**From:** Sara Martinez
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Support for ACR 10
**Date:** Tuesday, October 5, 2021 8:31:07 PM

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Dear Board Members,

Over the last few years, we have watched our season be closed due to low king abundance. I am in support of ACR 10. Please consider this ACR to help protect Alaska's fisheries and Alaskan Fishermen.

Thanks,
Sara

--
Sara Martinez
saraamartinez92@gmail.com
(480) 234-5127

Submitted By
sarah pellegrom
Submitted On
10/6/2021 12:39:32 PM
Affiliation

If weak stock management takes precedence over exceeding board mandated escapement goals, then It’s just a waste of the State’s time and money to have sonar counters, employees, equipment, etc.

I support ACR10

Submitted By
Shayla Anderson
Submitted On
10/6/2021 5:55:52 PM
Affiliation

Phone
[redacted]
Email
[redacted]
Address
5521 101st St SW
Mukilteo , Washington 98275

My name is Shayla Anderson and I am a 4th generation comerical fisherman on Salamatof Beach. I spend my summers harvesting salmon alongside my parents, my siblings, my husband and now my 3 children. I am very proud of the legacy that we carry and wish to share that with my children for years to come.

I am writing today in suppprt of ACR 10. The last several years have shown shifting of run timing and more sockeye entering the Kenai River in August. In fact, on August 24th the Kenai River was at 2,441,825 sockeye past the counter which was 1,241,825 above the upper end of the goal. I support ACR 10 as written and believe that in years of low abundant king salmon, this "tool" would allow the Department to direct the harvest of excess sockeye salmon all while conserving king salmon.

Thank you for your time and your dedication to our fisheries.

Shayla Anderson, 4th Generation UCI setnetter

Submitted By
Staci Steffy
Submitted On
10/5/2021 6:19:27 PM
Affiliation

Phone
[redacted]
Email
[redacted]
Address
21912 55th Ave SE
Woodinville, Washington 98072

I support ACR 10.

-Staci Steffy, UCI commercial fishermen

**From:** Taylor Markham
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Support for ACR 10
**Date:** Tuesday, October 5, 2021 8:29:26 PM

---

Dear Board Members,

Over the last few years, we have watched our season be closed due to low king abundance. I am in support of ACR 10. Please consider this ACR to help protect Alaska's fisheries and Alaskan Fishermen.

Thanks,
Taylor

--
**Taylor Markham**
taylormarkham@gmail.com
(480) 241-0841

Submitted By
Ted Crookston
Submitted On
10/6/2021 11:27:31 PM
Affiliation
Commercial Setnetter

Phone
[redacted]
Email
[redacted]
Address
53509 Veco Ave
Kenai, Alaska 99611

Dear Board of Fish Members;

The comments below are submitted in response to the ADF&G Staff Comments on ACRs which were recently made public. In particular these comments are specific to ACR 10 concerning the use of a 600 foot near shore setnet fishery in times of low king salmon abundance. Implied in my comments is my support for ACR 10 and my urgent request that the Board accept ACR 10 for advancement and inclusion in an upcoming Board Meeting Agenda for deliberation and action.

Response to Staff Comments regarding ACR 10:

Heading #1; What this ACR seeks to change. This information is accurate and I agree with it.

Heading #2; Present Situation. Also accurate and I agree with it.

Heading #3; Staff Assessement of ACR 10

This heading section contains no information whatsoever as to the reasoning for, nor provides any evidence to support the "NO" determinations on all 3 criteria. As commercial fishermen we have appropriately engaged with many members of the ADF&G staff regarding these matters. We are aware there certainly are members of ADF&G staff who have serious concerns about the issues addressed in ACR 10. Specifically regarding criteria a) and c).

Criterion "a)" asks — Is there a fishery conservation purpose or reason? Considering the enormous repeat and predictable over escapement of sockeye into the Kenai and Kasilof rivers and the already measurable decrease in returning run sizes, and also given the poor production of the Kenai River main stem spawning king salmon, there clearly is a long term conservation purpose and reason to ACR 10. It is to provide a much needed tool and method to area managers to enable them to manage to meet the appropriate escapement goals in a balanced effective manner so as to avoid the long term conservation concerns for both sockeye and kings caused by the unchecked, repeat, all time record high levels of over escapment.

Criterion "c)" asks — Does the ACR address an effect of a regulation on a fishery that was unforeseen when that regulation was adopted. Once again, there is no information as to the reasoning for, and no evidence to support, a "No" determination. However, the Board Members will recall the position presented by the commissioner at this summer's emergency meeting on the same issue. In short, it was represented to the Board that the "fishery" in question was the ESSN fishery and that the "effect" in question was the mandatory closure of the ESSN as a result of a previously adopted regulation. It is logical to presume perhaps the same source of influence was once again brought to bear in the finding of the "No" determinations in this staff assessement. This representation is misleading and fails to comprehend the true scope and purpose of ACR 10. The "fishery" addressed by ACR 10 is the whole Upper Cook Inlet Salmon Fishery, which includes interested communities and industries and individual persons involved in and effected by that fishery. The regulation it addresses is the regulation adopted which completely and mandatorily closes the entire ESSN if projected late run large king salmon escapement is less than 15,000 fish — regardless of all other factors. Now the meat of this question is focused in the consideration of overwhelming evidence of the negative effects of the regulation (cited previously) on a fishery (the whole Upper Cook Inlet fishery) that were unforeseen when that regulation was adopted.

These unforeseen effects include:

• The inability for fisheries area biologists and managers to check and harvest unprecedented all time record high over escapements of sockeye into the main rivers.

• The combined losses to the fishery, which includes all persons, communities and industries that enable a fishery to even exist, of staggering porportions. Using the valuatrion provided by KPEDD of $100 per sockeye the loss in this 2021 season alone on the forfeited 1,443,684 sockeye totals over $144,000,000 in economic loss to the "fishery" (and all those directly and indirectly connected to the fishery). Additionally, enormous similar losses occurred in 2019 and 2020.

• The biological alteration of the sockeye run return timing — shifting to larger and later run peaks cause by unbalanced harvesting throughout an entire run span.

- The unfair and unjustifiable total exclusion of the setnet fishery from all harvest opportunity, while transferring that allocation to other user groups who are fishing at full force.

- Other significant factors which have bearing on the dramatic effect of the stated regulation and its impact on the ability of fisheries managers to manage in a balanced approach for the mixed stock difficulties presented by strong sockeye numbers and weak king numbers are: 1) It was unknown and unforeseen to the Board in 2020 that fishing setnets only in near shore waters, close to the water line results in a dramatic reduction of the incidental king harvest number by setnets. This was clearly demonstrated in the few 600 foot setnet openings in the 2021 season; 2) it was unknown and unforeseen to the Board in 2020 that the current Administration of the State of Alaska and the leadership of the Dept. of Fish and Game would inexplicably refuse to cooperate with federal authorities to manage the EEZ waters of UCI and force the council to close this large fishing area to commercial drift gillnet fishing. This new, unprecedented and unforeseen action further exacerbates the need for a change to the existing regulation so as to allow for some meaningful method of harvesting sockeye while greatly reducing the harvest of king salmon.

All of these factors and the abundance of evidence clearly demonstrate that ACR 10 does in deed address an effect of a regulation on a fishery that was unforeseen when that regulation was adopted. The answer to the question asked in criterion "c)" is "Yes."

The fact that the Staff Assessment states "No" to both "a)" and "c)" raises some serious questions for the Board to consider. The message of the Staff Assessment has the unspoken implication that the entire ADF&G staff somehow unanimously agreed that ACR 10 does not meet any of the criteria. Yet we know from personal conversations this is not the case. There is no explanation provided as to how the assessment was determined. Was it based on broad cooperative input and a careful analysis by senior staff? Was there a vote? If so - what were the results? Who and how many felt the ACR does or does not meet the criteria? The question emerges as to whether the assessment determination was made in the same manner as in the well documented emergency meeting this past summer, wherein the commissioner issued a finding based his narrow representation that the only effect in question was the closure the ESSN. He declared that was an anticipated event and therefore was not unforeseen and hence no emergency existed.

The true scope of ACR 10 is to address the many serious negative effects caused as a result of the closure of the ESSN, which effects were unforeseen by the Board. Not merely to state that the closure itself was an unforeseen event.

Additionally the Board is left to consider why the highest level of authority in the department is not providing leadership and sound problem solving skills and actions and also management skills to address the problem and to enable a more balanced and effective mangement and utilization of the vital salmon resource. Why is a valid proposed effective solution method not embraced, explored, employed and considered in an open, honest, collaborative and positive manner? How does one explain the dismissal and marginalization of the proposed solution and also the denial of the very existence of an enormous problem so obvious to others? Where is the leadership, the stewardship, the responsibility, and the accountability?

Details provided under the heading #4 ADDITIONAL INFORMATION are accurate and concise. It should be helpful to the Board in understanding some, though certainly not all, of the history behind this current situation. It further explains some of the flaws in the 600 foot fishery as currently defined from an application standpoint. It also summarizes the looming challenges and uncertainty associated with the Cook Inlet EEZ closure. But one thing is certain, fish unharvested in the EEZ cannot possibly be harvested along the UCI beaches if there are no setnetters fishing in the water at all! In general the additional information section tends to endorse the needs addressed in ACR 10.

However, there is an obvious ommission of the all the relevant data obtained by the department which positively showed the extreme effectiveness of the near shore fishery method. This data has been presented to the Board in other documentation and discussions. Suffice it to say here that significant numbers of sockeye were harvested and the number of kings harvested was almost insignificant — extremely low numbers were taken. Again, the question arises — why is this highly relevant data not included in the ADDITIONAL INFORMATION section for the Board to consider? This is yet again a prime example of how influencers in the ADFG are not sincere in their role to educate and advise the BOF to assist you in your duties but rather to present questionable and unjustified information, just like these assessment evaluations and withhold and hide certain highly relevant from you, just like the catch data and evidence of the effectiveness of the 600 foot setnet openings. It flies in the face of good judgement and wise management and defies any sincere intent (by some) to solve real problems with real solutions.

I acknowledge the collective judgement of this Board and express appreciation for your sincere intentions to solve real problems with real solutions. Many conversations have indicated a willingness to learn the facts and understand the issues and a resolve to take positive action to overcome the serious problems inherent in the current regulation structure and to do so even out of cycle and amidst the difficulties caused by the pandemic. Thank you.

Warm regards,

Ted Crookston, Tide Chaser Fishery, LLC — Kenai Setnetter

**From:** Thomas Hindman
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** ACR 10
**Date:** Wednesday, October 6, 2021 11:19:17 AM

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l would like to show my support for ACR 10. As a long time set netter in Cook Inlet, i believe that the adoption of ACR 10 would help in the reductio of over escapement of Sockeye salmon during King return years.

Thanks
Thomas Hindman
Cook Inlet set netter
Central District, East Forlands

**From:** Travis Every
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** ACR 10
**Date:** Wednesday, October 6, 2021 9:08:57 AM

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Members of the Alaska Board of Fisheries, I am writing this in response to staff comments provided on ACR 10.

Does the agenda change request address an effect of a regulation on a fishery that was unforeseen when that regulation was adopted? Yes, I believe that it does.

The pending closure of the Cook Inlet EEZ to commercial salmon fishing was not discussed during any BOF meeting when the current Kenai River Late Run King Salmon Management Plan was modified. When the current paired restrictions were adopted into the management plan the UCI drift fleet had access to substantially more fishing area, as well as fishing areas farther south, than they will in 2022 when the EEZ waters of Cook Inlet will be closed to commercial salmon fishing.

2021, and previous years, experienced sockeye salmon runs to both the Kenai and Kasilof rivers that substantially exceeded each rivers sockeye escapement management objectives. According to ADFG fish count website, the Kenai River was to be managed to an In-river goal of 1,000,000 to 1,200,000 sockeye passed the counter in 2021. As of August 24th, the number of Sockeye past the counter was 2,441,825. 1,241,825 above the upper end of the sockeye goal. The Kasilof River is managed to a BEG of 140,000 to 320,000 with an OEG of 140,000 to 370,000. On August 15th the count in the Kasilof River was 521,859. 201,859 above the BEG.

With the ESSN closed, large escapements were achieved in these river systems even though the Drift fleet was fished more aggressively by ADFG in an attempt to slow the entrance of sockeye. UCI set net, and drift fleets are sockeye targeted fisheries.

With the newly introduced restrictions on the UCI drift fleet it is a true statement that , " It is unknown to what extent harvest in the drift gillnet fishery may change because of this decision", but one thing is certain more sockeye will make it into these river systems resulting in even more over escapements, forgone harvest, and economic loss.

ACR 10 is simply seeking some limited opportunity to target sockeye in the ESSN when there is a harvestable surplus, while reducing incidental chinook harvest by utilizing the 600 ft fishery.

Travis Every.

Sent from my iPhone

**From:** Zachary Markham
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Support for ACR 10
**Date:** Tuesday, October 5, 2021 3:03:14 PM

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Dear Board Members,

Over the last few years, we have watched our season be closed due to low king abundance. I am in support of ACR 10. Please consider this ACR to help protect Alaska's fisheries and Alaskan Fishermen.

Zach Markham
Permit # R773996

--

Zachary Markham

480-773-1855

Submitted By
Christine Brandt
Submitted On
10/4/2021 7:55:59 PM
Affiliation

Phone
[redacted]
Email
[redacted]
Address
1412 4th Ave.
Kenai, Alaska 99611

October 03, 2021

Boards Support Section

P.O. Box 115526

Juneau, AK 99811-5526

Chair Carlson-VanDort, Board Members,

My Name is Christine Brandt, and I am a set net fisherman in the Kasilof Subdistrict, South K-Beach. We are a 4-generation site that has been fishing since the late 1960s. We hold the original permits and they have stayed in the family.

I am opposed to any changes at this time. In 2020 my son submitted ACR 5 to the BOF Work Session that requested clarification by the BOF to give clarity to the Commissioner as to when to use the 600 ft. under the following conditions; when the Kasilof and Kenai River will meet the escapement goals and when the lower end of the late run Kenai King Salmon escapement may not be met. At that time the BOF members did not support this to be brought up at the Statewide Meeting and suggested that it be submitted as a proposal at the next Upper Cook Inlet Meeting cycle. Commissioner Laing said he would like to see it used as a tool the next summer to see how it works.

I personally do not have a beach net. We hold 4 permits and out of those 4 only 2 have beach nets. I also know that there are a majority of permit holders in the Kasilof subdistrict that do not have beach nets. This is a historical fishery that has always been managed for the most part by the Kasilof River Management plan. The Kasilof River needs to be managed separately, and the tools to do this are already in place in the Kasilof River Salmon Management Plan 5 AAC 21.365.

The tools are there for the Commissioner and fishery managers to use. We have continuously over escaped both the Kasilof and Kenai Rivers in a hope to make the King runs return. I believe that this management strategy is flawed. Do we really know the effect that these large returns into the Kenai River have on the King eggs and redds? How about the millions of pinks that go up the middle of the river and are predators to King Salmon eggs what effect do these have on the King redds? How about the Rainbow Trout and the Dolly Varden? These fish are also predators and impact King Salmon and I know that a biologist 10 years ago was concerned about their large populations.

The last 3 years the large King escapement in the Kenai River has been 11,499 to 11,868. I believe that we should lower the bottom end of the large Kenai River Late Run King escapement to 11,000. Kings are showing up later and later every season as are the Kenai River Sockeye Salmon.

Over escaping the Kasilof and Kenai Rivers is a waste of resources. The Department has unnecessarily reallocated the sockeye runs to all users except for the set net fleet. Our opportunity to harvest has been taken even though the reds are plentiful.

I do not want the 600 ft. to turn into the status quo and I believe that this is what will happen if we do not wait until an Upper Cook Inlet Board Cycle happens.

ACR's 11, 13 and 14 have valid questions that should be answered and addressed at this BOF Work Session.

Please consider directing Commissioner Laing to stay within Sockeye goals. I am not suggesting that we should forget about the King escapements but the restrictions placed on set netters are having very little impact on getting more Kings into the river and instead we are impacting the Sockeye runs.

The definition of insanity: Doing the same thing over and over and expecting different results.

Respectfully,

Christine Brandt

Permit holders, Brian, Keary and Gary Koski

Submitted By
Gary L Hollier
Submitted On
10/4/2021 1:42:42 PM
Affiliation
Self

Hello BOF Chair Mrs. Carlson-Van Dort and BOF Members,

My name is Gary L Hollier. I am a life long resident of Kenai. I have been an ESSN fisherman since 1971, I fish Kalifonsky Beach, mostly North Kalifonsky Beach, statistical area 244-32. My fish sites are a multi-permit family operation, that fish locations from beach nets out to the 1.5 mile boundary.

I would like to submit a few comments on proposals that the BOF will address at the workshop in October, 2021.

I OPPOSE ACR 9, which would seek to make changes to the Kenai River Late-Run King Salmon Management Plan (KRLRKSMP). One item in ACR 9, seeks to open the Kasilof Section 1/2 mile fishery during times when there are low King Salmon returns to the Kenai River. In the KRLRKSMP there are hourly restictions placed on the ESSN fishery 48,36,24 depending on what step downs are being taken in-river. AS ADF&G has stated in their comments " Additionally, when fishing in the Kasilof Section within one-half mile of shore, the hours used count toward the maximum number of hours that the entire ESSN fishery may be open". Fishing restricted hours, in the Kasilof 1/2 mile fishery, that impacts the entire ESSN fishery is wrong. I also believe that the King Salmon harvest would be much higher than a 600 ft fishery. For these two major reasons I oppose ACR 9.

I SUPPORT ACR 10, which also seeks to make changes in the KRLRKSMP, by fishing a limited 600 ft fishery on the ESSN fishery. ACR 10, as written is pretty straight foreward. I do believe that there are unforseen consequences of some parts of the KRLRKSMP that went into regulation in 2020. I think that an emergency does exsit. In 2021 the Kenai River exceeded its upper end sockeye in-river goal by over 1 Million and its SEG by over 200%. In 2020 the BOF, on recommendations from ADF&G, lowered the BEG in the Kasilof River by 20,000 on the upper and lower end (140,000-340,000). Yet it 2021 the Kasilof River had an escapement of over 520,000. I believe ACR 10 should pass at this BOF Work Shop. At the BOF Statewide meeting in March 2022, all user groups and ADF&G can work on possibly making some changes to ACR 10 and the KRLRKSMP , so grossly exceeding BOF mandated goals might not occur.

I OPPOSE ACR 11. This ACR asks to eliminate the 29 mesh gear restrictions that occur in the KRLRKSMP. A 5 inch mesh net that is 45 meshes deep fishes over 18 ft deep at slack tide. The same gear that is 29 meshes deep fishes about 12 ft deep at slack tide. I believe that fishing 29 mesh deep nets is a tool that enables the ESSN fishery to harvest sockeye will reducing King Salmon harvests, during times of low King Salmon returns.

Thank you,

Gary L Hollier

Kenai, Ak.

**From:** Mark Ducker
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Comment and Information regarding ACR 11 and ACR 14
**Date:** Wednesday, October 6, 2021 11:51:34 PM
**Attachments:** ADFG response to Kintama report.pdf

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Glenn,

First of all, the Department's response to ACR 11 negated the issue and provided nothing that was germane to the ACR in RC 2 by ADFG response. Second, ACR 14 was treated similarly with nothing germane to my ACR being provided to the public or board within RC 2.

The issue was explained in ACR 11. I will attach the Department's response to the Kintama Report since RC 2 negated the germaneness. Also on page 19 of the Kintama report the author misrepresents Kenai late-run king salmon model estimates as 5,098 Kenai River king salmon but were in fact all UCI king salmon harvested (Northern District, Kaligan Island, West side, and Eastside harvest as stipulated by Pat Shields in the memorandum notation).

ACR 14 was specific to yield loss and a management concern; i.e., surplus to escapement harvest foregone and predictable recruitment production losses resulting from chronic high escapement levels as a direct result of provisions found in the Kenai River late-run king salmon management plan and specified within ACR 14. However, RC 2 failed to mention any escapements nor BEG yield analysis for the public or board. I will attach files to address this issue including escapement tables on Kasilof sockeye salmon and Kenai late-run sockeye salmon. In the last 5 years alone 928,962 (nearly 1 million) Kasilof River sockeye salmon - surplus to escapement above the midpoint went into escapement and were foregone. Yield loss on Kenai late-run relative to surplus yield available was 3,349,703 sockeye over the last 5 years. Both sockeye stocks combined represents 4,278,665 sockeye (foregone harvest) - 21,393,325 pounds of commercial fish which represents 43 million dollars in ex-vessel value alone. The recruitment loss can represent an additional 43 million in economic losses.

I will forward escapement tables and CPUE sockeye data tables for the last 5 years which is germane to ACR 11 and ACR 14.

Thanks,

Jeff Beaudoin

Willette et al. Animal Biotelemetry (2015) 3:4
DOI 10.1186/s40317-015-0027-x

COMMENTARY

Open Access

# Oversimplification of complex harvest modeling issues outlined in Welch *et al*. (2014)

T Mark Willette[1*], Pat Shields[1] and Eric C Volk[2]

**Abstract**

In their paper, ‘Migration behavior of maturing sockeye (*Oncorhynchus nerka*) and Chinook salmon (*O. tshawytscha*) in Cook Inlet, Alaska, and implications for management,’ Welch *et al*. (Anim. Biotelem. 2:18, 2014) report data on migratory behavior and relative swimming depths of Chinook and sockeye salmon near the Eastside Setnet (ESSN) fishery, Cook Inlet, Alaska, using acoustically tagged fish and an anchored array of acoustic receivers. Using this information, they provide a model to estimate changes in Chinook and sockeye salmon harvests associated with potential regulatory changes affecting surface gillnet depths in this fishery. We are concerned that the modeling exercise paints an unrealistic picture of how simply changing gillnet dimensions would translate into a viable management approach to preserve or increase sockeye salmon harvests while minimizing catch of Chinook salmon. Much of this fishery occurs in very shallow water, and Cook Inlet tides range about 10 m with tidal current speeds reaching about 9 km $hr^{-1}$. Model assumptions that gillnets in this dynamic environment were hanging vertically and that gillnets did not reach the bottom are not valid. Gillnets in this fishery billow in strong currents causing the lead lines at the bottom of the nets to rise in the water column, and an unknown but high fraction of all gillnets reach the bottom for some portion of each tide cycle. We believe further information and a more sophisticated analysis is needed to realistically model changes in Chinook and sockeye salmon harvests in relation to gillnet depths, and we are concerned about unintended consequences that may arise from unrealistic solutions based on limited data proposed in the regulatory arena.

**Keywords:** Chinook salmon, *Oncorhynchus tshawytscha*, Sockeye salmon, *Oncorhynchus nerka*, Acoustic telemetry, Migratory behavior, Swimming depth, Gillnet fishery, Harvest modeling, Fishery management

## Background

In their paper, ‘Migration behavior of maturing sockeye (*Oncorhynchus nerka*) and Chinook salmon (*O. tshawytscha*) in Cook Inlet, Alaska, and implications for management,’ Welch *et al.* [1] provide interesting insights on migratory behavior and relative swimming depths of Chinook and sockeye salmon near the Eastside Setnet (ESSN) fishery, Cook Inlet, Alaska, using acoustically tagged fish and an anchored array of acoustic receivers. Based on data from 11 Chinook and 25 sockeye salmon, a central finding of their paper is that Chinook were deeper swimmers than sockeye salmon in the study area, with median migration depths of 4.8 and 1.8 m, respectively. Conceptually, these differences in water column distributions offer a means to selectively avoid the deeper migrating species in set gillnet fisheries by using shallower nets. The authors provide a modeling exercise ([1], Figure nine) which uses this data to predict how changes in gillnet dimensions could preserve desired harvest of migrating sockeye salmon while avoiding deeper swimming Chinook salmon, a species of particular concern returning to the Kenai River. Unfortunately, limited data from very few fish and a number of caveats, some noted by the authors, make their approach unrealistically simple and potentially misleading in the highly contentious regulatory environment of Cook Inlet fisheries.

## Main text

The ESSN fishery is conducted in a 90-km section along the eastern shore of Cook Inlet extending from the beach to approximately 2.4 km offshore [2]. The bottom slope is very shallow with extensive mud flats at low

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* Correspondence: mark.willette@alaska.gov
[1] Alaska Department of Fish and Game, 43961 Kalifornsky Beach Rd. Suite B, Soldotna, Alaska 99669, USA
Full list of author information is available at the end of the article

tide. South of the Kenai River, water depths at mean lower low water (MLLW) average about 10 m along the offshore boundary of the fishery (http://www.ngdc.noaa.gov). North of the Kenai River, in the Salamatof statistical area, where many Chinook salmon are caught, water depths near the offshore boundary at MLLW average about 15 m. Nets are often fishing in much shallower water towards shore. Spring tides in Cook Inlet range about 10 m and tidal current speeds can reach about 9 km $hr^{-1}$ [3,4]. The tide stage at one end of the district is out of phase with the tide stage at the opposite end of the district by about 60° (http://tidesandcurrents.noaa.gov). The marine array of acoustic receivers used by Welch *et al.* [1] consisted of 16 acoustic receivers located along the offshore boundary of the ESSN fishery (approximately 2.4 km from shore) and 54 acoustic receivers located along transects extending 15 km offshore of the seaward boundary of the ESSN fishery. Thus, migration depth data were generally collected in water much deeper than where the fishery actually occurs.

A fundamental assumption used by Welch *et al.* in calculating the potential harvests of Chinook and sockeye salmon based on swimming depth data is that gillnets hang straight down, with a standard 45 mesh net covering about 5.5 m in depth. While we understand that this assumption was adopted for simplicity, the actual fishing depths of nets in this fishery are undoubtedly far more dynamic. In reality, gillnets in this fishery billow like a sail in strong currents causing the lead lines at the bottom of the nets to rise in the water column. The authors acknowledge that deep nets may rise off the bottom more than shallow nets due to their greater surface area and, thus, resistance in the strong current, potentially reducing some of the assumed difference in net depths. But, there are other variables that can affect the effective fishing depth of gillnets including current speed, which changes during the tide cycle; the weight of the lead line; and the number of fish caught in the net at any given time, which increases drag but also adds weight to the net. Effective fishing depth of individual gillnets changes through a tide cycle, and because tides are out of phase in different parts of the fishing district, effective fishing depths of nets at various locations in the district can be very different at any given time. It is likely that actual harvests of either species would differ substantially from those predicted under the simple scenario advanced in this study.

A second concern is the implicit assumption in the authors' analysis that gillnets would not rest on the sea bottom, allowing fish to swim below the nets. They point out that sport fishers frequently troll for Chinook salmon in very shallow water in this area. Since water depth in much of the ESSN fishery is very shallow, particularly south of the Kenai River, it is clear that a high fraction of all gillnets reach the bottom for some portion of each tide cycle during the fishery. Fishermen may also move their nets through the tide cycle depending upon conditions. Without a better understanding of net locations with respect to the sea floor through a tide cycle, it is very difficult to predict actual harvest changes with altered net depth. In addition, differences in depth distributions of Chinook and sockeye salmon in deep water will not be maintained in shallow water where the bottom forces their distributions to overlap, and shallower nets will not affect harvests of Chinook relative to sockeye salmon when nets reach the sea floor.

In an earlier study focused on how to minimize harvests of Chinook salmon in the ESSN fishery, Bethe and Hansen [5] found that the highest average harvest rate of Chinook salmon (0.41 per net set) occurred in set nets located at intermediate distances from shore where gillnets were likely reaching the bottom at low tide. The average harvest rate of Chinook salmon further inshore (0.23 per net set) and offshore (0.15 per net set) was lower. Bethe and Hansen's [5] data are consistent with the notion that Chinook salmon are most often captured as they migrate inshore and first encounter gillnets that reach the bottom. Reducing the depth of gillnets may simply shift the harvest closer to the beach where nets again reach the bottom. Importantly, this study [5] also found that the vertical distribution of Chinook salmon catches in gill nets was essentially uniform at all distances from shore.

Finally, size distributions of acoustically tracked Chinook salmon and those captured in the ESSN fishery were very different. The smallest acoustically tracked Chinook salmon was about 85 cm in length [6], whereas 82% of Chinook salmon captured in the ESSN fishery were <85 cm (mode 50 cm) in length [7]. Welch *et al.* [6] found that Chinook salmon mean swimming depths were not correlated with length, but this may have been due to the limited sample size and data range. Folkedal *et al.* [8] found that smaller Atlantic salmon swam at shallower depths in commercial sea cages.

## Conclusions

In our view, analyses in Welch *et al.* [1] oversimplify problems associated with estimating changes in Chinook and sockeye salmon harvests that may occur with changing gillnet depths, and actual harvest changes would likely differ substantially. We do not take issue with the central findings of the study which document migratory behavior of these species within the study area where the acoustic array was located. Unfortunately, despite best efforts, this study tagged very few Chinook salmon and not all of those were Kenai River origin fish. We do not know how well these fish represent Kenai River Chinook salmon behavior in general or how their migration depths may change as they leave the study area for the river and shallower water. Combined with the complexities of net and fishermen behavior as the fishery is prosecuted, predicting actual harvest impacts to Chinook and sockeye salmon from simple changes in net dimensions is very difficult and uncertain. We are concerned that this harvest modeling exercise paints an unrealistic picture of how simply changing gillnet dimensions would translate into a viable management approach to preserve or increase sockeye salmon harvests while minimizing Chinook salmon harvests.

The complexity of the problem may require simulating gillnet behavior in tidal currents and the migratory behavior of Chinook and sockeye salmon in the ESSN fishery. Modeling gillnet behavior will require information on locations of all gillnets and bottom depth at each net location. The effective fishing depths of gillnets should also be determined over a range of current speeds with nets that are hung with various amounts of web and lead line. Use of time-depth recorders on various parts of the net could be used to refine our understanding of net behavior. These data could be used in conjunction with a tide model to simulate the behavior of gillnets during the course of a fishing season. Simulating Chinook and sockeye salmon migratory behavior will require information on swimming depths of Chinook and sockeye salmon in shallower waters and a thorough understanding of how these fish migrate within the fishery. Developing the level of understanding of these processes necessary to accurately estimate harvest changes will be very costly and challenging. We are committed to providing the best information possible to the Alaska Board of Fisheries as they deliberate regulatory changes. However, we are also acutely aware of unintended consequences that may arise from unrealistic solutions based on limited data proposed in the regulatory arena.

### Abbreviations

ESSN: Eastside Setnet; MLLW: Mean lower low water.

### Competing interests

The authors declare that they have no competing interests.

### Authors' contributions

TMW, PS, and ECV co-wrote the manuscript. All authors read and approved the final manuscript.

### Authors' information

TMW has been employed by the State of Alaska Department of Fish and Game (ADF&G) for 23 years and currently holds the position of Research Project Leader for the ADF&G, Commercial Fisheries Division in upper Cook Inlet. He has been in this position for the past 14 years.
PS has been employed by the ADF&G for 30 years and currently holds the position of Area Management Biologist for the ADF&G, Commercial Fisheries Division in upper Cook Inlet. He has held this position for the past 4 years and previously held the position of Assistant Area Management Biologist for 10 years.
ECV has been employed by the ADF&G for 10 years and currently holds the position of Chief Fishery Scientist for salmon, Commercial Fisheries Division, Headquarters.

### Acknowledgements

The preparation and submission of this manuscript was funded by the State of Alaska.

### Author details

[1]Alaska Department of Fish and Game, 43961 Kalifornsky Beach Rd. Suite B, Soldotna, Alaska 99669, USA. [2]Alaska Department of Fish and Game, 333 Raspberry Rd, Anchorage, Alaska 99518, USA.

Received: 3 February 2015 Accepted: 11 March 2015

### References

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**From:** Mark Ducker
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Fwd: Info request
**Date:** Wednesday, October 6, 2021 11:52:20 PM
**Attachments:** image001.png

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---------- Forwarded message ---------
From: **Marston, Brian H (DFG)** <brian.marston@alaska.gov>
Date: Tue, Oct 5, 2021 at 4:00 PM
Subject: RE: Info request
To: Mark Ducker <mandsduckerak@gmail.com>

That table contains final counts so I don't want to put that in the table…..but below are preliminary numbers for 2021 and are available on the fish count web site

The preliminary numbers for 2021 are

Kenai 2441825

Kasilof 521855

Fish Creek 22271, weir pulled early on 7/28 but still made goal

Brian Marston

Fishery Biologist

UCI Commercial Fisheries

Alaska Department of Fish and Game

9074207740 cell

9072629368 office

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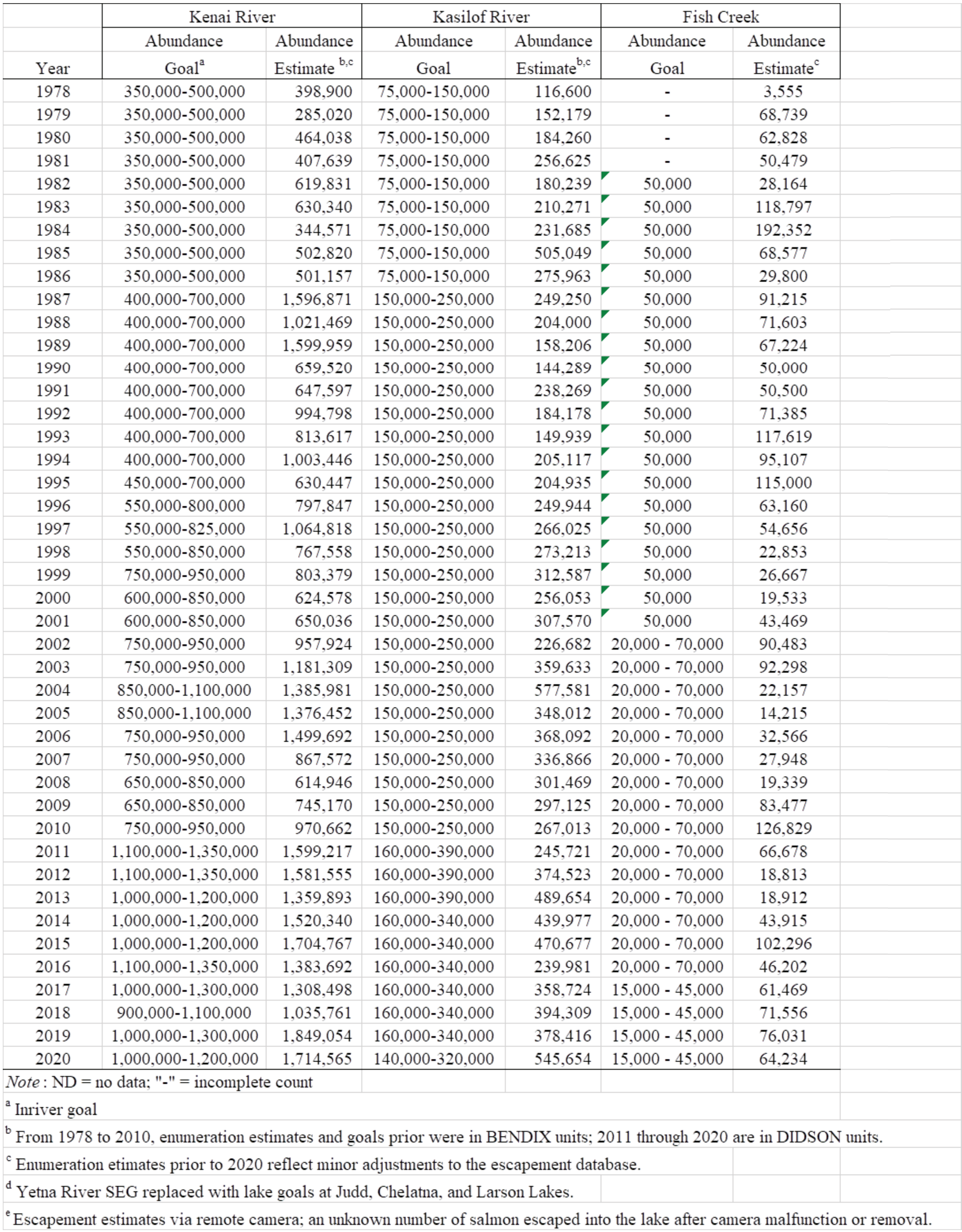
**From:** Mark Ducker <mandsduckerak@gmail.com>
**Sent:** Tuesday, October 5, 2021 3:43 PM
**To:** Marston, Brian H (DFG) <brian.marston@alaska.gov>
**Subject:** Re: Info request

Thanks - please include 2021 numbers as this year we got jacked by 2/3 loss of gear / less than half hours allowed / and nearly half the time fished in a cup of water.

Jeff

On Tue, Oct 5, 2021 at 3:02 PM Marston, Brian H (DFG) <brian.marston@alaska.gov> wrote:



| | Kenai River | | Kasilof River | | Fish Creek | |
|---|---|---|---|---|---|---|
| | Abundance | Abundance | Abundance | Abundance | Abundance | Abundance |
| Year | Goal[a] | Estimate [b,c] | Goal | Estimate[b,c] | Goal | Estimate[c] |
| 1978 | 350,000-500,000 | 398,900 | 75,000-150,000 | 116,600 | - | 3,555 |
| 1979 | 350,000-500,000 | 285,020 | 75,000-150,000 | 152,179 | - | 68,739 |
| 1980 | 350,000-500,000 | 464,038 | 75,000-150,000 | 184,260 | - | 62,828 |
| 1981 | 350,000-500,000 | 407,639 | 75,000-150,000 | 256,625 | - | 50,479 |
| 1982 | 350,000-500,000 | 619,831 | 75,000-150,000 | 180,239 | 50,000 | 28,164 |
| 1983 | 350,000-500,000 | 630,340 | 75,000-150,000 | 210,271 | 50,000 | 118,797 |
| 1984 | 350,000-500,000 | 344,571 | 75,000-150,000 | 231,685 | 50,000 | 192,352 |
| 1985 | 350,000-500,000 | 502,820 | 75,000-150,000 | 505,049 | 50,000 | 68,577 |
| 1986 | 350,000-500,000 | 501,157 | 75,000-150,000 | 275,963 | 50,000 | 29,800 |
| 1987 | 400,000-700,000 | 1,596,871 | 150,000-250,000 | 249,250 | 50,000 | 91,215 |
| 1988 | 400,000-700,000 | 1,021,469 | 150,000-250,000 | 204,000 | 50,000 | 71,603 |
| 1989 | 400,000-700,000 | 1,599,959 | 150,000-250,000 | 158,206 | 50,000 | 67,224 |
| 1990 | 400,000-700,000 | 659,520 | 150,000-250,000 | 144,289 | 50,000 | 50,000 |
| 1991 | 400,000-700,000 | 647,597 | 150,000-250,000 | 238,269 | 50,000 | 50,500 |
| 1992 | 400,000-700,000 | 994,798 | 150,000-250,000 | 184,178 | 50,000 | 71,385 |
| 1993 | 400,000-700,000 | 813,617 | 150,000-250,000 | 149,939 | 50,000 | 117,619 |
| 1994 | 400,000-700,000 | 1,003,446 | 150,000-250,000 | 205,117 | 50,000 | 95,107 |
| 1995 | 450,000-700,000 | 630,447 | 150,000-250,000 | 204,935 | 50,000 | 115,000 |
| 1996 | 550,000-800,000 | 797,847 | 150,000-250,000 | 249,944 | 50,000 | 63,160 |
| 1997 | 550,000-825,000 | 1,064,818 | 150,000-250,000 | 266,025 | 50,000 | 54,656 |
| 1998 | 550,000-850,000 | 767,558 | 150,000-250,000 | 273,213 | 50,000 | 22,853 |
| 1999 | 750,000-950,000 | 803,379 | 150,000-250,000 | 312,587 | 50,000 | 26,667 |
| 2000 | 600,000-850,000 | 624,578 | 150,000-250,000 | 256,053 | 50,000 | 19,533 |
| 2001 | 600,000-850,000 | 650,036 | 150,000-250,000 | 307,570 | 50,000 | 43,469 |
| 2002 | 750,000-950,000 | 957,924 | 150,000-250,000 | 226,682 | 20,000 - 70,000 | 90,483 |
| 2003 | 750,000-950,000 | 1,181,309 | 150,000-250,000 | 359,633 | 20,000 - 70,000 | 92,298 |
| 2004 | 850,000-1,100,000 | 1,385,981 | 150,000-250,000 | 577,581 | 20,000 - 70,000 | 22,157 |
| 2005 | 850,000-1,100,000 | 1,376,452 | 150,000-250,000 | 348,012 | 20,000 - 70,000 | 14,215 |
| 2006 | 750,000-950,000 | 1,499,692 | 150,000-250,000 | 368,092 | 20,000 - 70,000 | 32,566 |
| 2007 | 750,000-950,000 | 867,572 | 150,000-250,000 | 336,866 | 20,000 - 70,000 | 27,948 |
| 2008 | 650,000-850,000 | 614,946 | 150,000-250,000 | 301,469 | 20,000 - 70,000 | 19,339 |
| 2009 | 650,000-850,000 | 745,170 | 150,000-250,000 | 297,125 | 20,000 - 70,000 | 83,477 |
| 2010 | 750,000-950,000 | 970,662 | 150,000-250,000 | 267,013 | 20,000 - 70,000 | 126,829 |
| 2011 | 1,100,000-1,350,000 | 1,599,217 | 160,000-390,000 | 245,721 | 20,000 - 70,000 | 66,678 |
| 2012 | 1,100,000-1,350,000 | 1,581,555 | 160,000-390,000 | 374,523 | 20,000 - 70,000 | 18,813 |
| 2013 | 1,000,000-1,200,000 | 1,359,893 | 160,000-390,000 | 489,654 | 20,000 - 70,000 | 18,912 |
| 2014 | 1,000,000-1,200,000 | 1,520,340 | 160,000-340,000 | 439,977 | 20,000 - 70,000 | 43,915 |
| 2015 | 1,000,000-1,200,000 | 1,704,767 | 160,000-340,000 | 470,677 | 20,000 - 70,000 | 102,296 |
| 2016 | 1,100,000-1,350,000 | 1,383,692 | 160,000-340,000 | 239,981 | 20,000 - 70,000 | 46,202 |
| 2017 | 1,000,000-1,300,000 | 1,308,498 | 160,000-340,000 | 358,724 | 15,000 - 45,000 | 61,469 |
| 2018 | 900,000-1,100,000 | 1,035,761 | 160,000-340,000 | 394,309 | 15,000 - 45,000 | 71,556 |
| 2019 | 1,000,000-1,300,000 | 1,849,054 | 160,000-340,000 | 378,416 | 15,000 - 45,000 | 76,031 |
| 2020 | 1,000,000-1,200,000 | 1,714,565 | 140,000-320,000 | 545,654 | 15,000 - 45,000 | 64,234 |

*Note* : ND = no data; "-" = incomplete count

[a] Inriver goal

[b] From 1978 to 2010, enumeration estimates and goals prior were in BENDIX units; 2011 through 2020 are in DIDSON units.

[c] Enumeration etimates prior to 2020 reflect minor adjustments to the escapement database.

[d] Yetna River SEG replaced with lake goals at Judd, Chelatna, and Larson Lakes.

[e] Escapement estimates via remote camera; an unknown number of salmon escaped into the lake after camera malfunction or removal.

Brian Marston

Fishery Biologist

UCI Commercial Fisheries

Alaska Department of Fish and Game

9074207740 cell

9072629368 office

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**From:** Mark Ducker <mandsduckerak@gmail.com>
**Sent:** Tuesday, October 5, 2021 2:58 PM
**To:** Marston, Brian H (DFG) <brian.marston@alaska.gov>
**Subject:** Info request

Please send the updated escapement table for Kasilof sockeye and Kenai late-run sockeye.

Jeff B.

**From:** Mark Ducker
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Fwd: Data request follow-up
**Date:** Thursday, October 7, 2021 12:01:41 AM
**Attachments:** 2021 announcements in recordings of ESSN king harvest2.docx
Copy of Copy of Beaudoin_request_CPUE-bhm3.xlsx

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---------- Forwarded message ---------
From: **Marston, Brian H (DFG)** <brian.marston@alaska.gov>
Date: Sat, Sep 4, 2021 at 2:18 PM
Subject: Data request follow-up

Jeff attached please find my response to your data requests.

You asked for the sockeye and king harvest by stat area in the ESSN fishery for year 2017-2021, the gear allowed, and the area open (see excel file). As per your request, I also calculated a cpue for those harvests by stat area. Feel free to calculate that differently if you wish…

You also asked for the recorded announcements and the data (I added the data used to the earlier file I had sent) used to calculate those announcements for Kenai stock compositions for the Kenai and Kasilof section harvests of king salmon in 2021 (see word file).

I realize you also asked for calculations of the Kenai large king harvest by each opening and stat area…

As stated in an email to you on 8/31, the department will not be calculating Kenai large stock composition of harvests by stat area as the sample size is not sufficient to provide those estimates.

