The First NPAFC Workshop on

Developing a Mechanistic Understanding of the Impact of a Changing Climate on Salmon Abundance and Distribution Trends

North Pacific Anadromous Fish Commission

June 4–5, 2024
Vancouver Airport Marriott Hotel
Richmond, BC, Canada

Organizing Committee

Ed Farley, Chairperson (Auke Bay Laboratory, NMFS, USA; SSC)
Jackie King (Pacific Biological Station, DFO, Canada; SSC)
Dong Wook Yang (Marine Living Resources Division, FIRA, Korea; SSC)
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The North Pacific Anadromous Fish Commission (NPAFC) is pleased to invite you to the First NPAFC Workshop on "Developing a Mechanistic Understanding of the Impact of a Changing Climate on Salmon Abundance and Distribution Trends," to be held on June 4–5, 2024, in Richmond, BC, Canada. The Workshop will bring together scientists, managers, and other stakeholders to consider the current status and future of salmon and their habitats for the conservation of anadromous populations in a changing world.

Background

The North Pacific Anadromous Fish Commission (NPAFC) established a new NPAFC Science Plan to build on previous international cooperative research conducted within the International Year of the Salmon (IYS). The primary goal of the 2023–2027 Science Plan is to: "Establish a research framework to develop a mechanistic understanding of the impact of changing climate on salmon abundance and distribution trends in the North Pacific Ocean." The research objectives are to:

1. Improve knowledge of the relative biomass, distribution, migration, and fitness of Pacific salmon in the ocean (Present Knowledge); and
2. Understand causes and anticipate changes in the production of Pacific salmon and the marine ecosystems producing them (Forward Action).

Improved understanding of the mechanisms that regulate the distribution and abundance of Pacific salmon will promote the conservation of anadromous populations in the North Pacific Ocean, allow for better projections, or at least include realistic uncertainty given climate change, of Pacific salmon production trends in the future, and enhance sustainable fisheries management, food security, and economic security in member nations.

Workshop Objectives

- Improve knowledge of the migration, growth and survival of salmon and their environments
- Increase understanding of the causes of variations in salmon production in changing environments
- Anticipate future changes in salmon ecosystems and resulting changes in the distribution, survival, and abundance of salmon
- Provide a forum for results from International Year of the Salmon winter surveys
- Discuss application of new and developing technologies and analytical methods to research and manage salmon

Topic Sessions

Topic 1. Pacific Salmon and Steelhead Trout in a Changing Nort Pacific Ocean (Forward Action)
Moderator: Ed Farley

Outcome: The effects of natural environmental variability and human factors affecting salmon distribution and abundance are understood and quantified.

Climate change may result in significant variability and overall declines in the carrying capacity and usable habitat (distribution) of Pacific salmon in the North Pacific Ocean, potentially leading to expanded use of the Arctic Ocean, at least seasonally. An improved understanding of linkages between environmental changes and Pacific salmon production will help to plan for the economic consequences of these changes. The objectives are to understand and quantify the effects of environmental variability and anthropogenic factors affecting salmon distribution and abundance, and to project future changes with improved models.

1-1. Pacific salmon distribution/migration, climate and ocean changes
1-2. Pacific salmon density dependence, carrying capacity, climate and ocean changes
1-3. Pacific salmon critical periods, climate and ocean changes
1-4. Modeling the future for salmon
1-5. Summary and discussion

Topic 2. New Technologies
Moderator: Ed Farley

Outcome: New technologies and analytical methods are advanced and applied to salmon research.

Novel stock and fish identification methods including new molecular techniques, hatchery mass marking, and intelligent tags continue to be developed, and these tools are integral to comprehensive and cost effective monitoring and mechanistic studies to facilitate the formulation of effective models predicting the distribution and abundance of salmon populations. Although considerable progress has been made in both the basic understanding of population differentiation of mixed marine salmonid assemblages and in genetic research technologies, this knowledge is still insufficient to understand the spatial distribution of different populations in the ocean and the differences in their responses to changing environmental conditions. Implementing genetic methods to differentiate mixed marine salmonid assemblages and to expand the database of reference samples are increasingly needed.

2-1. New tools and activities to improve salmon identification
- additional pink salmon genetic baselines
- develop and standardize Pacific salmon genetic data and analysis methods for comprehensive coastwide genetic baseline database

2-2. New tools to improve an understanding of salmon marine ecology including: genomics, eDNA, marking, intelligent tags, remote sensing/autonomous vehicles, tracking
2-3. Summary and discussion

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
Moderator: Jackie King

Winter is believed to be a critical period for salmon where reduced prey resources and increased competition may impact survival. One major objective for the IYS was to conduct international collaborative research in the North Pacific Ocean during winter to help understand winter marine ecology for Pacific salmon. Two expeditions during winter 2019 and 2020 focused on Pacific salmon winter ecology in the Gulf of Alaska and initial results were discussed at a virtual conference held in April 2021. A large-scale international research survey was conducted during winter 2022 and included four research vessels sampling from the eastern to the central North Pacific Ocean. Initial survey results were presented at the IYS Synthesis Symposium in Vancouver, BC, Canada in October 2022. This session is intended to provide a venue for new results from ongoing analyses being conducted by international scientists.

3-1. New results from the International Year of the Salmon winter surveys
3-2. Summary and discussion: overview of lessons learned for future challenges

Oral Presenters

Please have your presentation saved on a USB memory stick and give it to the Secretariat when you arrive to register at the workshop. Please see the following schedule so the Secretariat can have your presentation saved on the presentation computer well in advance of the session.

If you have not submitted your presentation when you pick up your registration materials at the registration desk at the workshop, **the latest time to submit your oral presentation to the Secretariat is the following:**

If your presentation time is	Bring your presentation to the Secretariat by
June 4 (Tuesday) a.m. (morning)	June 4 (Tuesday) **between** 9:30–10:30
June 4 (Tuesday) p.m. (afternoon)	June 4 (Tuesday) **by** 13:40
June 5 (Wednesday) a.m. (morning)	June 5 (Wednesday) **by** 10:30
June 5 (Wednesday) p.m. (afternoon)	June 5 (Wednesday) **by** 14:20

Virtual Presenters

Please submit your presentation to the NPAFC Secretariat by May 31, 2024 (Vancouver time). During the workshop the NPAFC Secretariat will be actively communicating with you prior to your presentation.

Poster Presenters

Posters should be delivered to the registration desk on Tuesday, June 4, between 09:30–10:30. Posters should be removed on Wednesday, June 5, by 18:00. Posters not removed by 18:00 may be discarded.

Tentative Program

(*Subject to change without notice*)

**Presenter*

June 4 (Tuesday) Oral Presentations

June 5 (Wednesday) Oral Presentations

<u>Topic 1. (Continued)</u>

(Moderator: Ed Farley)

Topic 2. New Technologies

(Moderator: Ed Farley)

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys

(Moderator: Jackie King)

June 4, 2024	Timeslot					
Item	**Vancouver Time**	**Tokyo/Seoul time (+16 hrs)**	**Vladivostok time (+17 hrs)**	**Duration**	**Topic**	**Presenter**
Registration	9:30–10:30	1:30–2:30	2:30–3:30	1 hr		
Opening Remarks	10:30–10:50	2:30–2:50	3:30–3:50	20 min		E. Farley, Y. Kondo
Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action)—Moderator: Ed Farley						
Introduction	10:50–11:00	2:50–3:00	3:50–4:00	10 min		E. Farley
Oral-1	11:00–11:20	3:00–3:20	4:00–4:20	20 min	T1-1	J. Langan
Oral-2	11:20–11:40	3:20–3:40	4:20–4:40	20 min	T1-1	W. Greentree
Oral-3	11:40–12:00	3:40–4:00	4:40–5:00	20 min	T1-1	S. Latham
Oral-4	12:00–12:20	4:00–4:20	5:00–5:20	20 min	T1-2	J. Cassinelli
Lunch Break	12:20–13:40	4:20–5:40	5:20–6:40	1 hr 20 min		
Oral-5	13:40–14:00	5:40–6:00	6:40–7:00	20 min	T1-2	C. Neville
Oral-6	14:00–14:20	6:00–6:20	7:00–7:20	20 min	T1-3	S. Surma
Oral-7	14:20–14:40	6:20–6:40	7:20–7:40	20 min	T1-3	K. Dunmall
Oral-8	14:40–15:00	6:40–7:00	7:40–8:00	20 min	T1-3	E. Duffy
Oral-9	15:00–15:20	7:00–7:20	8:00–8:20	20 min	T1-3	S. Esenkulova
Oral-10	15:20–15:40	7:20–7:40	8:20–8:40	20 min	T1-3	B. Beckman
Poster Session (Coffee Break)	15:40–16:20	7:40–8:20	8:40–9:20	40 min		
Oral-11 (pre-recorded)	16:20–16:40	8:20–8:40	9:20–9:40	20 min	T1-1	K. Honda
Oral-12 (virtual)	16:40–17:00	8:40–9:00	9:40–10:00	20 min	T1-1	A. Somov
Oral-13 (pre-recorded)	17:00–17:20	9:00–9:20	10:00–10:20	20 min	T1-1	M. Kaeriyama
Oral-14	17:20–17:40	9:20–9:40	10:20–10:40	20 min	T1-4	S. Peacock
Oral-15 (pre-recorded)	17:40–18:00	9:40–10:00	10:40–11:00	20 min	T1-3	A. Litvinenko

