SCIENCE INFORMATION TO SUPPORT CONSULTATIONS ON BC CHINOOK SALMON FISHERY MANAGEMENT MEASURES IN 2018

Context

The 2018 draft Integrated Fisheries Management Plans (IFMP) for Pacific Salmon include a number of proposed fisheries management measures for Chinook Salmon (*Oncorhynchus tshawytscha*) in 2018. Fisheries Management has requested that DFO Science provide information (trends in abundance, productivity and current exploitation) for key Chinook Salmon management units to support consultations on potential additional BC Chinook Salmon fishery management measures in 2018.

This Science Response (SR) represents the best available science information on Chinook Salmon at present compiled on a short timeline. Therefore, the data and interpretations presented here are subject to change as new information becomes available.

This Science Response Report results from the Science Response Process on April 11, 2018 on Science information to support consultations on BC Chinook Salmon fishery management measures in 2018.

Background

Large-scale patterns of environmental change and increased environmental variability have been associated with broad declines in productivity[1] of Chinook Salmon across their range in recent decades. Potential effects of recent events, such as the persistence of the warm ocean water 'blob' which formed in the North Pacific in 2014 and moved onshore in 2015, and El Niño conditions in early 2016, have lowered expectations for returns of Chinook Salmon in 2018 (PFMC 2018).

Chinook Salmon spawn in many river systems covering a broad geographic range from California to Alaska along the west coast of North America. Given this broad geographic distribution, encompassing diverse spawning habitats for adults and rearing habitats for juveniles, and the wide variation in early life history, age of maturation, ocean distribution, return timing, and other characteristics, typically only some populations will show declines in response to acute, single-season environmental pressures. These wide-ranging traits also complicate evaluation of the influence of factors affecting Chinook Salmon productivity, abundance and survival. For example, increasing frequency and intensity of El Niño events through the 1990s have resulted in increasing variance in the North Pacific Gyre Oscillation and have been associated with declines in Chinook Salmon populations coast-wide and increased survival rate

[1] Productivity is the intrinsic rate of growth of a population, estimated from the observed relationship between spawners and adult recruits over time (also referred to as "recruits per spawner").

synchrony (Kilduff et al. 2014; Mantua 2015). Varying responses at the local population level have been observed during the same time period.

Declines in productivity and abundance of many southern Chinook Salmon stocks were observed during consecutive large El Niño events in the early and late 1990s. Stock groups such as West Coast Vancouver Island and Strait of Georgia experienced dramatic declines in marine survival rates and resulting productivity. Other stocks such as the Fraser Summer 4_1 management unit (e.g., South Thompson ocean-type summer run timing Chinook Salmon) were less affected by these changes, but these stocks as well as others have recently shown declines in abundance, productivity and survival rate. The most recent Wild Salmon Policy (WSP) integrated biological status assessment of Southern BC Chinook Salmon identified 11 conservation units (CUs) as ‘red’ (i.e. spawning abundance is likely below the lower biological benchmark) out of 15 CUs for which consensus was reached on an integrated status designation; an additional nine CUs were designated as data deficient and status could not be evaluated for 11 CUs (Table 1; DFO 2016).

Transboundary and Northern BC Chinook Salmon stocks (e.g., Alsek, Taku, Stikine, Skeena and Nass rivers), which in the 1990s and 2000s appeared to maintain a higher productivity, are showing more recent declines in abundance and productivity. Recent declines are also apparent for the Fraser Summer 4_1 (South Thompson) Chinook Salmon and other Fraser River stocks, especially the stream-type spring and summer run timed stocks. In contrast, Southern BC coastal stocks, which had the greatest initial decline in productivity and remained at low levels, have recently exhibited some increases in escapement (Figure 1), particularly along the east coast of Vancouver Island. Note that the degree to which these increases can be associated with increases in productivity is uncertain at present. In contrast, marine survival rates of east coast Vancouver Island stocks have remained consistently below their time series average (Figure 2a,b). Along the west coast of Vancouver Island, recent marine survival rates from Robertson Creek Hatchery appear to be near average historic levels, while low abundance of local wild populations, such as those in Clayoquot Sound, remains a concern in southwest Vancouver Island.