If you notice or feel there are errors in these files please contact me so we can rectify the situation. I had to go back to each specific EO individually for all 5 years to get the hours and gear allowed and area open…. so there was a lot searching and of transcription involved. The gear allowed per area is often complex. Please let me know if you have questions or concerns about this file, or if you feel I have misunderstood your requests.

Let me know that you received this please, and if it fulfills your current requests. Also please include me in any further data request directly so that these can be fulfilled ASAP.

Brian

Brian Marston

Fishery Biologist

UCI Commercial Fisheries

Alaska Department of Fish and Game

9074207740 cell

9072629368 office

UCI recording announcements of estimated Kenai River king salmon harvested in the 2021 ESSN fishery and date first announced.

**All data that went into these recordings was preliminary and the recordings reflect the best estimates of large Kenai River king harvest available at that time. Final analysis of the genetic samples may change these estimates to some degree.**

**Changes to the daily tally of total kings harvested may have changed the announcements (see the 7/14 and 7/15 announcements). Each announcement was repeated until the tally changed with each proceeding commercial opening.**

Formula used

(Total kings)*(2021 pooled proportion large)*(previous years' average Kenai stock)

**Calculations and recorded announcements**

7/7; As of 7/5, the total season harvest of Kenai River large king salmon in the ESSN fishery was 56 fish, and the total harvest of king salmon of all sizes and stocks was 352.

(Total kings)352*(2021 pooled proportion large).23*(previous years' average Kenai stock).69

7/8; As of July 7, the 2021 total season harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 56 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 356.

(Total kings)356*(2021 pooled proportion large).23*(previous years' average Kenai stock).69

7/11; As of July 9, the 2021 total season harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 91 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 525.

(Total kings)525*(2021 pooled proportion large).25*(previous years' average Kenai stock).69

7/14; As of July 12, the total harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 99 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 718.

(Total kings)718*(2021 pooled proportion large).20*(previous years' average Kenai stock).69

7/15; As of July 12, the total harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 106 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 768.

(Total kings)768*(2021 pooled proportion large).20*(previous years' average Kenai stock).69

7/21; As of July 19, the total harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 168 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 1,160.

(Total kings)1160*(2021 pooled proportion large).21*(previous years' average Kenai stock).69

7/22; As of July 20, the total harvest estimate of Kenai River late run large king salmon in the ESSN fishery was 187 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 1,234.

(Total kings)1234*(2021 pooled proportion large).22*(previous years' average Kenai stock).69

7/26; The total harvest estimate to date of Kenai River late run large king salmon in the ESSN fishery was 187 fish, and the total ESSN harvest of king salmon of all sizes and stocks was 1,234. **This above announcement was repeated until 8/2 in the morning and all announcements of king harvests were discontinued after that time.**

(Total kings)1234*(2021 pooled proportion large).22*(previous years' average Kenai stock).69

Sockeye

Species Code 420

Shaded cells are preliminary data from inseason assessment

Sum of Number Of Animals harvested

| | Stat Area | | | | | | | | Hours | Hours | Hours | Hours | Hours | Hours | Hours | Stat Area<br>CPUE sockeye per hour | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stat area | 24421 | 24422 | 24425 | 24431 | 24432 | 24441 | 24442 | All ESSN | 24421 | 24422 | 24425 | 24431 | 24432 | 24441 | 24442 | **24421** | **24422** | **24425** | **24431** | **24432** | **24441** | **24442** | gear allowed | area open |
| 2017 | | | | | | | | | | | | | | | | **2017** | **2017** | **2017** | **2017** | **2017** | **2017** | **2017** | | |
| 06/24 | 7,437 | 2,572 | | 3,040 | | | | 13,049 | 13 | 13 | | 13 | | | | 572.0769 | 197.8462 | | 233.8462 | | | | all | Kas Full |
| 06/26 | 9,964 | 5,799 | | 5,290 | | | | 21,053 | 14 | 14 | | 14 | | | | 711.7143 | 414.2143 | | 377.8571 | | | | all | Kas Full |
| 06/28 | 3,250 | 2,097 | | 2,533 | | | | 7,880 | 9 | 9 | | 9 | | | | 361.1111 | 233 | | 281.4444 | | | | all | Kas Full |
| 06/29 | 5,250 | 2,053 | | 1,738 | | | | 9,041 | 12 | 12 | | 12 | | | | 437.5 | 171.0833 | | 144.8333 | | | | all | Kas Full |
| 07/01 | 9,930 | 3,829 | | 7,282 | | | | 21,041 | 17 | 17 | | 17 | | | | 584.1176 | 225.2353 | | 428.3529 | | | | all | Kas Full |
| 07/03 | 12,152 | 7,121 | | 6,567 | | | | 25,840 | 14 | 14 | | 14 | | | | 868 | 508.6429 | | 469.0714 | | | | all | Kas Full |
| 07/05 | 10,434 | 2,760 | | 2,929 | | | | 16,123 | 9 | 9 | | 9 | | | | 1159.333 | 306.6667 | | 325.4444 | | | | all | Kas Full |
| 07/06 | 13,637 | 4,840 | | 2,865 | | | | 21,342 | 12 | 12 | | 12 | | | | 1136.417 | 403.3333 | | 238.75 | | | | all | Kas Full |
| 07/08 | 17,396 | 10,250 | | 6,184 | | | | 33,830 | 17 | 17 | | 17 | | | | 1023.294 | 602.9412 | | 363.7647 | | | | all | Kas Full |
| 07/10 | 22,021 | 8,395 | | 3,150 | 3,139 | 6,165 | 1,700 | 44,570 | 12 | 12 | | 12 | 12 | 12 | 12 | 1835.083 | 699.5833 | | 262.5 | 261.5833 | 513.75 | 141.6667 | all | KKE Full |
| 07/12 | 23,649 | 8,321 | | 2,973 | 2,432 | 4,172 | 949 | 42,496 | 16 | 16 | | 16 | 16 | 16 | 16 | 1478.063 | 520.0625 | | 185.8125 | 152 | 260.75 | 59.3125 | all | KKE Full |
| 07/13 | 20,070 | 8,658 | | 2,393 | 2,679 | 3,991 | 987 | 38,778 | 15 | 15 | | 15 | 15 | 15 | 15 | 1338 | 577.2 | | 159.5333 | 178.6 | 266.0667 | 65.8 | all | KKE Full |
| 07/15 | 24,599 | 14,298 | | 4,406 | 4,397 | 6,947 | 1,314 | 55,961 | 15 | 15 | | 15 | 15 | 15 | 15 | 1639.933 | 953.2 | | 293.7333 | 293.1333 | 463.1333 | 87.6 | all | KKE Full |
| 07/17 | 36,513 | 16,824 | | 14,643 | 15,689 | 39,023 | 5,944 | 128,636 | 12 | 12 | | 12 | 12 | 12 | 12 | 3042.75 | 1402 | | 1220.25 | 1307.417 | 3251.917 | 495.3333 | all | KKE Full |
| 07/20 | 20,662 | 12,589 | | 8,897 | 9,590 | 30,803 | 5,911 | 88,452 | 12 | 12 | | 12 | 12 | 12 | 12 | 1721.833 | 1049.083 | | 741.4167 | 799.1667 | 2566.917 | 492.5833 | all | KKE Full |
| 07/29 | 17,731 | 13,408 | | 5,018 | 5,052 | 24,324 | 3,599 | 69,132 | 14 | 14 | | 14 | 14 | 14 | 14 | 1266.5 | 957.7143 | | 358.4286 | 360.8571 | 1737.429 | 257.0714 | all | KKE Full |
| 07/31 | 9,100 | 4,977 | | 4,188 | 5,721 | 16,151 | 3,169 | 43,306 | 12 | 12 | | 12 | 12 | 12 | 12 | 758.3333 | 414.75 | | 349 | 476.75 | 1345.917 | 264.0833 | all | KKE Full |
| 08/03 | 16,383 | 8,255 | | 5,731 | 5,429 | 8,040 | 3,756 | 47,594 | 12 | 12 | | 12 | 12 | 12 | 12 | 1365.25 | 687.9167 | | 477.5833 | 452.4167 | 670 | 313 | all | KKE Full |
| 08/07 | 5,943 | 5,884 | | 3,291 | 4,117 | 13,813 | 4,772 | 37,820 | 12 | 12 | | 12 | 12 | 12 | 12 | 495.25 | 490.3333 | | 274.25 | 343.0833 | 1151.083 | 397.6667 | all | KKE Full |
| 08/09 | 4,118 | 3,713 | | 2,303 | 2,365 | 3,099 | 1,178 | 16,776 | 15 | 15 | | 15 | 15 | 15 | 15 | 274.5333 | 247.5333 | | 153.5333 | 157.6667 | 206.6 | 78.53333 | all | KKE Full |
| 08/10 | 6,369 | 6,499 | | 3,253 | 4,270 | 5,148 | 1,792 | 27,331 | 12 | 12 | | 12 | 12 | 12 | 12 | 530.75 | 541.5833 | | 271.0833 | 355.8333 | 429 | 149.3333 | all | KKE Full |
| 08/14 | 2,563 | 2,981 | | 1,223 | 2,463 | 6,300 | 1,728 | 17,258 | 16 | 16 | | 16 | 16 | 16 | 16 | 160.1875 | 186.3125 | | 76.4375 | 153.9375 | 393.75 | 108 | all | Kas .5 mile (4), KKE Full (12) |
| 08/15 | 1,852 | 1,562 | | 1,497 | | | | 4,911 | 13 | 13 | | 13 | | | | 142.4615 | 120.1538 | | 115.1538 | | | | all | Kas .5 mile |
| 2018 | | | | | | | | | | | | | | | | **2018** | **2018** | **2018** | **2018** | **2018** | **2018** | **2018** | | |
| 06/25 | 7,341 | 2,657 | | 1,568 | | | | 11,566 | 12 | 12 | | 12 | | | | 611.75 | 221.4167 | | 130.6667 | | | | all | Kas Full |
| 06/28 | 7,283 | 3,035 | | 1,464 | | | | 11,782 | 12 | 12 | | 12 | | | | 606.9167 | 252.9167 | | 122 | | | | all | Kas Full |
| 06/30 | 5,695 | 3,375 | | 3,121 | | | | 12,191 | 14 | 14 | | 14 | | | | 406.7857 | 241.0714 | | 222.9286 | | | | all | Kas Full |
| 07/04 | 9,652 | 5,663 | | 4,655 | | | | 19,970 | 16 | 16 | | 16 | | | | 603.25 | 353.9375 | | 290.9375 | | | | all | Kas Full |
| 07/07 | 4,391 | 1,988 | | 2,532 | | | | 8,911 | 8 | 8 | | 8 | | | | 548.875 | 248.5 | | 316.5 | | | | all | Kas Full |
| 07/09 | 5,675 | 2,521 | | 1,819 | 1,184 | 2,582 | 1,056 | 14,837 | 12 | 12 | | 12 | 12 | 12 | 12 | 472.9167 | 210.0833 | | 151.5833 | 98.66667 | 215.1667 | 88 | all | KKE Full |
| 07/12 | 10,726 | 14,737 | | 7,954 | 6,277 | 19,376 | 4,958 | 64,028 | 12 | 12 | | 12 | 12 | 12 | 12 | 893.8333 | 1228.083 | | 662.8333 | 523.0833 | 1614.667 | 413.1667 | all | KKE Full |
| 07/14 | 4,504 | 5,535 | | 2,904 | | | | 12,943 | 12 | 12 | | 12 | | | | 375.3333 | 461.25 | | 242 | | | | all | Kas .5 mile |
| 07/16 | | | | | | | 1,939 | 1,939 | | | | | | | 12 | | | | | | | 161.5833 | all | EF full |
| 07/18 | 2,654 | 5,380 | | 4,394 | | | | 12,428 | 7 | 7 | | 7 | | | | 379.1429 | 768.5714 | | 627.7143 | | | | all | Kas 600 ft |
| 07/19 | 6,905 | 17,663 | | 8,504 | 6,885 | | | 39,957 | 12 | 12 | | 12 | 12 | | | 575.4167 | 1471.917 | | 708.6667 | 573.75 | | | all | Kas .5 mile, NKB 600 |
| 07/21 | 7,585 | 4,711 | | 3,037 | 2,172 | | | 17,505 | 12 | 12 | | 12 | 12 | | | 632.0833 | 392.5833 | | 253.0833 | 181 | | | all | Kas .5 mile, NKB 600 |
| 07/22 | 3,490 | 1,636 | | 2,588 | | | | 7,714 | 14 | 14 | | 14 | | | | 249.2857 | 116.8571 | | 184.8571 | #DIV/0! | | | all | Kas 600 ft |
| 07/23 | 5,469 | 2,367 | | 2,240 | 2,595 | 15,018 | 3,713 | 31,402 | 12 | 12 | | 12 | 12 | 12 | 12 | 455.75 | 197.25 | | 186.6667 | 216.25 | 1251.5 | 309.4167 | all | KKE Full |
| 07/26 | 2,408 | 2,153 | | 2,083 | | | | 6,644 | 12 | 12 | | 12 | | | | 200.6667 | 179.4167 | | 173.5833 | | | | all | Kas 600 ft |
| 07/28 | 1,718 | 1,405 | | 1,491 | | | | 4,614 | 8 | 8 | | 8 | | | | 214.75 | 175.625 | | 186.375 | | | | all | Kas 600 ft |
| 08/08 | | | 1,377 | | | | | 1,377 | | | 12 | | | | | | | 114.75 | | | | | all | KRSHA |
| 08/09 | | | 3,855 | | | | | 3,855 | | | 24 | | | | | | | 160.625 | | | | | all | KRSHA |
| 08/10 | | | 2,642 | | | | | 2,642 | | | 24 | | | | | | | 110.0833 | | | | | all | KRSHA |
| 08/11 | | | 1,965 | | | | | 1,965 | | | 24 | | | | | | | 81.875 | | | | | all | KRSHA |
| 08/12 | | | 1,571 | | | | | 1,571 | | | 8 | | | | | | | 196.375 | | | | | all | KRSHA |
| 2019 | | | | | | | | | | | | | | | | **2019** | **2019** | **2019** | **2019** | **2019** | **2019** | **2019** | | |
| 06/27 | 6,811 | 3,260 | | 1,896 | | | | 11,967 | 12 | 12 | | 12 | | | | 567.5833 | 271.6667 | | 158 | | | | all | Kas Full |
| 06/29 | 6,720 | 3,459 | | 2,012 | | | | 12,191 | 8 | 8 | | 8 | | | | 840 | 432.375 | | 251.5 | | | | all | Kas Full |
| 07/01 | 8,904 | 5,382 | | 3,576 | | | | 17,862 | 12 | 12 | | 12 | | | | 742 | 448.5 | | 298 | | | | all | Kas Full |
| 07/04 | 5,519 | 5,176 | | 4,216 | | | | 14,911 | 14 | 14 | | 14 | | | | 394.2143 | 369.7143 | | 301.1429 | | | | (i) | Kas Full |
| 07/08 | 10,107 | 8,718 | | 5,867 | 4,128 | 4,114 | 2,352 | 35,286 | 16 | 16 | | 16 | 16 | 16 | 16 | 631.6875 | 544.875 | | 366.6875 | 258 | 257.125 | 147 | (i) except EF | KKE Full |
| 07/11 | 7,714 | 6,212 | | 4,668 | 6,539 | 14,373 | 6,334 | 45,840 | 15 | 15 | | 15 | 15 | 15 | 15 | 514.2667 | 414.1333 | | 311.2 | 435.9333 | 958.2 | 422.2667 | (i) except EF | KKE Full |
| 07/13 | 5,227 | 4,507 | | 4,112 | 3,227 | | | 17,073 | 12 | 12 | | 12 | 12 | | | 435.5833 | 375.5833 | | 342.6667 | 268.9167 | | | (i) | Kas .5 mile, NKB 600 |
| 07/15 | 5,383 | 6,571 | | 4,708 | 7,329 | 12,254 | 5,043 | 41,288 | 14 | 14 | | 14 | 14 | 14 | 14 | 384.5 | 469.3571 | | 336.2857 | 523.5 | 875.2857 | 360.2143 | (i) | KKE Full |
| 07/18 | 5,481 | 8,011 | | 5,563 | 8,938 | 19,751 | 7,758 | 55,502 | 15 | 15 | | 15 | 15 | 15 | 15 | 365.4 | 534.0667 | | 370.8667 | 595.8667 | 1316.733 | 517.2 | (i) | KKE Full |
| 07/21 | 6,349 | 5,656 | | 5,524 | 8,076 | | | 25,605 | 14 | 14 | | 14 | 14 | | | 453.5 | 404 | | 394.5714 | 576.8571 | | | (i) | Kas .5 mile, NKB 600 |
| 07/22 | 4,214 | 4,055 | | 2,418 | 7,266 | 34,390 | 12,084 | 64,427 | 15 | 15 | | 15 | 15 | 15 | 15 | 280.9333 | 270.3333 | | 161.2 | 484.4 | 2292.667 | 805.6 | (i) | KKE Full |
| 07/25 | 8,532 | 8,928 | | 8,699 | 13,125 | 47,460 | 16,731 | 103,475 | 17 | 17 | | 17 | 17 | 17 | 17 | 501.8824 | 525.1765 | | 511.7059 | 772.0588 | 2791.765 | 984.1765 | (i) | KKE Full |
| 07/28 | 17,734 | 17,378 | | 9,289 | 14,133 | 22,625 | 9,872 | 91,031 | 16 | 16 | | 16 | 16 | 16 | 16 | 1108.375 | 1086.125 | | 580.5625 | 883.3125 | 1414.063 | 617 | all | KKE Full |
| 07/29 | 13,064 | 8,774 | | 5,280 | 12,666 | 20,067 | 8,433 | 68,284 | 16 | 16 | | 16 | 16 | 16 | 16 | 816.5 | 548.375 | | 330 | 791.625 | 1254.188 | 527.0625 | all | KKE Full |
| 07/31 | 14,234 | 9,608 | | 5,064 | 8,746 | 36,729 | 18,308 | 92,689 | 16 | 16 | | 16 | 16 | 16 | 16 | 889.625 | 600.5 | | 316.5 | 546.625 | 2295.563 | 1144.25 | all | KKE Full |
| 08/01 | 7,165 | 7,136 | | 2,554 | 5,551 | 14,923 | 13,050 | 50,379 | 16 | 16 | | 16 | 16 | 16 | 16 | 447.8125 | 446 | | 159.625 | 346.9375 | 932.6875 | 815.625 | all | KKE Full |
| 08/02 | 2,099 | 1,052 | | 653 | 1,331 | | | 5,135 | 12 | 12 | | 12 | 12 | | | 174.9167 | 87.66667 | | 54.41667 | 110.9167 | | | all | Kas 600 Ken 600 |
| 08/03 | 5,747 | 3,297 | | 1,381 | 2,163 | 11,339 | 7,671 | 31,598 | 11 | 11 | | 11 | 11 | 11 | 11 | 522.4545 | 299.7273 | | 125.5455 | 196.6364 | 1030.818 | 697.3636 | all | KKE Full |
| 2020 | | | | | | | | | | | | | | | | **2020** | **2020** | **2020** | **2020** | **2020** | **2020** | **2020** | | |
| 06/23 | 4,769 | 3,614 | | 5,257 | | | | 13,640 | 15 | 15 | | 15 | | | | 317.9333 | 240.9333 | | 350.4667 | | | | (ii) | Kas Full |
| 06/25 | 6,365 | 4,528 | | 1,816 | | | | 12,709 | 12 | 12 | | 12 | | | | 530.4167 | 377.3333 | | 151.3333 | | | | (ii) | Kas Full |
| 06/27 | 5,193 | 3,740 | | 2,282 | | | | 11,215 | 9 | 9 | | 9 | | | | 577 | 415.5556 | | 253.5556 | | | | (ii) | Kas Full |
| 06/30 | 4,231 | 3,821 | | 8,288 | | | | 16,340 | 12 | 12 | | 12 | | | | 352.5833 | 318.4167 | | 690.6667 | | | | (ii) | Kas Full |
| 07/02 | 8,263 | 3,967 | | 2,823 | 1,897 | | | 16,950 | 15 | 15 | | 15 | 15 | | | 550.8667 | 264.4667 | | 188.2 | 126.4667 | | | (i) Kas, NKB 4.75 | NKB Kas full |
| 07/04 | 5,916 | 3,977 | | 2,280 | 684 | | | 12,857 | 9 | 9 | | 9 | 9 | | | 657.3333 | 441.8889 | | 253.3333 | 76 | | | (i) Kas, NKB 4.76 | NKB Kas full |
| 07/06 | 8,747 | 9,939 | | 6,506 | 2,260 | | | 27,452 | 13 | 13 | | 13 | 13 | | | 672.8462 | 764.5385 | | 500.4615 | 173.8462 | | | (i) Kas, NKB 4.77 | NKB Kas full |
| 07/07 | 3,154 | 2,416 | | 1,291 | 1,796 | | | 8,657 | 13 | 13 | | 13 | 13 | | | 242.6154 | 185.8462 | | 99.30769 | 138.1538 | | | Kas all, NKB 4.75 | Kas 600, NKB 600 |
| 07/08 | 6,070 | 2,615 | | 1,144 | 629 | | | 10,458 | 8 | 8 | | 8 | 8 | | | 758.75 | 326.875 | | 143 | 78.625 | | | Kas (ii), NKB 4.75 | Kas 600, NKB 600 |
| 07/09 | 6,145 | 4,040 | | 1,406 | 1,479 | 2,587 | 889 | 16,546 | 15 | 15 | | 15 | 15 | 15 | 15 | 409.6667 | 269.3333 | | 93.73333 | 98.6 | 172.4667 | 59.26667 | KKE (ii) | KKE all |
| 07/13 | 6,966 | 4,145 | | 3,781 | 3,032 | 9,918 | 3,833 | 31,675 | 12 | 12 | | 12 | 12 | 12 | 12 | 580.5 | 345.4167 | | 315.0833 | 252.6667 | 826.5 | 319.4167 | KKE (ii) | KKE all |
| 07/15 | 4,256 | 3,159 | | 4,201 | 3,420 | 7,260 | 1,577 | 23,873 | 12 | 12 | | 12 | 12 | 12 | 12 | 354.6667 | 263.25 | | 350.0833 | 285 | 605 | 131.4167 | KKE (ii) | KKE all |
| 07/16 | 2,583 | 992 | | 940 | 2,275 | | | 6,790 | 12 | 12 | | 12 | 12 | | | 215.25 | 82.66667 | | 78.33333 | 189.5833 | | | all | Kas 600, NKB 600 |
| 07/20 | 5,644 | 2,962 | | 2,994 | 2,947 | 24,066 | 6,840 | 45,453 | 12 | 12 | | 12 | 12 | 12 | 12 | 470.3333 | 246.8333 | | 249.5 | 245.5833 | 2005.5 | 570 | KKE (ii) | KKE all |
| 07/21 | 1,601 | 979 | | 1,382 | | | | 3,962 | 8 | 8 | | 8 | | | | 200.125 | 122.375 | | 172.75 | | | | all | Kas 600 |
| 07/22 | 2,084 | 1,727 | | 1,926 | 2,207 | 17,788 | 11,032 | 36,764 | 12 | 12 | | 12 | 12 | 12 | 12 | 173.6667 | 143.9167 | | 160.5 | 183.9167 | 1482.333 | 919.3333 | (ii) | KKE all |
| 2021 | | | | | | | | | | | | | | | | **2021** | **2021** | **2021** | **2021** | **2021** | **2021** | **2021** | | |
| 22-Jun | 6,632 | 4,457 | | 5,748 | | | | 16,837 | 12 | 12 | | 12 | | | | 552.6667 | 371.4167 | | 479 | | | | (ii) | Kas all |
| 24-Jun | 8,207 | 5,888 | | 5,030 | | | | 19,125 | 15 | 15 | | 15 | | | | 547.1333 | 392.5333 | | 335.3333 | | | | (ii) | Kas all |
| 26-Jun | 7,502 | 4,364 | | 3,831 | | | | 15,697 | 14 | 14 | | 14 | | | | 535.8571 | 311.7143 | | 273.6429 | | | | (ii) | Kas all |
| 28-Jun | 9,688 | 12,244 | | 10,121 | | | | 32,053 | 15 | 15 | | 15 | | | | 645.8667 | 816.2667 | | 674.7333 | | | | (ii) | Kas all |
| 1-Jul | 7,367 | 4,987 | | 4,982 | 2,162 | | | 19,498 | 15 | 15 | | 15 | 15 | | | 491.1333 | 332.4667 | | 332.1333 | 144.1333 | | | Kas (ii), NKB 4.75 | Kas all, NKB 600 |
| 3-Jul | 6,081 | 5,377 | | 4,999 | 2,530 | | | 18,987 | 17 | 17 | | 17 | 17 | | | 357.7059 | 316.2941 | | 294.0588 | 148.8235 | | | Kas (ii), NKB 4.76 | Kas all, NKB 600 |
| 5-Jul | 6,473 | 3,986 | | 4,672 | 3,110 | | | 18,241 | 15 | 15 | | 15 | 15 | | | 431.5333 | 265.7333 | | 311.4667 | 207.3333 | | | Kas (ii), NKB 4.77 | Kas all, NKB 600 |
| 6-Jul | 4,387 | 1,165 | | 894 | 2,243 | | | 8,689 | 18 | 18 | | 18 | 18 | | | 243.7222 | 64.72222 | | 49.66667 | 124.6111 | | | Kas (i), NKB 4.75 | Kas 600, NKB 600 |
| 7-Jul | 3,453 | 4,260 | | 3,875 | 2,734 | | | 14,322 | 15 | 15 | | 15 | 15 | | | 230.2 | 284 | | 258.3333 | 182.2667 | | | Kas (ii), NKB 4.75 | Kas all, NKB 600 |
| 8-Jul | 4,558 | 4,558 | | 2,828 | 4,181 | 7,233 | 3,139 | 26,497 | 18 | 18 | | 18 | 18 | 18 | 18 | 253.2222 | 253.2222 | | 157.1111 | 232.2778 | 401.8333 | 174.3889 | (ii) | all |
| 12-Jul | 2,697 | 3,638 | | 3,615 | 4,415 | 8,361 | 4,510 | 27,236 | 12 | 12 | | 12 | 12 | 12 | 12 | 224.75 | 303.1667 | | 301.25 | 367.9167 | 696.75 | 375.8333 | (ii) | all |
| 13-Jul | 1,848 | 1,673 | | 1,550 | 2,158 | | | 7,229 | 17 | 17 | | 17 | 17 | | | 108.7059 | 98.41176 | | 91.17647 | 126.9412 | | | (ii) | Kas 600, NKB 600 |
| 14-Jul | 1,511 | 1,783 | | 1,895 | 3,329 | | | 8,518 | 17 | 17 | | 17 | 17 | | | 88.88235 | 104.8824 | | 111.4706 | 195.8235 | | | (ii) | Kas 600, NKB 600 |
| 15-Jul | 3,412 | 3,367 | | 2,245 | 3,341 | 9,370 | 2,583 | 24,318 | 12 | 12 | | 12 | 12 | 12 | 12 | 284.3333 | 280.5833 | | 187.0833 | 278.4167 | 780.8333 | 215.25 | (ii) | KKE all |
| 18-Jul | | | 1,465 | | | | | 1,465 | | | 12 | | | | | | | 122.0833 | | | | | all | KRSHA |
| 19-Jul | 3,219 | 7,621 | | 8,831 | 16,813 | 57,285 | 14,346 | 108,115 | 12 | 12 | | 12 | 12 | 12 | 12 | 268.25 | 635.0833 | | 735.9167 | 1401.083 | 4773.75 | 1195.5 | (ii) | KKE all |
| 20-Jul | 1,906 | 1,471 | | 1,865 | 3,460 | 18,489 | 9,477 | 36,668 | 12 | 12 | | 12 | 12 | 12 | 12 | 158.8333 | 122.5833 | | 155.4167 | 288.3333 | 1540.75 | 789.75 | (ii) | KKE 600 |

**Abreviations**

**Kas = Kasilof section**

**KKE - Kenai, Kasilof, and East Foreland sections**

**KRSHA = Kasilof special harvtes area**

**NKB = North K Beach stat area**

**EF = East Forelands section**

All Kings

Shaded rows are preliminary harvest data from inseason assessment

Species Code 410

| | Sum of Number Of Animals harvested | | | | | | | | | | | | | | | Stat Area | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stat Area | | | | | | | | Hours | Hours | Hours | Hours | Hours | Hours | Hours | CPUE kings per hour | | | | | | | gear allowed | area open |
| | 24421 | 24422 | 24425 | 24431 | 24432 | 24441 | 24442 | All ESSN | 24421 | 24422 | 24425 | 24431 | 24432 | 24441 | 24442 | **24421** | **24422** | **24425** | **24431** | **24432** | **24441** | **24442** | | |
| 2017 | | | | | | | | | | | | | | | | 2017 | 2017 | 2017 | 2017 | 2017 | 2017 | 2017 | | |
| 06/24 | 21 | 20 | | 13 | | | | 54 | 13 | 13 | | 13 | | | | 1.615385 | 1.538462 | | 1 | | | | all | Kas Full |
| 06/26 | 26 | 22 | | 18 | | | | 66 | 14 | 14 | | 14 | | | | 1.857143 | 1.571429 | | 1.285714 | | | | all | Kas Full |
| 06/28 | 7 | 15 | | 9 | | | | 31 | 9 | 9 | | 9 | | | | 0.777778 | 1.666667 | | 1 | | | | all | Kas Full |
| 06/29 | 16 | 13 | | 16 | | | | 45 | 12 | 12 | | 12 | | | | 1.333333 | 1.083333 | | 1.333333 | | | | all | Kas Full |
| 07/01 | 16 | 20 | | 29 | | | | 65 | 17 | 17 | | 17 | | | | 0.941176 | 1.176471 | | 1.705882 | | | | all | Kas Full |
| 07/03 | 44 | 45 | | 27 | | | | 116 | 14 | 14 | | 14 | | | | 3.142857 | 3.214286 | | 1.928571 | | | | all | Kas Full |
| 07/05 | 27 | 21 | | 15 | | | | 63 | 9 | 9 | | 9 | | | | 3 | 2.333333 | | 1.666667 | | | | all | Kas Full |
| 07/06 | 56 | 32 | | 21 | | | | 109 | 12 | 12 | | 12 | | | | 4.666667 | 2.666667 | | 1.75 | | | | all | Kas Full |
| 07/08 | 66 | 64 | | 43 | | | | 173 | 17 | 17 | | 17 | | | | 3.882353 | 3.764706 | | 2.529412 | | | | all | Kas Full |
| 07/10 | 106 | 27 | | 23 | 39 | 122 | 5 | 322 | 12 | 12 | | 12 | 12 | 12 | 12 | 8.833333 | 2.25 | | 1.916667 | 3.25 | 10.16667 | 0.416667 | all | KKE Full |
| 07/12 | 51 | 43 | | 44 | 42 | 125 | 1 | 306 | 16 | 16 | | 16 | 16 | 16 | 16 | 3.1875 | 2.6875 | | 2.75 | 2.625 | 7.8125 | 0.0625 | all | KKE Full |
| 07/13 | 99 | 67 | | 57 | 65 | 226 | 6 | 520 | 15 | 15 | | 15 | 15 | 15 | 15 | 6.6 | 4.466667 | | 3.8 | 4.333333 | 15.06667 | 0.4 | all | KKE Full |
| 07/15 | 80 | 45 | | 53 | 60 | 170 | 3 | 411 | 15 | 15 | | 15 | 15 | 15 | 15 | 5.333333 | 3 | | 3.533333 | 4 | 11.33333 | 0.2 | all | KKE Full |
| 07/17 | 73 | 62 | | 78 | 61 | 188 | 7 | 469 | 12 | 12 | | 12 | 12 | 12 | 12 | 6.083333 | 5.166667 | | 6.5 | 5.083333 | 15.66667 | 0.583333 | all | KKE Full |
| 07/20 | 27 | 64 | | 99 | 122 | 172 | 8 | 492 | 12 | 12 | | 12 | 12 | 12 | 12 | 2.25 | 5.333333 | | 8.25 | 10.16667 | 14.33333 | 0.666667 | all | KKE Full |
| 07/29 | 27 | 35 | | 86 | 67 | 341 | 16 | 572 | 14 | 14 | | 14 | 14 | 14 | 14 | 1.928571 | 2.5 | | 6.142857 | 4.785714 | 24.35714 | 1.142857 | all | KKE Full |
| 07/31 | 28 | 24 | | 65 | 62 | 178 | | 357 | 12 | 12 | | 12 | 12 | 12 | 12 | 2.333333 | 2 | | 5.416667 | 5.166667 | 14.83333 | 0 | all | KKE Full |
| 08/03 | 37 | 11 | | 43 | 59 | 99 | 1 | 250 | 12 | 12 | | 12 | 12 | 12 | 12 | 3.083333 | 0.916667 | | 3.583333 | 4.916667 | 8.25 | 0.083333 | all | KKE Full |
| 08/07 | 6 | 19 | | 17 | 22 | 76 | 1 | 141 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.5 | 1.583333 | | 1.416667 | 1.833333 | 6.333333 | 0.083333 | all | KKE Full |
| 08/09 | 9 | 13 | | 17 | 15 | 54 | 1 | 109 | 15 | 15 | | 15 | 15 | 15 | 15 | 0.6 | 0.866667 | | 1.133333 | 1 | 3.6 | 0.066667 | all | KKE Full |
| 08/10 | 10 | 15 | | 12 | 16 | 26 | 1 | 80 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.833333 | 1.25 | | 1 | 1.333333 | 2.166667 | 0.083333 | all | KKE Full |
| 08/14 | 2 | 6 | | 4 | 2 | 5 | 1 | 20 | 16 | 16 | | 16 | 16 | 16 | 16 | 0.125 | 0.375 | | 0.25 | 0.125 | 0.3125 | 0.0625 | all | Kas .5 mile (4), KKE Full (12) |
| 08/15 | 3 | | | 5 | | | | 8 | 13 | 13 | | 13 | | | | 0.230769 | 0 | | 0.384615 | | | | all | Kas .5 mile |
| 2018 | | | | | | | | | | | | | | | | **2018** | **2018** | **2018** | **2018** | **2018** | **2018** | **2018** | | |
| 06/25 | 27 | 24 | | 8 | | | | 59 | 12 | 12 | | 12 | | | | 2.25 | 2 | | 0.666667 | | | | all | Kas Full |
| 06/28 | 31 | 81 | | 19 | | | | 131 | 12 | 12 | | 12 | | | | 2.583333 | 6.75 | | 1.583333 | | | | all | Kas Full |
| 06/30 | 45 | 70 | | 18 | | | | 133 | 14 | 14 | | 14 | | | | 3.214286 | 5 | | 1.285714 | | | | all | Kas Full |
| 07/04 | 74 | 105 | | 57 | | | | 236 | 16 | 16 | | 16 | | | | 4.625 | 6.5625 | | 3.5625 | | | | all | Kas Full |
| 07/07 | 55 | 39 | | 36 | | | | 130 | 8 | 8 | | 8 | | | | 6.875 | 4.875 | | 4.5 | | | | all | Kas Full |
| 07/09 | 36 | 54 | | 49 | 51 | 102 | 6 | 298 | 12 | 12 | | 12 | 12 | 12 | 12 | 3 | 4.5 | | 4.083333 | 4.25 | 8.5 | 0.5 | all | KKE Full |
| 07/12 | 25 | 62 | | 87 | 177 | 110 | 4 | 465 | 12 | 12 | | 12 | 12 | 12 | 12 | 2.083333 | 5.166667 | | 7.25 | 14.75 | 9.166667 | 0.333333 | all | KKE Full |
| 07/14 | 39 | 63 | | 37 | | | | 139 | 12 | 12 | | 12 | | | | 3.25 | 5.25 | | 3.083333 | | | | all | Kas .5 mile |
| 07/16 | | | | | | | 17 | 17 | | | | | | | 12 | | | | | | | 1.416667 | all | EF full |
| 07/18 | 2 | 19 | | 11 | | | | 32 | 7 | 7 | | 7 | | | | 0.285714 | 2.714286 | | 1.571429 | | | | all | Kas 600 ft |
| 07/19 | 38 | 46 | | 41 | 5 | | | 130 | 12 | 12 | | 12 | 12 | | | 3.166667 | 3.833333 | | 3.416667 | 0.416667 | | | all | Kas .5 mile, NKB 600 |
| 07/21 | 34 | 25 | | 24 | 6 | | | 89 | 12 | 12 | | 12 | 12 | | | 2.833333 | 2.083333 | | 2 | 0.5 | | | all | Kas .5 mile, NKB 600 |
| 07/22 | 10 | 5 | | 12 | | | | 27 | 14 | 14 | | 14 | | | | 0.714286 | 0.357143 | | 0.857143 | #DIV/0! | | | all | Kas 600 ft |
| 07/23 | 27 | 26 | | 40 | 59 | 196 | 5 | 353 | 12 | 12 | | 12 | 12 | 12 | 12 | 2.25 | 2.166667 | | 3.333333 | 4.916667 | 16.33333 | 0.416667 | all | KKE Full |
| 07/26 | 7 | 6 | | 7 | | | | 20 | 12 | 12 | | 12 | | | | 0.583333 | 0.5 | | 0.583333 | | | | all | Kas 600 ft |
| 07/28 | 10 | 11 | | 4 | | | | 25 | 8 | 8 | | 8 | | | | 1.25 | 1.375 | | 0.5 | | | | all | Kas 600 ft |
| 08/08 | | | 3 | | | | | 3 | | | 12 | | | | | | | 0.25 | | | | | all | KRSHA |
| 08/09 | | | 7 | | | | | 7 | | | 24 | | | | | | | 0.291667 | | | | | all | KRSHA |
| 08/10 | | | 8 | | | | | 8 | | | 24 | | | | | | | 0.333333 | | | | | all | KRSHA |
| 08/11 | | | 4 | | | | | 4 | | | 24 | | | | | | | 0.166667 | | | | | all | KRSHA |
| 08/12 | | | 6 | | | | | 6 | | | 8 | | | | | | | 0.75 | | | | | all | KRSHA |
| 2019 | | | | | | | | | | | | | | | | **2019** | **2019** | **2019** | **2019** | **2019** | **2019** | **2019** | | |
| 06/27 | 21 | 19 | | 12 | | | | 52 | 12 | 12 | | 12 | | | | 1.75 | 1.583333 | | 1 | | | | all | Kas Full |
| 06/29 | 20 | 12 | | 12 | | | | 44 | 8 | 8 | | 8 | | | | 2.5 | 1.5 | | 1.5 | | | | all | Kas Full |
| 07/01 | 17 | 19 | | 9 | | | | 45 | 12 | 12 | | 12 | | | | 1.416667 | 1.583333 | | 0.75 | | | | all | Kas Full |
| 07/04 | 22 | 24 | | 28 | | | | 74 | 14 | 14 | | 14 | | | | 1.571429 | 1.714286 | | 2 | | | | (i) | Kas Full |
| 07/08 | 39 | 39 | | 49 | 26 | 96 | 6 | 255 | 16 | 16 | | 16 | 16 | 16 | 16 | 2.4375 | 2.4375 | | 3.0625 | 1.625 | 6 | 0.375 | (i) except EF | KKE Full |
| 07/11 | 31 | 43 | | 37 | 39 | 90 | 8 | 248 | 15 | 15 | | 15 | 15 | 15 | 15 | 2.066667 | 2.866667 | | 2.466667 | 2.6 | 6 | 0.533333 | (i) except EF | KKE Full |
| 07/13 | 24 | 23 | | 41 | 4 | | | 92 | 12 | 12 | | 12 | 12 | | | 2 | 1.916667 | | 3.416667 | 0.333333 | | | (i) | Kas .5 mile, NKB 600 |
| 07/15 | 26 | 45 | | 30 | 39 | 80 | 3 | 223 | 14 | 14 | | 14 | 14 | 14 | 14 | 1.857143 | 3.214286 | | 2.142857 | 2.785714 | 5.714286 | 0.214286 | (i) | KKE Full |
| 07/18 | 50 | 53 | | 51 | 77 | 170 | 10 | 411 | 15 | 15 | | 15 | 15 | 15 | 15 | 3.333333 | 3.533333 | | 3.4 | 5.133333 | 11.33333 | 0.666667 | (i) | KKE Full |
| 07/21 | 25 | 26 | | 41 | 13 | | | 105 | 14 | 14 | | 14 | 14 | | | 1.785714 | 1.857143 | | 2.928571 | 0.928571 | | | (i) | Kas .5 mile, NKB 600 |
| 07/22 | 24 | 27 | | 27 | 37 | 107 | 13 | 235 | 15 | 15 | | 15 | 15 | 15 | 15 | 1.6 | 1.8 | | 1.8 | 2.466667 | 7.133333 | 0.866667 | (i) | KKE Full |
| 07/25 | 19 | 14 | | 35 | 26 | 30 | 2 | 126 | 17 | 17 | | 17 | 17 | 17 | 17 | 1.117647 | 0.823529 | | 2.058824 | 1.529412 | 1.764706 | 0.117647 | (i) | KKE Full |
| 07/28 | 7 | 9 | | 15 | 12 | 53 | 4 | 100 | 16 | 16 | | 16 | 16 | 16 | 16 | 0.4375 | 0.5625 | | 0.9375 | 0.75 | 3.3125 | 0.25 | all | KKE Full |
| 07/29 | 7 | 9 | | 16 | 16 | 43 | 2 | 93 | 16 | 16 | | 16 | 16 | 16 | 16 | 0.4375 | 0.5625 | | 1 | 1 | 2.6875 | 0.125 | all | KKE Full |
| 07/31 | 7 | 7 | | 14 | 15 | 25 | 2 | 70 | 16 | 16 | | 16 | 16 | 16 | 16 | 0.4375 | 0.4375 | | 0.875 | 0.9375 | 1.5625 | 0.125 | all | KKE Full |
| 08/01 | 4 | 13 | | 17 | 11 | 7 | 4 | 56 | 16 | 16 | | 16 | 16 | 16 | 16 | 0.25 | 0.8125 | | 1.0625 | 0.6875 | 0.4375 | 0.25 | all | KKE Full |
| 08/02 | | 1 | | 3 | | | | 4 | 12 | 12 | | 12 | 12 | | | 0 | 0.083333 | | 0.25 | 0 | | | all | Kas 600 Ken 600 |
| 08/03 | 3 | 3 | | 4 | 2 | | 1 | 13 | 11 | 11 | | 11 | 11 | 11 | 11 | 0.272727 | 0.272727 | | 0.363636 | 0.181818 | 0 | 0.090909 | all | KKE Full |
| 2020 | | | | | | | | | | | | | | | | **2020** | **2020** | **2020** | **2020** | **2020** | **2020** | **2020** | | |
| 06/23 | 15 | 25 | | 7 | | | | 47 | 15 | 15 | | 15 | | | | 1 | 1.666667 | | 0.466667 | | | | (ii) | Kas Full |
| 06/25 | 10 | 17 | | 1 | | | | 28 | 12 | 12 | | 12 | | | | 0.833333 | 1.416667 | | 0.083333 | | | | (ii) | Kas Full |
| 06/27 | 7 | 18 | | 2 | | | | 27 | 9 | 9 | | 9 | | | | 0.777778 | 2 | | 0.222222 | | | | (ii) | Kas Full |
| 06/30 | 11 | 17 | | 9 | | | | 37 | 12 | 12 | | 12 | | | | 0.916667 | 1.416667 | | 0.75 | | | | (ii) | Kas Full |
| 07/02 | 16 | 20 | | 6 | 1 | | | 43 | 15 | 15 | | 15 | 15 | | | 1.066667 | 1.333333 | | 0.4 | 0.066667 | | | (i) Kas, NKB 4.75 | NKB Kas full |
| 07/04 | 23 | 23 | | 6 | | | | 52 | 9 | 9 | | 9 | 9 | | | 2.555556 | 2.555556 | | 0.666667 | 0 | | | (i) Kas, NKB 4.76 | NKB Kas full |
| 07/06 | 11 | 27 | | 18 | 1 | | | 57 | 13 | 13 | | 13 | 13 | | | 0.846154 | 2.076923 | | 1.384615 | 0.076923 | | | (i) Kas, NKB 4.77 | NKB Kas full |
| 07/07 | 5 | 12 | | 7 | 1 | | | 25 | 13 | 13 | | 13 | 13 | | | 0.384615 | 0.923077 | | 0.538462 | 0.076923 | | | Kas all, NKB 4.75 | Kas 600, NKB 600 |
| 07/08 | 13 | 25 | | 2 | | | | 40 | 8 | 8 | | 8 | 8 | | | 1.625 | 3.125 | | 0.25 | 0 | | | Kas (ii), NKB 4.75 | Kas 600, NKB 600 |
| 07/09 | 16 | 9 | | 2 | 1 | 41 | 2 | 71 | 15 | 15 | | 15 | 15 | 15 | 15 | 1.066667 | 0.6 | | 0.133333 | 0.066667 | 2.733333 | 0.133333 | KKE (ii) | KKE all |
| 07/13 | 7 | 13 | | 9 | 5 | 33 | | 67 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.583333 | 1.083333 | | 0.75 | 0.416667 | 2.75 | 0 | KKE (ii) | KKE all |
| 07/15 | 16 | 12 | | 11 | 6 | 60 | | 105 | 12 | 12 | | 12 | 12 | 12 | 12 | 1.333333 | 1 | | 0.916667 | 0.5 | 5 | 0 | KKE (ii) | KKE all |
| 07/16 | 5 | 5 | | 4 | | | | 14 | 12 | 12 | | 12 | 12 | | | 0.416667 | 0.416667 | | 0.333333 | 0 | | | all | Kas 600, NKB 600 |
| 07/20 | 9 | 16 | | 9 | 13 | 63 | 2 | 112 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.75 | 1.333333 | | 0.75 | 1.083333 | 5.25 | 0.166667 | KKE (ii) | KKE all |
| 07/21 | 4 | 5 | | 3 | | | | 12 | 8 | 8 | | 8 | | | | 0.5 | 0.625 | | 0.375 | | | | all | Kas 600 |
| 07/22 | 14 | 13 | | 13 | 15 | 56 | 4 | 115 | 12 | 12 | | 12 | 12 | 12 | 12 | 1.166667 | 1.083333 | | 1.083333 | 1.25 | 4.666667 | 0.333333 | (ii) | KKE all |
| 2021 | | | | | | | | | | | | | | | | **2021** | **2021** | **2021** | **2021** | **2021** | **2021** | **2021** | | |
| 22-Jun | 20 | 21 | | 8 | | | | 49 | 12 | 12 | | 12 | | | | 1.666667 | 1.75 | | 0.666667 | | | | (ii) | Kas all |
| 24-Jun | 23 | 9 | | 5 | | | | 37 | 15 | 15 | | 15 | | | | 1.533333 | 0.6 | | 0.333333 | | | | (ii) | Kas all |
| 26-Jun | 22 | 13 | | 7 | | | | 42 | 14 | 14 | | 14 | | | | 1.571429 | 0.928571 | | 0.5 | | | | (ii) | Kas all |
| 28-Jun | 20 | 32 | | 20 | | | | 72 | 15 | 15 | | 15 | | | | 1.333333 | 2.133333 | | 1.333333 | | | | (ii) | Kas all |
| 1-Jul | 20 | 11 | | 19 | - | | | 50 | 15 | 15 | | 15 | 15 | | | 1.333333 | 0.733333 | | 1.266667 | 0 | | | Kas (ii), NKB 4.75 | Kas all, NKB 600 |
| 3-Jul | 15 | 15 | | 18 | 1 | | | 49 | 17 | 17 | | 17 | 17 | | | 0.882353 | 0.882353 | | 1.058824 | 0.058824 | | | Kas (ii), NKB 4.76 | Kas all, NKB 600 |
| 5-Jul | 16 | 12 | | 20 | 2 | | | 50 | 15 | 15 | | 15 | 15 | | | 1.066667 | 0.8 | | 1.333333 | 0.133333 | | | Kas (ii), NKB 4.77 | Kas all, NKB 600 |
| 6-Jul | 3 | 1 | | 1 | - | | | 5 | 18 | 18 | | 18 | 18 | | | 0.166667 | 0.055556 | | 0.055556 | 0 | | | Kas (i), NKB 4.75 | Kas 600, NKB 600 |
| 7-Jul | 8 | 9 | | 8 | 1 | | | 26 | 15 | 15 | | 15 | 15 | | | 0.533333 | 0.6 | | 0.533333 | 0.066667 | | | Kas (ii), NKB 4.75 | Kas all, NKB 600 |
| 8-Jul | 12 | 14 | | 15 | 5 | 97 | 4 | 147 | 18 | 18 | | 18 | 18 | 18 | 18 | 0.666667 | 0.777778 | | 0.833333 | 0.277778 | 5.388889 | 0.222222 | (ii) | all |
| 12-Jul | 11 | 23 | | 24 | 48 | 76 | 3 | 185 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.916667 | 1.916667 | | 2 | 4 | 6.333333 | 0.25 | (ii) | all |
| 13-Jul | 9 | 10 | | 1 | 3 | | | 23 | 17 | 17 | | 17 | 17 | | | 0.529412 | 0.588235 | | 0.058824 | 0.176471 | | | (ii) | Kas 600, NKB 600 |
| 14-Jul | 7 | 16 | | 4 | - | | | 27 | 17 | 17 | | 17 | 17 | | | 0.411765 | 0.941176 | | 0.235294 | 0 | | | (ii) | Kas 600, NKB 600 |
| 15-Jul | 15 | 21 | | 17 | 38 | 89 | 8 | 188 | 12 | 12 | | 12 | 12 | 12 | 12 | 1.25 | 1.75 | | 1.416667 | 3.166667 | 7.416667 | 0.666667 | (ii) | KKE all |
| 18-Jul | | | 2 | | | | | 2 | | | 12 | | | | | | | 0.166667 | | | | | all | KRSHA |
| 19-Jul | 18 | 30 | | 38 | 29 | 100 | 8 | 223 | 12 | 12 | | 12 | 12 | 12 | 12 | 1.5 | 2.5 | | 3.166667 | 2.416667 | 8.333333 | 0.666667 | (ii) | KKE all |
| 20-Jul | 8 | 4 | | 11 | 4 | 43 | 2 | 72 | 12 | 12 | | 12 | 12 | 12 | 12 | 0.666667 | 0.333333 | | 0.916667 | 0.333333 | 3.583333 | 0.166667 | (ii) | KKE 600 |