June 5, 2024	Timeslot					
Item	**Vancouver Time**	**Tokyo/Seoul time (+16 hrs)**	**Vladivostok time (+17 hrs)**	**Duration**	**Topic**	**Presenter**
Topic 1. Continued—Moderator: Ed Farley						
Oral-16 (virtual)	10:30–10:50	2:30–2:50	3:30–3:50	20 min	T1-3	A. Krovnin
Oral-17 (virtual)	10:50–11:10	2:50–3:10	3:50–4:10	20 min	T1-3	A. Krovnin
Oral-18	11:10–11:30	3:10–3:30	4:10–4:30	20 min	T1-5	S. Ainsley
Topic 2. New Technologies—Moderator: Ed Farley						
Introduction	11:30–11:40	3:30–3:40	4:30–4:40	10 min		E. Farley
Oral-19	11:40–12:00	3:40–4:00	4:40–5:00	20 min	T2-2	K. Berry
Oral-20	12:00–12:20	4:00–4:20	5:00–5:20	20 min	T2-2	S. Narum
Oral-21	12:20–12:40	4:20–4:40	5:20–5:40	20 min	T2-2	Y. Gou
Lunch Break	12:40–14:00	4:40–6:00	5:40–7:00	1 hr 20 min		
Topic 3 (Special Session). New Results from International Year of the Salmon Surveys—Moderator: Jackie King						
Introduction	14:00–14:10	6:00–6:10	7:00–7:10	10 min		J. King
Oral-22	14:10–14:30	6:10–6:30	7:10–7:30	20 min	T3-1	C. Neville
Oral-23	14:30–14:50	6:30–6:50	7:30–7:50	20 min	T3-1	M. Konik
Oral-24	14:50–15:10	6:30–6:50	7:50–8:10	20 min	T3-1	J. King
Oral-25	15:10–15:30	7:10–7:30	8:10–8:30	20 min	T3-1	M. Quindazzi
Oral-26 (virtual)	15:30–15:50	7:30–7:50	8:30–8:50	20 min	T3-1	T. Miller
Poster Session (Coffee Break)	15:50–16:30	7:50–8:30	8:50–9:30	40 min		
Oral-27	16:30–16:50	8:30–8:50	9:30–9:50	20 min	T3-2	E. Farley
Summary and Discussion	16:50–17:50	8:50–9:50	9:50–10:50	1 hr		E. Farley
Closing Remarks	17:50–18:00	9:50–10:00	10:50–11:00	10 min		Y. Kondo

Speakers: 15 min presentation + 3 min question/discussion = 18 min + 2 min speaker change-over

Tusday June 4, 2024 and Wednesday June 5, 2024

Item	Poster Session	Topic	Presenter	Authors
Poster-1	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-1		Byoungsun Yoon, Dooho Kim, Jongkuk Choi, and Jukyoung Kim
Poster-2	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-2	Dejan Brkic	Dejan Brkic, Eric Taylor, Angela Phung, and Stephen Latham
Poster-3	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-3	Neala W. Kendall	Neala W. Kendall, Megan Moore, Michael Malick, and Gary Marston
Poster-4	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-3		Ksenia Bogdanova, Maxim Koval, and Vladimir Kolomeitsev
Poster-5	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-3		Elena Kalchenko, Sofia Gorodovskaya, Alexey Lozovoy, and Alexander Popkov
Poster-6	June 4, 15:40–16:20 June 5, 15:50–16:30	T1-3	Angela Phung	Angela Phung, Stephen Latham, and Catherine Michielsens

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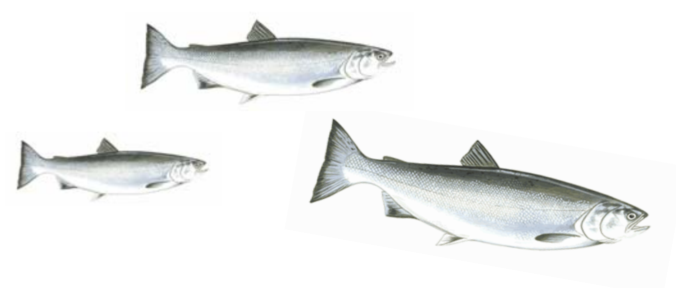
Oral Presentations



Oral Presentation-1

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

Pacific Salmon at Sea: Using Historical Data to Characterize Distributions in a Warming Ocean

*Joseph A. Langan[*1,2], Curry J. Cunningham[2], Jordan T. Watson[3], and Skip McKinnell[4]*

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[2]College of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Juneau, AK, USA
[3]Pacific Islands Ocean Observing System, University of Hawaiʻi Mānoa, Honolulu, HI, USA
[4]Salmoforsk International Environmental Consulting, Victoria, BC, Canada

Pacific salmon spend a large part of their life cycle in the open ocean, where climatic and oceanographic conditions are thought to strongly influence habitat selection, trophic interactions, and survival. Although salmon as a group are abundant in the surface waters of the North Pacific, critical knowledge gaps regarding their ocean ecology and distributions persist. As a result, it has been difficult historically to assess how high seas environmental conditions influence the marine distribution and thermal habitat use of these culturally and socioeconomically important fishes. To address this issue, we assembled a suite of datasets covering coastal and high seas regions spanning the 1950s to the present to: (1) model and compare the marine spatial distributions of six salmon species, (2) characterize how species-specific temperature preferences influence marine distributions, and (3) evaluate how distributions may be changing in a warming ocean. Results from multiple spatiotemporal modeling approaches indicate that each salmon species has a unique marine distribution that evolves throughout the seasonal cycle. Sea surface temperature was found to significantly influence the seasonal distribution of all species, where tolerances for warm temperatures were more similar than predicted for cold temperatures. Based on this finding, it appears that recently observed warm conditions may limit salmon thermal habitat during the North Pacific summer season to a greater degree than in the past. At the opposite range edge, however, summer thermal habitat may be expanding into the Arctic. These results help to advance our understanding of salmon ocean distributions and thermal niches, opening a unique window into this less observed but crucial portion of the life cycle, and serve as a baseline for the future investigations aimed at mitigating bycatch, reducing illegal fishing, and interpreting productivity changes linked to altered patterns of marine habitat suitability across the North Pacific.

Oral Presentation-2

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

Chinook Salmon Overwinter Residency in the Strait of Georgia: Insights from Acoustic Telemetry

Wesley Greentree[*1], *Will Duguid*[2], *Nick Bohlender*[3], *Katie Innes*[2], *Bridget Maher*[1], *Jamieson Atkinson*[4], *and Francis Juanes*[1]

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[2]*Pacific Salmon Foundation, 1385 W 8th Ave #320, Vancouver, BC, V6H 3V9, Canada*
[3]*South Coast Stock Assessment, Fisheries and Oceans Canada, 315-940 Alder St, Campbell River, BC, V9W 2P8, Canada*
[4]*British Columbia Conservation Foundation, 105-1885 Boxwood Rd, Nanaimo, BC, V9S 5X9, Canada*

The marine migrations of Chinook salmon are coarsely resolved in space and time, with little known about how individual traits influence timing and extent of migration. In Chinook salmon populations from rivers draining into the Strait of Georgia (British Columbia, Canada), ocean-type juveniles spend their first summer feeding and growing within the Strait. At an unresolved time after the first ocean summer, some juveniles emigrate to the continental shelf, while others remain resident in the Strait of Georgia for most or all their marine life. Migrants and residents likely experience different prey fields, predator communities, and fishery pressure. Whether an individual migrates or remains resident is likely a trade-off between growth and survival, meaning that environmental conditions or individual-level variation (which may be genetic or a result of environmental conditions) may influence migration strategies. To identify if migratory strategy variation is linked to individual traits, we implanted acoustic transmitters in 329 Chinook salmon from two ocean entry cohorts in their first fall (September 2023, October 2022 and 2023) and winter at sea (January 2023 and 2024). In the first cohort, overwinter residency in the Strait of Georgia was common, with migrants primarily detected leaving the Strait of Georgia after the first ocean winter. Data from acoustic receiver arrays monitoring overwinter movements of the second cohort will be received in April 2024. The two cohorts experienced starkly different early marine conditions, which may help build hypotheses about how the environment shapes salmon marine distributions. The 2022 ocean entry cohort was characterized by both an abnormally cold spring and intense fall drought, with smaller fish sizes entering the first winter at sea compared to the 2023 cohort that experienced more-normal conditions. We will test for relationships between different migration strategies (Strait of Georgia residency or outmigration) and individual traits (length, body condition, scale-derived early marine growth). Understanding how the environment and individual condition influence Chinook salmon residency in the Strait of Georgia will aid ongoing efforts to estimate stage-specific marine survival rates.

