State of Canadian Pacific Salmon: Responses to Changing Climate and Habitats

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2019

Canadian Technical Report of Fisheries and Aquatic Sciences 3332

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. Fs97-6/3332E-PDF ISBN 978-0-660-32265-0 ISSN 1488-5379

Correct citation for this publication:

Grant, S.C.H., MacDonald, B.L., and Winston, M.L. 2019. State of Canadian Pacific Salmon: Responses to Changing Climate and Habitats. Can. Tech. Rep. Fish. Aquat. Sci. 3332. ix + 50 p.

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At DFO’s first State of the Salmon meeting in 2018, scientists concluded that Canadian Pacific salmon and their ecosystems are already responding to climate change. Northeast Pacific Ocean warming trends and marine heatwaves like “The Blob” are affecting ocean food webs. British Columbia and Yukon air and water temperatures are increasing and precipitation patterns are changing, altering freshwater habitats. The effects of climate change in freshwater are compounded by natural and human-caused landscape change, which can lead to differences in hydrology, and increases in sediment loads and frequencies of landslides. These marine and freshwater ecosystem changes are impacting Pacific salmon at every stage of their life-cycle.

Some general patterns in Canadian Pacific salmon abundances are emerging, concurrent with climate and habitat changes. Chinook numbers are declining throughout their B.C. and Yukon range, and Sockeye and Coho numbers are declining, most notably at southern latitudes. Salmon that spend less time in freshwater, like Pink, Chum, river-type Sockeye, and ocean-type Chinook, are generally not exhibiting declines. These recent observations suggest that not all salmon are equally vulnerable to climate and habitat change.

Improving information on salmon vulnerability to changing climate and habitats will help ensure our fisheries management, salmon recovery, and habitat restoration actions are aligned to future salmon production and biodiversity. To accomplish this, we must integrate and develop new research across disciplines and organizations. One mechanism to improve integration of salmon-ecosystem science across organizations is the formation of a Pacific Salmon-Ecosystem Climate Consortium, which has been recently initiated by DFO’s State of the Salmon Program.

RÉSUMÉ

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Lors de la première réunion du MPO en 2018 sur la situation du saumon, des scientifiques ont conclu que le saumon du Pacifique canadien et ses écosystèmes réagissaient déjà au changement climatique. Les tendances au réchauffement du nord-est de l'océan Pacifique et les vagues de chaleur marines telles que « The Blob » affectent les réseaux alimentaires des océans. La température de l'air et de l'eau augmente en Colombie-Britannique et au Yukon, et les régimes de précipitations changent, modifiant les habitats d'eau douce. Les effets du changement climatique sur les eaux douces sont aggravés par les modifications du paysage d'origine naturelle et humaine. Ils peuvent entraîner des différences hydrologiques, une augmentation de la charge en sédiments et des glissements de terrain bien plus fréquents. Ces changements dans les écosystèmes marins et d'eau douce ont des répercussions sur le saumon du Pacifique à tous les stades de son cycle de vie.

Certaines tendances générales de l'abondance du saumon du Pacifique canadien apparaissent parallèlement aux changements climatiques et de l'habitat. Les saumons quinnats sont en déclin dans l'ensemble de leur aire de répartition en Colombie-Britannique et au Yukon, tandis que les saumons rouges et cohos le sont plus particulièrement dans les régions du sud. Les populations de saumons qui passent moins de temps en eau douce, comme le saumon rose, le kéta, le saumon rouge de rivière et le saumon quinnat de l'océan, n'ont généralement pas une tendance à décliner. Ces observations récentes suggèrent que tous les saumons ne sont pas vulnérables au changement du climat et de l'habitat de la même façon.

L'amélioration de la collecte d'informations sur la vulnérabilité du saumon et de ses habitats aux changements climatiques permettra de garantir que les mesures de gestion de la pêche, le rétablissement du saumon et la restauration de l'habitat correspondent à la production et à la biodiversité futures du saumon. Pour ce faire, nous devons développer de nouvelles recherches dans plusieurs disciplines et les intégrer aux organisations. La création d'un consortium sur le climat et les écosystèmes du saumon du Pacifique, récemment mis en place par le programme sur la situation du saumon du MPO, est un des mécanismes permettant d'améliorer l'intégration de la science des écosystèmes du saumon à toutes les organisations.

ACKNOWLEDGMENTS

We gratefully acknowledge the following for participating in Fisheries and Oceans Canada's first State of the Salmon meeting May 15 & 16, 2018. This report was constructed from input provided by these individuals during this meeting (Agenda provided in Appendix 1). These participants represented expertise on B.C. and Yukon Pacific salmon populations, B.C. and Yukon freshwater and the Northeast Pacific Ocean ecosystems, and salmon population modeling.

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HEADLINES

These headlines summarize observed changes in Canada's Pacific salmon populations and their ecosystems. They reflect the integration of expert judgement and results provided by Fisheries and Oceans Canada (DFO) Science participants at DFO's first State of the Salmon meeting, held in May 18-19, 2019. Background and relevant references supporting these headline statements are provided in the main body of this report. This report represents a starting point for more detailed work, broader participation, and peer-review processes.

The planet is warming, the last five years have been the warmest on record. The increase in global temperatures above pre-industrial levels is irreversible over the coming centuries. The extent that we are able to curb our CO_2 and other greenhouse gas emissions will determine the magnitude of future warming. There is still time to moderate climate change impacts on salmon and people.

Canada's climate warming has been double the global average, and warming at northern latitudes has been even greater.

Canadian Pacific salmon and their ecosystems are responding to global climate change. Marine heatwaves, warmer rivers and lakes, food web changes, increased floods and droughts, and other freshwater habitat changes are all affecting salmon.

An unprecedented marine heatwave nicknamed 'The Blob' persisted from 2013 to 2017 in the Northeast Pacific Ocean, where most Canadian Pacific salmon growth occurs. Ocean temperatures were 3-5°C above seasonal averages, extending down to depths of 100 m. After a one year hiatus, a marine heatwave re-developed in the Northeast Pacific in 2018. A strong El Niño event further increased temperatures in late 2015 to early 2016, to the hottest observed throughout the 137 years of ocean monitoring.

Less nutritious zooplankton species, typically found in latitudes south of B.C., dominated the Northeast Pacific Ocean during these warming periods. The heatwaves altered physical and biological ocean processes, with considerable effects on the marine food webs on which salmon rely.

Unusual fish species from Mexico and other southern latitudes appeared in local marine waters, along with the proliferation of gelatinous plankton, known as pyrosomes.

Above average temperatures have been observed in B.C. and Yukon rivers and lakes that salmon use for migration, spawning and early development. In some months and southern locations these temperatures exceed upper thermal limits of migrating salmon, having lethal and sub-lethal consequences.

Climate change and habitat alteration are destabilizing salmon freshwater habitats. Many freshwater habitats are becoming less productive for early salmon life stages due to increased sedimentation and landslides, and alteration of river hydrology. These changes are caused by an increased frequency of extreme rain events and droughts, coupled with deforestation and other human activities.

No single factor can explain all of the recent observed patterns in salmon abundances. Along with ecosystem changes, fisheries, hatcheries, disease, and contaminants can also affect salmon. There are many gaps in our understanding regarding how all factors act alone or cumulatively to affect salmon population trends, and how these factors will interact with climate change.

Chinook salmon abundances are declining throughout their B.C. and Yukon range. Chinook are also returning to spawn at younger ages, their sizes are decreasing for a given age, and egg numbers and egg sizes are decreasing. Chinook might be particularly sensitive to changes in freshwater, given their site-specific adaptations to spawning and rearing habitats. There are exceptions to these declines, such as populations that spawn on the East Coast of Vancouver Island.

Many Sockeye and Coho population abundances are declining in southern latitudes. A number of these populations are considered Endangered or Threatened by COSEWIC. Some Sockeye in southern B.C. are faring better than others, including Sockeye that occupy more remote, high altitude lake habitats for juvenile rearing. More recently, some northern Sockeye populations have also declined.

Pink and Chum are generally doing better than other salmon species throughout their ranges, with exceptions. Most of these populations have not declined in numbers, although there are some exceptions of populations that are doing poorly, such as Skeena and Nass Chum.

Some salmon populations and species have been more resilient to recent warm conditions, which may provide insights into salmon responses to future climate change. Traits of salmon generally not exhibiting long-term abundance declines include populations that: spawn in northern Canadian latitudes; have limited to no freshwater rearing stages; use largely undisturbed freshwater habitats; and are not specifically adapted to a particular spawning site. Other factors, such as adult upstream migration distances, migration timing, ocean distributions, and unique physiologies, also contribute to salmon responses to climate change.

Continued, consistent, and expanded monitoring and research on Pacific salmon, their ecosystems, and climate science is required. This is critical at this time of rapid environmental change.

Sustaining future salmon populations in the face of climate change requires collaboration. A Pacific Salmon-Ecosystem Climate Consortium has been initiated by DFO to foster integration of our collective science on salmon, their ecosystems, and climate. Integrating information across experts through collaborative, structured processes will rely on existing and evolving methods. This work will build on efforts in countries like the U.S., as well as recent DFO activities conducted to improve our understanding of Pacific salmon vulnerability to climate change. This work can help ensure that fisheries management, habitat restoration, and salmon recovery efforts are aligned to future salmon production and diversity under climate change.

1 INTRODUCTION

The planet is warming. Earth's average land-ocean temperature has risen by 1˚C over the last century, and the last five years were the warmest on record (Morice et al. 2012, Hartmann et al. 2013). Global temperatures are projected to rise 1.5° to 3.7°C above the 1850-1900 average by the end of this century. The extent that human society curbs our CO_2 and other greenhouse gas emissions will determine where in this range future temperatures fall (IPCC 2013).

The Intergovernmental Panel on Climate Change (IPCC) recommends we do not exceed temperature increases of 1.5°C above pre-industrial levels, since the predicted planet's responses above this level are significant (IPCC 2018). As human activities are already estimated to have caused 1.0°C warming to date, ranging from 0.8°C to 1.2°C, we will reach the IPCC limit between 2030 and 2052 unless emissions are significantly curbed (IPCC 2018).

Temperature increases in Canada have been double the global average, with even higher rates of warming in the north (Bush and Lemmen 2019). Over half of this warming is due to human-caused CO_2 emissions (Bush and Lemmon 2019).

Observed and projected climate change impacts include increased temperatures and more severe weather events, such as heavy precipitation and droughts (IPCC 2018, Bush and Lemmen 2019). Since human caused warming overlays natural climate variability, environmental changes will not be constant or homogenous across time and space. However, the net global temperature trend is upward.

These climate changes are already altering the ecosystems that Canadian Pacific salmon rely on throughout their life-cycle. Broadly, the Northeast Pacific Ocean is warming, affecting salmon and their food webs. British Columbia and Yukon freshwater temperatures are also increasing, and the associated habitat changes contribute to observed salmon trends.

Pacific salmon populations are uniquely adapted to the conditions they have experienced historically in the diverse river, lake, and ocean habitats they rely on throughout their lives. The current rate of ecosystem change is likely exceeding the adaptation potential of many salmon populations. For this reason, it is essential to understand which populations are more or less resilient to the effects of climate and habitat change, in order to optimize habitat restoration, and fisheries management actions.

Currently, salmon recovery, habitat restoration and fisheries management actions operate under the assumption that future salmon production will function similarly to how it has in the past. However, under rapidly changing climate conditions this assumption is no longer valid. Changing climate means that conditions are increasingly falling outside the bounds of historical observations. This can alter the effectiveness of activities currently relied upon to manage salmon and their ecosystems, and ultimately puts salmon populations at risk.

This report presents the first high-level overview of Canadian Pacific salmon responses to a rapidly changing world, and provides a foundation for further detailed work required to assess the vulnerability of salmon populations. Here we compile observations, and expert opinion, contributed by DFO Science staff working on the different salmon life-stages and ecosystems, during a meeting held in Nanaimo, B.C., May 15-16, 2018. References are also provided where readily available.