**Abreviations**

**Kas = Kasilof section**
**KKE - Kenai, Kasilof, and East Foreland sections**
**KRSHA = Kasilof special harvtes area**
**NKB = North K Beach stat area**
**EF = East Forelands section**

Submitted By
Joseph Person
Submitted On
10/6/2021 3:20:19 AM
Affiliation

Board of Fish Members

My name is Joseph Person and I am a third generation, life long East Side Setnetter on the Ninilchik Beach. While our fishery has suffered tremendously over the past several seasons and will likely continue to do so under the current management plan, I have severe reservations about the slate of Agenda Change Requests (ACRs) submitted for our fishery. Firstly I wholeheartedly agree with the deparment comments that none of them really meet the requirements of an ACR. While the management in our fishery the past several seasons has been an utter travesty, precisely none of it was unexpected or unanticipated based on the actions taken by the Board at the last in cycle meeting and the managment environment at the state level that we currently have. In light of that, I am extremely hesitant to have the Board reapproach what amounts to the entirety of the Kenai River Late Run Chinook Management Plan outside of the processes and procedures afforded it in an in cycle meeting. There is a reason the ACR system is not meant for merely challenging results from the previous meeting that people are unhappy with, and despite my unhappiness with the current situation I do not think it appropriate to throw the entire Board of Fish process out the window. While there are some ACR's in this slate that I would support as an in-cycle proposal (particularly ACR 9), there are also several (specifically ACRs 8,10) with potentially long term consequences that I feel deserve the care and consideration accorded by an in cycle meeting. This is a complex fishery covering a very large area and many proposed changes that appear to be purely beneficial have gross allocative and long term implications. That said, if the board feels that the last two seasons of the Upper Cook Inlet East Side Setnet Fishery have not been managed optimally, I would love to see support from the Board encouraging the department to make a more concerted attempt within the restraints of the current management plan to agressively harvest surplus Kenai and Kasilof Sockeye. While I do agree fundamentally with the ACR proposers that the current managment plan is fundamentally flawed, that the Kenai River Late Run Chinook OEG (realistically the highest goal ever placed on the river) is unrealistic and punitive in light of current realities, and that the lost sockeye opportunity of the last few seasons is unreasonably damaging both conservationally and economically; I also believe that a significant amount of relief is available within the current plan which has been used as restrictively as possible even prior to significant number of Kenai Chinook being in the district. Furthermore I do not believe that there is anything magical from a Chinook conservation point of view about a 600 foot fishery, it is merely the most restrictive option available and consequently the least effective at all types of harvest. It is also extraordinarily allocative and has highly varying levels of effectiveness for different areas of the beach. In some it is essentially a full fishery, and others it is virtually no fishery at all. While it is true that I personally would have much preferred the option to continue to fish after July 21st of this season even in a restricted fashion, I firmly believe that fundamental changes of this magnitude to a fishery should take place within the normal process and not through an ACR. Thank you for your consideration.

Joseph Person

October 5, 2021

Alaska Department of Fish and Game
Boards Support Section
P.O. Box 115526
Juneau, AK 99811-5526

Re: Board of Fish 2021 Work Session –
Agenda Change Requests 8-14 (Upper Cook Inlet)

Dear Chair Carlson-van Dort and Members of the Board:

The Kenai River Sportfishing Association (KRSA) offers the following comments to the Alaska Board of Fisheries regarding the six Agenda Change Requests addressing Upper Cook Inlet, under consideration at the 2021 Work Session.

KRSA strongly recommends that the Alaska Board of Fisheries reject all six Agenda Change Request asking the Board to take up critical aspects of 5 AAC 21.359. Kenai River Late-Run King Salmon Management Plan. KRSA offers the following rationale for this recommendations:

1. 5 AAC 21.359. Kenai River Late-Run King Salmon Management Plan is one of the cornerstone fishery management plans governing salmon management in commercial, sport and personal use fisheries in the Upper Cook Inlet. Upper Cook Inlet supports the most complex mix stock, mixed species, mixed user group salmon fisheries in the State and is also home to a majority of Alaska's resident population and destination for hundreds of thousands of visitors annually.

   Any change to the Kenai River Late-Run King Salmon Management Plan will unavoidably result in challenges with implementation of the other important management plans in Upper Cook Inlet. KRSA recommends rejecting the six Agenda Change Requests in favor of taking up the issues within the requests when all of Upper Cook Inlet comes up in the regular Board cycle.

2. None of the six Agenda Change Request meet the three criteria identified by the Board as necessary for accepting a request to take up issues out of the regular cycle. The Alaska Department of Fish and Game has submitted a detailed document laying out the reasons that none of the requests meet the three criteria. KRSA agrees with the assessments submitted by the Department.

3. The difficult situation that exists when we are failing to meet minimum escapement objectives for Kenai River Late-Run King Salmon, while at the same time missing opportunity to commercially harvest hundreds of thousands of sockeye salmon, is indeed unfortunate. A careful examination of the 30 plus years of regulatory history (since 5 AAC 21.359 has been codified) makes it abundantly clear that dealing with this situation was not unforeseen by this Board or its predecessors. Step down measures leading to a concurrent closure of all fisheries has always been the basis of this plan.

4. Although one could argue that taking up elements of the King Plan out of cycle, through acceptance of an Agenda Change Request, would not result in changes that are predominately allocative, any change would be allocative in some respect. This plan is the result of 30 plus years of regulatory history; any change in this plan must allow for the transparency and public participation created by action taken within the regular cycle.

KRSA appreciates the challenges seen on the Kenai over the past several years, where king salmon have failed to meet minimum escapement goals resulting in closure of opportunity across multiple user groups. We look forward to working with the Board, the Department of Fish and Game, and the public in seeking reasonable conservation and harvest strategies in Upper Cook Inlet within the regular cycle.

Sincerely,

Ben Mohr
Executive Director

October 1, 2021

State of Alaska, BOF members

I'm writing this letter in support of both ACR 10 and ACR 8. Both of these ACR's support changes in the Cook Inlet East Side Set Net fishery which has suffered great financial consequences due to unforeseen effects of early fishing closures.

During the 2020 season, the Kenai District set netters only got 5 days of fishing and in 2021, the season was again shut down after only 5 days. This was due to the set net fleet catching 11 kings while harvesting over 35,000 sockeye on what then became our last day of the season. An additional 1.0+ million sockeye then returned upriver, generating next to "zero" income to the borough, local families and businesses. As an example of this, I went red fishing on the Kenai and spent less than $50.00 on two days of fishing, a far cry from what I and my crew would have spent in the community if we had caught more fish on our set net site. I even cancelled a $13,000.00 new outboard motor purchase that I was scheduled to pick up this fall due to lack of funds.

In order to pay summer bills not covered in our 5 days of set netting, I then sold my "back up skiff" to a Bristol Bay set netter. So, the borough loses the tax revenue on my skiff, the local outboard motor dealer loses the associated repairs etc while Bristol Bay gains another asset at Cook Inlet's expense.

In regards to ACR's 10 and 8, I believe that the 29 mesh gear restriction does in fact reduce the number of kings caught by the set net fleet. I do believe that the 29 mesh gear, especially when fished in the 600' fishery, catches even fewer kings. I do believe that the flagged net idea mentioned in ACR 8 might be an additional "step down" tool to be used by the department after use of the 600' fishery.

Please address the negative effect that the current king salmon management plan has on the peninsula economy and enact ACR 10 and give consideration to ACR 8 as a final option to completely closing down the season.

Sincerely,

Lance Alldrin

Cook Inlet Set Netter

East Forelands subdistrict

Alaska Board of Fish Members,

9/30/2021

ACR 10: The 600’/29 mesh fishery is a valuable tool to harvest Cook Inlet sockeye while catching a minimal number of king salmon. This 600’ fishery, though it was made available to the Board in 2020, has rarely been used in the Kenai and East Forelands subsection of the ESSN fishery. During the 2021 season this fishery option was used on the last day of our 5-day fishing season and the king catch was approximately .03% of the days catch (11 kings/36,000 sockeye). It proved to be a viable means in limiting the number of king salmon harvested, however, even with this lower percentage, the ESSN fishery was once again shut down premature. When using gillnets, fishermen alike are unable to target only sockeye, as all salmon species swim in Cook Inlet waters. Therefore, we are trying our best to exclude the king salmon from our harvests by using 29 mesh nets and fishing our gear closer to shore (600’). These alterations to the ESSN fishery appear to be another suitable option to consider using as part of the Late Run Kenai King Salmon management plan. Please support ACR 10.

ACR 8: This ACR addresses an interesting option and that is using flagged nets. A flagged net would catch fewer fish as a fish has to be truly gilled in the net vs trapped in the “bag” due to the pressure of the current. Most kings are not gilled but rather held in the net due to the intense pressure of Cook Inlet tides. I believe flagged nets would catch very few kings while allowing fisherman to catch some sockeye. Perhaps consider ACR 8 as possibly the very last restriction after the 600’ fishery? I’d rather fish flagged nets than no nets at all.

Thank you.

Luke Alldrin

Cook Inlet, East Forelands district

October 5th, 2021

To: Alaska Board of Fisheries

Executive Director Glenn Haight

PO Box 115526

Juneau, AK 99811-5526

Re: Board of Fisheries – Worksession – Agenda Change Requests (ACR's)/ October 20-21, 2021

SOuth K-beach Independent Fishermen's Association (SOKI) is a community organization that aspires to represent the common interests of accessibility to the Alaska Board of Fisheries (BOF). Comprised of Cook Inlet setnet permit holders and others, our purpose is to elevate the concerns of the Kasilof Section of the East Side Set Net (ESSN) fishery. Our primary targeted fishery is the Kasilof River bound sockeye.

SOKI met on 09.23.21 to discuss the upcoming BOF worksession and the ACR's that the have been submitted for board actions.

We would like to submit our comments on individual ACR's;

ACR 8 – There was no support for this concept by any individual present

ACR 9 – There was general support for this action

ACR 10 – There was NO general support for this agenda change as many in the Kasilof section or statistical area within had reservations as to whether this would improve the opportunity for many or more likely it would enhance the opportunity for some within the historically predominant "beachnet" locations of the Kenai section exclusively. Many individual commented that the 600-foot fishery was not utilized by many in the South Kalifornsky Beach, Coho and Ninilchik statistical areas in the latter portions of the season as they produced very limited harvests and because of the bathymetry of their locations. Most commented that it simply was not an effective tool to harvest Kasilof bound sockeye. Others were concerned that this restriction would be implemented from the beginning of the season on and that many fishermen in this section did not have locations in the 600-foot limited area. A few were not supportive of any actions to be considered by this board.

ACR 11 – The group agreed with the individual that no actual credible post analysis of the use of 29 mesh deep gear was debated at the 2020 BOF Upper Cook Inlet (UCI) Regulatory meeting. There were comments from some that a reduction of an estimated 70+ % of gear effectiveness has already been implemented since 2014. This would include the mesh restriction and numbers of nets. Restrictions of area would exacerbate this negative effect further.

ACR 12 – The group accepted this request as a necessary step in modifying the plan in 2020 to give direction to the department through flexible actions dependent on escapements. Managing for escapement goals have been the hallmark of fishery management since statehood and fisheries managers need to maintain sustainable returns. Managing for biological goals should be the baseline for all management plans.

ACR 13 – SOKI submitted this ACR after submitting an Emergency Petition that the board declined to address in season. Recommendations from some of the BOF members comments was that the petitions had merit but that they would be better addressed through the regulatory process.

Conserving and developing the fishery resources is mandated by statute as a requirement for BOF actions. We believe that this agenda change request asks the board to review whether the actions taken in 2020 preserve or conserve large late run Kenai kings as predicted. There is reason to consider other measures that may allow the reduction of these kings while continuing to allow reasonable access to harvesting abundant stocks of sockeye bound for the Kasilof River. Staff comments did not address the specific biological assessment or reason to why this agenda change request is not a conservation or reason. The department gave us a limited historical review of board action or non-actions but did not address any other conservation concerns associated with intersection management plans or objective in their reason to deny this agenda request.

**a) Is there a fishery conservation purpose or reason? ABSOLUTELY Yes!**

The Commissioner has said that the regulation of closing the ESSN fishery in the king plan restricted him from applying any other step-down measures and suggested that that requirement needed to be taken out of the current language. While it is not clear on how this would be accomplished in the view of the Commissioner, he did express a desire to have other “tools” in the tool bag. We take this to mean that the regulation is contradictory, and the boards intent is not clear on how it may be implemented by fisheries managers. Clearly, the department relies only on 2020 board actions and does not appear to understand the full boards intent or to take into consideration previous board actions.

**b) Does the agenda change request correct and error in regulation? Yes**

Many BOF members were new to the process in 2020. The Department we feel did not give members a complete review of the consequences of their actions. Estimates were made but many data sets were not included for discussion purposes. The department continues to rely on limited presentations of vital information that board members need to make fair, valid, and reasonable decisions. It is clear that after two years of implementation of the 2020 regulatory changes to the Kenai late run king salmon plan that sockeye escapements into the Kenai and Kasilof Rivers have far exceeded their goals. The disparity of burden sharing is *acutely* painful to the ESSN fishery and the associated processing and commercial fishing support businesses. The board is said to establish the “fisheries policies” for the Sate through its arm as a quasi-judicial body, granted authority to delegate regulations by the legislature.

SOKI simply would ask: <u>Is it the intent of the State of Alaska through the actions of the Alaska Board of Fisheries to decimate a historical and economically functioning commercial fishing industry in Cook Inlet?</u>

**c) Does the agenda change request address an effect of a regulation on a fishery that was unforeseen when that regulation was adopted? Most emphatically, YES!**

ACR 14 – The group also supported this request as to furthering the justification established in the adoption of an optimal escapement goal (OEG). We do not believe that a clear and though review was submitted to the board members on ramifications of adopting this goal. Information is not available for the board to review if the board requests this information.

We respectfully urge the Alaska Board of Fisheries to consider and accept this supported ACR's and to schedule a hearing at their March Statewide meeting.

Thank you,

Paul A. Shadura II

Spokesperson for: SOKI

P.O. Box 1632

Kenai, AK. 99611-1632

907.283.5098

**Ahtna Intertribal
Resource Commission**
PO Box 613 – Glennallen, Alaska 99588 www.ahtnatribal.org
Phone: (907) 822-4466 Fax: (907) 822-4406 connect@ahtnatribal.org

To the Alaska Board of Fisheries:

We are writing to express strong concern about the stated intention of the Alaska Department of Fish & Game (ADF&G) in its Prince William Sound Escapement Goal memo with regard to Copper River king salmon. We feel that the lower bound of the proposed king salmon escapement goal, 21,000 fish, is not adequate to ensure sustainable returns. We urge the Board of Fisheries to look to Prince William Sound proposal 5, which would establish an optimum escapement goal of 24,000 - 40,000 fish, as a preferable, although still inadequate, alternative. We feel that there should be an optimum escapement goal of 35,000 – 50,000 Chinook salmon.

We oppose ADF&G's efforts to lower the goal for management purposes. The past two decades have seen unprecedented declines in Copper River Chinook salmon runs. It is difficult to foresee any path to recovery from these declines when ADF&G is repeatedly lowering its own goals. The current Chinook escapement goal, 24,000, has already been lowered from the previous one of 28,000.

In addition to the dramatic declines in king salmon run sizes, the sizes of the fish, themselves, are getting markedly smaller as well. This has clear implications for their reproductive potential: smaller fish have fewer eggs and are otherwise less productive. In order to maintain the same level of returns, then, ADF&G should be increasing its escapement goal—not decreasing it—in response to these changes in body size.

As a justification for lowering its escapement goals, ADF&G has often argued that it must avoid over-escapement, and the associated risks of diminished productivity and returns. This was part of its original rationalization for lowering the escapement goal from 28,000 to 24,000. After the goal was lowered, however, Chinook salmon run sizes continued to decline to historically low levels and under-escapement became commonplace. Lowering the goal again is likely to normalize this pattern of under-escapement by lowering expectations and shifting the management baseline.

Low Chinook runs are already having detrimental impacts on Ahtna tribal citizens and other upriver users who depend on the Copper River for their livelihoods. The 2021 season saw the closure of all state fisheries to Chinook retention. This harms subsistence users who depend on salmon as an important source of food, but it also harms the economic opportunities brought by the upper river sport and personal-use fisheries.

Finally, the problems with Chinook under-escapement and low returns are compounded by a lack of alignment between the escapement goals and the in-river goal. The in-river run goal specified in the management plan is only 17,500 other salmon, which includes both Chinook and coho salmon. This number is inadequate to meet an escapement goal of 21,000—let alone 24,000. The management plan must be revised to reflect appropriate objectives for Copper River Chinook salmon escapement needs.

Along these same lines, the Copper River District Salmon Management Plan (CR District Plan, 5 AAC 24.360) contain different escapement goals that are not consistent with one another. This raises the question of whether ADF&G managers in the Copper River district are effectively coordinating with those of the upper Copper River district to work toward system-wide conservation of Chinook salmon.

One obvious reason for this inconsistency is that the department is managing for commercial uses and take, rather than prioritizing subsistence fisheries as required in AS 16.05.258. ADF&G must manage for the conservation and sustainability of the resource.

We appreciate this opportunity to share our concerns and perspectives on ADF&G's stated intentions to revise the SEG for Copper River king salmon and the Kenai River Sportfishing Associations' Proposal 5 to instead establish an Optimal Escapement Goal as we discuss in more detail below. With increasing salmon conservation concerns and the resulting dire impacts to Alaska tribal communities ancestral tribal uses of salmon across the State of Alaska, it is important for ADF&G to live up to its oft-cited claim that it has the most public involvement in fish and wildlife management in the United States.

To such an end, we encourage the Alaska Board of Fisheries and the ADF&G to honor the Policy for statewide salmon escapement goals that requires "...a process that facilitates public review of allocative issues associated with escapement goals" (5 AAC 39.223). In the past and in other regions of Alaska, ADF&G has held meetings with the public while reviewing and developing revisions to escapement goals to ensure public involvement in the escapement goal setting process. Throughout this present regulatory cycle, involvement and consultation with the public appears to have been minimal such that we are left with this one opportunity to be involved in this significant decision that directly affects the ability of our federally recognized tribes in fulfilling its self-governance and responsibilities to ensure access to these tribal resources to meeting these needs of their respective tribal citizens. In the absence of any opportunities for public comments or formal tribal consultations at the upcoming Alaska Board of Fisheries Work Session, we are once again limited to sharing our concerns in this letter.

Furthermore, we encourage the Alaska Board of Fisheries and the ADF&G to adhere to its own policy as outlined 2002-216-FB, which requires government-to-government consultation with federally-recognized tribes on issues that significantly affect the interests of the Ahtna tribal governments such as reallocating Copper River Chinook salmon from spawning escapement and priority customary and traditional subsistence and ancestral tribal uses of king salmon to the commercial fishery.

In the absence of substantive consultation and communication with the public stakeholders with interests in Copper River salmon management and the sovereign tribal governments of the Copper Basin who have stewarded salmon resources for thousands of years, we submit these written comments that summarize our requests and concerns regarding revisions to the Copper River king salmon escapement goal.

Respectfully,

Karen Linnell

Karen Linnell
Executive Director

Corporate Headquarters
PO Box 649
Glennallen, Alaska 99588
Office: (907) 822-3476
Fax: (907) 822-3495

Ahtna, Incorporated

Anchorage Office
110 W 38th Avenue, Suite 100
Anchorage, Alaska 99503
Office: (907) 868-8250
Fax: (907) 868-8285

Our Culture Unites Us; Our Land Sustains Us; Our People are Prosperous

October 5, 2021

ADF&G Support Section
ATTN: Board of Fisheries Comments
P.O. Box 115526
Juneau, Alaska 99811-5526

*Via email to dfg.bof.comments@alaska.gov*

To members of the Alaska Board of Fisheries:

We are writing to express strong concern about the stated intention of the Alaska Department of Fish & Game (ADF&G) in its Prince William Sound Escapement Goal memo with regard to Copper River king salmon. We feel that the lower bound of the proposed king salmon escapement goal, 21,000 fish, is not adequate to ensure sustainable returns. We urge the Board of Fisheries to look to Prince William Sound proposal 5, which would establish an optimum escapement goal of 24,000 - 40,000 fish, as a preferable, although still inadequate, alternative. We feel that there should be an optimum escapement goal of 35,000 – 50,000 Chinook salmon.

We oppose ADF&G's efforts to lower the goal for management purposes. The past two decades have seen unprecedented declines in Copper River Chinook salmon runs. It is difficult to foresee any path to recovery from these declines when ADF&G is repeatedly lowering its own goals. The current Chinook escapement goal, 24,000, has already been lowered from the previous one of 28,000.

In addition to the dramatic declines in king salmon run sizes, the sizes of the fish, themselves, are getting markedly smaller as well. This has clear implications for their reproductive potential: smaller fish have fewer eggs and are otherwise less productive. In order to maintain the same level of returns, ADF&G should be increasing its escapement goal—not decreasing it—in response to these changes in body size.

As a justification for lowering its escapement goals, ADF&G has often argued that it must avoid overescapement, and the associated risks of diminished productivity and returns. This was part of its original rationalization for lowering the escapement goal from 28,000 to 24,000. After the goal was lowered, however, Chinook salmon run sizes continued to decline to historically low levels and underescapement became commonplace. Lowering the goal again is likely to normalize this pattern of underescapement by lowering expectations and shifting the management baseline.

Low Chinook runs are already having detrimental impacts on Ahtna tribal citizens and other upriver users who depend on the Copper River for their livelihoods. The 2021 season saw the closure of all state fisheries to Chinook retention. This harms subsistence users who depend on salmon as an important source of food, but it also harms the economic opportunities brought by the upper river sport and personal-use fisheries.

Finally, the problems with Chinook underescapement and low returns are compounded by a lack of alignment between the escapement goals and the in-river goal. The in-river run goal specified in the management plan is only 17,500 other salmon, which includes both Chinook and coho salmon. This number is inadequate to meet an escapement goal of 21,000—let alone 24,000. The management plan must be revised to reflect appropriate objectives for Copper River Chinook salmon escapement needs.

Along these same lines, the Copper River District Salmon Management Plan (CR District Plan, 5 AAC 24.360) contains different escapement goals that are not consistent with one another. This raises the question of whether ADF&G managers in the Copper River district are effectively coordinating with those of the upper Copper River district to work toward system-wide conservation of Chinook salmon.

One obvious reason for this inconsistency is that ADF&G is managing for commercial uses and take, rather than prioritizing subsistence fisheries as required by AS 16.05.258. ADF&G must manage for the conservation and sustainability of the resource.

We appreciate this opportunity to share our concerns and perspectives on ADF&G's stated intentions to revise the SEG for Copper River king salmon and the Kenai River Sportfishing Associations' Proposal 5 to instead establish an Optimal Escapement Goal as we discuss in more detail below. With increasing salmon conservation concerns and the resulting dire impacts to Alaska tribal communities' ancestral tribal uses of salmon across the State of Alaska, it is important for ADF&G to live up to its oft-cited claim that it has the most public involvement in fish and wildlife management in the United States.

To such an end, we encourage the Alaska Board of Fisheries and the ADF&G to honor the Policy for statewide salmon escapement goals that requires " . . . a process that facilitates public review of allocative issues associated with escapement goals." (5 AAC 39.223). In the past and in other regions of Alaska, ADF&G has held meetings with the public while reviewing and developing revisions to escapement goals to ensure public involvement in the escapement goal setting process. Throughout this present regulatory cycle, involvement and consultation with the public appears to have been minimal such that we are left with this one opportunity to be involved in this significant decision. In the absence of any opportunities for public comments or formal tribal consultations at the upcoming Alaska Board of Fisheries Work Session, we are once again limited to sharing our concerns in this letter.

Furthermore, we encourage the Alaska Board of Fisheries and the ADF&G to adhere to its own policy as outlined 2002-216-FB, which requires government-to-government consultation with federally recognized tribes on issues that significantly affect the interests of the Ahtna tribal governments. The reallocation of Copper River Chinook salmon from spawning escapement and prioritizing customary and traditional subsistence and ancestral tribal uses of king salmon over the commercial fishery are significant to our customary and traditional way of life.

In the absence of substantive consultation and communication with the public stakeholders with interests in Copper River salmon management and the sovereign tribal governments of the Copper Basin who have stewarded salmon resources for thousands of years, we submit these written comments that summarize our requests and concerns regarding revisions to the Copper River king salmon escapement goal.

Respectfully,

Nicholas Jackson, Chair
Customary & Traditional Committee
Ahtna, Incorporated

March 3, 1849

# United States Department of the Interior

NATIONAL PARK SERVICE

**Wrangell-St. Elias National Park & Preserve**
**Mile 106.8 Richardson Hwy. P.O. Box 439**
**Copper Center, AK 99573-0439**
**907 822 5234 Fax 907 822 3281**
**http://www.nps.gov/wrst**

NATIONAL PARK SERVICE

**IN REPLY REFER TO:**

I.A.2

OCT 0 5 2021

Alaska Board of Fisheries
c/o Boards Support Section
Alaska Department of Fish and Game
P.O. Box 115526
Juneau, AK 99811-5526

Dear Members of the Board:

As the delegated in-season manager of Federal subsistence fisheries in the Copper River Drainage, I am writing to offer comments for consideration by the Alaska Board of Fisheries (Board) during its October 20-21, 2021 work session.

On August 20, 2021, I submitted an Agenda Change Request (ACR) for the Board to revise its schedule to include consideration of a proposed regulatory change during its upcoming meeting in Cordova, December 2021. My submission was not accepted as an ACR for Board consideration during the October work session because the subject matter pertained to Copper River salmon escapement goals and thus was considered to be an "in-cycle" subject. Although the ACR was not accepted, I understand that it will be included in the workbook for your October work session and that the Board may consider generating a proposal addressing the issue for the December regulatory meeting. Below, I offer comments in support of such an action.

The regulatory problem that I ask the Board to address is lack of consistency between the king salmon escapement goals in the Copper River District Salmon Management Plan (CR District Plan, 5 AAC 24.360) and the Copper River King Salmon Management Plan (CR King Salmon Plan, 5 AAC 24.361). This inconsistency results in stakeholder uncertainty and concern about how the department is managing the commercial and subsistence fisheries in the Copper River District in coordination with Upper Copper River District fisheries to ensure conservation of Copper River salmon. The CR District Plan specifically directs the department to manage the Copper River District commercial salmon fishery to achieve an inriver goal of salmon, as measured at the sonar counter near Miles Lake. The spawning escapement component of the goal consists of the lower end of the sockeye salmon sustainable escapement goal (360,000 salmon) and ***17,500 other salmon***, which would include king salmon and a relatively small number of coho salmon returning before sonar operations cease in late July. The CR King Salmon Plan specifically directs the department to manage the Copper River commercial and all other fisheries to achieve a sustainable escapement goal of ***24,000 or more king salmon***. The different king salmon escapement goals in these two plans appear to reflect an error in regulation.

To correct this apparent error, the spawning escapement goal of 17,500 other salmon in the CR District Plan should be revised to match *or exceed* (to account for early returning coho in addition to king salmon) the 24,000-king salmon goal of the related CR King Salmon Plan. I ask that the Board generate a regulatory proposal to revise the relevant section of the CR District Plan, 5 AAC 24.360 (b) to read as follows, with revised text **underlined in bold**, and regulatory text to be deleted fully capitalized and enclosed in brackets:

(b) The department shall manage the Copper River District commercial salmon fishery to achieve an inriver goal of salmon, as measured at the sonar counter near Miles Lake, based on the total of the following categories:

Spawning escapement

- lower end of sockeye salmon sustainable escapement goal
- **24,000 king salmon** [17,500 OTHER SALMON]
- **500 other salmon** *(or the department's best estimate for the number of coho included in sonar counts)*

This apparent regulatory error has implications that warrant its resolution through a board-generated proposal during this cycle. From correspondence with department staff, I understand that the CR King Salmon Plan is the primary guidance for king salmon management, and that the department does not consider the king salmon escapement goals in the two plans to be contradictory. But the apparent inconsistency strongly suggests to stakeholders that the total inriver goal of salmon, announced annually, is at least 6,500 too low. The continued apparent inconsistency between the two plans will result in ongoing uncertainty and concern among stakeholders regarding the department's management of Copper River sockeye and king salmon.

This is particularly important given the recent history of king salmon run strength in the Copper River. King salmon escapement in 2020 was the 6th lowest since 2001 and did not meet the escapement goal. It appears that the goal may not have been met again in 2021. If this is the case, it will have been the 4th time in the past 10 years, with the lowest run since 2001 having occurred in 2016 when spawning escapement was estimated to be 12,485 salmon. As an example of inconsistency and potential for confusion among stakeholders, in response to the weak king salmon run during the 2021 season, the department enacted restrictions in several upriver fisheries for the purpose of king salmon conservation; meanwhile the commercial fishery in the Copper River District continued to be managed with routine openings and additional king salmon harvest after upriver restrictions were announced.

Resolving the apparent regulatory inconsistency will clarify for all stakeholders the department's management intent relative to king salmon escapement. This transparency in management intent also may help to address longstanding concerns expressed by local subsistence users in communities nearest the headwaters of the Copper River. Past research and Alaska Native traditional knowledge indicate that sockeye salmon stocks associated with headwater tributaries are among the earliest stocks to enter the river, with run timing similar to king salmon. Since at least 2004 (e.g., Board proposal 53 in 2005) and as recently as 2021, subsistence users in headwater communities have repeatedly urged fisheries managers to allow more early run salmon to escape upstream of the Gulkana River to increase subsistence harvest opportunities. Conservation measures that aim to ensure adequate king salmon escapement have the potential to benefit early migrating sockeye salmon stocks and local subsistence users who depend on these headwater stocks for meeting their subsistence needs.

Sincerely,

Ben Bobowski, Ph.D.
Superintendent

**Cordova District Fishermen United**
PO Box 939 | 509 First Street | Cordova, AK 99574
phone. (907) 424 3447 | fax. (907) 424 3430
web. www.cdfu.org

October 6, 2021

Alaska Department of Fish and Game
Alaska Board of Fisheries
Boards Support Section
P.O. Box 115526
Juneau, AK 99811-5526

Submitted electronically via: dfg.bof.comments@alaska.gov

Re: CDFU Comments for October Work Session

Dear Members of the Alaska Board of Fisheries,

Cordova District Fishermen United (CDFU) is a 501 (c)5 non-profit membership organization dedicated to advocacy for the commercial fisheries of Alaska's Area E -- Prince William Sound, the Copper River, and the Northern Gulf Coast. Our organization is comprised of Divisions, with each gear-type group represented through their own respective Division: Seine, Gillnet, Groudfish/Shellfish, and Herring. On behalf of the CDFU Gillnet Division, I encourage your review of the following comments:

An ACR addressing the issues in the Main Bay Subdistrict was submitted independently by an Area E fisherman, but after evaluation, the CDFU Gillnet Division would like to voice support for this ACR. Unfortunately, no Prince William Sound ACRs were accepted to the 2021 Work Session Agenda, due to it being a PWS Cycle Year, and in spite of the fact that it has now been 2 fishing seasons since the proposal deadline has passed. At the January 25 Special Meeting, after discussion by members of the Board of Fisheries, Boards Support staff clarified that the ACR process would be available for PWS issues that arose in the upcoming year because although the meetings would be held in 2021, the cycle year should have been 2020 had the Covid-19 pandemic not led to widespread cancellations and postponement of the original meeting schedule.

The issues addressed in the ACR submitted by Mr. Gilman can be primarily identified as conservation issues, as both cost recovery and broodstock at PWSAC hatcheries in Prince William Sound are placed in danger by current management practices. The issue has unfortunately been extremely exacerbated in the 2021 season and led to the submission of an ACR by an Area E fisherman following unprecedented and significant delays in cost recovery and broodstock operations at the hatchery this past season. The ACR seeks to mitigate some of the issues observed by regional residents, fishermen, and those more closely involved with regional hatchery organizations.

It is important for all user groups that the Main Bay Hatchery remain sustainable and economical in perpetuity. Currently, a significant amount of damage and conflict has been observed in the Main Bay Subdistrict and around the barrier seine. Additionally, some users have expressed frustration at the commercial fishermen engaging in hatchery operations, not fully understanding the importance of cost recovery and broodstock to the continuation of Alaska's hatchery programs and the production of sockey salmon in Main Bay. The CDFU Gillnet Division urges the Board of Fish to re-evaluate and accept this ACR to address these growing issues in the Main Bay Subdistrict.

It is vital for all Area E fisheries for Prince William Sound Aquaculture Corporation to operate effectively and efficiently. Conflict, interference, and damage to the barrier seine impact PWSAC's ability to operate, and CDFU Gillnet Division expresses concern that it will lead to increased costs of operation, user conflicts, and quality degradation of sockeye salmon -- impacting the economics of regional fisheries and the hatchery itself.. If this problem is not resolved this Board cycle, CDFU Gillnet Division is concerned about the economic damage to the Area E drift fleet due to lost harvest potential and product degradation when cost recovery is unable to be achieved.

CDFU is in support of the ACR submitted by Mr. Gilman, and urges the Board to consider taking up this issue and adding it to this cycle year. Thank you for your time and consideration, please feel free to reach out to CDFU with any comments, questions, or concerns on the matters addressed above.

Sincerely,

Chelsea Haisman

Chelsea Haisman
Executive Director

**From:** dave@hookycharters.com
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** King Salmon Conservation
**Date:** Monday, October 4, 2021 4:25:55 PM

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It is time to take drastic measures to save our king salmon! I moved to the Kenai area in the spring of 1976. I ran a commercial drift boat for about fifteen years in the Cook Inlet. I have friends that are set netters. I am a fishing guide on the Kenai River. I have been active in the Board Of Fish process for many years fighting to save our king salmon. We through the Board process put closures in place to protect king salmon up and down the Kenai river. The sport fishing pressure is much less now than it was in the eighties and nineties and still our kings are failing to meet minimum goals. It is time to close all king salmon fishing in Cook Inlet. Yes sport fishing will suffer, but we need to fix the problem now. Back in the seventies and eighties there was a need for set gill netting, but now with the influx in population and the growth of the tourism industry in Alaska we can no longer justify set gill netting. They simply kill too many king salmon. The Cook Inlet drift fleet can be used to catch the excess sockeye and the ones that get past them can be harvested by dip netters from all around the state as well as sprot fishermen. The resource belongs first to the residents of Alaska and individuals who travel to this state to take fish home.

David Goggia
9087-252-3503

From: **Gale K. Vick**
Date: Thu, Jul 15, 2021 at 8:11 PM
Subject: Recent declines in salmon body size impact ecosystems and fisheries
To: Mckenzie Mitchell

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7438488/

# Recent declines in salmon body size impact ecosystems and fisheries

Few organismal traits are as profoundly important as body size, given its role in reproductive fitness, physiology, demography, predator–prey dynamics, and value for human use[1]. Yet major selective forces such as climate change and harvest may be causing widespread declines in organismal body size[2–5]. Climate change has been linked to body size declines in many species[2,3], including Soay sheep in Scotland[6], aquatic ectotherms across Europe[7], and migratory North American birds[8]. Harvest is also known to result in smaller body size[5,9], for example, declines in body size and age-at-maturity preceded the collapse of Atlantic cod stocks off the eastern coast of Canada . Understanding the causes of body size declines is daunting given the influence of numerous, potentially interacting factors. Individually or in unison, these underlying factors can influence body size through shifting population age structure, changing growth rates, or a combination thereof. Age truncation can compound the effects of body size on population productivity by increasing demographic variability in response to changing environments11. Body size declines influence species' demography4 and trophic interactions12 and may reduce the sustainable delivery of ecosystem services such as fisheries yield9.

Here, we examine changes in body size for four species of Pacific salmon (*Oncorhynchus* spp.), by assembling a 60-year (1957–2018) database of size and age measurements from 12.5 million individually-measured fish. The uniquely large spatial and temporal scale of our dataset enabled us to conduct one of the most comprehensive studies to quantify system-wide body size declines across multiple species and identify potential causal mechanisms, and one of the first studies to quantify ecological and socioeconomic consequences of those observed size declines. Our overarching goals were to understand the magnitude and consistency of size declines across regions and species, evaluate potential causes, and quantify the consequences of these changes for ecosystems and people.

nature COMMUNICATIONS

ARTICLE

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# Recent declines in salmon body size impact ecosystems and fisheries

K. B. Oke [1,2]✉, C. J. Cunningham [2,3], P. A. H. Westley [4]✉, M. L. Baskett [5], S. M. Carlson [6], J. Clark [7], A. P. Hendry [8], V. A. Karatayev [5], N. W. Kendall [9], J. Kibele [7], H. K. Kindsvater [10], K. M. Kobayashi [1], B. Lewis [11], S. Munch [1,12], J. D. Reynolds [13], G. K. Vick [14] & E. P. Palkovacs [1]✉

Declines in animal body sizes are widely reported and likely impact ecological interactions and ecosystem services. For harvested species subject to multiple stressors, limited understanding of the causes and consequences of size declines impedes prediction, prevention, and mitigation. We highlight widespread declines in Pacific salmon size based on 60 years of measurements from 12.5 million fish across Alaska, the last largely pristine North American salmon-producing region. Declines in salmon size, primarily resulting from shifting age structure, are associated with climate and competition at sea. Compared to salmon maturing before 1990, the reduced size of adult salmon after 2010 has potentially resulted in substantial losses to ecosystems and people; for Chinook salmon we estimated average per-fish reductions in egg production (−16%), nutrient transport (−28%), fisheries value (−21%), and meals for rural people (−26%). Downsizing of organisms is a global concern, and current trends may pose substantial risks for nature and people.

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[1] Department of Ecology and Evolutionary Biology, University of California, Santa Cruz, CA 95060, USA. [2] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK 99801, USA. [3] Fisheries, Aquatic Science & Technology Laboratory, Alaska Pacific University, Anchorage, AK 99508, USA. [4] College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, AK 99775, USA. [5] Department of Environmental Science and Policy, University of California, Davis, CA 95616, USA. [6] Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720, USA. [7] National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, CA 93101, USA. [8] Department of Biology and Redpath Museum, McGill University, Montreal, QC H3A 2K6, Canada. [9] Washington Department of Fish and Wildlife, Olympia, WA 98501, USA. [10] Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA. [11] Division of Commercial Fisheries, Alaska Department of Fish and Game, Anchorage, AK 99518, USA. [12] National Marine Fisheries Service, Fisheries Ecology Division, Southwest Fisheries Science Center, Santa Cruz, CA 95060, USA. [13] Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada. [14] GKV & Sons, Contracting to Tanana Chiefs Conference, Fairbanks, AK 99709, USA. ✉email: kristaoke@gmail.com; pwestley@alaska.edu; epalkova@ucsc.edu

Few organismal traits are as profoundly important as body size, given its role in reproductive fitness, physiology, demography, predator–prey dynamics, and value for human use[1]. Yet major selective forces such as climate change and harvest may be causing widespread declines in organismal body size[2–5]. Climate change has been linked to body size declines in many species[2,3], including Soay sheep in Scotland[6], aquatic ectotherms across Europe[7], and migratory North American birds[8]. Harvest is also known to result in smaller body size[5,9], for example, declines in body size and age-at-maturity preceded the collapse of Atlantic cod stocks off the eastern coast of Canada[10]. Understanding the causes of body size declines is daunting given the influence of numerous, potentially interacting factors. Individually or in unison, these underlying factors can influence body size through shifting population age structure, changing growth rates, or a combination thereof. Age truncation can compound the effects of body size on population productivity by increasing demographic variability in response to changing environments[11]. Body size declines influence species' demography[4] and trophic interactions[12] and may reduce the sustainable delivery of ecosystem services such as fisheries yield[9].

