification, indicating impacts on ecosystem integrity. [1202] By 2050, in Southeast Alaska as well as at higher latitudes, undersaturation (unavailability) of aragonite in surface waters may preclude pteropods from forming shells.[1203] It is possible that pteropods will not survive in seawater that is undersaturated with aragonite, causing a population shift to shallower depths and lower latitudes.[1204] Pteropods are one of the more important foods in the North Pacific food web, feeding a variety of plankton and fish, and making up over one-half of the pink salmon diet.[1205] Thousands of individual pteropods can be found in a cubic meter of ocean (equivalent to a 250-gallon tank).[1206]

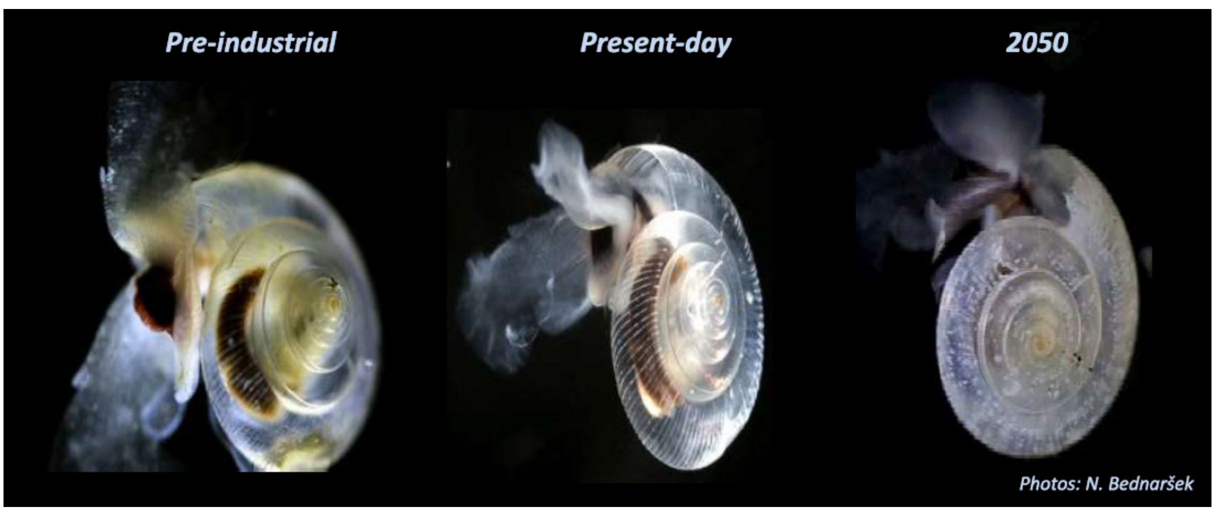


Figure 16: Graphic credit: Jeremy Mathis, 2016. Using An Environmental Intelligence Framework to Evaluate the Impacts of Ocean Acidification in the Arctic, ARCUS Arctic Research Seminar Series. Funded by the NOAA Climate Program Office, Silver Spring, MD. https://www.youtube.com/watch?v=V1kq7I3X5SY.

Ocean acidification causes severe shell dissolution and reduced survival of pteropods. Considerable evidence shows shell dissolution is occurring. A study of pteropod populations found in the California Current Ecosystem (CCE) shows they may be at the limit of their capacity to adapt to corrosive conditions. The CCE is experiencing CO2 concentrations similar to levels projected for Alaska marine waters. Scientists estimate that ocean acidification was responsible for doubling incidences of severe pteropod shell dissolution in near-shore habitats over the past one and a half centuries, and increasing severe shell dissolution is expected in the near future. The study concludes that some pteropod populations are already at risk of extinction under projected acceleration of ocean acidification over next 30 years.

Salmon in Double Jeopardy: Marine and Freshwater Environment

Salmon is by far Alaska's most important commercial fish species, generating $715 million in 2019 ex-vessel values and over one-third of statewide fisheries value.[1207] The recent marine heat-waves were a primary cause of fisheries disaster declarations for 10 salmon fisheries throughout Alaska. The recurring heatwaves secondarily caused other unfavorable ocean conditions that contributed to the low abundance and poor marine survival of all salmon species in the Gulf of Alaska.[1208]

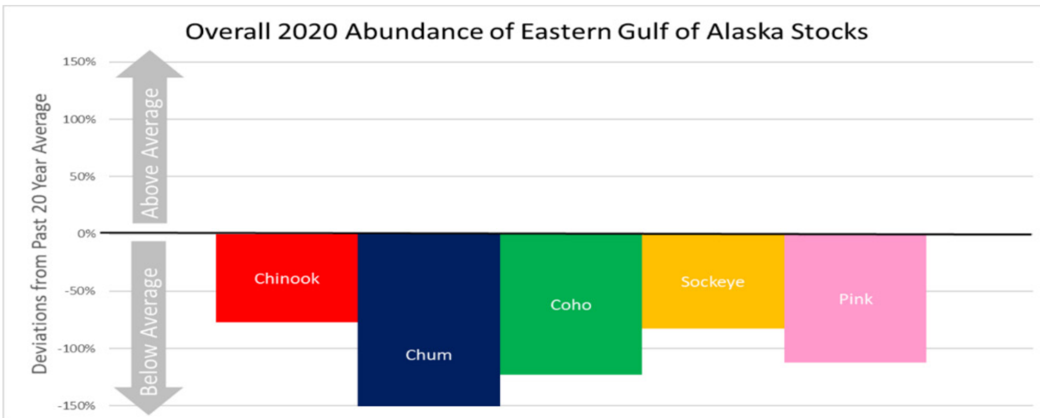


Figure 17: Graphics credit: Alaska Department of Fish and Game Undersea World of Salmon and Sharks. Available at: www.facebook.com/ADFGUnderseaWorldOfSalmonAndSharks.

Salmon use a combination of freshwater, estuarine and marine habitats at different stages of their lifecycle, resulting in exposure to multiple climate-change-related threats.[1209] Climate change is already stressing salmon stocks by altering summer and winter stream flows and increasing both marine and freshwater temperatures.[1210] Water temperature is a major driver of salmon system productivity, influencing spawn timing and the incubation, growth, distribution and abundance of eggs. [1211] Each salmon stock is adapted to local conditions in a watershed, including temperature and stream flow patterns.[1212]

Stream warming, summer water deficits and changes in summer stream flow can reduce habitat values for growth, spawning and survival.[1213] In many cases, higher stream temperatures can function as dams that block migratory corridors.[1214] Even prior to the recent onset of warming stream temperatures, there was a long history of pre-spawning mortality events in the smaller watersheds (usually caused by a combination of warm temperature effects on metabolism and the oxygen capacity of water), respiration by a high density of returning salmon and low summer water discharge.[1215] Smaller watersheds and small streams which provide salmon habitat and benefit water quality in larger systems are prevalent in the region and are most vulnerable to pre-spawning die-offs.[1216]

Projected increases in Southeast Alaska's regional air temperature and changing precipitation patterns will continue to affect watersheds and salmon.[1217] Even though climate change models project overall precipitation increases, projected decreases in summer rain and snow droughts in winter may reduce summer stream flows while increasing stream temperatures.[1218] Regional snowfall may decline 40 percent by 2100; summer flows may be lower in snow-fed as well as rain-fed streams.[1219]

Stream warming will affect each salmon species and stock differently.[1220] Stocks with the longest migrations (Chinook) and species with a longer freshwater phase of their lifecycle (coho) have high vulnerability to stream warming and other hydrologic regime changes.[1221] Low late-summer flows and high temperatures which periodically occur in southern Southeast Alaska streams are likely to become more common throughout the region, increasing pre-spawning mortality for pink and chum salmon returning to spawn during summer months.[1222]

There is some variability in how SeaBank salmon systems will respond to warming because of differences in elevation, terrain, lake coverage and the proportion of stream-flow-derived rainfall runoff or snowmelt.[1223] Scientists starting to study regional streams and other Alaska watersheds are identifying watershed-specific factors that may help predict stream susceptibility to increasing air temperatures.[1224] In Southeast Alaska, lower-elevation watersheds with higher lake coverage will be most vulnerable to warmer air temperatures.[1225] Warmer summer stream temperatures are likely because lakes have the most 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.[1226] In normally colder streams, fish productivity may increase because of enhanced juvenile growth potential.[1227]

Systems influenced by glacier melt are less vulnerable to increased air temperatures so long as glaciers persist.[1228] In some glacier-fed systems, rivers that are currently too cool to support high levels of salmon productivity may support increasing numbers of salmon as they warm.[1229] Melting glaciers in Glacier Bay are currently creating small streams colonized by pink salmon.[1230] As glaciers continue melting, northern Southeast Alaska inside waters and the Gulf of Alaska coast to Yakutat and beyond will have stream systems capable of producing hundreds of thousands or even millions more salmon, depending on the species.[1231]

Alaska's water quality standards for temperature are 15° C (59° F) for salmon migration routes and rearing areas, and 13° C (56° F) for spawning areas and egg and fry incubation.[1232] Temperatures above 20° C (68° F) are generally deemed lethal for salmon. Stream temperatures in 2019 in many parts of Alaska far exceeded the 59° F threshold for migrating and rearing fish and a 56° F threshold for spawning fish, in some cases reaching 80° F.[1233] Surveys of Western Alaska systems in June and July 2019 found that thousands of summer chum salmon died while migrating upstream to spawning grounds as stream temperatures reached 64° F, exceeding typical temperatures for that tributary by 3° to 5° F.[1234]

These concerns are present in Southeast Alaska. Low stream flows and/or high temperatures may have played a significant role in low juvenile pink salmon abundance indices during the recent, warmer drought years. 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. In Staney Creek, a heavily-logged watershed near Klawock on Prince of Wales Island, summer stream temperatures exceeded lethal levels each of the past three years.

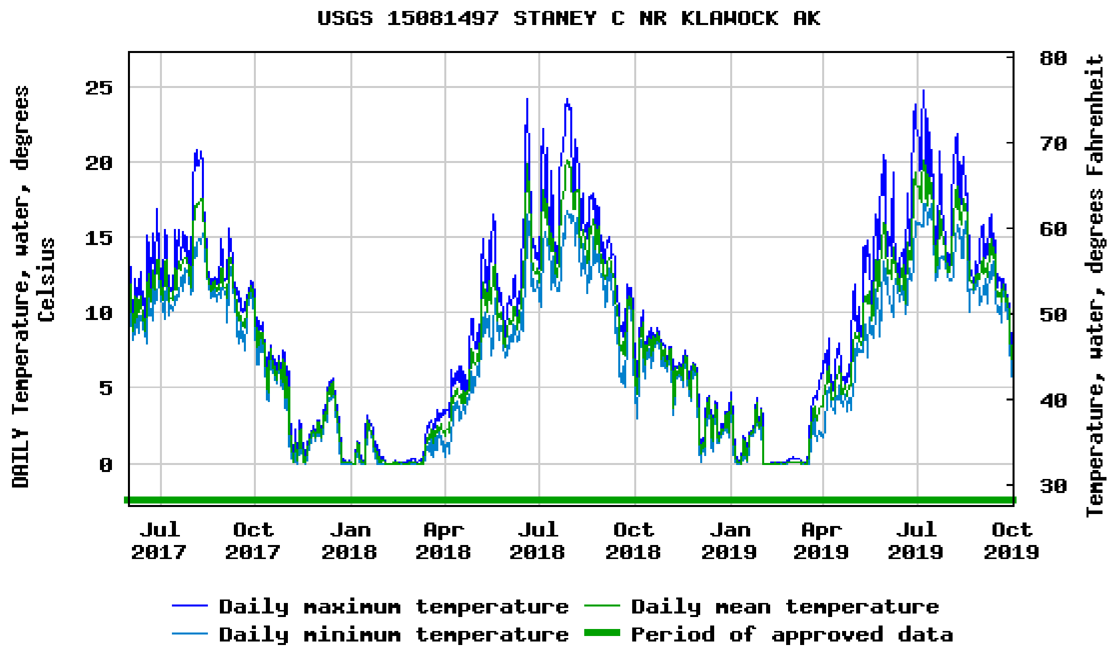


Figure 18: Graphics credit: Graphics credit: Alaska Coastal Rainforest Center. University of Alaska Southeast, Juneau, AK.

Even the glacier-fed Situk River near Yakutat exceeded temperature thresholds in 2019.

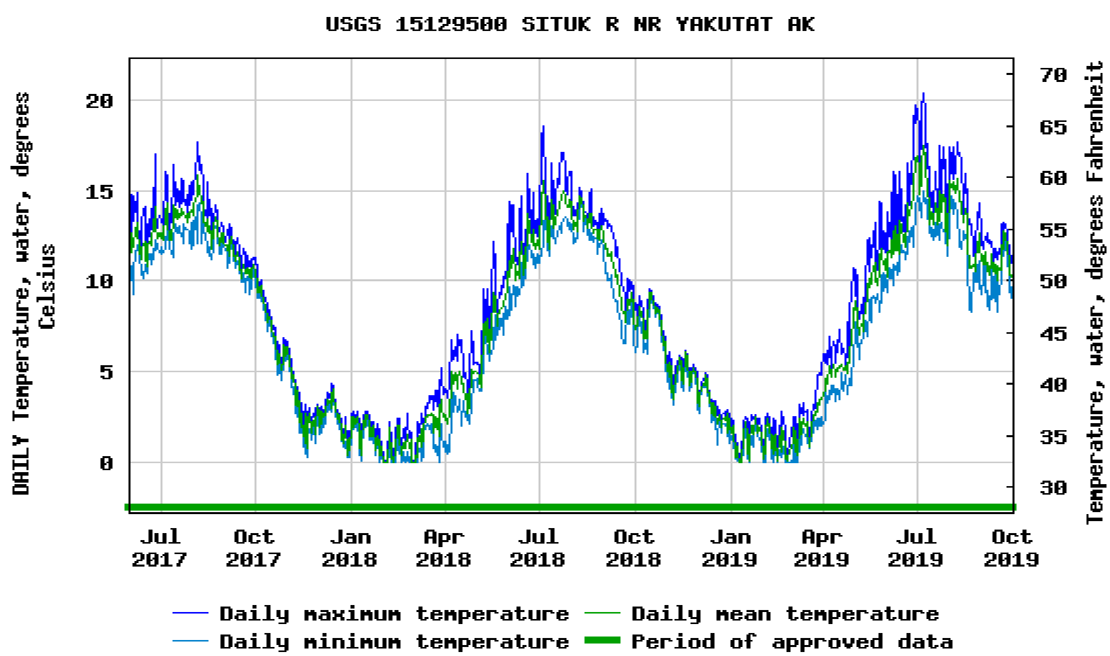


Figure 19: Graphics credit: Graphics credit: Alaska Coastal Rainforest Center. University of Alaska Southeast, Juneau, AK.