Oral Presentation-3

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

What do Catches of Fraser River Sockeye in Alaska Tell us About Changing Migration Routes in the North Pacific Ocean?

Stephen Latham and Angela Phung*

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Infrequent bycatch of Fraser sockeye in Alaskan pink salmon fisheries (mean <1%) can constitute a non-negligible fraction of the total Fraser sockeye abundance in some years. As stated in the Pacific Salmon Treaty, however, “the extent of these incidental catches is unpredictable from year to year.” Samples of DNA have been shared internationally to facilitate identification of specific Fraser sockeye stocks in Alaskan catches, with the goal of accumulating a long-term data set for studying the migrations of these stocks and, eventually, for making successful predictions regarding their various marine distributions and vulnerabilities to harvest. We studied the inter- and intra-annual variation of Fraser stock compositions in Alaskan catches from 2005–2022. These samples were compared to collections taken over the same time periods near the Fraser River, nearly 1,000 km to the south. On an annual basis, compositions of Fraser sockeye in Alaska differed consistently from the compositions observed in catches to the south, e.g., stocks that return to the Fraser earlier and take a more southern route around Vancouver Island were under-represented in Alaskan samples. When analyzed on a weekly basis, however, Alaskan samples were similar to samples collected on the same dates near the Fraser River. This concordance of stock proportions challenges assumptions about the behaviour of Fraser sockeye and has implications for the interpretation of estimated interceptions in Alaska. Correcting for fishing effort, this analytical framework may help combat the unpredictability of marine migration routes as climate changes.

Oral Presentation-4

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-2. Pacific salmon density dependence, carrying capacity, climate and ocean changes)

Trends in Adult Return Abundance of Idaho Salmon and Steelhead Relative to Pink Salmon Abundance the Year of Ocean Entry

John Cassinelli and Josh McCormick*

*Idaho Department of Fish and Game, Headquarters Office, 600 S Walnut St., Boise, ID, 83646, USA (*E-mail: john.cassinelli@idfg.idaho.gov; Tel: 1-208-854-8963)*

Historically, the Columbia River basin produced some of the largest runs of pacific salmon and steelhead in North America. Within the Columbia River basin, the Snake River basin is the largest tributary, producing more than half of the Chinook Salmon and steelhead in the entire basin. The Snake River basin contains four runs of ESA listed anadromous salmonids (Spring/Summer Chinook Salmon, Fall Chinook Salmon, Sockeye Salmon, and steelhead) as well as several large hatchery mitigation programs. Within a given juvenile outmigration year, millions of juvenile salmon and steelhead from the Snake River basin enter the Pacific Ocean, where they will typically spend one to three years before returning to freshwater and migrating back to their natal waters in Idaho. While year- and species-specific adult return abundance of Idaho's anadromous salmonids is highly variable, in the early 2010s managers began to notice some distinct every-other-year patterns in adult returns across many of Idaho's stocks. Concurrently, commercial Pink Salmon harvest in the North Pacific Ocean surpassed 400M fish in 2009 and odd-year abundance and commercial harvest has remained high since that time. We developed a state-space model to estimate abundance of Idaho's returning salmon and steelhead and embedded a regression model to estimate the effect of Pink Salmon abundance (using AK commercial harvest as a surrogate) during the year of ocean entry, on the intrinsic growth rate. For all species of pacific salmon and steelhead returning to Idaho, Pink Salmon abundance had a strong negative effect on intrinsic growth rate and the negative effect has increased through time. Additional work understanding the mechanism for increasing odd-year pink salmon abundance effects on Columbia basin anadromous salmonid ocean survival is needed, especially given the increasing impacts in a changing ocean climate.

Oral Presentation-5

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-2. Pacific salmon density dependence, carrying capacity, climate and ocean changes)

What happened in 2023—The Best Coho Salmon Fishing in the Strait of Georgia in 30 Years

Chrys Neville and Richard Beamish*

*Pacific Biological Station, Fisheries and Oceans Canada, 3190 Hammond Bay Rd., Nanaimo, BC, V9T 6N7, Canada (*E-mail: chrys.neville@dof-mpo.gc.ca; Tel: 1-250-756-7185; Fax: 1-250-756-7053)*

Recreational fishing for Coho salmon in the Strait of Georgia collapsed in 1995 when their behaviour changed and virtually all juveniles left the Strait of Georgia late in their first ocean year and did not return until their spawning migration in the following year. This resulted in the closure of one of a major sport fisheries in British Columbia at that time. This behaviour continued for over a decade. It was not until 2017–2018 that there was evidence that some Coho salmon remained within the Strait of Georgia over the winter. Additionally, some of the Coho salmon that had migrated offshore, returned to the Strait of Georgia in the early spring of the following year. The abundances of Coho salmon available for the recreational fishery in the strait continued to increase with total catches in 2023 the largest since the early 1990s. The increased abundance in 2023 was a result of increasing ocean survival which resulted from increased growth during their early marine period in the strait. In addition to this increased early marine growth there was an increased ocean carrying capacity for juvenile Coho salmon in the strait. These changes were related to an increasing trend in plankton production that started about 2008. As early marine growth of the juveniles Coho salmon increased, there was also an increase in the number of juvenile Coho salmon in the strait in September of their first marine year and more of these juveniles remained in the Strait of Georgia over the winter. The exceptional recreational catch in 2023 resulted from a combination of improved ocean survival and greater winter residency in the Strait of Georgia. Catch rates of ocean age 1 Coho salmon in June-July scientific trawl surveys in the Strait of Georgia in 2013 to 2023, had a similar trend to the recreational catch and indicate that this survey could provide an early season indication of abundances to managers. Additionally, the abundance and average lengths of juvenile Coho salmon in the 2023 fall scientific surveys were larger than previous years and possibly indicate that the recreational catch in 2024 in the Strait of Georgia will good as or perhaps better than in 2023.

Oral Presentation-6

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon density dependence, carrying capacity, climate and ocean changes)

Impacts of Hatchery Production on Natural-run Salmon and Subarctic Pelagic Ecosystems

Szymon Surma[*1,2], Evgeny A. Pakhomov*[1,2], Brian P.V. Hunt*[1,2], Genyffer C. Troina*[1,2], Joanne Breckenridge*[1,2], and Kerim Y. Aydin*[3]

[1]*Institute for the Oceans and Fisheries, University of British Columbia, Canada (*E-mail: s.surma@oceans.ubc.ca)*
[2]*Department of Earth, Ocean, & Atmospheric Sciences, University of British Columbia, Canada.*
[3]*Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, USA.*

The pelagic phase of Pacific anadromous salmonid life cycles is crucial in regulating the growth and survival of these species, which are of vital ecological, economic, and cultural importance to North Pacific countries. However, interactions among salmonids, and with their predators, prey, and competitors, in the subarctic Pacific Ocean remain an area of active research. It has been suggested that rearing salmon (primarily chum and pink; *Oncorhynchus keta* and *O. gorbuscha*) in hatcheries, intended to supplement natural runs and enhance fisheries yields by reducing mortality in early freshwater life stages, may be detrimental to natural runs due to competition for shared marine prey. This paper investigates this hypothesis using models of the pelagic ecosystems of the eastern and western subarctic Pacific (ESA and WSA), constructed in Ecopath with Ecosim and designed for cross-ecosystem comparability of results. Firstly, prey niche overlap (i.e. pairwise similarity in diet composition between consumers) and mixed trophic impact (i.e. instantaneous effect of a unit change in the biomass of one species on another) were computed for all salmonids in both ecosystems. Secondly, in each model, mean pelagic biomass of adult and juvenile of hatchery-reared chum, pink, and sockeye (*O. nerka*) salmon in 2011–2015 was (i) kept constant, (ii) doubled, and (iii) halved in dynamic ecosystem simulations lasting 2016–2040. Ratios of average biomass in the final decade following stabilization of simulated biomasses (2031–2040) in scenarios (ii) and (iii) relative to (i) were computed in each model for all functional groups (i.e. species or groups thereof sharing basic ecological traits), including all natural-run *Oncorhynchus* spp., predators, and competitors. Prey niche overlap and especially mixed trophic impact indicated the potential for notable inter- and intraspecific competition among salmon in the ESA and WSA ecosystems. In the ESA, doubling hatchery-reared salmon biomass had noticeable adverse impacts on all natural-run salmonids (particularly coho salmon *O. kisutch*, Chinook salmon *O. tshawytscha*, and steelhead trout *O. mykiss*) while strongly benefiting daggertooth (*Anotopterus nikparini*), a mesopelagic predator of salmonids. In the WSA, doubling hatchery-reared salmon biomass exerted substantial negative impacts on natural-run pink, sockeye, and particularly chum salmon, while supporting increases in higher predators. Across ecosystems, impacts of halving hatchery-raised salmon biomass had opposite signs and lower magnitudes relative to the doubling scenario. This research advances our knowledge of the pelagic ecology of Pacific salmonids, particularly exploitation competition and the impacts of hatchery production on food web structure and dynamics in the subarctic Pacific.