Here, we examine changes in body size for four species of Pacific salmon (*Oncorhynchus* spp.), by assembling a 60-year (1957–2018) database of size and age measurements from 12.5 million individually-measured fish. The uniquely large spatial and temporal scale of our dataset enabled us to conduct one of the most comprehensive studies to quantify system-wide body size declines across multiple species and identify potential causal mechanisms, and one of the first studies to quantify ecological and socioeconomic consequences of those observed size declines. Our overarching goals were to understand the magnitude and consistency of size declines across regions and species, evaluate potential causes, and quantify the consequences of these changes for ecosystems and people.

Pacific salmon are integral ecosystem components and contribute to human well-being, primarily as sources of food security and cultural connection[13,14]. The annual return of salmon to their natal streams provides vital nutrient subsidies that support freshwater, riparian, and terrestrial ecosystems[15]. Alaska is widely considered a stronghold of intact, functioning salmon–people ecosystems, largely free of the factors that have severely depressed salmon abundances elsewhere, such as over-harvest, habitat-loss, net pen aquaculture (prohibited by law in Alaska), dams, and water diversion[16]. However, accumulating evidence from local and indigenous knowledge suggests that adult salmon body sizes are decreasing, including in Alaska where salmon provide critical support for ecosystems and people[17–19], cf. ref. [20].

Serious consequences for ecosystems and people could result from salmon size declines. Smaller salmon transport less marine-derived nutrients and produce fewer offspring[21,22]. Smaller salmon could threaten food security in rural salmon-dependent communities, where diminished access to calorie-rich salmon directly influences well-being and human health[13]. From an economic perspective, smaller salmon translate to lost commercial fisheries profit due to reduced flesh recovery rates (proportionally more skin, viscera, and bones but less muscle), increased processing cost, and lower prices. In some cases, losses due to changing salmon size could be mitigated by increasing conspecific abundances for certain ecosystems services and species. However, the opportunity for mitigation will be limited for species like Chinook salmon that have generally experienced declines in abundance concurrent with size declines[23] or for ecosystem services for which abundance cannot replace size. For example, recreational anglers highly value catching large fish, which influences decisions on fishing trip destinations[24]. In addition, abundant species like sockeye and pink salmon cannot replace many ecosystem services provided by Chinook salmon because Chinook salmon generally have much greater migration distances, fat content, and cultural importance. For salmon in Alaska, the extent to which body size is changing across species and regions, the causes of size changes, and the consequences for nature and people are poorly known.

We synthesize patterns of salmon body size change across the state of Alaska for Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), coho (*O. kisutch*), and sockeye salmon (*O. nerka*). While previous studies have documented changes in size and age in Pacific salmon[17,18,20], our investigation across species, decades, and locations allows a uniquely comprehensive analysis of consistency in trends, causes, and consequences of those changes at an unprecedented spatial and temporal scale. Our analysis is based on six decades of salmon size and age measurements collected by the Alaska Department of Fish and Game from 1014 sampling locations across Alaska's diverse landscapes—from temperate rainforests to Arctic ecosystems.

We show that body size has declined significantly across Pacific salmon species in Alaska, but that the rate of change has not been constant over time. Changing age structure (younger age-at-maturity) consistently explains a greater proportion of overall size changes than do changing growth rates (smaller size-at-age); salmon are getting smaller primarily because they are returning to reproduce at a younger age than they did in the past. Climate change and competition with highly abundant wild and hatchery-produced salmon appear to be widespread drivers of size declines. We found limited evidence for a widespread role of size-selective harvest. The consequences of these changes for ecosystems and people are widespread: size declines are likely causing decreases in key ecological processes and human uses, including per-capita egg production, marine-derived nutrient subsidies, rural food security, and commercial value for harvesters.

## Results

**Consistency in salmon size declines**. In all four salmon species, average body sizes were smaller after 2010 compared to before 1990 (the earliest baseline with sufficient data, Fig. 1). Comparing mean body length pre-1990 to mean body length post-2010, Chinook salmon exhibited the greatest magnitude decline, averaging an 8.0% decline in body length, compared to 3.3% in coho salmon, 2.4% in chum salmon, and 2.1% in sockeye salmon. Within species, the magnitude of declines varied among regions and populations (Fig. 1). For example, Chinook salmon populations in Westward Alaska and Arctic–Yukon–Kuskokwim declined by 10% on average, whereas conspecifics in Southeast Alaska declined by 4%.

General additive models (GAMs) confirmed that average sizes declined through time in each species (nonlinear year effect for each species $p < 0.0001$, $R^2 = 0.453$, 0.621, 0.687, 0.784 for Chinook, sockeye, coho, and chum salmon respectively, Fig. 2a), although the common (among location) pattern in average size across time differed between species. To evaluate whether there was greater support for species-specific nonlinear year effects through time, or a single shared temporal pattern, we fit competing GAMs to mean-variance standardized length observations from each location. Inclusion of species-specific nonlinear year effects explained much more variance ($R^2 = 0.80$) compared to a single shared (i.e., shared among species) nonlinear year effect ($R^2 = 0.04$). This result was confirmed by fitting an additional model that included both the common and species-specific nonlinear year effects, in which species-specific trends were significant ($p < 0.0001$) while the common trend was not ($p = 0.3$). All species are declining in body size but patterns of decline differ among species, thus species-specific trends were analyzed and are discussed separately.

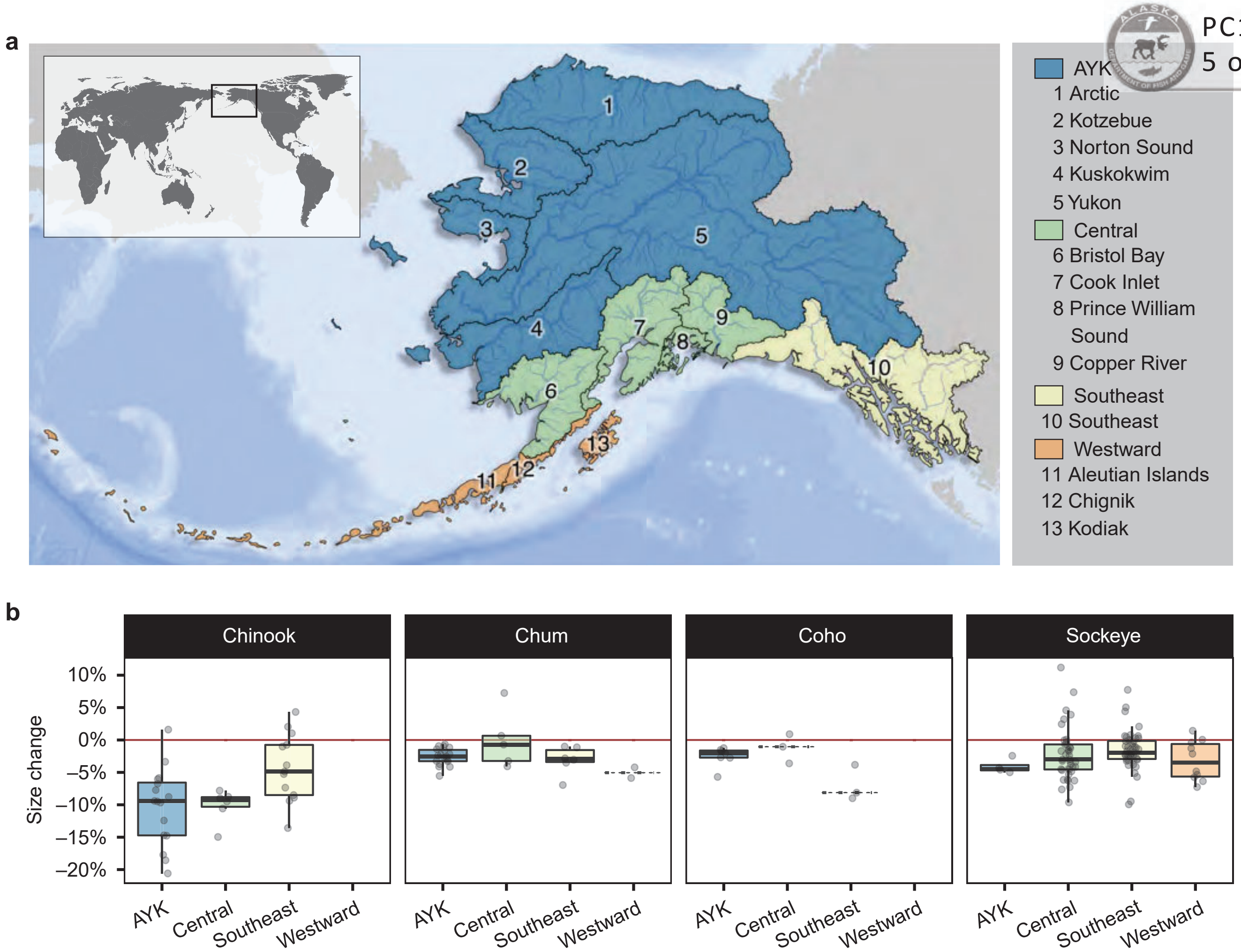

**Fig. 1 Across Alaska, average salmon body size has gotten smaller.** On average, salmon body size was smaller post-2010 compared with pre-1990 across all areas and species examined. **a** Map of sampling area with regions numbered and colored by Alaska Department of Fish and Game management area. Our analyses included data from all regions shown except Arctic. **b** Boxplots show percent change in mean length between data collected before 1990 and after 2010. Points show change in mean length for individual populations. Red line indicates no change. Center line represents the median, box limits represent the upper and lower quantiles, whiskers represent the 1.5× interquartile range. Only populations for which we had data in both periods were included (100 sockeye, 34 Chinook, 32 chum, and 13 coho salmon populations). If sufficient data were available for three or fewer populations, the box was replaced by a gray dashed line at the median. AYK represents the Arctic–Yukon–Kuskokwim management area. Sample sizes are presented in Supplementary Data 4.

Within each species, size trends were nonlinear (effective degrees of freedom = 3.75 for Chinook, 8.86 for chum, 7.78 for coho, and 8.81 for sockeye salmon; Fig. 2a) and included several periods of increasing and decreasing size. Separate species-specific models (Fig. 2a) revealed similarities among sockeye, chum, and coho salmon, including shared size declines starting in the mid-1980s followed by recovery in the early-1990s. These three species all showed an abrupt decline in body size starting in 2000 and intensifying after 2010. Size declines were more linear in Chinook salmon than in other species, but the rate of decline also accelerated after 2000.

Comparing model fits for GAMs that incorporate regional- and population-level trends revealed that Chinook and coho salmon exhibit high spatial variation in patterns of body size change, best explained by population-specific nonlinear year effects. In contrast, sockeye and chum salmon populations exhibited less spatial variability, which was best explained by regional-level patterns (Supplementary Table S1).

**Contributions of declining age versus growth**. Across species, shifts in age structure explained 88% of interannual variation in mean size on average (Fig. 3). In general, salmon are currently smaller than in the past because adults are returning to spawn at younger ages (Fig. 2). Changing size-at-age (Supplementary Fig. S1), which might result from decreased growth, explained a greater proportion of size change in coho salmon (20% on average) than in other species (7.4% in Chinook salmon, 7.1% in chum salmon, 5.9% in sockeye salmon), yet across all species and regions the contribution of changing size-at-age to declines in body sizes was less important than that of changing age structure.

**Causes of salmon size declines**. Both environmental change and increased competition at sea with highly abundant wild and hatchery salmon could result in body size declines through reductions in the availability or quality of food resources[18,20]. Climate warming might also reduce ectotherm body size by increasing metabolic and developmental rates[2]. Finally, all of

PC123
6 of 15

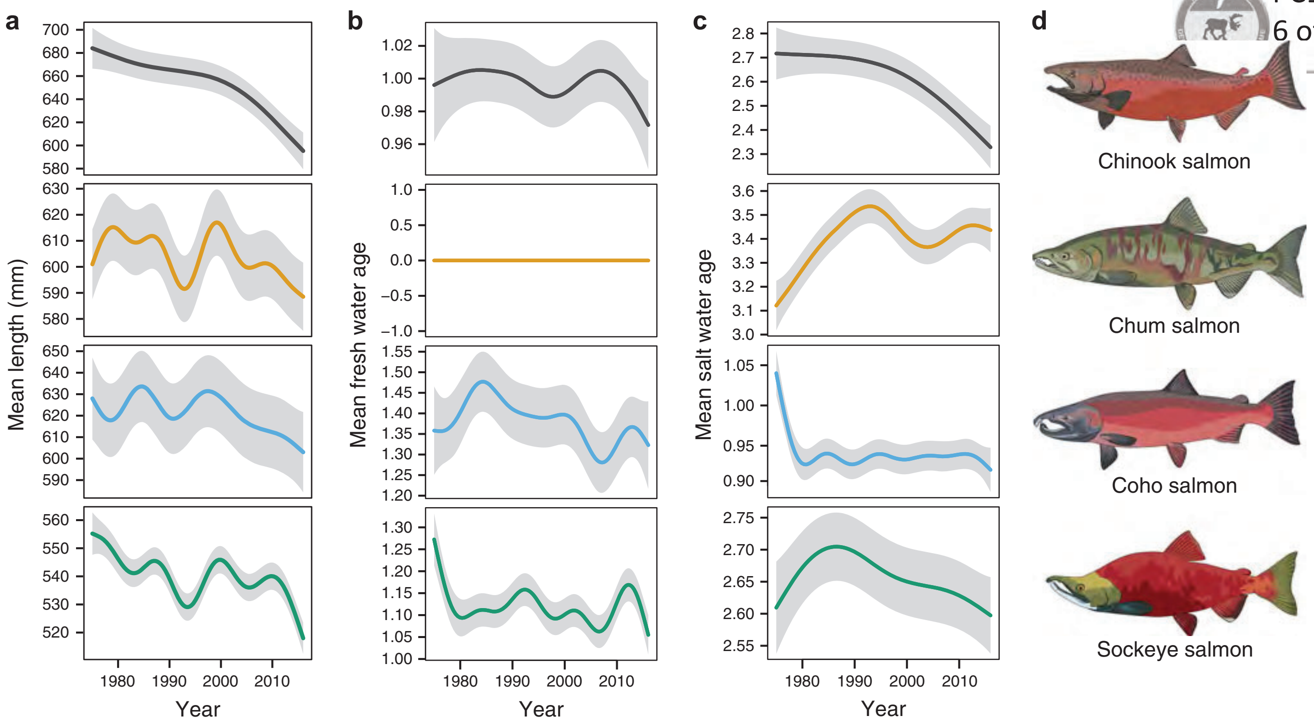

**Fig. 2 Body size declines are significant and nonlinear. a** Mean fish length has changed in a nonlinear pattern, as demonstrated by the nonlinear year effect from GAMs on mean population length with fixed effects of region and population. **b** Mean freshwater age (in years) has generally declined, except for chum salmon, which leave freshwater shortly after emergence. **c** Mean saltwater age (in years) has also generally declined, except in chum salmon, which increased in saltwater age until around 1990, then decreased. Plots are conditioned on reference populations with the longest time series for each species, but the pattern plotted is the common pattern through time calculated for all populations. Gray areas represent 95% confidence intervals for the nonlinear year effect. **d** Male salmon in spawning coloration. Sample sizes are presented in Supplementary Data 5.

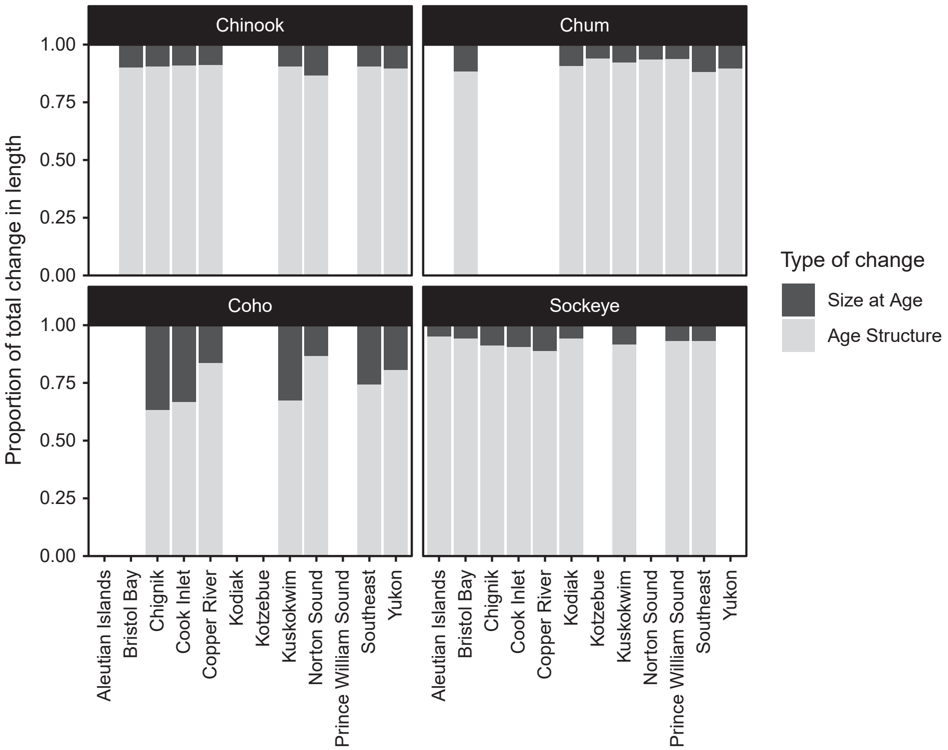

**Fig. 3 Body size declines result primarily from shifting age structure.** Changes in population mean length are primarily due to changing age composition (gray) and to a much lesser extent changing size-at-age (black). For each population the mean among-year contribution was calculated, then region means calculated from population-level means. Sample sizes are presented in Supplementary Data 6.

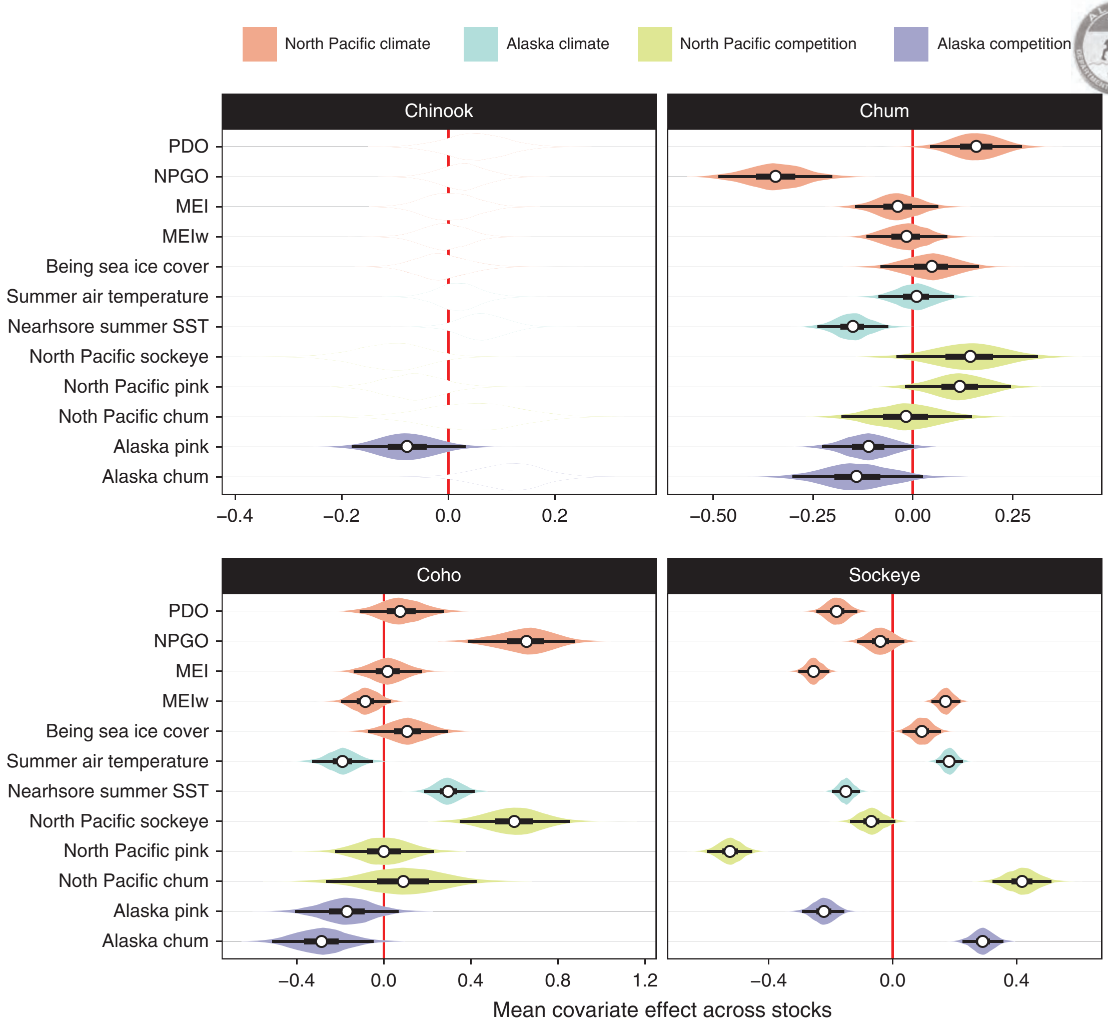

**Fig. 4 Climate and competition influence salmon body size.** Effects of climate and competition proxies (detailed in Methods, MEIw is winter MEI) on body size varied among species, as estimated by hierarchical Bayesian models describing length-environment relationships. Posterior probability distributions (in color) for estimated species-specific (group) mean effects of climate and competition covariates across locations. Posterior medians, 50% and 95% credible intervals are described by the white point, thick and thin black lines. Negative effects indicate high values of a covariate are correlated with smaller salmon body size on average across locations in Alaska. See Supplementary Fig. S4 for population-specific covariate effect estimates. Sample sizes are presented in Supplementary Data 7.

these environmental factors could result in increased natural mortality in the ocean, leading to reduced average age-at-return to freshwater.

To evaluate the hypothesized effects of climate and competition at sea (Supplementary Figs. S2, S3), we fit hierarchical Bayesian models estimating the association between temporal trends in location-specific salmon size and a range of environmental covariates, while also estimating a nonlinear year effect describing temporal trends in length that were common across populations but not explained by covariates. After accounting for absolute body size differences among populations, our ability to explain changes in body size ranged from a Bayesian[25] $R^2$ of 0.28 in sockeye salmon, 0.29 in Chinook salmon, 0.35 in chum salmon, to 0.48 in coho salmon.

Multiple factors with small individual effects were associated with body size declines (Fig. 4). Although the relative importance of each metric differed among species (Fig. 4) and populations (Supplementary Fig. S4), at least one climate metric and one competition metric were important for each species. Only Alaskan pink salmon abundance had a negative association with body size across all species, but the negative association was weak in all cases except sockeye salmon. Some factors emerged as particularly important for individual species. For sockeye salmon, North Pacific pink salmon abundance had a particularly strong negative association with body size. For chum salmon, a strong negative association with the North Pacific Gyre Oscillation (NPGO) contrasted with a similarly strong positive association for coho salmon. No single factor was a particularly important predictor of body size in Chinook salmon; instead many factors had moderate contributions to body size change. After controlling for covariate effects, each species-specific model included a common residual trend that showed overall decline in salmon size across time (Supplementary Fig. S6). This result suggests that salmon might be responding to one or more physical or biological drivers that were not included among the environmental covariates explored.

Metabolic effects of temperature on size[26] do not appear to be driving body size changes in Alaska salmon (see Supplementary Methods section “Metabolic effects of temperature on size”). Relationships between salmon body size and temperature did not fit the predictions of the metabolic theory of ecology[26]. Rather, the variable influence of climate drivers suggests that the impact of climate on salmon body size is species-specific and to a lesser extent location-specific

PC123
8 of 15

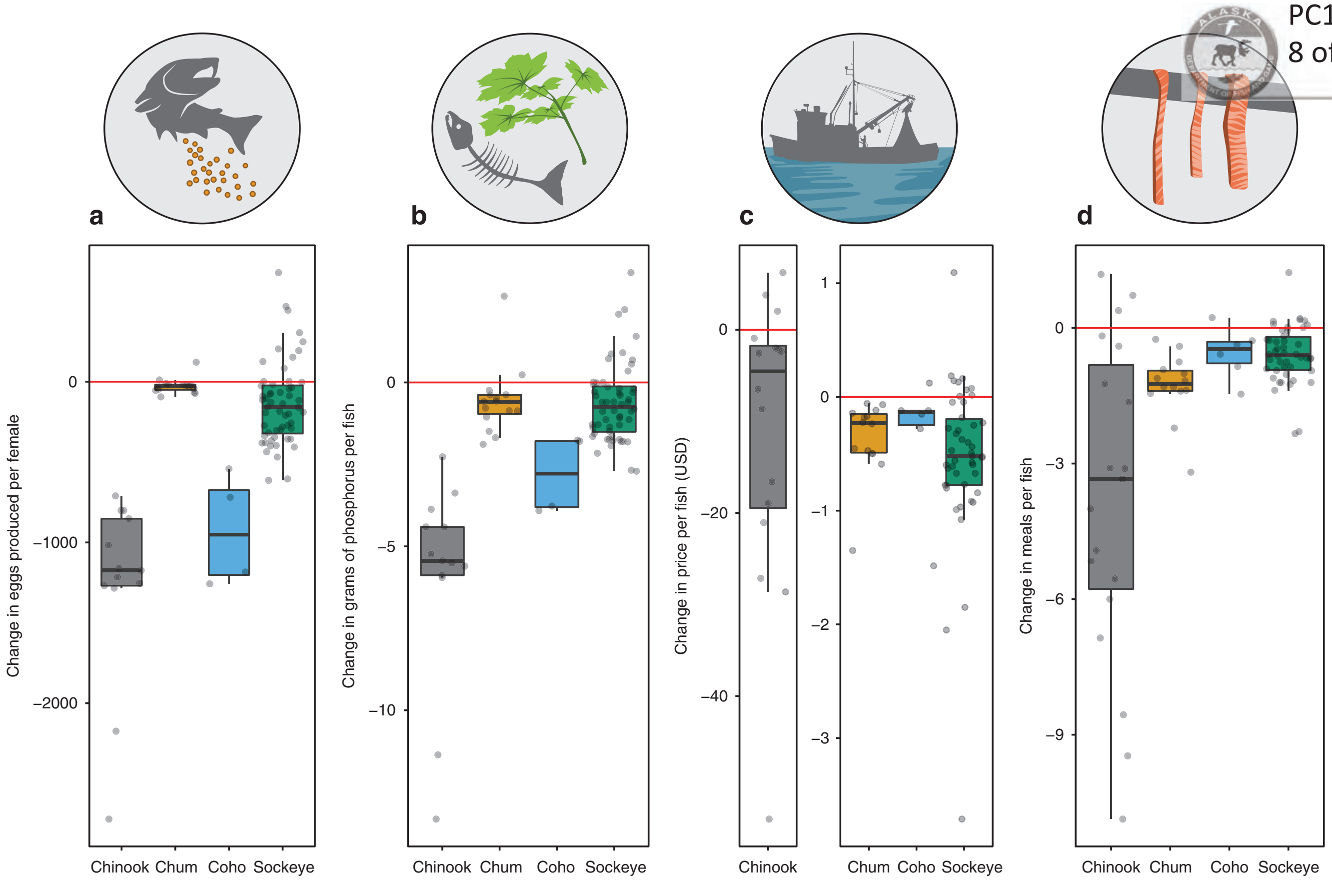

**Fig. 5 Size declines could result in negative consequences for ecosystems and people.** Salmon body size declines over the past 30 years have negative consequences for **a** fecundity, **b** nutrient transport, **c** commercial fishery value, and **d** rural food security. We estimated the difference in ecosystem services provided by an average salmon before 1990 versus after 2010, by converting change in mass to change in services provided. A meal is the species-specific average reported meal size in grams reported by subsistence users from two villages in nearby Yukon Territory, Canada, see Methods for details. Each gray point represents an estimate for an individual population. The red line represents no change in ecosystems services provided by each fish. Center line represents the median, box limits represent the upper and lower quantiles, whiskers represent the 1.5× interquartile range. Sample sizes are presented in Supplementary Data 4.

(see Supplementary Fig. S4), perhaps occurring through climate-mediated changes in food availability or quality. A similarly variable relationship between temperature and body size across species was recently uncovered in a large-scale analysis of size trends in Australian reef fishes[27].

Due to limited data availability, we investigated the effects of average harvest rate on long-term body length change in a separate analysis on the subset of populations for which we had sufficient harvest information. We expected that if fisheries-induced size structure truncation, or evolution, contributed to size declines, populations subjected to higher rates of size-selective harvest would show greater magnitude declines[28]. We tested this hypothesis using 33 populations (25 sockeye and eight Chinook) with sufficient data to rigorously calculate harvest rate. Counter to expectations, we detected no significant relationship between harvest rate and change in body size among populations (Supplementary Fig. S5, $R^2 = 0.02$, $F_{1,30} = 0.56$, $p = 0.46$).

**Consequences of declining body size**. To quantify the per-capita change in several ecosystem services resulting from observed declines in body size, we used species-specific length-weight relationships to convert change in length to change in mass (see Methods for details). Next, we converted change in mass to per-capita changes in fecundity, nutrient transport, human nutrition, and commercial value (Fig. 5). The per-capita effects of size declines will be most impactful when accompanied by decreases in abundance, as observed for Chinook salmon, whose abundances[23] and body sizes have both declined in recent years. Our estimates suggest that the dramatic body size declines observed in Chinook salmon translate to equally dramatically reduced per-capita contributions to people and nature, including median reductions in egg production (−15%), commercial value (−25%), meals provided (−26%), and nutrient transport (−26%). Reductions for other species were less dramatic, but still substantial (Fig. 5, Supplementary Data 1–3).

## Discussion

We provide comprehensive evidence that four species of Pacific salmon in Alaska are now smaller than they were historically, with the rate of decline having accelerated since the year 2000. Declining body size overwhelmingly results from younger maturation (i.e., age-at-return) rather than reductions in growth (i.e., size-at-age). Although no single factor explained size declines, we revealed that both climate and competition at sea are associated with changes in salmon size across Alaska. This result extends the findings of other recent studies that also show impacts of climate and competition on salmon body size[20] and age-at-maturity[29]. Finally, we show that declines in body size over the past 30 years have likely translated into important ecological and socioeconomic consequences for salmon-dependent ecosystems and peoples in Alaska, especially for the largest of the species, Chinook salmon.

Widespread declines in body size occurred over the past four decades across four salmon species (Fig. 1, Fig. 2a). This finding generalizes previous species- and region-specific analyses[19,30,31]. Size trends were more similar for a given species across regions than for a given region across species (Fig. 1), with Chinook salmon showing the greatest decline in size (−8.0%), followed by coho salmon (−3.3%), chum (−2.4%) and sockeye (−2.1%). In contrast to many previous studies that assume monotonic linear changes in size[18,19], our use of general additive models revealed markedly nonlinear changes, including an apparent recent acceleration of size decline beginning around 2000 that was shared among all four species, and several common periods of high and low average size among sockeye, chum, and coho salmon (Fig. 2a). Identifying the putative drivers of specific periods of time exhibiting shared body size change was beyond our scope, but is likely a fruitful avenue for future research.

Underlying the general body size decline observed across species, a considerable amount of among-region and among-population variation in body size change was observed within species. Body size trends were best explained by models that allowed region-specific (chum and sockeye salmon) or population-specific (Chinook and coho salmon) responses through time, rather than a single response shared among regions and populations (Supplementary Table S1). We interpret this result to reflect the large number of populations sampled from diverse habitats across Alaska, from temperate rainforest ecosystems in Southeast Alaska to subarctic ecosystems in Kotzebue. The idiosyncratic responses of body size to climate indices we observed could be partially explained by differential responses across species, regions, and populations according to site-specific habitat climate filtering, evolutionary histories, and relative location in their species range or climate envelope.

To an unknown extent, other external factors likely also contributed to variation in patterns of size declines among regions and species. For example, the relatively low magnitude body size declines in Southeast Alaska Chinook salmon (Fig. 1) could be explained by an unusual characteristic of the Southeast Alaska troll fishery for Chinook salmon, which catches a high proportion of immature salmon from British Columbia, Washington, Oregon, and California[32]. Reductions in the size and age of Chinook salmon originating from these areas outside of Alaska have not been as extreme as those observed for Alaskan Chinook salmon populations[20,31].

Earlier maturation (age-at-return), rather than slower growth (size-at-age), was primarily responsible for observed size declines across species and regions (Fig. 3). Chinook salmon, which exhibit the greatest life history diversity and thus greatest capacity for change in age-at-maturity, showed the greatest magnitude of decline in both body size and age-at-maturity. This result formalizes and extends findings from previous studies that age truncation appears to play an important role in declining Chinook salmon body size[19,30,31,33]. Compared to Chinook salmon, changes in age-at-maturity were more variable through time in chum and sockeye salmon (Fig. 2), which also showed size declines but of lower magnitude. Both chum and sockeye salmon showed an initial increase in average saltwater age, but this increase has been followed by generally decreasing age-at-maturity, coinciding with the pronounced recent declines in body size.

Although our results provide strong evidence that salmon are becoming smaller because they are returning from the ocean at a younger age, we were unable to distinguish the contributions of changing maturation schedules from increasing marine mortality. Younger age structure could result from numerous scenarios, including plastic responses to positive growth conditions that allow salmon to reach a threshold size earlier[34], evolutionary shifts in maturation schedules[35], increased late-stage mortality[36], compounding risk from overall increased mortality[36], or any combination of the above. Finer-scale information about marine mortality is needed to explore these non-mutually exclusive scenarios. It is also important to recognize that the potential for growth rate to influence age-at-maturity[34] means that, despite the lesser contributions of changing size-at-age, some proportion of the changes in age-at-maturity that contribute to body size declines might ultimately result from changes in growth rate.

Climate and competition at sea clearly influence salmon size. Results for each species indicated a strong effect of at least one climate metric. However, specific metrics varied in their direction and magnitude across species, underscoring the complex effects of climate on body size (Fig. 4). Recent work on salmon productivity has shown that relationships between salmon and climate variables vary through time[37], and the influence of climate on body size could be similarly non-stationary.

Competition metrics also had important but variable effects on salmon body size (Fig. 4; Supplementary Fig. S4). The strongest negative association we detected was between sockeye salmon body size and the North Pacific-wide abundance of pink salmon. This result corroborates previous studies documenting negative influences of Asian pink salmon abundance on Alaskan sockeye salmon, which share similar prey communities and distributions during their final years at sea[38]. Indeed, the only consistently negative effect across all species was that of Alaskan pink salmon abundance (Fig. 4), although this effect was weak in most species. Intriguingly, the shared acceleration of size declines post-2000 occurred during a period of unusually high (though variable) pink salmon abundance in Alaska[39], suggesting high pink salmon abundances could be accelerating or exacerbating size declines. Our results provide further evidence that wild and hatchery-enhanced pink salmon abundance in the North Pacific has reached such high levels that they appear to be exerting an influence on ecosystem structure and function[40].

For each species, we detected an underlying trend shared among populations (i.e., a nonlinear year effect) that was not fully explained by any climate or competition covariates (Supplementary Fig. S6). These shared trends suggest that, within species, populations are responding similarly to other broad-scale factors we did not identify as a priori hypotheses and as a result were not included in our models.

Our results are consistent with previous studies that suggest fisheries are likely not a major driver in broad patterns of salmon size decline[20,29,41], yet might play an important role for some populations[42,43]. Harvest has been implicated in size and age declines for many marine fishes[5,28] and has long been expected to contribute to declining salmon size[17]. We did not detect any overall relationship between harvest rate and size change, but our analysis was necessarily limited to a subset of intensively monitored Chinook and sockeye salmon populations with adequate data. Furthermore, the potential for differences in size selectivity across fisheries and gear types[44] could limit the extent to which these results can be extrapolated to other fisheries.

We lacked sufficient data to investigate several factors that could contribute to size declines, especially in certain species or regions. In Alaska, there is relatively little contribution of hatchery production to the overall abundances of sockeye, coho, and Chinook salmon[29,39], but hatchery selection[45] could contribute to size declines in regions with high hatchery production, such as chum salmon in Prince William Sound and Southeast Alaska. We were unable to rigorously test for an effect of hatchery selection, but populations from hatchery-intensive regions did not appear to show greater magnitude declines in body size compared to populations from other regions (Fig. 1). We also lacked sufficient data on predator abundances to test for effects of size-selective predation, but bioenergetic modeling has shown that size-selective predation from killer whales (*Orcinus orca*)[41] and salmon sharks (*Lamna ditropis*)[46] could be contributing to body size declines in Chinook salmon. The limited diet data available for Alaska resident killer whales[47,48] suggests that they show lower selectivity on Chinook salmon than do killer whales from Washington and British Columbia[49] upon which these models are based[41]. Additional data on hatchery selection, predator abundances, selectivity for salmon, and size-selectivity are needed in Alaska in order to rigorously test these hypotheses.

We estimate that the observed salmon size declines could already be causing substantial reductions in fecundity, nutrient transport, economic value, and food security (Fig. 5). Declines in fecundity can impede population productivity and recovery[50]. Due to these effects on productivity, declines in body size have been used in other systems to predict population declines and collapses[51]. Reduced salmon size also decreases the per-capita transport of marine-derived nutrients into terrestrial ecosystems, with important implications for a wide array of ecological processes including riparian productivity and biodiversity[15]. Salmon are economically important; in 2017, the ex-vessel value (price paid to fishermen) of Bristol Bay salmon fisheries alone was over $214,000,000[52]. Meanwhile, the value of subsistence salmon fisheries for rural and Indigenous communities is profound, with broad implications for food security, well-being, and cultural connectivity[13,14]. Socioeconomic impacts of declining salmon size have long been of concern for Alaskans, especially those whose well-being, food security, and economic livelihoods depend on salmon[14].

We considered per-capita delivery of ecosystem services, but the realized consequences of declining body sizes will also depend on salmon abundances. The consequences of declining size could, to some extent, be balanced by increasing abundances in some species such as sockeye and chum salmon whose abundances have generally increased in recent years throughout the state[39]. In contrast, Chinook salmon abundances have generally declined across Alaska[23], so the socioeconomic impacts of declining Chinook salmon size are already compounded by reduced abundance and resulting regulatory limitations on harvest opportunity. Because Alaska salmon are managed according to a fixed escapement policy under which the number of adult salmon that reach the spawning grounds is held generally constant across years, increases in total abundance tend to result in large harvests but generally do not translate into increased escapement. The relatively stable numbers of salmon on the spawning grounds, even in years of high abundance, will result in limited ability for high abundances to mitigate the per-capita ecological consequences of declining size. How increasing salmon abundance might offset the costs of declining body size for the commercial fishery is a complex topic worthy of further exploration, especially for sockeye and chum salmon.

We also acknowledge that other external factors will impact the consequences of declining body size. For example, the economic costs of declining body size are also influenced by idiosyncrasies of production costs and market fluctuations due to trade policies or the availability of market substitutes like farmed Atlantic salmon[53]. These complexities are extremely difficult to fully address at a state-wide multispecies level, but in-depth species-specific considerations of the potential consequences of size declines that account for abundance are important topics for future investigation.

Our findings contribute to the mounting body of evidence that maintenance of body size, in addition to abundance, is critical for maintaining healthy salmon-people and salmon-ecosystem relationships. Yet, what are the options to slow or even reverse these size declines? While the impacts of size declines are experienced locally, the primary causes appear to be regional and even global. Of the two primary drivers associated with size declines, climate forcing and ocean abundance of salmon and particularly Alaska pink salmon, the latter is within local management control. Across the Pacific Rim, ca. 5 billion hatchery salmon[39] are released into the North Pacific each year where they add to already high abundances of wild pink, chum, and sockeye. While signals of conspecific and interspecific competition are increasingly evident[38,40,54,55], managers currently lack tools to help inform difficult decisions regarding hatchery releases. Tools that quantify the apparent trade-offs between the releases of one species and the impacts of size and productivity on conspecifics and other species are urgently needed.

Our large-scale consideration of salmon body size extends and generalizes previous findings, showing that body size declines are ongoing and more widespread than previously reported. The direct relationship between smaller salmon and economic and social losses has not been estimated previously. Our conservative calculations of the potential per-capita consequences of recent body size declines show the ecological, economic, and social losses could be substantial. We compared current size to a pre-1990 baseline, but this captures only a small window of commercial salmon fisheries in Alaska, which started in the late 1800s. Size declines were observed long before 1990[17], and thus we expect that analyses over longer time series would likely reveal even more dramatic impacts. Despite widespread reporting of body size declines across diverse taxa[2,3], the ecological and socioeconomic consequences of body size declines are underappreciated. Using Pacific salmon in one of the few remaining intact, largely pristine salmon ecosystems on Earth as a test case, we show the consequences for people and ecosystems could be substantial.

## Methods

**Age-length (AL) datasets**. Alaska Department of Fish & Game (ADF&G) monitors the number, body size, sex, and age of Alaska salmon harvested in a variety of fisheries and on their return breeding migration from the ocean to freshwater. Age and body length (AL) data have been collected on mature adults from commercial, subsistence, and sport harvests, escapement (spawning population) projects, and test fisheries since the early 1900's. ADF&G data has historically been archived in regional offices; however, for this project we were able to compile all available data from across the state (Supplementary Figs. S7–S10) into a single dataset, representing over 14 million raw AL samples.

The majority of Alaska salmon fisheries target mature adults during their breeding migration into freshwater. Data from commercial harvests represent the largest proportion (57%) of measurements and are generally collected from marine waters and near river mouths. Although many Alaska salmon fishing districts are designed to operate as terminal fisheries, targeting fish destined for their river of origin, even terminal fisheries can intercept salmon returning to other Alaskan populations, and many other districts are non-terminal. Because most commercial salmon fisheries in Alaska catch a combination of fish from the target stock and intercepted fish returning to other populations, commercial samples often include a mix of fish from different populations within a river drainage and outside the drainage (e.g., Southeast Alaska troll fishery may be >80% non-local fish at times). Commercial samples from some fisheries targeting wild salmon could include a relatively low but unknown proportion of hatchery-origin salmon, which could not be excluded from our analyses without individual-level information on origin (hatchery or wild). Samples from escapement enumeration projects (sampling projects that count the number of mature adults that 'escape' the fishery and return to freshwater) make up the next highest proportion of AL measurements (33%). Escapement projects collect AL data from fish sampled in the freshwater environment, close to or on the spawning grounds, generally at counting towers, weirs, or fences. A variety of other sampling project types (test fishing, subsistence catch, sport catch) make up the remaining portion of these data, with no single project type representing more than 5% of the samples. ADF&G recorded the name of the sampling project, generally as the name of a given river (e.g., Fish Creek) or district (e.g., Togiak District), which we refer to as sampling locations. To ensure as much as possible that methods of data collection were consistent across locations and species, we excluded data collected from projects other than commercial harvest and escapement monitoring from statistical analyses.

Age and length (AL) measurements were collected by ADF&G personnel using standard methods[56]. Briefly, fish length is collected to the nearest millimeter using a measuring tape or a manual or electronic measuring board, depending on project and year. Fish age was most commonly estimated by ADF&G scientists reading growth annuli on scales[57]. For many AL measurements, specimen sex was also recorded, predominantly using external characteristics for sex determination. Sex determination with external characteristics in ocean-phase fish is frequently unreliable[58]. Because most of our data come from commercial harvests that occur in ocean-phase fish prior to the development of obvious external secondary sexual characteristics, we did not analyze the sexes separately. However, other studies examining length at age with reliable sex determination have shown similar trends in size and age for males and females[33,59]. As in Lewis et al.[19], we assume our results reflect similar trends in male and female salmon.

