Commercial Salmon Fishing Livelihoods and Environmental Changes in Southcentral and Southeast Alaska

Technical Report for EPSCoR Fire and Ice: Coastal Margins
Institute of Social and Economic Research

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Abstract

Current and anticipated effects from climate change in coastal regions of the Gulf of Alaska include melting glaciers, warming ocean and riverine temperatures, and a greater proportion of annual precipitation falling as rain. These changes in the physical environment may affect abundance, distribution, health, and size of salmon, which will directly and indirectly impact salmon fishing livelihoods. Fishers' adaptations documented in prior research included increases or decreases in fishing effort, diversification of fishing portfolios, changes in species, gear, and harvest location, and exit from the fishery. We conducted semi-structured interviews with fishery participants and institutional representatives involved with commercial salmon fisheries in the Kachemak Bay and Lynn Canal regions in the Gulf of Alaska to learn about observations and adaptations related to environmental changes, management changes, and co-occurring pressures. Interviews were transcribed and inductively coded for themes using Atlas.ti software using grounded theory methodology. Results will address a research gap about the local knowledge and adaptive strategies of commercial salmon fishermen to multiple stressors in both south central and southeast Alaska, as well as the role of local and regional institutions in supporting the resilience of those fisheries.

A story map that summarizes the study may be accessed at the following link:

https://storymaps.arcgis.com/stories/a2160e02eea347c9b16e4bb39be45bda

Table of Contents

Tables and Figures

1. Introduction

1.1 Background

1.1.1 EPSCoR Fire and Ice

The Established Program for Stimulating Competitive Research (EPSCoR) Fire and Ice Project: Coastal Margins explored research questions about biophysical and biogeochemical changes in estuaries and watersheds with varying glacial cover in southcentral Alaska (Kachemak Bay) and southeast Alaska (Lynn Canal), both sub-arctic ecosystems with receding glaciers. In the Gulf of Alaska, salmon harvest is central to many Alaska Natives' lifeways and many Alaska residents' livelihoods. Salmon management and harvest were a major focus in Alaska's statehood in 1959 (King, 2009). Subsistence, sport, and commercial salmon fisheries define the workforce and economic development in some coastal communities (Himes-Cornell and Kasperski, 2015). We explored the impacts of changes in the environment and management on commercial salmon fishers in two fisheries-dependent communities to understand the current and anticipated future changes due to these and other stressors. We also learned how some of Alaska's commercial salmon fishers are adapting to co-occurring stressors.

During 2021-2022, we interviewed 34 commercial salmon fishermen with a minimum of 10-years of experience about changes they observed in the environment, their target species, and management over time, as well as their strategies for adaptation. We also interviewed 19 institutional representatives from relevant groups ranging in size, scale, and focus from professional trade associations, non-profit conservation organizations, private non-profit hatcheries, processors, and state and federal agencies. We asked about the institutional representative's perceptions of the stressors facing commercial salmon fishers and what strategies could be used by institutions to support fishers, as well as how their institutions were able to adapt to changes.

1.1.2. EPSCoR Coastal Margins research sites

This research is part the National Science Foundation EPSCoR Fire and Ice Project, part of which explores glacial change in two areas of the Gulf of Alaska (Figure 1). These two areas have been studied together for over 15 years. The EPSCoR study areas have varying proportions of watershed glaciation from 0-60%. The inset on the left shows Kachemak Bay, which is located near Homer, Alaska. On the right, Lynn Canal is located near Juneau, Alaska. The red circles on the maps show the approximate locations of research sites where biophysical data are being collected for the project.

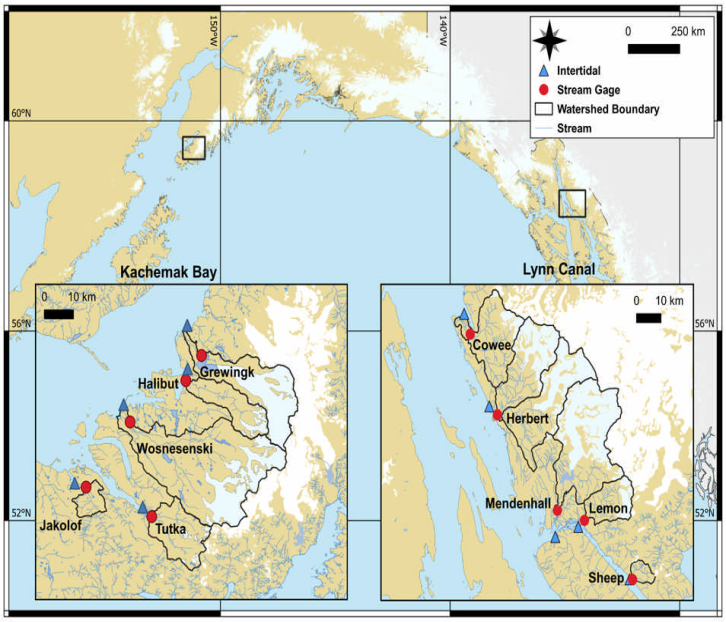


Figure 1. EPSCoR Fire and Ice research sites. The inset on the left shows Kachemak Bay, which is located near Homer, Alaska. On the right, Lynn Canal is located near Juneau, Alaska. The red circles on the maps show the approximate locations of research sites where biophysical data are being collected for the project.

1.1.3. Environmental impacts and coastal communities

Environmental impacts in some of Alaska's coastal communities can be linked to climate change directly in cases of coastal erosion, sea level rise, and natural disasters (Trainor et al., 2007; Colburn et al., 2016; Himes-Cornell and Kasperski, 2015). Environmental impacts on some fish species and fisheries-dependent communities can also be indirectly linked to warming ocean temperatures, an increase in harmful algal blooms, and both coastal and ocean acidification (Mathis et al., 2015; Dorn et al., 2017).

Since the start of the industrial revolution in the 1850s, oceans have absorbed about 30% of the anthropogenic carbon dioxide produced (Hoegh-Guldberg et al., 2018). Consequently, ocean acidification can be observed, particularly in higher latitudes where colder water absorbs more carbon dioxide (Mathis et al., 2015; Markon et al., 2012). This change can be observed in the inability of animals to grow calcareous shells, such as pteropods and mollusks (Dorn et al., 2017), which impacts predators including pink salmon (*Oncorhynchus gorbuscha*) (Mathis et al., 2015). Warmer waters increase metabolic and growth rates in finfish. However, the rate of food consumption in warmer waters does not increase, even in the case of abundant available food (Whitney et al., 2016). Increased water temperatures can also influence disease resistance and timing of migration and spawning (Shoen et al., 2017). Warmer water temperatures and changes in abundance and size of Chinook and chum salmon are already being observed in marine ecosystems in the Gulf of Alaska (Jones et al., 2020; Schoen et al., 2017; Oke et al., 2020).

1.1.4 Risk, vulnerability, adaptation, and resilience: fisheries-dependent communities

The Intergovernmental Panel on Climate Change (IPCC, 2014) defines risk as a combination of hazards, exposure, and vulnerability. Cinner et al. (2013) more explicitly differentiate ecological vulnerability due to exposure and sensitivity to biophysical changes from social-ecological vulnerability that links ecological vulnerability with social sensitivity and adaptive capacity.

According to Himes-Cornell and Kasperski (2015), on a social-vulnerability index, Homer ranks high as a fisheries-dependent community in Alaska, relative to other Alaskan communities. It ranks high in adaptive capacity, and it ranks correspondingly low on limitations to adaptation. It has relatively low exposure to biophysical impacts from climate change. Juneau also ranks high as a fisheries-dependent community in Alaska. Juneau has high exposure to the anticipated biophysical effects of climate change due to potential hydrological impacts from melting glaciers. However, relative to other Alaskan communities, Juneau ranks low for limitations on local adaptive capacity due to the variety of employment fields available. The assessed potential for adaptive capacity is high for both Homer and Juneau due to employment opportunities available other than commercial fishing (Himes-Cornell and Kasperski, 2015).

Local and regional institutions have been linked to helping individuals and communities adapt to changes in natural resources. Berman et al. (2020) found that self-organized local institutions can play a role in the ability of communities to adapt to climate change and other co-occurring pressures. Green et al. (2021) reported that strong institutions could support adaptation in households that demonstrated diversity and flexibility, and also learning and knowledge.

1.2. Study Area

1.2.1 South central Alaska: Homer

Homer is located in the traditional territories of the Dena'ina Peoples. It is at 59 degrees north latitude, in sub-Arctic Alaska. The population was 5,531 people in the 2020 census. Homer can be accessed by the road system on the Kenai Peninsula. The primary vegetation is a mix of Lutz spruce, Sitka alder, and willow and paper birch. Homer faces Cook Inlet to the west and Kachemak Bay to the south.

Homer is located at the Lower Cook Inlet management area, within the Southern district for salmon fisheries, which are primarily set gillnet and purse seine fisheries. Set gillnet fishers target primarily sockeye salmon, while seine operators target pink salmon. Cook Inlet Aquaculture Association (CIAA) took over operation of the Tutka Bay hatchery from the state in 1991. CIAA stocks pink salmon and sockeye salmon in Kachemak Bay. Kachemak Bay had strong shellfish fisheries for crab and shrimp until the late 1970s, at which time a stanza shift related to the Pacific Decadal Oscillation resulted in warming marine temperatures. ADF&G biologists reported that this change in temperature was one of multiple drivers that shifted the biomass and fisheries in Kachemak Bay away from shellfish and toward salmon (King, 2009; Mantua et al., 1997). Salmon harvest has shown an overall decline since the 1980s (Figure 2).

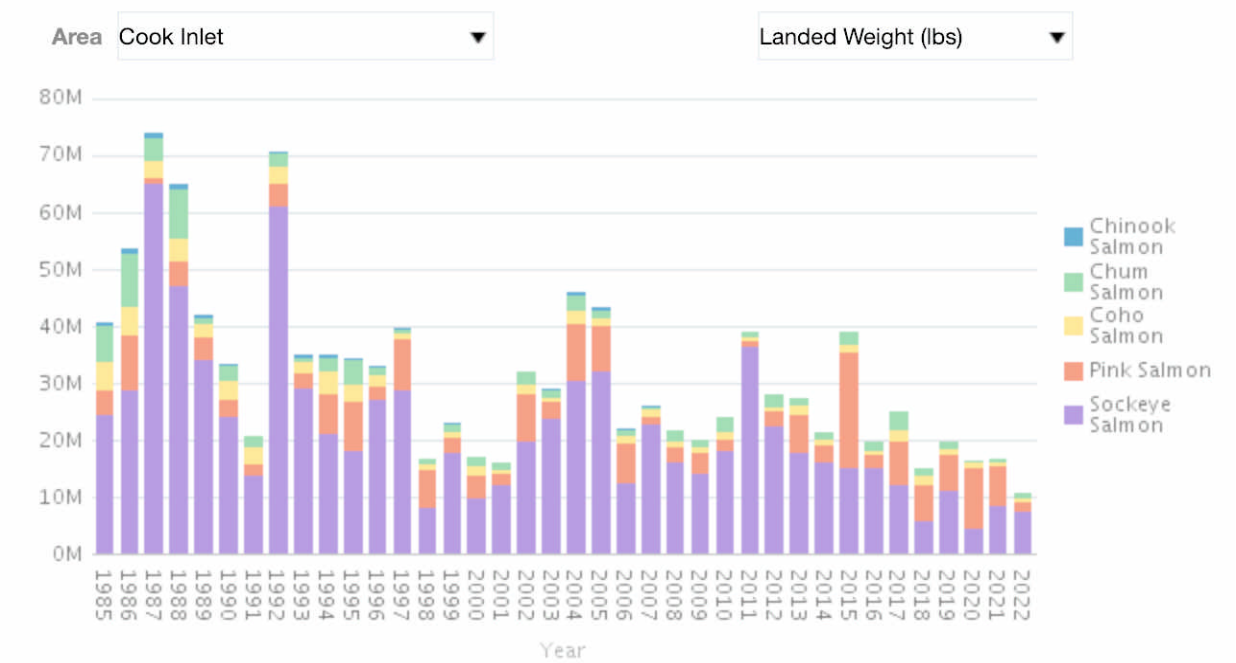


Figure 2. Commercial salmon landings by area, by species for the Cook Inlet region (northern and southern districts combined), represented by landed weight in pounds, as reported on salmon fish tickets (Alaska Department of Fish and Game): https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmon_landings

1.2.2 Southeast Alaska: Juneau

At approximately 58 degrees north latitude, southeast Alaska is a sub-arctic ecosystem. A series of over 1,000 islands make up the Alexander Archipelago (Mekbeb et al., 2009), with glaciers as far south as the LeConte Glacier near Petersburg, Alaska. Southeast Alaska is also the location of one of the world's largest intact temperate rainforests. The Tongass National Forest contains 17.1 million acres of land, with dominant tree species of western hemlock (*Tsuga heterophylla),* Sitka spruce (*Picea sitchensis*) and Sitka alder (*Alnus viridis*) found near Juneau. There are over 5,500 salmon streams and tributaries, as well as 18 hatcheries, in Southeast Alaska (Himes-Cornell et al., 2013).