Climate change research studying Chinook populations in Southcentral Alaska showed that warmer streams exceeding Alaska's temperature standards reduced population productivity at multiple life stages.[1235] There was increased mortality of migrating adults and eggs and lower survival for rearing juvenile fish.[1236] The study confirmed 68° F as a lethal threshold.[1237] Observed productivity declined when temperatures ranged between 64.4° and 71.6° F during spawning.[1238] Concurrently, conditions such as heavy fall rains occurred simultaneously across many different spawning and rearing streams. [1239] These findings and other climate change effects in Alaska increasingly indicate that changes in freshwater habitat conditions caused by fall and winter storms, drought and warming stream temperatures have had a significant role in causing recent salmon population declines in Alaska.[1240]

Some scientists suspect that extreme precipitation or flooding events may be equally or even more harmful to Southeast Alaska salmon than rising summer stream temperatures.[1241] An overall warmer, wetter climate will intensify precipitation events in the fall and winter when salmon eggs incubate.[1242] Increased precipitation, and more precipitation falling as rain instead of snow, is likely to increase fall and winter flooding 17 percent by 2050 and 28 percent by 2100.[1243] The higher flows have mostly negative effects that include increased embryo mortality.[1244] Stream bed scouring reduces egg-to-fry survival and increases fine sediment levels.[1245] 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.[1246] 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.[1247] High flow events may eliminate as much as 10 percent of coho spawning habitat over the next two decades.[1248] 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.[1249]

Warmer winter months accompanied by even modest increases in stream temperature will alter salmon egg incubation rates and emergence timing.[1250] Watersheds with identified warming trends are already demonstrating fish responses. Bristol Bay sockeye are leaving warmer freshwater lakes earlier.[1251] The proportion of sockeye spending one year instead of two years in freshwater is increasing because climate-change-related growth opportunities enabled earlier migration to the ocean.[1252] Auke Creek near Juneau is a low-elevation watershed identified as vulnerable to rising air temperatures.[1253] Long-term temperature increases have resulted in observed shifts in spawning timing.[1254] As average long-term water temperatures increased for the incubation stage, pink salmon fry began outmigration to the marine environment earlier.[1255] The earlier fry migration in turn caused earlier returns by pink salmon adults.[1256] Researchers suspect that Auke Creek could become unsuitable habitat for pink salmon in the long-term because early migrations have caused adults to return earlier during high summer stream temperatures, which increases the risk of pre-spawning mortality.[1257]

These climate driven changes associated with the timing of key life history events such as fry emergence and spawning are affecting salmon body sizes. All Alaska salmon species are becoming smaller, mainly because they are returning to reproduce at a younger age than in the past.[1258] Most of the body size declines are recent – sockeye, chum and coho all showed abrupt decline in body size starting in 2000, and intensifying after 2010.[1259] Declines in body size over the past 30 years are most notable for the largest of the species, Chinook salmon.[1260] Declining body size has significant implication for productivity – smaller Chinook salmon produce 16 percent fewer eggs, 21 percent lower fisheries values and 26 percent less rural food supply.[1261]

As explained in more detail in Chapter 6, other anthropogenic stressors such as mining, logging and road construction will intensify climate change vulnerabilities by contributing to increased stream temperatures, landslide risks and high and low extremes in stream flow.[1262]

Photo Credit: Tim Hancock

Chapter 6: Threats from Logging

The many provisioning, supporting, regulating and cultural services provided by Southeast Alaska's most productive ecosystems – used for commercial fishing, subsistence, recreation and tourism, climate and intrinsic existence purposes – are highly vulnerable to forest degradation caused by past, present and future industrial-scale clearcut logging. Between 1954 and 2004, industrial-scale logging on a mix of federal, state and privately owned lands removed much of the large, contiguous old-growth forest, leaving fragmented landscapes.[1263] Timber companies targeted the largest old-growth trees, removing roughly two-thirds of the highest-volume forest by 2004, with disproportionate impacts on the most productive fish and wildlife habitat.[1264]

The Tongass National Forest is the only national forest still subjected to substantial amounts of old-growth logging in recent decades.[1265] The Forest Service's 2016 amendment to the Tongass Land and Resource Management Plan ("Forest Plan") authorized continued high levels of old-growth logging over the next decade while also seeking to transition over time to logging second-growth forests.[1266] In July 2021, the U.S. Department of Agriculture (USDA) announced that it would end large-scale old-growth timber sales on the Tongass.[1267]

Although the Forest Service has been unable to attain its planned level of logging in recent years,

These photos show the intensity of recent clearcutting on private land on Prince of Wales Island. Photo credit: Resnick, J. & Stone, E. 2022. (Grist, CoastAlaska and Earthrise Media). Still photography by Eric Stone; Drone photography & video by SEAKdrones LLC.

annual forest loss has ranged from 3,000 to 5,000 acres over the past decade, and continues.[1268] Nearly one-half of that logging occurs on formerly public lands transferred from the Forest Service to state or private entities through Congressionally-approved land exchanges.[1269] In the last three decades of the 20th century, the Alaska Division of Forestry, the Alaska Mental Health Trust, the University of Alaska and corporate landowners contracted out the logging of over 400,000 acres of their old-growth forestland holdings in Southeast Alaska. They have been responsible for most of the logging in the region in the 21st century.[1270] These land exchanges to entities that generate revenue from timber sales are among the most significant threats to SeaBank ecosystem services.

The most intensive clearcutting of these larger-tree, old-growth forests occurred in federal and nonfederal forestlands on several major islands: Etolin, Kupreanof, Mitkof, Kuiu, Prince of Wales, Revillagigedo, Wrangell and Zarembo.[1271] These areas have suffered habitat loss at a much greater rate than other portions of Southeast Alaska.[1272] Prince of Wales Island is by far hardest hit, with timber companies having logged nearly 400,000 acres on the island accompanied by over 5,000 miles of road construction. Logging there was most intense for four decades beginning in the 1950s, but is still substantial with losses of over 80,000 acres in the last 30 years. Substantial amounts of nonfederal, old-growth forests are at risk in the near future.[1273] Another major concern is the need to restore Roadless Rule protections to

Recent clearcuts by non-federal landowners are present throughout the Prince of Wales Island landscape. Photo credit: Colin Arisman.

Tongass roadless areas. The Roadless Rule protected nearly 9.4 million acres of intact habitats in Southeast Alaska, including some contiguous areas that exceed 1 million acres.[1274] The USDA published the Roadless Rule in January 2001.[1275] It prohibited logging and road construction in inventoried roadless areas on the Tongass because of the high value of the region's unique ecosystems and abundance of intact habitats.[1276] Two years later, the USDA reversed that decision and exempted the Tongass.[1277] Years of litigation followed, eventually resulting in reinstatement of the Roadless Rule in 2011, which the State of Alaska later unsuccessfully challenged in federal court. [1278]

In 2018, the State of Alaska petitioned the USDA to consider a state-specific rule to again exempt the Tongass from the Roadless Rule. [1279] After accepting the petition and conducting a regulatory process, the agency removed all 9.4 million acres from Roadless Rule protections and published its final rule exempting the Tongass in October 2020.[1280] Roughly a year later, in November 2021, the USDA initiated a regulatory process to reinstate the Roadless Rule based on the increasing value of undisturbed forestlands for ecosystem services such as wildlife and fish habitat, recreation, cultural value and the contributions these services make to regional socio-economic well-being.[1281] In particular, the agency recognized the importance of roadless areas to the two primary private sector economic drivers of tourism and fishing.[1282]

The timber industry in Alaska is not a significant economic driver, in part because of competitive disadvantages in the national and global economy.[1283] The federal timber sale program operates at a massive taxpayer loss due to the amount of public funds spent on roads, timber sale preparation and other related costs in excess of timber sale revenues.[1284] Over time, several independent reviews of the timber sale program have estimated that annual taxpayer losses range from $20.5 million to $33.8 million depending on the time frame analyzed.[1285]The Forest Service intended the 2020 Roadless Rule exemption to benefit the two timber companies that

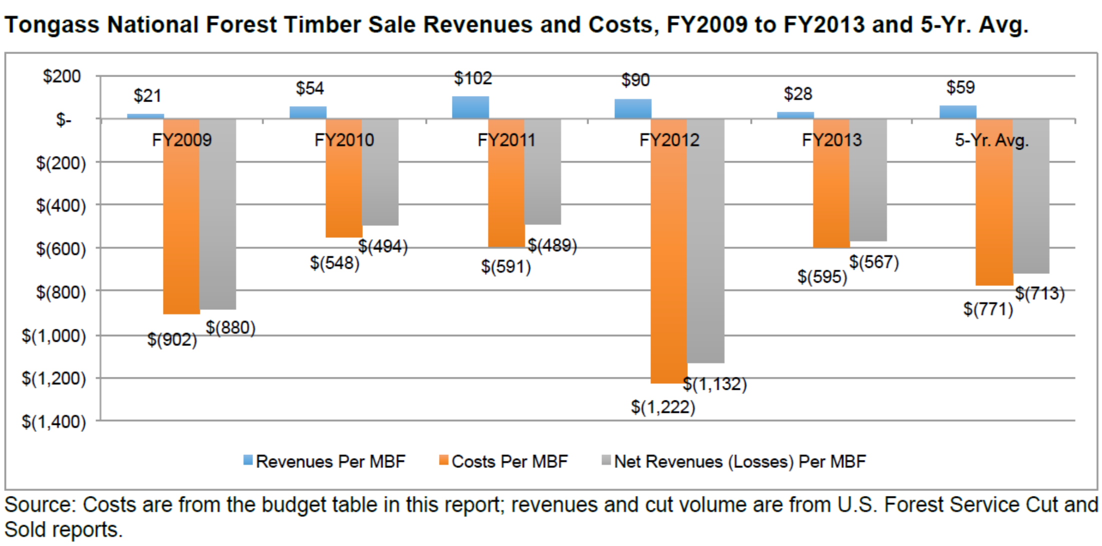


Figure 1: The Forest Service incurs substantial losses per thousand board feet (MBF) of timber sold, and on average spends at least 10 times as much money on timber sale administration and infrastructure as logging companies pay for the timber. Graphics credit: Headwaters Economics. 2014. The Tongass National Forest and the Transition Framework: A new path forward?

purchase all of the larger federal timber sales.[1286] Forest Service policies allow these two timber sale purchasers to export one-half of the hemlock and spruce and most of the more valuable cedar as unprocessed logs, mostly for processing in Asia.[1287] The agency projects that these companies would likely export roughly two-thirds of the timber as unprocessed logs.[1288] There are additional concerns related to mismanagement of timber sales purchased by these companies. The Forest Service's own 2016 and 2020 investigative reports acknowledged the controversial ecological and financial costs and management problems associated with the Tongass timber sales program.[1289] Both reports identified multiple management concerns related to inadequate oversight, contractual and appraisal issues and other discrepancies that increased the cost of these sales to the public.[1290]

Logging Impacts to Wildlife Biodiversity

SeaBank biodiversity assets include over 300 mammal and bird species.[1291] Its old-growth forests and largest undisturbed tracts of land have high biological value for these diverse animal communities.[1292] Large and ecologically-rich tracts of roadless land are refuges for biodiversity, making it urgent to retain protection of these areas from habitat loss and degradation – the most significant threats to biodiversity.[1293]

The natural fragmentation of Southeast Alaska's island ecosystems makes it uniquely sensitive to additional fragmentation caused by intensive logging and road construction.[1294] The region's vast, relatively undisturbed roadless areas benefit species that have large home ranges or are sensitive to human activity, as well as other wildlife and salmon.[1295] The cumulative degradation and loss of habitat in many island ecosystems heightens the value of these intact areas.[1296]

Habitat fragmentation occurs when clearcutting and timber road construction divide forested landscapes into smaller patches and convert areas having interior forest conditions into edge habitat. Fragmentation reduces overall ecosystem functionality and can cause a biodiversity loss of 13 to 75 percent.[1297] Clearcuts and associated roads can affect a landscape area three times larger than the directly-impacted surface area.[1298] These effects last at least several decades after the original impact occurred.[1299] Fragmentation and associated decreases in connectivity between patches of suitable habitat can isolate populations of certain species, increasing risks of inbreeding, local extirpations or extinctions.[1300] Deer are an example of another kind of fragmentation impact. As the value of a forested area used by deer as winter range is reduced, crowding into small patches isolated by snow during severe winter weather results in starving deer and damaged browse.[1301]

On the Tongass, reinstating the Roadless Rule will help maintain the region's wildlife biodiversity because of two key prohibitions. First, it prohibits road construction, and roads generally have negative effects on forest species distribution, composition and population size and can convert habitat to non-habitat for many species. Second, it prohibits logging in intact forests, and logging is the leading cause of global forest loss and is accompanied by "an outsized impact on biodiversity."[1302] These two prohibitions conserve large areas that provide connectivity and biological strongholds for a variety of species and promote biodiversity conservation at a landscape level.[1303]

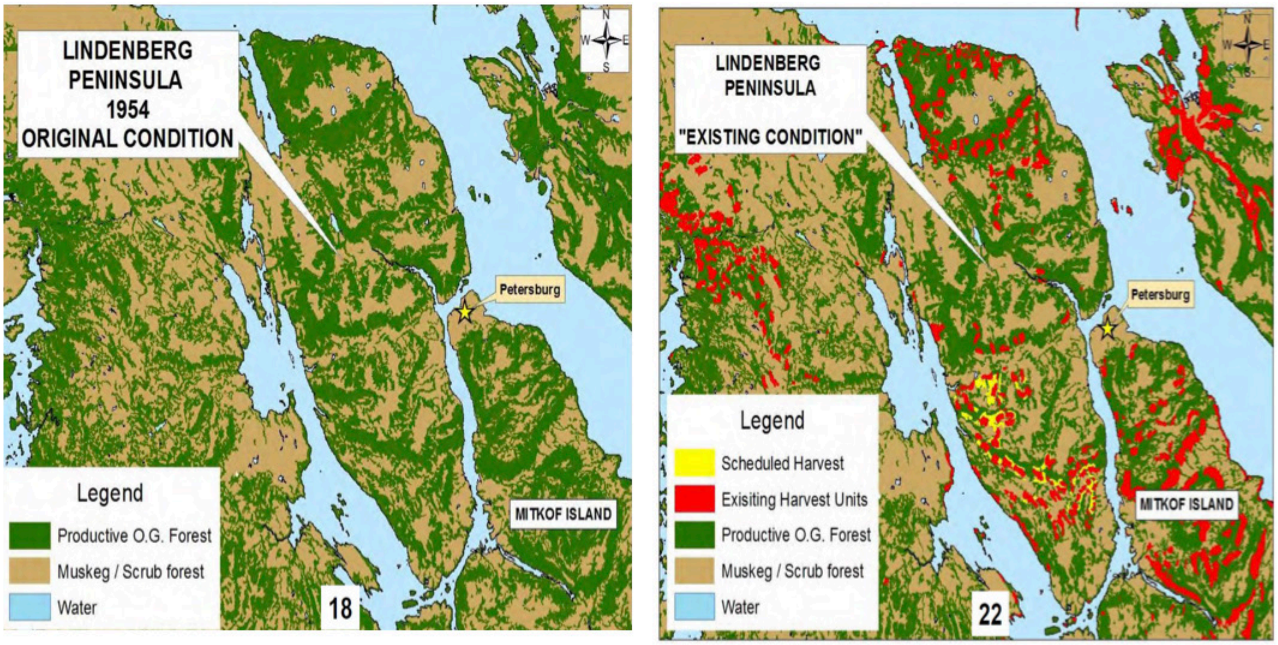


Figure 2: Logging has extensively fragmented portions of Lindenberg Peninsula on Kupreanof Island, Mitkof Island and the mainland near Thomas Bay. Graphics credit. Alaska Department of Fish and Game. 2013. Petersburg Area Overview. PowerPoint Presentation to the Alaska Board of Game. Sitka, Alaska, January 11-15, 2013.