Key observational data in British Columbia are derived from ‘indicator’ stocks distributed throughout BC. Spawning abundance is estimated for each indicator stock using methods ranging from high precision fence counts to lower precision escapement enumeration methods. Coded Wire Tag (CWT) indicator stocks, generally associated with hatcheries, provide information such as marine survival, fishery exploitation rates, and ocean distribution information. These data are tracked by the Pacific Salmon Commission and results are accessible through the publications of the Chinook Technical Committee. The key Chinook Salmon management units under consideration and associated indicator stock data are summarized in Table 1. The information from these indicator stocks shows regional variation in escapement abundance and marine survival rate trends (Figure 1 and Figure 2a,b). At finer spatial scales, local habitat and ecosystem factors may explain some variations in abundance. In some cases, such as the Cowichan River Chinook Salmon stock, watershed and habitat restoration may be important factors in recent increased returns.

Dorner et al. (2017) associated the broad pattern of declines in Chinook Salmon productivity, from Alaska to Oregon, with unfavourable large-scale climatic change in the North Pacific Gyre Oscillation and the North Pacific Current, as well as increased frequency of large scale events such as El Niño, and in 2014-15, the persistence of warm ocean waters in ‘the blob’. Other researchers such as Ohlberger et al. (2018) suggest that the biological mechanisms behind the decline in productivity also include changes in population demographics, such as younger age-at-maturity, reduced size-at-age, and reduced fecundity of female spawners. Some of these demographic effects are now being observed in BC Chinook Salmon populations (Table 2, Figure 3a,b). Selective exploitation of large Chinook Salmon is likely a contributing factor to the decline in body size (Ohlgerger et al. 2018) and other demographic changes, as is predation by seals, sea lions, killer whales, and salmon sharks (Ford et al. 2009; Trites and Rosen 2018; Chasco et al. 2016; Nagasawa 1998). In addition, degradation of freshwater spawning and rearing habitat may contribute to the longer term declines in productivity observed in many BC management units (summarized in Riddell et al. 2013).

Sustainable exploitation rates (E_{MSY}) are directly related to productivity; when productivity declines, fishery exploitation should be reduced[2]. Since the early 1980s, two of five southern B.C. indicator stocks with productivity estimates have exhibited declines in productivity exceeding 40%, while productivity for a third indicator stock shows declines of approximately 25% and the remaining two are relatively stable (Riddell et al. 2013). The associated reduction in sustainable exploitation rate depends on the initial productivity of the stock. Marine area fishery catch and exploitation were reduced over time, starting with the first Pacific Salmon Treaty in 1985. In southern BC, total Chinook Salmon catch was reduced by 78% from the early 1980s (Table 3). In northern BC, total marine Chinook Salmon catch was reduced by about 47% from the early 1980s (Table 4). Resulting annual exploitation rates were reduced by an average of 44% for BC CWT indicator stocks (Table 5 and Figure 4) because stocks were considered to be overexploited at the time. Formal recognition of the link between productivity and sustainable exploitation supports the need for re-evaluation of prior ER estimates that were thought to be conservative (Hilborn & Walters, 1992). Dorner et al. (2017) suggest that, for some BC stocks, there have been declining trends in productivity ranging from about 15 to 66% over the available time series (brood years 1979-2008; Table 6). Based on these trends in productivity, further reductions in exploitation may also be warranted.

Analysis and Response

Fishery Managers requested DFO Science provide and organize available data and other information to address the questions outlined below. These responses will facilitate consultation with First Nations, Industry and other stakeholders in the development of additional fishery management measures that may be required to address declines in Chinook Salmon stock productivity.

Q1. Provide information to determine which stocks require a reduction in fishery exploitation.

Criteria (based on information available at this time) that may be used to determine which stocks may require further management measures to adjust fishery impacts include:

- Recent average exploitation rates relative to estimates of sustainable exploitation (E_{MSY}) given current stock productivity (Table 6);
- Level of recent escapement (and forecasts for WCVI stocks only) relative to escapement goals (Table 7);
- Evidence of recent declines in marine survival rate (Figure 2);

[2] E_{MSY}, or sustainable exploitation rate is derived from the 'Ricker a' parameter, an estimate of productivity, by numerical approximation (Hilborn and Walters 1992).