Juneau is located in the traditional homeland of the Lingít Peoples, who have netted, trapped, processed, and stewarded salmon populations for millennia (Mathews and Turner, 2017). Juneau is also the capital of Alaska, the third most populous city in the state with a population of 32,240 people reported from the 2020 census. It was incorporated as a city in 1900 following an influx of settlers for gold mining (Himes-Cornell, et al. 2013). Juneau is considered an urban area and is designated a non-subsistence fishing area. There are multiple commercial salmon fisheries distinguished by gear type and salmon species. There are also sport salmon and halibut fisheries near Juneau, and diverse shellfish and dive fisheries (Himes-Cornell et al., 2013).

The commercial fishing that takes place near the EPSCoR Fire and Ice biophysical research sites is primarily salmon fishing. Coho salmon have the longest juvenile stream residency of the five salmon species, at two years. Drift gillnetters in Lynn Canal fish for coho salmon, although in lower quantities than chum and sockeye. Trollers also fish for coho.

Commercial salmon fisheries located near Juneau are primarily drift gillnet, purse seine, and

troll fisheries. Drift gillnet fishers target sockeye salmon (*Oncorhynchus nerka*), pink salmon (*O. gorbuscha*), and chum salmon (*O. keta*) during summer, as well as coho salmon (*O. kisutch*) in the fall. Purse seine fishers target primarily pink salmon and chum salmon, and fishers operating troll vessels in inside or outside waters target Chinook (*O. tshawystcha*) and coho salmon.

Snettisham Bay, located south of Juneau, was one of the first hatchery sites in Alaska in the 1970s (Heard, 2012). Declining salmon catches in the 1930s and 40s was one of the primary motivations for pursuing statehood, which put salmon management under state control instead of federal control (King, 2009). After very low salmon catches at the time of Alaska's statehood in 1959, the wild and hatchery salmon runs generally grew from the 1980s to early 2000s (Figure 3). However, there have been unexplained declines in Chinook salmon and chum salmon in recent years (King, 2009; Oke et al., 2020)

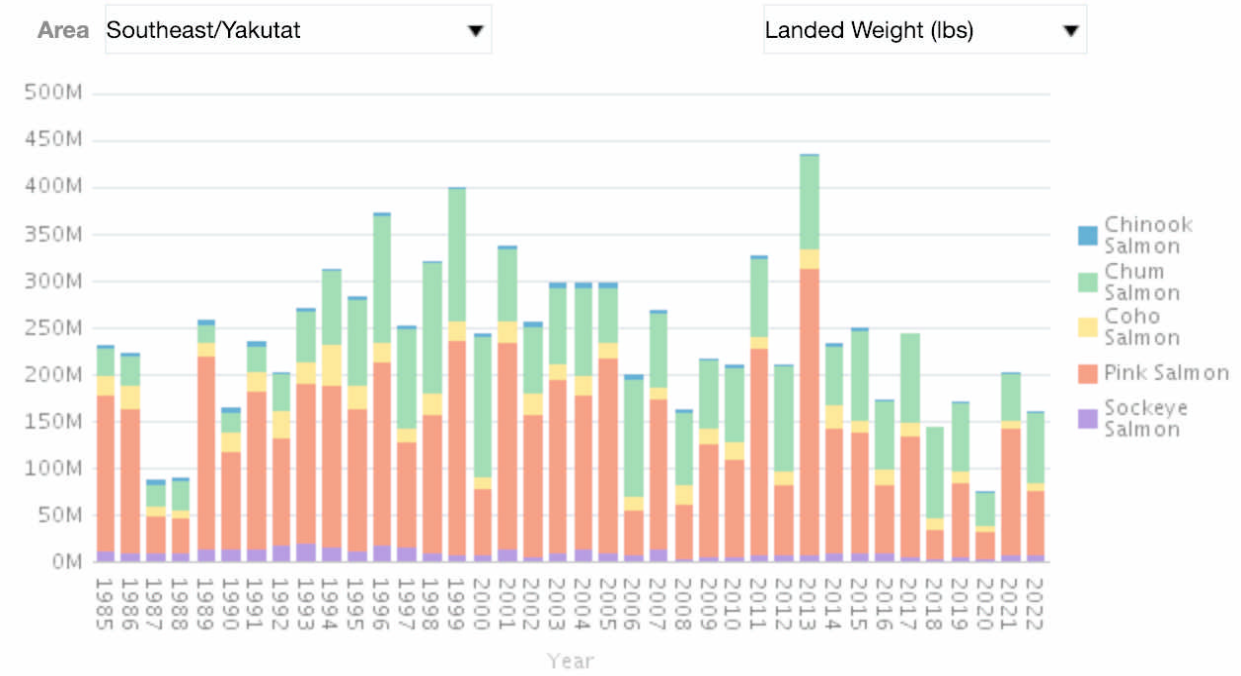


Figure 3. Commercial salmon landings by area, by species for the Southeast/Yakutat region, represented by landed weight in pounds, as reported on salmon fish tickets (Alaska Department of Fish and Game): https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmon_landings

In Homer-Kachemak Bay, the EPSCoR sites are located in the Southern district of Lower Cook Inlet. In Juneau-Lynn Canal, research sites are located in fishing Districts 11 and 15 (Figure 4). There are terminal hatchery fisheries in Tutka Bay (Homer) and near each of the biophysical data sites in Juneau.

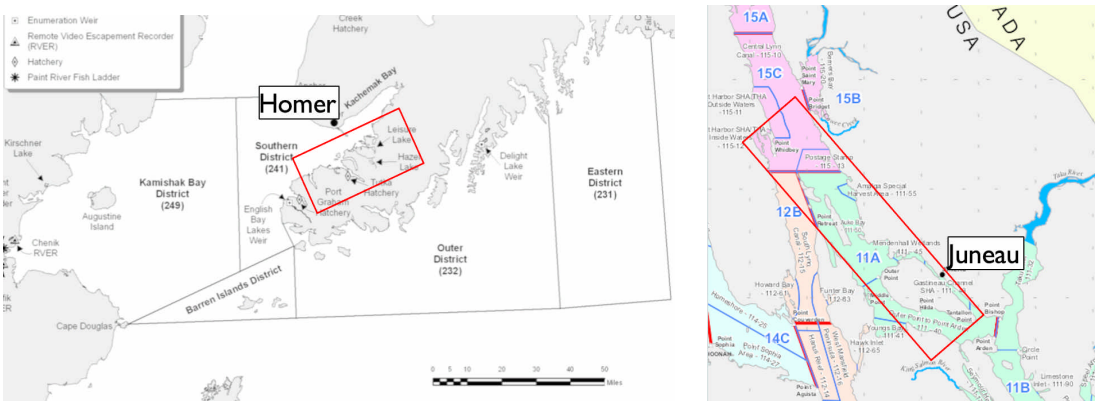


Figure 4. Commercial salmon fishing districts and EPSCoR Coastal Margins research sites near Kachemak Bay/Homer (left) and Lynn Canal/Juneau (right).

1.3 State of Knowledge

1.3.1 Current and anticipated environmental changes in Alaska

Current and anticipated environmental changes in Alaska include changes within terrestrial and aquatic ecosystems. The following changes have been documented in the scientific literature: precipitation volume and form, riverine and estuary water composition, ocean conditions, and size and abundance of some species of salmon; precipitation and stream flows are predicted to be inconsistent in the future (Markon et al., 2012; Dorn et al., 2017). The occurrence of extreme weather events, incidences of thermal extremes, and average seasonal temperatures will increase under the influences of climate change (Markon et al., 2012; Solomon et al., 2007; Pachauri et al., 2014; O'Neill et al., 2017). In addition, Harmful Algal Blooms, which can be caused or exacerbated by prolonged warm water events, can result in disturbances in populations of species at the base of the food web. Plankton and copepods are food for juvenile salmon and some adult salmon species (Dorn et al., 2017; Markon et al., 2012; Suryan et al., 2021; Crozier et al., 2019).

Overall, Alaska is considered to be warming about twice as fast as the Continental United States. Lynn Canal is warming approximately 1.3 times the rate, and Kachemak Bay is warming approximately 1.9 times the rate of warming in the Continental U. S. (Littell, 2020). Changes in the marine environment like ocean acidification have thus far occurred faster in southeast Alaska than south central Alaska (Mathis et al., 2015). The predictions for increases in extreme precipitation and warmer ambient air temperature are predicted to be more severe for south central than southeast Alaska (Littell, 2020).

1.3.2 Current and anticipated impacts from environmental changes on Pacific salmon

Pacific salmon are anadromous, living in freshwater and marine water at distinct phases of their life cycle. Pacific salmon are affected differently by environmental changes in different life history stages (Crozier et al., 2019). Juvenile salmon are sensitive to changes in temperature and water chemistry (Schoen et al., 2017; Ou et al., 2015). Juvenile Pacific salmon could increase their growth rates in warmer waters if food and habitat conditions are favorable (Crozier et al., 2019; Schoen et al., 2017). However, salmon survivorship in egg and fry stages could decline and growth rates could be reduced due to increased respiration and metabolism in warmer streams (Schoen et al., 2017). Crozier et al. (2019) compared the vulnerability of different

Pacific salmon populations based on their sensitivity and exposure to different environmental conditions. They found that generally the piscivorous salmon species (Chinook and coho) are more vulnerable than planktivorous species (sockeye, chum, and pink salmon) to anticipated negative effects of environmental changes. The prey species of salmon have shown vulnerabilities as well. Mathis et al. (2015) showed a positive correlation between the impact of coastal acidification on pteropods (zooplankton) and pink salmon that consume them.

Some salmon habitat is also being lost from post-glacial isostatic rebound, and some opportunities will arise from new habitat created by glacial melt and straying salmon. In watersheds with <10% stream gradient, Pitman et al. (2021) predicted relative increases in salmon-suitable habitat. This amounts to an anticipated 1% increase in suitable habitat near Kachemak Bay and 6% near Lynn Canal.

EPSCoR research sites represent mostly snow and glacier regimes (Sergeant et al., 2020; Figure 5). Homer has a mixture of glacier, snow, and even some rain regimes near the coast. Snow-rain regimes for the Juneau area are mostly glacial, except very near the coast where elevation drops and there is a snow regime. Of the six original riverine/estuary EPSCoR monitoring sites near Juneau, five are snow-dependent streams. Cowee Creek is a glacier-dependent stream.

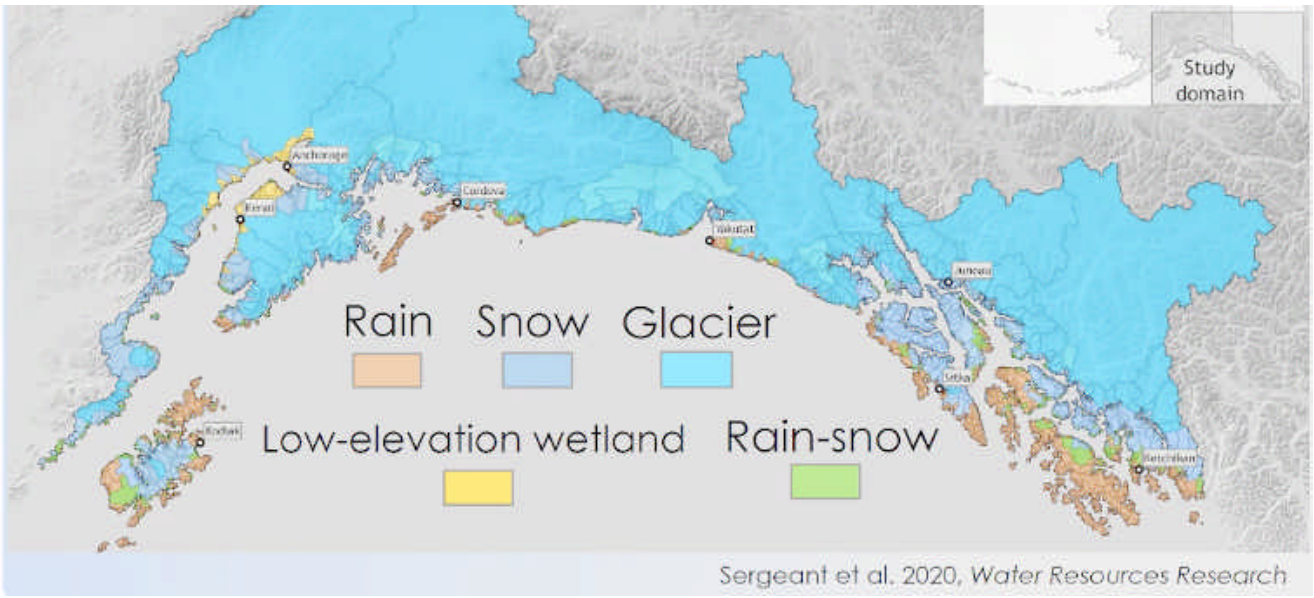


Figure 5. Snow-rain regimes across the Gulf of Alaska (Sergeant et al., 2020).