Logging Threats to Large Mammals: Deer, Wolves and Bears

Logging Threats to Deer: Succession Debt

Deer are the most heavily hunted large mammal in Southeast Alaska and are highly valued for their meat and, in some areas, for guided hunting.[1304] Clearcut logging causes long-term harmful habitat changes for deer.[1305] After clearcutting, a "stem exclusion" stage of forest succession begins when the forest canopy closes, creating unsuitable habitat for many old-growth-associated wildlife species, including deer.[1306] Scientists call this impact "succession debt" because of low-forage conditions that last 100 to 150 years, a prolonged debt that can be repaid only by nature's work in returning to an old-growth condition (if given the chance) [1307] Deer populations will likely decline because of the poor quality of forage in the extensive amount of second-growth forest – natural capital debt incurred by logging as far back as 30 or more years ago.[1308]

Losses in habitat quality and quantity caused by clearcut logging, combined with severe winter weather and predation by wolves and bears, are the main threats to Sitka black-tailed deer.[1309] The disproportionate logging of low-elevation, old-growth forest – essential winter habitat for deer – worsens the impacts of severe winters, particularly in areas where deer are prey for wolves or bears.[1310] The effect of coming climate change on deer and deer habitat is unknown.[1311] However, warming temperatures and milder winters will not necessarily diminish the importance winter habitat. Risks of severe snowfall associated with expected increases in precipitation and severe storms may exacerbate risks to deer as a warming climate makes weather more chaotic.[1312]

A severe population decline in deer has occurred on central Tongass islands, where most logging took place on low-elevation, south-facing slopes favored by deer.[1313] One-half of all the large-tree, old-growth forests and nearly one-quarter of the prime winter deer habitat on Kupreanof and Mitkof Islands is gone.[1314] Deer numbers are extremely low on Kuiu, Kupreanof and Mitkof islands and have been since a series of harsh winters in the 1970s.[1315] Record-setting snowfalls in 2006/2007 and 2007/2008 resulted in further declines.[1316] Other central Southeast Alaska islands such as Etolin and Zarembo (near Wrangell) have also lost over 20 percent of their historical deer habitat due to logging.[1317] In general, the extensive habitat loss has forced deer to concentrate in smaller old-growth stands during deep-snow winters – reducing forage, increasing exposure to predation by wolves and reducing hunting opportunities.[1318] Extensive clearcutting of Revilla and Gravina Islands and the Cleveland Peninsula has similarly reduced deer habitat in the Ketchikan area.[1319]

Past clearcutting has also reduced long-term deer carrying capacity in some portions

These state of Alaska clearcuts at Leask Lakes near Ketchikan will reduce deer carrying capacity and local hunting opportunities for decades. Photo credit: Reeck, J. 2014. Saddle Lakes Project Wildlife and Subsistence Report. Tongass National Forest, Ketchikan/Misty Fiords Ranger District.

of Baranof and Chichagof Islands.[1320] Admiralty, Baranof and Chichagof Islands have large, protected wilderness areas and less predation (there are no wolves or black bears on these islands) so that deer have been able to recover from population declines caused by recent severe winters.[1321] The three islands now produce over one-third of the statewide deer harvest.[1322]

Prince of Wales Island produces nearly one-quarter of the statewide deer harvest and is the second most important provider of deer in the region.[1323] However, biologists expect the Prince of Wales deer population to decline because of habitat loss caused by logging. [1324] The substantial and disproportionate 40 percent loss of large-tree forestlands to logging on northern Prince of Wales Island contributes to one-half of the winter deer habitat lost so far.[1325] Recent federal timber sales targeted most of the last remaining stands of high-quality winter deer habitat and deer travel corridors in the north and central parts of the island.[1326] Federal and nonfederal logging on the island has created the highest density of clearcuts in Southeast Alaska.[1327]

The decline in deer carrying capacity has long-term consequences in terms of reductions in deer hunting opportunity and the inability to meet projected hunter demand and subsistence needs.[1328] The island's deer are the region's largest, notable for their trophy value. They support a substantial and increasing hunting effort – Prince of Wales Island residents, hunters from other Southeast Alaska communities and non-resident hunters may harvest as many as 3,600 deer each year.[1329] This increased hunting pressure concerns subsistence hunters who face increasing difficulty harvesting deer on the island.[1330] The Alaska Department of Fish and Game has concerns about the cumulative adverse effects of past, ongoing and future industrial-scale clearcutting on the future dividends of island deer:

> "We should better inform the public regarding the effects of logging on deer populations, so they are aware of trade-offs between timber harvest and wildlife. We anticipate that logging related reductions in important winter habitat will reduce deer carrying capacity for decades to come. The long term consequences of habitat loss include loss of hunting opportunity and the inability to provide for subsistence needs of rural residents."[1331]

Reinstating the Roadless Rule is critical to maintaining the provisioning and cultural ecosystem services provided by SeaBank deer. The Roadless Rule protects substantial proportions of remaining winter deer habitat in heavily-logged areas – on north Prince of Wales Island, large roadless areas protect over one-half of the remaining winter deer habitat.[1332] Large roadless areas also protect over 60 percent of the remaining winter deer habitat on other islands with high levels of past logging, such as Gravina, Kuiu, Kupreanof, Mitkof and Revilligigedo.[1333]

Impacts to Alexander Archipelago Wolves: Fewer Deer and Vulnerability to Roads

Alexander Archipelago wolves have large home ranges, prefer low-elevation, old-growth forest with high-quality deer habitat and avoid logged forests.[1334] Like deer, they use young clearcuts briefly but avoid older clearcuts.[1335] Wolf and deer abundances are intertwined – substantial reductions in deer populations caused by logging and succession debt will eventually result in smaller wolf populations, and wolves can prevent overgrazing by ungulates.[1336] It is likely that wolves may have had to adapt to reductions in high-quality winter deer habitat by expanding home pack range sizes.[1337]

The areas with the largest wolf populations correlate with the most productive forest stands lost to industrial-scale clearcutting.[1338] The habitat loss has changed conditions for deer and wolves on Kuiu, Kupreanof, Mitkof, Zarembo, Revillagigedo, and Wrangell Islands which, in conjunction with the Prince of Wales Archipelago, sustain most of the wolf population in Southeast Alaska.[1339] Higher road densities increase the likelihood of human-caused wolf mortalities, often excluding them from accessing deer during the fall.[1340] The U.S. Fish and Wildlife Service is considering whether to list the species as threatened or endangered under the Endangered Species Act because of threats caused by logging and road development, illegal trapping and hunting, climate change and loss of genetic diversity.[1341]

Multiple studies show how increased road densities correlate to increased wolf mortality risks.[1342] High road densities also significantly reduce denning habitat.[1343]

The area of greatest concern – as suggested by the road density graphic to the left – is on Prince of Wales Island and surrounding islands (GMU 2).[1344] Roadless areas are of increasing importance to large mammals that, like wolves, have diverse habitat needs because of the cumulative degradation and loss of habitat in adjacent areas.[1345] Reinstating the Roadless Rule will prevent further losses of habitat for deer and other old-growth-reliant species in roadless areas, and provide refugia for wolf populations from trapping and hunting, denning habitat, better chances of reproductive success, population connectivity and other benefits associated with preventing further fragmentation and degradation of habitat. [1346]

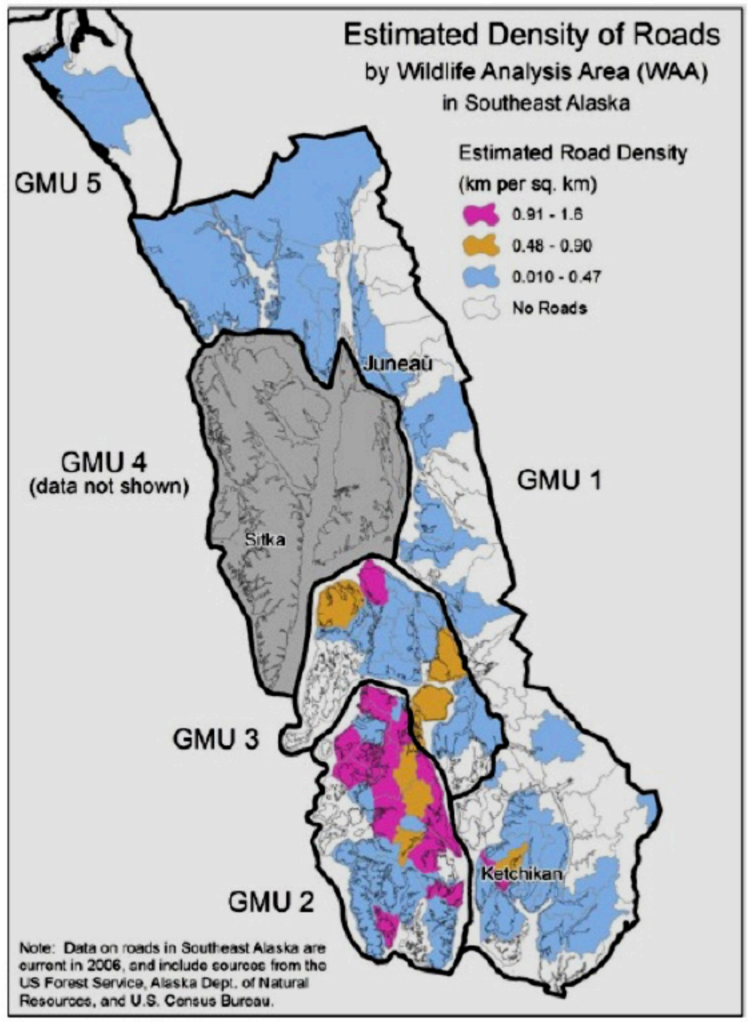


Figure 3: The area of greatest concern – as suggested by the road density graphic above – is on Prince of Wales Island and surrounding islands (GMU 2).

Impacts to Brown and Black Bears: Fewer Fish for Forage and Vulnerability to Roads

Logging and timber road construction have similar adverse impacts to bears by reducing old-growth forest denning and foraging habitat, increasing disturbances during summer and increasing vulnerability to human harvest.[1347] Bears, like wolves, are susceptible to hunting and, like deer, experience significant succession debt – i.e., the long-term loss of foraging opportunities as clearcuts regenerate into unsuitable habitat.[1348] Bears utilize some of the same food resources as wolves, such as deer and salmon, which both fluctuate and are at risk to the combined effects of logging and climate change.[1349]

Admiralty, Baranof and Chichagof Islands provide some of the best brown bear hunting and viewing opportunities in the world.[1350] Past logging has caused habitat loss for brown bears, particularly significant habitat degradation on eastern Chichagof Island.[1351] Both female and male brown bears fish for salmon in intact forested riparian areas and remain near salmon streams for a significant portion of the summer.[1352] But in altered landscapes, female bears with cubs venture farther from salmon streams in order to avoid male bears, and eat less salmon than solo female bears occupying intact habitats. [1353] Displacement from salmon streams is a concern because of the relationship between salmon consumption and bear population productivity. [1354]

For black bears, logging is the most serious long-term habitat threat.[1355] Wildlife biologists believe there are 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 over the past decade.[1356] These changes may be evidence of reduced carrying capacity due to habitat loss.[1357]

Retention of high-volume, old-growth habitat, such as areas protected by a reinstated Roadless Rule, would buffer bears against the variability of food resources and anthropogenic impacts such as logging and climate change. This is particularly true during cold winters when food is scarce and the effects of timber harvest on bear denning habitat are magnified.[1358] Like wolves, black bear populations decline as road density increases.[1359] Roadless areas are the remaining biological strongholds for bears the depend on large, undisturbed areas of land. The importance of such areas is high because bears are sensitive to human disturbances that disrupt migration, reproduction and rearing or that increase physiological stress.[1360]

Logging Threats to Salmon

At one time, the Pacific Northwest supported the largest salmon runs and fisheries in the world.[1361] But habitat loss has been a major factor in the decline of Pacific salmon populations at the southern end of their range.[1362] 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.[1363] In the Pacific Northwest, such habitat destruction necessitated billions of dollars of expenditures on hatcheries and restoration actions in order to maintain salmon and salmon fisheries.[1364] Intact, functioning forested ecosystems provide ecosystem services needed for fish, such as clean water, at no cost.