- Identification of other fishery related impacts, such as selective fishing practices, that may be contributing to declines in stock productivity; and
- WSP integrated status assessments.

A significant issue for these preliminary analyses is that data quality and amount varies across management units. For example, the WSP integrated biological status assessment for southern BC Chinook resulted in status assessments for 15 stocks but identified 11 data deficient CUs for which integrated status assessment could not be determined. There are also inherent sources of uncertainty associated with the available data and with the estimation of management parameters (such as E_{MSY}) but it is the best information currently available to inform the current request for Science advice. Examples of inherent uncertainty include the CWT expansions used in sport and First Nations fisheries, and estimates of total catch in some fisheries. Further work is required to develop and evaluate stock assessment methods that can be applied to more data limited Chinook Salmon stocks. Science is currently developing these methods and more complete information to inform data limited assessments and risk-appropriate management responses will be available through future work (e.g., the Fisheries Management Framework Initiative). Forecasts are provided for a limited number of stocks, but their performance has varied historically and the methods used have not been fully reviewed by Science.

Q2. What tools and information can Science provide to inform trade-offs associated with a range of potential reductions in fishery exploitation rates?

Reductions in fishery exploitation rates to achieve stock rebuilding objectives and fishery objectives inherently involve management choices such as rebuilding times and risk tolerance (i.e., the probability of achieving those objectives). Co-management processes, such as the Southern BC Chinook Initiative, are recommended as appropriate venues to conduct such management strategy evaluations due to their inclusivity and broad representation. While the Southern BC Chinook Initiative is underway, results from the initiative will not be available in a suitable time frame to assist with current management objectives.

Information that may be useful in considering reductions in fisheries includes run timing, CWT-based distribution of total mortality, creel survey interview data and biological sampling, the iREC survey of licence holders, DNA stock composition, and commercial and test fishery data.

For northern stocks, this information is available through the results of a special joint initiative in 2018 involving DFO biologists and biologists from the Alaska Department of Fish and Game (available from I. Winther, DFO by request). In southern BC, recreational fishery data summaries from creel surveys and iREC surveys are available from W. Luedke, DFO by request. Summaries of the CWT data and associated mortality distribution tables current to 2017 are available upon request (G. Brown or C. Parken, DFO).

These types of data have been used in simulations or retrospective analyses to explore a range of fishery-specific reductions intended to reduce fishery impacts and to increase passage of fish to spawning grounds (e.g., Starr and Argue, unpublished working paper[3]). These data products can identify benefits and costs associated with a range of fishery reductions and management strategies. Simulations in the form of retrospective scenarios of assumed Canadian and US fishery reductions using the PSC Coast-Wide Chinook Model have recently been conducted to better understand the likely range of stock-specific increases in abundance and also, the impact

[3] Starr, P.J., and Argue, A.W. 1991. Evaluation Framework for Assessing 1989 Strait of Georgia Sport Fishing Regulation Changes. Pacific Stock Assessment Review Committee. Working paper 91-3.

to fishery catches, The development of scenarios have been informed by the use of stock- and fishery-specific CWT-based estimates of exploitation rates. Further simulation work is possible and would be best guided by management input in the form of development of target objectives for evaluation, and the identification of potential management strategies to achieve those objectives.

Science, working with other DFO sectors and through various joint technical processes involving First Nations and stakeholders, is currently completing work that will provide more comprehensive advice to adequately inform the decision-making context. This work includes developing stock assessment methods that can be applied for more data limited situations, developing robust methods for estimating sustainable exploitation rates, and developing evaluation tools that can be used to inform management trade-offs when setting fishery and stock objectives for rebuilding. There is also a technical review underway to evaluate management actions implemented in 2012 to reduce fishery impacts on Fraser River Chinook Salmon. As this work is completed, the information that Science can provide to managers will be more comprehensive and robust.

Q3. What information can Science provide to inform development of management measures if it is determined reductions are required?