Melting glaciers will cool the rivers downstream, initially. However, when the glacier is gone and the stream continues to warm, salmon migration is likely to be impacted. Schoen et al. (2017) reported a stream temperature threshold of 18°C/64°F, at which point salmon stall their upstream migration. As stream temperature increases, dissolved oxygen decreases (Fellman et al., 2015), which can be a contributing factor in pre-spawn mortality (von Biela et al., 2022).

Hydrologic changes such as streams transitioning from glacier- to snow- to rain-fed systems over time can result in larger daily water temperature extremes, but also more homogeneous localized stream temperatures. Heterogeneous streams with varying stream temperatures are thought to support up to 20% greater growth potential in Pacific salmon because fish feed in one area and

rest in another (Fellman et al., 2022). Streams with heterogeneous temperature profiles, which act as thermal refugia, support spawning salmon populations better than streams with homogenous temperatures (von Biela et al., 2022).

1.3.3 Anticipated changes and adaptive strategies in Alaska's commercial salmon fisheries
Changes in Pacific salmon populations, such as abundance, distribution, vigor, and size of fish are having, and will continue to have, a direct impact on the livelihoods of commercial salmon fishermen. Based on these changes, fishermen will need to continue to adapt. Past research with commercial fishermen in other states and regions found that adaptations include increasing or decreasing fishing effort, diversifying fishing portfolios (Beaudreau et al., 2019; Badjeck et al., 2010; Kasperski and Holland, 2013), adjusting fishing strategies including changing species, gear, and harvest location (Himes-Cornell and Kasperski, 2015; Salgueiro-Otero and Ojea, 2020), and exit from the fishery (Himes-Cornell and Hoelting, 2015).

Commercial salmon fishers in south central and south east Alaska are restricted by additional management regulations limiting fishing effort through local geographical spatial and temporal limitations that have intensified over time. These restrictions influence, and may determine, which adaptive strategies are available to fishers in each commercial gear group: drift gill net, purse seine, and troll fisheries in Southeast Alaska and purse seine and set net fisheries in south central Alaska.

1.3.4 Influence on commercial salmon fisheries from regional and local institutions
Institutions are generally understood as having formal constraints (i.e., rules, laws, and constitutions) or informal agreements (i.e., norms of behavior, conventions) that mold interaction in a society (Galappaththi et al., 2019).

The Alaska Department of Fish and Game (ADF&G) is an agency that has managed state fisheries, including Pacific salmon species, since Alaska's Statehood in 1959. ADF&G manages for sustained yield, in regional areas, and with public participation through the Board of Fisheries (King, 2009). ADF&G defines maximum sustained yield as "an average annual yield that results from a level of salmon escapement that can be maintained on a continuing basis; a wide range of average annual yield levels is sustainable; a wide range of annual escapement levels can produce sustained yields." Escapement is defined by ADF&G as the "annual estimated size of the spawning salmon stock" returning to a specific river.

Management strategies have changed through time. King (2009) summarized broad, regional institutional responses in Alaska enacted first to support the longevity of fish stocks and later for the safety of fishers as well. These management regulations have included mechanisms for lowering the number of participants by instating Limited Entry Permits for salmon (1973) and instating Individual Fishing Quotas for halibut, King crab, and Tanner crab. Policy changes such as the Magnuson-Stevens Act of 1976, which was amended in 1996 and 2006, claimed more domestic fishing area for the United States by extending the Exclusive Economic Zone, currently defined as 3-200 miles offshore. One effect of the MSA has been to lessen international fishing pressure on the mixed stocks of Pacific salmon before they approach their natal streams. International agreements and institutions such as the Pacific Salmon Commission (Canada and United States) and the North Pacific Anadromous Fisheries Commission (United States, Canada,

Japan, Korea, Russia) create bilateral and multilateral agreements about national allocation of fishes whose migration patterns include life stages in more than one country.

Local institutional adaptations in Alaska generally help to support the survival and life history stages of Pacific salmon. For example, these institutions support salmon habitat protection and advocate for buffers around salmon streams where development will take place. Professional trade associations lobby for specific gear groups such as purse seine or drift gillnet, or for broader user groups like commercial salmon fisheries, such as North Pacific Fisheries Association in Homer and the United Fishermen of Alaska. Organizational members may also share a lowered expense for vessel insurance through a trade association, such as Southeast Alaska Fishermen's Alliance (SEAFA).

1.4 Goals and Objectives

We sought to contribute to filling a research gap about the local knowledge and adaptations of commercial salmon fishers in Kachemak Bay and Lynn Canal regions related to environmental change, co-occurring stressors, adaptive strategies, and current social contexts.

Our aim was to record observations of commercial salmon fishers with long-term local knowledge near the EPSCoR biophysical research areas and watersheds, learn about fishers' adaptations to previous and current stressors, and gain insight into potential future adaptations. This research also explored how various institutions could support the adaptive strategies of commercial salmon fishers.

The central research questions were as follows:

1) What changes have long-term fishers observed related to the environment and management?
2) How do commercial salmon fishers adapt to perceived environmental, management, and other co-occurring stressors?
3) How do representatives at institutions, for example Alaska Department of Fish and Game, trade associations and local non-profits, perceive current environmental changes and co-occurring pressures affecting commercial salmon fishermen?
4) What adaptive strategies are institutions using to support commercial salmon fishermen?

2. Methods

2.1 Interview protocol

We conducted semi-structured interviews with longtime (10 or more years) commercial salmon fishery participants (Beaudreau and Levin, 2014) near Kachemak Bay and Lynn Canal. Respondents were asked to describe changes in their participation level, target species and fishing areas, and the reasons for those changes. We also documented fishermen's perceptions of long-term, local ecological changes. In addition, we interviewed representatives from local institutions such as resource managers, professional organizations, and local non-profits. We

used these responses to assess adaptation strategies and to examine potential institutional shifts to reduce community vulnerability.

This research used a mixed-methods approach, which included interviews with fishermen who were identified initially through the Alaska Commercial Fisheries Entry Commission public databases for vessel and permit owners. We identified fishers who have held permits for salmon fisheries for longer than 10 years. We called those people, and sometimes when phone numbers were not in service, left hand-written notes on their vessels. We also posted recruitment materials on harbor bulletin boards and used intercept sampling (Bernard, 2011), walking the docks at the three harbors in Juneau (Auke Bay, Aurora, and Douglas Island Harbor) and in Homer. We conducted initial interviews with fishers who responded to our calls, notes, or flyers. Thereafter, we used a purposive sampling technique to identify additional respondents (Bernard, 2011).

We also interviewed institutional representatives from local and regional areas whose work influences salmon and salmon fisheries. Institutions included governmental agencies such as the Alaska Department of Fish and Game, representatives from hatcheries, professional fishing organizations, and local non-profit conservation organizations, all of which were relevant to the resilience of commercial salmon fishers and fisheries-dependent communities.

Due to the influence of Covid-19, we conducted some interviews in person and other via Zoom or over the phone. Our consent forms were printed, emailed, or read and agreed to as spoken consent on audio recordings. Participating fishers were offered honoraria in the form of Amazon gift cards in the amount of $49.99. Interviews with fishermen took approximately 45 to 60 minutes to conduct. Interviews with institutional representatives took approximately 30 minutes. Institutional respondents were not offered honoraria.

2.2 Qualitative data analysis

Following each of the interviews, the audio content was transcribed into text. If the interview was conducted via a University of Alaska Zoom account, a transcript was available. Audio recordings were transcribed using Temi, an online paid service for transcription. We then edited the transcriptions for accuracy and coded them in Atlas.ti using inductive methods based in grounded theory (Bernard, 2011; Glaser and Strauss, 1967). A grounded theory approach uses the collected data to develop emergent themes rather than deductive coding where a list of codes may be developed in advance.

Two researchers coded the interview transcripts. Beginning after the first three interviews, which both researchers coded, we compared codes and agreed on naming conventions and terms (Campbell et al., 2013). Then we continued to code independently of one another. We also created memos to comment on the coding of the other person. The process of coding involved highlighting text as a quotation and applying terms representative of the content. For example, many of our terms centered around “change” (fishers’ observed changes) and “action” (adaptive strategies). We used an iterative process of inductive analysis, which was strengthened by having two researchers review a portion of the transcripts and discussing codes throughout the process.

3. Results

This section describes results from fishers and institutional representatives to semi-structured interviews about stressors facing commercial salmon fishers and adaptive strategies to those stressors. The results are based on 34 interviews with commercial salmon fishers who are owner/operators or their own vessels (Table 1). Three of the 34 interviews included both a husband and wife who had fished together for decades. Fishers whose home-port was in Kachemak Bay included 16 purse seine and two set gillnet fishers. Individuals whose vessels were home-ported in Juneau included fishers from two purse seines, eleven drift gillnets, and three power trollers. In cases where fishers participated in more than one commercial salmon fishery, the permit fished most frequently is represented.

Table 1. Commercial salmon fishers represented four salmon fisheries in two regions (n=34)

	Purse seine	Drift gillnet	Set gillnet	Troll	Total
Homer, AK	16	0	2	0	18
Juneau, AK	2	11	0	3	16

The mean number of years that fishers had participated in commercial fishing in Alaska was 40.2 years. Thirty-one out of a possible 34 fishers responded to this question. The mean age of fishers being interviewed across both regions was 60.2 years (n = 33/34 possible respondents). Of the 33 fishers who responded to the question asking their race, six fishers (18%) identified as Alaska Native or Native American (including those who identified as mixed-race including Alaska Native or Native American), and 27 fishers (82%) identified as white or Caucasian (Table 2). In cases where two people were interviewed together, the demographics of the permit-holder are included.

Table 2. Demographics (age and race) of commercial salmon fishers, combined from both study regions. N = x indicates the number of people who responded to the question out of a total of 34 possible fishers.

	Aggregated responses from Homer and Juneau	
Years commercial fishing in AK	40.2 years	n = 31
Mean age	60.2 years	n = 33
Alaska Native of Native American	6 (18%)	n = 33
White	27 (82%)	n = 33

Our qualitative data analysis described above enabled us to identify key themes in responses given by fishers to questions about observations of change in the environment, target species, and management, as well as strategies for adaptation to changes. We summarized responses from institutional representatives across multiple scales and kinds of organizations or agencies.

3.1 Commercial salmon fishers' observations

3.1.1 Commercial salmon fishers' historic and current observations of environmental changes
Commercial salmon fishers across both regions noted changes in the environment where they fish. In both areas, fishers mentioned warmer weather, warmer oceans, droughts, and receding glaciers (Table 3).

Table 3. Commercial salmon fishers' observations of environmental changes through time

Observation	Homer	Juneau
Warmer weather	X	X
Warmer ocean	X	X
Drought	X	X
Receding glaciers	X	X
Isostatic rebound		X
More rain		X
Flooding		X
More sea otters	X	X
More whales		X
More algae		X
More jellyfish		X

Warmer weather:

In Kachemak Bay and Lynn Canal area, some fishers reported warmer weather.

> Juneau fisher: "So, and we also had, combined with all this, we also had four or five years in a row where it was sunny, 80 degrees. And, uh, so our snow pack, couple of years, we didn't have much snow pack. Snow pack was gone before summer even came. And that is not very healthy for rearing salmon. They need to have that fresh water coming into their habitat in order to survive, increases their chances of survival."

Droughts:

Summer droughts and variable river volumes were also reported in both locations. A Homer fisher said,

> "Yeah. 81 degrees. And also the rivers were low. And so I was going to be concerned about pink salmon returns, it's on a two year cycle. So any adult fish that were spawning two years ago, their parents were, you know the fry are coming back this year. So I know in some of the rivers in the outer coast in Port Dick and several rivers down that way, if you went up the rivers at high tide, you would find pools of dead, a hundred, 200, 500 dead fish in the pools up in the rivers and think, what happened here? But I think what happened is these pools, normally when the rivers are a normal level, at low tide there would have been fresh water in those pools and the fish would have lived. But the rivers were so dry that they died of oxygen depletion in those pools. And then at the same we normally, I won't say always, but normally fishing some of these river systems."

Receding glaciers:

There were reports of receding glaciers from both study areas. An example from a Homer fisher:

> "I mean in the 50 years I've been doing it, I mean, I've seen the environmental change. You know what I mean? Like the glaciers, when we were kids, the glaciers were, when I was a kid glacier spit used to bump into Kachemak Bay. You could look out there and there's little icebergs floating around. But the retreat of the glaciers has been going on for

a long time and it's just the warming of the world, you know? I won't even go into what it's caused by, it doesn't even matter to me. It's happening, you know?"

In Juneau and Lynn Canal, responses about observed changes in the environment also included isostatic rebound, more rain, fall flooding, less snow, and variable stream volumes.

> Juneau fisher: "I grew up here in Juneau. I was born here, so I've seen changes in my lifetime. Um, and a lot of it deals with, uh, snow pack that we get during the winter, which, uh, feeds our rivers during the summer. And, uh, year to year, our, our snowfall has been drastically, uh, from one, you know, from, from nothing to, you know, this year we had a ton of snow. Um, so there's definitely a lack of snow pack that's feeding the rivers in the summer, um… We have been basically seeing less and less snow. Um, even though we have gotten some good years…I think that the overall average has gone down and I, I can just see it in the mountains around here. There's, there's a lot less snow, um, you know, sticking around through the summer than there used to be, than 10 or 20 years ago. And a lot of the mountains are really bare by August where they used to have, you know, feet of snow up there still. Um, and you know, when you combine that with the hot summer, um, a lot of our rivers, smaller creeks, um, are really dry and, you know, not allowing a lot of those fish to get up the river or, or leading to very, very crowded streams some years."