SeaBank assets include one of the largest remaining productive salmon systems in the world, in large part because of natural capital that includes hundreds of pristine watersheds of all sizes within the planet's largest tract of undisturbed coastal temperate rainforest.[1365] These areas are critical for maintaining the productivity and health of the region's fish and fishing industry.[1366]

Salmon typically account for more than one-half of Southeast Alaska's commercial catch and help to maintain thousands of local and non-resident jobs in the region's seafood sector even as harvests fluctuate.[1367] Salmon also support significant subsistence harvests, tourism, guided sport fisheries and hundreds of related businesses.[1368]

The Tongass National Forest is still by far the leading producer of wild salmon of any national forest.[1369] Alaska fisheries scientist Dr. Mason D. Bryant describes the physical and biological diversities of Southeast Alaska's salmon-producing watersheds as globally unique.[1370] Its salmon portfolio and "globally impressive productivity" rely in large part on the large number of intact watersheds where "ecological integrity, water quality, biophysical diversity and the productive capacity of freshwater habitat remain high."[1371]

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 have reduced salmon populations in the Pacific Northwest are present here, too.[1372] During the initial phase of industrial logging, impacts were highest in the most productive watersheds.[1373] The loss of habitat was, and still is, significant; by the end of the 20th century, industrial-scale logging had impacted nearly one-half of salmon stream miles, to varying degrees. [1374] It is likely the most heavily-impacted watersheds have been producing fewer salmon. [1375] But the extent of effects on population productivity are unknown.[1376]

"The Tongass and Chugach national forests were major contributors to the overall number and value of commercially caught Pacific 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 salmon fisheries."

Figure 4: Johnson, A.C., J.R. Bellmore, S. Haught, and R. Medel, 2019. Quantifying the Monetary Value of Alaska National Forests to Commercial Pacific Salmon Fisheries. *North American Journal of Fisheries Management, 39*(6).

Scientists who study Southeast Alaska's salmon identify logging and timber roads, along with climate change, as the greatest risks to SeaBank salmon habitat.[1377] The changing productivity of the marine environment increases the importance of freshwater habitat.[1378] A major concern is "double jeopardy" – wherein high levels of habitat degradation caused by logging and timber roads coincide with periods of low marine productivity, which climate change is making more frequent and severe.[1379] Intensively-logged watersheds have some value for fish during times of high marine productivity.[1380] But during times when low marine productivity and freshwater habitat degradation coincide, there may be long-term harm to salmon populations.[1381]

Reducing impacts from logging and timber roads will be important to maintaining a salmon population portfolio in a changing climate. Risks to freshwater habitat include more severe disturbance events, such as atmospheric rivers, and other precipitation changes, such as droughts (including winter snow droughts) that cause lower summer stream flows in turn worsened by warmer temperatures. Logging alone can cause stream temperature threshold exceedances which will more frequently rise to lethal levels in a warming climate.[1382]

The potential for increases in landslide frequency caused by climate change threatens fish habitat.[1383] Logging and timber roads exacerbate these risks.[1384] Landslides cause egg and embryo mortality by scouring redds as they move through spawning areas and then depositing sediments downstream.[1385] Increased stream scouring and sedimentation may also reduce spawning success and winter survival for some salmon species, such as coho, with potential long-term population effects.[1386] British Columbia scientists studying salmon habitat are also reviewing the combined effects of climate change and logging on salmon.[1387] Logging reduces the regulating service of forests that mitigates more severe and frequent floods, which wash away rearing habitat or suffocate salmon with sediment in the early stages of their lifecycle.[1388]

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

Even without considering climate change, clearcutting and timber road construction in salmon habitat reduces productivity for salmon in numerous ways. There is wide recognition that logging and timber road construction are a principal cause of declining Pacific salmon runs in Washington, Oregon and California. In general, roadless watersheds or watersheds with low road densities were two to three times as likely to support more abundant and diverse salmon populations than watersheds with high road densities, because timber roads and clearcutting can increase sedimentation, degrade water quality, fragment habitat and increase high temperature events.[1389]

Sedimentation of streambeds is a principal cause of declining salmon populations throughout their range.[1390] Roads cause ongoing, chronic sediment delivery that flows downstream and degrades salmon spawning and rearing habitat.[1391] There is chronic sedimentation affecting fish habitat throughout Southeast Alaska islands heavily impacted by clearcutting and timber road densities.[1392] It is nearly impossible to mitigate this impact.[1393]

Adverse impacts to salmon are likely, even with other measures in place that attempt to mitigate habitat harms.[1394] Significant habitat degradation of riparian areas occurs even with forested buffers, which are required on known anadromous streams.[1395] In Southeast Alaska, the buffers are narrow and tend to blow down, losing their effectiveness over time.[1396] And buffer requirements are minimal for most landowners and most stream sizes.[1397] Even where buffers do remain intact, they provide little protection against landslides caused by upslope logging or against road-caused sediment delivery.[1398] The absence of any requirement for buffers along smaller, non-anadromous headwater streams makes adjacent logging a significant source of sediment and downstream water quality degradation.[1399] Because logging and road construction cause high stream temperature in various ways, buffers alone do not prevent stream temperature increases. Some studies found stream temperatures to be up to 7° to 11° warmer in logged areas.[1400] These warmer temperatures alter fish behavior and the timing of lifecycle events, and can cause population declines or even collapses.[1401]

A major habitat problem for Southeast Alaska salmon is the number of stream miles blocked by failed culverts ("barrier" or "red" culverts). When less habitat is accessible to salmon for spawning, rearing and other lifecycle needs, there can be a significant loss of population productivity, to the point of local extirpations.[1402]

A primary purpose of the Roadless Rule was to address cost concerns – particularly the costs of building new roads in inventoried roadless areas given the USDA's large maintenance backlog. The deferred maintenance backlog (which included culvert replacement) was increasing along with rising repair costs and declining funding.[1403] By 2000, the deferred maintenance backlog was $8 billion and in the long run the agency could only fund maintenance on 20 percent of its existing road system.[1404] The Tongass National Forest alone accounted for a deferred maintenance backlog of nearly $1 billion (in 2002 dollars).[1405] In 2019, estimates of the funding/repair ratio worsened, with a total budget of $450 million sufficient only to address 10 percent of the national maintenance backlog of $5.2 billion[1406] The Forest Service currently is not allocating the funds necessary to maintain or decommission roads on the Tongass, and anticipates continuing adverse effects to fish and water quality as older roads and stream crossings deteriorate.[1407]

Culverts are the most common method used by road builders to cross streams.[1408] They cost less than bridges but it is difficult to maintain fish passage with constantly changing stream and debris flows, so culverts eventually impede fish passage or become complete barriers to fish movements.[1409] Culverts can also become barriers by creating high-velocity stream flows.[1410] Floods magnify this impact.[1411] Overflow that bypasses barrier culverts also increases sedimentation and stream temperatures.[1412]

The risks to salmon are much more extensive than the obvious problem of eliminating adult salmon spawning habitat.[1413] Salmon require habitat connectivity.[1414] In addition to other lifecycle migrations, juvenile salmon will move within a watershed to rearing or overwintering habitat or explore other habitats at times in pursuit of food.[1415] They also move to seek refuge from adverse environmental conditions such as floods or debris flows from landslides.[1416] Coho salmon in particular use all stream tributaries in all seasons, particularly in the fall when they move upstream in large numbers from main channels and during their outmigration in the spring.[1417] Barrier culverts (often erected throughout a watershed) block those movements, cumulatively reducing population productivity by impairing foraging opportunities that slow growth and development, and by blocking access to refugia.[1418]

Barrier culverts and other stream crossings that impair fish habitat are prevalent throughout Southeast Alaska. The cumulative impacts of road networks and multiple stream crossings threaten major adverse effects on fish habitat.[1419] Roughly two decades ago, the Alaska Department of Fish and Game surveyed 60 percent of Forest Service roads to assess fish passage problems in the region.[1420] Permanent roads crossed salmon streams more than 920 times and smaller streams more than 1,700 times.[1421] Only one-third of the stream crossings provided adult and juvenile fish passage.[1422] The Forest Service made an effort to address some of these problems between 1998 and 2006, fixing roughly 50 sites per year, but cancelled the program due to funding reductions.[1423] Now there are 1,100 culverts blocking over 270 stream miles of fish habitat, with most of them concentrated in the Petersburg and Prince of Wales (Thorne Bay and Craig) Ranger Districts.[1424]

There are at least 447 failed culverts on Prince of Wales Island alone which the Forest Service is fixing at a slow rate of 5-6 per year. Photo credit: Alaska Sustainable Fisheries Trust.

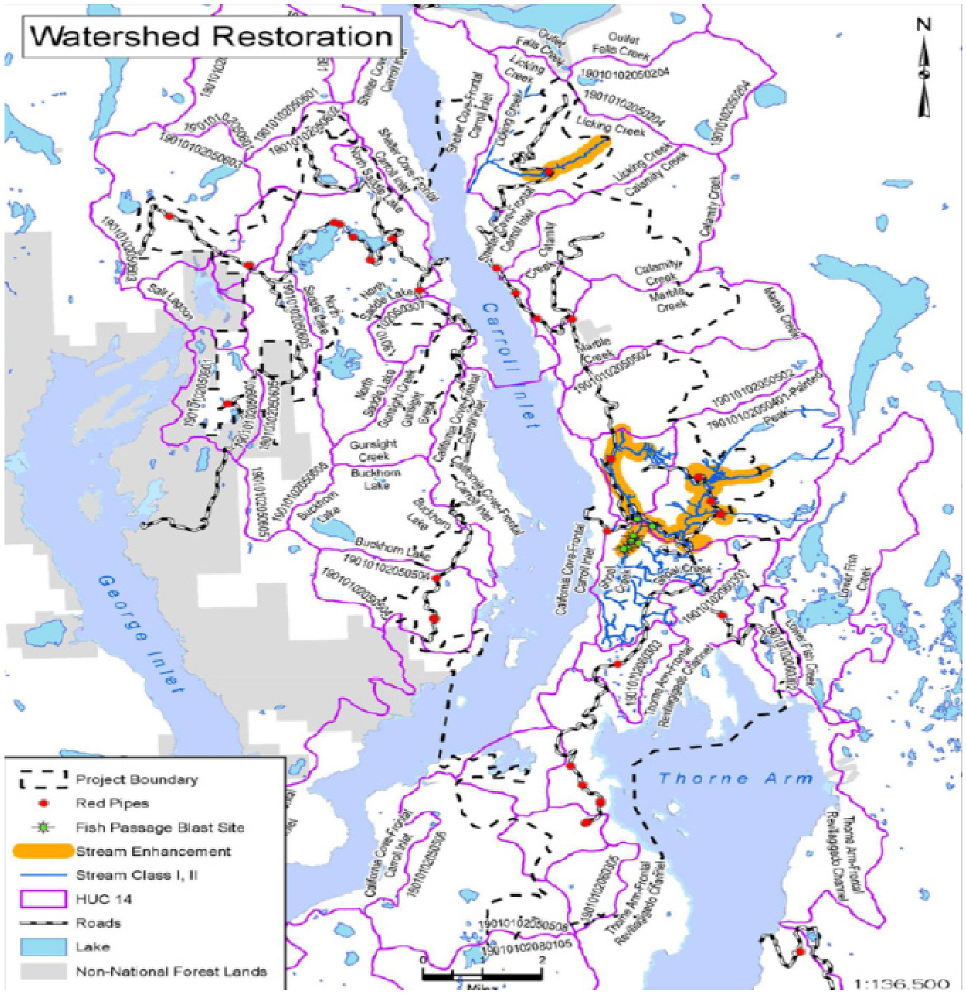


Figure 5: This map show how 32 red culverts in the Saddle Lakes area near Ketchikan block 18.5 miles of upstream habitat. Four red culverts alone block 11 miles of habitat. The Forest Service plans to fix culverts in only one watershed and replace them with bridges. Graphics credit: U.S. Forest Service. 2020. South Revillagigedo Integrated Resource Project Draft Environmental Impact Statement Volume 1.

Another review of five major salmon systems surveyed in heavily-logged portions of northeast Chichagof Island during the late 1990s showed 35 of 38 culverts had some degree of blockage, resulting in a loss of over one-third of the high- and moderate-quality upstream salmon habitat.[1425] Many were obvious barriers, verified by the relative absence of upstream salmon – all together, there were seven times as many juvenile salmon downstream from the barrier culverts as there were upstream.[1426]

This substantial past, present and ongoing habitat loss reduces ecosystem services that support salmon fisheries. Canadian researchers have developed methods to estimate the loss of salmon-related economic values caused by logging and related road construction. Conservative estimates indicate that each salmon-spawning stream mile is worth $10,000, so that Tongass National Forest barrier culverts cost commercial fishermen $2.7 million annually.[1427]

Removing barrier culverts is a primary means of restoring salmon populations.[1428]It improves fish passage, immediately increases the amount of available habitat, increases juvenile fish abundance upstream from the barrier and has higher certainty in terms of effectiveness than other restoration actions.[1429] Scientists recommend that in forested areas land managers should focus on projects like barrier culvert removals that improve low-flow and moderate stream temperatures because of climate change.[1430] Reinstating the Roadless Rule would help reduce the vulnerability of salmon to local extirpations. The absence of stream crossings in inventoried roadless areas is an important reason why they function as biological strongholds and refuges for salmon.[1431]

Increased logging by nonfederal landowners on Prince of Wales Island is a significant and immediate risk to SeaBank salmon.[1432] Prince of Wales Island is the most important island ecosystem in Southeast Alaska for commercial fish production, on the basis of identified sockeye habitat, number of stream miles for coho and pink salmon and number of Alaska Department of Fish and Game "Primary Salmon Producer" watersheds.[1433] The island's watersheds have been one of the most important parts of Southeast Alaska's salmon system and primary producers of wild salmon stocks that support sport, subsistence, seine, gillnet and troll fisheries.[1434]

Another significant concern is the Forest Service's second-growth timber targets that will negatively affect southern Southeast Alaska watersheds currently in recovery from past clearcutting. Forested aquatic ecosystems take decades to recover after logging.[1435] 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."[1436]

Reinstatement of the Roadless Rule and its regulatory protections are critical because roadless characteristics have unique values for salmon and other fish species. A primary purpose of the Roadless Rule was to maintain aquatic ecosystems that provide habitat for fish, based on wide recognition that lakes, streams and rivers within inventoried roadless areas are biological strongholds for salmon and other fish species.[1437] .

A Roadless Rule exemption would authorize both building more roads that impact fish habitat and more industrial logging of old-growth and recovering second-growth forests, all at a time when the region's salmon production capacity is vulnerable to the multiple climatic, terrestrial, aquatic and marine factors discussed in this report. Roadless areas will provide some buffering effect against climate impacts, as thermal refugia and for ecosystem resiliency.[1438] As explained by aquatic ecosystem

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."

Dr. Mason D. Bryant, 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 expert Jonathan Moore at British Columbia's Simon Fraser University, "[t]he more logging that happens, the less climate change [salmon] can withstand" and "the more watersheds are protected, the more climate change resilient they are."[1439]

> **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.**

Figure 6: Mason D. Bryant, fisheries scientist, Douglas Alaska. Comments on the proposed Alaska Roadless rulemaking.