Declines in productivity as described in the Background section may warrant either reduction in exploitation rates and/or measures to reduce fishery-related impacts that may contribute to negative demographic changes in populations (e.g., harvest practices that selectively remove older and larger fish). Increased exploitation of the oldest age classes have been observed in North Coast stocks, West Coast Vancouver Island stocks but not the lower Strait of Georgia or Fraser River stocks. Once the stocks of concern and target levels for potential reductions are identified, more specific input can be provided by Science to inform development of specific management measures. Methods used to assess proposed fishery measures on a by-fishery basis will depend on how proposed reductions are implemented (e.g., reductions in total allowable catch or fishing effort and area closures in times when stocks of concern are prevalent can both be informed by analyses of CWT indicator stock distributions in fisheries; while bag limits, size limits, and other gear restrictions (e.g., net mesh size) may help to mitigate demographic changes for some stocks. Science can use data including historical fishery impacts, stock distribution and timing, size at catch and fishing effort to model expected reductions in fishery impacts. Information, data availability and data quality will range from high to low across Chinook stocks in British Columbia. The use of proxy data (i.e., data from a stock considered to exhibit a similar life history pattern and ocean distribution is ‘borrowed’ for a stock with missing information) is a common approach in data limited cases. Limitations of available data are particularly important in consideration of the scale of reductions that can be modeled. Finer-scale or incremental reductions in fisheries are best supported with good quality data. Data of sufficient quality and resolution are available for some CWT stocks but data are more limited for others.

Q4. What are the potential metrics/indicators that could be used to assess whether or not objectives have been met? Provide commentary on strengths and weaknesses of proposed assessment methods.

Metrics/indicators that could be used to assess whether or not objectives have been met should be similar to the criteria used to set targets for reduction. That is, for the management units in which management actions are taken, performance metrics could include:

- A reduction in observed exploitation rate to a level *below* E_{MSY} (which will provide a buffer to better account for the uncertainty associated with estimation of E_{MSY});
- An increase in escapement of indicator stocks within the management unit (i.e., observed rebuilding to a level above an established benchmark, such as the WSP absolute abundance metric Sgen);
- An observed reduction in size-selective fishery impacts; and
- Observed reversal of declining trends in escapement (e.g., improvement in established metrics from lower WSP zone, red status to amber or green).

In all cases, the sources of uncertainty associated with potential metrics and data deficiency should be considered and targets set accordingly. The ability to assess the achievement of specific reduction targets post-season on a by-fishery basis is dependent on catch monitoring and sampling programs conducted during the fishing season. The choice of performance metrics/indicators identified on a by-fishery basis that are inconsistent with current stock assessment and catch monitoring frameworks (or highly sensitive to the uncertainty of the available data) may require additional monitoring and sampling programs. Some escapement programs produce relatively imprecise estimates of spawning abundance. Finally, detecting measurable improvements associated with fishery actions taken in 2018 may not be possible given inter-annual variation in environmental conditions that influence marine survival rate and stock abundance.

Key Observations

- Chinook Salmon productivity is estimated to have declined from 25-40% since the early 1980s across many BC indicator stocks. According to stock assessment principles, sustainable exploitation (E_{MSY}) is directly related to productivity; when productivity declines, fishery exploitation should be reduced.
- Reliable estimates of productivity rely on complete brood year information (which is only available once the oldest age for the cohort has spawned and coincidentally once all fisheries have occurred on the cohort); presently, current productivity estimates are only available up to the 2012-2013 brood years and do not reflect any recent changes in productivity. The uncertainty introduced by this information lag, along with low escapements and recent declines in calendar year exploitation rates may explain why additional reductions in exploitation are being considered despite recent exploitation rates falling below E_{MSY}.
- Factors potentially affecting the productivity of recent brood years (i.e., that are not reflected in the available E_{MSY} estimates) include anomalous ocean conditions such as “the blob” in 2014-15, an El Niño in the first half of 2016 and freshwater habitat issues relating to drought conditions in the southern interior B.C. (2015-2016). Further, anecdotal reports suggest that there was an acute decrease in abundance of juvenile Chinook Salmon entering the ocean in the summer of 2017 (observed in standardized surveys along the Washington coast and in Alaska; L. Weitkamp, pers. comm., January 2018), which suggests adult returns for these brood years may also be low (roughly corresponding to returns in 2018 through to 2021).
- Patterns in Chinook Salmon productivity have also become more synchronous in recent years, similar to results reported for other species of Pacific salmon. Such recent changes may reduce the resilience of the species to effects of climate change and habitat modification (Dorner et al. 2017).