Fishers in both Kachemak Bay and Lynn Canal noted more marine mammals over the years. However, there were more mentions of sea otters in Kachemak Bay and humpback and killer whales in Lynn Canal. A handful of fishers also noted increases in jellyfish, algae, salmon sharks, kelp, and instances of paralytic shellfish poisoning.

> Juneau fisher: "A couple of years ago, we had a stellar summer. The surface waters were warmer. We have 30' deep nets, so we are sampling the top 30' of the water. When it is sunny and there is warm water, there is an increase in jelly fish."

Some fishers from each area had not observed changes in the environment. Other fishers had observed cyclic changes, or changes that didn't appear to be a long-term trend.

> Juneau Fisher: "It all goes in cycles though. You know what I mean? So, um, I would say probably the biggest factor in my neck of the woods is glacial rebound. And, um, taking out spawning beds and stuff. But you know, water warms up, water gets cold. It's change so... But it seems, it does seem to go in cycles? That's what I've noticed."

3.1.2 Commercial salmon fishers' observations of changes in target salmon species

Fishers with different vessels and gear types target select salmon species. However, target salmon species are not consistent even among fishers with similar gear and vessels. Results here are provided by region (Table 4). Note that there were a couple of fishers who said they had observed no change in their catch.

Table 4. Commercial salmon fishers' observations of changes in target salmon species

Observations of salmon species	Homer	Juneau
Smaller salmon	X	X
Fewer salmon	X	X
Straying		X
Behavior changes	X	

Fishers harvesting salmon species near Kachemak Bay and Lynn Canal remarked that there were fewer and smaller returning salmon.

> Homer Fisher: “From Kings to Reds to Chums. When I was a kid, uh, red salmon in Upper Cook Inlet were eight and a half pounds. That's a big, that's a big red salmon. And I think now it's like five and a half or six. So obviously, um, but with that of course there was still this axiom with commercial fishermen way back that, um, big run, small fish.”

> Homer fisher: “I mean, one year in Port Dick, we had a lot of fish there. The average pink out there was like two and eighth-pound average, really small. Back in the seventies and eighties, I mean, we were catching seven, eight-pound pinks. I mean, you'd even see a 10- or 12-pound pink once in a while.”

In Juneau, fishers reported smaller wild fish and smaller hatchery fish. In particular, there were smaller and younger king salmon and chum salmon returning in Lynn Canal. There were inconsistent reports of smaller red salmon, coho salmon, and pink salmon in Juneau. There were also some reports of crowded streams and straying fish there.

> Juneau Fisher: “Especially among large king salmon species, the size has decreased. In the past, average was 15-17-pound kings. Eleven- to twelve-pound kings are more average now. In general, the sockeye size has decreased. Also chum size decreased. The 5-year-old chums are not as big anymore.”

Regarding behavior, some Homer fishers stated that when it is warm, the salmon are not schooling to enter rivers. Others stated that salmon appear to be swimming deeper, in some cases deeper than a 30’ drift gillnet.

> Homer Fisher: “They just, they’re just going deeper and deeper to get away from the warmer water up top, a little harder to catch actually. I was fishing a two and a half strips seine my whole life until this season. I had to put an extra half strip on it to the max legal depth just because they’re going so deep.”

Other fishers in Homer said Fishers in Juneau mentioned that salmon seem to be transiting areas where fishing vessels had previously been and are no longer are allowed.

> Juneau Fisher: “They're offshore more, they're... The way salmon works is they come in off the beach, right? And then as they get older and start to get closer to spawning, they hit the beach really hard. So that is just, that's a normal factor, but they've been staying off the beach a little longer, but I think it's all due to the constraints that we're on due to management. So we're stuck in a small area. So more fish are milling around, not being caught because we're not allowed to catch 'em. Out in the historical areas, you know what I mean? So that makes 'em track in, different areas, because they're not being caught where they used to be caught.”

3.1.3 Fishers’ observations of co-occurring stressors

Commercial salmon fishers face many kinds of uncertainty and can have multiple, co-occurring and sometimes compounding stressors. These may include economic and market shifts, fish stock population dynamics, natural or anthropogenic disasters, and changes in regulations, allocation, and policies. Fishers in both Homer and Juneau areas mentioned fish price changes,

boat and permit cost, management regulations and allocations, and competition between and within user groups as stressors (Table 5).

Table 5. Fishers' observations of co-occurring stressors

Stressor	Homer	Juneau
Fish price changes	X	X
Vessel and permit cost	X	X
Management regulations	X	X
Management allocations	X	X
User groups	X	X
1964 earthquake	X	
1989 Exxon Valdez Oil Spill	X	
Processor changes	X	
Gas and oil development	X	
Pacific Salmon Treaty		X
Cruise ship pollution		X
Tourism		X

The cost of vessels and permits were discussed as barriers to entering fishing and barriers to changing or entering an additional fishery. Sport user groups were mentioned in both locations, along with allocation decisions and a perceived lower monitoring of catches and standards for self-reporting charter and sport-personal use catches (see next section).

Kachemak Bay has been impacted by natural disasters such as the 1964 Good Friday Earthquake and the 1989 Exxon Valdez Oil Spill in Prince William Sound. These historic events have continuing resonance and consequences, and they were mentioned among respondents in Homer. Lower Cook Inlet fishers near Homer also mentioned an increase in sea otters. Concerns about previous and potential future oil and gas development were also mentioned by participants in southcentral.

One theme unique to Juneau was about the Pacific Salmon Treaty, which does not impact salmon fishers in the Homer area. Other codes specific to southeast included cruise ships, related water pollution and air quality, and competition from tourism as whale watching and charter fishing.

3.1.4 Competition between and within resource user groups

One stressor mentioned by fishers in both areas was "user groups" (Table 5), which can be understood as competition between salmon fishers. It is related to the stressor "management allocations."

Competition between user groups (commercial and sport/charter)

Competition between user groups, when stated by commercial fishers, usually means commercial interests competing with sport interests. Commercial salmon fishers noted that charter fishers have fewer spatial regulations and that sport-fishing clients can also target king salmon in a marine environment, which may belong to stocks of concern.

> Juneau Fisher: "Charter fishermen are catching double what commercial salmon fishermen are…People think sport fishing is one guy with one pole. But you have to multiply by numbers. The charter fishing guides are people who can target it even more.

It becomes the equivalent of commercial fishing. We don't have a good account of what's taken."

Juneau Fisher: "Well, yeah, it certainly was, uh, relatively bigger in the region than it is now. That's because what has, uh, evolved in the last 25 years is the big tourist industry. And, um, that has put a very different set of pressures on the salmon resource. Because all of a sudden there is a very active, very loud charter fishery, which is not necessarily resident, um, who have, you know, a big economic stake and, uh, are quite -- I was trying not to go down this path -- but they tend to get the focus on some stocks and some species, and, uh, to a fair extent, undercut the more traditional longstanding part of the industry here. They are in direct competition in most respects. Certainly, in political competition, they tend to prevail, which is a function of money."

Competition within user groups (commercial and commercial)

Competition within user groups means commercial fishers competing against others with their same gear and vessel types. A Homer fisher said, "You shouldn't have to play 'last man standing' to be in an industry." A fisher in Juneau said,

"Everybody comes up here now anyway. We were doing really good up here for a few years, and then a couple guys caught onto it. So, we get everybody up here now, from Ketchikan, Wrangell, Petersburg. Lots of competition."

3.1.5 Fishers' observations of changes in management through time

We asked fishermen about stressors that impact their decision-making and livelihoods. Across both regions and gear groups, commercial salmon fishers spoke extensively about aspects of management. In Homer, fishers mentioned shorter openings, fewer flyovers to count returning fish, and changes in the regulatory markers from physical to GPS points.

Management regulations and additional limitations to protect Chinook salmon

Juneau fishers spoke about shorter openings and also reduced size of allowable fishing areas for some gear groups. Many fishers mentioned that management for a single salmon species (Chinook) limits fishing for other species. In the Southeast, this is amplified by allocation agreements of the Pacific Salmon Treaty.

Juneau Fisher: "Well they've cut our days back so much. Um, we can't fish at night. In the start of the season, we can't fish at night anymore. Um, just areas are getting smaller and smaller, and, um, the price is up on the fish, so you have more boats in smaller areas. So, um, that's one thing."

Juneau Fisher: "They used to have 4-5-day openers. Now they are down to 2-day openers. This year they start on June 20. Opening is noon Sunday to noon Tuesday. But they have to pull their nets from 10pm to 4am. It's based on good science. The Kings are coming up at night between 10-4 when it's darker. Then they are deeper down in the day. Pulling nets at night is helping to avoid catching Kings…It's based on good science, and also based on the Pacific Salmon treaty and salmon returns in Washington and Oregon… So they're closing it at night to let the king salmon by. But, uh, it kind of affects my income quite a bit, so, kind of frustrating, but…"

Other comments included that management is not as flexible and responsive as it could be. One fisher shared the perception that managers seem to use fewer years of previous data to forecast and make decisions about openings. Another Juneau fisher said that the environment seems more dynamic now, yet management decisions seem more static.

Management allocation

There was also a concern that fishing regulations seem to result in changes in allocation outcomes, not conservation outcomes. A fisher from Homer said, "If you look at our maps where we're supposed to be able to fish, for our area we can only fish in about half of them, mainly because of the fish going up the inlet." A fisher from Juneau stated specifically:

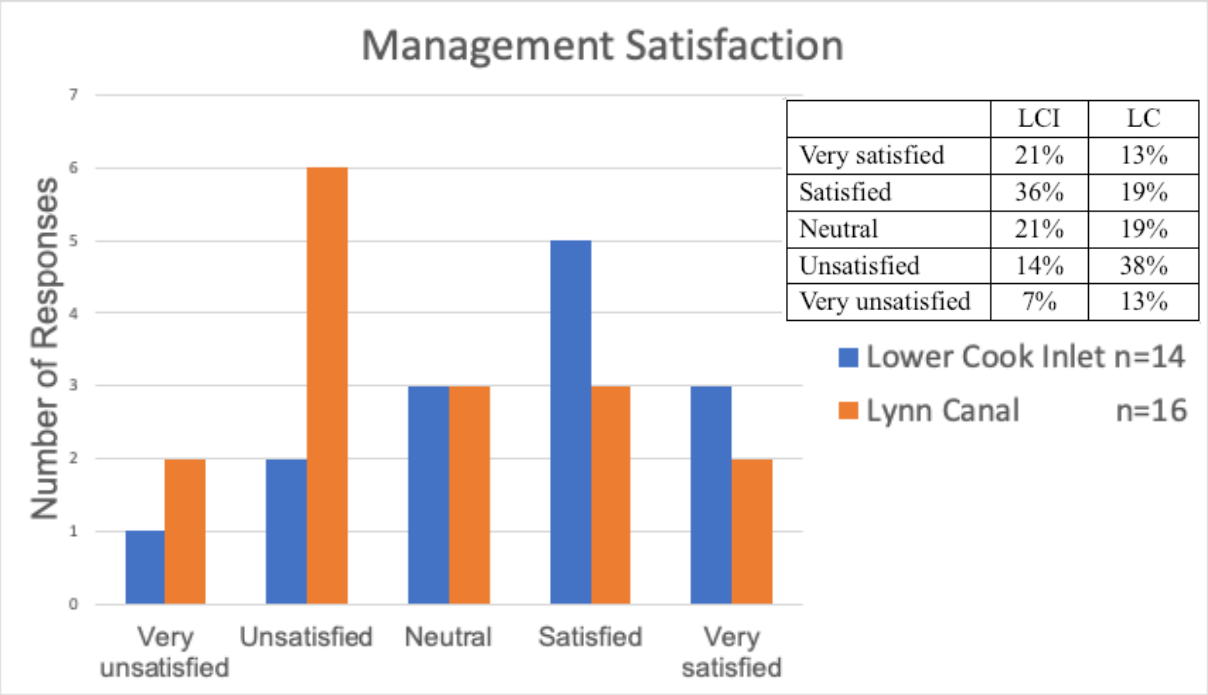
> "We got the Golden North Salmon Derby going on in Juneau so that everybody can fish and donate to charity. Good on 'em. I'm all for charity, don't get me wrong. But the guy that's trying to make his bill, to pay his insurance, needs a new engine rebuild, yada yada, yada, um, can't fish during the most productive part of the year. And, uh, and that's an allocative thing. It has nothing to do with conserving them. What fish are they conserving? They're not conserving anything. It's all allocative. And, um, so there's fighting between, that's the other thing, commercial user groups fighting between trollers, seiners, gill netters. And of course, they all are allocated, fighting for a certain percentage as well. And so the managers, when they're doing their, uh, their little bit of -- their decisions are made, not because of, uh, not for financial or commercial conservative issues. They're just made because who gets a bigger piece of the pie."