Logging Threats to Recreation and Tourism

Recreation experiences and nature-based tourism in landscapes such as intact forests largely undisturbed by human pressure are of high value for their cultural ecosystem service.[1440] Large, intact, forested areas are increasingly scarce globally, heightening the value of SeaBank forests.[1441] Indeed, the Tongass is a national and global treasure for recreation opportunities, in large part because policies like the Roadless Rule maintain wild, remote and undeveloped areas, preserving recreational opportunities that are not available in developed areas.[1442] Fish and wildlife that inhabit large, contiguous, old-growth forests add to the high value of the recreation experience. [1443] Nature-based tourism (wildlife viewing, hiking, kayaking, fishing and hunting) generates substantial revenues in the region's tourism industry, which overall generates more than one-quarter of regional employment and earnings.[1444]

Clearcutting and logging activities degrade the quality of the forest recreation experience for both residents and visitors, reducing the value of this ecosystem service and the marketability of Southeast Alaska as an adventure-travel destination.[1445, 1446] Even though the Tongass National Forest is large, the terrain and topography make much of the forest inaccessible for outdoor recreation.[1447] Timber industry activities can displace visitors from large areas for decades because they change the non-industrial character of the landscape, displace wildlife and harm their habitat, reducing the value of SeaBank cultural services as an adventure destination.[1448] The degradation of the scenery resource and presence of timber industry activities reduce the limited land base available, concentrating guide companies, their clients and private recreationists into smaller, more crowded areas.[1449, 1450]

The Roadless Rule is critical for perpetuating quality recreation experiences for both residents and visitors. There are few alternative areas with qualities similar to intact roadless areas.[1451] Larger commercial guide businesses operate extensively, or even almost exclusively, in inventoried roadless areas for that reason and because federal policies allow only very small guided groups in designated wilderness areas and a number of other undeveloped areas.[1452]

Roadless areas are often the only other relatively undisturbed landscapes available.[1453] If left in place, the 2020 exemption rulemaking would allow timber industry activities in areas commonly used by many guides and visitors.[1454]

Small cruise companies avoid this recent Cleveland Peninsula clearcut by traveling at night and have had to stop using adjacent shoreline areas. Photo credit: Joe Sebastian.

Increased guided public use of North Kuiu Island illustrates how industrial-scale logging affects nature-based tourism. Active timber operations ceased there in 2000.[1455] Small cruise vessels and guided visitors avoided the area while logging was ongoing and afterwards when clearcuts dominated the landscape.[1456] The island's bays have since become recreational hotspots with increasing numbers of visitors each year over the past decade.[1457] Multiple nature-based tourism businesses, particularly small cruise vessels, provide over 2,300 guided visitors with widely-dispersed kayaking, beachcombing, sportfishing, hiking, and marine and terrestrial wildlife viewing experiences each year.[1458]

However, for over a decade the Forest Service has persistently sought a purchaser for a timber sale on north Kuiu Island.[1459] The 2020 Alaska Roadless rulemaking removed logging and road construction prohibitions from nearly 53,400 acres in this area.[1460] The Forest Service believes that removing Roadless Rule protections from this area will increase the likelihood of a larger, more attractive timber sale.[1461]

Timber industry activities would displace guided visitors and independent recreationists and concentrate them in other areas.[1462] Displacement would occur in two ways: direct displacement by timber extraction activities and long-term displacement from other unlogged but adjacent areas because of the visible clearcuts.[1463] Visitor displacement on North Kuiu Island alone would affect four guide-use areas, which combined comprise nearly 300,000 acres.[1464]

The growth of nature-based tourism over the past two decades has created challenges for Forest Service recreation managers in terms of providing sufficient access to remote recreation opportunities while maintaining quality experiences for all users.[1465] Some guide-use areas are at or near capacity for guided use, exacerbating potential displacement problems caused by timber industry activities.[1466] Most nature-based tourism businesses avoid other groups and seek alternative areas when there are multiple parties in a bay.[1467] Several companies work with other guides to maintain a quality recreation experience for all users by developing systems for planning and communications that avoid overlaps of user groups. The loss of access to north Kuiu Island – and other locations with similar access opportunities – would have significantly adverse impacts on nature-based tourism businesses and the 640,000 visitors who use their services to experience Southeast Alaska's forests, bays and wildlife.

Logging Threats to Regulating Services: Worsening Climate Risks

More obvious ecosystem services provided by unlogged, roadless forests and watersheds include provisioning services with recognizable economic values: scenery, recreation opportunities and habitat for fish and wildlife. With the exception of carbon sequestration, the economic value of regulating ecosystem services provided by intact, forested habitat and roadless watersheds are not as widely recognized but are of increasing importance. [1468] Regulating services provided by naturally-functioning forest ecosystems reduce risks caused by severe weather events and include flood control, storm protection, water regulation and purification, air quality maintenance and air temperature regulation.[1469] For example, forested ecosystems moderate waterflows into streams during peak storm events and mitigate the effects of high air-temperature events on stream warming.[1470] Industrial-scale logging and timber road construction will reduce the economic value of these regulating ecosystem services and, worse, exacerbate damage caused by severe weather events.[1471]

For example, logging increases landslide risks by altering groundwater to surface waterflow regimes and by reducing the anchoring and reinforcing effect of tree roots that is critical to maintaining soil stability in high-risk areas.[1472] Intense rainfall on saturated soils – particularly during fall and winter multi-day storms – is the primary cause of landslides in Southeast Alaska.[1473] Large-scale clearcutting, ongoing since the 1950s, accelerates landslide activity during heavy precipitation events.[1474] Studies specific to Southeast Alaska show that logging increases the frequency of landslide occurrences, with landslide rates in logged areas typically 3 to 5 times higher than in unlogged areas.[1475] Similar studies in British Columbia's Haidi Gwaii (formerly the Queen Charlotte Islands) and other areas in western North America have identified even higher landslide occurrence rates after logging and logging road construction.[1476] Roadless Rule reinstatement is critical to weathering these storms because of the value for forest ecosystem resilience. [1477]

Deckhands on a trawler sort out large numbers of halibut. Photo credit: Tholepin. (http://tholepin.blogspot.com/)

Chapter 7: The Bycatch Problem – Threats from Trawling

The National Marine Fisheries Service (NMFS) and the North Pacific Fishery Management Council (NPFMC) manage hook-and-line, pot and trawl groundfish fisheries in the Gulf of Alaska and Bering Sea.[1478] Trawl gear is responsible for the largest proportion of valuable fish species killed as bycatch in the Bering Sea and Gulf of Alaska.[1479] This bycatch impacts Southeast Alaska coastal communities and their small-boat commercial and sport fleets, which are highly vulnerable to reductions in regulated access to salmon, halibut and sablefish resources.[1480]

Overview: Trawl Bycatch and Habitat Harms

Bycatch is the take of non-target species while fishing for other species.[1481] The trawl industry's footprint is the most appropriate focus for bycatch management because of the economic waste associated with its tremendous volume of bycatch and the habitat degradation and high impacts to biodiversity that result from this fishing method.[1482] Bottom trawling has the highest overall environmental impact of the 10 major fishing gears used in U.S. fisheries.[1483] Trawling, particularly bottom trawling, is highly non-selective compared to other fishing gears – and is the largest source of bycatch. This bycatch includes a high proportion of juvenile fish, which reduces future yields for fishermen who would otherwise harvest the bycaught fish once mature.[1484] Selective fishing gears – such as those used in the Southeast Alaska's hook-and-line and pot fisheries that target salmon, sablefish, halibut and crab – allow for the survival of escaping or released juvenile, undersized or non-target fish species.[1485]

Mortality of non-target or unrecovered target fish due to trawling has several causes: crushing by the trawl on the seafloor; mortality in the trawl or onboard the vessel; or mortality after being discarded due to stress, injury, increased vulnerability to predation or delayed responses to air temperature.[1486] Trawlers tow continuously while the net is deployed, concentrating captured fish in the back of the net.[1487] Captured fish "burst swim" at their maximum swimming speed until exhausted and often die before being hauled on deck for sorting.[1488] Fish that survive the trawl may then die due to capture and handling injuries on deck.[1489] The large volumes of fish caught in trawls can result in long sorting times and, consequently, a common cause of death is extended exposure to air.[1490] Fish discarded alive but weakened by air exposure, injury or other stressors frequently die and are vulnerable to the predators that commonly concentrate around trawl vessels.[1491] There is considerable variability regarding the future survival of live fish discarded in good condition, but in some cases discarded fish die.[1492]

Bottom trawling is comparable to the clearcutting of old-growth forests because of extensive damage to the ocean's most biologically-productive seabed habitats. [1493] The gear constantly contacts the seafloor, degrading or destroying habitats and damaging a variety of seafloor species.[1494] Trawlers damage many kinds of structural habitats used by fish, such as rocky habitats when boulders are overturned or buried, or the seafloor when resident species such as corals and plants are crushed.[1495] Cold-water coral reefs in particular have high value for many high-latitude fish species.[1496] Trawlers mow them down, leaving behind crushed remains and barren habitats.[1497] Trawl gear, especially bottom trawl gear, destroys sensitive habitats used by fish for rearing, refuge, spawning, breeding and feeding.[1498] The habitat loss can be permanent.[1499]

Bottom trawling is also one of the most significant disturbances to soft-sediment benthic communities and habitats, particularly in highly-productive, shallow, continental-shelf ecosystems.[1500] Nets, beams, doors, chains and rollers remove a large proportion of benthic biomass, reducing productivity and biodiversity and impairing other ecological functions.[1501] The numerous species damaged or killed include shellfish such as mollusks, crab and shrimp, echinoderms such as starfish, sea urchins and sea stars, and polychaetes such as tube worms and other marine worms.[1502] Many of these species are essential parts of the marine food web.[1503] Impairment of the food web reduces fish productivity by lowering ecosystem carrying capacity, reducing fish growth, intensifying competition for prey and delaying the recovery of rebuilding fish populations.[1504] Bottom trawling's intensive and extensive seabed disturbances may degrade ecosystem productivity and food web stability to such a degree that these indirect impacts of bottom trawling may be worse than its well-known direct impacts.[1505]

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).

Trawl Bycatch in the Federal Groundfish Fisheries

Congress enacted the Magnuson-Stevens Act in 1976 in large part because of impacts from foreign trawl fleets on U.S. fisheries.[1506] However, domestic trawl fleets developed and began to similarly impact smaller boats.[1507] In 1996, Congress amended the Magnuson-Stevens Act through the Sustainable Fisheries Act in large part to address bycatch increases, particularly bycatch by trawlers in the North Pacific, and their impacts on other U.S. fisheries and fishing communities. [1508] The Sustainable Fisheries Act added National Standard 9, which directed NMFS and the NPFMC to minimize bycatch and bycatch mortality.[1509] Congress intended for these provisions to reduce economic waste and avoid fisheries failures for commercially-important fish stocks.[1510]

Over a quarter century later, NMFS and the NPFMC have failed to implement meaningful bycatch reduction measures. There is an illusion involved in this issue – although the amount of trawl bycatch declined over the past decade (after peaking near the end of the 20th century), the cause for the decline is now often a reduced abundance of the bycaught species. In other words, trawl fisheries are not necessarily "cleaner."[1511] Additionally, climate change is increasing the vulnerability of numerous Alaska fish species that become trawl bycatch.[1512]

NMFS and the NPFMC designate salmon, halibut and sometimes sablefish as prohibited species that trawlers must avoid while fishing for their target groundfish species.[1513] Bycatch limits apply for halibut and Chinook salmon so that when trawlers exceed their limit, NMFS directs an early closure of their target fishery and they must then cease fishing in the area where the limit applies.[1514] In general, NMFS and the NPFMC set bycatch limits that exceed actual bycatch levels in order to allow year-round operation of trawl vessels – an illusion of regulation.[1515] Allowable bycatch of sablefish and chum salmon is unlimited.

As shown below, over the last five years the trawl industry has taken large numbers of Chinook and chum salmon, sablefish and halibut. Many of these fish, to varying degrees, would be available for harvest by Alaska subsistence, sport and commercial fishermen – or to support recovery of salmon populations which are at such low-abundance levels that Alaska fisheries managers have had to close or severely restrict harvest opportunities.

Table 7.1 Trawl Bycatch High Value Species 2017-2021

(salmon in numbers of fish; sablefish and halibut in round pounds, respectively)

Year	Bering Sea and Gulf of Alaska Chinook Salmon	Bering Sea and Gulf of Alaska Sablefish	Bering Sea and Gulf of Alaska Halibut	Bering Sea Chum Salmon
2021	32,993	1,937,843	2,799,291	467,678
2020	47,742	9,625,284	3,730,183	295,064
2019	55,330	5,943,602	5,259,624	347,882
2018	34,478	3,084,235	4,957,043	320,478
2017	61,286	769,405	4,718,946	530,626
Total	231,829	21,360,369	21,465,087	1,961,728

The bycatch numbers above are estimates. The actual numbers of fish killed and wasted by trawlers may be much higher than estimated because of problems with the NMFS observer program, which include low observer-coverage levels in the Gulf of Alaska and vessel manipulation of bycatch rates when observed. [1516] Bycatch limits are "a high-precision management tool" that require sufficient monitoring by observers to support precise bycatch estimates.[1517] The feasibility and costs of a monitoring program that can accurately estimate bycatch is a major challenge for managing bycatch limits.[1518]

Gulf of Alaska trawlers fund only a small portion of their monitoring costs and rely on a common pool of fees paid by halibut and sablefish fishermen to cover observer costs on just over 20 percent of their trips.[1519] NMFS extrapolates bycatch rates from observed trawlers and applies those rates to the unobserved portion of the fleet.[1520] Because observer-collected data can affect whether or when trawlers exceed bycatch limits, trawlers have an incentive to influence bycatch estimates in order to prevent closures in a fishery or fishery area.[1521] Regardless of the observer coverage rate, vessels with onboard observers may alter their fishing behavior, harass or intimidate observers, or remove bycatch species from observer samples. [1522]

Halibut and Sablefish Bycatch

Halibut abundance has been declining since the 1990s, but with conservative management of directed fisheries, it is now stabilizing at low harvest levels.[1523] As abundance has declined, trawlers have taken a disproportionate share of the halibut resource over the past two decades because of the delayed development of appropriate bycatch limits. During the 1990s, NMFS and the NPFMC set trawl halibut bycatch limits at 6.2 million pounds (net weight) in the Bering Sea and 3.3 million pounds in the Gulf of Alaska – nearly one-half of the total harvest in recent years.[1524] By 2016, high bycatch levels combined with lower abundances threatened to eliminate directed halibut fisheries in the Bering Sea, and NMFS dropped the trawl bycatch limit to roughly 4.1 million pounds.[1525]