Results from this science process provide the first integrated overview of B.C./Yukon Pacific salmon and ecosystems changes observed during the recent period of notable warming and longer term habitat alteration. This report does not represent an exhaustive literature review, and the contents of this report have not gone through a formal peer review process. Instead it provides a starting point for future work that will expand on the observations presented, through data compilation, analyses, and the integration of expert judgement.

This first State of the Salmon meeting (Agenda: Appendix 1) included DFO staff only, with the intention of expanding to experts external to the organization in subsequent meetings. This paper is grouped into the following sections:

1. **Pacific Salmon Background**: This section includes background on the five Pacific salmon species managed by DFO: Sockeye, Chinook, Coho, Pink and Chum. An overview of the general biology of each species is provided.
2. **Ecosystem Trends:** Trends and observations are presented for the Northeast Pacific Ocean, and B.C./Yukon freshwater ecosystems.
3. **Canadian Pacific Salmon Trends:** Here we present trends for the five species of Pacific salmon managed by DFO: Sockeye, Chinook, Coho, Pink and Chum.
4. **Lessons learned from the recent period of warm ocean and freshwater conditions:** This section highlights salmon populations that have not exhibited declining abundances during the recent warm period, and salmon traits that might have contributed to these positive outcomes. This early exploration may provide preliminary insights into factors that may make particular salmon populations more resilient to future climate change.
5. **Conclusions and Next Steps:** This section presents conclusions of this report, and identifies the next steps required to expand our understanding of salmon vulnerability to a changing climate.
6. **References:** This section provides key literature relevant to this report, but does not represent an exhaustive literature review related to salmon and climate change.
7. **Agenda:** The 2018 State of the Salmon meeting agenda is provided here.
8. **Wild Salmon Policy and COSEWIC status assessments:** Statuses are available for Fraser River Sockeye, Southern B.C. Chinook and Interior Fraser Coho.

2 CANADIAN PACIFIC SALMON BIOLOGY

2.1 PACIFIC SALMON DIVERSITY

Five species of Pacific salmon are assessed and managed by Fisheries and Oceans Canada (DFO): Sockeye (*Oncorhynchus nerka*), Chinook (*O. tshawytscha*), Coho (*O. kisutch*), Pink (*O. gorbuscha*) and Chum (*O. keta*). These salmon are anadromous and semelparous, meaning they migrate from the ocean to freshwater to spawn, and die shortly after spawning.

Over 10,000 years ago, there were no salmon in B.C., since these areas were covered in ice from the last ice age. Ice-free areas during this period provided refuges for the salmon populations that formed the foundation for all current Pacific salmon diversity in B.C. and the Yukon (McPhail and Lindsey 1970).

Pacific salmon species and populations exhibit considerable biological variation. Many Sockeye and Chinook populations, and all Coho populations, rear in freshwater for one to two years as juveniles, before migrating to the ocean. Other Sockeye and Chinook populations, and all Chum and Pink populations, migrate to the ocean shortly after hatching and emergence, with only a limited freshwater juvenile stage. Salmon are adapted to the particular freshwater and marine conditions they experience throughout their life-cycles. Adaptive traits that are unique to each population include age of maturity, distribution in freshwater and the ocean, timing of migration and spawning, and thermal tolerance ranges, among others.

The population structure of Pacific salmon is complex and hierarchical, where each level of organization is the aggregate of its subcomponent parts. The spawning site is the smallest unit of organization, and this level forms increasingly broader groupings from the population, to the conservation unit (CU) or designatable unit (DU), to the species (DFO 2005, Holtby and Ciruna 2007). The precision of salmon fidelity to their natal spawning locations affects the extent of gene flow among populations, and determines the basic genetic organization of Pacific salmon.

The Conservation Unit (CU) has been identified as the fundamental unit of Canadian Pacific salmon biodiversity under DFO's Wild Salmon Policy (WSP) (DFO 2005). A CU is defined as 'a group of salmon living in an area sufficiently isolated from other groups that, if the salmon were to become extirpated it is unlikely that area would be recolonized naturally in a human life time.' Individual CUs are genetically and ecological distinct (Holtby and Ciruna 2007). In B.C. and the Yukon, 377 CUs currently have been identified: 184 Sockeye CUs, 76 Chinook CUs, 43 Coho CUs, 32 Pink CUs, and 42 Chum CUs (Table 1; Wade et al. 2019).

It is critical to understand which characteristics of these salmon populations make them more resilient, and might mitigate the effects of climate and habitat changes on future salmon production and biodiversity.

Table 1. Summary of Canadian Pacific Salmon Conservation Units (CUs), reprinted from Wade et al. (2019).

	Sockeye (lake-type)	Sockeye (river-type)	Chinook	Coho	Pink (odd year)	Pink (even year)	Chum	**Total**
Current CUs	165	19	76	43	19	13	42	**377**
Extirpated CUs	6							**6**

The Committee for the Endangered Wildlife in Canada (COSEWIC) identifies designatable units (DUs) as the fundamental units of biodiversity for Canadian wildlife species. A DU is defined as “discrete and evolutionarily significant units of the taxonomic species', where 'significant' means that the unit is important to the evolutionary legacy of the species as a whole, and if lost would likely not be replaced through natural dispersion.”

DFO WSP CUs and COSEWIC DUs are identical for Fraser Sockeye, and there are slight variations for Southern B.C. Chinook and Interior Fraser Coho (Appendix 2; COSEWIC 2016, 2017). Very few DU's have been currently identified, as this work only occurs preceding COSEWIC status assessments for particular groups of Pacific salmon, though it is likely they will largely align with DFO's CUs (Table 1).

2.2 SOCKEYE

Sockeye age of maturity varies by latitude; most Sockeye in Southern B.C. mature at four years of age, while further north in B.C. and the Yukon, they mature at five years. Most Sockeye populations rear for one to two years as juveniles in lakes, after their egg stage, and are referred to as lake-type Sockeye. Since lake-type populations are reproductively isolated and adapted to their particular lake systems, they comprise the largest numbers of CUs in B.C. and the Yukon, totalling 165 (Table 1; Wade et al. 2019). River-type populations are a second ecotype of Sockeye, and these 19 CUs spend limited time rearing in freshwater after emergence (Table 1; Wade et al. 2019).

Lake-type Sockeye remain in near-shore areas upon entering the ocean in the spring. By their first winter they reach offshore rearing sites in the Gulf of Alaska, following a northwest migration (Tucker et al. 2009). River-type Sockeye are smaller than their lake-type counterparts when they first enter the ocean in late-spring to early-summer, and spend more time rearing in river estuaries before migrating offshore (Beamish et al. 2016). Upon reaching maturity, Sockeye salmon migrate back to their natal freshwater spawning habitats from spring to fall, depending on the population. This species is iconic to Canadians, due to its distinctive red body and green head, which develop when they reach spawning maturity.

2.3 CHINOOK

Chinook are the largest bodied of the salmon species, and can reach up to seven years of age before returning to spawn. Their large size, along with their high fat content and year round availability make them a preferred prey species for some resident Killer Whale (*Orcinus orca*) populations (Ford et al. 1998, Ford and Ellis 2005).

Chinook populations exhibit considerable variability in their life-histories. They are uniquely adapted to their particular spawning, freshwater, and marine rearing habitats. Ocean-type Chinook populations migrate to the ocean shortly after they emerge from the gravel as under one year old fry. River-type Chinook rear in freshwater rivers as juveniles for one to two years before they migrate to the ocean. There are 76 Chinook CUs in B.C. and the Yukon (Table 1; Wade et al. 2019), exhibiting a range of life-histories.

Most ocean-type Chinook migrate to the ocean earliest in the spring, from March to May, followed by river-type Chinook, which migrate from April to May (Healey 1991). Ocean distributions vary among Chinook populations. Chinook may remain in coastal marine areas, near their natal rivers, for one to three years after they enter the ocean (Orsi and Jaenicke 1996; Trudel et al. 2009). The length of time they spend in coastal areas depends on the Chinook population, where some populations may remain in nearshore waters for their entire marine period, or they may migrate from these areas either into deeper offshore waters or north to Alaska, to rear. Most populations that enter the marine environment in the Strait of Georgia remain there for three to five months (Beamish et al. 2011), although some leave earlier (Tucker et al. 2011, 2012). West Coast of Vancouver Island populations remain coastal for one year after ocean entry, before migrating north along the continental shelf. Meanwhile, northern populations remain in coastal Alaskan waters until their second year in the ocean (Orsi and Jaenicke 1996).

Chinook salmon complete their life-cycle by migrating back to their natal freshwater spawning habitats between spring and fall, depending on the population.

2.4 COHO

Coho age-at-maturity varies by latitude; most Coho in B.C. mature at three years old, while further north and in the Yukon, they mature at four years. This species shares a common early life-history across populations. Coho rear as fry for one year in small rivers and creeks near, or downstream from, where they were spawned. Coho fry prefer rearing in structurally complex streams, in back eddies, log jams, and undercuts. Fry are territorial, and if densities are too high in preferred habitats, new arrivals will use less optimal habitat downstream. Fry are also vulnerable to stream flows. High flows can sweep them downstream, out of suitable habitats, while low flows and droughts can reduce habitat availability, or result in stranding of fry if their habitat becomes isolated. There are 43 Coho CUs in B.C. and the Yukon (Table 1; Wade et al. 2019).

In the ocean, there are two key types of Coho salmon: those that migrate rapidly northwest to the Gulf of Alaska after ocean entry, and others that remain near their ocean entry location in coastal waters over winter (Morris et al. 2007, Beacham et al. 2016). Most populations that enter the ocean on the West Coast of Vancouver Island and in the Strait of Georgia tend to be slower migrators, while more northern populations migrate more rapidly northwest upon ocean entry (Morris et al. 2007, Beacham et al. 2016). However, there are a few exceptions to these slower migrators in the south, like Thompson River Coho in the Fraser watershed, which migrate more rapidly northward in the Strait of Georgia after ocean entry, exiting via the Johnstone Strait and moving into the Northeast Pacific Ocean (Beacham et al. 2016). Many other populations that enter the Strait of Georgia remain there from spring to fall, subsequently moving to the West Coast of Vancouver Island via the Juan de Fuca Strait (Beamish et al. 2010).

Coho salmon complete their life-cycle by migrating back to their natal freshwater habitats as adults during late-summer to fall, and spawn from October to March, depending on the population. They generally begin migrating to their spawning grounds when there is an increase in river flow, and typically have longer upstream migrations than Pink and Chum salmon, but do not migrate as far as Sockeye and Chinook (Sandercock 1991).

2.5 PINK

Pink salmon mature at two years of age, and are the smallest of the Pacific salmon species. There are two distinct and genetically isolated brood lines of Pink that return in odd versus even years (Heard 1991). The odd year brood line dominates central and Southern B.C. populations, and the even year dominates northern B.C. and Yukon populations (Irvine et al. 2014). Although there are a number of proposed causes for dominance of one brood line over the other, there is insufficient evidence to make any broad conclusions as to why this occurs (Heard 1991).

Pink salmon immediately migrate to the ocean after their egg incubation stage, similar to river-type Sockeye, ocean-type Chinook, and Chum salmon. Genetic evidence indicates that the population structure of Pink salmon is less differentiated across broader areas in freshwater (Holtby and Ciruna 2007). These salmon also have the simplest age structure, maturing consistently at two years of age. For these reasons, Pink salmon have the fewest number of CUs. There are 13 even year Pink CUs and 19 odd year Pink CUs in B.C. and the Yukon (Table 1; Wade et al. 2019).

There has been relatively little work conducted to understand the distribution of Pink salmon in the Northeast Pacific Ocean (Trudel and Hertz 2013). Generally, Pink salmon remain near shore, or in areas protected from waves and currents, for several months in their early sea life, similar to Chum (Heard 1991, Salo 1991). Pink fry are often observed schooling with Chum fry during their early ocean stages. At larger sizes, Pink salmon move from nearshore to offshore waters, although the exact size that triggers this shift varies by area. Pink salmon migrate rapidly northward following coastlines up to the Gulf of Alaska, where they rear with Sockeye and Chum, although Pinks may overwinter farther south than Sockeye (Heard 1991).