To ensure data were of high quality, a number of quality assurance checks were established, and data failing those checks were excluded from analysis. These checks include ensuring that ages and lengths were within reasonable bounds for each species, that sample dates were reasonable, that data were not duplicated, and that data were all of the same length measurement type (mid-eye to fork of tail). Because mid-eye to fork length was by far the most commonly used length measurement type (85% of samples) within the data, and the vast majority of sample protocols use mid-eye to fork measurements, we assumed that observations where no length measurement type was reported (0.08% of samples) were mid-eye to fork. No other unique length measurement type accounts for more than 2% of samples. We also excluded any samples that measured fewer than ten fish for a given year/location combination. After these extensive checks, we were left with measurements on over 12.5 million individual salmon.

A wide variety of gear types were used to collect samples. The three most common gear types included gillnet, seine, and weir. Sampling methods within projects did not change systematically over time; however, for at least some projects, changes did occur, such as changes in gillnet mesh materials and sizes (for commercial harvest[60]) or sampling location within a watershed (for escapement projects). Some of these methodology changes are sporadically reflected in the data (e.g., mesh size), whereas others are not included and difficult to capture (e.g., weir location changes). Given the inconsistency in data and metadata associated with these fine-scale methodology changes, and the spatial and temporal scale of this dataset, changes in mesh size, gear type, or fine scale location changes (movement of a project within the same river system) were not included in our analyses.

**Consistency in salmon size declines**. To quantify the spatial and temporal extent of body size change, we estimated the average length of fish for each species in each sampling location and return year (the year when the fish was caught or sampled on its return migration to freshwater), which we interpret as putative biological populations (henceforth referred to as populations). For each population, we averaged these annual means to find the mean body length during a baseline period before 1990 and recent period after 2010. The pre-1990 period included all data collected before 1990, though relatively little data was available before 1980. Comparing data from two discrete time periods avoids potential edge effects that would be introduced in dividing a consecutive time series. Only populations for which we had data in both periods were included (100 sockeye, 34 Chinook, 32 chum, and 13 coho salmon populations). We established a criterion of at least 3 years of data for each population during each time period for inclusion in this analysis. Although somewhat arbitrary, we chose 1990 as the end of the early period to ensure a large number of populations had sufficient data to be included, while still being early enough to provide a meaningful baseline for comparison with current data. Because our goal was to investigate trends experienced by resource users in Alaska, we included data from some stocks that are known to capture salmon that originated from areas other than Alaska. For example, estimates for Chinook salmon from Southeast Alaska are likely influenced by the inclusion of troll-caught Chinook salmon, which are largely composed of salmon originating from British Columbia (B.C.) and the U.S. West Coast. For visualization, the results of this analysis were then scaled up to the level of the fisheries management areas established by ADF&G (Fig. 1).

To quantify and visualize continuous changes in body size across time, we fit general additive models (GAMs) to annual mean population body length for each species. To avoid convergence problems due to small sample sizes, data collected before 1975 were excluded from this analysis. In contrast to previous studies that assumed monotonic linear changes in size[18,19], year was included as a nonlinear smoothed term because preliminary analyses suggested that the rate of length change varied through time. We included data from all populations for which observations from five or more years were available (276 sockeye salmon populations, 202 Chinook salmon populations, 183 chum salmon populations, 142 coho salmon populations). We knew a priori that salmon populations differ in average body size, so to preserve original units (mm) while controlling for variation in absolute body length among populations, we included two fixed factors: population and region. We assigned regions based on terrestrial biomes and the drainage areas of major watershed (shown numbered on Fig. 1, colored by ADF&G management region). Repeating these GAMs on escapement data alone provided equivalent results (Supplementary Fig. S11), which confirms that our results are not due to an artifact of sampling procedures through time.

To visualize changes in age structure and size-at-age, we fit very similar GAMs to age and length-at-age data. As above we included fixed effects for population and region, as well as a nonlinear year effect. Using the same dataset as the previously described GAMs, we used either mean freshwater age, mean saltwater age, or mean length-at-age as the response variable. For length-at-age, we separately fit GAMs for the four most common age classes in each species, except coho salmon, for which sufficient data was available for only three age classes.

To determine the extent to which patterns of body size change are consistent across space within a species, we re-fit these GAMs by replacing the main year effect by either a region-by-year or population-by-year interaction and compared model fit using AIC. These nonlinear interactions allow regions or populations to differ in their patterns of length change through time. These models are more data intensive than the previous GAMs, so we included data from all populations for which our time series consisted of any 20 or more years of data (123 sockeye salmon populations, 37 Chinook salmon populations, 38 chum salmon populations, 14 coho salmon populations).

**Contributions of declining age versus growth**. To partition the contribution of changes in population age structure versus size-at-age to changes in mean population length, we used the chain rule[61]. We used the discrete time analog of the chain rule

$$\Delta(xy) = y\Delta x + x\Delta y, \tag{1}$$

and assume that change in mean length is a function of changes in population age structure, $p(a)$, and mean length-at-age, $x(a)$. For each species and population, age structure in year $t$ was calculated as the proportion of individuals in each age $a$. Mean length in year $t$ is given by

$$x_t = \Sigma_a p_t(a) x_t(a), \tag{2}$$

and the year-to-year change in length is given by

$$\Delta x_t = x_{(t+1)} \quad x_t = \Sigma_a p_t(a) x_t(a) + \Delta p_t(a) x_t(a), \tag{3}$$

where

$$p_t(a) = 1/2 \;\, p_{t+1}(a) + p_t(a) \;\, , \tag{4}$$

and

$$\Delta p_t(a) = \;\, p_{t+1}(a) - \;\, p_t(a) \;\, . \tag{5}$$

Solving these formulas year-to-year for each species in each population, we estimated the proportion of change in mean length due to changes in age structure and size-at-age. We included all populations for which we had five or more years of data (though change can only be estimated for consecutive years of data) and averaged the results across populations in each region.

**Causes of age and size changes**. To identify potential causes of change in salmon body size, we quantified associations with a variety of indices describing physical and biological conditions in Alaska's freshwater and marine salmon habitats. Each candidate explanatory variable was selected based on existing biological hypotheses or inclusion in previous analyses of salmon size or population dynamics.

We considered several ocean climate indicators as potential causes of change in salmon size over time. Pacific Ocean conditions are often quantified using large-scale climate indices such as the Pacific Decadal Oscillation (PDO), El Niño Southern Oscillation (ENSO), and NPGO. These large-scale indices of ocean conditions, as proxies for climate and marine environment, have been shown to affect the survival and productivity of Pacific salmon in the North Pacific Ocean[62,63]. PDO, NPGO[64], and MEI[65,66] indices were all accessed and downloaded online (PDO, http://research.jisao.washington.edu/pdo/; NPGO, http://www.o3d.org/npgo/npgo.php, accessed 2018-02-07; MEI, https://www.esrl.noaa.gov/psd/enso/mei/, accessed 2018-02-08; MEIw, https://www.beringclimate.noaa.gov/, accessed 2018-02-08). In this analysis, winter means of NPGO and MEI were used in addition to an annual mean of MEI. Two ice cover metrics were also used to capture ocean climate conditions. Bering Sea ice cover and retreat were downloaded from https://www.beringclimate.noaa.gov/, originally derived from the National Snow and Ice Data Center data. Bering Sea ice cover index represents the winter anomaly, relative to 1981–2000 mean. Bering Sea ice retreat is an index representing number of days with ice cover after March 15.

Sea surface temperature (SST) was also explored as a potential cause of the changes in salmon size and age. SST has proven to be closely linked to salmon productivity. Mueter et al.[67] found that regional-scale SST predicted survival rates better than large-scale climate indices such as the PDO. They concluded that survival rates were largely driven by environmental conditions at regional spatial scales. SST was extracted from the Extended Reconstructed Sea Surface Temperature (ERSST) version 4[68]. To approximate SST values close to the river mouths which juvenile salmonids are most likely to experience after ocean entry, a double layer of the grid cells tracing the coastline of Alaska were extracted and the mean summer SST was calculated for each region.

Because in situ fluvial temperature measurements are sparse, both spatially and temporally, compared to the coverage of the AL dataset, air temperature was used as a proxy for temperature during the freshwater life stages. Air temperature data were extracted and sorted from remote-sensed satellite observations into multi-monthly regional means by season[69].

Finally, we considered the potential for competition with other salmon to influence salmon size by including the abundances of several highly abundant salmon species as explanatory covariates. Using data compiled by Ruggerone and Irvine[39], we evaluated the abundance of adult pink, chum, and sockeye salmon returning to Asia and North America as a proxy for the abundance of adult salmon of each species in the North Pacific. In addition, we also considered the more localized abundance of pink, chum, and sockeye salmon returning to Alaska, because salmon body size has been shown to vary with salmon abundance in the year of return migration in some species[70] at finer spatial scales. The abundances of coho and Chinook salmon were not included, because they occur at much lower abundance than sockeye, chum, and pink salmon.

We also explored marine mammal abundances as potential predictor variables, but found that the data available precluded rigorous statistical comparison with our time series of salmon size and age structure. For example, the only estimates of orca abundance available for our study area (that from Southeast Alaska and Prince William Sound) show steady, near monotonic increases through our study period[71,72]. Statistically, this leads to insufficient replication and high collinearity with year effects. Although caution is warranted in interpretations of any models for which the assumptions are so obviously violated, we note that preliminary analyses including marine mammal abundance were not dramatically superior in terms of variance explained or model fit. Because of these limitations, we determined that a reliable test of the effect of marine mammal predation was not possible for Alaska.

Ultimately, we only selected covariates with an absolute correlation among covariate time series of less than 0.61. By establishing this threshold for absolute pairwise covariate correlation we sought to include only covariates for which separate associations with salmon size could be identified. The final set of covariates included in our analyses were: (1) ocean climate indicators (PDO, NPGO, MEI, winter MEI (MEIw), and Bering Sea ice cover index); (2) sea surface temperature (SST); (3) air temperature as proxy for freshwater temperature; and (4) ocean salmon abundance (abundance of Alaska sockeye, pink, and chum salmon, and North Pacific wide abundance of sockeye, pink, and chum salmon).

To test hypothesized associations between temporal trends in the average body size (length) of salmon and environmental conditions, we fit a series of Bayesian hierarchical models to data describing size trends across sampling locations for each species. Because the chain rule analysis showed that changes in age structure explained greater interannual body size variation than did changes in size-at-age, we analyzed age-aggregated mean body length. Time series, starting in 1975, of annual mean length by species for each sampling location (*l*) and environmental covariates were mean-variance (*Z*) standardized prior to model fitting. Models of the form

$$L_{i,t} = \sum_c (\beta_{l,c} \quad X_{t \quad \delta_{c,} c}) + s(t) + \varepsilon_{l,t}, \tag{6}$$

were fit to each salmon species separately using Bayesian methods, where $L_{l,t}$ is the standardized length at each location (*l*) in each return or observation year (*t*), $\beta_{l,c}$ are coefficients describing the effect of each covariate (*c*) on average length at each location, and $X_{t \quad \delta_{c,} c}$ is the standardized value of each covariate in each year. The reference year for each covariate is specified relative to the return year, or year in which salmon length compositions are observed (*t*), by a species and covariate-specific offset $\delta_c$ that associates covariate effects with the hypothesized period of interaction in each species' life history (Supplementary Table S2). Location-specific covariate effects are structured hierarchically such that parameters describing the effect of each covariate on observed changes in average length were subject to a normally-distributed prior whose hyperparameters (group-level means and standard deviations for each covariate) were estimated directly from the data:

$$\beta_{l,c} \quad \text{Normal} \ \mu_c, \tau_c^2 \ , \tag{7}$$

This hierarchical structure permitted us to quantify both the average (group-level) association between length observations at each sampling location (*l*) and hypothesized covariates (i.e., the hyperparameter $\mu_c$), and the level of among-location variation in these effects (i.e., $\tau_c^2$). Prior distributions for model parameters were generally uninformative, with the exception of the prior on the group-level mean covariate effects ($\mu_c$) which included a mild penalty toward zero,

$$\mu_c \quad \text{Normal}(0, 1). \tag{8}$$

The prior distribution of the group-level (hyper) standard deviation of covariate effects was broad and truncated at zero,

$$\tau_c \quad \text{Normal}(0, 10)[0, \ , \tag{9}$$

allowing the model to freely estimate the appropriate level of among-location variability in covariate effects.

Observation error was assumed to be normally distributed $\varepsilon_{l,t} \sim Normal(0, \sigma_\varepsilon^2)$, with a common observation error variance ($\sigma_\varepsilon^2$) estimated as a free parameter and subject to a broad prior distribution

$$\sigma_\varepsilon \quad \text{Normal}(0, 10)[0, \ . \tag{10}$$

Each species-specific model also included a smoothed nonlinear year effect *s(t)* describing residual trends in length across time that were shared among sampling (observation) locations but were not explained by the covariates. The degree of nonlinearity for the univariate smooth *s(t)* quantifying the common residual trend in length is controlled by the variance term ($\sigma_s$) for the coefficients forming the spline[73], for which a broad zero-truncated prior distribution was defined:

$$\sigma_s \quad \text{Normal}(0, 10)[0, \ . \tag{11}$$

Hierarchical Bayesian models describing the temporal trend in location-specific salmon length were fit using the brms package[73,74] in R (R Core Team 2018), which generates posterior samples using the No U-Turn Sampler implemented in the Stan software platform[75]. Three independent chains were run for 20,000 iterations with a 50% burn-in and saving every tenth posterior sample, resulting in 3000 posterior samples. Convergence of all chains was diagnosed by ensuring potential scale reduction factors ($\hat{R}$) for each parameter were <1.05[76]. The sensitivity of model results to prior choice was evaluated by testing more and less restrictive normally-distributed priors for the hyperparameters describing the group-level average effect of each covariate (standard deviation 1.0 and 0.1); estimated covariate effects were insensitive to prior choice.

The influence of harvest on body size was considered separately from that of climate and competition. Reviews of fisheries-induced evolution have shown that populations subject to higher harvest rates show greater magnitude trait change[28], thus we expected that if fisheries-induced evolution contributes to size change, populations subjected on average to higher harvest rates should show greater magnitude negative size change. To test this hypothesis, we estimated harvest rate as a continuous variable for all populations with sufficient data.

Harvest rate was back-calculated from brood tables, which are datasets curated by ADF&G for management purposes that include the number of offspring from each brood year (year of birth) that return in each of the subsequent years (return year). Brood tables are only available for the most intensively managed salmon stocks. We were able to link brood table data to populations included in our AL datasets for 25 sockeye salmon populations and three Chinook salmon populations. Harvest rates were found from the literature for an additional five Chinook salmon populations[77–79]. To calculate the total harvest in each population and year, we subtracted escapement estimates from the overall estimate of returns (i.e., total run size, or both fish that escaped and were harvested). Harvest rate was calculated as the harvest divided by the estimated run size in each year, then averaged across the time series for each population to obtain the average harvest rate experienced by each salmon population. Averaging across the time series was deemed appropriate, because previous studies from the few Alaska salmon fisheries with sufficient data to consider harvest rate through time have shown that harvest rate is interannually variable but relatively stable through time[33,60]. Estimates from before 1990 or after 2010 (for sockeye) or 2008 (for Chinook) were excluded due to incomplete data availability. Each population for which both a brood table and AL data were available had a long time series of AL data (at least 30 years), so body size change was calculated by fitting a linear model of body length by year and extracting the slope. We regressed change in body size (slope coefficient of length-year regression) against population-specific harvest rate averaged through time (1990–2012), with a fixed effect for species. A harvest rate by species interaction was included but removed because it was not significant. *P* values were obtained from an ANOVA with type II sum of squares.

**Consequences of declining body size**. To estimate the potential consequences of salmon body size declines, we calculated the change in ecosystem services that would be expected given the observed change in body length for several important social, economic, and ecological roles filled by salmon in Alaska. For each species and population, we calculated percent change in body size (body length, $\Delta L$) from pre-1990 to post-2010 using the same methods as described for Fig. 1. Specifically, we calculated absolute change in body size as:

$$\Delta L = \text{Mean length}_{\text{post} \quad 2010} \quad \text{Mean length}_{\text{pre} \quad 1990}, \tag{12}$$

and percent change in body size as:

$$\text{Percent size change} = \frac{\text{Mean length}_{\text{post} \quad 2010} \quad \text{Mean length}_{\text{pre} \quad 1990}}{\text{Mean length}_{\text{pre} \quad 1990}}. \tag{13}$$

However, the magnitude of many of the ecosystem services we investigated vary with salmon body mass, rather than directly with body length. To predict salmon weight (*W*) based on body length (*L*), we fit a standard length–weight relationship of the form $W = a(L)^b$. Weight data were not available for most regions, so we estimated the *a* and *b* parameters for each species by fitting the logarithmic linearized version of this equation to high-quality datasets collected in Alaska for each species (Supplementary Table S3). Using these species-specific length-weight relationships, for each species and location, we calculated the change in weight between 1990 and 2010 ($\Delta W$) by finding the weight of an average post-2010 salmon and subtracting the weight of an average pre-1990 salmon. Detailed results are presented in Supplementary Data 1–3.

To consider the ecological consequences of salmon body size change, we focused on data collected by "escapement projects". These projects usually sample salmon in-river at a weir or counting tower as they migrate upstream onto spawning grounds. For each location with sufficient data (three or more years in each time window, before 1990 and after 2010), we estimated the ecological consequences of salmon size decline as the change in marine-derived phosphorus transported and the change in the number of eggs produced per fish. To calculate change in phosphorus inputs, we modified previously-developed models for anadromous fish nutrient loading to include only the import of nutrients into fresh waters by spawning adults[80,81]. We used a previously-estimated phosphorus content for spawning adult salmon of 0.38% of wet weight[80,81]. We calculated the difference in phosphorus content using the mean weight before 1990 versus after 2010. We ignored the effect of juvenile export on nutrient loading due to insufficient data and because previous studies have found its effect to be negligible unless adult biomass and escapement are extremely low[81].

To calculate the change in female fecundity, we used fecundity–length relationships to estimate the fecundity of the average female before 1990 and after 2010 and found the difference. We used published, species-specific fecundity–length relationships estimated for populations within Alaska. Because fecundity data were not available for all regions, we based these relationships on high-quality datasets from representative populations within Alaska (Supplementary Table S4).

To consider the economic consequences of body size change, we focused on data sampled from commercial fisheries. For each location with sufficient data (three or more years in each time window), we asked how much higher per-fish ex-vessel prices would be if fish had not changed in size in the period between 1990 and 2010. That is, using current price-per-pound estimates, we compared the price of two fish: one that weighed the same as an average fish post-2010 and one that weighed the same as the average fish pre-1990. First, we identified the most recently reported ex-vessel prices for each species and region[82]. For each species and region, we then multiplied the weight of the average pre-1990 salmon by its corresponding price-per-pound to calculate the average ex-vessel price for a pre-1990s salmon in today's market. This value was then subtracted from the average ex-vessel value of a post-2010 salmon, calculated in the same way, to estimate the change in ex-vessel per-capita salmon value due to salmon size change.

To consider the social consequences of size change, we focused on data from salmon caught in subsistence fisheries. However, length measurements taken from subsistence projects were rarely available before 1990. For this reason, we also included data from salmon caught in commercial harvest, which are expected to use the most similar gear types (i.e., gillnets) to subsistence harvest. For each location with sufficient subsistence or commercial data (three or more years in each time window), we modeled the social consequences of salmon size decline as the change in nutrient content and total servings or meals per fish. First, we determined the change in edible mass ($M$) of each fish by scaling according to species-specific values for seafood processing recovery rates[83]. We assumed that subsistence recovery rates are similar to the reported recovery rates for hand-filleted skin-on fillets, which were 55% for Chinook salmon, 60% for chum salmon, 57% for coho salmon, and 53% for sockeye salmon. We expect fillets to be the most commonly used salmon part but acknowledge that subsistence users could use different body parts (including the head and eyes) and that true recovery rates will likely vary among locations and users. We then calculated the nutrient value of the average pre-1990 and post-2010 fish and calculated the change in nutrient value, using species-specific nutritional ratios for protein (g), fat (g), and calories (kcal) per 100 g serving[84]. We used nutritional ratios for raw fish (National Nutrient Database for Standard Reference IDs: 15,078 for Chinook, 15,081 for coho, 15,085 for sockeye, and 15,079 for chum salmon). We also asked how many fewer 100 g servings and how many fewer meals of salmon were available per fish. We assume a standard serving size of 100 g, but note that many individuals will eat more than one serving in a sitting. Because of this uncertainty in serving size, we also included the change in meals by dividing M by the average self-reported estimates of portion sizes of salmon (227 g for Chinook salmon, 165.5 g for chum salmon, 178 g for coho salmon, and 163.5 g for sockeye salmon) from subsistence users in the nearby villages of Old Crow and Teslin, Yukon Territory, Canada[85].

**Reporting summary**. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

## Data availability

Our data have been publicly archived on the Knowledge Network for Biocomplexity (KNB): Jeanette Clark, Rich Brenner, and Bert Lewis. 2018. Compiled age, sex, and length data for Alaskan salmon, 1922–2017. Knowledge Network for Biocomplexity. https://doi.org/10.5063/F1707ZTM. Krista B Oke, Curry Cunningham, and Peter Westley. 2020. Collated dataset of covariates that could influence body size of Alaska salmon. Knowledge Network for Biocomplexity. https://doi.org/10.5063/F1N29V9T. In addition, we used publically available data from the following sources: US Department of Agriculture (USDA), Agricultural Research Service Laboratory. USDA National Nutrient Database for Standard Reference, Legacy Version. Available at: http://www.ars.usda.gov/nutrientdata. Alaska Department of Fish and Game. Commercial Salmon Fishery Exvessel Prices by Area and Species (2018). Available at: https://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherysalmon.salmoncatch_exvessel (Accessed: 2018-04-23). Kibele, J. & Jones, L. Historic air temperatures in Alaska for 1901–2015, with spatial subsetting by region. (2017). https://doi.org/10.5063/F1RX997V. Huang, B. et al. Extended Reconstructed Sea Surface Temperature (ERSST), Version 4. Accessed on April 16, 2018 (2015). https://doi.org/10.7289/V5KD1VVF. Di Lorenzo et al., 2008: North Pacific Gyre Oscillation links ocean climate and ecosystem change, GRL. Available at: http://www.o3d.org/npgo/npgo.php (Accessed: 2018-02-08). NOAA, Multivariate ENSO Index. Available at: https://www.esrl.noaa.gov/psd/enso/mei/ (Accessed: 2018-02-08). JISAO, Pacific Decadal Oscillation (PDO). Available at: http://www.research.jisao.washington.edu/pdo/ (Accessed: 2018-02-08). NOAA, Bering Sea Ice Cover Index. Available at: beringclimate.noaa.gov (Accessed: 2018-02-08). NOAA, Winter Multivariate ENSO Index. Available at: https://www.beringclimate.noaa.gov/data/BCresult.php (Accessed: 2018-02-08).

## Code availability

Code has been archived publicly and is available at: https://github.com/KristaOke/salmon-size-declines.

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## Author contributions

E.P.P., N.W.K., and P.A.H.W. conceived of the study; E.P.P. and K.B.O. refined study goals; K.B.O., C.J.C., P.A.H.W., M.L.B., S.M.C., J.S., A.P.H., V.A.K., N.W.K., J.K., H.K.K., K.M.K., B.L., S.M., J.D.R., G.K.V., and E.P.P. guided study design; J.C. lead data collection and QA/QC; K.B.O., C.J.C., S.M., V.A.K., J.K., N.W.K., and K.M.K. analyzed data; K.B.O., C.J.C., E.P.P., J.D.R., B.L., P.A.H.W., K.M.K., and J.C. contributed to writing; K.B.O., C.J.C., J.K., and K.M.K. created figures; K.B.O., C.J.C., P.A.H.W., M.L.B., S.M.C., J.S., A.P.H., V.A.K., N.W.K., J.K., H.K.K., K.M.K., B.L., S.M., J.D.R., G.K.V., and E.P.P. edited the paper.

## Competing interests

The authors declare no competing interests.

## Additional information

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**Correspondence** and requests for materials should be addressed to K.B.O., P.A.H.W. or E.P.P.

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**Gale K. Vick**
**Fairbanks, Alaska 99709**

# COMMENTARY TO THE ALASKA BOARD OF FISHERIES
## October 6, 2021
## Regarding: Area M Test Fishery

My name is Gale Vick. I am a 53 year resident of Alaska, a former drift gillnetter in Prince William Sound, and for 30 years a contractor on fisheries policy. I have been working on Yukon River fisheries issues since 2014 and I am a member of the Fairbanks Advisory Committee.

My first caution is that all species of salmon in Alaska are in obvious trouble, with the exception of Bristol Bay sockeye. You do not need to be a scientist to fully appreciate this. Most of us who have fished all over the state know, for instance, that Chinook salmon abundance and size is dramatically decreasing.[1] Our science supports this and our trajectories suggest that we have not hit bottom yet. While this has been critical mass in the Yukon for many years, we have in the last two years seen record low numbers of chum and coho salmon as well. These numbers mirror other places in part but are much more dramatic in the Yukon.

At the same time, Area M (False Pass) enjoyed record harvests of chum salmon. Because Area M is an intercept fishery for the North Pacific in the Bering Sea, and because there have been past indicators that a sizeable portion of chum salmon could be AYK stocks, it is incumbent upon managers to provide the information through tissue sampling that would give clarity to the origins of all intercepted stocks. Including Chinook.

This is an issue as old as the fishery. The debate is often based on perception because the only reliable figures we have per year are the harvest numbers. But there have been a number of isolated studies, most notably the 2002-2009 WASSIP (Western Alaska Salmon Stock Identification Program) that have given us a window of information. Except for Chinook.

Sometime in the late 1970's, the Alaska Board of Fisheries established a commercial harvest allocation of 8.3% for South Penninsula fisheries of annual Bristol Bay sockeye forecast to Area

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[1] I was a co-author on a paper published in *Nature Communications* 2018 on the decline in size of Alaska salmon stocks. This paper was authored by several well-known salmon scientists at Department of Ecology and Evolutionary Biology, University of California, Santa Cruz, College of Fisheries and Ocean Sciences, University of Alaska Juneau, Fisheries, Aquatic Science & Technology Laboratory, Alaska Pacific University, College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Department of Environmental Science and Policy, University of California, Davis, Environmental Science, Policy, and Management, University of California, Berkeley, National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, Department of Biology and Redpath Museum, McGill University, Montreal, Canada, Washington Department of Fish and Wildlife, Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, Division of Commercial Fisheries, Alaska Department of Fish and Game, Anchorage, National Marine Fisheries Service, Fisheries Ecology Division, Southwest Fisheries Science Center, Santa Cruz, Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC Canada, Tanana Chiefs Conference, Fairbanks.

M fisheries for the month of June. In 1982 there was a major chum crash in the Yukon. Subsequently, an Area M chum cap was instituted. This was based on the sockeye to chum ratio and varied by season. During this time Virgil Umphenor wrote a petition to the BOF on behalf of YRDFA. The Fairbanks Advisory Committee supported. Tanana Chiefs and Kawarek helped with gathering signatures up and down the river. Alaska's Congressional Delegation became involved. The chum cap was subsequently lowered again. But as AYK chum stocks fluctuated, there was general lack of enforcement within Area M harvesting. In 2000, Alaska State Troopers video taped Area M fishermen throwing chum salmon overboard. Virgil, as a member of the BOF, was instrumental in helping to secure staggered openers. Prior to 2001, ADF&G had to do a test fishery to find out the chum to sockeye ratio.

The origins of *harvested* False Pass salmon will invariably change over time, which is why an institutionalized test fishery in the Shumigan Islands and South Unimak is the only way we can have anything close to accuracy.

While the ACR that was submitted on this subject by Virgil Umphenour (Fairbanks Advisory Committee), is not a regulatory issue at this point, we are asking the Alaska Board of Fisheries to consider this issue on record. It will be presented to the Alaska Department of Fish and Game, the Alaska Governor's office and the Alaska Congressional Delegation in the near future.

Thank you.

Cc: Members, Fairbanks Advisory Committee
Serena Fitka, Yukon River Drainage Fisherman's Association
P.J. Simon, Tanana Chiefs Conference
Ben Stevens, Tanana Chiefs Conference

# AGENDA CHANGE REQUEST FORM
## ALASKA BOARD OF FISHERIES

The Board of Fisheries (board) reviews each state managed fishery under its authority once every three years in what is referred to as the board's "three-year cycle". Each year the board takes up regulatory subjects from a consistent set of regions and species, repeating every three years. Regulatory subjects in the current meeting cycle are referred to as "in-cycle" subjects.

The board recognizes there are times when "out-of-cycle" subjects require more immediate attention and created the "agenda change request" (ACR) process to allow consideration of these subjects. The board solicits ACRs 60 days prior to its fall work session. Accepted ACRs are scheduled at a subsequent meeting during the current meeting cycle. More on the board's long-term meeting cycle is here.

For the 2021/2022 meeting cycle, the following regulatory regions, species and uses are "in-cycle" including:
- Prince William Sound Finfish and Shellfish species, all uses.
- Southeast and Yakutat Finfish and Shellfish species, all uses.
- All Shellfish in all other regions, all uses.

The deadline for ACRs is August 23, 2021. ACRs received regarding in-cycle subjects will not be accepted as they are effectively proposals that missed the April 2020 deadline.

The board accept requests to change its schedule under certain guidelines set forth in 5 AAC 39.999. The board will accept these agenda change requests (ACRs) only:
1) for a fishery conservation purpose or reason; or
2) to correct an error in regulation; or
3) to correct an effect on a fishery that was unforeseen when a regulation was adopted.

The board will not accept an ACR that is predominantly allocative in nature in the absence of new compelling information, as determined by the board [5 AAC 39.999 (a) (2)].

Please answer all questions to the best of your ability.

1) CITE THE REGULATION THAT WILL BE CHANGED IF THIS ACR IS HEARD. If possible, enter the series of letters and numbers that identify the regulation to be changed. If it will be a new section, enter "5 AAC NEW".

Alaska Administrative Code Number 5 AAC: 39.22

The Policy for the Management of Sustainable Salmon Fisheries (SSFP; 5 AAC 39.222, effective 2000, amended 2001) directs the Alaska Department of Fish and Game (ADF&G) to provide the Alaska Board of Fisheries (Board) with reports on the status of salmon stocks and identify any salmon stock that present a concern.

2) WHAT IS THE PROBLEM YOU WOULD LIKE THE BOARD TO ADDRESS? STATE IN DETAIL THE NATURE OF THE CURRENT PROBLEM. Address only one issue. State the problem clearly and concisely. The board will reject multiple or confusing issues.

The AYK has seen a steadily declining loss of Chinook salmon in both size and run strength over the past 20 years. At the same time, there have been periodic crashes of summer and fall chum salmon in the AYK, with the 2021 season culminating in record losses for the second year in a row. As a result, the Yukon River especially has not had any directed commercial harvest of Chinook since 2008 with lessening subsistence harvest and in 2021, **no** commercial or subsistence harvest of Chinook or summer chum. All recent year salmon escapements have not met requirements for ANS (amounts needed for subsistence.) In addition, 2021 escapement goals have not been made for the Yukon Border passage and escapement goals on the Alaska side of the Yukon have not been met or are unknown in most tributaries. Coho salmon, a traditional late harvest, have, to date, been tracking at the lowest level, possibly on record.

In contrast, Area M *harvested* what may be a record for chum salmon.

The continuing and dramatic declines of Chinook and chum salmon for the AYK have resulted in food security and cultural crises. Concern over the survival of the stocks themselves is paramount. Stakeholders and researchers understand that there are multiple contributing factors to the decline of these stocks but are having a difficult time assessing what factors are potentially under human management vs. environmental factors that are not.

In addition, researchers and stakeholders have become increasingly concerned over impacts of hatchery pink salmon, including straying.

More critical genetic data is needed for the AYK.

Alaska state regulations require the Alaska Department of Fish and Game managers to apply precautionary principles in the conservation of stocks. Three primary tools for this management are stock identification, harvest methodology and harvest restriction.

In previous years, a massive undertaking to identify Western Alaska salmon stocks was facilitated through the Western Alaska Salmon Stock Identification Program (WASSIP) which between 2006 and 2009 joined with stakeholders to collect genetic samples for salmon stocks from Chignik Bay to Kotzebue Sound. This added to genetic baseline data and DNA markers within mixed stock analyses (MSA) to identify stock composition of chum and sockeye salmon in relation to salmon passage between Central and Western Alaska. The reporting did not, however, include Chinook salmon. And it ended in 2009.

3) WHAT SOLUTION DO YOU PREFER? Or, if the board adopted your solution, what would the new or amended regulation say?

This ACR requests a Test Fishery for Area M to discern genetic origins of chum, Chinook and pink salmon stocks and to report those findings to the Alaska Board of Fisheries on an annual basis.

Because the 2021 decline of Chinook and chum is so extreme in the AYK, and because there is a potential threat of too many pink salmon, this ACR requests that the Alaska Board of Fisheries (BOF) direct the Alaska Department of Fish and Game to report to the BOF on an annual basis the results of genetic compositions these stocks that potentially migrate from Central to Western Alaska and to identify the gaps in data. In addition, to summarize this data in a way that is informational to AYK stakeholders and managers.

There has never been a genetic analysis of Chinook salmon caught in the Area M June fishery. ADF&G considers the Yukon River Chinook stocks as a "Stock of Concern" and it is incumbent on the Department to identify where stocks might be intercepted.

There has not been a genetic analysis of summer and fall chum salmon through the Area M fishery since 2009. And there has never been an assessment of pink hatchery salmon that might be migrating from the Gulf of Alaska.

There has never been a genetic sampling of coho salmon in Area M nor has there been an assessment of pink salmon genetics.

4) STATE IN DETAIL HOW THIS ACR MEETS THE CRITERIA STATED BELOW. If one or more of the three criteria set forth below is not applicable, state that it is not.

a) for a fishery conservation purpose or reason: Identifying AYK stocks that might be part of capture in intercept fisheries will help identify management options for protection of depleted stocks

b) to correct an error in regulation:

c) to correct an effect on a fishery that was unforeseen when a regulation was adopted:

5) WHAT WILL HAPPEN IF THIS PROBLEM IS NOT SOLVED PRIOR TO THE REGULAR CYCLE?

We could have a continued dramatic loss in the AYK of specific year classes of chum and Chinook salmon without knowing percentages of AYK stock that might be intercepted. We just need to know where the Area M June fish are heading to spawn.

We also need to know if Southeast or Central hatchery salmon are (migrating) through Area M to the BSAI.

6) STATE WHY YOUR ACR IS NOT PREDOMINANTLY ALLOCATIVE.

There has been no or severely limited commercial fishery in the AYK for chum salmon in the last two years, and there has been no Chinook directed fishery since 2008. And subsistence fisheries have also been extremely curtailed or completely closed. This ACR request is for genetic information.

7) IF THIS REQUEST IS ALLOCATIVE, STATE THE NEW INFORMATION THAT COMPELS THE BOARD TO CONSIDER AN ALLOCATIVE PROPOSAL OUTSIDE OF THE REGULAR CYCLE.

8) STATE YOUR INVOLVEMENT IN THE FISHERY THAT IS THE SUBJECT OF THIS ACR (e.g., commercial fisherman, subsistence user, sport angler, etc.)

I have been a member of what is now the Yukon River Panel longer than any member of either Canada or the United States since 1988.

9) STATE WHETHER THIS ACR HAS BEEN CONSIDERED BEFORE, EITHER AS A PROPOSAL OR AS AN ACR, AND IF SO, DURING WHICH BOARD OF FISHERIES MEETING.

NO… genetics taken for chum salmon back in the 1990s, except for WASSIP 4-year period ending in 2009 and none has been taken for Chinook or pink salmon ever.

Submitted by:
**NAME** Virgil Umphenour
**Individual or Group**

878 Lynnwood Way, North Pole, AK 99705
**Address** **City, State** **Zip**

| | | |
|---|---|---|
| 907-328-8857 | 907-456-3885 | akhunt@ak.net |
| **Home Phone** | **Work Phone** | **Email** |

**SIGNATURE:** **Virgil Lee Umphenour** **DATE:** **8/22/21**

Note: Addresses and telephone numbers will not be published.

Mail, fax, or e-mail this completed form to:
Alaska Board of Fisheries
P.O. Box 115526
Juneau, AK 99811-5526
Fax: 907-465-6094

E-mail: dfg.bof.comments@alaska.gov

Submitted By
Gerald W Foster
Submitted On
10/5/2021 3:20:11 AM
Affiliation

Phone
[redacted]
Email
[redacted]
Address
36238 Bradford Rd. PO Box 1147
Sterling, Alaska 99672

I went halibut fishing out of Homer this summer on a "charter-free" Wednesday and there were charter boats (binoculars) anchored in the first two spots I usually stop, so I moved on until we were clear of any other fishers.

As I reflect on the new "fishing quoto" program from my point of view it seems like a clever reallocation of halibut from sport to charter operators who are clearly commercial fishers. Sport fishers are not a cohesive political lobbying group and I suspect their views were not represented in whatever process was used.

When I fish halibut in the Juneau area I've seen small structures "plugged" with charters - given the more limited number of fish, this is a problem.

I wanted to voice my displeasure with this program and although the feds manage the halibut fisheries, Alaska also plays an important role.

**From:** John/Karen Krieg
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Agenda change request by Virgil Umphenour
**Date:** Monday, October 4, 2021 7:47:59 AM

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To Alaska Board of Fish,
Please consider the Agenda change request from Virgil Umphenour. While profits may be up for many in the fishing industry, the people along the Yukon have been devastated by the poor runs of resent years. This has been a way of life for thousands of years and they they deserve to have answers for the low runs. Genetic testing may provide some.
Thank you for your time
John Krieg
P.O. Box 56515
North Pole, Alaska 99705

Sent from my iPad

Submitted By
    John Renner
Submitted On
    10/6/2021 3:38:44 PM
Affiliation
    CRPWS/AC

Phone
[redacted]
Email
[redacted]
Address
    P.O. Box 756
    cordova, Alaska 99574

Members of the Board,

On January 25th, 2021 BOF teleconference concerns were expressed about the valitity of the proposals for PWS Copper River due to 2 years Covid delay. We and other board members questioned how to address the 2 year COVID delay and address issues that have come up in the meantime. Glen Haight stated that the ACR process would be available to us. Eight ACR's were put in by members of our constituency all were rejected because we were in cycle. We still feel that isues have change dramatically on the Copper River and PWS. It has been to long, we need to either call for proposals again or open the process up for new input for current issues. Please feel free to call me to discuss options at 907-253-7564

Sincerely,

Chairman  Copper River PWS/AC

John K Renner

**From:** Kenneth Jones
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** October work session written comments
**Date:** Thursday, September 30, 2021 8:48:10 PM

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Esteemed board of fish members,

I submitted multiple ACRs this year that were timely before the deadline, which were denied due to being in cycle. However during your spring work session it was said that people should use the ACR process for in cycle topics because the meeting had been delayed due to covid. I would like you to please consider placing my ACR requests as proposals for the December PWS in cycle meeting, this will be the best time to have participants take up these topics that meet multiple ACR criteria, many of which relate to a new fishing technology that did not exist yet when the proposal deadline closed. This fishing technology can curb bycatch and whale depredation and is the future of our fisheries. It would be unfathomably disappointing to many PWS fishers if we had to wait another cycle for these topics to be discussed at an in region meeting.

Thank you for your consideration and I urge you to allow these ACRs for the in cycle PWS meeting.

**Kenneth B Jones**
**Samani Fisheries LLC**
**Cell : 9073603456**
**FV Serenity**
**FV Second Wind**

**From:** Nancy Hillstrand <halibuts@gmail.com>
**Sent:** Wednesday, July 14, 2021 9:09 PM
**Subject:** Will different salmon species adapt before the climate votes them off the island?

July 2021 article
Which salmon do we prefer?

# Survivor: Salmon Edition

## Will different salmon species adapt before the climate votes them off the island?

July 6, 2021 | 4,600 words, about 23 minutes

*This article is also available in audio format. Listen now, download, or subscribe to "Hakai Magazine Audio Edition" through your favorite podcast app.*

On a small, grassy point overlooking the lower Fraser River in southwestern British Columbia, a lone angler reels in his line. He checks his lure and gazes out over the broad ribbon of silty water flowing to the sea. Then he casts again. It's a late August afternoon, and I'm traveling by boat with biologist Dave Scott through the estuary of what is considered one of the world's greatest salmon rivers. But for the moment, there's a stillness stretching over the water: the only disturbance is a trail of wakes our boat leaves behind. As we push downstream, I look back at the lone angler perched on the bank. Shoulders slouched, he stands at the water's edge, line cast, waiting. But the river seems in no hurry to reward his patience.

Salmon tend to be few and far between here in the late summer season, but Scott, a salmon biologist with the Raincoast Conservation Foundation in British Columbia, also knows these are hard times on the river. Many of the Fraser’s wild salmon populations are in serious trouble, with steadily declining numbers, and Scott and his colleagues have embarked on a new project in the estuary to improve the survival of juvenile salmon. A few days ago, he invited me out on the water to see their progress. Earlier this afternoon, Scott, a lanky, outdoorsy, West-Coast millennial in a black T-shirt and forest-green cargo shorts, welcomed me and a photographer aboard a small motorboat in the historic harbor of Steveston, and the three of us set off.

Perched on the bank of the lower Fraser River, the village of Steveston is now a quiet suburb of Vancouver. But during the early 1900s, canneries crowded the Steveston waterfront, where they packed Fraser River salmon into tins that were shipped around the world. The village boomed, and locals took to calling it Salmonopolis. Now times have changed, and few people call it Salmonopolis anymore. Today, much of the fishing talk in Steveston is about conserving and protecting the Fraser’s dwindling salmon stocks.

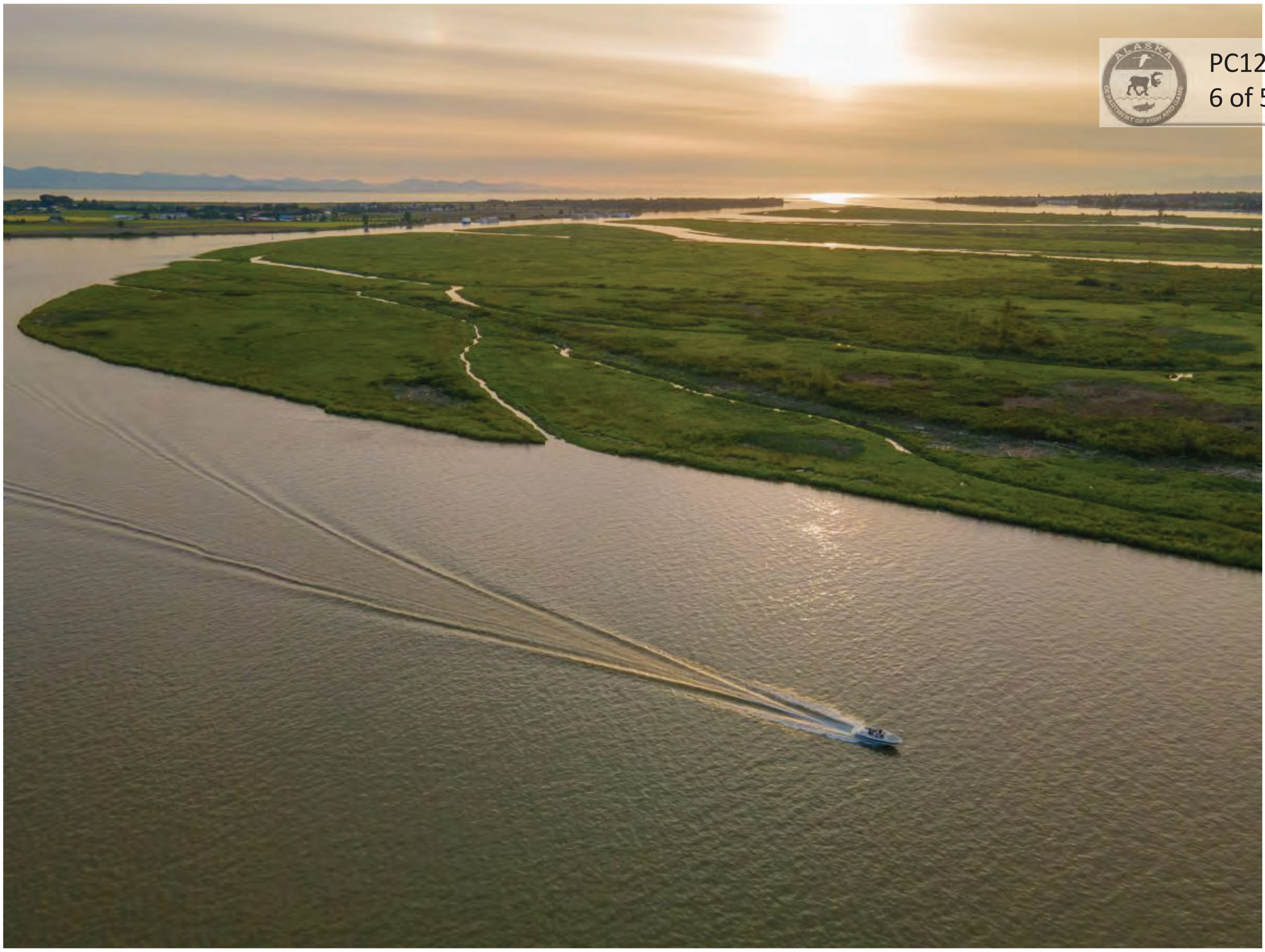
As we cruise downstream, Scott gives me a short primer on the Fraser estuary. Each year, he explains, five species of Pacific salmon travel through the waters of the estuary. They have specific streams they call home, specific times they migrate out to sea, and specific routes to get there. In other words, most salmon are finicky, so habitats that all five species use are of great importance. The Fraser River estuary is just such a place.