Oral Presentation-7

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes).

Pacific Salmon Expansion into the Canadian Arctic Under Rapid Climate Change

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Rapid climate change is altering Arctic ecosystems at unprecedented rates. These changes in the physical environment may open new corridors for species range expansions, with substantial implications for subsistence-dependent communities and sensitive ecosystems. Over the past 20 years, rising incidental harvest of five species of Pacific salmon by subsistence fishers has been monitored across a widening range spanning multiple land claim jurisdictions in Arctic Canada. In this study, we connect Indigenous and scientific knowledges to explore potential oceanographic mechanisms facilitating this ongoing northward expansion of Pacific salmon into the western Canadian Arctic. A regression analysis was used to reveal the roles of thermal and sea-ice conditions in the Chukchi and Beaufort seas in creating a seasonal range-expansion corridor for salmon, driving the variation in annual catches reported within this region. Furthermore, there is a body of knowledge to suggest that these conditions, and consequently the presence of Pacific salmon, will become more persistent in the coming decades. Our collaborative approach positions us to document, explore, and explain mechanisms driving changes in salmon ranges that have the potential to, or are already affecting, Indigenous rights-holders in a rapidly warming Arctic.

Oral Presentation-8

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

The Puget Sound Offshore Monitoring Program: An Essential Management Tool for Salmon in a Changing Climate

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Juvenile salmon experience rapid change during early marine stages in estuarine, nearshore, and offshore marine habitats. Size and growth, particularly in offshore habitats, strongly influence survival to adulthood and are linked to food supply, predators, and environmental conditions. The Salish Sea Marine Survival Project (SSMSP) found that food supply and predation during early marine residence are the primary factors contributing to the persistent low marine survival for Chinook and coho salmon in Puget Sound and the Strait of Georgia. Further, climate change appears to be driving shifts in the food web that will likely exacerbate conditions. For salmon to survive in the long run, managers and recovery planners need time series data that helps connect the dots between climate, plankton, forage fish, and salmon—both locally and across the greater Puget Sound ecosystem. To fill this critical data gap, the Tulalip Tribes, the U.S. Geological Survey, and Long Live the Kings have established a collaborative Puget Sound Juvenile Salmon and Herring Offshore Monitoring Program following protocols from an offshore purse seine survey refined under the SSMSP (2014–2015) that sampled water, zooplankton, and juvenile salmon and herring. Since 2021, we have conducted annual summer offshore surveys spanning Puget Sound, Hood Canal, and northern Washington waters. We will present preliminary results on trends in catch, size, and diets from these recent surveys as well as comparisons to the 2014–2015 SSMSP surveys. Our goal for this program is to answer two crucial questions for sustaining salmon in a changing climate: (1) What mechanisms in early marine life are impacting salmon survival; and (2) Can we identify Salish Sea ecosystem indicators to improve forecasting, fisheries management, and salmon recovery efforts?

Oral Presentation-9

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

Salmon, Oceanography, and Heterosigma: Insights from a 23-year Observations in the Strait of Georgia

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The Strait of Georgia, Canada, is an important rearing ground for Pacific salmon. In recent decades, many salmon populations have experienced dramatic declines. We explore links between 23 years of observations (2000–2023) of summer juvenile salmon CPUE, taxa richness, biodiversity indices (based on Fisheries and Oceans Canada juvenile survey data), and oceanographic parameters (temperature, salinity, stability index) as well as Heterosigma akashiwo counts (single cell algae that often blooms in the Strait). Higher taxa richness was observed in the first decade compared to the second decade. Over the years, there was an apparent shift towards a greater dominance of a few species and a more uniform distribution. Temperature anomalies (shifted ~6 months) correlated with PDO, while salinity correlated with NPGO for 2015–2023 but not for 2000–2015. Statistical analysis (RDA, PCC) of partial Heterosigma data unveiled significant links to temperatures, stratification, nutrients (N, P, Si), rainfall, and cloud cover. Preliminary findings suggest a possible relationship between Coho and Heterosigma abundance levels. This correlation can reflect ecosystem shifts. Understanding the complex relationships between oceanographic factors, plankton, and salmon can provide valuable insights for modelling and future conservation efforts.

Oral Presentation-10

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

Is Early Marine Growth Related to Salmon Survival? Two Decades of Data from Juvenile Coho Salmon in the Northern California Current

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Early summer growth for juvenile coho salmon has been assessed in the Northern California Current since 2000. Mean insulin-like growth factor 1 (IGF1) levels (an indicator of growth) differed significantly over succeeding decadal intervals (2000–2009 vs 2011–2022) with IGF1 levels since 2010 being consistently higher than found before 2010. Across the time series, IGF1 levels were correlated with a prey index for juvenile salmon derived from plankton samples collected in the upper water column during juvenile salmon surveys. There are no apparent correlations between juvenile salmon growth and basin-scale oceanographic indictors including the PDO, NPGO or ONI. Neither is there a correlation between juvenile salmon growth and upper water column temperatures concurrent with the survey. From 2000–2009 early marine growth was correlated with an index of coho salmon survival (OPIH), there was no correlation of growth with survival in the subsequent decade (2011–2022). These data don't easily fit with current paradigms suggesting that variation in juvenile salmon growth and survival is correlated with California Current ecosystem productivity driven by variation in basin-scale ocean processes indexed as by the PDO or NPGO. Indeed, the highest IGF1 level measured in the time series were unexpectedly found during the 2016 El Nino. Together, these data suggest that there isn't a simple relationship between early marine growth and survival for coho salmon in the NCC. Moreover, any relationship that does exist changed over a decadal time scale (2000–2009 vs 2011–2022). Finally, it may be difficult to establish mechanistic insights into growth and survival within the framework of current environmental variation in the NE Pacific Ocean.

Oral Presentation-11 (pre-recorded)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

Characteristics of Juvenile Chum Salmon Inversely Migrating Westward After Ocean Entry from Rivers Along Pacific Coast of Hokkaido, Japan

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Japanese juvenile chum salmon (*Oncorhynchus keta*) migrate northeasterly to the central Sea of Okhotsk. Although the existence of some juveniles originating from rivers in the Hokkaido Pacific region migrate inversely to the western waters was previously reported, much of their ecology is unknown. In this study, we compiled historical juvenile chum collection data to determine which river-origin juveniles migrate westward and over what distance. Then, targeting 398 juveniles originating from two rivers in the Hokkaido Pacific region, the characteristics of ocean-entry condition and growth rate of those collected in the west and east were estimated by otolith daily-increment analysis. Results showed that 2,124 (210) juveniles were collected in coastal waters >50 (> 200) km southwest of the origin river mouths in 2001–2021. Juveniles collected in the west tended to enter the ocean earlier than those collected in the east, and many entered before the sea surface temperature reached 5°C (the lower limit of the favorable temperature). In the west, a number of small-sized juveniles were collected within a short period after ocean entry, and these were assumed to have migrated passively against the westward cold current, Coastal Oyashio. While individuals collected in the east tended to grow faster and show lower condition factor at capture than those collected in the west. These were thought to be due to the growth-dependent mortality during their long-distance migration against the Coastal Oyashio, as well as to the consumption of a reasonable energy amount. Moreover, many juveniles in the west experienced near 13°C sea surface temperature (the upper limit) at capture. In recent years, there has been a shortening of the favorable water-temperature period in this region and a drastic decline in the number of adult chum returns there. Thus, an increase in the abortive migration by juveniles traveled westward is concerned.

Oral Presentation-12 (virtual)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

Comparison of Juvenile Pacific Salmon Abundance, Distribution, and Body Condition between Western and Eastern Bering Sea Using Spatiotemporal Models

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Recent changes in climate have had different impacts on salmon stocks in the eastern and western Bering Sea (WBS). Eastern Bering Sea (EBS) salmon stocks have periodically experienced reduced productivity, size, and survival, whereas salmon stocks in the western Bering Sea (WBS) have tended to be more stable, with some stocks increasing in abundance. This difference could be partially attributed to the different habitats that juvenile salmon occupy during their first marine year, which often determines recruitment. Here, we used salmon surveys in the EBS and WBS to compare the status of juveniles in these two large marine ecosystems. We applied spatio-temporal vector autoregressive spatio-temporal (VAST) models to adjust for differences in timing, vessels and trawl gear used, and to compare the relative abundance and body condition indices (length, weight, and Fulton's condition factor) of three juvenile salmon species (*Oncorhynchus gorbuscha, O. keta, and O. nerka*) between the WBS and EBS from 2002 to 2022. Juvenile salmon in WBS exhibited a consistent trend of larger size and higher Fulton's condition factor, with greater abundance compared to EBS in even years. A clear even-odd year pattern, which is believed to be driven by pink salmon (*O. gorbuscha*), occurred in all species' relative abundance and body condition in the WBS, with a limited impact of interannual temperature changes. Conversely, temperature had a significant impact on EBS salmon, with much of the variation in relative abundance and body condition occurring between warm and cold periods, and even/odd patterns were found only in pink salmon relative abundance and body condition. We detected different WBS-EBS migration patterns, with EBS juveniles dispersing from nearshore habitats earlier than WBS juveniles but migrating offshore later that is connected to bathymetry and the broad shelf in the EBS.