- As noted previously, a number of key uncertainties are associated with the data presented here. Due to the wide-ranging age-at-return of many Chinook populations, complete brood year information can take up to six years to accrue and modelled estimates are often used in the interim. Additionally, the productivity of hatchery populations may differ from associated natural populations, but the available data does not provide a means of differentiating between hatchery and natural populations. This limits the ability to make inferences about natural productivity which is of greatest concern.
- Contrary to the basin-scale pattern of declines in productivity, increases in escapement have been observed for some Vancouver Island stocks; at present, the specific natural and/or human-caused mechanism(s) leading to these increases have not been isolated.

Conclusions

1. Declining productivity is still a concern for many Chinook Salmon stocks and it is unclear whether current estimates of sustainable exploitation are appropriate for current productivity levels.
2. Given the variability and time lag in the existing data, detecting changes in productivity will take several years. General trends can be identified from broader consideration of changes in recent escapement and calendar year exploitation rates along with brood year information, despite the uncertainties inherent in these data sources.
3. While there is an attempt to identify sources of uncertainty in this preliminary response to inform the broader decision-making process, these uncertainties have not been presented with sufficient detail to fully understand their impact on local scale decision-making processes.
4. A range of initiatives are currently underway that will improve the ability to provide science advice to support management decision making, such as the Southern BC Chinook Initiative. Additionally, information that may be useful in considering reductions to specific stocks that are currently available, include (but are not limited to) run timing, CWT-based distribution of total mortality, creel survey interview data and biological sampling, the iREC survey of licence holders, DNA stock composition, commercial and test fishery data, recent simulation work with the PSC Coast-wide Chinook Model, and additional information from DFO members of the CTC. The sources of data available vary by stock and area.
5. Science, working with other DFO sectors and through various joint technical processes involving First Nations and stakeholders, is currently completing work that will provide more comprehensive tools and methods to inform the decision-making context.

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Tables and Figures

Table 1. Key characteristics of data used to inform the analysis for Transboundary and BC Chinook management units.

Chinook Management Unit	Life History Type	CWT Indicators	CTC Model Stock	Escapement Indicators	Associated Conservation Units[4]
Transboundary	Stream	Taku (TAK), Stikine (STI)	Transboundary	Taku, Stikine	*CK-60: Stikine_early* *CK-61: Stikine_late* *CK-63: Taku_early* *CK-64: Taku_mid* *CK-65: Taku_late*
			Alsek	Alsek	*CK-67: Alsek*
North Coast	Stream	Kitsumkalum (KLM)	Northern BC	Nass, Skeena, Kitsumkalum	*CK-46: Ecstall* *CK-48: Lower Skeena* *CK-49: Kalum_early* *CK-50: Kalum_late* *CK-51: Lakelse* *CK-53: Middle Skeena-large lakes* *CK-54: Middle Skeena-mainstem tribs,* *CK-55: Upper Bulkley River* *CK-56: Upper Skeena* *CK-57: Portland Sd-Observatory Inlet-Lower Nass*
Central BC	Ocean	Atnarko (ATN)	Central BC	Atnarko	*CK-39: Bella Coola-Bentinck*
Upper Georgia Strait	Ocean	Quinsam Hatchery (QUI) Phillips River (PHI)[5] Puntledge Hatchery (PPS) Big Qualicum (BQR)	Upper Georgia Strait	Aggregate index	*CK-28: Southern Mainland-Southern Fjords* CK-29: East Vancouver Island-North
			Middle Georgia Strait		*CK-27: East Vancouver Island-Qualicum & Puntledge-fall timing*

[4] Conservation Units appearing in *grey italics* have not yet undergone a Wild Salmon Policy integrated status assessment or remain unassessed following the 2012 status assessment due to data deficiencies or the unknown impact of hatchery produced fish within the CU (DFO 2016).
[5] Phillips River is a new CWT indicator with consistent data time series starting with catch year 2014.