Fishers in both areas seemed to organize and remember their years fishing by who was the area management biologist at the time, what the biologist's personality and management style was, and how accessible they were.

> Juneau Fisher: Well competition now, I mean it used to be back, when we first started fishing in the sixties, the seiners were in Icy Straits, and they would pretty much block off the Sockeye and everything coming in. And then we were starving up in the canal. And then after they closed down Icy Straits to seining, it started coming back. And then we got bad management, you know, with, uh, the biologist… And he did panic management and would open everything at the mouth of the rivers or shut everything down. And, you know, and then he'd advertise, you know, on the fish reports, you know, how many extra days would be given. Instead of three days, there'd be five days at the mouth of the river. So, everybody from Ketchikan, Petersburg, Wrangell -- they'd all come up.

Management satisfaction

We asked fishers in both study areas how satisfied they were with management in their region. They selected from five choices: very satisfied, satisfied, neutral, unsatisfied, or very unsatisfied (Figure 6). Of the 18 commercial salmon fishers interviewed in Lower Cook Inlet (Homer area), 14 fishers responded. Eight of the 14 fishers who answered were satisfied or very satisfied, while three were unsatisfied or very unsatisfied. In Lynn Canal (Juneau area) 16/16 respondents answered the question. Eight of 16 fishers were unsatisfied or very unsatisfied with the current management, while five fishers were satisfied or very satisfied.



	LCI	LC
Very satisfied	21%	13%
Satisfied	36%	19%
Neutral	21%	19%
Unsatisfied	14%	38%
Very unsatisfied	7%	13%

Figure 6. Management satisfaction of commercial salmon fishers in fishing districts near Homer and Juneau. In Lower Cook Inlet (LCI, Homer area), 14 of 18 possible respondents answered. In Lynn Canal (LC, Juneau area), 16 of 16 respondents answered. Satisfaction ratings were LCI: 21% very satisfied, 36% satisfied, 21% neutral, 14% unsatisfied, 7% very unsatisfied; LC: 13% very satisfied, 19% satisfied, 19% neutral, 38% unsatisfied, 13% very unsatisfied.

3.1.6 Fishers' recommendations for management

Commercial salmon fishers from both areas made the following suggestions for management in their fishing districts. One fisher stated succinctly, "Manage by science, not by politics."

- Fund the Alaska Department of Fish and Game.
- Use more info, weirs, aerial surveys, walks to monitor.
- Return to longer openings.
- Make fewer salmon permits available.
- More opportunities for test fisheries.

Additional suggestions from Juneau included:

- Talk with fishermen.
- Let managers make decisions. Use decentralized management.
- Start Regional Board(s) of Fisheries
- Require a wait period to move between fishing districts
- Provide: help for fishermen marketing out of state
- Create an ADF&G app that sends fishermen their own records
- Provide a reliable weather forecast and VHF radio coverage

3.2 Commercial salmon fishers' adaptive strategies

Fishers use adaptive strategies suitable for the individual or household commercial salmon fisher. Adaptive strategies named by fishers included diversifying fishing permit portfolios, changing gear, changing location, altering fishing strategies, getting further involved in the industry (i.e., professional trade associations and local organizations), continuing to learn while fishing, and taking on additional jobs. Also mentioned were direct marketing, leaving the fishery, teaming up with others, and improving salmon habitats.

Among fishers who participated in our study, adaptive strategies in Alaska are similar to those found in other fisheries in Alaska (Szymkowiak and Rhodes-Reese, 2020; Beaudreau et al., 2019) and elsewhere in the United States (Badjeck et al., 2010). Chief among these adaptations is diversifying the fisheries in which they participate, followed by changing gear, changing locations and strategies, and seeking additional jobs. Due to the Alaska's pathways for public participation in Alaska state fisheries, adaptations in Alaska may also include joining professional organizations, participating in a test fishery with ADF&G, or speaking directly with an Area Management Biologist about local observations.

> Juneau fisher: "Well, just being proactive and trying to work with management and, you know, feeding them information that I'm seeing on the field, if they don't have time to get out and fly. Or just sharing information with what I know is going on, as far as fish in streams, you know, by local people here. Or what I'm seeing on the water, I'm in contact with my managers, you know, two or three times a week, I think, during the season to tell them what I see on the water in my travels."

Previous adaptive strategies:
Alaskan commercial salmon fishing fleets have previously adapted to changes in the environment and global markets. Fishers told us about improving the quality of their catch through icing and slushing techniques in some fisheries. Additional improvements in technology such as navigation tools, hydraulics on purse seiners, and Spectra fishing line have all improved aspects of efficiency and safety, according to respondents. For example, a Juneau fisher said,

> "The changes, most of the changes were, were pretty easy to adapt to, or bring into your fishing operation, because they were labor savers or money savers. Equipment lasted longer, or it got more done with less horsepower. I had a good, good time watching what this aerospace industry did with some of that material. It got tested in that program and ended up on the deck of these boats."

Portfolio diversity:
Risk management can be approached through portfolio diversity (as in Beaudreau et al., 2019; Szymkowiak and Rhodes-Reese, 2020). All of the fishermen that we spoke with are involved in more than one fishery and hold more than one permit.

> Juneau fisher: "And you know, that to me is a really powerful tool for fishermen being able to, uh, to diversify. You know, I mean, that's commercial fishing 101. You're gonna be a commercial fisherman, you know, diversify. Now you can diversify outside of fishing by being a school teacher or having another career that you participate in when you're not fishing. Or as a fisherman, you need to diversify into other fisheries. And if you can diversify into other fisheries, with gear you already own, it's a real leg up."

Portfolio diversity could also involve participating in a test fishery with ADF&G or new fisheries such as mariculture.

> Juneau fisher: You know, uh, I got some buddies that are starting to gather seaweed. And, uh, I mean, that's great. It's amazing they're letting 'em do it. I don't know. You know, it took people years, years, and years to get permits to go do this…And it took quite a bit of tenacious effort to get, get these things to happen. Uh, and so just being open to different things. I would love to go fish for octopus. I like them, and, uh, you know, they're there. I fish shrimp -- I guarantee you, you know, there's a lot of octopus to be caught, and they don't let us do it.

Economic and financial considerations:

Planning and budgeting for probable future boom and bust years was another strategy mentioned by fishers in both regions. Financial strategies may start with a state loan program or a loan through the Commercial Fishing and Agricultural Bank (CFAB). Small business re-investment strategies of saving and keeping some finances available becomes important for changing or adding permits, or for weathering a poor season in one or more fisheries, according to respondents. Interview participants had mixed responses to economic mechanisms such as state disaster declarations, largely because the funds may not arrive for an extended period of time, and the payment may be in the hundreds, rather than thousands, of dollars. Other fishers said that the free market will adjust the number of vessels, permits, and fishing effort. Growing up in a fishing family can confer an advantage of skills, and sometimes a vessel and gear.

Change gear:

Some gear changes take place on-deck, like changing mesh size. Net fishers change gear periodically to replace old nets or specialize for certain ecosystems where they fish. Commercial salmon fishers may switch their mesh size to catch different-sized species of salmon. The same strategy can be used to adapt to smaller returning salmon of the same species. For example, one Juneau fisher said, “We’ve reduced our net size by an eighth to a quarter of an inch to try to catch some smaller fish.” Another Juneau fisher said:

> “So, the size of the fish that are coming back are smaller. Um, you know, we've reduced our net size by an eighth to a quarter of an inch to try to catch some smaller fish. Um, and just not seeing a great big five-year-old chum salmon returning anymore. They’re getting two or three years in the ocean and then they're coming back…having to shrink the size of the net just to, to accommodate the fish is something fairly new.”

Other gear changes involve buying additional fishing gear or upgrades to the vessel, such as a new refrigerated sea water system.

> Homer fisher: “I think that, one thing that I could put in there that I don't know if it should be in there, but I think that the water temperatures are higher and that means we have to run our RSW higher, run our refrigerated sea water a lot longer. I think that's a real financial thing that's affecting more than just me and we're seeing bigger. And we used to do things like fill up our water tanks at the glacier where there was cooler water and we just can't do that anymore because the glaciers don't touch tide water. And the temperatures around there would be, if you fill up your tank outside of a glacier, you can

drop 10 or 15 degrees easily. And now I don't think that's really, with the glaciers generally not touching tide water that's not as true."

Change location:
Fishers can change locations and fishing strategies within or between districts. A fisher may change locations within a district if there are marine mammals such as seals near the vessel. One Juneau fisher said, "Seals destroy the nets. It's unfishable. You have to move. For example, there are 100 fish in the net, all with bites. They are unsellable. You have to move."

Another Juneau fisher describes changing locations between fishing districts: "Yes. And move districts, and you just have to move a lot more, not necessarily in the same district, just you move districts also -- just try and maximize as much fishing time as you can get, you know?" A Homer fisher explains a similar strategy:

> Homer fisher: "Eventually, I figured I just couldn't make a living here in the lower inlet. My boat was good enough that it could face other places. So, I bought a Kodiak permit, fished down in Kodiak…I think I spent a year in Prince William Sound at that point too, but those fisheries weren't nearly as much fun as here in the lower inlet."

The negative consequences of having to adapt can be seen in the previous quote about changing location and the following quote about changing fishing strategies.

Change fishing strategy:
Changing fishing strategies could mean working faster and harder.

> Juneau fisher: "You kind of gotta be a little more aggressive. You only have so much time in the day, you can't make up for it at night, or if you had a bad day, you can't make up for it at night, or everybody goes to bed at night. So a few guys could stay out there and fish all night and make a bunch more money, but you can't do that anymore."

> Juneau fisher: "We're having to haul the net and set it with more frequency, you know, typically let the head go for 45 minutes to an hour or so – sometimes longer, sometimes less. I find letting it go a half hour now instead of 45 minutes or so and just hauling the net, cleaning it out – it's definitely more work involved as far as just trying to keep the net clean and invisible to fish. So, we're using our net washers every set."

Flexibility and learning from experience:

> Juneau fisher: "Openings right now start at noon. So I'll go out the day before at 5-6am to start logging observations about the tide every 15 min. I have my own records about catch, tide, wind, and currents. You can't predict it, but you can start to get a sense of what will happen in the coming days."

Additional jobs:

> Juneau fisher: "Until the hatchery returns do start coming back, it's going to be a challenge to keep fishing. I do other jobs now, you know, I have a handyman carpenter licensed and, um, do other, other things to make money throughout the year and not rely on salmon as much."

Direct marketing:

> Juneau fisher: “I do some direct marketing trying to get another dollar or two a pound for the fish [sic] and bringing fish back to town. So, you know, those are things that I guess we started to do to try to make a few more dollars out of the fish we are catching.”

Leave the fishery:

> Juneau fisher: “I mean, a lot of, a lot of guys, I know who used to gillnet, haven't put their gill net in the water for three or four years, and they bought a Dungeness crab permit. But I mean, when they, when you only get two days a week to fish and there's 150 boats crowded into, you know, a four-square mile area, you know, you, you can't outsmart that.”
>
> Juneau Fisher: “I'm tendering now. A lot of that's because I'm old, you know. I can't do what I used to physically. And that's part of it, too. Basically, why I got out of gillnetting was it was just, you know, king salmon, uh, the king salmon biomass was cycling down. Because of that, regulations were getting harder and fishmen were getting squeezed and I had a problem…Well, once I saw the writing on the wall, I got a crab permit. I started crabbing to try to hedge my bet against these kinds of wild moves.”

Barriers to adaptation were reported as resulting from management regulations, with some financial and policy barriers to enacting other strategies such as changing gear, permits, or fisheries. One fisher said, “The biggest barrier in my career is strictly a social-economic thing called exclusive area registration in the salmon net fisheries.”

3.3 Resilience

We asked fishers, who helps make the salmon fisheries more resilient? Research participants identified institutions and organizations that they perceived to support fisheries resilience. Most conversation centered around the influence of ADF&G and specific styles of Area Management Biologists. Fishers also mentioned state financial loan programs. The United Fishermen of Alaska is a professional trade association that lobbies for commercial fisheries. More fishers were members of UFA than any other organization, irrespective of gear groups. Some fishers also mentioned other professional trade associations that allowed them to obtain services less expensively. Some fishers also mentioned that salmon hatcheries make the salmon fisheries more resilient.

On the topic of resilience, one Juneau fisher said, “Fisheries will continue. It just needs to be flexible. I think management needs to be flexible. I think the government needs to be helpful with loan opportunities. And I think education would really go a long way for new fishing.”

3.4. Institutional representatives: perceptions and adaptive responses

Table 6. Institutions represented in research, by category

	Environ. non-profit	Government agency	Business	Prof. trade association	Other	Total
Southcentral Alaska	3	1	2	1	2	9
Southeast Alaska	4	3	0	3	1	11

Institutions are defined here as management agencies and local organizations that interact with diverse salmon fisheries and salmon and aim to support sustainability in the fisheries. We interviewed a total of 20 institutional representatives from governmental agencies, fish hatcheries and processors, professional trade associations, and local environmental non-profits. Our questions focused on stressors that institutional representatives perceive affecting the commercial salmon fisheries, how institutional representatives adapt to stressors, and how they support adaptations in the salmon fisheries.