In December 2021, the NPFMC considered reducing Bering Sea bycatch limits at different levels of halibut abundance.[1526] But the proposed new bycatch limit (not yet in regulation) will not align bycatch limits with abundance declines, and will not leave halibut harvesters even one-half of their historical share of the resource.[1527] Since 2015, the trawl industry has taken 18 million pounds of halibut bycatch, more than double the entire directed-fishery catch.[1528]

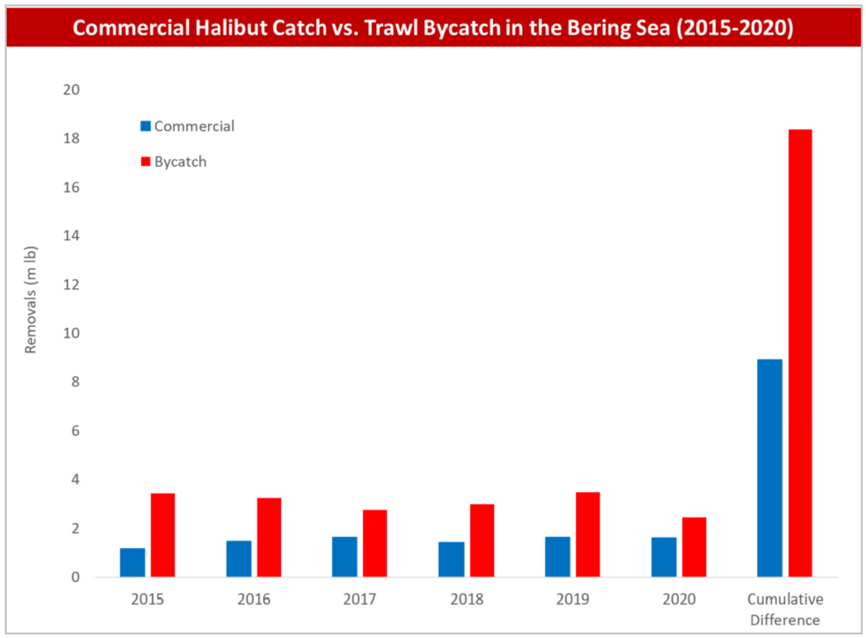


Figure 1. Bycatch and Commercial Halibut Removals

Figure 1: NMFS and the NPFMC authorize trawlers to take more halibut as bycatch in the Bering Sea than fishermen in the region are allowed to catch. Graphics Credit: Central Bering Sea Fishermen's Association. 2021. Comments on the North Pacific Fishery Management Council December 2021 Agenda Item C2 Concerning BSAI Halibut Abundance-Based Management (ABM).

The Gulf of Alaska trawl bycatch limit was static until 2013 when NMFS and the NPFMC reduced the 3.3-million-pound limit to 2.9 million pounds.[1529] Over the prior decade, directed fisheries shouldered the conservation burden of maintaining stock productivity, with harvests reduced by over 50 percent.[1530] Cuts to the trawl bycatch limit failed to align with larger declines in halibut abundance, resulting in bycatch as an increasingly larger proportion of the resource.[1531]

Much of the bycatch is juvenile halibut, causing additional losses associated with foregone future growth before maturity or harvest.[1532] The future loss is much greater than the weight of juvenile halibut taken as bycatch because foregone annual weight gains of that fish cohort would exceed loss from natural mortality.[1533] Typically, over one-half of the halibut taken in the Bering Sea and over one-third of the halibut taken in the Gulf of Alaska are juvenile fish (<26 inches in length).[1534] Juvenile halibut migrate extensively across the North Pacific, so that most of the bycatch in the Bering Sea affects downstream areas such as the Gulf of Alaska where most Southeast Alaska commercial and sport fishermen harvest halibut. Juvenile halibut taken as bycatch would otherwise grow over a period of years and be available to support future fisheries yields for SeaBank fishing communities.[1535]

In general, each pound of trawl halibut bycatch would otherwise generate more than a pound of yield to commercial halibut fisheries.[1536] The actual rate is variable over time and depends the location of the bycatch fishery and the size and age of halibut killed by trawlers.[1537] In general, directed fisheries would receive a 115-percent benefit from any bycatch reduction and as much as 139 percent.[1538] For example, every 2.2 pounds (1 kilogram) of eliminated bycatch would, under current conditions, generate a 2.7 to 2.8 pound yield gain to directed fisheries. [1539]

As with halibut, a significant portion of trawl sablefish bycatch consists of juvenile fish that form the fishery's future. As explained in Chapter 3 of this report, there were two large sablefish year classes in 2014 and 2016.[1540] There is increasing uncertainty about the actual size of these year classes and about how these now-maturing, late-stage juvenile and young adult sablefish will fare in a warmer marine environment.[1541] Even so, the two classes combined comprised nearly one-half of the 2021 spawning biomass and are key to future stock productivity.[1542]

Regulations allow trawlers to retain a portion of the harvestable sablefish quota.[1543] After trawlers catch their allocation, NMFS designates sablefish a "prohibited species" for the trawl fleet.[1544] Trawlers then discard sablefish taken while targeting other species.[1545] There are no bycatch limits or other requirements to avoid sablefish.[1546]

From 2018 to 2020, Bering Sea trawlers exceeded their sablefish quota by 123 million pounds during the 3-year period.[1547] In 2019, Bering Sea trawlers took 3.9 million pounds of sablefish as bycatch.[1548] In 2020, they took nearly 8 million pounds as bycatch.[1549] From 2018 to 2020, Central Gulf of Alaska trawlers took 6.1 million pounds as bycatch.[1550] Most of the bycatch consists of juvenile fish from the two large year classes.[1551] The figure to the left shows that, as with halibut, trawlers are killing an increasing proportion of the sablefish resource as bycatch.[1552]

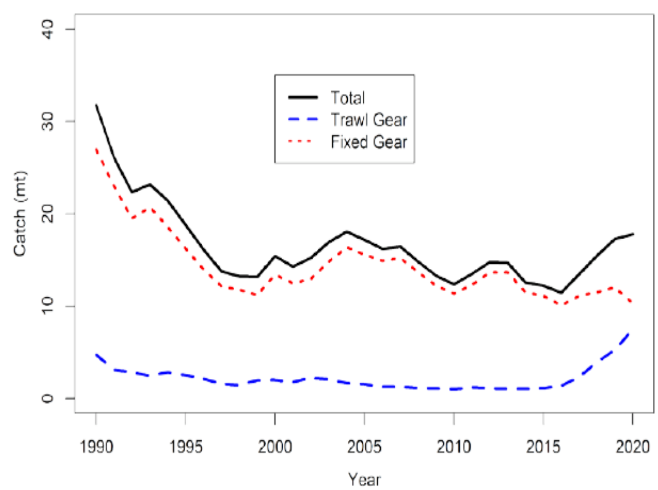


Figure 2: The proportion of sablefish taken by trawlers has increased over the last five years. Most of the increase consists of young fish killed as bycatch. Graphics credit: Graphis credit: NPFMC/NMFS 2021b. Considering Management Tools to Limit Trawl Sablefish Overages.

The effects of increased juvenile fish bycatch on the future productivity of recent large year classes are uncertain.[1553] While the IPHC has analyzed the impacts of trawl halibut bycatch on downstream users, NMFS and the NPFMC have not undertaken a similar effort. Consequently, sablefish stock assessment analysts characterize the effects to other users in different regions as "poorly understood."[1554] NMFS and the NPFMC have refused to pursue any measures to address the rising numbers of sablefish killed in the trawl fisheries.[1555] In 2021, the Bering Sea trawl fishery exceeded its catch limit again, by nearly 2 million pounds.[1556]

Chinook Bycatch

Chinook originating from Alaska streams migrate through the Gulf of Alaska and the Bering Sea, where trawlers take many as bycatch.[1557] Chinook taken in the Gulf of Alaska are a mix of diminishing Alaska populations and stocks from the Pacific Northwest and Canada.[1558] In any given year, between 10 and 20 percent of the bycaught Chinook killed in the Gulf of Alaska are from Southeast Alaska.[1559] The bycatch of these fish is significant because of the small size and current stock status of those runs.[1560]

NMFS bycatch estimates show that Gulf of Alaska trawlers have taken over 470,000 Chinook since 2000.[1561] There were peak years of 40,600 and 54,000 fish in 2007 and 2010, and recent estimates still show takes of over 24,000 fish.[1562] There were no Gulf of Alaska Chinook bycatch limits until bycatch reached "unacceptably high" levels in 2010.[1563] Pollock trawlers took 75 percent of the bycatch, averaging an estimated 19,000 fish per year, from 2003 to 2010.[1564]

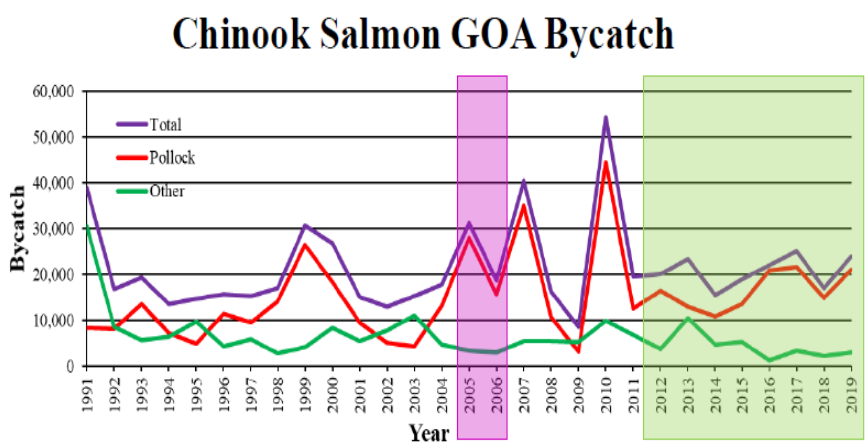


Figure 3: NMFS and the NPFMC allow trawlers to take large numbers of Chinook salmon in the Gulf of Alaska even while many state fisheries are closed or restricted for conservation purposes. Graphics credit: Guthrie III, C.M., Hv. T. Nguyen. K. Karpan & W.A. Larson. 2021b. Genetic stock composision analysis of Chinook salmon bycatch samples from the 2019 Gulf of Alaska trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-417. 35 p.

The NPFMC set a higher, 25,000-Chinook bycatch limit, out of concern that a lower limit could prevent trawlers from harvesting the pollock quota in some years.[1565] The limit functions mostly to incentivize initiatives that minimize Chinook bycatch in high bycatch years.[1566] NMFS did not implement bycatch limits for the non-pollock trawlers in the Gulf of Alaska until 2014.[1567] The combined bycatch limit for the Gulf of Alaska trawlers is 32,500 fish, while Chinook fishermen throughout the Gulf of Alaska bear the conservation burden and face severe restrictions in the hope of future resource recovery.[1568]

External Costs of Trawler Bycatch

The impact of trawler bycatch on coastal Alaska fishing communities is unsustainable, a result of the extraordinary bycaught proportion of high-value fish species killed, which causes a reduced availability of multiple target fish species and lowered catches and revenues. This is a classic "externalities problem," a conflict between the bycatch of high-value fish species being killed and wasted in the pursuit of lower-value – but higher-volume – trawl catches. That is, the trawl industry imposes a cost on other resource users, as well as devaluing high-quality resources.[1569]

Fisheries analysts from the University of Oxford explain that:

> "[]n economic terms, bycatch is a negative externality, comparable to carbon emissions and air pollution, which occurs when an economic transaction by a private economic entity (for example, a fishing firm) imposes a cost on society that is unpriced or only partially priced by markets. As a result, the environmental costs of fishing to society exceeds the private cost of fishing to firms, and the market maximizes private benefit for the firm, but not total benefit to society (i.e. social welfare, wherein economic welfare is a subset of social welfare).[1570]

Fisheries policies have often imposed disproportionate harm on smaller coastal Alaska communities.[1571] These include decisions by NMFS and the NPFMC that allow the trawl industry to boost profits through operations that create excessive bycatch, a harm transferred at considerable cost to small-boat salmon and fixed-gear fishermen who operate from these fishing communities. Of the trawl-harvested groundfish species, most of the value accrues to non-Alaska companies and workers in the Seattle area.[1572] The trawl industry exports most of its catch whole or with minimal processing to Asia for reprocessing and re-exporting.[1573] Except for Pacific cod, the species targeted by trawlers are mostly lower-value groundfish such as pollock and flatfish worth pennies per pound.[1574]

The University of Alaska's Institute for Social and Economic Research (ISER) explains that:

> …while total employment increases with resource extraction activities in the oil-rich North Slope borough in Alaska, local residents receive little to none of these benefits. A similar story may be true of Alaska's fisheries. While Alaskan fishers represented 71% of permit owners in 2015, they earned only 33% of the total value of catch. Further, only 65% of the wholesale value from commercial fisheries can be attributed to a processor based in Alaska. Thus, a large portion of the value of commercial fisheries in Alaska may never enter into local economies.[1575]

Trawl bycatch aggravates this problem by greatly reducing the availability of fish species to Alaska coastal community fishermen harvesting fish from smaller boats and fishermen using fixed gear such as hooks and pots or smaller nets used to harvest salmon. The socio-economic impacts vary by region, according to the abundance of bycaught fish, whether the bycaught fish are juveniles or adults, the potential for natural mortality or, in the case of salmon, area of origin.

For many salmon populations, conservation measures are necessary just to meet escapement goals and restore directed fishery harvests. For other species, lower bycatch by the trawl industry would increase harvests for fishermen who live in and/or deliver their catches to Alaska's coastal communities.