Chinook Management Unit	Life History Type	CWT Indicators	CTC Model Stock	Escapement Indicators	Associated Conservation Units[4]
Lower Georgia Strait	Ocean	Cowichan (COW)	Lower Georgia Strait	Cowichan	*CK-22: East Vancouver Island-Cowichan & Koksilah* *CK-25: East Vancouver Island-Nanaimo & Chemainus*
West Coast Vancouver Island	Ocean	Robertson Creek (RBT)	WCVI Natural	Aggregate index	CK-31: West Vancouver Island-South CK-32: West Vancouver Island-Nootka & Kyuquot CK-33: West Vancouver Island-North
			WCVI Hatchery	Aggregate index	-
Fraser Spring 4_2	Stream	Nicola (NIC)	Fraser Spring 1.2	Aggregate Fraser run reconstruction index	CK-16: South Thompson-Bessette Creek_SU_1.2 CK-17: Lower Thompson_SP_1.2
Fraser Spring 5_2	Stream	-	Fraser Spring 1.3	Aggregate Fraser run reconstruction index	*CK-04: Lower Fraser River_SP_1.3* *CK-06: Lower Fraser River_SU_1.3* CK-10: Middle Fraser River_SP_1.3 CK-12: Upper Fraser River_SP_1.3 CK-14: South Thompson_SU_1.3 CK-18: North Thompson_SP_1.3
Fraser Summer 5_2	Stream	-	Fraser Summer 1.3	Aggregate Fraser run reconstruction index	CK-09: Middle Fraser River-Portage CK-11: Middle Fraser River_SU_1.3 CK-19: North Thompson_SU_1.3
Fraser Summer 4_1	Ocean	Lower Shuswap (SHU) Middle Shuswap (MSH)	Fraser Summer 0.3	Aggregate Fraser run reconstruction index	*CK-07: Maria Slough_SU_0.3* CK-13: South Thompson_SU_0.3 *CK-15: South Thompson_SU_0.3*
Fraser Fall 4_1	Ocean	Harrison River (HAR)	Harrison Fall	Harrison River	CK-03: Lower Fraser River_FA_0.3
-	Ocean	Chilliwack Hatchery (CHI)	Chilliwack Fall	-	*CK-9008: Fraser-Harrison fall transplant_FA_0.3*

Table 2. Summary of recent trends in characteristics for select stocks within Transboundary and BC management units.

Management Unit	Stock	2017 Escapement	CU Escapement Trend[6]	WSP Integrated Status Assessment	Survival	Generation Time	Female Length	Fecundity
		(relative to 2003-13 avg)	(% change over 3 generations up to 2016)	Data to 2012 (DFO 2016)	(2007-2011 brood year avg relative to 1980-1990 avg)	(Decline rate)	(Trend)	(Trend)
Transboundary	**Alsek**	**-65%**	**-**	**-**	**Unk**	**Unk**	**Unk**	**Unk**
	Taku	**-73%**	**-**	**-**	**-39%**	**stable[7]**	**Declining**	**Unk**
	Stikine	**-71%**	**-**	**-**	**Unk**	**-0.026**	**Unk**	**Unk**
Northern BC	**Nass**	**-72%**	**-**	**-**	**Unk**	**Unk**	**Declining**	**Unk**
	Skeena **Kitsumkalum**	**-68%** **-66%**	**-**	**-**	**-36%**	**-0.025**	**Declining age-5,-6**	**Unk**
Central BC	**Atnarko Total** **Atnarko Wild**	**-13%** **-21%**	**-**	**-**	**28%**	**-0.015**	**Unk**	**Unk**
Upper Georgia Strait	**NEVI (Quinsam)**	**NA**	**NA CK-28[8]** **-60% CK-29**	**DD (CK-28)** **Red (CK-29)**	**-81%**	**-0.017**	**Declining age-4,-5**	**Declining since 2011**
	Big Qualicum	**-51%**	**-45% CK-27**	**TBD**	**-44%**	**-0.017**	**Declining age-3,-4**	**Declining since 2011**
	Puntledge Summers	**-45%**	**-80% CK-83**	**TBD**	**-9%**	**-0.009**	**Unk**	**Unk**
Lower Georgia Strait	**Cowichan**	**422%**	**386% CK-22**	**TBD**	**-73%**	**-0.008**	**Unk**	**Stable**
	Nanaimo		**-5% CK-25**	**TBD**	**Unk**	**Unk**	**Unk**	**Unk**
WCVI	**WCVI aggregate**	**164%**	**-12% CK-31** **287% CK-32** **-10% CK-33**	**Red (CK-31)** **Red (CK-32)** **TBD (CK-33)**	**-73%**	**stable**	**Unk**	**Unk**
Fraser Spring 4_2	**Fraser Spring 1.2 (Nicola)**	**-52%** **-67%**	**-51% CK-16** **98% CK-17**	**Red (CK-16)** **Red (CK-17)**	**-55%**	**stable**	**Declining, age-4**	**Unk**