Pink salmon return to their spawning grounds in the fall. Spawning migrations are relatively short in freshwater, since fish from this species have a limited capacity to leap over obstacles or swim through heavy flows (Heard 1991). During spawning, Pink salmon are characterized by a large hump on their back, hooked jaws, and teeth on their lower and upper jaws.

2.6 CHUM

Chum salmon mature at predominantly four or five years of age, and are the second largest bodied species, following Chinook. Chum immediately migrate to the ocean after their egg incubation stage, similar to river-type Sockeye, ocean-type Chinook, and Pink salmon. There are 42 Chum CUs in B.C. and the Yukon (Table 1; Wade et al. 2019).

There has been relatively little work conducted to understand the distribution of Chum salmon in the Northeast Pacific Ocean, similar to Pink salmon (Trudel and Hertz 2013). The limited information available indicates that Chum salmon remain near-shore for several weeks in their early sea life, similar to Pink salmon (Heard 1991, Salo 1991). Chum fry are often observed schooling with Pink fry during early ocean stages (Heard 1991). Unlike Pink, however, Chum remain in near-shore waters into the summer months, before migrating offshore (Holtby and Ciruna 2007). They migrate north and rear in the Gulf of Alaska with Pink and Sockeye salmon.

Despite being strong swimmers, Chum spawning migrations are relatively short in freshwater, because they are not leapers and, therefore, generally do not move past barriers in a river (Salo 1991). There are exceptions among northern Chum populations, such as Yukon River Chum, which have spawning migration distances up to 2,500 km (Holtby and Ciruna 2007). During spawning, Chum salmon are characterized by mottled burgundy/black/green colouration, and canine teeth on their upper and lower jaws.

3 ECOSYSTEM TRENDS

3.1 CLIMATE CHANGE: GLOBAL, REGIONAL, AND LOCAL

The planet is warming. Earth's average land-ocean temperature has risen by close to 1˚C over the last century (Figure 1), with the last five years registering as the warmest on record (Morice et al. 2012, Hartmann et al. 2013). Global surface temperatures are projected to rise by 1.5° to 3.7°C on average by the end of this century compared to the 1850-1900 average, depending on the extent humans moderate our CO_2 emissions (IPCC 2013). Climate change is effectively irreversible. Even with cessation of human-caused CO_2 gas emissions, temperatures will remain at the current elevated levels over the coming centuries (Solomon et al. 2009, IPCC 2014).

Climate is responding on global, regional, and local scales, through increased temperature extremes, changes in precipitation, and more severe weather events. Since human caused warming overlays natural climate variability, temperature increases will not be constant or homogenous across time and space. However, the net global temperature trend is upward.

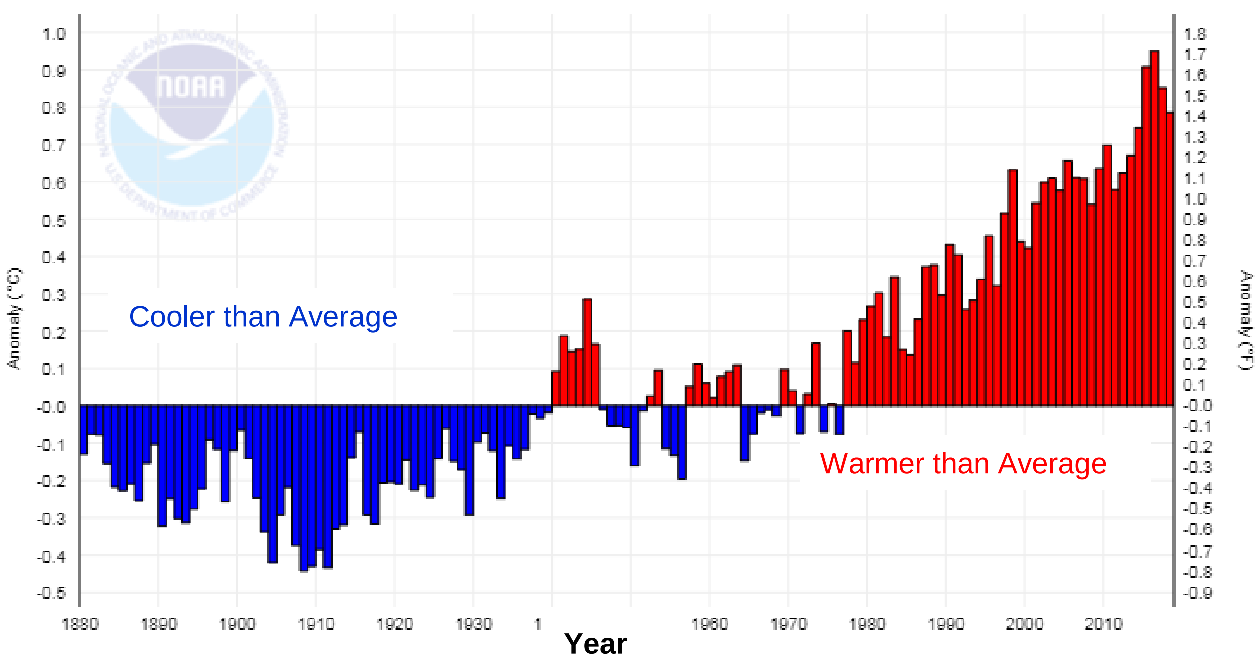

Figure 1. Global land and air temperature anomalies. Normalization period includes 1981-2010. Source: NOAA: https://www.ncdc.noaa.gov/cag/global/time-series/globe/land_ocean/ytd/12/1880-2019).

The rate of global warming is greater at northern latitudes. For this reason, Canada's current and projected warming is double the global average, and in more than double in the north (Bush and Lemmen 2019). Precipitation in Canada is also responding to global climate change. Rainfall has increased and has become more extreme, except in summer months, while snowfall has decreased in the west.

3.2 MARINE HEATWAVES IN THE NORTHEAST PACIFIC OCEAN

An unprecedented heatwave, nicknamed "The Blob", dominated the Northeast Pacific Ocean from 2013-2016 (Figure 2). This ocean warming contributed to physical and biological changes, some of which continue to persist. Sea-surface-temperatures (SST) during the heatwave were 3-5°C above seasonal averages, extending down to depths of 100 m (Bond et al. 2015, Ross and Robert 2018, Smale et al. 2019). Climate modeling has shown that this heatwave can best be explained by human-caused warming (Walsh et al. 2018).

Concurrently, a strong El Niño event further increased temperatures in late 2015 to early 2016, to the hottest observed throughout the 137 years of ocean temperature monitoring (Figure 2). The frequency of extreme El Niño events is expected to increase with climate change (Cai et al. 2014, 2015, Santoso et al. 2017, Wang et al. 2017).

Although SSTs in the Northeast Pacific cooled towards the second half of 2016, warm temperatures persisted at depths of 100-200 m until early 2018 (Ross 2017, Ross and Robert 2018). Any reprieve from abnormal ocean temperatures was short-lived, as warmer than average seasonal temperatures were again observed in the Northeast Pacific and Bering Sea in the fall of 2018 (Britten 2018, Livingston 2018).

Underlying these heatwaves has been a steady increase in North Pacific Ocean temperatures of 0.1°C/year to 0.3°C/year from 1950 to 2009 (Poloczanska et al. 2013, Holsman et al. 2018).

Detailed information on the State of the Pacific Ocean is reported annually (Chandler et al. 2015, 2016, 2017, 2018).

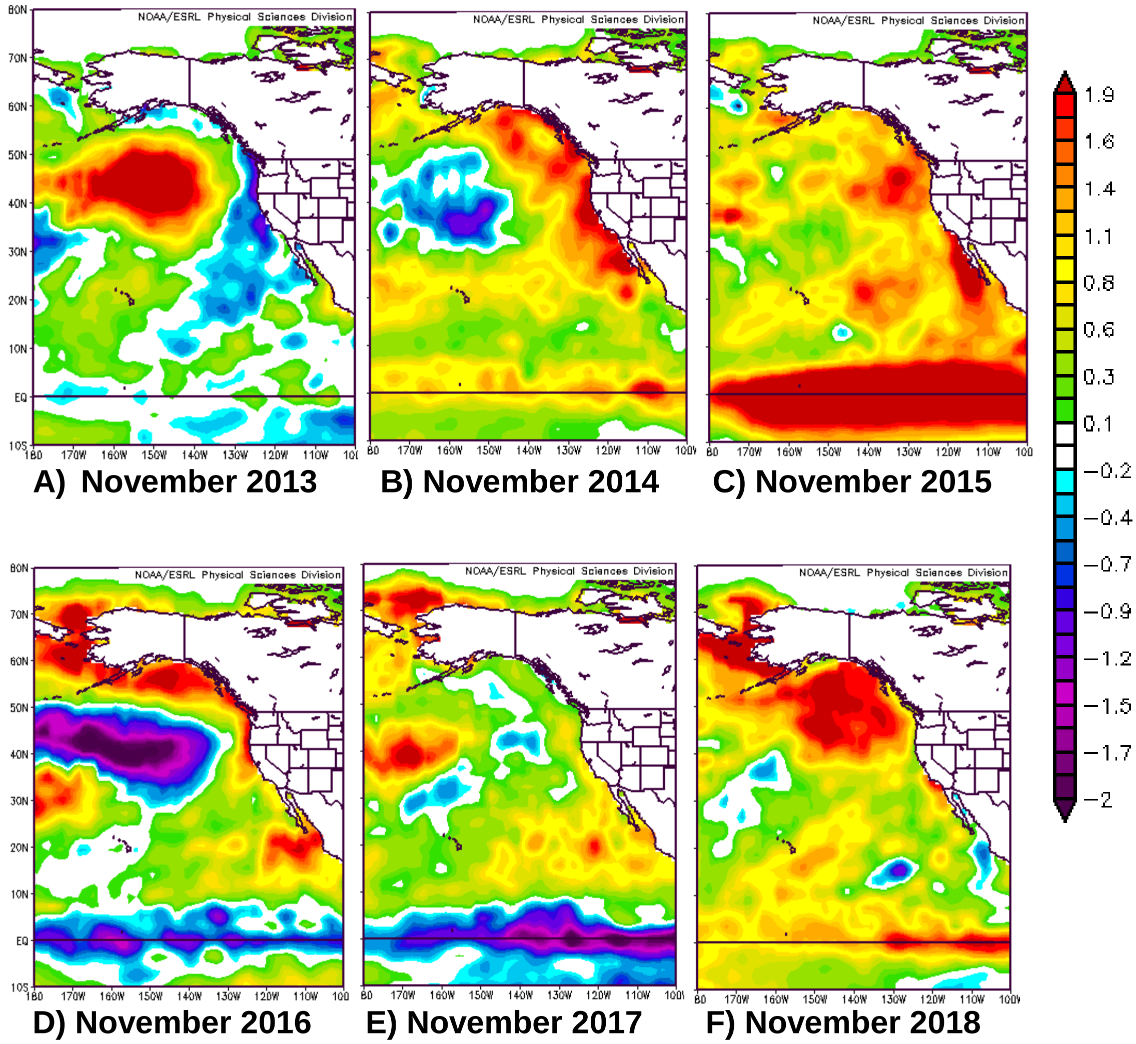

Figure 2. Sea-surface-temperature anomalies in the Northeast Pacific Ocean are presented for the month of November from 2013 to 2018. These maps do not show absolute temperatures, but indicate how much above (red) or below (blue) average the ocean surface temperatures were, compared to a thirty year average from 1981 and 2010. The coloured bar on the right of the maps provides greater detail to interpret the monthly deviations from average.