Salmon biologist Dave Scott heads out on the Fraser River in British Columbia to check a major new habitat restoration project for Pacific salmon in the estuary. Photo by Alice Sun

Before the arrival of European settlers, the estuary was a maze of water channels, sandflats, eelgrass beds, and marshlands. It served as a rest area and nursery for vast numbers of migrating juvenile salmon. But those numbers fell as the marshlands were drained for farms and housing developments, and stone jetties blocked water channels to some of the surviving wetlands. So Scott and his colleagues are looking for ways to give young salmon more access to the estuary's remaining wetlands. They're also trying to educate the public about the estuary and its critical importance to dwindling salmon stocks. "We're trying to hit it on all angles," Scott says, his brown hair tousled by the breeze.

But the Fraser isn't the only salmon river in trouble. Scientists are also recording worrying declines in wild salmon stocks in other parts of the Pacific Northwest, too. Land development along freshwater habitats is a common problem in the region, but it's only one of several factors shaping the current picture. Logging, landslides, and climate change also pose serious threats. Rising water temperatures, for example, can impact the intricate food webs that salmon depend upon in both rivers and oceans. And not all salmon species are affected equally, suggesting that genetic diversity within a species also plays an important part in the picture. Remarkably, one of the more genetically diverse and geographically widespread species, chinook salmon, seems to have fared the worst in North America over the past couple of decades.

Given all the changes that salmon populations have seen over the past century, scientists are now looking ahead with a new urgency, bracing for what the future may bring. And many are grappling with several questions. In a future shaped by rapid climate change, which salmon populations will do worse, and which will do better? And how will climate change affect the geographical distribution of salmon in the future? With this information in hand, researchers hope to develop new ways of protecting today’s salmon stocks—and prepare for tomorrow’s.



A boat cruises at sunset in the lower Fraser River estuary. The estuary is vital fish habitat: all five species of Pacific salmon pass through it on their journey to the sea. Photo by Fernando Lessa/Alamy Stock Photo

Much like social scientists, who look at a person’s formative years to understand their behavior and predict how they might act in the future, biologists say they are examining the evolutionary history of salmon as part of the research needed to envision the future of these iconic fish. Where, they ask, did Pacific salmon species evolve, and what experiences shaped their evolution and survival? In other words, what informed *their* formative years?

In the past, salmon had millennia to adapt to changes. Now we are forcing them to do so again in a matter of decades.

At the University of Washington in Seattle, ecologist Daniel Schindler has given much thought to the question of how salmon evolved and adapted to their local habitats. Over the past 25 years, Schindler has studied populations of Pacific salmon in many ecosystems in western Alaska, examining how they respond to both climate change and land-use issues. On the day we talk over Zoom, Schindler sports a brushy, graying beard after just returning from a four-month field season in western Alaska. As a principal investigator in the Alaska Salmon Program, the ecologist regularly takes graduate and undergraduate students north to monitor juvenile and adult salmon populations and check on how they are faring there. "That's what keeps me in the business," he says, one corner of his lips turned upward. "But teaching is fun, too."

Schindler is fond of using analogies when he wants to make an important point about salmon. When our conversation turns to the question of how salmon will adapt to freshwater habitats during climate change, he begins by likening the process to a peanut butter and jam sandwich. One slice of bread is the landform—the mountains and river valleys. The other slice is climate. "The lumpy peanut butter is the habitat," Schindler explains, "and the jam is the genetics. Then if you squeeze those two things together, the genetics are responding to the habitat, which is, in its own way, its own living entity."

For salmon, the "living" habitats are landscapes shaped by the dynamic forces of nature—flooding, the movement of ice sheets and glaciers, and landslides. Almost half of the current North American range of Pacific salmon, for example, was blanketed in ice during the Last Glacial Maximum between 26,500 and 19,000 years ago. When the climate finally warmed, the glaciers retreated, carving out U-shaped valleys in the Pacific Northwest, altering water flow and temperature in downstream tributaries, and unlocking new areas for fish to colonize over a period of thousands of years. These momentous events changed the shape of riverscapes, selecting for salmon that could adapt to a dynamic environment. And more was to come. Erosion, land development, and many other factors have continued altering riverscapes over the centuries, creating new conditions for salmon to adapt to. Just where and how a species evolved profoundly shapes its genetic inheritance.

Among the Pacific salmon species, chinook have the greatest degree of diversity in terms of ecology, life history, and habitats. Often called king salmon by the public, a chinook typically weighs in at around 13 kilograms, though fishers have landed some as large as 50 kilograms, about one-third the weight of a panda bear. And while juvenile chinook dine mainly on insects and crustaceans, the adults feed primarily on other fish.

Long considered to be the royalty of the salmon world, chinook are in decline across much of the Pacific Northwest. Today, some scientists worry they could be the canary in a coal mine, sounding the alarm for other salmon species. Photo by Mark Conlin/Alamy Stock Photo

Along the west coast of North America, chinook have adapted to a wide range of environments. They can be found all the way from Northern California to the glacier-fed streams of Alaska. And they have a remarkably varied life history. Some set off for the ocean just a few months after they hatch; others spend a year or more in their natal streams before venturing to the sea. (These two groups are aptly named ocean-type and stream-type chinook, respectively.) In addition, some chinook can remain at sea for up to six years before migrating home; others stay there just a year.

Schindler likens chinook's diverse populations and habitats to an investor with a varied financial portfolio. In the financial world, he says, wise investors don't put all their eggs in one basket. Instead, they place their money in a variety of investments—stocks, bonds, real estate, and the like—and this strategy reduces their risk of losing everything in times of financial turmoil. By keeping a lot of options in the game, it's more likely there will be a winner somewhere, Schindler notes. This is very similar to what chinook salmon have done. The rich diversity of its wild populations and habitats reduces the odds of the entire species being wiped out in the event of a disaster in one region.

With its varied portfolio, chinook salmon would look like a good bet for the future. But some statistics cast doubt on this. In 2020, the Committee on the Status of Endangered Wildlife in Canada designated seven chinook populations in southern British Columbia as either endangered or threatened. Much the same is true in the Columbia River watershed in the northwestern United States, where chinook populations may have lost more than one-third of their genetic diversity. More worrying still, the rate of young salmon returning as adults to rivers from California to Alaska over the past half-century has plummeted to one-third of earlier levels.

It's a picture that puzzles many researchers. A myriad of variables impact salmon survival and it takes time and research to untangle them. Land use—from mining to damming and irrigation, for example—has affected chinook stocks in the Pacific Northwest at critical life stages, but it can't be blamed for what's happening in the northern latitudes. Many of Alaska's rivers and streams remain almost untouched by development, and in certain areas, the amount of salmon habitat appears to be growing as melting glaciers produce new rivers and tributaries for salmon to colonize. Yet, wild chinook stocks are struggling in Alaska, far more than other salmon stocks. So what's going on?

Through a viewing glass, a child gazes at a chinook in a fish ladder at the Winchester Dam in Oregon. Much of the decline of the chinook in Canada and the northern United States has been attributed to land development, particularly the damming of rivers. Photo by ZUMA Press, Inc./Alamy Stock Photo

At the University of British Columbia in Vancouver, fisheries scientist Scott Hinch rubs his chin in puzzlement. That's "the $64-million question," he says. Currently, studies suggest that much of the problem lies with what chinook stocks are eating in the ocean. The marine diet of some salmon species is changing, but it's not easy to tease out the particulars. Food webs in the ocean are complex, he says. Predator levels change, or prey levels, or the number of fish that compete for the same prey, and these can affect the entire ecosystem. "It's not as simple as saying the oceans are warmer," Hinch observes.

For many ecologists, the fragile state of chinook salmon today is worrisome, given their diverse population stocks and their far-ranging distribution. And there is another puzzling side to this story. Pink salmon tend to be at the other end of the diversity spectrum. Their populations are relatively homogenous. But unlike chinook, pink salmon are an impressive success story.

The pink salmon is the bantam of the Pacific salmon family, with an average weight of two kilograms. Silvery in color as a juvenile, it later develops darker coloration and its flesh eventually turns pink as a result of its marine diet of shrimp and krill, both of which are rich in a reddish-orange pigment. Then, shortly before spawning, the males undergo yet another transformation, developing a large hump of connective and bony tissue near the dorsal fin. This bulge has given rise to a popular name for the species—humpback, often shortened to just humpy.

The pink has a very different life history from the genetically diverse chinook, although the two species evolved in broadly similar latitudes. Pink salmon lay their eggs in coastal habitats, rarely venturing far into the watershed, and the juveniles spend little time in fresh water, heading off to the ocean relatively quickly. Moreover, pink salmon have a fixed, two-year life span. They spawn, migrate, return, and die all within two years, and that often translates into an odd-year–even-year return cycle. Depending on the run, returns can fluctuate widely: odd years will see a flood of returning pinks, even years not so much. Or vice versa. Whether odd or even, however, the year with bumper numbers of pinks has an impact on the ocean food web. Pinks outcompete other species for food.

Nicknamed humpies due to the appearance of the males before spawning, pink salmon are highly resilient and appear to colonize new habitats with ease. These pinks are migrating through Prince William Sound, Alaska, where glacial retreat has accelerated over the past few decades, exposing new, pristine freshwater habitat. Photo by Chris and Monique Fallows/Minden Pictures

Pinks, however, get relatively little love from foodies in North America, compared with chinook or sockeye. There's a good reason for that. Pinks put much of their energy into growing quickly, whereas chinook and sockeye take more time to grow and store more of their energy as fat. And in the culinary world, the fat content of a salmon translates into taste. Pinks, Schindler says, "just aren't as luscious and juicy and delicious as a nice sockeye or chinook."

Still, pink salmon have a lot going for them. They are accustomed to wandering and they aren't picky about which stream they spawn in. They're adept at colonizing unfamiliar rivers, and they need only a year and a half at sea before returning home to complete their life cycle—traits that make pink salmon reproductive machines.

And it shows. The pink is the most abundant Pacific salmon species. Between 1990 and 2015, more than 400 million pink salmon roamed the North Pacific Ocean and into the Bering Sea annually, far outnumbering chum and sockeye salmon there. But this reproductive success has a serious downside. Pink salmon are now outcompeting other species for food. In the southern Bering Sea region, for example, pinks are extremely abundant in odd years, and they gobble up vast quantities of the small crustaceans that other salmon species and seabirds need for survival. Some researchers think a similar scenario is taking place in the North Pacific, which could contribute to declining numbers of chum and chinook in the region, as well as the diminishing body size of chinook there: they're just not getting enough to eat. For their size, pinks are stronger swimmers. In addition, they grow more quickly, head to the ocean sooner, and have a higher food consumption rate than their fellow salmon.

For all these reasons, pink salmon may well hold the winning lottery ticket for the future. Certainly, they are the salmon of the present. But their penchant for roaming and colonizing has created a new set of problems in places such as Norway, which is home to native populations of Atlantic salmon.

Just how pink salmon ended up in Norway is a tale that begins in the old Soviet Union. During the 1950s, someone in the Soviet Union came up with the idea of introducing pink salmon to the White Sea, a nearly landlocked finger of the Arctic Ocean along Russia's northwest coast. The idea may have been to boost local commercial fisheries, "but this was back in the Khrushchev days, so exactly why they did what they did—that's difficult to know," says Henrik Hårdensson Berntsen, a salmon researcher with the Norwegian Institute for Nature Research, on a recent Zoom call. A clean-shaven man in a button-down shirt, Berntsen has been trying to piece together exactly what happened.

In 1957, Soviet scientists introduced pink salmon fry from Sakhalin, a Russian island north of Japan, to rivers that drained into the White Sea. The researchers then continued stocking these rivers with pink salmon eggs over the next two decades, and the program led to large catches in the Soviet rivers during most odd years. But the fish failed to establish breeding populations, probably because they could not adapt to the cold polar waters of the White Sea. So the Soviets eventually switched sources, taking eggs from pink salmon populations in the River Ola, north of Sakhalin. Then in 1999, the stocking project suddenly ended, likely because it was deemed a failure and due to the politically turbulent time in Russia.

Berntsen thinks fishers continued to catch pink salmon in rivers draining into the White Sea. In addition, some evidence showed that the fish also ranged farther north and west—into the Barents Sea and the North Atlantic. This suggested that pink salmon were breeding in the wild after all. Then, in 2017, something startling happened. Norway saw a huge spike in the number of pinks in its northern rivers. Some researchers estimated that more than 10,000 were in northern Norway, and Berntsen thinks that number is likely an underestimate, since the Norwegian fisheries management agency was taken off guard by the surging numbers and likely failed to record many catches.

Pink salmon return to spawn along a streambed in one of the Shantar Islands off Russia’s east coast. During the 1950s, Soviet scientists introduced pink salmon from Sakhalin island, north of Japan, to the White Sea, where they probably began breeding in the wild. Photo by ITAR-TASS News Agency/Alamy Live News

Even more surprising was the appearance of pink salmon on the other side of the Atlantic in 2017—in Newfoundland and Labrador. Some researchers think these fish may be traced back to the Soviet project in the White Sea. Although no one knows how they got all the way to Canada’s east coast, it’s possible they migrated across the Atlantic Ocean from newly established populations in the United Kingdom and Ireland. Hinch and others think pinks are the weeds of the salmon world. Give them an opportunity to colonize a new area, and they will often take it and excel.

Indeed, they could be doing *too* well in Norway. When the Norwegian government recently studied the possible impact that pink salmon could have on the country’s wild and farmed salmon, it listed several major concerns—introduction of pathogens carried by the pinks, growing competition between the pinks and the native Atlantic salmon for food and habitat, and declining water quality in some rivers when large numbers of pink salmon return to spawn, leaving behind their decaying carcasses.

Then, as northern waters warmed over the years, researchers recorded another big spike in pink catches in Norway in 2019. According to Berntsen, this surge could indicate that the fish has now established its two-year life cycle in Norway, a possibility that fits with research findings from other northern regions. Scientists monitoring rivers and streams around the northern Bering Sea between 1995 and 2018, for example, recently found some evidence suggesting that warming freshwater temperatures contribute to higher survival for pink salmon.

But Berntsen cautions against drawing conclusions too quickly. Other factors could be at play, too. Hypothetically, he says, an increase of even 0.2 °C in the sea might be very beneficial for the prey of pink salmon, thereby increasing the food supply. Or a warming ocean could be detrimental to marine predators of pinks, such as whales and sharks. Just as the odd-year abundance of pink salmon in the North Pacific affected an entire ecosystem and the survival of other species, a slight change in conditions in the waters off Norway might tilt the ecosystem there in favor of the pinks.

But while warming temperatures in northern European waters might be helping pink salmon, a changing ocean off Canada’s west coast could spell serious trouble for other salmon species.

Tucked in the middle of an unusually quiet and empty forestry building at the University of British Columbia, the water pumps and other equipment in Scott Hinch’s lab can be heard from the hallway outside. The fisheries scientist has spent much of his career studying adult salmon migrations, and in a day’s time, he will be inducted into the Royal Society of Canada for his research. Hinch greets me and lets slip that he has to work on his acceptance speech for the ceremony after my visit. Still, he’s made time to show me the performance tests that he and graduate student Natalie Butler are running in the lab.

Hinch shows me four fiberglass troughs, each filled with water and about 125 young chinook salmon. All the fish are stream-type chinook and all are just under a year old: they were obtained from hatcheries in British Columbia’s Shuswap region.

The experiments are designed to test the thermal tolerance of the young fish, and Hinch hopes this work, along with research he’s done on other populations and other life stages, will shed light on chinook salmon in a future shaped by climate change. The water in each of the fiberglass troughs is kept at a specific temperature: 15 °C, 18 °C, 20 °C, or 24 °C. The three coolest temperatures reflect the range that chinook salmon have encountered both in historical times and today, while the warmest represents what they might soon experience. For the past two to three weeks, the juvenile fish have been acclimatizing to the water temperature in their respective trough.

Hinch and his team have already completed one experiment, which showed that some young chinook could tolerate waters as warm as 29 °C to 31 °C for a short period of time. Now the researchers are testing something more ecologically relevant—how long the young fish can swim at a specific temperature. To do this, they move fish from the fiberglass troughs into swim tunnels kept at a specific temperature between 15 °C and 24 °C, and they observe what happens. The experiment entails a lot of waiting. “Natalie just sits here and watches all day as they fail,” Hinch says, laughing. And by “fail,” he means the fish stop swimming and go belly-up. When that happens, she moves the struggling fish to a recovery tank.

So far, they’ve learned that many young fish fail pretty quickly when they’re made to swim at a higher temperature—even if they had previously acclimatized to that temperature. “Just because … fish can acclimate, doesn’t mean they can ecologically perform at those temperatures,” Hinch says. And outside the lab, in a fast-flowing river or stream, the fish need to be able to perform.

Juvenile chinook salmon gleam in a tank at the Seattle Aquarium in Washington State. At the University of British Columbia, fisheries scientist Scott Hinch is studying the thermal tolerance of juvenile chinook to see how they may fare in a time of climate change. Photo by Images By T.O.K./Alamy Stock Photo

These results could indicate a troubled future for many stream-type chinook salmon. But they don't mean that all chinook populations face serious peril. With a varied "financial portfolio," chinook salmon have many different options in the game, many different populations, and some of these produce juveniles that migrate to the sea within their first three months of life, thereby reducing their dependence on freshwater habitats. This poses the question: does the future of salmon lie with populations that spend little time in streams and rivers, heading off to the ocean at the first opportunity? That's certainly the strategy of the pink salmon.

Hinch notes that researchers have long considered oceans to be "risky" places for salmon, since marine environments abound in big, hungry predators such as sea lions and sharks. But what was once considered “safe” or “risky” habitat seems to be shifting. In the Pacific Northwest, humans have urbanized, developed, and dammed much of the freshwater habitat that once provided safe havens and nurseries for juvenile salmon. And that may mean that the ocean is looking better.

So might pink salmon, with their brief sojourns in fresh water, have taken a gamble that’s paying off? Hinch thinks so. Pink salmon may not be the most consistent species, with their steeply fluctuating numbers shaped by their two-year life cycle, but they *are* the most productive today.

Moreover, things are also looking bright for them down the line. According to some climate models, the glaciers of western North America will lose 80 percent of their ice over the next 80 years, creating brand-new landscapes and shifting the ranges of many species. In the 1970s, pinks were the first salmon to colonize Glacier Bay in Alaska after the ice retreated from the fjord. Today, climate change is forcing salmon to adapt to dynamic habitats once again, at a pace they’ve never had to before. And to date, pink salmon have shown they’re able to keep up.

But that doesn’t mean it’s time to throw in the towel on other salmon species. Just ask Dave Scott. In 2016, he and his colleagues at Raincoast began working on ways to help struggling coho and chinook salmon in the Strait of Georgia and the Salish Sea. Scott focused on assisting juvenile salmon in accessing the marshlands of the Fraser estuary before they ventured off to sea. He wants to show me the habitat restoration project that resulted.

As we cruise downstream through the estuary, Scott steers the boat with one hand and points out some of the sights along the way. Some 15 minutes later, we arrive at a spot along the Steveston Jetty, an eight-kilometer-long rock wall that runs parallel to the bank of the Fraser.

Along the Fraser River, Dave Scott points to a newly constructed breach in the eight-kilometer-long Steveston Jetty. The breach serves as an off-ramp, allowing young migrating salmon to exit the Fraser River and reach the marshes in the estuary. Photo by Alice Sun

Constructed roughly a century ago, the jetty acts much like a guardrail on a highway. It guides the flow of ships through the water channel and keeps them from straying into the marshland beyond the riverbank, keeping them on course between the river and the sea. But the construction of the jetty also had an unforeseen consequence. It prevented many young migrating salmon from reaching the maze of marshlands, streams, and mudflats beyond—habitats the fish need in order to rest and adjust to salt water before entering the ocean. In essence, the jetty blocks off some of the access to Sturgeon Bank for the young fish. The Fraser River, Scott says, is "the highway, and we're trying to give them some off-ramps."

To create those "off-ramps," Scott and his colleagues drew up plans to build a few large holes in the jetty, allowing juvenile salmon to swim into the adjacent wetlands. Starting in 2018, a crane was barged to three parts of the jetty. It dug out holes nearly 50 meters wide and stabilized the bottom of each channel with two layers of rock. “We basically rebuilt the jetty here with an opening,” Scott says.

Scott waves at some of his team members, who are standing in waders on grassy mudflats near the opening, clipboards in hand. They have set up a net in the newly made channel, ready to catch any fish as they travel through this breach. Then they release them. But this August afternoon, as water temperatures reach 19 °C in the estuary, few young salmon are seeking out the channel. It’s too late in the season. Earlier in the spring, however, when the waters were a favorable 7 °C, the team caught as many as 300 juvenile chinook and chum salmon a day, each taking the new off-ramp into neighboring wetlands. “We couldn’t believe our eyes as we kept retrieving them,” Scott noted in an article on the Raincoast Conservation Foundation website.

For a sampling project, students working with the Raincoast Conservation Foundation maneuver a net across one of the new breaches in the Steveston Jetty. In the spring, the team caught, counted, and released as many as 300 juvenile chinook and chum salmon per day using the breach—a clear measure of success. Photo by Alice Sun

Reducing barriers to wetlands and improving access to vital habitat in the Fraser estuary is only one small part of the work that needs to be done to conserve the Fraser River's famous salmon, however. Much more remains, and it's clear that—much like the salmon—we are on a tight deadline.

If we can't find a way to slow the pace of climate change and give Pacific salmon a chance to adapt to the brave new world of the Anthropocene, then we might all have to get used to the idea of fewer Pacific salmon species in the world.

**From:** Nancy Hillstrand
**Sent:** Thursday, July 15, 2021 1:08 PM
**Subject:** Profit, Genetic Diversity Loss, and BC's Salmon Collapse

Alaska follows this pattern

**https://watershedsentinel.ca/articles/profit-genetic-diversity-loss-and-bcs-salmon-collapse/?mc_cid=e71f8202ec&mc_eid=fa4ff75642**

"The reality is that the collapse of west coast salmon lies in the collapse of wild salmon genetics. **Notwithstanding the good intentions** of DFO's "Wild Salmon Policy," the vast majority of BC salmon are now largely hatchery stock, and **little attention is given to the importance of a largely-lost diversity of small populations.** The DFO strategy is intended to maintain the diversity of "the stock" – the fisheries stock (not the "populations") – while continuing to make it available as an economic resource. In other words, the economy continues to be the priority and conservation pays the piper.

What this leads to has been spelled out by H.H. Price in a January 2021 study[3] on the collapse of population and wild genetic diversity in Skeena sockeye. Based on long-term data from 1912 onwards, what is reported is that one population, the Babine population, which consists mainly of hatchery stock, now makes up 91% of returns in the Skeena fishery.

With many smaller populations having been extirpated, abundance has contracted throughout the entire watershed and population diversity has declined by 70%. Life histories needed to respond to changes in ocean conditions have shifted or disappeared. The return of wild salmon is 31% of historic numbers – and as we know from standard fisheries modeling, 30% is the critical limit at which fisheries should be shut down. The actual low genetic diversity of these sockeye makes them extremely vulnerable to climate change impacts."

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RESEARCH ARTICLE

# Portfolio simplification arising from a century of change in salmon population diversity and artificial production

**Michael H. H. Price**[1] | **Jonathan W. Moore**[1] | **Brendan M. Connors**[1,2] | **Kyle L. Wilson**[1] | **John D. Reynolds**[1]

[1]Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC, Canada

[2]Fisheries and Oceans Canada, Institute of Oceans Sciences, Sidney, BC, Canada

**Correspondence**
Michael H. H. Price
Email: mhprice@sfu.ca

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## Abstract

1. Population and life-history diversity can buffer species from environmental variability and contribute to long-term stability through differing responses to varying conditions akin to the stabilizing effect of asset diversity on financial portfolios. While it is well known that many salmon populations have declined in abundance over the last century, we understand less about how different dimensions of diversity may have shifted. Specifically, how has diminished wild abundance and increased artificial production (i.e. enhancement) changed portfolios of salmon populations, and how might such change influence fisheries and ecosystems?
2. We apply modern genetic tools to century-old sockeye salmon *Oncorhynchus nerka* scales from Canada's Skeena River watershed to (a) reconstruct historical abundance and age-trait data for 1913–1947 to compare with recent information, (b) quantify changes in population and life-history diversity and the role of enhancement in population dynamics, and (c) quantify the risk to fisheries and local ecosystems resulting from observed changes in diversity and enhancement.
3. The total number of wild sockeye returning to the Skeena River during the modern era is 69% lower than during the historical era; all wild populations have declined, several by more than 90%. However, enhancement of a single population has offset declines in wild populations such that aggregate abundances now are similar to historical levels.
4. Population diversity has declined by 70%, and life-history diversity has shifted: populations are migrating from freshwater at an earlier age, and spending more time in the ocean. There also has been a contraction in abundance throughout the watershed, which likely has decreased the spatial extent of salmon provisions to Indigenous fisheries and local ecosystems. Despite the erosion of portfolio strength that this salmon complex hosted a century ago, total returns now are no more variable than they were historically perhaps in part due to the stabilizing effect of artificial production.
5. *Policy implications*. Our study provides a rare example of the extent of erosion of within-species biodiversity over the last century of human influence. Rebuilding a diversity of abundant wild populations—that is, maintaining functioning portfolios—may help ensure that watershed complexes like the Skeena are robust to global change.

**KEYWORDS**
artificial production, biodiversity loss, conservation genetics, fisheries, historical ecology, population diversity, portfolio effects, salmon abundance

## 1 | INTRODUCTION

The conservation of common species often is poorly aligned with extinction-focused assessments (Gregory et al., 2005). For example, roughly 95% of the loss in abundance among the world's birds derives from <10% of species, and the vast majority of these are assessed as least concern by the International Union for the Conservation of Nature (Baker et al., 2019). Likewise, the diversity in life-history characteristics and population processes within and among populations is far greater than among species (Hughes et al., 1997), yet global biodiversity assessments typically are species focused (e.g. Maxwell et al., 2016); such emphasis can substantially underestimate the changing state of nature (Luck et al., 2003). Abundance and diversity within populations are important conservation assets independent of global extinction risk (Balmford et al., 2003). Indeed, abundant species and their diverse populations disproportionately influence ecosystems (Gaston et al., 2018).

Biodiversity has many dimensions that contribute multiple benefits to humanity (Morris et al., 2014). One key benefit of biodiversity is that it helps stabilize ecosystem processes and functions, thereby bestowing resilience to environmental change. Such stability can arise through portfolio effects, where the aggregation of asynchronous dynamics dampens variability (Doak et al., 1998; Figge, 2004). Accordingly, portfolio effects can be stronger in systems with higher (a) richness—the number of species or populations in the system, (b) evenness—the proportional distribution of abundance or mass among the units (e.g. populations) of biodiversity and (c) asynchrony—the different responses of biodiversity to environmental forcing through time (Doak et al., 1998). For example, the intact habitat complexes of southwestern Alaska support high levels of population richness and asynchrony in sockeye salmon *Oncorhynchus nerka* that, in turn, stabilize commercial fishery catches (Schindler et al., 2010). There also is a growing appreciation of diversity among individuals, which can contribute to population-level resilience. For example, a diversity of life histories (e.g. different ages-at-maturity) within a population can spread risk across the demographic structure of that population, thereby buffering it from environmental variation over time (Greene et al., 2010; Moore et al., 2014). The spatial distribution of biodiversity can further influence the beneficial extent of that diversity, such as the degree to which consumers can access consistent prey resources across space and time (e.g. Deacy et al., 2016; Nesbitt & Moore, 2016). Thus, understanding the potential long-term shifts in the dimensions of biodiversity is a key frontier for conservation science.

Pacific salmon *Oncorhynchus* spp. are common and abundant species with substantial population and life-history diversity (Groot & Margolis, 1991). However, there is a growing appreciation that salmon have been undergoing major shifts in the dimensions of their diversity due to human activities. Most apparent is the decline in abundance and extinction of many populations in southern portions of their range resulting from habitat loss and over-exploitation (Gustafson et al., 2007; Slaney et al., 1996). In response to decreasing abundance, artificial production (i.e. enhancement) programmes—such as hatcheries and spawning channels—have increasingly been initiated. This enhancement may increase abundances for some populations but also can erode local diversity (Naish et al., 2008), homogenize life-history traits (Satterthwaite & Carlson, 2015) and further erode wild salmon abundances through competition in the ocean (Connors et al., 2020) or the subsidization of fisheries (Meffe, 1992). Life histories also are shifting with climate change (Oke et al., 2020). While several studies have documented shifts in dimensions of salmon diversity over the last several decades (e.g. Carlson & Satterthwaite, 2011; Moore et al., 2010), it has remained a challenge to understand potential changes over longer periods, such as the last century of major human impacts.

Here, we study Canada's Skeena River watershed to ask: how has sockeye salmon diversity changed over the last century of enhancement and other human activities (e.g. fishing and habitat alteration) and how might such change affect current fisheries and ecosystems? We use modern genetic tools with century-old fish scales to (a) reconstruct historical abundance and age-trait data for the 1913–1947 time period to compare with contemporary information, (b) quantify changes in population and life-history diversity and the role of enhancement in population dynamics, and (c) quantify the risk to fisheries resulting from observed changes in diversity and enhancement. Our results demonstrate substantial loss in abundance and diversity of wild sockeye populations over the last century. While enhancement has offset declines in wild populations and maintained aggregate abundances—which underpins the Skeena commercial fishery—loss in abundance from wild populations undermines food security and ecosystem provisions throughout much of the watershed.

## 2 | MATERIALS AND METHODS

The Skeena watershed is composed of 31 sockeye Conservation Units (CU; Holtby & Ciruna, 2007), which are grouped into 13 population complexes (Price et al., 2019; Figure 1; hereafter referred to as *populations*). Commercial fishing for sockeye began at the mouth of the Skeena River in 1877 (Wood, 2008), and a scale-collection programme began in 1912. We sampled scales from 35 to 50 fish from the collection for each of nine fishing weeks from years 1913, 1916, 1918–1923, 1933, 1935, 1937, 1943, 1945 and 1947 for a total of 5,400 scales. Sampling either began 1 week late or ended 1–2 weeks early in some years (i.e. 1913, 1916, 1918, 1920, 1937, 1943 and 1945) such that scales were unavailable

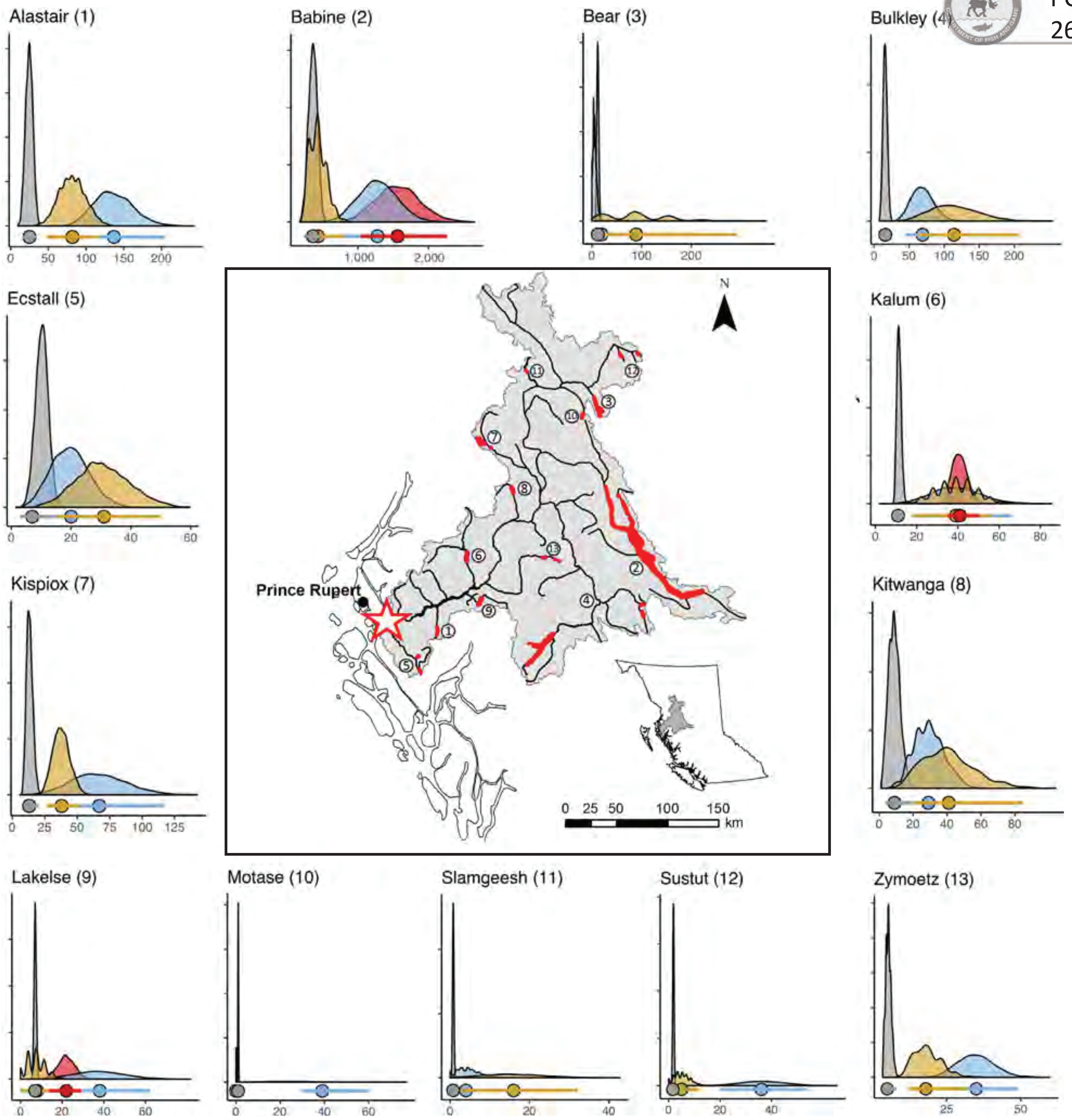

**FIGURE 1** Skeena River watershed and sockeye salmon population abundances. Inset: Skeena River watershed showing locations of each sockeye salmon population complex (numbers 1–13) identified in genetic analyses, with associated nursery lakes (in red), and approximate location of historical scale sample collection and current Skeena Tyee Test Fishery (white-filled red star). Border: estimated population abundance (in thousands) during the 1913–1923 (blue), 1933–1947 (orange) and 2010–2017 (grey) time periods. Red distributions (#2, 6, 9) denote total (wild plus enhanced) abundance during 2010–2017. Circles and horizontal lines are the arithmetic mean and 95% bootstrapped confidence intervals

in some weeks. Because these omissions likely were due to low availability of fish to fisheries, we consider the implications to our analyses negligible. We digitally photographed one scale per fish, and aged each scale by annuli counts (Gilbert, 1913). DNA was extracted from scales, genotyped at up to 12 microsatellite loci, and individuals were assigned to population via genetic stock identification (see Appendix S1). All scale samples were from existing collections and therefore exempt from Simon Fraser University's Animal Care Protocol.

We estimated annual historical (1913–1947) numbers (i.e. catch plus spawning fish, which throughout we refer to as *abundance*) of sockeye at the population level in a four-step process (Figure S1; Price et al., 2019), which included three year- and week-specific data inputs: (a) Annual abundance derived from catches (Argue & Shepard, 2005) and exploitation rates (Shepard & Withler, 1958) reconstructed from Skeena cannery and fishery data. (b) Daily counts of sockeye entering the Skeena River from each of 7 years (2011–2017), partitioned into nine fishing weeks equivalent to the historical scale-sampling periods. (c) Weekly proportions of Skeena-origin populations identified in scales. Briefly, with these data, we randomly drew from one of the 7 years of weekly abundance proportions, multiplied these by a given historical year's aggregate abundance, then multiplied these weekly abundances by population proportions, and summed population abundances across weeks. We repeated these steps 50,000 times, and then derived a median abundance estimate for each population for each historical year.

Estimates of total abundance during the modern (2004–2017) era are available from PSF (2020) and English et al. (2018), and detailed in our Supporting Information. Major enhancement projects have occurred since 1970 for three sockeye populations: Babine, Kalum and Lakelse; minor enhancement efforts had occurred for at least two populations (Lakelse and Babine) prior to 1970, with little success (Foerster, 1968). To estimate wild-only abundance for the Babine population, we combined annual abundance estimates for the four wild Babine CUs. Annual estimates of wild fish for Kalum were derived from run-reconstructions detailed in the citations above, but with spawning channel contributions removed (Appendix S2). Finally, to estimate wild-only abundance for the Lakelse population, we substituted years 2002–2009 (pre-enhancement) for 2010–2017 (post-enhancement) because we could not disaggregate enhanced contributions for the latter years, which greatly increased the abundance of sockeye returning to Lakelse.

We quantified the spatial contraction of population abundance throughout the Skeena watershed, and the potential loss of fish available to in-river fisheries and wildlife. This required estimates of in-river abundance for each population for the two time periods: (a) historical (1913–1947; quantified by subtracting commercial catch from our reconstructed historical abundance estimates) and (b) modern [2004–2017; quantified by adding annual in-river fishery catch (English et al., 2017) to spawning escapement (wild and enhanced fish combined)]. We then compared the change in in-river abundance between time periods for each population (tributary system), and each main-stem section of the Skeena River between populations, by subtracting each population's abundance downstream of each main-stem river section from the total in-river abundance.

We used several sources of age-at-maturity data depending on our question. For example, we used age data from fish (aggregate of populations) caught in commercial fisheries, as reported in annual fisheries reports for the years 1916–1956 (Province of British Columbia, 1957), and from fish caught in the Tyee Test Fishery for the years 1973–2016, to estimate changes in life-history diversity and age-at-maturity. We used data from fish (identified to population) collected from commercial fisheries for 1913–1947, and from the Tyee Test Fishery for 2000–2013 to estimate changes in age traits within populations, and to explore the strength of salmon portfolios during various time periods. Because sockeye returning to the Skeena River during 1877–1950 were caught exclusively by linen gill-nets in commercial fisheries, we applied a correction factor to historical age data based on the selectivity of sockeye captured during the modern era by gill-nets in the Tyee Test Fishery to more accurately characterize the historical proportion of ages-at-maturity (Appendix S3). When describing various age-related life-history expressions (i.e. age traits), we use the European designation where the first number denotes the years spent in freshwater, and the second number denotes the years in the ocean (e.g. 1.2 represents 1 year in freshwater and 2 years in the ocean, and 1.*x* represents fish spending 1 year in freshwater and any number of years in the ocean).

We quantified the extent to which diversity among populations in abundance and life history has changed over time (historical versus modern era). Specifically, we calculated Pielou's Evenness, $E$, as a measure of diversity each year:

$$E = H/\ln S \tag{1}$$

where $S$ is the number of populations ($n = 13$) or age traits ($n = 4$), and $H$ is the Shannon diversity index:

$$H = -\sum_{i-1}^{S} p_i \ln p_i \tag{2}$$

where $p$ is the proportional contribution of group $i$ such that $\sum_i^S p_i = 1$ (Oksanen et al., 2019). Evenness is bounded between 0 and 1, with 1 being a completely even distribution among populations ($S$). To examine how enhancement of populations post-1970 has affected both population- and age-diversity, we calculated evenness separately using 'wild-only' and 'total' (enhanced plus wild) abundances; these abundances were applied separately to age-trait proportions to generate annual estimates of each age trait before calculating evenness.

We explored whether the strength of salmon portfolios in the Skeena has changed over time by calculating portfolio effect for each period (1913–1923, 1933–1947, and 2010–2017); here we compared the coefficient of variation (CV; defined as the ratio of the standard deviation to the mean) for the Skeena sockeye complex as a whole (i.e. meta-population CV) to the arithmetic mean CV for individual component population abundances and age traits (i.e. average CV). We chose the 8-year period of 2010–2017 for recent years to be comparable with the eight data-years of 1913–1923; Ecstall and Motase populations were excluded due to lack of recent data.

With these data, we then quantified the individual and combined consequences of (a) portfolio effects, (b) population abundances, and (c) enhancement, on the probability of commercial fishery closures for sockeye returning to the Skeena over the three time periods. Annual commercial fishery openings for Skeena sockeye currently are based on an aggregate abundance target of 1.05 million fish (900,000 spawning escapement plus 150,000 for Indigenous fisheries; DFO, 2003), below which the mixed-stock commercial fishery is closed. We simulated annual pre-fisheries abundances of wild sockeye in each time period by drawing from a log-normal distribution with a bias-corrected mean and standard deviation (i.e. CV, equal either to the meta-population CV or average CV). We repeated this for each time period across 10,000

Monte Carlo trials, and then calculated the proportion of trials where system-wide abundance fell below the aggregate abundance threshold of 1.05 million fish. For the recent period, we simulated wild-only and total (wild plus enhanced fish combined) abundances separately to quantify the degree to which enhancement may influence the probability of commercial fishery closures. Admittedly, our simulation ignores the potential confounding effects of forecast error and changes in exploitation on subsequent population dynamics.

All analyses were performed in R (R Core Team, 2020) using the BOOT, ECOFOLIO, and VEGAN packages.

## 3 | RESULTS

The total number of wild adult sockeye returning to the Skeena River during the modern era is 69% lower than during the historical era of commercial fishing. All wild populations have declined (median = −80%) over the last century, several by more than 90%, and headwater populations (i.e. situated upstream of Babine; #2) have declined the most (average: −93%; Figure 1). While most populations had declined in abundance by 1933–1947, five populations had increased, but then declined over the modern era. For example, the Bear population (#3) increased from an average of 22,000 to 89,000 (range: 0–415,000), and Bulkley (#4) from 69,000 to 114,000 (range: 25,000–276,000). Population composition also has shifted between periods such that the Babine population once accounted for 68% of all wild sockeye returning to the Skeena, declined to 48% by 1933–1947, then increased to 75% recently. When enhanced fish are combined with wild fish, Babine now accounts for 91% of all sockeye returning to the Skeena watershed (Figure 2a).

Skeena sockeye currently exhibit the 10 age traits identified in scales collected one century ago, of which 99% are one of four dominant freshwater/ocean ages: 1.2, 1.3, 2.2, or 2.3 (Figure 2b; Appendix S4). Two additional contemporary life histories—fish that reared in freshwater lakes for 3 years and returned to spawn after either 2 (3.2) or 3 (3.3) years in the ocean—were not among those caught in historical fisheries. While the average age (freshwater plus ocean) of populations has not changed, there has been a shift in age composition. For example, the proportion of wild fish with the *x*.3 (longer residency in the ocean) life history has increased from 37% to 47% (Figure 2b). When enhanced fish are included, 51% of sockeye spent 3 years in the ocean, and the proportion of fish in a given year migrating to the ocean after one freshwater year increased from 87% to 96% (Figure 2c).

Individual contributions of wild populations to aggregate abundances have greatly diminished. For example, mean evenness of wild population contributions to overall abundances declined by 35% (from 0.62 to 0.40) between the historical and modern era. When enhanced fish are combined with wild fish, the decline over the last century is even greater (evenness = 0.18 in the recent period, a 70% total decline; Figure 3a). The evenness of age traits declined by 19% (from 0.68 to 0.55) during the period since 1973, and inclusion of enhanced fish only modestly reduced the evenness further (to 0.54; Figure 3b).