Oral Presentation-13 (pre-recorded)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-1. Pacific salmon distribution/migration, climate and ocean changes)

Production Trend of Hokkaido Chum Salmon Estimated by Multivariable Models Incorporating Environmental Factors and Biological Interactions in the North Pacific Ocean

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Pacific salmon (*Oncorhynchus* spp.) play an important role as a keystone species and provider of ecosystem services in the North Pacific ecosystems. Their total catch indicates an increasing trend since the late 1970s, but regional variations in salmon populations have been affected by climate warming. It is of great concern that the abundance of chum salmon (*O. keta*) in Japan has been declining since the late 2000s. Japanese chum salmon are a southernmost population, and they migrate widely, inhabiting different ecosystems in the North Pacific and adjacent seas, depending on their life stage and season. This complicated life history makes it difficult to understand the mechanisms of their population dynamics. This study aims to predict and consider the production trend of chum salmon in Hokkaido (northern Japan) using multivariate models, taking into account their seasonal marine life history. We analyzed dozens of variable indicators of environmental factors and biological interactions in the major marine habitats: coastal and nearshore waters around Hokkaido, the Sea of Okhotsk, the North Pacific Western Subarctic Gyre, the Gulf of Alaska, and the Bering Sea, using the backward elimination method of multiple regression analysis (SPSS Statistics ver. 21.0). Generalized additive models (GAM; R package "mgcv") were used to fit a Gaussian model with effective parameters (covariates) and annual chum salmon returns in Hokkaido (response variables) over 23 years. Our models suggest that the production trend of Hokkaido chum salmon is predicted by a combination of specific indicators such as spring sea surface temperatures (SST) in coastal waters around Hokkaido, winter SST in the Gulf of Alaska, and zooplankton biomass and abundance of other salmon populations in the Sea of Okhotsk and Bering Sea. We will consider the effects of climate warming and inter- and intra-specific interactions on the production of chum salmon throughout their marine life history.

Oral Presentation-14

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-4. Modeling the future for salmon).

Quantifying Climate Change Exposure of Pacific Salmon and Steelhead in Canada

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Increasing incidence of climate extremes—such as floods, heat domes, wild fire, and drought—have highlighted the urgency of the climate crisis in Canada, and yet there has not been a comprehensive assessment of how climate change may impact salmon and steelhead. The effects of climate change are felt by anadromous salmonids at every stage of their life cycle, through both freshwater and marine environments. To understand which populations are most vulnerable and why, we assessed the exposure to climate changes for 60 distinct populations of Pacific salmon and steelhead—called "Conservation Units"—in Canada's Fraser River basin. Drawing on climate model projections for stream temperature, stream flow, sea surface temperature, and sea surface salinity through to 2100, we quantified exposure based on the unique life history timing and spatial distribution for six life stages of each Conservation Unit.

The results suggest that exposure is highest for lake-type sockeye, driven by increasing stream temperatures during adult freshwater migration and spawning stages as well as relatively low thermal tolerance of sockeye marine life stages. Chinook salmon, in particular stream-type Chinook, are the next most exposed species, while coho, pink, and chum salmon had relatively low climate change exposure. Steelhead trout were unique in that their exposure was driven by high stream temperatures during the incubation stage, which occurs over summer.

In general, our calculations of exposure were driven by stream temperature and sea surface temperature because we were limited in our ability to quantify relative exposure to other climate changes. For example, sea surface salinity is projected to decline, with a greater magnitude of change in the coastal environments affecting the early marine stage. However, there was little information on how these changes may impact certain species or Conservation Units, and so salinity did not differentiate relative exposure among these groups.

We show how these climate change exposure assessments can be applied to help identify and prioritize actions to improve the resilience of salmon to climate changes. Our framework for assessing climate change exposure of Conservation Units is scalable and can be applied to other regions of Pacific Canada as data become available.

Oral Presentation-15 (pre-recorded)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific Salmon critical periods, climate and ocean changes)

Geochemical History of the Area and its Reflection in the Metal Content in the Salmon Fish of Iturup Island

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For the first time, data were obtained on the content of trace elements in lake keta from Lake Blagodatnoye, located on the Pacific coast of Iturup Island. The concentrations found were compared with earlier data on the content of heavy metals in river keta from the Reidovaya River, located on the Okhotsk coast of Iturup. It was found that lake chum salmon surpasses river chum in terms of Zn and Cu content, while chum salmon from the Reidovaya River, which repeatedly crossed the impact high-fat Sakhalin-Kuril zone during migrations, has a high concentration of Pb. The Cd content in the gonads of chum salmon from Lake. Blagodatnoye is approaching the maximum permissible concentration, and the concentration of this toxic metal in the liver of both river and lake chum salmon is several times higher than the levels allowed by SanPiN (2002). The amount of toxic metals in the chum salmon fillet meets the requirements of regulatory documents. Since the bowl of Lake Blagodatnoye lies below the slope on which the military unit is located, it is natural to expect both anthropogenic and man-made runoff from it. In the previous thirty years, the release of destroyed parts or parts of military equipment was repeatedly observed. The combination of the analyzed elements and their increased concentrations in fish make it possible to identify the most likely source of environmental pollution. If the predominant elements in the organs and tissues of chum salmon are Zn and Cu, then this indicates an anthropogenic impact, but if Cu and Fe, then it indicates the presence of fragments of military equipment in the water. Steel is alloyed with copper so that it does not magnetize. We noticed this interesting fact while working in Novik Bay on, the Island Russky. Despite the fact that the warehouse of mine-torpedo equipment in one of the coastal settlements was liquidated back in the 1930s, the revealed increased content of these two elements immediately told us about the history of the area.

Oral Presentation-16 (virtual)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

Recent Shift from Even- to Odd-year Dominance in West Kamchatka Pink Salmon Stock: Does it Mean a New Climatic Tendency in the North Pacific?

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Along with considerable variations in the catches, West Kamchatka (WK) pink salmon stock is characterized by a clear dominance of either odd-year or even-year generations over periods of 3–4 decades. Thus, odd-year returning pink salmon provided the high catches from the early 1940s to 1983, while the returns in even-numbered years were abundant in 1914–1940 and 1986–2020. Both periods of the high level of WK pink salmon stock in the even-numbered years coincided with the pronounced strengthening of tendency toward warming of surface waters in the North Pacific, though climatic mechanisms of the warming, and correspondingly, areas of its maximum manifestation were different. On the contrary, the period of dominance of the odd-year generations during the 1950s–1970s was characterized by a sharp decline of the stock. Its catches in odd-numbered years dropped from more than 100,000 tons in 1953 to 1,700 tons in 1969. The period of dominance of odd-year generations in WK pink salmon stock, accompanied by its decline, coincided with a prominent slowdown of the North Pacific warming, especially during the wintering season, Moreover, from 1963 to the mid-1970s a short-term countertrend against the background of the longer-term warming trend was observed. Those were the years, when the catches of WK pink salmon were minimal. A new shift to dominance of odd-year generations in WK pink salmon stock occurred in 2021, and in 2023 the WK pink salmon catch was 232,000 tons, i.e. almost 50% of the total Russian pink salmon catch. The above shift may indicate a lessening of warming rates in the North Pacific and subsequent decrease in the stock, as it was observed in the second half of the last century. Some signs of warming rate lowering were observed in the Northwest Pacific (NWP) area in the early 2020s. In particular, the lower (compared to the previous years) winter SST in the northern North Pacific region resulted in decrease in the Kamchatka pink salmon catches in 2020–2021. It should be taken into account that the long-term variations of all NWP salmon stocks are almost coherent. Hence, the switches between odd- and even-year dominance in WK pink salmon stock may serve as an indicator of upcoming changes in the state of all Asian salmons.