[6] Based on the short-term trend metric present in DFO (2016) and updated to include escapement time series ending in 2016 for all sites within the CU (wild and enhanced combined). Trends were estimated from a linear trend in $\log_e$(spawner abundances) over 3 generations, based on all years with reviewed escapement time series data and using infilled values where applicable.
[7] The complete time series is stable, but shows a consistently declining trend since 1990.
[8] CK-28 is represented by the Phillips River which is a relatively new CWT indicator (established in 2014) and as such, does not presently have a three generation time series to calculate trend.

Fraser Spring 5_2	**Fraser Spring 1.3**	**-59%**	**-44% CK-04 -43% CK-06 -3% CK-10 -53% CK-12 -45% CK-14 -79% CK-18**	**TBD (CK-04) DD (CK-06) Red (CK-10) Red (CK-12) Red/Amber (CK-14) Red (CK-18)**	**Unk**	**Unk**	**Unk**	**Unk**
Fraser Summer 5_2	**Fraser Summer 1.3 (Chilko)**	**-68%**	**-86% CK-09 -48% CK-11 -72% CK-19**	**Red (CK-09) Amber (CK-11) Red (CK-19)**	**Unk**	**Unk**	**Declining, age-5**	**Unk**
Fraser Summer 4_1	**Fraser Summer 0.3 (L Shuswap)**	**-21% -53%**	**-27% CK-07 -12% CK-13 -36% CK-15**	**TBD (CK-07) Green (CK-13) TBD (CK-15)**	**-42%**	**-0.020**	**Declining age-3,-4,-5**	**Declining**
Fraser Fall 4_1	**Fraser Fall (Harrison)**	**-68%**	**-28% CK-03 19% CK-9008**	**Green(p) (CK-03) TBD (CK-9008)**	**-45%**	**-0.016**	**Declining age-3,-4,-5**	**Unk**

Table 3. Average landed catch of Chinook in Southern BC marine fisheries, 1975 – 2016 (CTC 2017a). Note: Fraser River catch is not included in this table.

Catch Years	SBC ISBM First Nations marine[9]	SBC ISBM Net	SBC ISBM Sport	SBC ISBM Troll	WCVI AABM Troll	-WCVI AABM Sport	Total Average Catch	% Change Relative to 1975-84
1975 to 84	1,020	73,170	347,356	214,393	511,790	No Est	1,147,729	-
1985 to 98	7,201	34,710	167,438	26,300	221,065	20,572	477,286	-58%
1999 to 08	15,707	10,713	93,711	425	102,317	37,729	260,601	-77%
2009 to 16	12,189	11,229	97,324	0	70,080	58,494	249,315	-78%

Table 4. Average landed catch of Chinook in Northern and Central BC marine fisheries, 1975 – 2016 (CTC 2017a). Note: Transboundary catches are not included in this table.