Chinook salmon, halibut and sablefish are among Alaska's most valuable commercial fish species and, with the exception of small sablefish, typically fetch ex-vessel prices ranging between $5.00 and $8.00 per pound.[1576] Availability of these fish for harvesting and processing is critical to Alaska's coastal fishing community economies. [1577] Resident permit holder earnings – and local landings by non-resident fishermen – create induced economic activity that supports a diverse array of other businesses.[1578] Every $1 million in local fish harvests generates over $1.5 million in earnings by other local economic endeavors.[1579] Trawl bycatch thus harms a wide range of businesses by suppressing Alaska resident harvests and local landings. Fishermen spend less locally on fuel, fishing gear, groceries, vessel repair and maintenance, resulting in less indirect employment and wage incomes.[1580]

In annual economic value, Alaska's fixed gear fisheries for halibut and sablefish are among the nation's top 10 most valuable fisheries – typically accruing over $300 million per year. [1581] The IPHC's 2022 "Pacific Halibut Multiregional Economic Impact Assessment" reviewed the economic benefits as harvested halibut migrate from hook to plate, generating economic activity for processors, wholesalers, retailers and services.[1582] Each dollar in commercial halibut landing value generates over $4 in economic activity: the 2019 coastwide value of $134.1 million was worth over $550 million in total economic outputs, generating over 5,000 jobs.[1583] The economic benefits accrue mostly in Alaska where residents own over 90 percent of the active vessels and individual permits.[1584] Over two-thirds of revenues from the 2019 halibut fishery accrued in Alaska communities.[1585] Residents of other states, mostly Washington, own over one-third of the Alaska halibut quota but deliver almost all their fish in Alaska.[1586] The similar sablefish fishery includes between 260 and 290 smaller- and medium-size pot and longline vessels in the Gulf of Alaska that account for more than 90 percent of the annual fishery value.[1587]

Trawl bycatch significantly suppresses the value of these fisheries to Alaska fishing communities. Between 2010 and 2019, five trawl companies, based mostly in Seattle, took 28.7 million pounds of halibut bycatch in the Bering Sea.[1588] If allowed to migrate and mature, these fish would have over time yielded a 33-million-pound harvest to fishermen in Alaska and the Pacific Northwest.[1589] This bycatch resulted in an external cost of $165 million imposed by the trawl companies on halibut harvesters at a conservative price of $5.00 per pound. Because each dollar in commercial halibut landings generates four dollars in economic outputs, the external cost of the halibut killed by these five companies withheld $66 million a year from coastal communities, for a total of $660 million per decade. Most of this loss accrued in Alaska, including significant losses to Southeast Alaska.

The table on page 135 shows the total round pounds of sablefish and net pounds of halibut taken as trawl bycatch over the last five years. It also displays the price per pound paid to fishermen targeting the two species, suggesting the potential value of the catch if caught later as mature fish rather than wasted by the trawl industry. Sablefish fishermen believe the costs of trawl sablefish bycatch are likely much higher. Sablefish taken as bycatch by the trawl fleet are young and small, so foregone gains in value, had this bycatch not occurred, are substantial.

However, only published studies pertaining to halibut consider the impacts of Alaska trawl bycatch on a directed fishery yield. NMFS and the NPFMC have not evaluated the impact of trawl sablefish bycatch on other fisheries. The table below is highly conservative because it assumes a 1:1 bycatch/sablefish fishery yield ratio and lower prices than would likely occur over time. The table is also conservative because it includes prices from the pandemic year.

Table 7.2 Direct External Costs to Alaska Communities: Trawl, Halibut and Sablefish Bycatch 2017-2021

Year	Sablefish	Price	Value	Halibut	Price	Value	Total Loss
2021	1,937.843	$2.19	$4,243,876	2,799,291	$6.73	$18,839,228	$23,083,104
2020	9,625,284	$2.07	$19,924,338	3,730,183	$4.36	$16,263,598	$36,187,936
2019	5,943,602	$3.29	$19,554,451	5,259,624	$5.55	$29,190,193	$48,774,644
2018	3,084,235	$4.53	$13,971,585	4,957,043	$5.88	$29,147,413	$43,118,998
2017	769,405	$5.30	$4,077,846	4,718,946	$6.46	$30,484,391	$34,562,237
Total	21,360,369		$61,772,096	21,465,087		$123,924,823	$185,696,919

The next table shows some of the other economic losses caused by trawl bycatch of sablefish and halibut, using results from recent analyses of fisheries economies by the IPHC and ISER. The third column in the table shows the total loss of multiregional economic outputs based on the 2022 Pacific Halibut Multiregional Economic Assessment. Alaska communities suffer most of these losses. The table combines sablefish and halibut because the two fisheries are very similar and at times are assessed as a single fishery.[1590]

The remaining columns cover impacts exclusive to Alaska coastal communities. The fourth column indicates the range of crew job losses – $1 million in local landings generates 1.36 crew jobs, or 3.4 crew jobs if landed by a resident fishing permit holder.[1591] One million dollars in landings generates 9 processing jobs regardless of fishing permit holder residency.[1592] One million dollars in local landings generates 2 "spillover" jobs (i.e., non-fishing or processing) and each $1 million in landed resident catch generates 7.2 spillover jobs.[1593] The final column shows the range of earnings lost to trawl bycatch in Alaska communities, which vary based on whether a resident or non-resident permit holder lands the sablefish or halibut.[1594]

Table 7.3 Alaska Job and Income Losses Caused By Trawl Halibut and Sablefish Bycatch (in millions of dollars)

Year	Total Loss	Multiregional Economic Outputs	Alaska crew jobs lost	Alaska processing jobs lost	Spillover jobs lost	Community income lost
2021	$23.1	$92.3	31-78	208	46-106	$9.9-$35.6
2020	$36.2	$144.8	49-123	326	72-260	$15.5-$55.7
2019	$48.8	$195.1	66-166	439	97-351	$20.9-$75.2
2018	$43.1	$172.5	59-146	388	86-310	$18.4-$66.4
2017	$34.6	$138.2	47-118	311	69-249	$14.8-$53.3
Total	$185.7	$742.8	252-631	1,672	371-1,339	$79.4-$286

The impacts of Chinook salmon bycatch are more challenging to assess than sablefish or halibut bycatch impacts. Chinook salmon spend between one and five years in the marine environment before returning to spawn in their natal streams.[1595] Bycaught Chinook range in age from three to seven years old.[1596] Some bycaught fish may otherwise return to spawn or support directed fisheries in future years, or be vulnerable to mortality via predation by marine mammals or other fish.[1597] Efforts to quantify this multi-year impact for Bering Sea Chinook bycatch were controversial.[1598] There is not enough data from the Gulf of Alaska fisheries to inform where bycaught Chinook would have returned to spawn.[1599] Assumed natural mortality rates range from 30 percent for 3-year-old fish to 10 percent for fish five years of age or older.[1600] These factors and the diverse stocks taken in trawl fisheries make it difficult to count the costs of trawl Chinook bycatch because of challenges in determining the river of origin, timing of return and effect of other sources of mortality.

The primary external cost imposed by trawl Chinook bycatch is the potential for disproportional impacts on vulnerable populations, which can result in constant fisheries closures.[1601] Most wild Chinook stocks in Southeast Alaska failed to meet escapement goals in consecutive years since 2014, with times of record-low escapements.[1602] Extended commercial and sport fishery closures lasting for months and covering large areas prevented harvest of these wild Chinook but also eliminated fishing opportunities for more abundant Chinook stocks, reducing harvests and the number of active fishermen. [1603] Multiple other Chinook stocks originating in other parts of the Gulf of Alaska have also failed to meet escapement goals in recent years, resulting in similar restrictions throughout the Gulf of Alaska.[1604]

Trawlers continue to kill Chinook as bycatch even when all other resource users stop fishing in order to reduce impacts on vulnerable populations. Alaska salmon fishery managers use spawning escapement goals to maintain salmon productivity.[1605] Regulations require conservative management responses to escapement failures, such as the ongoing implementation of Chinook fishery restrictions.[1606] Every individual fish is important to meeting escapement goals and achieving long-term salmon productivity.[1607] Neither NMFS nor the NPFMC require trawlers to reduce bycatch in order to meet escapement goals, creating a severe disconnect between state and federal management.[1608] The NPFMC's primary concern is that setting lower limits would prevent trawlers from harvesting their full quota in some years.[1609]

The federal failure to connect escapement needs with bycatch impacts means that the conservation burden is borne solely by Alaskans who depend on Chinook for cultural values, food and fishery income in rural and urban communities.[1610] The value of subsistence harvests in rural Alaska is substantial but often unmeasured.[1611] Trawlers also kill fish listed under the Endangered Species Act which are of high value because of their rarity and costs incurred by numerous industries in the Pacific Northwest.[1612] In short, the cost of trawl Chinook bycatch to other fishermen and society vastly exceeds direct losses to other harvesters because of the loss of individual fish that could otherwise contribute to escapements and restoration of fishery access.

Bottom trawling also poses a negative externality on other fishermen and society because it is a destructive fishing practice that harms habitats, particularly habitats that support large concentrations of fish species.[1613] Damage to cold-water coral habitats, for example reduces the availability of fish to other fishermen immediately and in the future, reducing their catch rates and increasing harvest costs.[1614] The estimated area impacted by trawl gear in Alaska – over 275 million acres – in a 3-year period can be nearly 10 percent of the seabed in the Gulf of Alaska and up to one-third of the seabed in the eastern Bering Sea.[1615]

Habitat impacts also lead to increased concentrations of CO_2 in the ocean and atmosphere. The top three feet of seafloor sediments globally store vast amounts of carbon – over 1 billion tons, and more than terrestrial soils.[1616] Most of the storage is in continental shelf areas exposed to intensive trawling.[1617] Trawling disturbs these sediments, releasing the carbon into both the water column and atmosphere as CO_2, increasing ocean acidification and atmospheric CO_2.[1618] The emissions are of similar size to those of aviation and agriculture.[1619] The most substantial emissions occur the first year after trawling.[1620] Impacts continue with continuous trawling and eventually stabilize at a rate roughly 40 percent of initial CO_2 emissions.[1621] NOAA has estimated that on the U.S. west coast (excluding Alaska) alone, trawling on roughly 119,000 square kilometers over three years from 2010 to 2012 released approximately 36 million metric tons of carbon.[1622] During roughly the same time period, trawlers in Alaska covered 1.1 million square kilometers – or nine times as much area.[1623] There are no available estimates for emissions from the Alaska trawlers but if occurring at the same rate as on the West Coast, emissions would amount to 324 million metric tons, equivalent to using 32 billion gallons of diesel fuel.[1624] Trawlers drug over 427,458 square kilometers in Alaska from 2016-2020 – over 97 percent of the area impacted by fishing gear of any kind.[1625]

Reducing the impact of industrial trawling on biodiversity and ecosystems through shifts to lower-impact gear will benefit coastal communities in Southeast Alaska and throughout the state that depend on fish for food, fisheries for income and fishing as a way of life.[1626] Climate change, and its effects on the marine environment, hasten the need to reduce the impacts of industrial trawl fisheries on biodiversity and ecosystems.

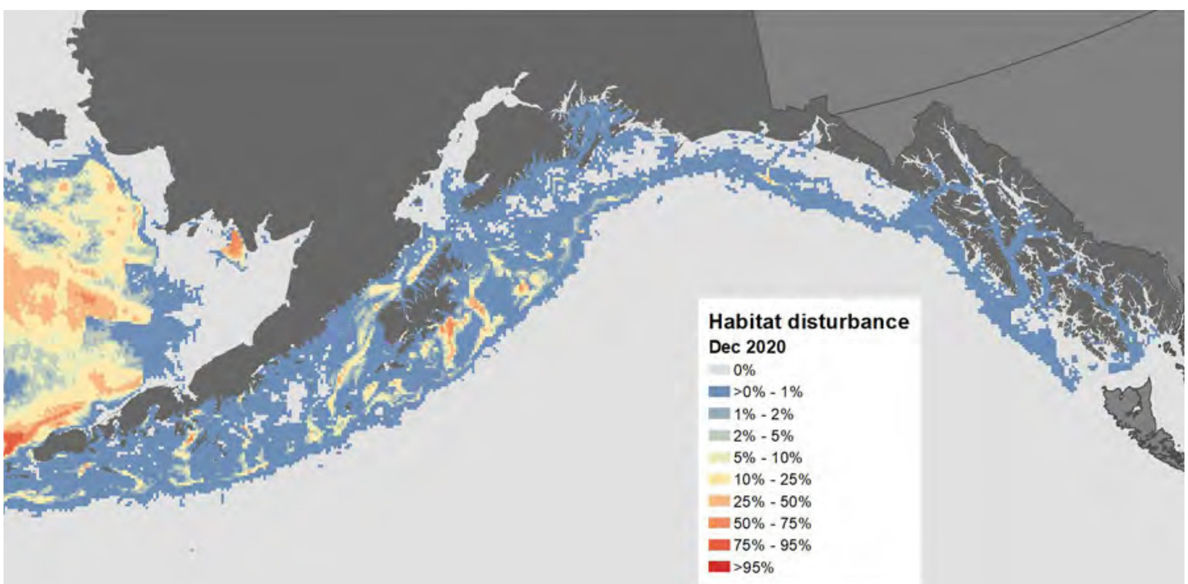


Figure 4: Trawling is responsible for nearly all of the habitat disturbance caused by fishing in Alaska. Graphics credit: Zaleski, M., T.S. Smeltz, S. Rheinsmith, J.L. Pirtle & G.A. Harrington. 2022. 2022 evaluation of fishing effects on essential fish habitat. September 2022. D8EFH Fishing Effects Discussion Paper.

Chapter 8: Threats to Watersheds from Mining Projects

An existing and growing threat to SeaBank capital are the massive mines upstream in the "Golden Triangle" of northwest British Cental review or permitting.[1627] The biggest mines are on low-grade copper deposits and will consequently create enormous volumes of waste tailings because of their large size and the area's low-grade ore.[1628] Mine developers are attracted to the overall large amount of copper in these deposits and the presence of some higher-value minerals such as molybdenum, silver and gold.[1629]

The Golden Triangle area also houses some of the most productive and least disturbed salmon habitat on the planet.[1630] The mines are in watersheds of the transboundary rivers that originate in British Columbia and flow into Southeast Alaska.[1631] The Taku River (100 miles long), Stikine River (400 miles) and Unuk River (80 miles) are three of the longest undammed rivers in North America.[1632] These rivers provide significant natural capital in support of Southeast Alaska's culture and economy, with an estimated value of $1.2 billion over the next 50 years.[1633] Chapter 3 of this report explains that these rivers are major producers of coho and sockeye salmon, and fishery managers have implemented conservation measures throughout the region to recover Chinook populations.

TOXIC TAILINGS

"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, 2020.

Julian D. Olden, Professor of Aquatic and Fishery Sciences, University of Washington, 2020.