A) 'The Blob' formed in the latter half of 2013; **B)** 'The Blob' moved into coastal waters in 2014; **C)** an El Niño formed in 2015 and remained until early 2016, adding to warming of 'The Blob'; **D)-E)** 'The Blob' was no longer a prominent feature in surface waters in 2016-2017, although it remained at depth; **F)** Warmer sea-surface-temperatures similar to 'The Blob' re-developed in 2018.

Data and map tools are from the U.S. National Centers for Environmental Prediction (NCEP) and from the National Oceanic and Atmospheric Administration (NOAA).

Warm ocean temperatures may be harmful to salmon through their effect on zooplankton composition, a key pathway potentially linking reduced salmon survival to temperatures in the Northeast Pacific Ocean (Mackas et al. 2007). Warmer temperatures cause shifts in the distribution of southern prey species northward, to occupy habitats previously too cold for them (Mackas et al. 2004). Zooplankton communities near the base of the food web in the Northeast Pacific Ocean shifted in warm "Blob" years towards a greater abundance of lipid-poor southern copepods, as these animals moved northward, and fewer lipid-rich subarctic and boreal copepods (Galbraith and Young 2018, Young et al. 2018). The warmer water species are considered to be poorer quality food for species higher up the food chain, due to their smaller size and lower fat content (Mackas et al. 2007).

Salmon metabolic demands also increase with temperature, therefore, food consumption must increase accordingly. Without a concurrent increase in prey quality or quantity, salmon growth and survival will decrease under warming conditions (Holsman et al. 2018). For example, in recent years Chinook body weight for a given length declined (Daly et al. 2017). Predation also can intensify in warmer ocean conditions, increasing mortality of salmon during these periods (Holsman et al. 2012).

Highly unusual and sporadic observations in Northeast Pacific Ocean food webs are less understood with regard to their effects on salmon survival. Southern Pacific fish species such as Louvar (*Luvaris imperialis*), Finescale Triggerfish (*Balistes polylepis*), and Pacific Pompano (*Peprilus medius*) were observed in Northeast Pacific waters during recent research cruises (King et al. 2019). These foreign species can potentially disrupt ecosystems as competitors and/or predators of local fish communities.

Other noteworthy observations in 2017 included vast numbers of pyrosomes (*Pyrosoma atlanticum*), a colonial tunicate typically found off the coast of California, which clogged fishing gear in coastal B.C. waters (Brodeur et al. 2017). Pyrosomes filter feed phytoplankton, the base of the food web, which could have a negative effect on the abundance of higher trophic level animals, including salmon.
Unusual phytoplankton blooms that can kill or harm migrating salmon (McCabe et al. 2016, Peña and Nemcek 2017) have been observed recently in coastal waters, linked to climate change (McKibben et al. 2017). It is difficult to predict salmon responses to such unusual and sporadic events. However, as the effects of climate change intensify, we can expect the frequency and magnitude of such events to increase.

Warmer regional temperatures also influence interactions between freshwater and marine ecosystems. Earlier snowmelt, increased precipitation, and melting of ice on land are some of the factors contributing to a freshening of the coastal Northeast Pacific surface waters (Bonsal et al. 2019, Greenan et al. 2019). Fresher and warmer surface waters increase ocean stratification, which limits the supply of nutrient rich deep ocean waters to the sunlit surface waters in the spring-to-fall growing season. This limits the nutrients available to support algal growth at the base of the salmon food web (Bush and Lemmen 2019).

3.3 CLIMATE RELATED CHANGES IN FRESHWATER

Air temperatures over British Columbia and the Yukon have reached record highs in recent years, with the Yukon warming twice as fast as southern Canadian latitudes (Streicker 2016, Bush and Lemmen 2019). Local air temperatures were particularly warm from 2015 to 2018 (Figure 3), coinciding with the marine heatwave in the Northeast Pacific Ocean (Figure 2).

Precipitation patterns are also more extreme in response to climate change, with greater variation between wet and dry conditions in the summer, and increased frequency and magnitude of storms and rainfall events (Pike et al. 2010a). Increased temperatures and precipitation, and a greater frequency of droughts, floods, and landslides are already being observed in B.C. (Pike et al. 2010b) and the Yukon, in response to climate change.

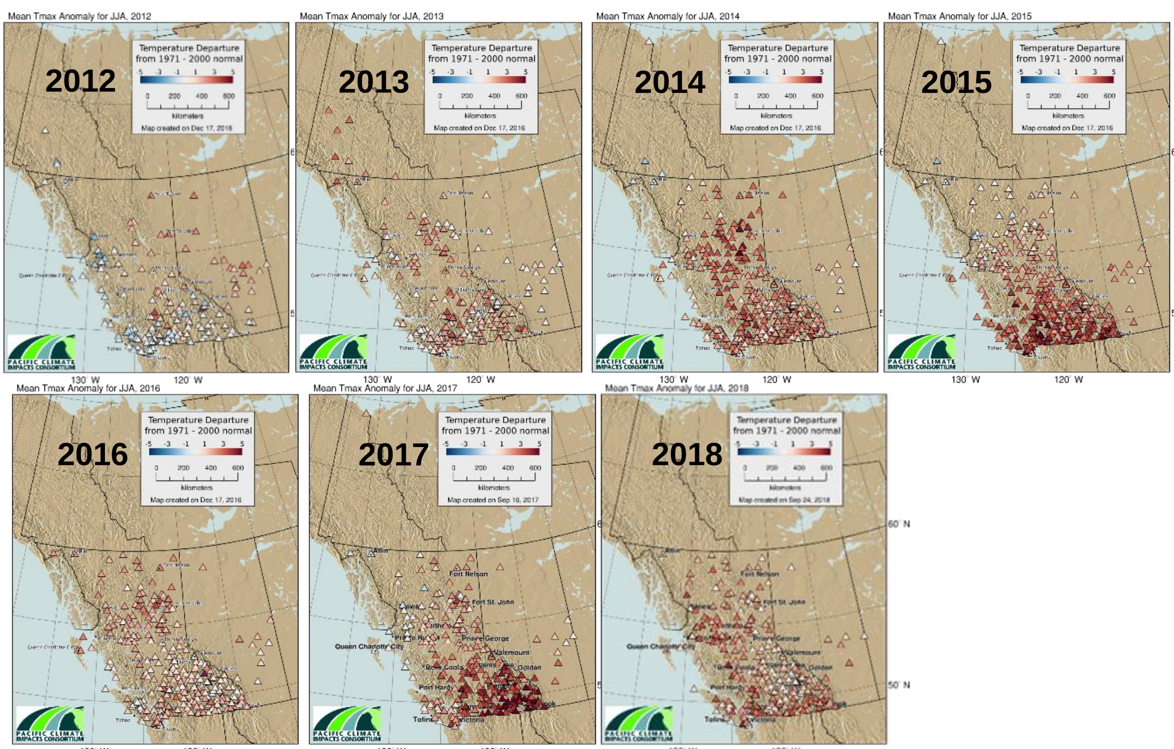

Figure 3. Air temperature anomalies in British Columbia. These are seasonal average temperatures for the summer months of June, July and August minus the total mean from 1971-2000. Data are from the University of Victoria's Pacific Climate Impacts Consortium. The colour table at the top of each map indicate the deviations from average; warmer colours are above average and cooler colours are below average temperatures. In recent decades, air temperatures have been above average for most season and years.

Changes in air temperatures and precipitation affect river temperatures and flows (Holsman et al. 2018), and also contribute to increased erosion and landslides (Pike et al. 2010a, 2010b). The impacts of these changes on salmon freshwater ecosystems are not homogenous, but vary depending on the latitude, altitude, and physical characteristics of these habitats, such as watershed vegetation, geology, groundwater flows, hydrology, size, etc.

Warmer air temperatures, lower spring snow packs, and receding glaciers are causing river temperatures to rise well above seasonal averages. Observations of river temperatures exceeding 18°C - 20°C in summer months are becoming more common in Southern B.C., including in the lower Fraser, and Somass watersheds (Eliason et al. 2011, Martins et al. 2011, Hyatt et al. 2015b, MacDonald et al. 2018).

Salmon that migrate to their spawning grounds in summer months are experiencing more stress and greater depletion of their energy reserves, negatively impacting swim performance and survival (Tierney et al. 2009, Burt et al. 2011, Eliason et al. 2011, Sopinka et al. 2016). Temperatures above 18°C can result in decreased adult swimming performance, and above 20°C can increase adult pre-spawn mortality and disease, reduce egg viability, and cause legacy effects that negatively impact juvenile condition (Tierney et al. 2009, Burt et al. 2011, Eliason et al. 2011, Sopinka et al. 2016). Salmon upstream migration is energetically demanding even in optimal conditions. These migration demands are exacerbated when temperatures fall outside the optimal range for salmon.

Climate changes are also affecting stream flows. In snow dominated hydrological systems in the B.C. Interior and/or northern latitudes, the snow-to-rain ratio is decreasing overall, glacier retreats are accelerating, and lake ice is melting earlier in the spring. Another key change in these systems is earlier than average peak river flows in the spring (Pike et al. 2008, 2010a).

Juvenile outmigration data for Sockeye indicate that in warmer spring seasons when Fraser River flows peak early, Sockeye smolts migrate downstream to the ocean several weeks earlier than normal (MacDonald et al. 2018). Shifts in salmon migration timing could lead to mismatches with the start of the plankton growing season in freshwater or marine ecosystems. If timing does not align, juvenile salmon will encounter suboptimal feeding conditions, grow more slowly, and face higher predation risk.

Rain-dominated hydrographic systems in coastal B.C. are experiencing more extreme conditions, reflecting the greater variability in climate conditions. These rivers are exhibiting more flash flooding, likely leading to increased egg losses from scouring (Holtby and Healey 1986, Lisle 1989, Lapointe et al. 2000). Droughts are also becoming more frequent, creating migration barriers to salmon and losses of incubating eggs and juveniles.

Erosion and landslides are increasing within watersheds. More prolonged periods of precipitation and warming temperatures are increasing the vulnerability of hillsides to landslides, and also increase the frequency of slide triggers from more intense rain events, changes in the freeze-thaw cycle, and severe shifts from dry to wet conditions (Pike et al. 2010a, Cloutier et al. 2016).

Increased sediment inputs into salmon-bearing watersheds reduce the quality and amount of available spawning and juvenile rearing habitat. Incubating salmon eggs can get smothered by increased sediment and debris loads, and juveniles may also have less relief from higher temperatures from the loss of deep pool refuges.

In severe cases, landslides can restrict access to suitable spawning and rearing habitats, and in some cases result in blockages of portions of river systems. There are several examples of major landslides in recent years, including the 2011 Kwinageese River rockfall in the Nass River watershed (Gaboury et al. 2015), and landslides in the Fraser River watershed including at Mount Meager in 2010 (Guthrie et al. 2012), Seton-Portage in 2015/2016 (K. Benner, Fraser Sockeye Stock Assessment, DFO, pers. comm., Dec. 11, 2018), and Big Bar on the Fraser mainstem in 2019 (DFO 2019). The latter landslide has largely blocked upstream access for critical Sockeye and Chinook populations. At the time of completing this report, options to mitigate this barrier were being considered. All of these landslides negatively affected spawning, migration or rearing habitat of a number of Pacific salmon populations.

Lake habitats are also changing. This is particularly important for the Sockeye salmon juvenile rearing stage. Thermal stratification and primary productivity in lakes consistently vary in recent assessments compared to historical data, where these data exist. These changes have had both positive (Chandler et al. 2018, MacDonald et al. 2018) and negative effects (Bradford et al. 2011, DFO 2018a) on juvenile Sockeye survival, for the two populations where these data are available, specifically Chilko and Cultus Fraser Sockeye populations.

3.4 HUMAN-CAUSED HABITAT CHANGES IN FRESHWATER

Human-caused changes to salmon-bearing watersheds can amplify the effects of climate change. The sum of such combined changes in freshwater ecosystems can affect overall salmon survival (Nelitz et al. 2007, McDaniels et al. 2010, Crozier et al. 2019).