The extent to which the population portfolio dampened inter-annual variation in abundance has eroded over the last century. For example, portfolio strength during 1913–1923 resulted in aggregate returns that were 2.04 times more stable than if the system had been composed of a single population with homogeneous dynamics (CV reduced from 1.01 to 0.50). For 1933–1947, the comparable value was 1.48 (CV reduced from 0.96 to 0.65). The benefits of population diversity for stabilizing returns have largely disappeared in recent (2010–2017) years (i.e. aggregate returns now are only 1.10 times more stable—CV reduced from 0.57 to 0.52; Figure 4a). Had

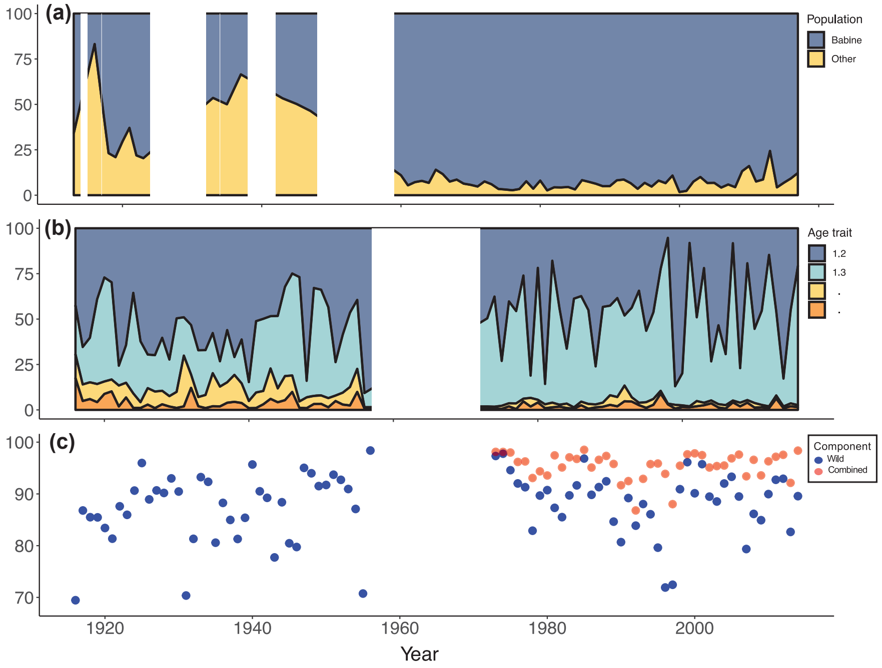

**FIGURE 2** Long-term change in sockeye salmon population and life-history diversity. (a) Percentage of population abundances, where *Other* combines all populations except Babine. (b) Percentage of the four dominant age traits. (c) Percentage of juveniles that emigrated to the ocean after 1 year in freshwater; blue and red circles denote wild fish, and wild and enhanced fish combined, respectively (i.e. for the years since enhancement began, data for each year are shown twice: once for wild fish, and once for wild and enhanced fish combined). Information gaps (white bars) differ in plots a and b because the data are derived from different sources (a: historical scale collection; b: annual government fishery reports)

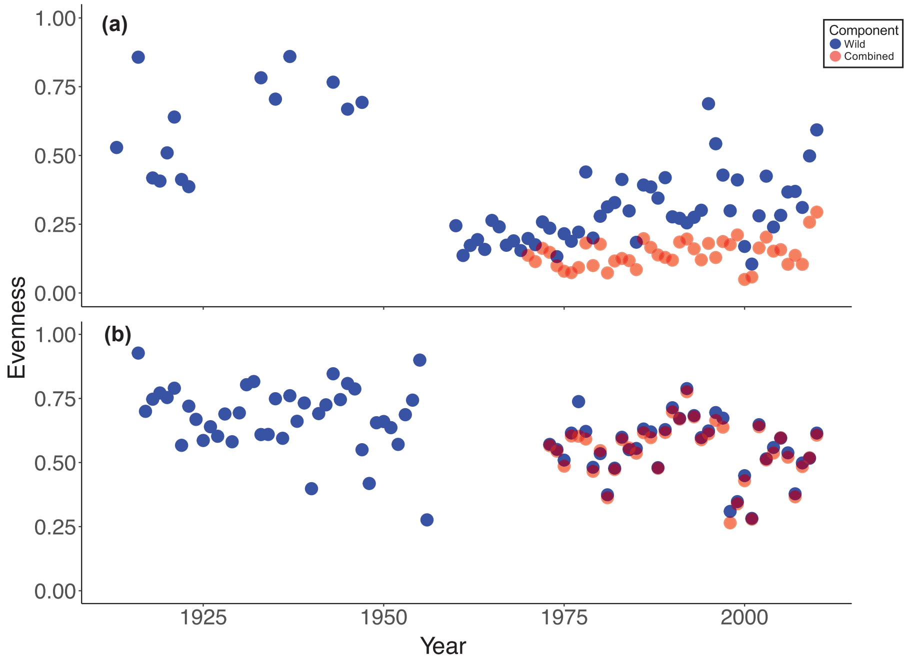

**FIGURE 3** Long-term change in sockeye salmon diversity. (a) Evenness in abundance across individual populations. (b) Evenness in age traits across aggregated populations. Blue and red circles denote wild fish, and wild and enhanced fish combined, respectively (i.e. for the years since enhancement began, data for each year are shown twice: once for wild fish, and once for wild and enhanced fish combined)

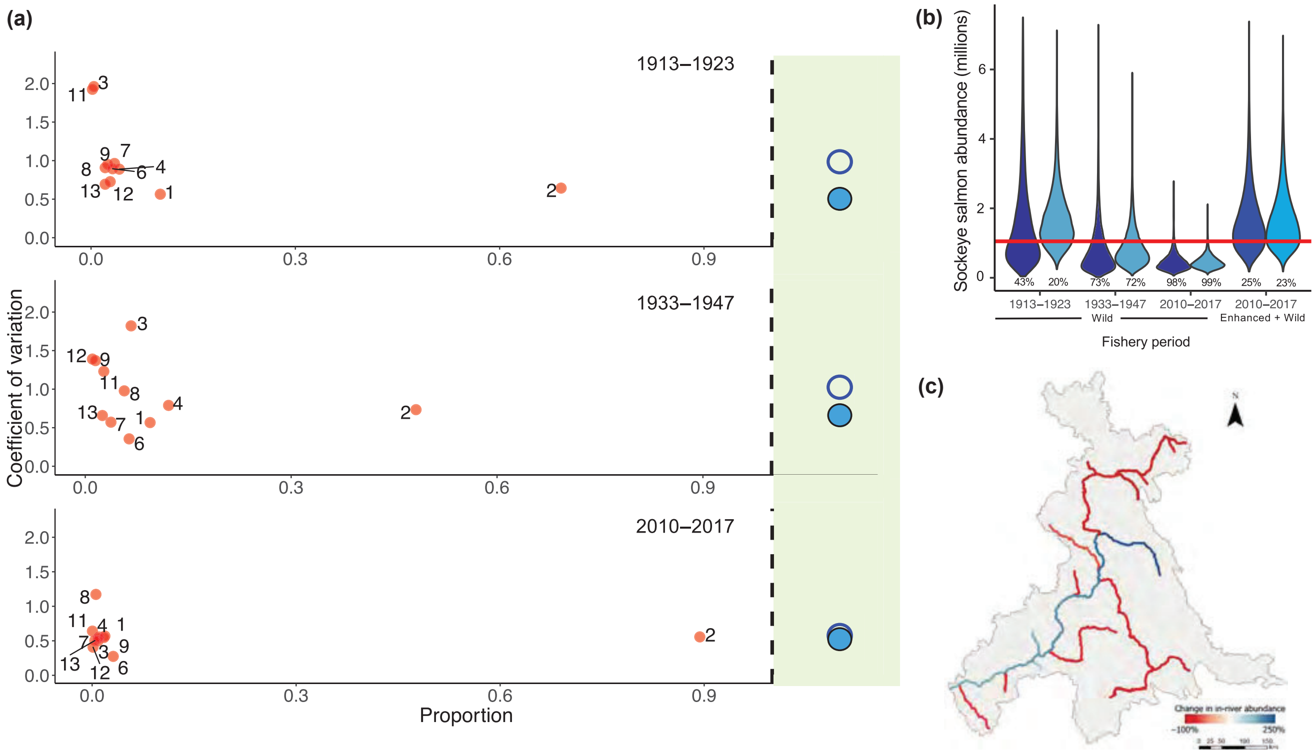

**FIGURE 4** Changes in sockeye salmon population diversity and their influence on fisheries and ecosystems. (a) Portfolio effect: each red-filled circle represents the coefficient of variation (CV) of abundance (wild and enhanced combined) across years for each time period as a function of the proportional contribution of each population to total returns; numbers correspond to Figure 1. Shown within green bar is the estimated CV based on the average of the CVs of the different populations (dark-blue circle), and the measured meta-population CV of the entire Skeena sockeye complex (filled light-blue circle). The difference between the estimated and measured CV is a measure of the magnitude of reduction in variation due to the portfolio effect. (b) Simulated abundance and risk of commercial fishery closures for each time period assuming either the average CV (dark blue) or meta-population CV (light blue). Red solid line is the aggregate abundance target of 1.05 million, above which the commercial fishery begins. Values below each distribution are the percentage of simulation trials that were below the abundance target. (c) Change in in-river sockeye abundance (number of fish in the Skeena River and tributaries after marine and lower river commercial fishery removals) between the historical (1913–1947) and modern (2004–2017) eras

the Skeena sockeye complex lacked the dampening effects that population diversity provides (i.e. using average versus meta-population CV), commercial fishery closures would have occurred 42% of the time (a 55% increase compared to a diverse system) during the 1913–1923 period, and 74% of the time (3% increase) during 1933–1947 (Figure 4b). While commercial fisheries based on wild fish now would be closed in at least 98% of years because of low abundance, enhanced sockeye production has effectively replaced the loss in wild fish and sustained commercial fisheries.

Finally, the observed changes in abundance are associated with spatial contraction of sockeye abundance throughout the Skeena watershed. Specifically, wild populations have undergone major declines in tributaries (41%–90% loss) and headwater main-stem sections (75%–87% loss; Figure 4c). Enhancement sustains abundance primarily in one major tributary (Babine) and the main-stem river downstream of Babine.

## 4 | DISCUSSION

Conserving a diversity of populations and their varied life histories can help buffer ecosystems from environmental change (Schindler et al., 2015). We applied modern genetic tools to century-old fish scales to reveal substantial loss in abundance and biodiversity of wild sockeye populations over the last 100 years for Canada's second largest salmon watershed, the Skeena River. While artificial enhancement has returned aggregate abundances to historical levels, declines in abundance across wild populations have increased the dependency of fisheries on enhanced fish, potentially widening the trade-off between exploitation and conservation of diversity in the watershed (Walters et al., 2008; Wood, 2008). Consequently, the Skeena has lost much of the stabilizing portfolio effects that population diversity had provided a century ago. Furthermore, there has been a spatial contraction in abundance throughout the watershed, which likely decreases the provisioning of salmon to local ecosystems and Indigenous fisheries.

Artificial salmon production has returned abundances to what they were a century ago, but such enhancement may compromise diversity across the watershed. While the abundance of all wild sockeye populations in the Skeena now is substantially lower than during the historical era, some populations—such as Babine—had already declined by the 1940s, which prompted the development of spawning channels by 1970 to rebuild diminished abundance (McDonald & Hume, 1984). Enhancement has since increased annual total sockeye returns to 99% of the estimated abundance of one century ago, which has renewed opportunities for commercial marine fisheries and Indigenous fisheries in Babine Lake and the main-stem river downstream. Despite these benefits to fisheries, enhanced production may impact wild Skeena populations in at least four ways: (a) Pathogen transfer from enhanced to wild fish could decrease survival. While there historically have been disease outbreaks at Babine spawning channels (Traxler et al., 1998), improvements may have decreased these risks. (b) Straying of enhanced fish may erode local adaptations in wild populations due to introgression (Naish et al., 2008). Sockeye salmon are known to spawn near their river-of-origin, and different Skeena populations remain genetically distinct (Beacham et al., 2014), yet enhanced fish may stray into wild spawning streams within the Babine system given the close proximity of spawning channels to neighbouring wild streams. (c) Enhanced fish could compete with wild fish (Peterman, 1982). However, there is no evidence that the production of enhanced sockeye has reduced the survival of wild populations (Price & Connors, 2014). (4) Enhanced fish could elevate mortality of wild fish as a result of their incidental capture in mixed-stock fisheries targeting enhanced fish (Meffe, 1992). Increases in aggregate abundance since 1970 are thought to have exacerbated the trade-off between mixed-stock fisheries catch and the protection of wild population diversity in the watershed (Walters et al., 2008; Wood, 2008). All wild populations likely were over-exploited in the decades immediately following spawning channel development due to their co-migration with enhanced sockeye (Walters et al., 2008). However, Canadian aggregate mixed-stock exploitation has declined in recent years [from 46% (1970–2009) to 28% (2010–2017); English et al., 2018], and may be sustainable for some wild populations. Thus, the degree to which enhancement now compromises sockeye diversity in the Skeena remains unclear.

Life-history diversity has remained relatively stable since the historical era, though there have been notable shifts in age composition. Sockeye in the Skeena currently display all age traits identified in scales that were collected one century ago, which may indicate the persistence of diverse habitats in the watershed (Waples et al., 2001). Nonetheless, fish are remaining longer in the ocean, with an increase (from 36% to 51%) in the proportion of fish that rear in the ocean for 3 years. Similar increases have been reported for sockeye from the Fraser River and Bristol Bay over the recent period (Cline et al., 2019; Ruggerone & Connors, 2015); increased biomass of salmon in the North Pacific Ocean and shorter residency in freshwater are thought to contribute to these trends. Our data also show that Skeena sockeye now spend less time in freshwater (e.g. decrease from 13% to 4% in the proportion of fish that rear for 2 years). While the reduced duration of freshwater residency across wild populations may be influenced by increasing lake temperatures (as has occurred in Alaska; Cline et al., 2019), enhancement of Babine fish is further increasing the overall prevalence of this life history (Appendix S5). This change in age-structure—where most juveniles now emigrate to the ocean in the same year—increases the risk that an entire cohort will encounter unfavourable conditions (e.g. Moore et al., 2014), and may reduce the resilience of the Skeena sockeye complex to future environmental change.

Portfolio effects have largely eroded in the Skeena over the last century. Had the dynamics of the Skeena sockeye complex a century ago been characterized by the most simplified population portfolio (i.e. a single population), they would have been 2.04 times more temporally variable than was observed. This strength in portfolio is similar to the Bristol Bay sockeye complex, which hosts hundreds of populations from largely undisturbed habitat, and does not have salmon enhancement (Schindler et al., 2010). By 1933–1947, portfolio strength in the Skeena had been reduced by one-third, yet the population complex still was 1.48 times more stable than if it had been composed of a single population. In recent years, the benefits of population diversity have nearly disappeared (i.e. aggregate returns now are only 10% more stable). Degraded portfolio performance is correlated negatively with anthropogenic impact on watersheds across western North America (Griffiths et al., 2014). However, even in a recently collapsed Chinook salmon *Oncorhynchus tshawytscha* system with extensive habitat degradation—where enhancement is thought to have significantly weakened the portfolio (Satterthwaite & Carlson, 2015)—the strength of the population portfolio since the mid-1980s is far greater than it is now for Skeena sockeye (Carlson & Satterthwaite, 2011), although there may be an inherent challenge in comparing across species. While enhancement has simplified the Skeena portfolio by tripling the abundance of sockeye returning to a single population since 2010—removal of enhanced fish from the analyses increased portfolio strength by a factor of five—declines in portfolio strength since the 1913–1923 period also were influenced by increased population synchrony (Appendix S5). Regardless of the mechanism, a notable consequence of the portfolio simplification is that commercial fisheries now depend on a single population that is largely composed of enhanced fish, whereas a diversity of populations sustained fisheries historically.

A simplified population portfolio should lead to an increase in variability of aggregate abundances. However, sockeye returns to the Skeena now are as stable as they were during the historical era despite a weakened portfolio. Such reduced variability may be because the aggregate's variability now is primarily influenced by a single population whose annual production is at least in part stabilized by artificial enhancement. While variability in population abundances also has decreased over the recent period, an inherent challenge in measuring change over long time periods such as ours is the different data collection methods used between eras. We used an admittedly coarse method to quantify population abundance during the historical era compared to higher precision methods of the modern era, which may inflate declines in portfolio strength between periods. However, when we compared the variability of populations between periods using genetic (rather than abundance) data, population variability remained lowest in the modern era (i.e. populations now are more stable than during either of the historical periods; Appendix S5). Indeed, sockeye populations in the Skeena have become more synchronized with one another, all but one (Babine) are at low levels of abundance, and perhaps are responding similarly to a low productivity phase that could be the result of reduced response diversity of these populations. Thus, despite the relative stability of sockeye returns to the Skeena over the recent period, the weakened portfolio may compromise its resilience to larger perturbations in the future.

The erosion of diversity in the Skeena is further expressed in the spatial contraction of salmon abundance throughout the watershed. Wild sockeye abundance has declined in all tributaries and headwater regions since the historical era, which—according to oral accounts—has compromised food security for Indigenous Peoples that rely upon these areas for subsistence fisheries (Cleveland et al., 2006; Gottesfeld & Rabnett, 2008). Furthermore, these tributaries are important corridors that provision salmon resources to local ecosystems. Such loss in abundance likely constrains foraging opportunities for wildlife dependent on salmon (Deacy et al., 2016), and lessens the overall delivery of salmon-derived nutrients to ecosystems (Gende et al., 2002), which can affect a large number of species (Walsh et al., 2020).

Our reconstruction of century-old portfolio performance provides a baseline for the recovery of a diminished watershed complex. Modern conservation policies for salmon, such as Canada's Policy for the Conservation of Wild Pacific Salmon, strive to maintain a diversity of populations (DFO, 2005). If the goal of fisheries management is to catch abundant channel-enhanced fish while conserving wild populations, increasing selectivity by moving a larger proportion of the fishery in-river and to terminal locations likely will improve conservation, though it may result in reduced catches (Freshwater et al., 2020). Prioritizing the rebuilding of wild salmon populations could mitigate such trade-offs, help increase fishing opportunities for Indigenous peoples that rely on wild populations and strengthen the sockeye portfolio within this now simplified watershed.

Our study provides a rare example of the extent of erosion of within-species biodiversity over a century of human influence. While the enhancement of salmon supports commercial fisheries, loss in abundance and diversity from wild populations has reduced the provisioning of salmon to local ecosystems and Indigenous fisheries throughout the watershed. What may be underappreciated is the lost stabilizing portfolio effects that this watershed complex hosted a century ago, which ultimately may weaken its resilience to increasingly variable environments. Conserving a diversity of abundant wild populations and their varied life histories—that is, maintaining functioning portfolios—may help ensure that watershed complexes like the Skeena are robust to global change.

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## AUTHORS' CONTRIBUTIONS

M.H.H.P., J.W.M., B.M.C., K.L.W. and J.D.R. conceived the ideas and designed the methodology; M.H.H.P. collected the data; M.H.H.P.

and K.L.W. analysed the data; M.H.H.P. led the project and writing of the manuscript. All authors contributed critically to drafts and gave final approval for publication.

## DATA AVAILABILITY STATEMENT

Data available via the Dryad Digital Repository https://doi.org/10.5061/dryad.n5tb2rbts (Price, 2021).

## ORCID

*Michael H. H. Price* https://orcid.org/0000-0002-2909-8836
*Kyle L. Wilson* https://orcid.org/0000-0002-0870-0509
*John D. Reynolds* https://orcid.org/0000-0002-0459-0074

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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# Portfolio simplification arising from a century of change in salmon population diversity and artificial production

## Appendix S1: Genetic identification of populations

Genetic material was extracted from fish scales by DNeasy extractions (Qiagen Inc, Valencia, CA) at Fisheries and Oceans Canada molecular genetics laboratory; samples were genotyped for up to 12 bi- and tetra-nucleotide microsatellites from anonymous regions of the sockeye genome using Polymerase Chain Reaction (PCR). While we employed standard genotyping protocols for the historical samples, we used several additional steps to ensure genotype accuracy. For example, we made adjustments to DNA concentrations depending on DNA quality by including more scales (up to 10 per individual fish), used de-multiplex loci to improve amplification on a locus by locus basis, and excluded loci with large base-pair size ranges because of DNA fragmentation. We used the following microsatellite primers to examine nuclear DNA polymorphisms in single PCR reactions: Ots2, Ots3, Ots100, Ots103, Ots107, Ots108, Oki1a, Oki1b, Oki6, Oki10, One8, and Omy77. The properties of these microsatellite markers and their ability to resolve coast wide sockeye stock structure have been reported elsewhere (e.g., Beacham et al. 2004, 2006, 2011). Microsatellites were size fractionated in an Applied Biosystems 3730 capillary DNA sequencer, and genotypes scored by GeneMapper software 3.0 (Applied Biosystems, Foster City, CA) using an internal lane fragment size standard.

We used the Bayesian mixed stock assignment C++ program CBayes (Neaves et al. 2005) using algorithms from the FORTRAN program BAYES (Pella & Masuda 2001) to assign historical scales to population. This mixture analysis assigns individuals to putative population of origin by fitting allele frequencies of the unknown individual to the allele frequencies of reference samples collected on the spawning grounds. For each mixed-stock sample, ten 20,000-iteration Monte Carlo Markov chains of estimated stock composition and individual assignments were run, where each chain was initialized with 90% assignment to a randomly selected reference sample. The last 1,000 iterations from each chain were combined with a Gelman-Rubin coefficient < 1.2 (Pella & Masuda 2001) to estimate probability of assignment to baseline population, then combined for each meta-population. Duplicate genotypes, non-sockeye salmon, and those individuals with more than 9 missing loci were removed before the final population assignment.

## Appendix S2: Population abundance data

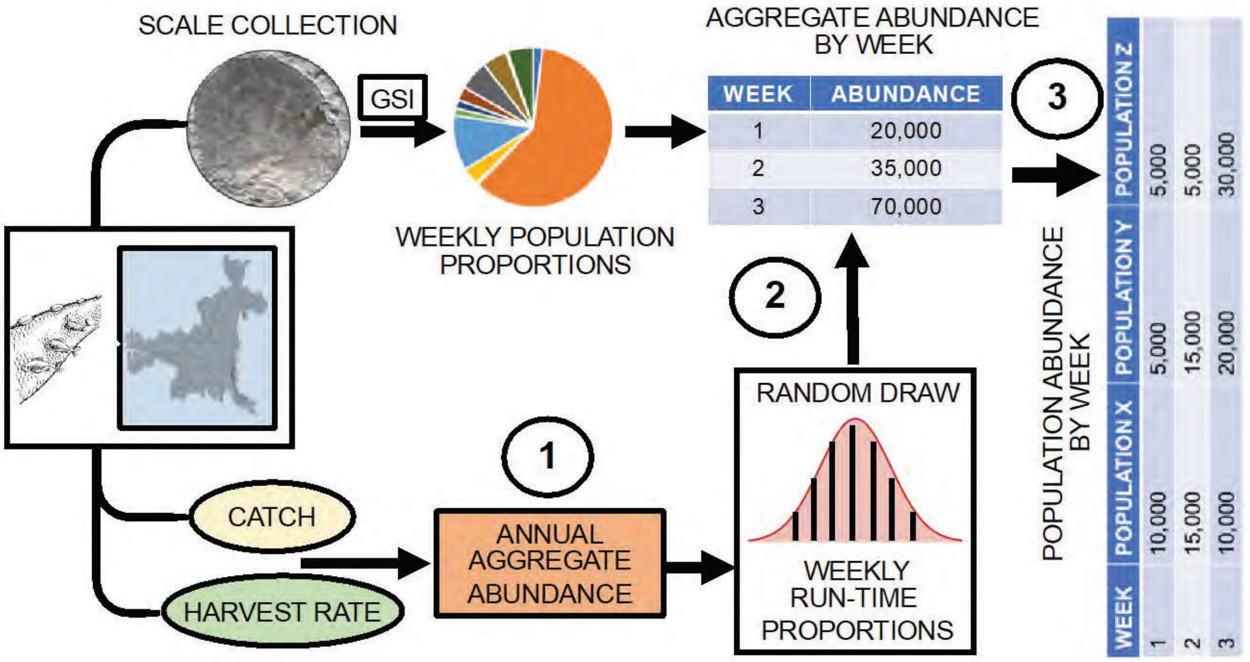
*Historical period*

Of two primary data sources (i.e., Shepard & Withler 1958, and Argue & Shepard 2005) available for historical catch of sockeye returning to the Skeena River dating back to the early 1900s, we use Argue & Shepard (2005) for several reasons. First, whereas annual sockeye catch records reported in Shepard & Withler (1958) begin in 1908, Argue & Shepard (2005) report numbers of sockeye caught at the onset of commercial fishing in 1877. Second, Argue & Shepard (2005) report numbers of sockeye caught of all ages, whereas Shepard & Withler (1958) report only those sockeye caught of age four and five, which spent one year in freshwater (the authors omit sockeye of age six, and those that reared for more than one year in freshwater). Despite these differences, annual estimates of sockeye caught between the two reports are remarkably similar (a difference of 11,000 fish on average for years 1913, 1916, and 1918-1923) once corrections for genetically-identified proportions of non-Skeena sockeye are applied to Argue & Shepard (2005) catch data for the Area 4 fishery.

While the historical (1913-1947) catch data was reconstructed from canned-pack data derived from canneries operating on the Skeena River, and much of the fishery occurred in the Skeena River and estuary, some fish that were caught were not of Skeena origin. This was most pronounced during 1933-1947 when the fishery was primarily of motorized vessels that could travel long distances. To correct for this potential overestimation, we applied our annual proportions of Skeena-origin fish quantified from scales to annual abundance estimates. Across the 14 historical years, Skeena sockeye populations accounted for 85% on average of the fish identified from scales.

Our use of scales to reconstruct historical abundance (Figure S1) relied largely on the genetic assignment of those scales to population. While a recent analysis demonstrated high (> 95%) assignment accuracy of Skeena sockeye populations from recently collected tissue (Beacham et al. 2014), lack of baseline data in our study may have manifest into some populations being over-estimated. For example, several historically-known headwater populations (e.g., Kluatantan, Kluayaz; see Brett 1952) currently are absent in the genetic baseline. Because geographically-proximate populations share distinctive genetic characteristics, any fish (scales) from these unidentifiable populations may have been assigned to the neighbouring populations of Sustut, Motase, or Bear. Similarly, fish from the only known extirpated population in the Skeena (i.e., Seeley Lake), or from others currently unknown but potentially identifiable from our collection (see Iwamoto et al. 2012), may have been mis-assigned - resulting in over-estimates of abundance - or may not have been assigned to a population. However, we believe that any mis-assignments would not largely inflate our historical estimates because populations currently not in the baseline that were assessed in the 1940s were small (i.e., < 1,000 fish; Brett 1952). Furthermore, our estimates for Babine, Bear, Bulkley, Kitwanga, and Lakelse generally agree with previous assessments (Brett 1952; Cleveland et al. 2006), demonstrating the relative robustness of our novel approach, and its importance in shifting baselines back half a century to more accurately assess loss over time.

Our historical abundance estimates were based, in part, on weekly run times of sockeye entering the Skeena River, which were derived from fish caught at the Tyee Test Fishery (location marked on Figure 1 of main text; Table S1). Examination of the seven years of recent run-time data that we used shows that the peak migration period for sockeye entering the Skeena was highly variable across years, with an average peak period of week 5 (of 9 weeks), and a range from week 3 to week 7. Analyses over the recent (1949-1999) period suggest that the Babine population (most abundant sockeye population in the Skeena) is tending towards earlier migrations (Hodgson et al. 2006). Price et al. (2019) investigated the robustness of baseline abundance estimates for each population during the 1913-1923 period by shifting the average proportion of fish estimated at the Skeena Tyee Test Fishery one week earlier for each sampling week, for each year (2011-2017) of data. Results showed only minor changes for a sub-set of populations. Thus, our historical abundance estimates – and our resulting diversity analyses - are derived from a range of run-times that likely occurred historically.



| WEEK | ABUNDANCE |
|---|---|
| 1 | 20,000 |
| 2 | 35,000 |
| 3 | 70,000 |

| WEEK | POPULATION X | POPULATION Y | POPULATION Z |
|---|---|---|---|
| 1 | 10,000 | 5,000 | 5,000 |
| 2 | 15,000 | 15,000 | 5,000 |
| 3 | 10,000 | 20,000 | 30,000 |

**Figure S1**. Graphic display of steps used to estimate the annual abundance of each Skeena River sockeye salmon population identified in genetic analyses during the historical (1913-1947) period from fish scales, catch records, catch rate estimates, and aggregate abundance proportions estimated at the Skeena Tyee Test Fishery.

**Table S1.** Weekly percentage of sockeye salmon entering the Skeena River estimated at the Tyee Test Fishery (location shown on Figure 1 of main text) across seven years of most recent data. These data were used in historical (1913-1947) abundance estimates.

| year | week1 | week2 | week3 | week4 | week5 | week6 | week7 | week8 | week9 |
|---|---|---|---|---|---|---|---|---|---|
| 2011 | 1.15 | 3.32 | 9.01 | 12.01 | 15.52 | 26.29 | 20.69 | 10.08 | 1.93 |
| 2012 | 1.32 | 2.62 | 11.46 | 28.41 | 26.82 | 15.78 | 11.62 | 1.00 | 0.97 |
| 2013 | 1.87 | 5.43 | 10.87 | 18.52 | 24.30 | 25.61 | 10.83 | 1.91 | 0.66 |
| 2014 | 1.27 | 4.50 | 19.25 | 18.03 | 15.52 | 13.10 | 10.11 | 14.82 | 3.40 |
| 2015 | 1.11 | 2.94 | 8.89 | 11.05 | 17.16 | 20.87 | 20.58 | 10.38 | 7.02 |
| 2016 | 4.32 | 7.10 | 8.69 | 9.12 | 16.77 | 20.65 | 19.22 | 10.53 | 3.60 |
| 2017 | 0.43 | 2.27 | 5.25 | 10.37 | 20.30 | 19.52 | 24.85 | 15.13 | 1.88 |

*Recent period*

Recent (2010-2017) estimates of abundance for all sockeye populations are available from PSF (2020) – with methods described in English et al. (2018) - except Sustut, which previously had not been estimated. We calculated annual abundance for Sustut by dividing the number of spawning sockeye counted annually at the Sustut weir (Mark Beere unpublished data) by 1-exploitation rates estimated for a population (Slamgeesh) with similar run-time (Cox-Rogers 2012). The Ecstall population complex has not been estimated since 2003; thus, we used the 14 most recent (1990-2003) years to estimate changes in abundance between historical (1913-1947) and modern time periods. Annual estimates of wild fish for Kalum were derived from run-reconstructions detailed in the citations above, but with spawning channel contributions removed. We estimate that 72% of the average total abundance during 2007-2014 was from spawning channel fish because sockeye that spawned at Kalum Lake accounted for 28% of the total annual returns to the population during 1954-1984, with the remaining production attributable to fish that spawned in watershed tributaries. During the years 2007-2014, after a spawning channel had been built (1985) and improved (1994), the total annual abundance contribution of Kalum Lake to the Kalum population has been 98%. Additionally, two populations consist of multiple Conservation Units (CU) that each have their own annual estimates of abundance (PSF 2020). For these populations, we simply summed the annual estimates of each CU within a given population for a combined total estimate of abundance. While infrequent, when one of multiple CUs for a given population complex had missing data in a given year, we inserted the arithmetic mean across recent years for the data-deficient CU into the missing year, and added this value to the abundance estimate of the other CU within the population complex for a combined total estimate of abundance.

As a sensitivity analysis for our main text evaluation of the change in in-river abundance of sockeye - and the potential loss of fish to in-river fisheries and wildlife - we also compared the change in total abundance (assuming zero loss to commercial fisheries; abundance included wild plus enhanced fish) of sockeye returning to tributary streams and the main channel of the Skeena River over the last century. Here, we compared the arithmetic mean abundance of sockeye between the historical (1913-1947) and modern (2004-2017) eras for each population. We quantified abundance for each main-stem section of the Skeena River between populations by dividing the total abundance of sockeye minus each population's abundance downstream of each mainstem river section for the two time-periods. All wild population tributaries, as well as the mainstem channel above Babine, now receive between 58% and 94% less sockeye annually than during the historical era (Figure S2).

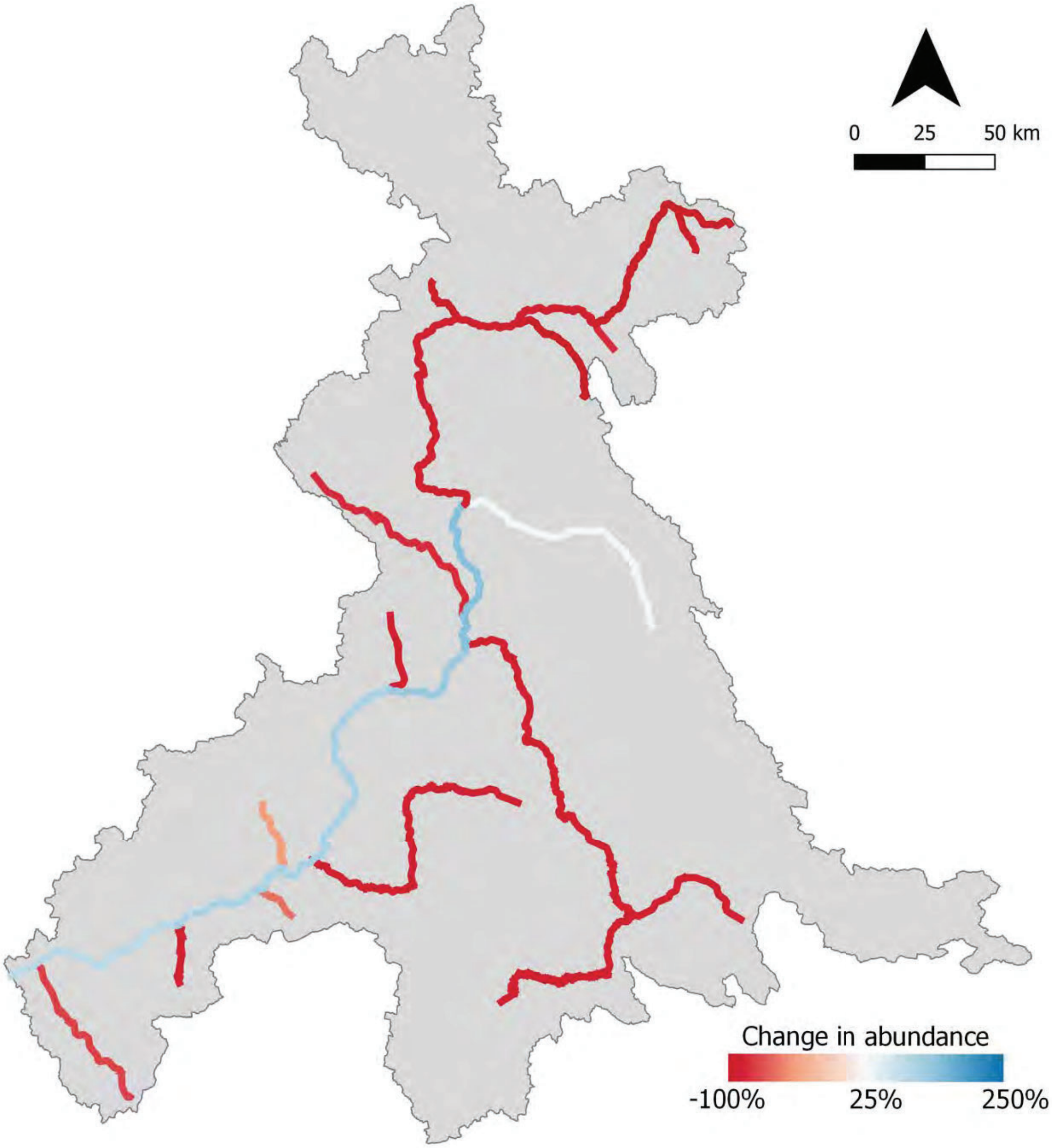


**Figure S2**. Change in total (wild plus enhanced) abundance (catch plus escapement) of sockeye salmon returning to the Skeena River watershed between historical (1913-1947) and recent (2004-2017) time periods assuming zero loss to commercial marine and lower river fisheries.

## Appendix S3: Gill-net selectivity

Sockeye salmon returning to the Skeena River were caught exclusively by linen gill-net in commercial fisheries from 1877 to 1950 (Milne 1955). Migrating sockeye would incidentally swim into the net and become trapped either by being wedged into the mesh opening or becoming tangled in the net. Because nets that targeted sockeye in the historical fishery were uniform in mesh size (5.75”), fish above a particular size likely would have been too large to be wedged, and fish below a particular size would have swum through the net, though both large and small sockeye may have been captured by becoming tangled in the net. Indeed, gill-nets routinely select for larger size-at-maturity (Peterson 1954; Hamley 1975; Gilhousen 1992), and older age-at-maturity to a lesser extent (because body-size is more closely correlated with number of ocean years, rather than absolute age). Given such selectivity, we quantified a correction factor based on the selectivity of sockeye captured by gill-nets in the Skeena Tyee Test Fishery to more accurately represent the historical age-distributions. The Skeena Tyee Test Fishery employs a multi-panel net consisting of various nylon mesh sizes (3.5” to 8.0”, at 0.5” increments). During 1992 to 1996, data were recorded on the number of sockeye caught in each mesh size, and each captured fish was aged.

We grouped all sockeye caught in all Skeena Tyee Test Fishery mesh size panels (i.e., the Population) into the four dominant (>99%) age-trait categories (i.e., 1.2, 1.3, 2.2, and 2.3); then, we calculated the proportion of fish caught in each category. We repeated this procedure for those fish caught only in the 5.5” mesh size panel (i.e., the Selective Catch), and calculated the difference between Population and Selective Catch for each age-trait category to derive estimates of selectivity. We then multiplied the number of fish caught historically in each age-trait category by the inverse selectivity estimate to generate a corrected estimate of the number of fish in those age-trait categories, and quantified the arithmetic mean age-at-maturity for the aggregate. We followed a similar procedure to derive selectivity estimates for each population for historical mean age-at-maturity for each population. Examination of the Skeena Tyee Test Fishery showed that the mesh size (5.5”) most similar to that used in the historical gill-net fishery strongly selected for sockeye that survived three marine years and a combined age of five (i.e., 1.3), and selected against sockeye that survived two marine years and a combined age of four (i.e., 1.2; Figure S3).

We adjusted for the age of sockeye caught in commercial fisheries during our historical period of interest based on the selective action of 5.5” mesh nylon nets for the following reasons: i) 5.75” linen nets were exclusively used to capture sockeye returning to the Skeena River during our period of interest, with a small proportion of sockeye intercepted by 7” linen nets that targeted Chinook (*O. tshawytscha*) salmon early in the fishing season (Milne 1955), ii) a comparative study on the size selectivity of Skeena River sockeye by linen versus nylon gill-nets reported similar size distributions between 5.63” (smaller mesh than historically used) linen and 5.25” (smaller mesh than we used for our analysis) nylon (Todd & Larkin 1971), and iii) Peterson (1954) showed that 5.75” linen nets caught sockeye returning to the Fraser River of average length 61.62 cm (1947) and 59.48 cm (1948), which is comparable to the average length (62.92 cm) of sockeye caught in 5.5” nylon mesh of the Tyee Test Fishery described above. While gill-nets tend to select *for* larger size- and age-at-maturity, we acknowledge that selectivity also can be *against* smaller size- and age-at-maturity in years when body-size is smaller on average than the norm (Todd & Larkin 1971).

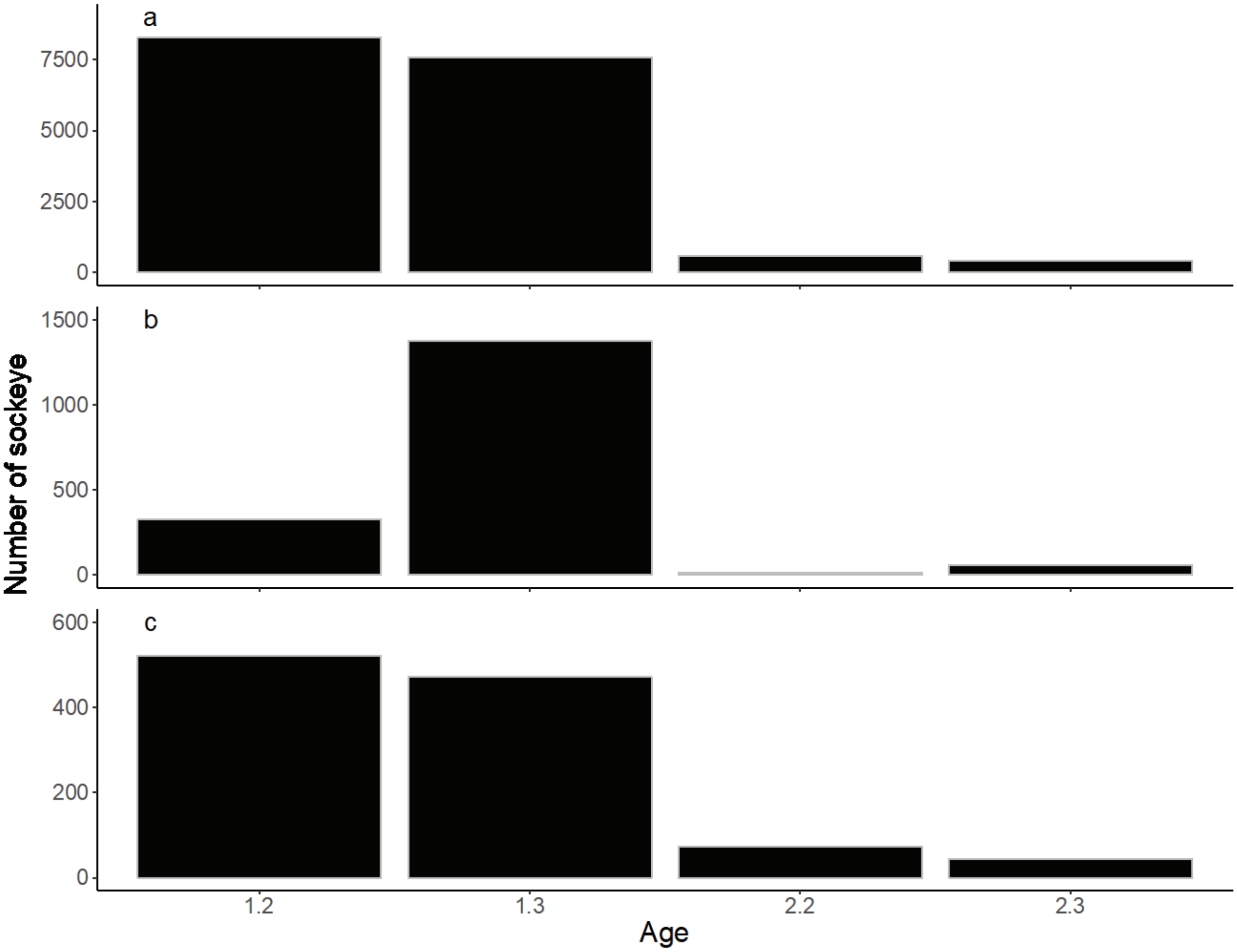


**Figure S3**. Number and associated age-at-maturity (1.2 = age-4, 1 freshwater + 2 ocean years; 1.3 = age-5, 1 freshwater + 3 ocean years; 2.2 = age-5, 2 freshwater + 2 ocean years; 2.3 = age-6, 2 freshwater + 3 ocean years) of sockeye salmon caught by gill-net on the Skeena River from: (a) Tyee Test Fishery (1992-1996) using all mesh sizes, (b) Tyee Test Fishery using only 5.5” nylon mesh, and (c) historical (1913-1923) commercial fishery using 5.75” linen mesh.

We examined the degree to which populations were subject to selection pressure via gill-nets, which could lead to bias in both estimates of absolute historical abundance and the magnitude of change over the last century. The magnitude of change would be biased high in populations that were most vulnerable to capture in the historical gill-net fishery, and biased low in those that had the lowest selectivity. We used catch data from the Skeena Tyee Test Fishery (described above) and body-size of fish caught in the historical fishery (genetically-assigned to population with >90% probability) to derive two selectivity factors: 1) selection *for* (for body-size 600 mm to 650 mm - which is the most frequent size range of fish caught historically - with calculated selectivity pressure index of +0.166), and 2) selection *against* (for body-size 500 mm to 550 mm, with calculated selectivity pressure index of -0.154). We multiplied the number of fish caught in each size category for each population for each historical period (1913-1923 & 1933-1947) by the respective selectivity indices to calculate the number of fish over- and under-selected; we then derived final selectivity scores for each period by calculating the proportion of "selected" fish in the total catch for each population. Populations most vulnerable to gill-net fisheries during 1913-1923 based on the selectivity estimates above include: Babine, Kispiox and Zymoetz (equally), and Alastair, which may have been overestimated in our historical reconstruction by 17%, 13%, and 12%, respectively; Motase and Sustut were the populations least selected for (Table S2). During 1933-1947, Bear, Kalum, and Sustut were most vulnerable to gill-nets (potentially over-estimated by 13%), and Ecstall and Kitwanga were the least vulnerable. These results, based on our bias-correction, suggest that there was considerable variation in the vulnerability of populations to selective gill-net fisheries between periods because of variability in body-size within populations. For example, the body-length of sockeye from the Sustut population averaged 662mm (beyond the most vulnerable size-range) during 1913-1923, yet average fish size declined to 648mm (within the most vulnerable size-range) during 1933-1947.