3.4.1 Stressors that fishers encounter, as identified by institutional representatives
We asked institutional representatives what main stressors are impacting commercial salmon fishers in their region. Many respondents clarified that their work supports salmon broadly, more so than salmon fishers specifically. Some of the key stressors identified by institutional representatives include climate change, uncertainty in the environment and markets, as well as changes in salmon. They also identified management, changes to the ocean environment, uncertainty, water quality and quantity, seafood markets, mining, land use, salmon habitats, pollution, cruise ships, extreme events, fishery evolution, industrialization, and increases in marine mammals.

3.4.2 Institutional representatives' adaptive strategies
Some of the key stressors identified by institutional representatives include climate change, uncertainty in the environment and markets, and changes in salmon. Adaptive strategies mentioned include habitat conservation and protection, which might include things like removing beaver dams and eradicating invasive species; maintaining flexibility in order to respond to stressors such as climate change or Covid-19; using technology to increase communication, sometimes using zoom for example (which started during the pandemic); and environmental monitoring, long-term planning and collaboration between stakeholders such as fishermen, scientists, managers, nonprofits and tribes.

Institutional representatives may focus on salmon habitat for all user groups and engage in research, environmental monitoring, and long-term planning. Similar to fishers, these interview participants also made comments about removing politics and managing with science. The following strategies help their institutions adapt to change: practicing flexibility in operating procedures, updating technologies, using collaboration and communication between organizations. Barriers to adaptation centered around funding constraints rather than information gaps. When asked, what role does your institution play in Alaska's commercial salmon fisheries, one institutional representative said,

> “We engage Alaskans, including commercial fishermen, when we have projects that we're concerned about -- when we see development projects that we think will have an impact on habitat and commercial fisheries … So, we engage commercial fishermen directly when we have projects that we're concerned about.”

However, some organizations focus specifically on commercial fisheries in Alaska and are concerned about decisions being made at multiple scales, from state to regional to gear groups. A representative from a professional trade association said,

> “We always lobby and always support the Alaska Department of Fish and Game budget. We don't wanna see their budget cut. When their budget gets cuts, then programs get pushed aside and some of those programs are to the commercial fishermen here, you know, statewide. So, one of our top concerns is making sure that the department has enough money to do what they need to do.”

4. Discussion

4.1 Fishers and management: perceptions and adaptive strategies

We combined fishers’ observations of change with their adaptive strategies by using a Sankey Diagram (Figure 7). On the left side, the primary theme Observed Changes is made up of 13 secondary themes, or codes. The width of the connecting lines between codes on the left and right sides represent a summing of the transcript quotations that have been coded using both of the linked codes. In this way, we can visualize overlap or co-occurrence between codes that appear together in the same quotations. The largest relative co-occurrence shown in this diagram is between observations about salmon (such as size, age, abundance and behavior) and changing gear (e.g., net mesh size), which is an adaptive response to changes in the target species. As described in the results section, there are multiple observations, co-occurring stressors, and adaptive strategies happening concurrently.

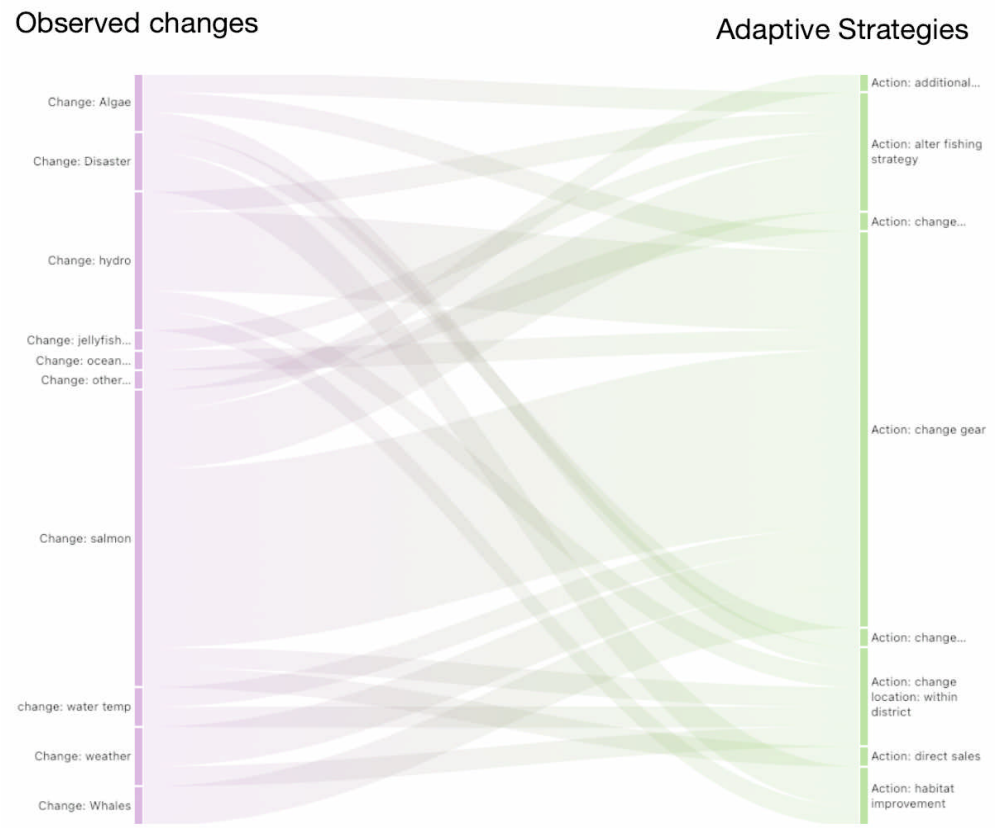


Figure 7. This Sankey diagram shows two columns of codes that are grouped together to create two themes: observed changes and adaptive strategies. The width of the line indicates the strength of the co-occurrence between the codes.

Commercial salmon fishers and changes to the environment and management:
Fishers' sentiments about environmental change represented primarily two ideas: that it represents a background influence and that is cyclic. The first idea is that the environment drives the changes in fish populations as well as management. Its influence underscores everything, yet changes in the environment are less significant when compared to more tangible things within their control. A Homer fisher said, "I think from a fisherman's perspective…you're constantly dealing with environmental curveballs." Because fishers cannot directly manipulate environmental change, it becomes less of a focus.

> Homer fisher: "The environment is, in some ways the most influential, because if there's no fish here, then we can't fish. In terms of what's happening, on a long-term scale, that's probably the most important. But in the short-term, like what we're going to do next year or what we're going to do in two years from now, no. We're going to be looking at other things."

A second perspective given why fishers did not name environmental change as an important factor related to their livelihoods is because fluctuations in weather and catch are typical over the years and couldn't necessarily be identified as long-term trends. Interestingly, fishers have seen rapid, and sometimes sudden, changes to the ecosystem due to isostatic rebound, earthquakes, and oil spills. Because some long-time fishers had to adapt to these sudden changes, this may

inform a more moderated response to observing comparatively more gradual changes in the environment.

Management is thought to have the greatest influence on commercial salmon fishers' day-to-day decision-making. Regulations and emergency openings and closures dictate daily decisions. There are also established pathways for influencing management as a participant in the Board of Fisheries, process through giving public testimony or serving on the regional Advisory Committee. It is also possible to contact the Area Management Biologist directly with current information and conditions, which has been a common practice among the interviewees that have been fishing the greatest number of years.

Institutions and strategies through time:
Throughout Alaska's statehood, institutions adapted using policy tools, changes in governance, and economic mechanisms. At Statehood in 1959, Alaska transferred management of the salmon fisheries from federal to state control, with the exception of Metlakatla reservation. Since then, salmon have been used as a negotiating piece in local and international politics.

In the 1960s and 1970s, the Alaska Department of Fish and Game responded to reduced catches with multiple strategies. They closed access to the Japanese and Russian fishing fleets with the 200-mile Exclusive Economic Zone through US legislation in the 1976 Magnuson Stevens Act. (King, 2009). ADF&G also managed with more conservative principles that guaranteed higher escapement levels for nearly two decades following statehood.

ADF&G also eliminated river-wide fish traps that were operated by out-of-state businesses, which are different from traditional Indigenous fish traps and weirs that did not harvest all salmon in a run prior to spawning (Atlas et al., 2021). ADF&G also created the Fisheries Rehabilitation, Enhancement and Development Division and installed four hatcheries to enhance salmon stocks (Heard, 2012). ADF&G set an agenda to learn more through basic and applied research into stock assessment, population counts and dynamics, and forecasting with the use of weirs, wheels, flights, and modeling. ADF&G created seasonal forecasting and management tools that included both action plans and emergency openings.

Additional state policy mechanisms sought to control fishing effort through Limited Entry Permits for commercial salmon fisheries, which went into effect in 1973. The intended outcomes of lower fishing effort and fewer deaths of fishers were lauded by many. However, the unintended consequences of privatizing a common good or resource have been borne inequitably. There are fewer numbers of fishers overall. Specifically, there are fewer commercial salmon permits in Alaska Native villages and among rural Alaskan residents (Langdon, 1989).

Where improvements for management were suggested, fishers' recommendations from these interviews suggested returning to the original pillars of ADF&G, including the separation of conservation of salmon performed by Area Management Biologists from the allocative decisions of the Board of Fisheries. Fishers seemed to believe that this no longer holds as strongly as it did. The original three principles of Alaska's state management performed by ADF&G are sustained yield, regional management, and public participation. Some fishers suggested going back to focusing on escapement goals fulfilled by mechanistic ground-truthing with fly-overs, stream-

walking, and weirs. Other fishers suggested borrowing tools and mechanisms from other fisheries, such as buy-backs or Individualized Fishing Quotas, which have been used in commercial purse seine and commercial halibut fisheries, respectively.

Managing all salmon species for king salmon protection:
Lower numbers of returning Chinooks in recent years and also smaller, younger returning salmon (Oke et al., 2021; Cline et al., 2019) have led to restricted fishing effort. Commercial salmon fishermen in both southcentral and southeast Alaska are regulated in order to protect or conserve king salmon stocks of concern whose numbers are declining the most across the Gulf of Alaska. In the Lynn Canal and Kachemak Bay areas, the salmon stocks of concern are in the following rivers (Table 8).

Table 7. Stocks of concern of Pacific salmon species in southeast and southcentral Alaska.

Area	**Stock of concern**
Cook Inlet Chinook	Chiltna, Theodore, Alexander Creek, East Susitna, Kenai
Cook Inlet Chum	McNeil
SE Chinook	Chilkat, King Salmon, Unuk, Stikine, Andrew Creek, Chickamin, Taku
SE Sockeye	McDonald Lake, Klukshu

In Upper Cook Inlet in southcentral Alaska, fisheries closures to protect king salmon that are traveling further north in Cook Inlet can impact the spatial and temporal opportunities for fishers to harvest sockeye salmon in nearby fishing districts. In Southeast Alaska, king salmon protections impact drift gillnet fishers targeting sockeye. Purse seine fishers targeting pink salmon are restricted for passage of king salmon as well as sockeyes, specifically due to bilateral agreements in the Pacific Salmon Treaty that aim to allow salmon to return to their natal streams in Alaska, Canada, and the Western United States (King, 2009).

Salmon fisheries management controls for fishing effort through spatial and temporal limitations. For example, salmon fisheries in northern Southeast Alaska that used to have openings for 24-hour periods in a day are now closed for six hours each night because king salmon feed at the surface overnight. Drift gillnet fishers in the Southeast region must fish within designated areas at designated times. Fishing effort from purse seine fishers is also controlled through timed openings in fishing districts. Regulations have been tightened over time when more vessels entered into a fleet or when efficiency improved through advances in technology and gear. Within these constraints, all net fishers (drift gillnet, purse seine, and set gillnet) reported changing their gear. Drift gillnet and set gillnet fishers used smaller mesh sizes to compensate for catching smaller returning salmon. Purse seine fishers extended their nets to reach a deeper depth to catch fish swimming deeper in comparatively cooler waters. Fishers noted that they rarely intercepted king salmon in their targeted fisheries before restrictions were put in place. Furthermore, from their perspective, limiting commercial fishers to protect king salmon does not seem to be working to increase the population sizes of king salmon Some fishers wonder if these additional restrictions provide a solution for this problem of king salmon declines.

Conservation or allocation:
Commercial salmon fishermen across gear groups are restricted from targeting specific salmon species in specific areas and at specific times. These may be restrictions on fishing sockeye to protect kings, or it may be restrictions on targeting hatchery chums to protect wild sockeye. Or it

may be closing trolling to let coho swim through the corridor from ocean to estuary toward their natal streams. Trollers fish outside waters, while drift gillnetters fish inside waters closer to the natal streams. These restrictions were put in place primarily to conserve salmon, and also to manage allocation of the total allowable catch between different salmon fisheries, gear groups, and user groups. Some commercial salmon fishers see them as preventing them from making a living.