Agriculture, mining, urbanization, forestry practices, and other land use activities have long been altering the freshwater habitats salmon rely on for part of their life cycles (Pike et al. 2010a, 2010b). These activities contribute to deforestation and water extraction, and increase inputs of nutrients into freshwater ecosystems. The combined effects of climate change and human land-use activities can result in even warmer river temperatures, greater changes in river flows, and even higher frequencies of erosion and landslides.

Deforestation is increasing, driven by human use, as well as climate change factors, such as the expansion of mountain pine beetle and the increasing magnitude of forest fires. Loss of forest canopies can reduce the capacity of rivers and lakes to buffer warmer temperatures through the cooling effects of shade.

Removal of forest canopies, combined with more extreme rain events caused by climate change, can further increase peak river flows. Loss of trees increases the amount of snow and rain reaching the ground, contributing to runoff. It also increases water volumes in the soil, since water is not removed from the soil to the atmosphere through evapotranspiration (Pike et al. 2010a).

Deforestation also amplifies slope instability caused by changing climate, since the stabilizing effect of tree root systems on soil is removed. Although climate change alone can increase the frequency of erosion and landslides, human landscape changes may be a more significant driver overall (Cloutier et al. 2016). The effects of increased erosion and landslides on salmon are described in the previous section.

Similar to forest canopy losses, water extraction magnifies climate-driven temperature increases in rivers and lakes. Increased water extraction from urbanization, agriculture, and industry, reduces stream flows and inputs of cooler groundwater into freshwater systems. This can diminish the capacity of aquatic systems to moderate higher air temperatures from climate change. It also interacts with increased prevalence of droughts, putting further strain on water availability, particularly during summer months.

Freshwater ecosystems closer to human development are especially challenged by human impacts. Increased nutrient inputs from human sources, particularly from agricultural activities, can have severe impacts on water quality for salmon. Cultus Lake provides an example of large changes in salmon productivity, linked to synergies between climate and habitat degradation (DFO 2018a, Putt et al. 2019).

Cultus Lake is located near Western Canada’s largest urban center, Vancouver, and is adjacent to areas of agricultural and residential land-use (Putt et al. 2019). This lake is experiencing severely depleted oxygen levels in deep water, due to the combined effects of rising lake temperature and increased nutrient inputs from agriculture, and other factors (COSEWIC 2003, DFO 2010, 2018a, Putt et al. 2019).

Juvenile Sockeye salmon that inhabit the deep water environment of Cultus Lake through winter are exhibiting extremely high freshwater mortality, as a result of oxygen depletion (DFO 2018a). The Cultus Lake Sockeye population is now facing an imminent risk of extirpation, with wild fish contributing negligible numbers to the small recent annual returns (COSEWIC 2017, DFO 2018b). As the climate continues to warm, responses across lakes will vary depending on local characteristics.

3.5 OTHER FACTORS THAT AFFECT SALMON

In the 2018 State of the Salmon meeting, participants identified many other factors that can affect salmon, acting alone or cumulatively. However, since the main purpose of this workshop was to identify the current state of salmon and their ecosystems during this recent warming period, the factors identified were not exhaustive. Here we present a short list of some of the factors that should be considered in subsequent iterations of this work, including how their effects on salmon will interact with climate change.

Fisheries and hatcheries directly influence salmon numbers through, respectively, removals from catch, and additions of juvenile salmon to supplement natural production. Considerable stock assessment and hatchery enhancement monitoring and research supports the management of these activities. Critical science inputs will be required to improve our understanding of the role of these two factors moving forward. This can help shape current fisheries and hatchery management practices to prepare and adapt to future salmon production and diversity.

Other factors that can affect salmon include disease, invasive species, contaminants, competition, increased predation, and ocean acidification, to name a few. The effects of these factors are less well understood, particularly in how they affect salmon population numbers, and also how they will interact with climate change. However, there is a growing body of research that can provide a greater understanding of these factors.

4 CANADIAN PACIFIC SALMON TRENDS

4.1 SUMMARY

Recent trends in Canadian Pacific salmon abundances were collated among participants attending the 2018 State of the Salmon meeting. These trends coincide with the recent warm period observed in salmon ecosystems. Many of these salmon trends vary along a north-south gradient, where northern populations of particular species are generally doing better than their southern counterparts. Northern salmon populations are defined in this report, as those that enter the ocean above the northern tip of Vancouver Island.

Chinook salmon populations are declining throughout B.C., the Yukon, and the Northern Transboundary region (B.C.-Southeast Alaska) (Table 2). Many southern Chinook CUs are doing particularly poorly (DFO 2016), while multiple Sockeye and Coho CUs in the south have also declined and are doing poorly (Table 2; Appendix 2; Grant and Pestal 2012, DFO 2015, 2018b). COSEWIC has identified many of these Sockeye, Chinook and Coho DUs as Endangered, meaning they are facing an imminent threat of extinction, or as Threatened (Appendix 2; COSEWIC 2016, 2017). Though there are exceptions to these generalizations.

This contrasts with abundance trends for northern Sockeye populations, which have shown declines only very recently. Pacific salmon populations that have generally not exhibited declines in recent years include northern Coho, apart from the Northern Transboundary populations, most Chum, and odd year Pink populations (Table 2).

Catch for all five DFO managed salmon species has declined, due to declines in target population abundances, or due to constraints placed on fisheries in order to protect co-migrating populations in poor status in mixed-stock fisheries (Figure 4).

4.2 SALMON DATA

Salmon abundance trends are presented qualitatively, based on expert input provided at the 2018 State of the Salmon meeting. Abundance information generally includes catch plus escapement. For the purpose of this report, populations in the north are those that enter the ocean above the northern tip of Vancouver Island, and southern populations enter below this boundary. Consolidation and standardization of salmon abundance data sets is on-going through both internal DFO data management initiatives, and through the Pacific Salmon Foundation-Pacific Salmon Explorer initiative.

There is higher certainty associated with Sockeye and Chinook trends, particularly at southern latitudes, and the Northern Transboundary systems, since these are more complete, higher-quality data sets. Northern Sockeye and Chinook, and most Coho, Pink and Chum data sets, in contrast, have more gaps, and/or are of lower precision, increasing uncertainty in trends reported for these populations.

Hatchery enhancement information is not presented in this report, since experts on hatchery production were not present at the 2018 State of the Salmon meeting to provide their input. This information will be included in subsequent processes.

4.3 SOCKEYE

Northern Canadian Sockeye populations in B.C., the Yukon, and Northern Transboundary systems have generally not exhibited declines in recent decades, contrasting with many Southern B.C. populations that have exhibited longer term declines. Only in very recent years have Northern B.C. and Northern Transboundary populations also started to decline (Table 2). Fecundity has also generally declined for some Sockeye populations, such as those in the Skeena and Fraser watersheds.

Longer term declines have been identified for Fraser River Sockeye populations. Almost half of Fraser Sockeye CUs have been placed in the WSP Red status zone (Grant and Pestal 2012, DFO 2018b), with most of these WSP Red CUs identified as Endangered by COSEWIC in their recent assessment (COSEWIC 2017; Appendix 2, Table A2-3). This group of salmon was the focus of the Cohen Inquiry into the declines of Sockeye salmon from the mid-1990's to 2009 (Cohen 2012a, 2012b, 2012c).

There are exceptions to the declining trend in Southern B.C. Sockeye populations. For example, Barkley Sound Sockeye on the West Coast of Vancouver Island (Hyatt et al. 2018), and Chilko and Shuswap Sockeye in the Fraser watershed (DFO 2018b, Grant and MacDonald 2018), have not declined in abundance. There are also cases, like Okanagan Sockeye, where declining population trends have been reversed when informed human interventions have coincided with favourable environmental conditions (Hyatt et al. 2015a). Another exception is the river-type Harrison Sockeye population in the Fraser watershed, which migrates to the ocean shortly after they emerge from their spawning gravel. This population has exhibited dramatic increases in abundances in recent decades, while many lake-type populations in the Fraser watershed have declined (Grant and MacDonald 2011, Chandler et al. 2018).

Fraser Sockeye are one group of salmon where freshwater and marine survival data have been tracked for two populations: Chilko and Cultus Lake Sockeye. These two populations potentially reflect bookends for Sockeye freshwater survival in Canada. Chilko Sockeye rear in a remote, high altitude, glacial lake, while Cultus Sockeye rear in a southern lake situated close to Vancouver, B.C. In contrast with Chilko Lake, Cultus Lake is subject to considerable recreational use, human development, and agricultural runoff. Marine survival has declined in recent decades for both populations, while freshwater survival has been above average for Chilko (Chandler et al. 2018, Grant and MacDonald 2018) and conversely, critically low for Cultus

(DFO 2018a). Differences in their freshwater habitats are potentially contributing to these large variations in overall abundance and survival trends between these populations.

Sockeye is a highly valued salmon species in B.C. and transboundary fisheries. Data quality and quantity are relatively high for a subset of productive Sockeye populations that are actively managed, compared to other salmon species (Table 2). However, this subset accounts for less than half of the total number of Sockeye populations within B.C. and the Yukon.

4.4 CHINOOK

Chinook salmon abundance trends are unique across Canadian Pacific salmon species, synchronously declining throughout B.C., Yukon and Northern Transboundary systems (Table 2). Synchrony in Chinook survival trends has been reported more broadly, from Oregon up to Alaska (Sharma et al. 2013, Kilduff et al. 2014, Dorner et al. 2018). Declining Chinook abundances are exacerbated by decreases in Chinook size-at-age, age-at-return, and reproductive potential, including reductions in the numbers of eggs-per-female and in egg size.

Abundances of Chinook salmon are reaching critically low levels in Southern B.C., where recent status assessments have placed over half of assessed Southern B.C. Chinook CUs in the WSP Red status zone (DFO 2016; Appendix 2, Table A2-4). COSEWIC has determined that many of the DUs in the B.C. Interior are Endangered or Threatened (Appendix 2, Table A2-4).

There are only a few exceptions to these declines in recent years, such as East Coast of Vancouver Island Chinook populations. Decreasing marine and freshwater survival are contributing to these trends, though data on freshwater survival is limited (Brown et al. 2019).

Chinook, similar to Sockeye, is a highly valued salmon species in B.C./Yukon fisheries. More data are collected on Chinook salmon than other species, apart from Sockeye, including escapement, catch, size, and age (Table 2).

4.5 COHO

Coho, like Sockeye, are currently experiencing better abundance trends in the north compared to the south (Table 2). Southern populations have had consistently low abundances for the past two decades, and Interior Fraser River populations were recently placed in the Amber WSP status zone (DFO 2015), or identified as Threatened by COSEWIC (COSEWIC 2016) (Appendix 2, Table A2-5).

There are many data gaps for Coho, particularly at northern latitudes (Table 2). As a result, there is greater uncertainty in these reported trends.

4.6 PINK

Odd year Pink salmon have not exhibited any declines in recent years, while even year brood lines have exhibited declines in some areas (Table 2; Irvine et al. 2014, Malick and Cox 2016). On a broader scale, this species dominates numbers of salmon in the Northeast Pacific Ocean (Ruggerone and Irvine 2018).

Pink can be resilient, rebounding from weak to strong run strength within regional populations in one or two generations (Heard 1991). They have been observed spawning in new locations within the Yukon, Skeena, and the Fraser watersheds, indicating a potential expansion of their range. Prevalence of Pink salmon has also increased in the Northeast Bering and Beaufort Seas in the Arctic, likely straying from more southern locations as these areas warm (K. Dunmall, DFO Arctic Region, pers. comm.).

Pink salmon populations can contribute large numbers to commercial, recreational and First Nations fisheries. However, in recent years, Pink catch has declined, due to concerns for at-risk co-migrating salmon populations (Figure 4). Declining stock assessments and the lower importance of this species to fisheries have limited the data available for Pink salmon (Table 2). Existing abundance estimates are highly aggregated and generally do not provide detail at the scale of individual populations.