Oral Presentation-17 (virtual)

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

The State of Pacific Salmon Stocks in the Russian Far East and its Relation to Climate Variations

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Pacific salmon stocks in the Russian Far East remain at the high level. The tendency to the northward shift of salmon distribution appeared several years ago, continues. In 2017–2023, the share of northern stocks in the total Russian pink salmon catch ranged from 79% (2020) to 94% (2023), with the main catches off Kamchatka. The shift was associated with substantial warming of surface waters in the northern North Pacific. From 2016 on, pink salmon stocks on the Sakhalin Island decreased essentially due both the climatic variations and excessive fishery pressure (legal and illegal), but in 2022 the catch of Sakhalin pink salmon exceeded that of West Kamchatka pink salmon. Beginning from 2021, the pink salmon stock in the Amur River basin dropped substantially that resulted in closure of its fishery. The growth of chum salmon stocks in the Far East Region began from the mid-2000s, and now they remain at a relatively high level. In 2020–2021, a decrease in sockeye salmon catches down to the level of 30,000–32,000 metric tons was observed, but during the last two years the catch increased again up to 37,000 metric tons. Also, after the high-abundant approaches of coho salmon in 2014–2015 the decrease in their stocks was noted, except for 2023, when the catch reached 13,000 tons. In the South Kurils area, since 2007 there was a decrease in pink salmon stock, and its fishery in 2023 has failed. The catch was only about 2,000 metric tons at the average level of 15,000 tons in the last odd years. As to chum salmon in this area, after the high-abundant 2019 year, a decrease in the catch and its stabilization at the average level occurred. The growth of chum salmon stock is related to both the increasing volume of hatching and favorable climatic conditions during the marine period of life. The character of variations in the Far East salmon catches during the last 3 years brings into question the reliability of existing long-range forecasts of their stock state. This, to a large extent, may be associated with the increased short-term climate variability in the North Pacific region. The cooling in the northern North Pacific region in winter seasons resulted in decrease in the Kamchatka pink salmon catches in 2020–2021. The total Russian catch of Pacific salmons in 2023 constituted more than 608,000 metric tons. This is the second-highest catch volume over the whole history of observations and does not exceed only the 2018 catch of 678,000 metric tons, i.e. it is record for odd-numbered years. The expected catch volume in 2024 is 320,000 metric tons, i.e. 2 times lower than in the record 2018 year.

Oral Presentation-18

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-5. Summary and discussion)

Salmon and Climate Initiative: Advancing A Climate-resilient Recovery Approach for Pacific Salmon throughout their North American Range

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Robust and resilient salmon populations are necessary to support thriving ecosystems, Indigenous rights and cultures, and local economies; however, many salmon populations are in crisis and salmon fisheries are declining. Our communities organized around salmon are working hard towards recovery, but we are not on a trajectory to achieve success. Rapid climate change is making our path more difficult and demands a broader strategy. To catalyze actions for salmon and salmon-reliant communities, we need a scale of effort that hasn't yet been brought to bear. Long Live the Kings, the Pacific Salmon Foundation, Salmon Defense, and partners are working to develop a decades-long Salmon and Climate Initiative (SCI). This collaborative effort with Indigenous and non-Indigenous technical experts, managers, and policy makers is focused on advancing climate-resilient recovery approaches for Pacific salmon throughout western North America. The SCI will provide a space to collectively examine what is occurring from California to Alaska, share information and collaborate across jurisdictional boundaries, consider which solutions are working and where more effort is needed. Further, the SCI will seek significantly greater support from funders and appropriators for the types of actions and resources required to ensure a healthy and thriving future for Pacific salmon and people. In December 2023, we convened 70 experts in Western and Indigenous knowledge and practice to discuss what we can meaningfully do for salmon at this broad geographic scale. Through a series of small group discussions, participants brainstormed, developed, and refined an expansive list of potential collaborative actions. Beyond the workshop, SCI has engaged more broadly with prospective partners, decision makers and other major programs to continue scoping conversations. We will present the outcomes of this program development and solicit NPAFC workshop participant feedback on the scope of the initiative with the goal of developing a Strategic Plan for the SCI in the fall of 2024.

Oral Presentation-19

Topic 2. New Technologies (2-2. New tools to improve an understanding of salmon marine ecology including: genomics, eDNA, marking, intelligent tags, remote sensing/autonomous vehicles, tracking)

An Ocean Intelligence System for the North Pacific Ocean

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The International Year of the Salmon (IYS) was an initiative across the Northern Hemisphere to support resilient management of salmon and understand the implications for people. One of the signature projects of the IYS in the North Pacific was a series of integrated ecosystem research expeditions to study the North Pacific Ocean in winter to better understand how changing ocean conditions are affecting salmon, and their related ecosystem. To build on the success and enhanced knowledge derived from the IYS expeditions, the North Pacific Anadromous Fish Commission (NPAFC) and the North Pacific Marine Science Organization (PICES) are planning to design, test, and implement a collaborative international ocean intelligence system for the North Pacific. The system will utilize innovative technology, enhanced monitoring (by ships, uncrewed autonomous vehicles, satellites, etc.), data mobilization and analytical methods to provide timely knowledge and advice to decision-makers about the effects of climate on ocean basin conditions and coastal socio-ecological systems. This presentation will introduce the project, known as BECI (Basin-scale Events to Coastal Impacts), which has been endorsed as a project under the UN Decade of Ocean Science for Sustainable Development. BECI is currently in the planning stage and is developing a science plan to build and guide the project over the course of the Ocean Decade.

Oral Presentation-20

Topic 2. New Technologies (2-2. New Tools to improve an understanding of salmon marine ecology including: genomics, eDNA, marking, intelligent tags, remote sensing/autonomous vehicles, tracking)

Monitoring Genomic Variation of Salmonids in the Columbia River

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Anadromous species such as steelhead (*Oncorhynchus mykiss)* undergo long-distance migrations across geographical regions that consist of highly heterogeneous habitats that has led to local adaptation. Adaptive variation is often associated with phenotypic traits and extensive genomics research has revealed strong signals of local adaptation in steelhead throughout the Columbia River. This includes results from gene-environment association tests that provide evidence that adaptive allele frequencies are more commonly significant for Steelhead in the migratory corridor compared to their natal habitat (91.2% versus 8.8% of adaptive loci, respectively). Additional studies in steelhead have identified that balancing selection maintains variation for phenotypic traits such as adult migration timing (e.g., summer vs. winter) and age-at-maturity (1-ocean vs. 2-ocean) in populations throughout the Columbia River. Genes of major effect have been identified for these two traits and development of markers from these candidate genes has enabled monitoring of phenotypic and genetic variation in natural populations or hatchery-reared stocks. This is a promising approach to maintain a broad portfolio of phenotypic diversity in steelhead that can buffer against exploitation and increase species persistence in disturbed ecosystems.

Oral Presentation-21

Topic 2. New Technology (2-2. New tools to improve an understanding of salmon marine ecology including: genomics, eDNA, marking, intelligent tags, remote sensing/autonomous vehicles, tracking)

Binary Approach Using Otolith and Eye Lens to Reconstruct the Migration and Metabolic Histories of Juvenile Chum Salmon

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Tracking the migration of anadromous fish is historically challenging because of their widespread movement and free-ranging distribution in the open sea, particularly on larva or juvenile, which are usually vulnerable throughout their entire life span. Although understanding primary migration ecology is urgent for stock management and resource conservation, the fact that few larval or juvenile fish are capable of extrinsic tagging devices calls for novel tracking approaches. Here, we employed isotope compositions within otoliths and eye lenses as chemical tracers to decipher the experienced temperatures, migration patterns, and metabolic histories of 1-year-old chum salmon sampled in the central Bering Sea in July 2020 and 2021.
Fish otolith oxygen isotope (δ^{18}O) fractionation against surrounding water exists strong temperature dependency, and this relationship has already been determined in chum salmon. Accordingly, by aligning the retrospective otolith δ^{18}O values on isoscape (isotope mapping that depicts the isotope characteristics of water mass), experienced temperatures for 1 year salmon can be ideally and practically reconstructed. Moreover, in case that the isoscape for $\delta^{18}O_{seawater}$ was developed based on salinity gradient relationships, for an alternative otolith δ^{18}O value at a specific migration period, several salinity-temperature combinations of water mass were therefore derived. Because the combinations of salinity-temperature for seawater mass were considered area-specific, possible movement patterns were simultaneously generated.
In contrast to δ^{18}O in otoliths, which is believed to be deposited near isotopic equilibrium, the fractionation of carbon isotopes (δ^{13}C) in otoliths does not follow the theoretical precipitation patterns into otoliths caused by metabolic/kinetic effects. δ^{13}C in otoliths is proportionally incorporated by carbon from seawater dissolved inorganic carbon (DIC) and metabolically derived carbon. Based on these, within the scope of respiratory metabolism, the relationship between metabolism-derived carbon and metabolic rate was experimentally determined in juvenile chum salmon by respirometry and spectrometry. Furthermore, for the δ^{13}C values of the surface North Pacific was stable, the metabolic histories of wild salmon can be estimated when δ^{13}C of diet respiration-derived carbon is known. As for that slight isotopic fractionation exists in

$\delta^{13}C$ between bulk eye lens and diet, the trophic discrimination factor between bulk eye lenses and food was determined through rearing experiment. Because vertebrate eye lenses also grow incrementally, the $\delta^{13}C$ of the eye lens was used to deduce the retrospective $\delta^{13}C$ values of diets by delaminating the eye lens layer-by-layer. Based on which, the proportion of metabolism-derived carbon was calculated, and the retrospective metabolic rates during each migration phase were consequently estimated according to the determined relationship.

In brief, we developed a binary approach using isotopic tracers in both otoliths and eye lenses to reconstruct the experienced temperatures, possible migration routes, and metabolic histories of 1-year-old chum salmon. The implementation of experienced environments and the metabolic traits utilized by chum salmon within each migration stage were expected to be pronounced in clarifying their primary migration ecology.