Fishers we spoke with in Southeast Alaska want to know what species they are saving, and for whom. They expressed support for escapement goals for sustained yield, which they perceive is in their best, long-term interest. However, some fishers wondered whether these fish might be caught upstream by sport fishermen whose permit-fees help to fund ADF&G. Commercial salmon fishers across gear groups near Juneau expressed that they support conservation, but noted that allocation is not conservation. Allocative decisions about the proportion of catch allotted to different user groups and to specific gear groups within commercial salmon fishing are made by the Board of Fisheries, members of which are appointed by the state governor.

4.2 Fishers and institutional representatives collaborating

One of the assumptions informing the research questions is that local institutions can respond to and represent fishers' concerns in regional and federal institutions that have different spheres of control that ultimately affect Alaska's fishers. Based on interviews conducted for this project, institutions seem to place more importance on fishers' engagement as one of their stakeholder groups than fishers seem to rely on institutions to deliver results for them. Two exceptions to note are that fishers named state loan funding programs and the United Fishermen of Alaska as institutions that contribute to the resilience of commercial salmon fisheries.

Institutional representatives named climate change specifically as a stressor and concern for fisheries and salmon, which was different from fishers' responses. This may be due to different scales of focus. A commercial salmon fisher is typically engaged in running their operation as a small business. Therefore, top priorities reflect what they must do and what they can influence. Even fishers who named environmental change and ocean warming as influential factors in their fishing decisions pointed out that not all fluctuations in ecosystem conditions, fish stocks, and seafood markets become trends. Both state management and commercial fishers expressed that they cannot directly manage the fish, so they have to manage what they can. In both cases, these are influential relationships with people.

Institutions and their representatives often focus on building relationships, collaborations and coalitions. Institutions work to support communities and perpetuate their own resilience by collaborating with additional stakeholders, tribes, agencies, and organizations. Comparatively larger institutions are focused on the continuity and resilience of larger groups of people, for example at the community, regional, state, federal, and international levels. Though an over-simplification, fishers can readily focus on specific actions to change immediate conditions on their vessel or at their home port. Institutional representatives may have different, often indirect, mechanisms to influence legislation and governance. There are two clear exceptions to this. Area Management Biologists can have an outsized influence on the lives of fishers and have access to institutions at larger scales. And fishers who become involved in the industry as members of professional trade associations, representatives on regional advisory committees to the Board of

Fisheries, or representatives for the state and the country on the Pacific Salmon Commission can, as individuals, strengthen their scope of influence.

4.3 Observations of fishers and institutional representatives in EPSCoR Fire and Ice context
EPSCoR research teams are studying biophysical and biogeochemical changes in the watersheds and nearshore ecosystems in the fishing districts of Lower Cook Inlet (Kachemak Bay) and Districts 11 and 15 (Lynn Canal). Assuming that glaciers will continue to melt in these locations, researchers can use unglaciated watersheds and rain-fed streams as an indicator of what may happen in the future to watersheds and streams that today are glacially influenced to different degrees. Long-time fishers may have observed these locations for longer periods of time than researchers. This local knowledge can be complementary to scientific research (Gordon et al., 2022; West and Hovelsrud, 2010). For example, Oke et al. (2020) synthesized age-sex-length data from across Alaska. They found that Chinook, chum, sockeye and coho salmon were, in fact, smaller in size and were returning at younger ages throughout the Gulf of Alaska. Fishers had also observed this. Now, fishers are observing that pink salmon are getting smaller as well.

Fishers are able to offer observations from their areas more specifically, and therefore can help inform research questions and priorities. For example, specific runs of salmon have weakened over the last thirty years in both Lynn Canal and Kachemak Bay. Related to observations like these, Bellmore et al. (2022) predicted that smaller watersheds and rain-fed streams will be the most vulnerable to future salmon loss. More of the streams in southeast and southcentral Alaska are currently transitioning from glacier- and snow-fed streams to rain-fed streams (Jones et al., 2020). This will likely inform future management regulations and could impact commercial salmon fishers. Fishers' local knowledge can be complementary to institutional representatives, including academics, in offering additional observations such as fishing pressure, stocking pressure, and terrestrial changes as alternate explanations for these changes because fishers are focused on pressures from multiple sources that affect their livelihoods.

4.4 Study limitations
Participants in this research represent commercial salmon fishers in two urban areas. Our findings cannot be generalized beyond this study. Due to COVID and funding restrictions, many voices are not represented here, both from sport and subsistence user groups and from across diverse voices that would represent the demographics of the state and Alaska's multiple cultures, observations, and ways of knowing.

A limitation of the EPSCoR research design is that hatchery terminal release sites are co-mingled and often directly match the research monitoring sites. A related limitation is that we specifically did not ask fishermen about hatcheries. Initially, a few fishers said they would not speak with us if we asked about hatcheries. Therefore, we did not ask explicitly about hatcheries or include the topic in our interview questions. Nor have we emphasized volunteered responses about hatcheries here. Hatcheries are a topic of research that currently underway in Alaska. It is also an area of study that could be a topic of future research.

5. Conclusion

Fisheries management in Alaska is unique due to its history and development over six decades. Control of management of salmon fisheries was a driving force in Alaska's statehood in 1959. The Alaska Department of Fish and Game was implemented at statehood with a management triad based on maximum sustainable yield, local area management, and input from fishermen through the Board of Fisheries process.

We asked commercial salmon fishers about their observations related to environmental change over a range of years. All respondents had been fishing for a minimum of 10 years, with some having fished commercially in Alaska for nearly 60 years, prior to the Limited Entry Permitting system in 1973. Many fishers described long-term changes in shrinking glaciers and seasonal impacts from summer droughts and fall floods in recent memory. Some fishers observed changes in their targeted salmon species, though others reported that they had not observed such changes. This may be explained in part by whether fishers were targeting hatchery salmon or wild salmon.

Fishers' main adaptive strategies were diversifying into multiple fisheries, changing gear, changing locations (within or between districts), altering fishing strategies, and getting involved in professional trade associations and industry groups. Participants most often named financial loan programs from the state government and professional trade associations as institutional entities that help make the fisheries more resilient. Fishers perceived decreases in fishing opportunities through the years, with shorter openings and smaller areas in some salmon fisheries. Recommendations from fishers included providing reliable funding to ADF&G and increasing data collection through the use of weirs, aerial surveys, and stream-walking. Regarding management, fishers were in favor of regulation decisions such as catch limits based in science, and wanted to ensure that conservation remains separate from allocation decisions.

We asked representatives from institutions related to commercial salmon fisheries what stressors they perceived for fishers and how the institution's work supported or impacted commercial salmon fisheries. Environmental non-profits answered that they primarily support salmon fisheries through protecting and restoring salmon habitat as well as engaging in environmental monitoring and long-term planning. They adapt to changes that impact their organization by being flexible in operating procedures and improving their technology and communication options. They support community and institutional resilience by collaborating with additional stakeholders and organizations.

Fishers (individuals and households), differed somewhat in their description of stressors and strategies for adaptation from institutions (community-scale or larger). Still, institutions rely on fishers' engagement, and fishers contribute their knowledge and experience to agencies, associations, non-profits, and national and international institutions.

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6. Appendices

Appendix A. Recruitment materials

Commercial Salmon Fishing Livelihoods and Environmental Change in Southcentral and Southeast Alaska

We would like to interview commercial salmon fishers in **Lower Cook Inlet** and **Southeast** (Districts 11 and 15).

We are conducting research about how commercial salmon fishermen and others in the fishing industry are responding to environmental change and other pressures. We will be interviewing experienced commercial salmon fishermen about their observations and concerns. Interview responses will be used to compare strategies for adaptation in salmon fisheries in the two regions. Findings will also be paired with biological research that is being conducted in the same areas.

We are looking for fishermen with
10+ years commercial salmon fishing experience

During a **45-60 minute interview,** there will be questions about:

- Changes you have noticed while fishing.
- How you have responded to changes.
- Information such as age, years fishing, and which fisheries you participate in.

Interviews will be conducted via Zoom, over the telephone, or in person depending on current Covid-19 guidelines from the University of Alaska.

Participants will be compensated with a $49.99 gift card to Amazon.

For more info: https://www.alaska.edu/epscor/fire-and-ice/coastal-margins-team/

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EPSCoR Established Program to Stimulate Competitive Research

Commercial Salmon Fishing Livelihoods and Environmental Change in Southcentral and Southeast Alaska

We are conducting research about how commercial salmon fishermen and others connected to the fishing industry are responding to environmental change and other pressures. We will be interviewing experienced commercial salmon fishermen and representatives from institutions that support the commercial salmon fisheries. Interview responses will be used to learn about strategies for adaptation in the two regions. Findings will also be paired with biological research that is being conducted in the same areas.

We are looking for **institutional representatives** from
governmental agencies, non-profit organizations, and businesses
related to commercial salmon fisheries in Lower Cook Inlet and Southeast Alaska.

During a **30-45 minute interview,** we will ask questions about:

- What role your institution plays in the commercial salmon fisheries.
- Challenges facing commercial salmon fisheries.
- How your institution responds to these challenges.

Interviews will be conducted via Zoom, over the telephone, or in person depending on current Covid-19 guidelines from the University of Alaska.

For more info: https://www.alaska.edu/epscor/fire-and-ice/coastal-margins-team/

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EPSCoR Experimental Program to Stimulate Competitive Research

Appendix B. Interview guide for fishers

Introduction

I am studying the commercial salmon fishery in Southcentral and Southeast, Alaska. I am interested in understanding how fishermen are able to adapt to changes in the environment, management and regulations, and other changes. I'm also interested in hearing about other issues of concern in your family or community, related to fisheries
While I can't promise this, I hope that by learning from experiences like yours, our study's results can help inform adaptations and responses to future changes.

I hope that by learning from you and other fishermen about how you've dealt with challenges in the past, I'm able to understand what kinds of options have been available and also bring more attention to current concerns.

If any of the questions I ask make you uncomfortable, please know that you do not have to answer. We can also stop the interview at any point in time. Finally, everything you say in this interview will be kept confidential. No one outside of my team will be able to link your name to what you share with me today. If it is okay, I would like to record the interview, but this is only for the purposes of transcription. The audio and video recording will be deleted at the end of the project.

Before we go ahead with the interview, do you consent to being recorded, and to being a part of this study?

Fishing

F1 Can you tell me a little about how you got into fishing?
F2 What kinds of fishing do you currently participate in in Alaska? [commercial, sport, subsistence, gear groups]
F3 Which best describes you: vessel owner, permit holder, captain, crew member, or other?
F4 How long have you been fishing?
- F4a How many years have you been commercial fishing?
- F4b Have you participated in other fisheries or gear groups in the past?

F5 Do you currently participate in more than one fishery?
F6 What are the main commercial fisheries that you participate in? [Salmon, Herring, Shellfish, Groundfish]
- F6a What are the main species that you target?
- F6b Has this changed [in the past 10? 20? 30 years?]

F7 Where do you typically fish?
- F7a Has this changed since you first began fishing? [Past 10? 20? 30 years?]
- F7b If so, why?

F8 How has the commercial salmon fishery changed since you first began fishing?
- F8a When did it start to change and what changes occured?

F8b Did they affect you? How?
F9 How much do you rely on fishing for your income? 100%, 75% 50%, 25%? Other?
F10 Which factors influence your ability to commercial fish? (Please place these topics in order: [environmental change, management, financial, competition, personal reasons, other?]
F10a How so?

Environmental/Climate Change

E1 If you have noticed changes in the environment where you fish, what have you observed?
[In water temperature, weather patterns, rain, other?]
E1a When did you begin noticing changes? [10? 20? 30 years?]
E1b Are changes more frequent/noticeable today?
E2 Have you noticed any changes in your catch?
E2a [In size of fish, number of fish, different species, timing of run, diseases?]
E2b When did you begin noticing changes? [10? 20? 30 years?]
E3 Do you think these environmental changes impact your target fish species? [y/n]
E4 If yes, do you consider these changes positive or negative?
E5 Do these changes impact how or where you fish?
E6 Are there other current risks that could affect the fishery and your livelihood as a fisherman?

Management/Industry

M1 What do you think about how the commercial salmon fishery is managed
M1a What could be improved?
M1b What situations do ADF&G or other agencies not address adequately?
M2 Do you think that climate change is an important issue that fisheries managers should consider? (Y/N)
M2a Why/Why not?
M3 Do you participate in public meetings about commercial salmon fishing? If yes, which issues have been most important to you? What issues are you most interested in?
M4 Do you think there are ways that we can preserve or improve the state of the species you catch?
M5 Talk about hatcheries: Which industry or professional organizations do you participate in?
M5a Are you a member of a hatchery? (Y/N)
M5b Do you participate in cost recovery?

Adaptation/Resilience

A1 Have you changed your fishing practices in response to environmental changes, management, financial, competition, or personal reasons?
A1a If yes, has this affected your income? Your family?
A2 Have you changed your general fishing location? If so, what is different about the locations?
A3 Could you describe the importance of the salmon fishery to you, to your community?
A3a In your opinion, does the community have the ability to adapt to the changes we discussed previously (environmental, mgmt, etc.)? (Y/N) Why/why not?

Adaptation is adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects.