**Table S2**. Gill-net fishery selection pressure indices for each Skeena River sockeye salmon population during the 1913-1923 and 1933-1947 time periods, based on fork-length for populations genetically identified in scales with ≥90% assignment probability. Dash represents populations assigned with <90% probability in either time period.

| Population | 1913-1923 | 1933-1947 |
|---|---|---|
| Alastair | 0.115 | 0.057 |
| Babine | 0.173 | 0.079 |
| Bear | - | 0.132 |
| Bulkley | 0.083 | 0.062 |
| Ecstall | 0.071 | 0.000 |
| Kalum | 0.071 | 0.125 |
| Kispiox | 0.125 | 0.067 |
| Kitwanga | 0.100 | 0.034 |
| Lakelse | 0.107 | 0.059 |
| Motase | 0.000 | - |
| Slamgeesh | - | - |
| Sustut | 0.056 | 0.125 |
| Zymoetz | 0.125 | 0.100 |

**Appendix S4: Age composition**

We extracted aggregate mean age-at-maturity (of the four dominant age traits: 1.2, 1.3, 2.2, 2.3, which comprised >99% of all age traits) data from fish caught in commercial fisheries (n = 77,126) reported annually in historical fisheries reports for the years 1916-1956 (Province of BC 1957), and applied selectivity corrections to the annual data. We used individual age-at-maturity data (of the four dominant age traits) from fish caught in the Skeena Tyee Test Fishery (n = 81,126 scales) for the recent (1973-2016) period. We also examined age-at-maturity and associated age-traits between time-periods at the population level. Here, we used age data for the years 1913-1947 from fish caught in commercial fisheries, and 2000-2017 from fish caught at the Tyee Test Fishery and terminal locations. We included only those scales that were identified to individual populations with a genetic assignment threshold of >90% probability; as a result, Slamgeesh population was not included. We evaluated changes in the diversity of age traits over the last century by comparing the number of unique traits (i.e., 0.3, 1.1, 1.2, etc.) in the historical (1913-1947; n = 5,400 scales) and recent (2000-2013; n = 9,337) period, and quantified the change in the proportion of the four dominant age traits between time periods.

We were interested to explore the influence of enhanced production on the shift in age composition over the last century. Because all age data in the recent period include enhanced fish - which constitutes ~70% of all sockeye returning to the Skeena, but are not genetically differentiated from wild fish – we quantified the proportions of age traits for wild-only sockeye in each year by calculating the proportion of wild fish (which included wild Babine) to total abundance (which included enhanced fish) for each year from 1973-2013, and applied these proportions to the 1.2 and 1.3 age-traits. The 2.2 and 2.3 age traits remained unchanged because over 99% of all Babine fish are of the 1.2 and 1.3 age traits.

Skeena sockeye currently display all 10 age-related life-history strategies that were identified in scales one century ago (Figure S4); two additional strategies (3.2 and 3.3) not among those of fish caught in historical fisheries are present in recently collected scales. It is highly probable that these “additional” strategies were present among sockeye returning to the Skeena during the historical period, but either were not caught by selective gill-net fisheries, or are present in the Gilbert/Clemens collection of 65,000 fish but were not among the limited number of scales that we analysed (5,400). Mean age-at-maturity for the Skeena sockeye aggregate has increased only slightly from the historical (1916-1956; 4.493 years) to the recent (1973-2016; 4.563 years) period (Figure S5), though some populations have experienced increases or decreases (Figure S6). The proportion of fish with the 1.*x* (one year in freshwater and any number in the ocean) life-history across all populations except Babine increased (from 67% to 87%) on average between historical and modern eras (Table S3). The inclusion of Babine fish further increased the proportion of the 1.*x* life history to 96% in the modern era; however, four of 12 populations did not increase between time-periods. Finally, the evenness of age traits significantly declined (from 0.68 to 0.55; 19%) between historical and modern eras (Figure S7).While different technicians were involved in the aging of scales over the last century, which can introduce interpretation error, any such error would have occurred for either time-period, and likely would not lead to any systemic bias in the age of fish.

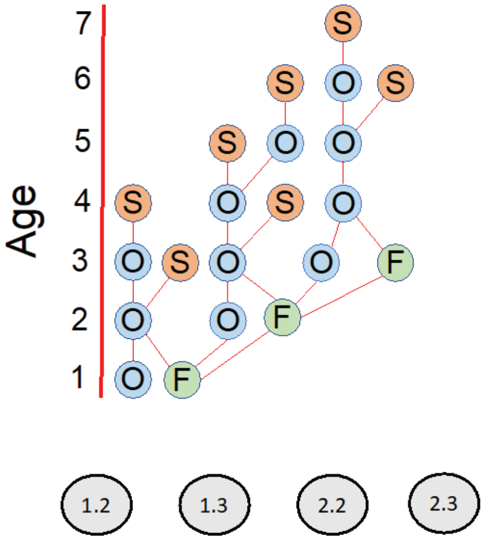


**Figure S4**. Networks illustrating the life-history strategies for sockeye salmon caught in commercial fisheries at the mouth of the Skeena River during 1913-1947. Each life stage is abbreviated with a letter and colour (F = freshwater, O = ocean, S = returning to freshwater to spawn). The age-at-maturity of the fish is denoted with a number. Also shown are the four dominant age traits (1.2 = age-4, 1 freshwater + 2 ocean years; 1.3 = age-5, 1 freshwater + 3 ocean years; 2.2 = age-5, 2 freshwater + 2 ocean years; 2.3 = age-6, 2 freshwater + 3 ocean years).

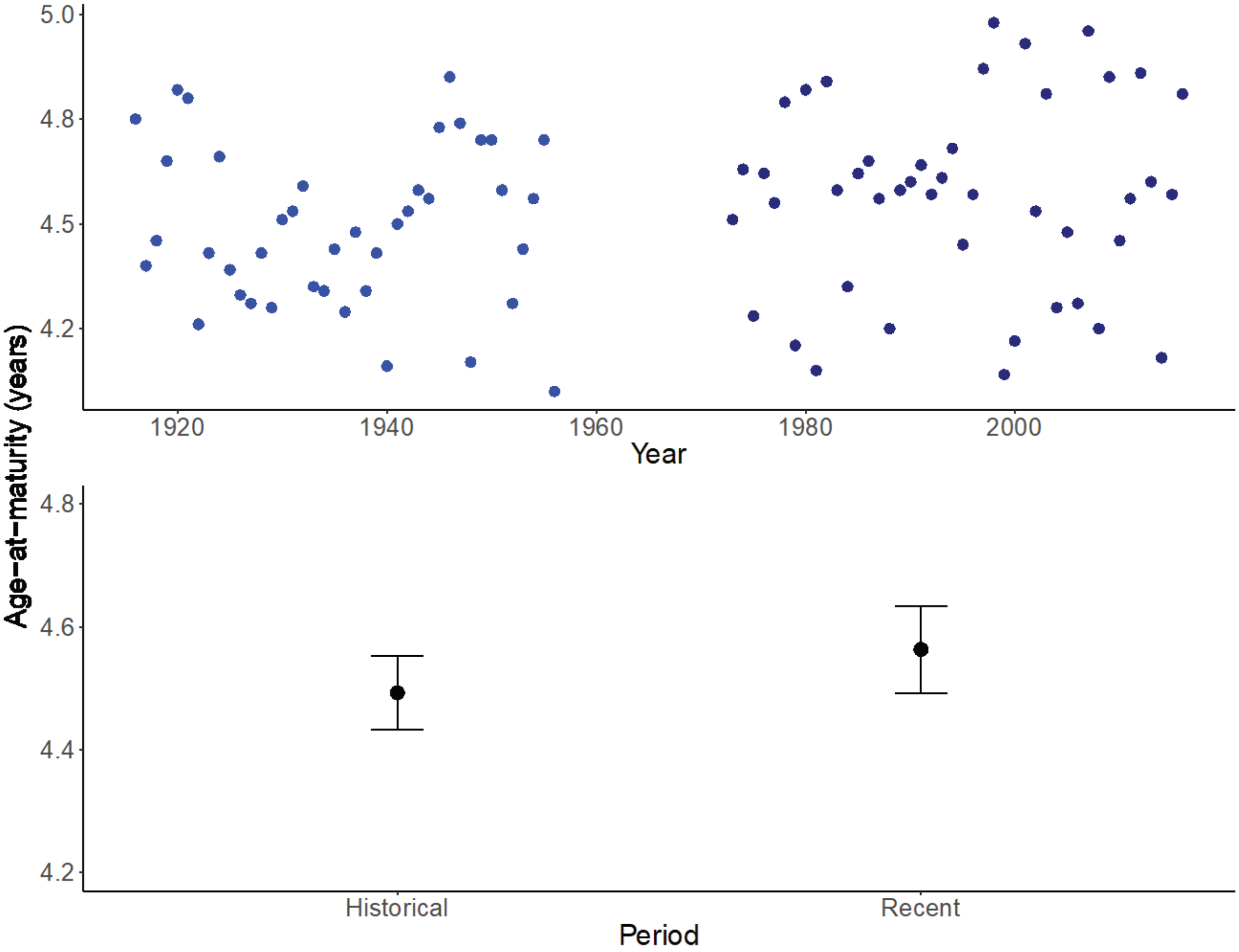


**Figure S5**. Mean annual aggregate age-at-maturity of sockeye salmon returning to the Skeena River during 1916-2016 (top; light-blue circles are from commercial fishery, dark-blue circles are from Tyee Test Fishery), and mean combined age-at-maturity between time-periods (bottom; Historical is 1916-1956, Recent is 1973-2016).

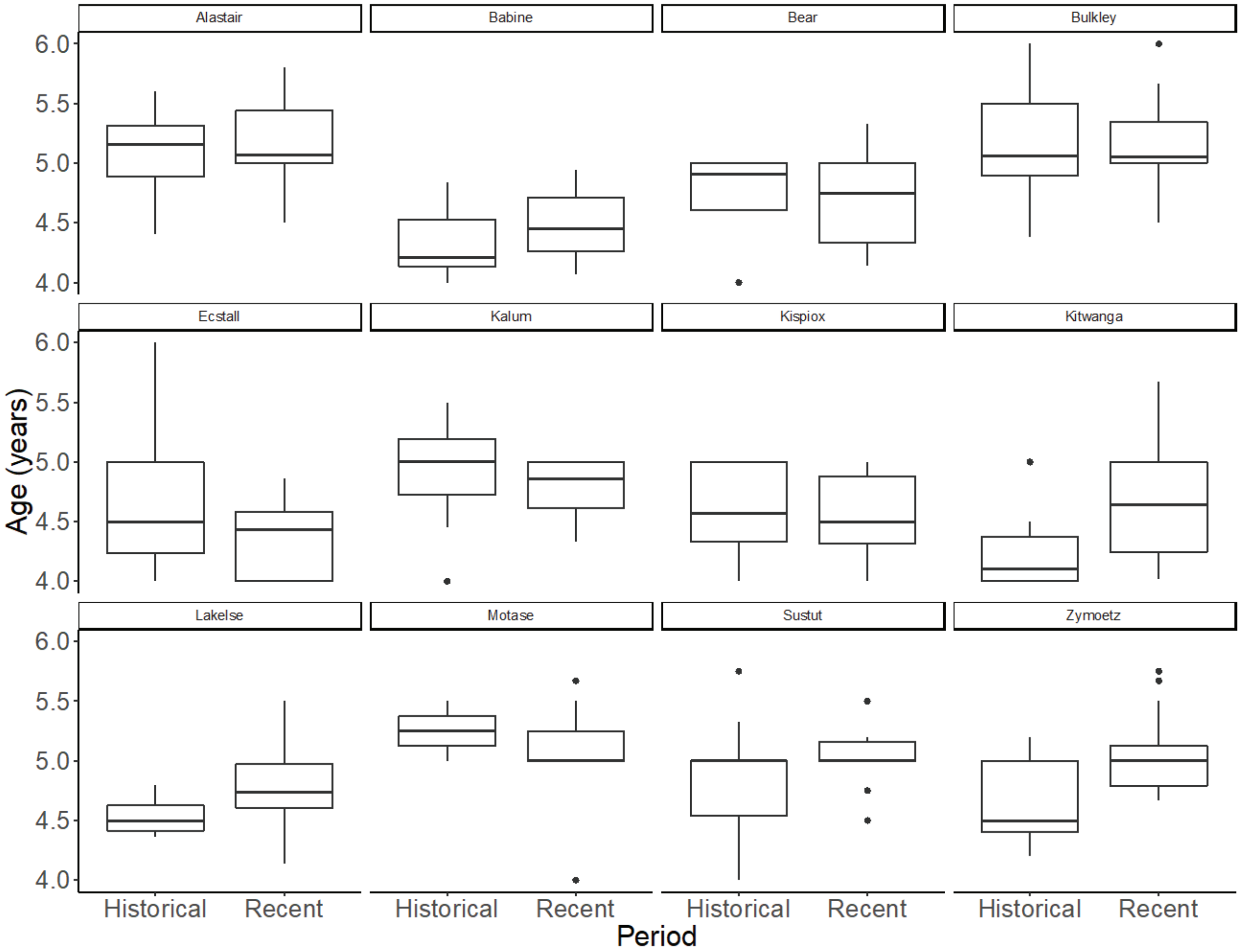


**Figure S6**. Median (black line) and quartiles (box) for age-at-maturity of each Skeena sockeye salmon population genetically identified with >90% assignment probability between Historical (1913-1947) and Recent (2000-2013) time-periods. Slamgeesh population is not included due to data limitations.

**Table S3.** Number of scales (*n*) analyzed for each Skeena sockeye salmon population during the Historical (1913-1947) and Modern (2000-2017) eras and the respective proportions of the 1.*x* (fish that reared for one-year in freshwater) life history. Only scales assigned to population with >90% probability were included.

| Population | Historical *n* | Modern *n* | Historical 1.*x* % | Modern 1.*x* % |
|---|---|---|---|---|
| Alastair | 184 | 208 | 39 | 75 |
| Babine | 830 | 5939 | 75 | 97 |
| Bear | 44 | 42 | 91 | 93 |
| Bulkley | 150 | 147 | 35 | 46 |
| Ecstall | 47 | 33 | 91 | 85 |
| Kalum | 39 | 133 | 85 | 94 |
| Kispiox | 53 | 192 | 83 | 82 |
| Kitwanga | 93 | 882 | 95 | 98 |
| Lakelse | 43 | 116 | 100 | 96 |
| Motase | 3 | 11 | 67 | 73 |
| Slamgeesh | 0 | 533 | - | 98 |
| Sustut | 22 | 168 | 77 | 70 |
| Zymoetz | 57 | 75 | 83 | 87 |

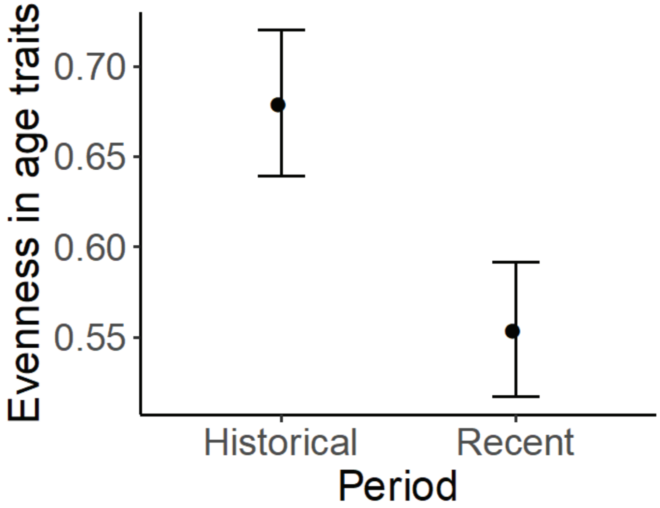


**Figure S7**. Arithmetic mean (black circle) and 95% confidence intervals (black whiskers) for evenness scores across the four dominant Skeena sockeye age traits (1.2, 1.3, 2.2, 2.3) between Historical (1916-1956) and Recent (1973-2016) time periods.

## Appendix S5: Portfolio effects

Similar to population abundances, we explored whether the strength of salmon portfolios in the Skeena had changed over the last century by measuring overall portfolio effect (PE) strength based on age traits. Here, we utilized population-specific age data generated from the Gilbert/Clemens scale collection (1913-1923, and 1933-1947) and Skeena Tyee Test Fishery (2006-2013). Age-structure diversity reduced year-to-year variability in abundance by 30%, 20%, and 32% compared to the scenario if populations were of a single age class over the three time-periods (Figure S8). Additionally, we quantified PE strength for population abundances of wild fish (in the absence of enhancement) for the recent (2010-2017) period. While we found that PE strength was reduced in the recent period (1.32 times more stable than had the Skeena consisted of a single wild population) compared to both of the early periods (2.04 during 1913-1923; 1.48 during 1933-1947; Figure S9), PE strength was greater for wild fish abundances than for abundances that included enhanced fish (1.10; Figure 4a of main text).

To estimate uncertainty in our coefficient of variation (CV) estimates (and overall population portfolio strength) across individual component population abundances (i.e., average CV) for each historical time period (i.e., 1913-1923 and 1933-1947), we calculated 10,000 independent estimates of average CV – each estimate drawing from a single iteration of population- and year-specific historical abundance – and calculated the arithmetic mean average CV and 95% confidence intervals for each time period. Arithmetic mean "average CV" based on 10,000 replicates for the 1913-1923 period was 1.07 (95% confidence interval of 0.97-1.19), and for the 1933-1947 period was 1.00 (95% confidence interval of 0.91-1.10; Figure S10). These results suggest that the strength of the population portfolio may range from 1.96 to 2.23 (1913-1923), and from 1.4 to 1.69 (1933-1947); all of which remain much higher than the recent period strength of 1.1.

We calculated portfolio strength by comparing the temporal CV of metapopulation abundance (the diversified portfolio) with the average-CV of individual population abundances (the single assets). This metric implicitly assumes that the slope (z) of a log–log plot of mean temporal abundance and variance (Taylor's power law) equals two. However, analyses of populations with z-scores less than two have been shown to overestimate the stabilizing effect of population diversity for metapopulations (Anderson et al. 2013). We calculated Taylor's power law for Skeena sockeye across the three (1913-1923, 1933-1947, and 2010-2017) time periods to test this assumption. While z-scores were lower than two for both historical time periods (e.g., z = 1.6 for 1913-1923, and z = 1.7 for 1933-1947), the difference in PE between mean-variance and average-CV based on these values is not statistically significant for salmonids (Anderson et al. 2013).

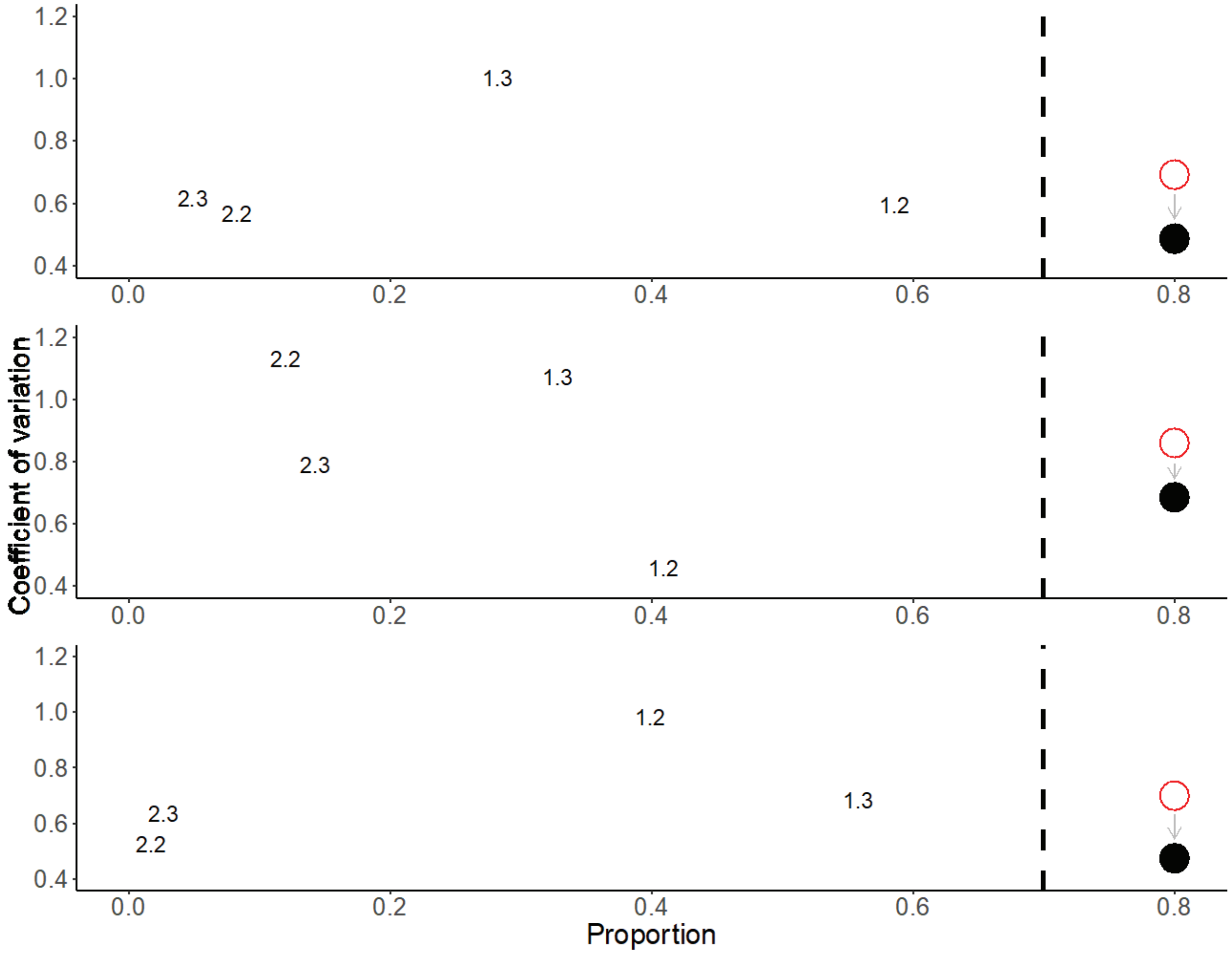


**Figure S8**. Life-history diversity and stability. Each red-filled circle represents the coefficient of variation (CV) of abundance across years for each time period as a function of the proportion contribution of each life history (1.2 = age-4, 1 freshwater + 2 ocean years; 1.3 = age-5, 1 freshwater + 3 ocean years; 2.2 = age-5, 2 freshwater + 2 ocean years; 2.3 = age-6, 2 freshwater + 3 ocean years). Shown to the right is the estimated CV based on the average of the CVs of the different life histories (red outline while-filled circle), and the measured CV of the entire Skeena sockeye complex (filled black circle). The difference between the estimated and measured CV is a metric of the portfolio effect, the degree to which diversity decreases stability.

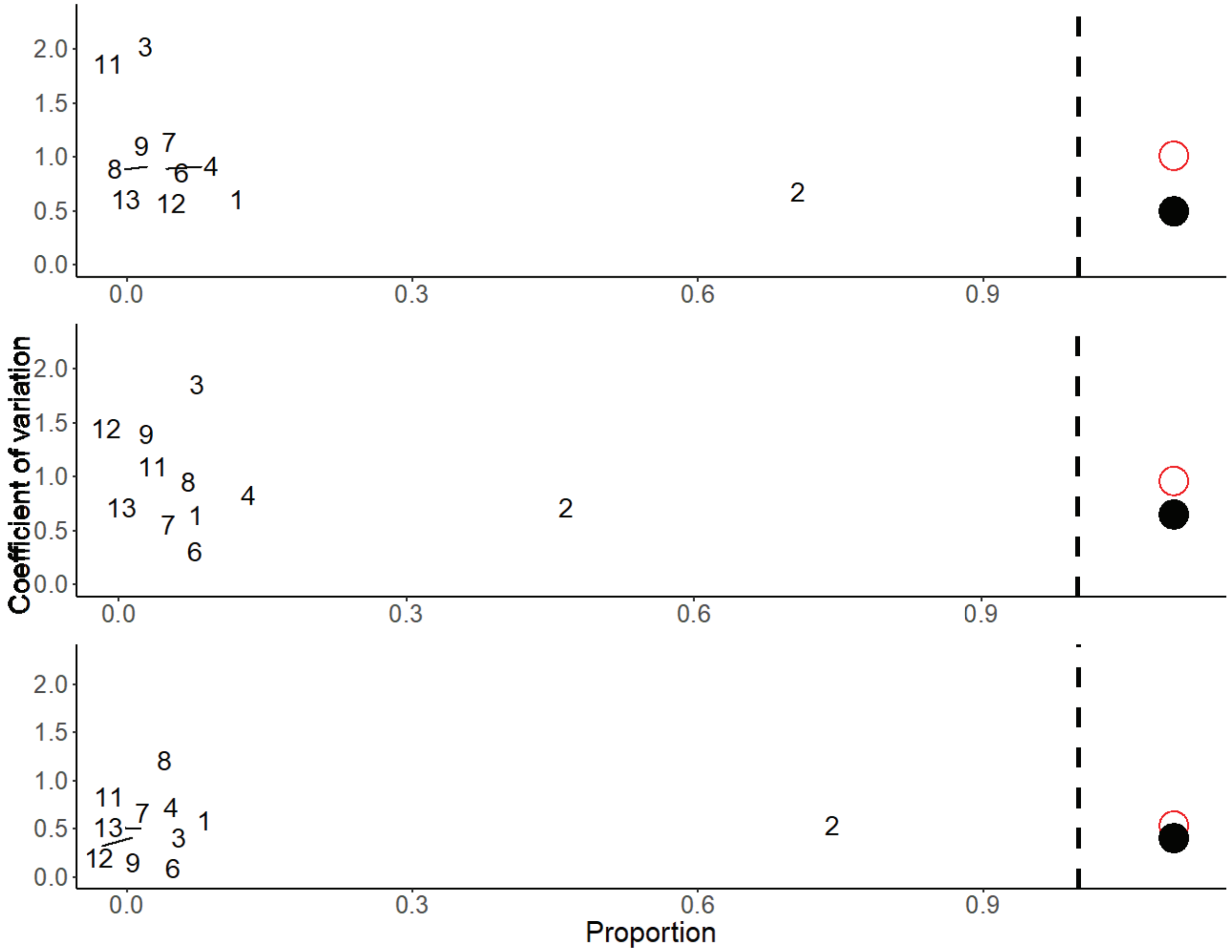


**Figure S9**. Population diversity and stability of *wild* populations. Each red-filled circle represents the coefficient of variation (CV) of abundance across years for each time period as a function of the proportion contribution of each wild sockeye population; numbers correspond to Figure 1 of main text. Shown to the right is the estimated CV based on the average of the CVs of the different wild populations (red outline while-filled circle), and the measured CV of the entire wild Skeena sockeye complex (filled black circle). The difference between the estimated and measured CV is a metric of the portfolio effect, the degree to which diversity decreases stability.

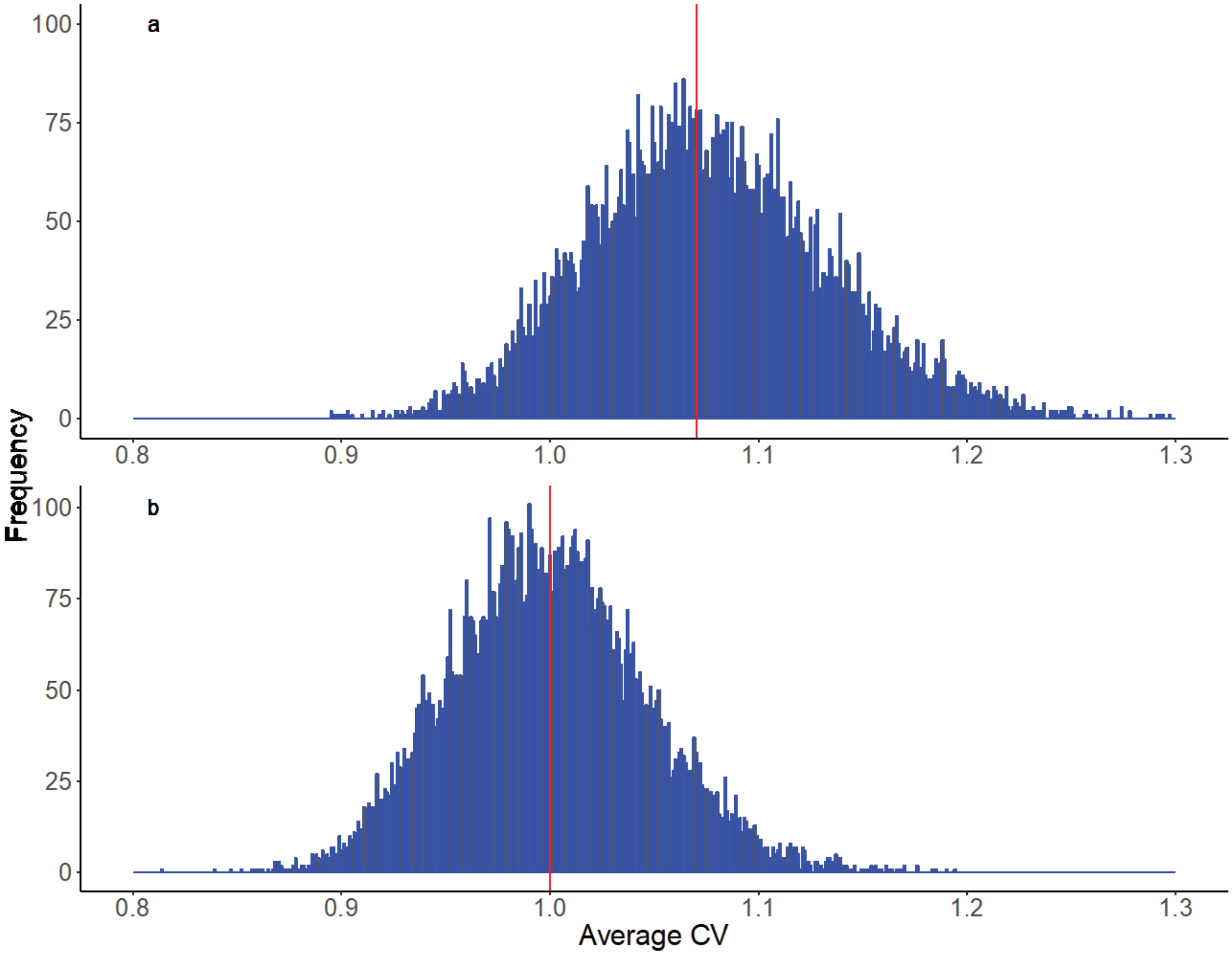


**Figure S10**. Estimates of coefficient of variation (CV) during a) 1913-1923 and b) 1933-1947 – each of 10,000 estimates were drawing from a single iteration of population- and year-specific historical abundance averaged across Skeena sockeye populations; red vertical line is the arithmetic mean average CV.

We were interested to understand the potential mechanism influencing the erosion in portfolio strength over the last century, and whether enhancement in the recent period had been a primary driver. Here we decomposed aggregate CV into abundance-weighted mean CV across populations and a synchrony index (Thibaut and Connolly 2013; Freshwater et al. 2019). The abundance-weighted mean CV is measured as the mean temporal CV of populations ($CV_p$) weighted by each population's mean abundance (i.e., the sum of the populations' CV scaled by each population's mean abundance):

$$CV_p = \sum_i \frac{\mu_i}{\mu_A} \frac{\sigma_i}{\mu_i}$$

where $\mu$ is mean abundance of population $i$, $\mu_A$ is the mean abundance across all populations, and $\sigma$ is the standard deviation of abundance. Synchrony is defined as the total temporal variance of the populations, divided by the variance of a hypothetical aggregate with the same population variances, but perfect covariance (Loreau & de Mazancourt 2008; Freshwater et al. 2019):

$$\varphi = \frac{\sum_{i,j} p_{i,j} \sigma_i \sigma_j}{(\sum_i \sigma_i^2)}$$

where $p$ represents the correlation between populations $i$ and $j$.

We report results for the abundance-weighted mean CV for each population (Ecstall and Motase populations were omitted because of insufficient data in the recent period) on Table S4; aggregate abundance-weighted mean CV for each time period was 0.680 (1913-1923), 0.838 (1933-1947), and 0.552 (2010-2017). While the Babine population has influenced variability of the Skeena sockeye aggregate over the last 100 years, Babine in the recent time period contributed most (93%; the abundance-weighted mean CV of Babine = 0.511, compared to 0.552 for the aggregate) of the variation. Synchrony scores across populations were highest during the 2010-2017 time period (0.903), compared to 1933-1947 (0.769) and 1913-1923 (0.665). Exploring synchrony over the entire contemporary period (1960-2017) time series showed an increasing trend with a noticeable rise in synchrony beginning in the early 2000s (Figure S11).

We observed lower variability among populations in the recent period compared to either of the historical periods, and we wondered whether different methods used for estimating abundance between eras may confound our results. Specifically, might such a difference in variability simply be an artifact of increased precision in the recent estimation of population abundances – or perhaps more likely, higher variability among populations during the historical era because of our coarse abundance reconstruction methods. To test this, we quantified the average CV across populations in each of our three time periods (1913-1923, 1933-1947, and 2009-2016) using annual genetic proportion data, and compared the results to average CV using population abundance data. Genetic data involve less assumptions, and generally are more comparable than abundance data. If the lower variation across populations in the recent period is simply because these populations are less variable recently, the genetic data should reflect this in a lower average CV score compared to the historical periods. Genetic data during the two historical periods were derived from fish caught in commercial fisheries, and during the recent period from fish caught in the Skeena Tyee Test Fishery (reported in our Appendix S1 section above). We found that CV scores averaged across populations in each of our time periods derived from genetic data generally were similar to average CV scores using abundance data. Specifically: 1913-1923 (CV_abundance = 1.0, CV_genetic = 1.1), 1933-1947 (CV_abundance = 1.0, CV_genetic = 0.9), 2009-2016 (CV_abundance = 0.6, CV_genetic = 0.7). This suggests that Skeena sockeye populations indeed have become less variable in the recent period, and likely are experiencing a lower productivity regime given their shared reduction in abundance and high synchrony dynamics reported above.

**Table S4**. Abundance-weighted mean coefficient of variation (CV) for each time period and Skeena River sockeye population (Ecstall and Motase populations were omitted due to insufficient data during recent period) - including the summed aggregate of populations.

| Population | 1913-1923 | 1933-1947 | 2010-2017 |
|---|---|---|---|
| Alastair | 0.044 | 0.052 | 0.008 |
| Babine | 0.473 | 0.360 | 0.511 |
| Bear | 0.006 | 0.184 | 0.003 |
| Bulkley | 0.030 | 0.102 | 0.005 |
| Kalum | 0.020 | 0.028 | 0.006 |
| Kispiox | 0.037 | 0.019 | 0.004 |
| Kitwanga | 0.015 | 0.045 | 0.006 |
| Lakelse | 0.021 | 0.013 | 0.007 |
| Slamgeesh | 0.005 | 0.023 | 0.000 |
| Sustut | 0.015 | 0.010 | 0.000 |
| Zymoetz | 0.013 | 0.014 | 0.002 |
| | | | |
| Aggregate total | 0.680 | 0.851 | 0.553 |

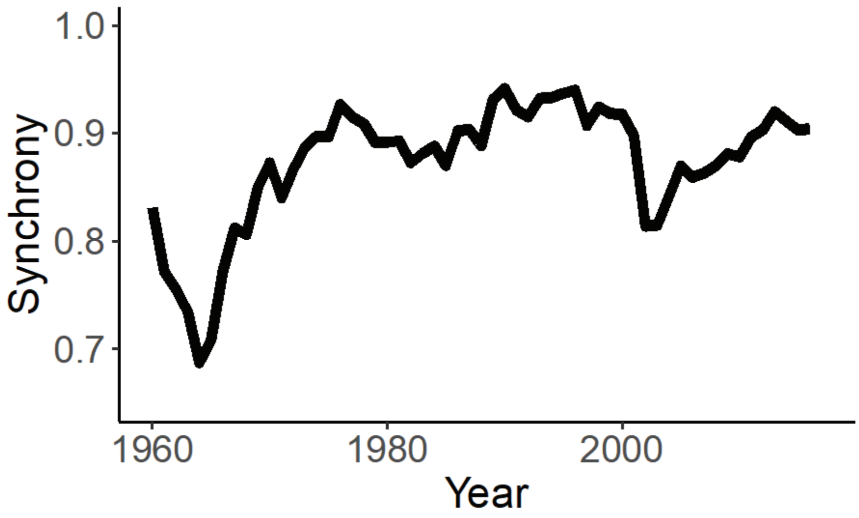


**Figure S11**. Observed trends in synchrony across Skeena River sockeye populations over the entire contemporary period (1960-2017) time series calculated for 10-year rolling windows.

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**From:** Paul Dale
**To:** DFG, BOF Comments (DFG sponsored)
**Subject:** Setnet cook inlet 600 foot fishing opportunity during low abundance of Chinooks.
**Date:** Tuesday, October 5, 2021 4:04:21 PM

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Give these setnetters a break, they deserve it and should always have had this consideration!  Thanks, Paul Dale, Kenai alaska

Sent from my iPhone

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ALL

Board Members:

My name is Rick Jewell. Have lived in + out of Alaska For different periods of my life. Been a Natural Resource Worker in Fishing + Loggin all my life. Started setnetting in 1983 on the East Forelands point + on that location For 27 seasons. Am presently Fishing sites just the North side of Rig-Tenders dock. This year could have been a good Season For setnetters, as the Fish were deFinitely here in numbers. As usual political games came into being. Our last opening, which was extended at the last moment, out too 600' showed a minimal King impact — 11 Kings versus almost 40K Reds. A small trade! That 600' rule worked + we should have gotten another 1-2-3 days. At least the boats had a good Season; with huge Numbers over the counters + we Not Fishing. Our Upper East Forelands

Sub-district doesn't catch hardly any Kings anyway! The pressure IN the River ON Kings For decades + decades have Reduced those RUNS — do you think maybe the pressure OF consistently over-escaping the system has contributed to these smaller Runs we see Now?? The RUN of 1987 came From a very small comparatively escapement. You have the tool to Manage the sockeye during low King abundance when Reds are plenty.

over →

You are Not within the management plan to be in the business of trying to allowcate to different User groups. When there's an excess of Reds we should be allowed to Fish them. The 600' Rule does just that!

Thank You;

Sincerly, Rick Powell

S04H59097W

Territorial Sportsmen INC.
Post Office Box 32712 • Juneau, Alaska 99803
Telephone: (907) 789-2399 • Fax: (907) 586-6020

September 21, 2021

Alaska Board of Fisheries
c/o Glenn Haight
Executive Director
ADF&G Board Support Section
PO Box 115526
Juneau, AK 99811-5526

Dear Board of Fisheries Members:

The Juneau-based Territorial Sportsmen, Inc. (TSI) respectfully requests that the Southeast Alaska/Yakutat Board of Fisheries meeting scheduled for January, 2022 be postponed until effective safeguards can be developed and implemented to deal with the ongoing COVID-19 pandemic. We believe virtual meetings do not allow for the full spectrum of information sharing and public engagement in the regulatory process, and we further believe it to be highly unlikely that the delta variant of Covid-19 will abate sufficiently by January 2022, thereby creating a health risk to participants.

While virtual meetings have become used for bringing organizations and the public together in the face of the pandemic, we oppose virtual meetings as a venue for the Board of Fisheries process for the following reasons:

1. Southeast Alaska fisheries issues are diverse, complicated, and challenging for board members as well as for members of the participating public. Added to this is the fact that several new board members have come onboard since the last Southeast meeting four years ago. From our experience, personal interactions with board members at scheduled meetings are critically important for members of the public who have interests and insights on issues that they wish to share and have considered in the decision-making process.
2. Board proposals are often amended, sometimes multiple times, before their final adoption. Through Alaska's open board process, the public often helps to formulate and guide final amended regulatory products through interactions with board members at

breaks, by submitting timely Record Copies (RCs), and by participating in impromptu gatherings to develop acceptable and suitable regulatory language. This would all be lost if the upcoming SE Alaska meeting were to be held online, with the risk of promulgating regulations that lack the benefit of broad, critical, and useful input from various and diverse interests.

TSI believes the current fisheries regulations can withstand another season without the need for a board meeting. This belief is based on our knowledge that department staff has Emergency Order (EO) authority to address fisheries conservation issues in a timely manner (as they did in 2021), and with the knowledge that the Commissioner and Board both have Emergency Regulation (ER) authority to handle conservation, allocation, or other emergencies, including stocks of concern, without general board meetings.

As far as other areas of the state are concerned, the fairest way to deal with postponement of the meetings for this cycle is to postpone all areas by one year, effectively creating a one-time 5-year cycle for regulatory board meetings.

When the board takes up Southeast fisheries issues in 2023, it can do so with direct and meaningful in-person input that is critical to sound decision making and the public process.

Thank you for the opportunity to provide input. Please don't hesitate to contact me if you have questions about our request.

Sincerely,

Ryan Beason, President
Territorial Sportsmen Inc.

Submitted By
Thomas Upah
Submitted On
9/5/2021 5:01:40 PM
Affiliation: none

There comes a time when the health of the ecosystems become more urgent then financial gain. Commerical fishing of all salmon is continually decreasing salmon numbers. It is true that banning all salmon fishing for at least one season maybe longer would devastate an industry and cause difficulties. If Commerical fishing of salmon is allowed to continue the salmon may not be able to recover. Certainly any people losing income or jobs will most likely recover. In my mind the choice is simple but unpopular. Thanks for listening

Boards Support Section, ADFG
P.O. Box 115526
Juneau, AK 99811-5526

Re: Yukon River Salmon Fishery Issues For Consideration

Chairman Carlson-Van-Dort and Members of the Board of Fisheries:

I am writing on behalf of the Yukon River Drainage Fisheries Association, a non-profit focused on conserving the subsistence and commercial fisheries, and traditional cultures, within the Yukon River system. Our mission is to serve as a voice for the fishing-dependent peoples of the Yukon, and to foster a meaningful dialogue between fishers and fishery managers of the region.

Today, that dialogue is focused on the salmon crisis in the Arctic-Yukon-Kuskokwim. A steady, multi-decade salmon decline on the AYK has been marked with periodic chum and Chinook stock crashes, culminating in a season of record loss in 2021. With zero commercial or subsistence harvest of Chinook or summer chum on the Yukon this year, and many stocks below needed escapement, we are looking for statewide collaboration to examine and address issues impacting the health of these iconic stocks. ***This is a critical matter of well-being in our region, impacting the health of our food systems, livelihoods, family structures, cultural traditions and more.*** While the AYK is not currently in cycle, we would like to call the board's attention to opportunities to discuss and address this crisis in the coming meetings.

Available in the Miscellaneous Section of the board workbook is a proposal submitted by Virgil Umphenour as a non-regulatory ACR. The ACR requests additional genetic scrutiny of chum, Chinook and pink salmon stocks harvested in the Area M salmon fishery. YRDFA strongly supports this request, and asks that the Board schedule a time to take up a meaningful discussion about this and other critical research needs addressing Yukon salmon declines. In particular, as you discuss committee meetings and agendas, please prioritize this issue for the Special Committee on Fisheries Management Research Needs.

Additionally, we ask that Yukon River issues be highlighted in the Committees on habitat and subsistence. Interaction with other fisheries is just one of the important areas to investigate in addressing this crisis, and we believe including it in these and other discussions is an important step.

We intend to work with other stakeholders, managers and state leaders to support public dialogues, project development, funding resources and eventual management responses that will address the Yukon River salmon crisis. Given the critical state of the stock, we ask that the Board support this ongoing process by prioritizing these and other requests addressing Yukon salmon declines. While these requests are non-regulatory, they are a matter of great public and management interest, and the Board process is a critical opportunity to gather public input, and to hold a multi-sector dialogue about the distinct and cumulative challenges facing the Yukon.

**In summary, we urge the board to prioritize critical review of the research needs and potential management strategies for addressing Yukon River salmon declines.**

The people of the Yukon are eager to partner with all stakeholders and decision makers in solutions to the stock crises we are experiencing on the Yukon. Thank you for prioritizing the discussions that will help us all move toward those solutions, and thank you for considering our comments.

Sincerely,

Victor Lord
Co-Chair - Nenana

William Alstrom
Co-Chair - St. Mary's