4.7 CHUM

Chum populations in the Yukon, Northern Transboundary, and Northern B.C. regions have generally not exhibited declines (Table 2). Meanwhile, southern Chum populations are showing mixed abundance trends, with some very recent declines in the Fraser watershed. There are some exceptions to these general trends, such as Skeena and Nass Chum, which are located in the north and have been doing poorly. On a broader scale, Chum dominate the overall biomass of salmon in the Northeast Pacific, due to contributions from populations in other countries (Ruggerone and Irvine 2018).

Chum salmon contribute lower numbers to all fisheries in B.C. and the Yukon, although they are particularly important to First Nations fisheries. Limited data exist for Chum salmon (Table 2). As a result, there is greater uncertainty in these reported trends.

Table 2. Recent abundance trends for the five species of Pacific salmon managed by DFO: Sockeye, Chinook, Coho, Pink and Chum, based on input from DFO participants at the May 2018 State of the Salmon meeting. These generally include catch and escapement

These trends are reported for four geographic areas from north to south: Yukon includes salmon populations spawning in the Yukon River; Northern Transboundary includes salmon populations that spawn and migrate through rivers that cross SE Alaska and B.C.; Northern B.C. includes B.C. salmon populations that enter the ocean north of the northern tip of Vancouver Island; and Southern B.C. includes salmon populations that enter the ocean south of the northern tip of Vancouver Island.

There are exceptions to these general trends, where some populations are not exhibiting the same overall patterns.

Area	Sockeye	Chinook	Coho	Pink-Odd Year	Pink-Even Year	Chum
Yukon	No trend (M)	Decline (M)	No trend (L)	NA	NA	No trend (L)
Northern Transboundary-B.C./SW Alaska	Recent decline (H)	Decline (H)	Recent decline (M)	No trend (VL)	Decline (VL)	No trend (VL)
Northern B.C.	Very recent declines (M)	Decline (M)	No trend (L)	No trend (L)	No trend (L)	No trend (L)
Southern B.C.	Decline (H)	Decline (M)	Decline (M)	No trend (L)	Decline (VL)	Mixed (L)

The data quality and quantity vary across areas and species and are indicated in brackets below: H (high); M (medium); L (low); VL (very low).

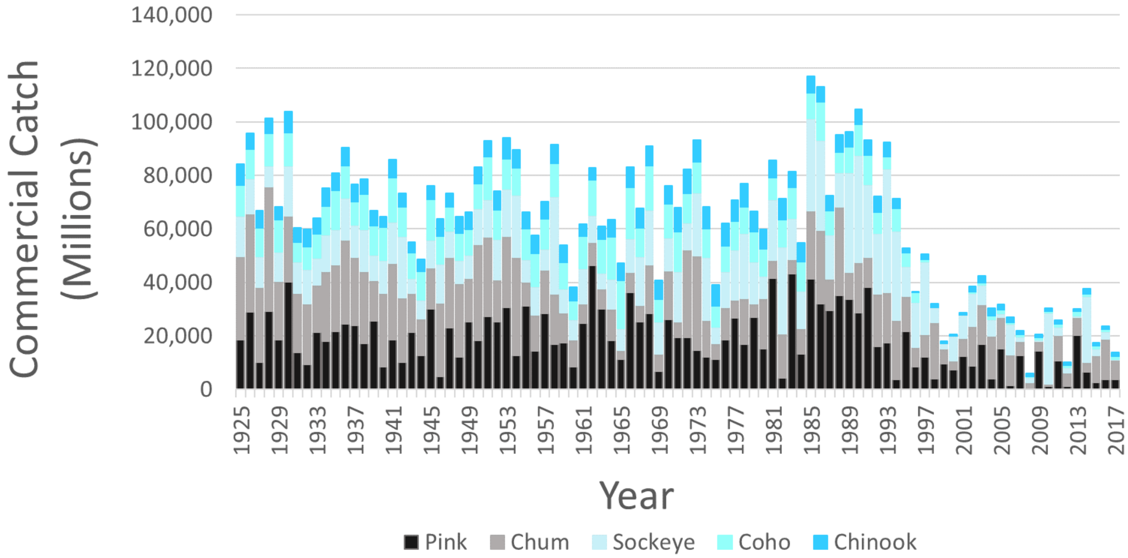

Figure 4. Canadian commercial catch numbers for Pink, Chum, Sockeye, Coho, and Chinook salmon. Data Source: North Pacific Anadromous Fish Commission (NPAFC). 2018. NPAFC Pacific salmonid catch statistics (updated 31 July 2018). North Pacific Anadromous Fish Commission, Vancouver. Available from www.npafc.org.

5 LESSONS LEARNED FROM THE RECENT PERIOD OF WARM CONDITIONS

5.1 SUMMARY

Responses of Canadian Pacific salmon to recent warm freshwater and marine conditions may provide insights into salmon resiliency to climate and habitat change. Current salmon trends indicate that northern Sockeye and Coho populations are doing better than their southern counterparts, and that salmon populations that spend little time in freshwater, including river-type Sockeye, ocean-type Chinook, and Pink and Chum populations, are not exhibiting persistent declines.

Spawning, rearing, and early ocean distributions in northern latitudes appears to be particularly advantageous to Sockeye and Coho populations. Although the rate of climate warming is greater in the north, temperatures remain cooler at northern latitudes relative to the south. Cooler temperatures in the north, relative to the south, can result in more beneficial marine food webs at these latitudes. In freshwater, these cooler northern temperatures, combined with generally better habitat quality, may also be contributing to more positive outcomes for northern salmon populations.

Another attribute of salmon populations that are not declining, is shorter periods of time spent rearing as juveniles in freshwater. River-type Sockeye, ocean-type Chinook, and Pink and Chum populations all migrate to the ocean shortly after gravel emergence. Short freshwater residence times decrease the exposure of these populations to temperature and habitat changes that are occurring in their freshwater habitats, and may be contributing to their overall improved survival.

Particular population traits such as adult upstream migration timing and distances, distribution in freshwater, physiology, fishery encounters, and/or ocean distribution can also affect a salmon population’s ability to survive climate and habitat change.

5.2 POPULATIONS IN THE NORTH

Sockeye, Chinook and Coho population trends vary by latitude. Sockeye and Coho are generally doing better in the north. Chinook are declining throughout their Canadian range, but are doing particularly poorly in southern latitudes (Table 2; DFO 2015, 2016, 2018). Two key factors that vary by latitude are temperature and the degree of human-caused habitat alteration.

Temperature is a key variable that influences Pacific salmon growth and survival. Although the rate of climate change is greater in the north, temperatures at these latitudes are still cooler compared to the south.

In the ocean, cooler temperatures in the north can lower salmon metabolism, reducing energy demands. This can contribute to better outcomes for salmon that enter the ocean at northern latitudes, particularly when combined with the presence of more energy rich zooplankton relative to the south (more details provided in Section 3.2 Marine Heatwaves in the Northeast Pacific Ocean).

Freshwater may present even greater temperature-related challenges for Pacific salmon. With a warming climate, summer river temperatures in some southern B.C. systems are now annually exceeding thermal tolerance ranges of migrating adult salmon (Eliason et al. 2011, Martins et al. 2012, MacDonald et al. 2018). This can have many effects on migrating adults, and can also affect egg viability and the fitness of their offspring (see previous section 3.3 Climate Related Changes in Freshwater for more details).

Other factors like increased deforestation, water extraction, and nutrient loading are all more concentrated at southern latitudes, where human populations are larger. Habitat alteration can amplify the impacts of climate-driven changes on salmon freshwater ecosystems (see previous section 3.4 Human-Caused Habitat Changes in Freshwater for more details). Northern freshwater ecosystems are less impacted by these changes, and therefore, may have better conditions for Pacific salmon compared to southern freshwater habitats. These factors may contribute to the north-south trends in Sockeye, Chinook and Coho salmon.

5.3 SPECIES AND POPULATIONS SPENDING LESS TIME IN FRESHWATER

Salmon populations with no prolonged juvenile rearing stage in freshwater, referred to as immediate migrants, are generally not exhibiting persistent declines. Their trends either vary around a mean, or are increasing. This includes many river-type Sockeye, ocean-type Chinook, Pink and Chum salmon populations.

Immediate migrants avoid longer exposure to the acute temperature and habitat changes that are occurring freshwater ecosystems. Since temperatures are higher, and habitat changes are greater in the south, this may be an important reason why immediate migrant Sockeye and Chinook populations at these latitudes are doing better than their freshwater rearing counterparts.

Immediate migrant salmon populations may have other unique traits that are providing advantages to their survival under changing climate and habitat conditions.

For example, the one river-type Fraser Sockeye population, Harrison Sockeye, has exhibited improving trends in survival and abundance, counter to most lake-rearing populations (Grant and Pestal 2012, Chandler et al. 2018, Grant and MacDonald 2018). This river-type Sockeye population has a limited freshwater rearing stage, migrates a relatively short distance upstream, has a later-timed downstream juvenile migration, and exhibits a different ocean distribution, compared to lake-type Fraser Sockeye (Birtwell et al. 1987, Tucker et al. 2009, Beamish et al. 2016). Any of these traits acting alone, or cumulatively, may be contributing to differences in survival between this immediate migrant population and those with longer freshwater rearing stages.

Pink and Chum salmon also have no freshwater rearing stage, migrating to the ocean after emerging from their spawning gravel. Their populations are generally doing well throughout their Canadian range, with the exception of even year Pinks that spawn at southern latitudes (Irvine et al. 2014), and some Chum populations, such as those originating in the Skeena and Nass River systems. Pink and Chum also generally have shorter migration distances to their spawning grounds. In the Fraser system, few Pink and Chum salmon spawn upstream of Hells Gate, located near Hope, B.C., whereas most of the Sockeye, Chinook and Coho production in this system occurs upstream of Hells Gate, in the B.C. Interior.

5.4 CONSERVATION UNITS WITH BROADER DISTRIBUTIONS IN FRESHWATER

Pink and Chum are generally exhibiting better recent survival than Sockeye, Chinook, and Coho salmon. Each Chum and Pink CU covers a wider spawning distribution in freshwater compared to Sockeye, Chinook, or Coho CUs, and this trait may provide them with greater adaptability to deteriorating conditions. A broader geographic distribution of populations within a CU may be able to maintain a CU, if the quality of some freshwater spawning locations declines. There are fewer Chum and Pink CUs compared to Sockeye, Chinook, and Coho. Chum and Pink CUs combined comprise only 20% of all Canadian Pacific Salmon CUs, (Table 1).

In contrast, Sockeye, Chinook, and Coho are the most highly adapted species to specific freshwater habitats, and are exhibiting declines in abundances across many populations. Together, they comprise 80% of all the Canadian Pacific Salmon CUs, which emphasizes the degree of specialization they represent (Table 1). Specific adaptations to particular habitats restrict their ability to redistribute to more optimal spawning or rearing habitats in the event of poor local conditions, and may limit the adaptability of these species to changing climate and habitats.

5.5 UPSTREAM MIGRATION TIMING AND OTHER SALMON POPULATION CHARACTERISTICS

Since salmon generally return to their natal rivers or lakes to spawn, populations are reproductively isolated from one another to varying degrees. Individual salmon share similar traits within a population, such as those related to their behaviors, body shapes, and thermal tolerances. These traits reflect genetic adaptations to the unique set of conditions these fish have encountered in their past (Hess and Narum 2011; Drinan et al. 2012; Narum et al. 2013), and have resulted in their persistence as populations to date. However, since salmon habitats are now rapidly changing, not all these traits will be suited to new conditions, and salmon populations may not have sufficient flexibility to adapt in time.

One example of a trait that may affect a salmon population's resilience to climate change is their upstream migration timing. This trait can vary from summer to winter months depending on the salmon species and population. Among Fraser Sockeye populations for example, some migrate during the summer, when river temperatures are at their hottest. Increasingly, river temperatures are exceeding the 18°C to 20°C upper thermal limits of these salmon in the summer (MacDonald et al. 2018). As a result, summer migrating populations are experiencing greater stress and greater depletion of their energy reserves, which reduces their ability to swim and survive to spawn (Tierney et al. 2009; Burt et al. 2011; Eliason et al. 2011; Sopinka et al. 2016), among other impacts (see section 3.3 Climate Related Changes in Freshwater for more details). This contrasts with later timed Fraser Sockeye populations, and other species like Chum, which migrate in the fall when cooler river temperatures provide more optimal conditions for their upstream migrations.