Examples of adaptation if needed: Increasing or decreasing fishing effort; changing harvest locations; diversifying into other fisheries; changing gear, changing target species/gear used; finding other jobs.

A4 Have you adapted to changes in the commercial salmon fishery?
- A4a If so, how have you adapted to past changes?
- A4b Has anything helped, or is anything currently helping you to adapt to changes?
- A4c What would help you adapt to future changes?
- A4d What may prevent you from adapting?
- A4e Have your adaptive strategies changed your daily or weekly routines?
- A4f Has changing your fishing practices been stressful? Has it affected your health?

A5 What do you think the fishery will look like in 10 years, in 20 years, or in 30 years?
A6 Are there any new opportunities you think may be available in the future? (e.g. new species, improved tech and gear, new markets)
A7 How long do you plan to commercial salmon fish? What factor may influence your decision? Please rank the following categories in order of relevance to your decision-making: environmental change, management, financial, competition, personal reasons.

Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimal damage to social well-being, the economy, and the environment.

A8 Are there organizations that help make the fishery more resilient? (e.g. gear group orgs, NGOs, ADF&G, BoF, etc).
A9 What would happen if you/your community no longer had a salmon fishery? What would change?
A10 What options are there in your community/region/fishery for the next generation to get involved in fishing?
A11 How could management, industry, other entities support you in adapting to changing conditions?

Wrap-Up

W1 What kind of information, if any, would be helpful for you as a fisherman going forward?
W2 What kind of information, if any, would be helpful for managers to know?
W3 What would you like to see in your community and region to support fishing in the future?
W4 Did I miss any important topics that you would like to talk about?
W5 Who else in the community is it important for us to talk with about this project?

The last few questions are about demographics. We will use this information to analyze results by characteristics such as fishing region, gear group, etc. As a reminder, your name will be removed from your responses unless you have specifically given consent otherwise.

W6 What is your:
- W6a Age
- W6b Gender
- W6c Race
- W6d Ethnicity
- W6e Home residence
- W6f Vessel home port

W7 Are you a:
- W7a Member of Gear Group
- W7b Member of industry group
- W7c Member of hatchery

I really appreciate learning a bit of your story, and I hope you enjoy the rest of your day!
Thank you!

Appendix C. Interview guide for institutional representatives

Interview Guide for Institutions

I am studying the commercial salmon fisheries and relevant institutions and organizations in Southcentral and Southeast, Alaska. I am learning about fishermen's observations of changes in the natural environment and their strategies for adaptation to changes in the environment, management and regulations, and other changes. I'm also interested in understanding how institutions that support the commercial salmon fishery perceive current environmental changes and co-occurring pressures and what adaptive strategies institutions use to support commercial salmon fishermen.

If any of the questions I ask make you uncomfortable, please know that you do not have to answer. We can also stop the interview at any point in time. If it is okay, I would like to record the interview, but this is only for the purposes of transcription. The audio and video recordings will be deleted three years after the project ends. This meets the protocols of the Institutional Review Board.

Institutions are generally understood as having formal constraints (i.e. rules, laws, and constitutions) or informal agreements (i.e. norms of behavior, conventions) that mold interaction in a society.

Background:

B1. What institution do you work for?

B2. Which category best describes your institution:

Government Business Non-profit Other

B3. How long have you worked for this institution?

B4. What is your role within this institution?

B5. What role does your institution play in Alaska's commercial salmon fisheries?

B6. What percentage of your institution's current work is focused on commercial salmon fisheries?

100% 99-75% 74-50% 49-25% less than 25%

B7. What else does your institution focus on?

B8. What percentage of your job responsibilities focus on commercial salmon fisheries?

100% 99-75% 74-50% 49-25% less than 25%

Institution and Fisheries

I1. What are the main stressors facing the commercial salmon fishery in this region?

[Ask the following question for each of the stressors named by the respondent:]
I2. How does your institution support commercial salmon fishermen to respond to [the stressor named]?

I3. CARD: Please rank the following factors according to the strength of their influence on the commercial salmon fishery. (1 = most important, 5 = least important): [environmental change, management, financial, competition, personal reasons (e.g. family, health, etc.]

I4. Any comments on the ranking? (e.g. why did you rank X high?)

Adaptation and Resilience

A1. What helps your institution adapt to stressors facing the commercial salmon fishery? [(e.g. adequate training, education, staff and resources/funding, etc.)]

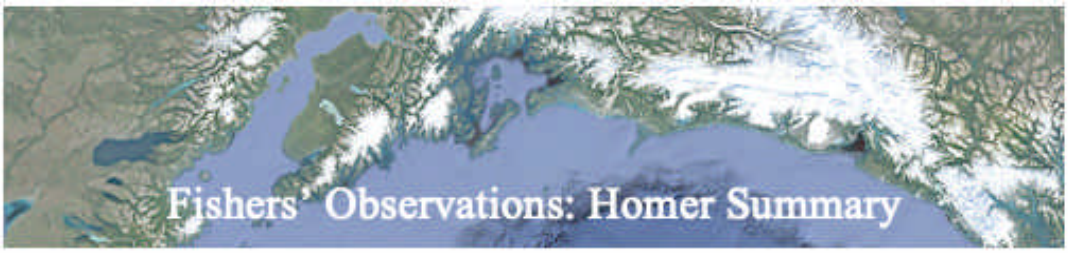
A2. Are there barriers to adapting to these stressors?
[(e.g. adequate training, education, staff and resources/funding, etc.)]

Wrap Up

Did I miss any important topics that you'd like to talk about?

Thank you for your time!

Appendix D. Community summary: Homer



Who? Commercial salmon fishers with 10 or more years of fishing experience shared their observations about changes in the environment, target species, and management, as well as their strategies for adaptation. A total of nineteen salmon fishers from the Kachemak Bay region participated in interviews in 2021 and 2022. They represented two gear groups: set gillnet and purse seine.

Where? This research took place near Homer/ Kachemak Bay in Southcentral Alaska

Why? Interviews were conducted as part of a study (EPSCoR Fire & Ice) looking at changes in watersheds with varying glacial cover in Kachemak Bay.

Observed changes in the environment

- Warmer ocean water
- Dry rivers
- Warmer weather some year, normal weather other years
- Receding glaciers
- River washout
- More sea otters

Observed changes in salmon

- Some sockeye, pink and king salmon are smaller
- Behavior changes: swimming deeper, more spread out, struggling to get into low rivers
- Less salmon to catch
- Some observations of no changes in salmon size or abundance

Observed changes in management

- Longer closures
- Changed regulatory markers from physical to GPS points
- Less flyovers to count fish

"We pulled fish out of the water that were 65 degrees. Like the water was 65 degrees. So that was pretty wild, I hadn't seen that before. Streams were just drying up so the fish couldn't even get up the stream, they were just piling up in front of them."

Adaptive strategies

- Change fishing gear and technology
- Change fishing location
- Alter fishing strategies
- Diversify portfolio of fishing permits
- Work additional or seasonal jobs
- Leave fishing
- Learning on the water
- Being flexible and ready for changes

Other changes or stressors observed

- Declining fish prices
- Increased permit and boat prices
- Changes in other fisheries, such as Kachemak Bay shellfish
- Declining number of commercial fishermen in LCI
- Increasing tourism and sportfishing
- Declining Cook Inlet processors and tender services
- 1989 Exxon Valdez Oil Spill
- 1964 earthquake

Fishermen's recommendations

- Return to longer openings in LCI seine
- Reduce number of participants
- More opportunity for test fisheries
- Increase ADF&G funding, especially for aerial surveys

"I think that the water temperatures are higher and that means we have to run our RSW higher, run our refrigerated sea water a lot longer…And we used to do things like fill up our water tanks at the glacier where there was cooler water and we just can't do that anymore because the glaciers don't touch tide water. And the temperatures around there would be, if you fill up your tank outside of a glacier, you can drop 10 or 15 degrees easily. And now I don't think that's really, with the glaciers generally not touching tide water that's not as true."

Thank you to all the fishermen and participants for sharing their knowledge, experience, and time with us

For more information contact Emma Kimball (207) 469 8072 emkimball2@alaska.edu
This work was supported by the National Science Foundation #OIA-1757348 and the State of Alaska

Appendix E. Community summary: Juneau

Who?

Experienced commercial salmon fishers shared observations about changes in the environment, target species, management, and how they are adapting to change. In 2021 and 2022, 16 fishers with 10-50 years of experience in Alaska's commercial salmon fisheries participated from three gear groups: drift gillnet, purse seine, and power troll.

Where?

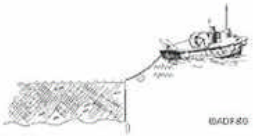
This research took place near Juneau, Southeast Alaska.

Why?

Interviews were part of a larger study looking at environmental changes in watersheds with varying glacial cover. Fishers' knowledge and observations helps inform our study and may help fishers in other locations adapt to stressors and changes.

Changes observed in management?

- Regulations: less time and space
- Management for a single species (Chinook) limits fishing for other species.
- Managers seem to use fewer years of previous data to forecast and make decisions about openings.
- Management not as flexible as it could be



Changes observed in the environment?

- Melting glaciers
- Isostatic rebound
- Less snow
- More rain. More extreme rain
- Fall floods and summer droughts
- More warm days and sunshine
- Warmer ocean water
- More whales, marine mammals

Changes observed in target species?

- Fewer, smaller, younger King & chum salmon
- Inconsistent reports of smaller red, coho, pink
- More crowded streams. Straying fish.
- No change.

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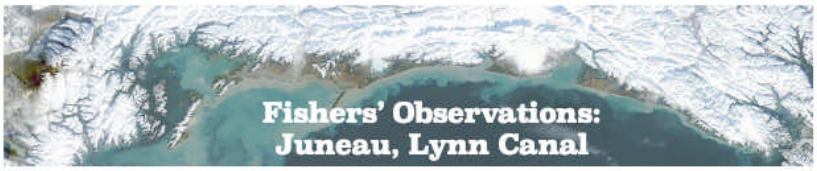
Adaptive strategies

- Diversification of fisheries
- Change gear
- Change location
- Alter fishing strategies
- Get involved in industry
- Learn while fishing
- Work additional jobs
- Direct marketing
- Leave fishery
- Protect salmon habitat



"Here's my number one rule fishing. There are no rules. And my number two rule fishing is, and those are the rules. That's adaptation baby. That's what we do... When things change, you gotta change with them. And the true fisherman has an imagination, and he's out there, the guy that's doing the adapting, the guy that's making the changes, the guys that's seeing the world or the fish or the environment or whatever it is in a different enough way that makes him more efficient. You know what I mean?" —Juneau fisher

Examples of some fishers' recommendations:

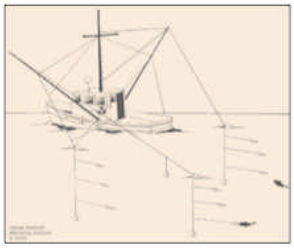
Fund the Alaska Department of Fish and Game.
Let managers make decisions.
Use decentralized management.
Start Regional Board(s) of Fisheries.

Use more info, weirs, flights, walks to monitor.
May need to tax the industry to pay for this.

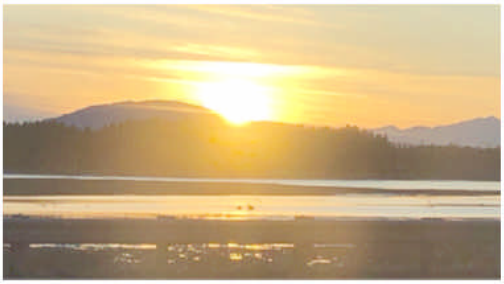
Allow longer openings.
Require a wait period to move between areas.
Create more hatchery production.
Make fewer salmon permits available.

Provide: help for fishers marketing out of state, ADF&G app that sends fishers' their own records, reliable weather forecast and VHF radio coverage.

Manage by science, not by politics.
Talk with fishermen.



A presentation will be offered in Juneau (and via Zoom) for both Juneau and Homer areas together during spring 2023.



With sincere thanks to all the fishermen who shared their knowledge, experience, and time.

Emma Kimball &
Karen Grosskreutz

Want more information? Contact Karen Grosskreutz | klgrosskreutz@alaska.edu
This work is supported by National Science Foundation #OIA-1757348 & the State of Alaska.

Appendix F. Fishers' Recommendations

Fund ADF&G.
Let manager's make decisions.
Use decentralized management.
Regional Board(s) of Fisheries

More info, weirs, flyovers to monitor escapement.
Hire more managers to walk streams & monitor.
Return to exploitation rate and CPUE.
Tax the industry to pay for this.
Require Area Mgmt. Biologist to crew in area.

Longer openings.
Require a wait period to move fishing areas.
More hatchery production.
Fewer salmon permits:
rationalize, IFQs, buy-backs, non-transferable permits.

More help for fishers marketing out of state.
Reliable weather forecast and VHF radio coverage.
Use visual regulatory markers instead of GPS lat/long.
Provide NOAA report on IUU fishing.

Future research: King Salmon River and glacial melt.
Provide data on run times of wild runs.
Make ADF&G app that sends fishers' their own records.

Manage by science, not by politics.
Talk with fishermen.