Oral Presentation-22

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
(3-1. New results from the International Year of the Salmon winter surveys)

What We Learned in Chum School

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On March 31, 2022 in the Gulf of Alaska there were 7 chum salmon caught in a panel of gillnet that was 3 m X 3 m with a mesh size of 55 mm. The 7 chum salmon were all in their first ocean winter with an average length 286 mm and range of 195 mm to 338 mm. Six of the seven chum had a scale annulus with 1 to 3 new circuli. These fish originated from three major locations from northern British Columbia to central Alaska with a straight line distance between southern and northern locations of 1,600 km. For these fish to be in the school in the gillnet they needed to have an inherited requirement and ability to navigate to a particular location in the Gulf of Alaska and arrive at a particular time. They also needed to produce chum specific pheromones and have a requirement to detect increasing concentrations of these pheromones. For all of this to happen, there needed to be an evolved survival advantage to be in a school in the first ocean winter. This is a resilience for ocean survival that needs to be better understood and considered in the management of chum salmon.

Oral Presentation-23

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
(3-1. New results from the International Year of the Salmon winter surveys)

Recent Decrease in Diatom Contribution to the Phytoplankton Community in the Eastern Subarctic Pacific Ocean

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Phytoplankton communities show a dynamic response to environmental variability, such as changes in light field and physical and chemical water properties, making them a good indicator of possible ecosystem shifts. Here, we investigate changes in the phenology of total chlorophyll-*a* concentration and the six phytoplankton functional types (diatoms, dinoflagellates, cryptophytes, cyanobacteria, green algae, and the merged group consisting of haptophytes and pelagophytes) from 2002 to 2022 based on satellite-derived GlobColour times series data for the subarctic Pacific Ocean. To evaluate regional changes across the subarctic Pacific the analyses were carried out within bioregions, defined by the climatology of the phytoplankton phenology and composition. Within the eastern subarctic Pacific bioregions we found a decrease in the diatom-to-dinoflagellate ratio, as well as the diatom to the small algae chlorophyll ratio, including haptophytes, pelagophytes, green algae, and cyanobacteria. These changes have been observed in recent years following the marine heatwaves reported in this area. The time series considered needs to be longer to conclude the future of the phytoplankton community structure in the North Pacific. However, with future ocean warming, what we believe now a lingering effect of the heatwaves is likely to become a new normal, and our research could be a herald of what ecosystem change we may expect.

Oral Presentation-24

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
(3-1. New results from the International Year of the Salmon winter surveys)

Winter Pacific Salmon Diets in the North Pacific

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During winter, competition for limited prey resources is an important component of Pacific salmon survival. However, our knowledge on the feeding ecology of Pacific salmon in the open ocean during the winter is limited. The IYS surveys provided a prime opportunity to increase our understanding of the Pacific salmon winter foraging ecology. The >1,100 Pacific salmon stomachs analyzed across the IYS 2022 surveys provided insights into regional differences in diet for any given species and for potential overlap in diets between species. Universally, stomach contents for all salmon species were dominated by prey items typically associated with that species' diet with detectable regional variability. Chum salmon diets contained mainly gelatinous prey (jellyfish and larvaceans). Coho salmon diets were dominated by cephalopods. Pink salmon preyed on a wide variety of prey. Sockeye salmon diets were dominated by euphausiids in most areas. Steelhead salmon prey was mostly cephalopods and fish. Chum salmon and sockeye salmon were the only species showing the size-specific differences in their diets; prey size increased concomitantly with fish size. Diet overlap among species varied regionally, from no overlap in eastern Gulf of Alaska and the Alaska Stream, to some overlap between pinks and sockeye in the western Gulf of Alaska, to moderate overlap between pink salmon and all other species in the central North Pacific. The overlap among pinks and the other species may be driven by the generalist nature of pink salmon prey selection, but overlap is also influenced by prey availability in a given region. As one might expect with a salmon field research project, results are not straightforward but they do highlight the complexity in understanding the trophic factors impacting Pacific salmon marine survival. Our results strongly suggest that, from a feeding ecology perspective, it does matter where Pacific salmon overwinter in the open ocean.

Oral Presentation-25

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (3-1. Pacific salmon distribution/migration, climate and ocean changes)

Tracking the Marine Migrations of Coho and Chinook Salmon

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During their marine life stage, Chinook (*Oncorhynchus tshawytscha*) and Coho Salmon (*Oncorhynchus kisutch*) from watersheds connected to the Salish Sea display two distinct migration phenotypes; Salish Sea resident and out-migrant. Knowledge of Chinook and Coho Salmon marine migrations has been limited to tagged individuals caught by anglers and researchers. It is unclear how fishing effort and angler compliance, as well as other factors influence the proposed migration pathways undertaken by different stocks. Amongst the migrant phenotype, these salmon may only move as far as the continental shelf just off the coast of Washington and Vancouver Island, or they may migrate offshore into the Gulf of Alaska. It is unknown how environmental and genetic factors cause some salmon to remain resident in the Salish Sea and others to out-migrate. Microchemical techniques, specifically trace element and stable isotope analyses, can be used to identify the marine migration life history of Chinook and Coho Salmon that return to their natal watersheds. Initial results on Chinook and Coho Salmon samples indicate that otolith trace elements can be used to determine differences between marine regions with an 85% classification success rate. Roughly 40% of Coho from a few Southern BC river systems remained as residents within the Salish Sea, which is consistent with other models. Early marine growth differs between these migration life history types, with residents growing more in their first summer at sea than migrants. Otolith microchemistry shows promise as a technique to identify marine migration life history types amongst salmon. The early life history of the salmon also seems to play a role in migration life history patterns displayed later in life.

Oral Presentation-26 (virtual)

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
(3-1. New results from the International Year of the Salmon Winter surveys)

Linking Juvenile Chum Salmon (*Oncorhynchus keta*) Nutritional Condition and Trophic Status to Genetic-based Stock Assignments

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Pacific salmon (*Oncorhynchus* spp.) stocks exhibit considerable mixing across the North Pacific, with a potential for intensified inter- and intraspecific resource competition during winter months when prey availability is lowest. Here we used genetic stock assignments of juvenile chum (O. *keta*) salmon from the winter International Year of the Salmon (IYS) 2022 North Pacific survey to assess stock-specific trophic overlap and differences in their nutritional condition. Trophic overlap was assessed using isotope-based relative trophic positions from $\delta^{15}N$ (relative trophic level) and $\delta^{13}C$ (source primary production). Nutritional condition was assessed through measurements of muscle percent lipid, energy density, and C:N ratio. Results from genetic assignments showed chum had origins ranging from Asia, Beringia, Gulf of Alaska, and the Pacific Northwest; specific assignments were used to assess stock differences in energetic condition and trophic overlap. The use of genetic assignments in interpretation of nutritional, trophic or other biological metrics provides a powerful means to interpreting analyses where stocks mix and have a shared prey resource.

Oral Presentation-27

Topic 3 (Special Session). New Results from the International Year of the Salmon Surveys
(3-1 Summary and discussion)

Where Have All the Chum Salmon Gone? An Assessment of Marine Critical Periods for Western Alaska Chum Salmon During Periods of Extreme Events in their Early Marine and Winter Ocean Habitats

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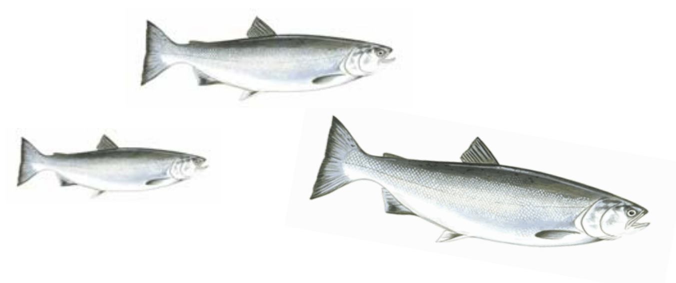
Record low run sizes of Chum salmon were observed in western Alaska from 2021 to 2023 following marine heat waves (extreme events) that occurred in their early marine and winter ocean habitats. Research results indicate that extreme warming during 2017 to 2019 on the northern Bering Sea shelf impacted the food web, resulting in lower quality prey for juvenile western Alaska chum salmon. This in turn led to reduced fitness of juvenile chum salmon at the end of their first summer at sea. Chum salmon captured during the International Year of the Salmon surveys were also experiencing reduced fitness in winter 2019, an anomalously warm sea temperature year, when compared to those captured during 2022, a year with cooler winter sea temperatures. These data indicate that large mortality events for chum salmon may occur when extreme events impact early marine and winter habitats simultaneously.