Risks of Chemical Pollution to Transboundary Rivers and Fish

Existing and proposed mines in the Golden Triangle can drastically damage transboundary rivers and their salmon, with adverse impacts to Southeast Alaska's fishing and tourism industries, Alaska Native culture and the way of life for most residents.[1634] The area's mines will produce watershed-scale pollution of kinds known to have severe, even population-level, impacts to salmon.[1635] Risks range from persistent pollutant leakage that chemically impacts spawning and rearing habitat to catastrophic tailings dam failures that can physically destroy the biotic function of an entire watershed and its values.[1636] Over three-fourths of the mines in Canada discharge toxic materials that harm fish and fish habitat.[1637] British Columbia allows most mining companies to exceed 'permitted' levels of pollutant discharge into salmon streams.[1638]

Acid rock drainage, running from stacked waste rock, is one of the more common chronic contaminants.[1639] This acidic effluent is heavy-metal rich.[1640] Acid rock drainage is common, mostly unavoidable and – importantly – continues for decades if not centuries after mine closure.[1641] The metal-laden effluents travel downstream hundreds of miles from the mine.[1642]

Globally each year, large mines similar to British Columbia's copper mines produce more waste than marketable minerals – mainly billions of tons of mine "tailings".[1643] Mines crush the ore into fine particles and treat them with chemicals in order to separate and extract the more valuable minerals.[1644] This process leaves behind tailings, which are a slurry mixture of rock particles, process water and chemical reagents that is often acidic and contains a high content of toxic substances.[1645]

Mine companies typically store the tailings in impoundments formed by large earth-filled embankment dams. They construct the dams with mine waste rock and often the coarser refinement tailings.[1646] These dams have a higher failure rate than dams built for hydropower or water storage due to the construction material and, since mine companies typically build the dams in stages over multiple years as mining and waste production progresses, the method of construction.[1647] These facilities are some of the world's largest engineered structures.[1648] Mining companies plan to leave the toxic tailings behind the dams forever, but failures over time are common.[1649]

Mine companies may seal the tailings by overtopping them with a lake ("wet tailings") or drain them.[1650] Wet-tailings storage facilities pose the greatest risk for catastrophic damage. Their failures amount to three-fourths of all major environmental disasters caused by mining.[1651] All wet-tailings disposal areas leak to some extent over time.[1652] Whether tailings escape through dam seepage or dam failure, the consequences of escaped tailings are irreversible.[1653] Globally over the past century, over 300 tailings dams have failed to varying degrees because of weakened foundations, seepage or earthquakes.[1654] In the U.S. and Canada over that time period there have been at least 130 tailings dams failures, and 28 percent of currently operating copper mines in the U.S. have had partial or full tailings dam failures.[1655]

Tailings dams and their toxic contents require maintenance forever.[1656] Even without catastrophic failures, increasing downstream metal concentrations and polluted groundwater directly harm aquatic organisms.[1657] Acid mine drainage additionally increases the amount of toxic metals in streams and rivers, a long-term problem.[1658] In a tailings dam failure of some sort (not necessarily total failure) that heavily pollutes waters, fish can die within hours to days.[1659] British Columbia copper mines utilize mineral deposits that are igneous rock consisting of coarse-grained crystals such as feldspar or quartz dispersed in a fine-grained matrix ("porphyry"). Normal drainage from their tailings and from the mines themselves will add to existing aquatic concentrations of iron, copper, cadmium and aluminum, nitrates, sulfates and mercury. These elements and compounds alone or in combination have a variety of sub-lethal effects on fish.[1660] A toxic "cocktail" may result that is more destructive than any single element.[1661]

An excess of heavy metals impairs fish reproductivity, survival, growth and development.[1662] Elevating the concentration of these metals beyond a naturally-occurring level may cause fish to avoid impacted habitat entirely. If so, this becomes a "toxic dam" that permanently obstructs salmon migration, eliminates upstream habitat and extirpates resident fish populations.[1663] Metal-rich water impairs fishes' sense of smell and their ability to avoid predators.[1664] Fish grow slower, swim slower and may be unable to reproduce.[1665] The pollutants degrade the food web, decreasing the richness and abundance of prey species for salmon, and some contaminants bioaccumulate throughout the web all the way to salmon.[1666]

Particularly, there is chronic, widespread selenium pollution from British Columbia's mines.[1667] This potentially toxic trace element is found in ore deposits containing heavy metals such as copper.[1668] Chemical processing of ore dissolves selenium, some of which becomes an effluent from tailings or waste water that flows downstream, contaminating the aquatic ecosystem.[1669] Selenium accumulates over time in the food chain, and can reach a high concentration. [1670] It poses one of the most serious risks to aquatic habitat and fish.[1671] At high concentrations it is toxic to fish and all aquatic life, causing deformities and reproductive failure.[1672]

Large mine developments also harm salmon populations through altered hydrology and loss or degradation of habitat.[1673] Pits, impoundments, ditches and roads alter groundwater and surface water connectivity, stream flow and temperatures.[1674] Mines and mining infrastructure can also alter or eliminate habitat by displacing, filling, rerouting or burying stream channels and wetlands.[1675] Tailings and sediments from mined areas or access roads can end up in streams through erosion, resulting in clogged spawning beds, blocked streams and flooding.[1676] On access roads, stream crossings, bridges and culverts can impede fish passage.[1677]

High Risks of Tailings Dam Failures

The potential for tailings dam failures to occur and impact transboundary watersheds is a serous concern.[1678] Dam failures pose a significant, potentially catastrophic risk to the environment and nearby communities.[1679] Globally each year, five or six significant tailings dam failures occur, extensively damaging the environment.[1680] The rate and severity of failures is increasing, particularly as mining companies build larger and higher dams to accommodate larger waste volumes.[1681] One of the main factors driving the increased risk is the development of low-grade, high-volume ore bodies such as those in the Golden Triangle.[1682]

In 2014, a tailings dam at a copper-gold mine elsewhere in British Columbia failed catastrophically.[1683] The "Mount Polley disaster" was the largest collapse in Canadian history and among the largest in the world.[1684] It dumped 6.6 billion gallons of toxic water and slurry waste into the environment.[1685] Much of the waste ended up in an important sockeye lake, Quesnel Lake.[1686] Before reaching the lake, the tailings slurry scoured, deforested and buried 6 miles of salmon stream habitat.[1687]

The independent review panel that investigated the Mount Polley disaster concluded that storing water and tailings together created "intrinsic hazards."[1688] The review panel concluded that separating the water and tailings prior to long-term storage was the only way to reduce risks of such failures.[1689] The panel projected that two dam failures will occur per decade in British Columbia unless significant changes to design, construction and management of mine waste are made.[1690] Other researchers have similarly identified water management as the critical problem, particularly in high-risk areas that combine steep terrain and high levels of seismic activity and precipitation.[1691]

Inadequate regulatory guidance is also a primary cause of these disasters. [1692] Mining companies have long known how to store dry tailings but, absent more protective standards, they have preferred to risk dam failures.[1693] It is possible to de-water, filter and store tailings in dry stacks and seal them.[1694] Mining companies have refused to adopt these technologies because of additional direct costs, despite the high risk of dam failures.[1695]

Threats From Mines in Tranboundary Watersheds and the Chilkat River

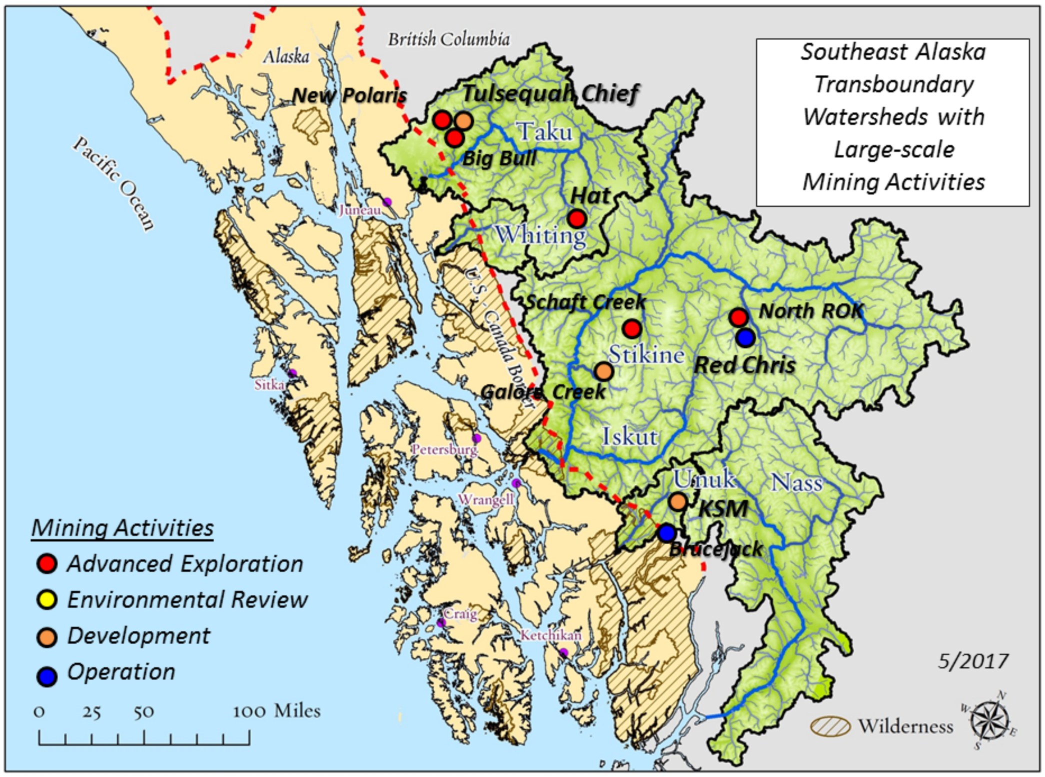


Figure 5: Graphic credit: Salmon Beyond Borders; available at www.salmonbeyondborders.org/map.html.

Imperial Metals – the same company responsible for the Mount Polley disaster – operates the Red Chris copper-porphyry mine, which is the first company project to get an operating permit after the Mount Polley disaster.[1696] The mine is upstream of the Iskut River, the largest tributary of the Stikine River. Its tailings dam is three times as high as the Mount Polley dam and holds seven times as much wet tailings.[1697] Red Chris and the three proposed large mines (Schaft Creek, Kerr-Sulphurets-Mitchell and Galore Creek) will produce acid-generating waste – this means tailings from each mine will be more toxic than those stored at Mount Polley.[1698] Tailings dams for the three proposed large mines will be two to six times higher than Mount Polley's tailings dam and will store six to twenty-seven times as much waste.[1699] Each mine will use the same wet tailings dam design used for Red Chris (shown below), which failed at Mount Polley.[1700]

The dam at the Red Chris mine is 341 feet high. Photo Credit: Southeast Alaska Indigenous Transboundary Commission; available at: https://www.seitc.org/lakes-of-poison.

The Kerr-Sulphurets-Mitchell mine is near the headwaters of the Unuk River, which flows into the Misty Fjords National Monument near Ketchikan, and would be the largest mine in British Columbia if developed.[1701] It has high potential for acid mine drainage and heavy metal pollution, in part because its enormity.[1702] The mine would require two large dams. [1703] The tallest would be 790 feet high and 4600 feet long – taller and wider than the Hoover Dam and six times as high as the Mount Polley dam.[1704] It would have 28 times the storage capacity of Mount Polley, storing underwater over 2.3 billion tons of acid-generating tailings.[1705] The site is wet and steep and has high seismic activity, heightening the risk of a tailings dam failure or leaks.[1706]

British Columbia and the Canadian federal government approved development of the Kerr-Sulphurets-Mitchell mine prior to the Mount Polley disaster and before the subsequent panel report that predicts additional future failures elsewhere.[1707] A recent analysis of British Columbia's tailings storage facilities identified Kerr-Sulphurets-Mitchell as having the most extreme risk among the province's mines, because of the dam's height and the site's characteristics.[1708] The potential for major, irreparable habitat destruction further intensifies the risk.[1709]

Making matters worse, climate change is increasing the frequency of landfall by atmospheric rivers and their intensity, thereby increasing the likelihood of tailings dam failures in any of British Columbia's Golden Triangle mines.[1710] Mining companies built existing infrastructure assuming a static environment. [1711] Design criteria anticipating the largest flooding event or earthquake the dam could experience are outdated.[1712] This is a particular concern for Kerr-Sulphurets-Mitchell, which would have to store and treat water for at least 200 years after mine closure,[1713] and actually in perpetuity.

Another Canadian company, Constantine Metals, is exploring development of a copper-zinc mine, the Palmer Project in the Chilkat River watershed near Haines.[1714] The mine is adjacent to the Klehini River and just outside the Chilkat River Bald Eagle Preserve and the Tlingit Village of Klukwan.[1715] Mineral extraction will likely result in increased toxicity in this highly productive salmon system, risking long-term damage to salmon runs and the entire Chilkat Valley ecosystem.[1716] The mine is likely to produce acid mine waste and no long-term treatment plans are evident.[1717] The area, like the Golden Triangle, has both high precipitation that is increasing with climate change and high seismic activity, putting the mine at high risk for a waste storage failure.[1718]

Mining companies often do not clean their messes such as this pollution from British Columbia's Tulsequah Chief mine upstream from Juneau, leaving the public to absorb the considerable direct and indirect costs caused by the pollution. Photo credit: Colin Arisman/Southeast Alaska Indigenous Transboundary Commission.

Regulations typically allow mining companies to externalize the costs of their pollution and disasters to the public. Impacts have extreme longevity and are often worse than predicted during planning. [1719] Implementation of mitigation measures is ineffective more often than not.[1720] In many cases, mining companies do not have to maintain insurance policies or post bonds to compensate those harmed by a disaster or even to clean up after one.[1721]

After closure, a large site may require active water treatment forever, and the risk that its water pollution will jump to a new level in the future endures.[1722] But mine companies abandon many sites after reclamation for various reasons that range from a lack of regulatory oversight to financial insolvency.[1723] British Columbia’s estimated reclamation liability for current major mine projects, for example, is $2.8 billion.[1724] Acid runoff from the Tulsequah Chief mine, roughly six miles upstream from the Taku River, has continued for decades since the mine ceased operations.[1725] Two of the three mine owners are out of business or in bankruptcy proceedings, complicating and delaying cleanup of the mine.[1726] The remaining owner has offered to pay just over 2 percent of the $61 million cleanup cost.[1727]

In sum, in the transboundary river watersheds and Chilkat River, mining companies propose to develop high-risk mines that have real potential for catastrophic failures. These are locations where the environmental vulnerability is so high, particularly in a changing climate, that there is no environmentally- or socially-acceptable way to develop these mines.[1728]

Conclusion

Coastal ecosystems such as SeaBank are the most productive economic systems in the world. SeaBank 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.

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 such as adding toxic mine pollution to watersheds, removing forested habitat or disrupting streams through industrial logging and timber road construction will degrade key assets, 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 SeaBank natural capital assets for habitat changes, trends in fish and wildlife abundance, and natural capital dividends, such as seafood sales and tourism numbers and revenue. Subsequent annual reports will update the status of SeaBank natural capital, annual sales and evolving asset risks in order to better inform the public as well as local, regional and national decision makers.

Photo credit: Linda Behnken

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