As river temperatures continue to warm, upstream migration distances, and population-specific physiology and body shapes, might moderate some of the impacts on summer migrating salmon. Shorter migration distances upstream in freshwater, for example, may reduce the exposure of a salmon population to high temperatures.

5.6 MORE SALMON POPULATIONS ARE EXHIBITING NEGATIVE TRENDS IN RECENT YEARS

Synchrony in salmon survival trends across populations is increasing (Peterman and Dorner 2012, Kilduff et al. 2015, Malick and Cox 2016, Dorner et al. 2018). This suggests that large-scale mechanisms are having stronger, or more consistent, effects on salmon survival (Malick and Cox 2016, Dorner et al. 2018). Large-scale, climate patterns have been identified as a potential driver of greater synchrony across populations, and have been increasing in variability and intensity in recent years

(Peterman and Dorner 2012, Kilduff et al. 2015, Dorner et al. 2018). These broad climate patterns can affect both marine and freshwater ecosystems.

The degree of synchrony varies by species. Synchronous declines in Chinook salmon survival throughout their range, from Oregon to Western Alaska, are of particular concern, and their degree of synchrony has been increasing (Dorner et al. 2018). Sockeye also are exhibiting greater synchrony, but at smaller spatial scales than Chinook. Sockeye show opposite survival patterns between Canadian and Southeast Alaskan populations, and those from central and western Alaska. Populations from Canada to Southeast Alaska are generally declining in survival, while central and western Alaska populations are increasing or showing no trend (Peterman and Dorner 2012).

Increasing synchrony in survival trends across populations puts salmon species at risk, due to the loss of portfolio effects (Schindler et al. 2010, Griffiths et al. 2014). Synchronization of salmon trends produces greater volatility in the short term. Increasing synchrony means that declines in one population will not be offset by concurrent increases in other salmon populations. The stability provided by variability across populations is critically important for maintaining ecosystem and fisheries resources (Schindler et al. 2010), and is a concern now that we are seeing more synchronization in salmon trends across areas and species.

The deterioration of diversity in survival responses reduces the overall resilience of salmon to changing conditions (Kilduff et al. 2015, Dorner et al. 2018). As climate patterns in Pacific salmon ecosystems continue to increase in variability and intensity, due to climate change, synchrony in regional salmon survival is expected to increase, as is the prevalence of more extreme highs and lows in salmon survival (Dorner et al. 2018).

6 CONCLUSIONS AND NEXT STEPS

“There are two major environmental crises facing the planet, climate change and catastrophic losses to nature” (CPAWS 2019). A number of global reports are alerting us to accelerating climate change and biodiversity losses on the planet (IPCC 2014, 2018, IPBES 2018, 2019). These warnings have been strongly echoed for Canada (WWF 2017, Bush and Lemmen 2019, CPAWS 2019). Climate change impacts may be particularly acute in Canada, since rates of warming at northern latitudes are double the global average (IPCC 2014, Bush and Lemmen 2019).

The impacts of recent, unprecedented, heatwaves in the Northeast Pacific Ocean, coupled with extremely warm freshwater temperatures, provide insight into the responses of Canadian Pacific salmon and their ecosystems to climate change. These changes are amplified by local salmon habitat changes in freshwater, such as deforestation and water extraction. As the climate continues to warm and precipitation patterns change, conditions observed during the recent period of high temperatures will likely become more common, and more extreme.

Fisheries have been identified as one of the major climate change risks to Canada, which could contribute to ‘significant losses, damages or disruptions over the next 20 years’ (Council of Canadian Academies 2019). There is still time to moderate the severity of climate change and its impacts, through mitigation and adaptation. The extent that we are able to curb our net CO_2 and other greenhouse gas emissions will determine the magnitude of future warming. We must also adapt to current and expected climate conditions and their effects, though research, planning, and actions.

Recent trends in salmon abundances yield a growing, but still incomplete, view of salmon vulnerability to climate change. This vulnerability is determined by multiple factors, including salmon spawning and rearing locations, warming water temperatures, ecosystem changes, freshwater habitat alteration, salmon traits, and more. All these factors acting alone or cumulatively increase our current uncertainty related to salmon population responses to climate change.

More detailed assessments of salmon vulnerability to climate change are required to understand and predict future trends in salmon populations. Work was initiated on Canadian Pacific salmon vulnerability assessments in 2007 (PFRCC 1999, Nelitz et al. 2007), and reinvigorated in 2015 more broadly on a number of fish species (Hunter and Wade 2015, Hunter et al. 2015). U.S. scientists recently completed vulnerability assessments for their own Pacific salmon populations (Hare et al. 2016, Urban et al. 2016, Crozier 2017, Crozier and Siegel 2018, Crozier et al. 2019). Other work, through the International Year of the Salmon initiative, is also fostering global research to help improve our understanding of the status and responses of Atlantic and Pacific salmon to climate change and other factors (Irvine et al. (*eds*) 2019, Young et al. (*eds*) 2019).

Improved integration across a wide variety of organizations that study and manage Canadian Pacific salmon, their habitats, and local climate change predictions, would advance efforts to address existing knowledge gaps in these areas.

In DFO's Pacific Region, participants attending a recent second annual State of the Salmon meeting, held in March 2019, agreed that a Pacific Salmon-Ecosystem-Climate Consortium would be one mechanism to assist with integration of scientific expertise across organizations. This Consortium is currently being initiated by DFO to advance our own assessments of Pacific salmon vulnerability to climate and habitat change.

This integrative work is critical to support changes to management, habitat restoration, and salmon recovery activities required now to prepare for future salmon production and diversity.

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APPENDIX 1. MAY 15 & 16 2018 STATE OF THE SALMON MEETING AGENDA

TUESDAY MAY 15 2018

Start	End	Time	Item	Lead
8:30 AM	9:00 AM	0:30	Registration & Getting Organized	MacDonald
9:00 AM	**9:05 AM**	**0:05**	**Welcome**	**Grant/MacDonald**
9:05 AM	**9:25 AM**	**0:20**	**FIRST ICEBREAKER**	**ALL**
9:25 AM	**9:30 AM**	**0:05**	**SOS MEETING DELIVERABLES: SOS Technical Report; Other Session Deliverables Identified**	**Grant**
9:30 AM	**9:50 AM**	**0:20**	**HOW WE ARE GOING TO ENGAGE TODAY & MEETING APPROACH**	**Grant**
9:50 AM	**9:55 AM**	**0:05**	**Theme 1: RECENT SALMON TRENDS (ABUNDANCE, PRODUCTIVITY, SIZE, FECUNDITY, ETC.)**	**Grant**
9:55 AM	10:00 AM	0:05	**Theme 1:** RECENT SALMON TRENDS: in the Yukon/TB Area Highlights	Foos
10:00 AM	10:05 AM	0:05	**Theme 1:** RECENT SALMON TRENDS: in the North Coast Area Highlightss	Cox-Rogers/Winther
10:05 AM	10:10 AM	0:05	**Theme 1:** RECENT SALMON TRENDS: in the South Coast Area Highlights	Luedke
10:10 AM	10:15 AM	0:05	**Theme 1:** RECENT SALMON TRENDS: in the Fraser Area Highlights	Whitehouse & Team
10:15 AM	10:20 AM	0:05	**Theme 1:** RECENT TRENDS: Pacific Chinook-maturation, age, fecundity and productivity	Brown
10:20 AM	**10:30 AM**	**0:10**	**CLARIFICATION QUESTIONS ONLY**	**Grant**
10:30 AM	**10:50 AM**	**0:20**	**BREAK**	
10:50 AM	**11:50 AM**	**1:00**	**Theme 1 BO Groups: SALMON TRENDS**	**Each BO group**
			1. Identify recent key salmon trends abundance, productivity, size-at age…	1 facilitator
			2. Are there similarities among species, watersheds, latitidue, life-history types, etc? Exceptions?	1 note taker
			3. Identify key gaps in assessments and knowledge: time lags in data avail, spatial gaps, etc.	
11:50 AM	**12:30 PM**	**0:40**	**Theme 1 PLENARY: SALMON TRENDS**	**Grant**
12:30 PM	**1:30 PM**	**1:00**	**LUNCH**	
1:30 PM	**1:35 PM**	**0:05**	**Theme 2: ECOSYSTEM: PHYSICAL & BIOLOGICAL IN RECENT YEARS**	**Grant**
1:35 PM	1:40 PM	0:05	**Theme 2:** ECOSYSTEM: Observations from E-Watch: temps, discharge, & salmon in freshwater	Patterson*/Robinson
1:40 PM	1:45 PM	0:05	**Theme 2:** ECOSYSTEM: Freshwater Lakes & Juvenile Rearing	Selbie
1:45 PM	1:50 PM	0:05	**Theme 2:** ECOSYSTEM: Pacific Ocean Ecosystem	Boldt/King*
1:50 PM	1:55 PM	0:05	**Theme 2:** ECOSYSTEM: Pacific Fish Surveys	King
1:55 PM	2:00 PM	0:05	**Theme 2:** ECOSYSTEM: Strait of Georgia Juvenile Salmon Surveys	Neville
2:00 PM	**2:10 PM**	**0:10**	**CLARIFICATION QUESTIONS ONLY**	**Grant**
2:10 PM	**3:10 PM**	**1:00**	**Theme 2 BO Groups: ECOSYSTEM: PHYSICAL & BIOLOGICAL RECENT TRENDS**	**Each BO group**
			1. Identify recent key ecosystem observations that are tracked by salmon life-stage	1 facilitator
			2. Are there ways to group these observations: latitude, altitidue, coastal, in-land, etc.?	1 note taker
			3. What can the recent warming period in FW/Mar tell us about salmon trends in the future	
			4. Identify Gaps in ecosystem assessments	
3:10 PM	**3:30 PM**	**0:20**	**BREAK**	
3:30 PM	**4:15 PM**	**0:45**	**Theme 2: PLENARY: ECOSYSTEM**	**Grant**
4:15 PM	**4:30 PM**	**0:15**	**Wrap up day 1 Exercise**	**Grant**

WEDNESDAY MAY 16 2018

Start	End	Time	Item	Lead
8:30 AM	9:00 AM	0:30	Getting organized: new seating assignments etc.	MacDonald
9:00 AM	**9:05 AM**	**0:05**	**Review yesterday**	**Grant**
9:05 AM	**9:10 AM**	**0:05**	**Theme 3: LINKAGES: SALMON & ECOSYSTEM & OTHER FACTORS**	**Grant**
9:10 AM	9:15 AM	0:05	Theme 3: LINKAGES: NE Pacific Salmon Abundances: Role of Hatcheries	Irvine
9:15 AM	9:20 AM	0:05	Theme 3: LINKAGES: Cumulative Effects	Hyatt
9:20 AM	9:25 AM	0:05	Theme 3: LINKAGES: Overview of Modeling Approaches	Holt/Bradford
9:25 AM	9:30 AM	0:05	Theme 3: LINKAGES: Fisheries	Dobson
9:30 AM	**9:40 AM**	**0:10**	**CLARIFICATION QUESTIONS ONLY**	**Grant**
9:40 AM	**11:00 AM**	**1:20**	**Theme 3 BO Groups: how much do we know about how factors we can control are influencing the salmon trends we are observing (Facilitators schedule 20 minute break)**	**Each BO group**
			1. List factors you think are contributing to salmon trends: group into what we can control or not	1 facilitator
			2. How do these different factors we can't control interact with those we can control?	1 note taker
			3. Identify Gaps and Potential Future Strategies to Address Gaps	
11:00 AM	**11:45 AM**	**0:45**	**Theme 3: PLENARY: LINKAGES**	**Grant**
11:45 AM	**12:45 PM**	**1:00**	**LUNCH**	
12:45 PM	**12:50 PM**	**0:05**	**HOW THE SCIENCE ORGANIZATION FITS TOGETHER**	**Grant**
12:50 PM	12:55 PM	0:05	Current Science Organization	Holmes
12:55 PM	1:00 PM	0:05	Salmon Coordinator	Dobson
1:00 PM	1:05 PM	0:05	Stock Asssessment Core Program	Thiess
1:05 PM	1:10 PM	0:05	State of the Salmon Program	Grant
1:10 PM	1:15 PM	0:05	Salmon Communications	Sloan
1:15 PM	**1:30 PM**	**0:15**	**General Discussion on how everything fits together**	**Grant**
1:30 PM	**1:45 PM**	**0:15**	**Break**	
1:45 PM	**1:50 PM**	**0:05**	**Key Questions on Collaboration & Communication on SOS**	**Grant**
1:50 PM	2:20 PM	0:30	Exercise on Communication	
2:20 PM	3:05 PM	0:45	SOS meeting: who, what, when, where, why, and how???	
3:05 PM	**3:20 PM**	**0:15**	**CLOSING ACTIVITY**	**Grant**
3:20 PM			**AJOURN**	

APPENDIX 2. DFO WILD SALMON POLICY AND COSEWIC STATUS ASSESSMENTS FOR CANADIAN PACIFIC SALMON

Fisheries & Oceans Canada (DFO) and the Committee on the Endangered Wildlife in Canada (COSEWIC) have both conducted status assessments for three groups of Canadian Pacific salmon, including Fraser Sockeye, Southern B.C. Chinook, and Interior Fraser Coho.