Poster Presentations



Poster Presentation-1

Topic 1. Pacific Salmon and Steelhead Trout in Changing North Pacific Ocean (Forward Action)
(1-1. Pacific salmon distribution/migration, climate and ocean changes)

Distribution and Migration Characteristics of Juvenile Chum Salmon (*Oncorhynchus keta*) in the Coastal Waters of Gangwon Province, Korea

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In order to analyze the distribution characteristics and migration characteristics of juvenile chum salmon, a survey was conducted 4 times from March to April 2019 using the surface water pair trawl in the coastal waters of Gangwon province. The survival rate per unit area of juvenile chum salmon averaged 2,302 individuals/km^2 (1,625 to 2,984 individuals/km^2), and the stock increased over time. The total length of juvenile salmon was 5.4±1.2 cm in the 1st survey, 5.8±0.9 cm in the 2nd survey, 6.6±0.9 cm in the 3rd survey, 6.8±0.9 cm in the 4th survey and the total length of juvenile chum salmon increased sharply between the 2nd and 3rd surveys. The condition factor of salmon was highest in the 1st survey, and showed a tendency to decrease in the 2nd and 3rd surveys, but increased in the 4th survey. As a result of analyzing the marked patterns of juvenile chum salmon otoliths, out of a total of 259 individuals, the 3-3-4H pattern accounted for 26 individuals (10.0%) and the 4n-4-2H pattern accounted for 2 individuals (0.8%).

Poster Presentation-2

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-2. Pacific salmon density dependence, carrying capacity, climate and ocean changes)

Trends in Size of Mature Sockeye and Pink Salmon Near the Southern Limit of their Range in the Eastern Pacific Ocean

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Size of salmon is of great importance to their value. In fisheries, body size affects the monetary and nutritional value of the catch. On the spawning grounds, egg size and fecundity are strongly related to body size, and nutrient transport to natal locations from the ocean relies directly on body size. Declines in size have been reported for Chinook, chum, pink and sockeye salmon in the eastern North Pacific Ocean. The data presented show declines in abundance and size-at-age of sockeye and pink salmon from the Fraser River, near the southern limit of their range in North America. The size of older age-classes of sockeye seems to have declined more than the size of younger age-classes. Leading hypotheses for declining sizes include climate-mediated effects on physiology, food availability, and inter-specific competition with more abundant northern stocks. The relevant data are available online through an R Shiny application to stimulate broader, improved research on this issue and on appropriate management responses.

Poster Presentation-3

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific salmon critical periods, climate and ocean changes)

Updated Pacific Northwest Steelhead Trout Marine Survival Data Reveal Continued Declines in a Changing Ocean

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Updated time series of steelhead trout smolt-to-adult return rates (smolt survival) from over 40 populations from Washington, Oregon, and British Columbia suggest that declines or stability at low rates detected seven years ago (Kendall et al. 2017) continue to be widely observed in recent years. Correlations between population pairs' time series and distance apart illustrated that in the past, smolt survival rates were more positively correlated for proximate populations, suggesting that important processes, including those related to ocean survival, occur early in the marine life of steelhead. However, in recent years these correlations appear to have weakened, suggesting that large-scale ocean processes have been stronger drivers of the trends. Finally, we compare early (survival within the Salish Sea) vs total marine survival of one steelhead population and show that these survival rates have not been correlated but that a high proportion of mortality, relative to the amount of time, occurs early in the marine stage.

Poster Presentation-4

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action)
(1-3. Pacific Salmon critical periods, climate and ocean changes).

Trophic Conditions of Juvenile Pink Salmon Feeding in the Coastal Zone of Northeast Kamchatka in 2021 and 2022

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The northeastern coast of Kamchatka is one of the most important pink salmon fishing areas in the Russian Far East. In the last decade, the catches of pink salmon here have reached historical maximum, although in some years, say, in 2020, the actual return of pink salmon to the coast was much lower than expected. One of the possible reasons for this could be unfavorable feeding conditions for juvenile pink salmon during the early marine period of life. Therefore, since 2021, monitoring studies have been organized in the coastal zone of Northeast Kamchatka, one of the objectives was to evaluate trophic conditions for feeding of juvenile pink salmon after emergence from rivers.
For this purpose, 63 zooplankton samples were collected using Jedi net with inlet diameter of 26 cm (112 µm mesh) to the isobath of 47 m in June 2021, 2022.
According to results of processing 36 samples, the composition of zooplankton in June 2021 and 2022 included 45 taxa and changed little in comparison with the 1970–1990s (Karpenko, 1998; Maksimenkov, 2007). Differences were revealed only in the taxonomic composition of Copepoda. The average value of zooplankton biomass in 2021 was 735.0 mg/m^3 and in 2022–1000.1 mg/m^3, and its structure in these two years differed significantly. In 2021, the biomass mainly consisted of hydromedusae (43%), copepods (15%) and molluscs (11%), in 2022–of copepods (63%), polychaetes (17%), and other groups (< 4%). The large oceanic species *Neocalanus plumhrus* (predominantly in II-IV instars) formed the basis of copepod biomass in these years, while small neritic copepods *Acartia longiremis*, *Pseudocalanus minutus*, *Centropages abdominalis* and *Oithona similis* were subdominants.
V. Karpenko (1998) suggested that starting biomass of forage zooplankton of 200 mg/m^3 should be considered as an index for assessing nutritional availability of juvenile pink salmon in the coastal waters of northeastern Kamchatka. In 2021, the biomass of forage zooplankton was 277.7 mg/m^3, and in 2022–777.2 mg/m^3, i.e. higher than the starting biomass. Thus, the conditions of feeding and survival of young pink salmon in the studied years were generally favorable, especially in 2022, when copepods formed the basis of the biomass. The latter is confirmed by the high return of pink salmon of Northeast Kamchatka in 2023.

Poster Presentation-5

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean (Forward Action) (1-3. Pacific Salmon critical periods, climate and ocean changes)

Muscle Fatty Acid Composition and Oogenesis Rate in Juvenile West Kamchatka Pink Salmon (*Oncorhynchus gorbuscha*) During Early Marine Life in Relation to Survival Rate

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The early marine life period of juvenile pink salmon is critical in the formation of generation abundance and is characterized by increased mortality. In this regard, much attention is paid to studies of the influence of environmental factors on the formation of pink salmon abundance in this period. Survival of smolts depends on their physiological condition. The aim of this work is to compare biochemical and histological indices of juvenile pink salmon during the early marine feeding period in the coastal zone of the Sea of Okhotsk in 2017, 2018, 2020.
Samples of juvenile pink salmon were collected on the west coast of Kamchatka in the area from 51° to 54°N in late July and early August 2017, 2018, 2020. Biological (length, body weight, sex), biochemical (fatty acid composition) and histological (reproductive system condition) parameters of the fish were evaluated. Feeding is a key factor in survival of juvenile pink salmon in the early marine life stage. Fatty acids (FAs) of fish are markers of the food sources. For example, the markers of marine copepods are monounsaturated FAs (20:1ω-11, 20:1ω-9, 22:1ω-11, 22:1ω-9). The part of these FAs in total lipids of pink salmon muscle tissue in 2017 was 10% of the sum of all FAs, in 2018 - 3%, in 2020 - 5%. Trophic and temperature factors influence the rate of oogenesis in juvenile pink salmon during the early marine feeding period. In the years analyzed oocytes of the 3rd and 4th stages of previtellogenesis and oocytes of the initial stage of vitellogenesis were present in the ovaries of females. The part of oocytes at the vitellogenesis stage in juvenile pink salmon in 2017 was 30% among all checked cells, in 2018—3%, in 2020—10%. Thus, juvenile pink salmon in 2017 had better food availability and high rate of oogenesis during the early marine period, what means significant potential for survival. The latter is confirmed by the high return of Western Kamchatka pink salmon in 2018.

Poster Presentation-6

Topic 1. Pacific Salmon and Steelhead Trout in a Changing North Pacific Ocean
(1-3. Pacific salmon critical periods, climate and ocean changes)

Post-smolt Sockeye Stock Ratios Inform Adult Stock Ratios, Implying Similar Survivability Between the Two Life History Periods

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Fraser River sockeye salmon vary greatly in return strength, year-to-year, in part due to highly variable post-smolt survival. Difficulties in understanding and predicting marine survival, as well as increasing climate volatility, have made pre-season forecasts of returns particularly challenging in recent years. Early in the migration run, one alternative predictive approach is to use the “Smolt Method of Updating Run Forecasts” (SMURF). The SMURF approach uses ratios among stocks in samples of juveniles collected more than a month after migration the sea; these ratios are combined with estimated abundance of an early-returning stock two years later to predict the abundance of later-returning stocks. Compared to pre-season forecast models, this approach should reduce the impact of climate variability on predictions of adult returns, as two years of climate impacts are integrated in the returns of the early stock. We found that the estimated ratio of Early to Late Shuswap post-smolt juveniles predicted the true ratio of Early to Late Shuswap adults, and the SMURF approach provided a more precise estimate of the Late Shuswap run size than the pre-season forecast. The useful similarity of stock ratios in juveniles and adults indicates either (a) there is no significant critical period after the juvenile sampling period or (b) early and late Shuswap stocks do not differ significantly in response to factors responsible for the critical period. Other stock comparisons between juvenile and adult ratios have been less informative, suggesting differences in mortality rates between stock groups during the post-smolt period. This is circumstantial support for hypothesis (a), above, that a critical period may exist after the initial months at sea, and variance among stocks in subsequent survival to recruitment may be predicted by how closely related they are.