DFO's WSP status assessments are conducted on Conservation Units (CU) (Holtby and Ciruna 2007; Grant et al. 2011; DFO 2013; Wade et al. 2019). CUs are placed into one of five WSP status zones: Red, Red/Amber, Amber, Amber/Green, and Green. Definitions of the three key status zones are provided in Table A-1, and Red/Amber and Amber/Green status zones are intermediate between these (DFO 2005; Grant & Pestal 2012). DFO WSP status can also include a data deficient category for CUs where there is insufficient data available to determine status.

COSEWIC groups salmon populations into Designatable Units (DUs), which are identical or very similar to DFO's CUs. They place DUs into five status zones: Endangered, Threatened, Special Concern, Data Deficient, and Not at Risk. Definitions are presented in Table A-2.

Table A2-1. Wild Salmon Policy biological status zones (DFO 2005; Grant and Pestal 2012)

Status	Definition
Red	"… established at a level of abundance high enough to ensure there is a substantial buffer between it and any level of abundance that could lead to a CU being considered at risk of extinction by COSEWIC"
Amber	"While a CU in the Amber zone should be at low risk of loss, there will be a degree of lost production. Still, this situation may result when CUs share risk factors with other, more productive units"
Green	"identif[ies] whether harvests are greater than the level expected to provide on an average annual basis, the maximum annual catch for a CU, given existing conditions…there would not be a high probability of losing the CU"

Table A2-2. The Committee on the Endangered Wildlife in Canada (COSEWIC) biological status zones and their definitions (COSEWIC 2010).

Status	Definition
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species that is likely to become an endangered if nothing is done to reverse the factors leading to its extirpation or extinction.
Special Concern (SC)	A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.
Data Deficient (DD)	A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Not At Risk (NAR)	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.

Fraser Sockeye WSP and COSEWIC statuses

There are 24 Fraser Sockeye CUs that were first assessed by DFO in 2012 (DFO 2012; Grant and Pestal 2012). These were re-assessed in 2017 (DFO 2018b). There are currently seven Fraser Sockeye CUs in the Red status zone, two in the Red/Amber status zone, four in the Amber status zone, six in the Amber/Green status zone, three in the Green status zone, and one data deficient CU (Table A-3, first column). COSEWIC aligned their Fraser Sockeye DUs exactly with DFO's WSP CUs. COSEWIC statuses also align with DFO's WSP statuses for Fraser Sockeye and COSEWIC identifies eight Endangered DUs, two Threatened, five Special Concern, and eight Not-at-Risk (Table A-3, last column).

Table A2-3: The 2017 Integrated status designations for ***the 24 Fraser River sockeye salmon CUs****, ranked from poor (Red zone) to healthy (Green zone) status based on the current 2017 assessment. Cyclic CU statuses are determined including abundance benchmarks estimated using the Larkin model* (DFO 2018b)*. For each CU, more commonly used stock names are presented. An asterisks (*) indicates provisional status designations; R/A: Red/Amber; A/G: Amber/Green; DD: data deficient; Undet: undetermined. The previous assessment's integrated statuses are also listed in the 2012* (DFO 2012; Grant and Pestal 2012)*. The COSEWIC 2017 status designations are presented in the final column (released 2018).*

2017		2012		Conservation Unit	Stock	COSEWIC 2017
R		R		Bowron-ES	Bowron	**Endangered**
R		R		Cultus-L	Cultus	**Endangered**
R		R		Takla-Trembleur-EStu	Early Stuart	**Endangered**
R		R*		Taseko-ES	Miscellaneous E. Summ	**Endangered**
R		R		Widgeon – River*	Miscellaneous Lates	**Threatened**
R		A		Harrison (U/S)-L	Weaver	**Endangered**
R		UD		Seton-L	Portage	**Endangered**
R	A	R	A	Quesnel-S	Quesnel	**Endangered**
R	A	R	A	Takla-Trembleur-Stuart-S	Late Stuart	**Endangered**
A		R		Nahatlatch-ES	Miscellaneous E. Summ	**SC**
A		A		North Barriere-ES	Fennel & Miscellaneous E. Summ	**Threatened**
A		A		Kamloops-ES	Raft & Miscellaneous E. Summ	**SC**
A		A	G	Shuswap-ES	Scotch, Seymour, Mis. E. Summ	**NAR**
A		G*		Lillooet-Harrison-L	Birkenhead	**SC**
A	G	R		Nadina-Francois-ES	Nadina	**NAR**
A	G	R	A	Chilliwack-ES	Miscellaneous E. Summ	**NAR**
A	G	R	A	Francois-Fraser-S	Stellako	**SC**
A	G	A		Anderson-Seton-ES	Gates	**NAR**
A	G	G		Harrison (D/S)-L	Miscellaneous Lates	**SC**
A	G	G		Shuswap Complex-L	Late Shuswap	**NAR**
G		A	G	Pitt-ES	Pitt	**NAR**
G		G*		Chilko-S & Chilko-ES agg.	Chilko	**NAR**
G		G		Harrison River – River Type	Harrison	**NAR**
DD		DD		Chilko-ES	Chilko	**NA**

Abbreviations: EStu: Early Stuart; ES: Early Summer; S: Summer; L: Late; Mis: miscellaneous;
**Widgeon (river-type) CU has a small distribution, therefore, this CU will be consistently in the Red status zone;*

Southern B.C. Chinook WSP and COSEWIC statuses

There are 34 Southern B.C. Chinook CUs that were assessed by DFO in 2016 (DFO 2016). There are currently 11 Red, one Red/Amber, one Amber, two Green, 10 to-be-determined, and 9 data deficient CUs. COSEWIC has identified 28 DUs that are slightly different from DFO's CUs (Table A-4), although most DUs align with DFO's WSP CUs. COSEWIC identifies 11 Endangered, four Threatened, one Special Concern, one Not-at-Risk DU, and two data deficient DUs. A number of status assessments for both DFO and COSEWIC are pending further work. Nuances with the data and hatchery contributions are currently being resolved in data sets to support status assessments.

*Table A2-4: The 2016 Integrated status designations for **the 34 Southern B.C. Chinook CUs**, ranked from poor (Red zone) to healthy (Green zone) status based on the current 2016 assessment (DFO 2016). For each CU, their name and CU ID is provided. The COSEWIC 2017 status designations for 28 DUs are presented in the final column (released Dec 4 2017).*

CU Name	CU	WSP 2016	DU	COSEWIC 2018	COSEWIC 2019
Okanagan_1.x	CK-01	Red	--	Endangered*	--
Middle Fraser River-Portage_FA_1.3	CK-09	Red	DU08	Endangered	--
Middle Fraser River_SP_1.3	CK-10	Red	DU09	Threatened	--
Upper Fraser River_SP_1.3	CK-12	Red	DU11	Endangered	--
South Thompson-Bessette Creek_SU_1.2	CK-16	Red	DU14	Endangered	--
Lower Thompson_SP_1.2	CK-17	Red	DU15	--	TBD
North Thompson_SP_1.3	CK-18	Red	DU16	Endangered	--
North Thompson_SU_1.3	CK-19	Red	DU17	Endangered	--
East Vancouver Island-North_FA_0.x	CK-29	Red	DU23	--	TBD
West Vancouver Island-South_FA_0.x	CK-31	Red	DU24	--	TBD
West Vancouver Island-Nootka & Kyuquot_FA_0.x	CK-32	Red	DU25	--	TBD
South Thompson_SU_1.3	CK-14	Red Amb	DU13	--	TBD
Middle Fraser River_SU_1.3	CK-11	Amber	DU10	Threatened	--
Lower Fraser River_FA_0.3	CK-03	Green(p)	DU02	Threatened	--
South Thompson_SU_0.3	CK-13	Green	DU12	Not At Risk	--
Shuswap River_SU_0.3	CK-15	TBD			
Lower Fraser River_SP_1.3	CK-04	TBD	DU03	Sp. Concern	--
Lower Fraser River-Upper Pitt_SU_1.3	CK-05	DD	DU04	Endangered	--
Lower Fraser River_SU_1.3	CK-06	DD	DU05	Threatened	--
Middle Fraser-Fraser Canyon_SP_1.3	CK-08	DD	DU07	Endangered	--
Southern Mainland-Georgia Strait_FA_0.x	CK-20	DD	DU18	--	TBD
East Vancouver Island-Nanaimo_SP_1.x	CK-23	DD	DU19	Endangered	--
Southern Mainland-Southern Fjords_FA_0.x	CK-28	DD	DU22	--	TBD
Homathko_SU_x.x	CK-34	DD	DU27	DD	--
Klinkaklini_SU_1.3	CK-35	DD	DU28	DD	--
Upper Adams River_SU_x.x	CK-82	DD	--	--	--
Boundary Bay_FA_0.3	CK-02	TBD	DU01	--	TBD
Maria Slough_SU_0.3	CK-07	TBD	DU06	--	TBD
Vancouver Island-Georgia Strait_SU_0.3	CK-83	TBD	DU20	--	TBD
East Vancouver Island-Goldstream_FA_0.x	CK-21	TBD	DU21	--	TBD
East Vancouver Island-Cowichan & Koksilah_FA_0.x	CK-22	TBD			
East Vancouver Island-Nanaimo & Chemainus_FA_0.x	CK-25	TBD			
East Vancouver Island-Qualicum & Puntledge_FA_0.x	CK-27	TBD			
West Vancouver Island-North_FA_0.x	CK-33	TBD	DU26	--	TBD
Fraser-Harrison fall transplant_FA_0.3	CK-9008	TBD	--	--	--

**CK-01 has been assessed by COSEWIC as a single DU under a separate process. The last assessment date for this DU was April 2017.*

Interior Fraser Coho WSP and COSEWIC statuses

There are five B.C. Interior Fraser Coho CUs that were assessed by DFO in 2015 (DFO 2015). There are currently three Amber and two Amber/Green CUs. COSEWIC has grouped these five CUs into one DU and assessed it's status as Threatened.

Table A2-5: The 2015 Integrated status designations for ***the five Interior Fraser Coho CUs****. The COSEWIC 2017 status designation groups these five CUs into a single DU and has assessed this DU as Threatened (released 2016).*

CU Name	WSP 2016	DU	COSEWIC 2019
Middle Fraser	Amber	Interior Fraser Coho	Threatened
Fraser Canyon	Amber		
Lower Thompson	Amber		
North Thompson	Amber		
South Thompson	Amber		