Catch Years	NBC ISBM First Nations	NBC ISBM Net	NBC ISBM Sport[9]	NBC ISBM Troll	NBC AABM Sport[10] and Troll	Total Average Catch	% Change Relative to 1975-84
1975 to 84	14,564	60,489	9,795	101,221	167,571	353,640	-
1985 to 98	27,038	40,600	10,432	26,594	154,977	259,641	-27%
1999 to 08	23,310	18,336	9,265	256	144,532	195,699	-45%
2009 to 16	14,529	6,797	9,237	0	146,369	176,932	-47%

[9] Includes Food, Social, Ceremonial (FSC) and Economic Opportunities (EO) fisheries.
[10] NBC Sport catches begin in 1977.

Table 5. Estimated calendar year annual exploitation rates (CYER) (2011-2016) for Transboundary and BC Chinook management units relative to historic levels (1980-1989). Although CTC model output may be available for some of these stocks, only CWT Indicator Stock data is included below. See Appendix Table A-1. Annual exploitation rate estimates represent total Adult Equivalency (AEQ)-adjusted mortality (i.e. includes estimated release mortality). All estimates exclude youngest age fish (i.e., age-2 for ocean-type stocks, and age-3 for stream-type stocks). [11]

Management Unit	CWT Indicator Stock	Average CYER 1980-89	Average CYER 2011-2016	% Change
Transboundary	**Stikine**	**-**	**23%**	**-**
-	**Taku**	**11%**	**16%**	**43%**
Northern BC	**Kitsumkalum River**	**43%**	**33%**	**-24%**
Central BC	**Atnarko River**	**-**	**40%**	**-**
Upper Georgia Strait	**Phillips**	**-**	**26%**	**-**
	Quinsam Hatchery	**71%**	**37%**	**-48%**
	Puntledge Hatchery	**63%**	**42%**	**-32%**
	Big Qualicum Hatchery	**73%**	**44%**	**-39%**
Lower Georgia Strait	**Cowichan River**	**-**	**62%**	**-**
WCVI	**Robertson Creek Hatchery**	**56%**	**35%**	**-37%**
Fraser Spring 4_2	**Nicola River**	**-**	**20%**	**-**
Fraser Spring 5_2	***None currently***	**-**	**-**	**-**
Fraser Summer 5_2	***None currently***	**-**	**-**	**-**
Fraser Summer 4_1	**Lower Shuswap River**	**35%[12]**	**44%**	**26%**
	Middle Shuswap	**-**	**44%**	**-**
Fraser Fall 4_1	**Harrison River**	**75%[13]**	**28%**	**-62%**
	Chilliwack River	**69%**	**28%**	**-59%**

[11] Table 5 has been revised from an earlier version of this SR; see Appendix table A-1 for comparison and explanation.
[12] Based on 1988-1989 only.
[13] Based on 1985-1989 only.

Table 6. Summary of the intrinsic productivity (Ricker α) and sustainable exploitation rates (E_{MSY}) for select management units based on Dorner et al. (2017; data available from B. Dorner upon request). Note: Dorner et al (2017) excludes hatchery stocks. Chinook productivity analysis for their full time series and for the recent five brood years up to 2008 for B.C. stocks. Also displayed are recent CWT exploitation rates for Transboundary and B.C. Chinook management units, expressed in brood years (BYER) and catch (calendar) years (CYER) [14]. Further work is required to estimate long term and recent productivity for several B.C. management units following the method applied by Dorner et al. (2017).

Management Unit	Indicator Stock	Long term productivity (Ricker α)	Recent productivity (Ricker α)	Relative change in prod.	Long term E_{MSY}	Recent E_{MSY}	Relative change E_{MSY}	Recent BYER 2004-2008	Average CYER 2011-2016
Transboundary	**Alsek**	**0.74**	**0.25**	**-66%**	**33%**	**12%**	**-64%**	**-**	**-**
	Stikine	**1.45**	**1.50**	**3%**	**58%**	**59%**	**2%**	**34%**	**23%**
	Taku	**0.94**	**0.70**	**-26%**	**41%**	**31%**	**-23%**	**24%**	**16%**
Northern BC	**Kitsumkalum**	**1.51**	**1.28**	**-15%**	**60%**	**53%**	**-12%**	**32%**	**33%**
Central BC	**Atnarko**	**-**	**-**	**-**	**-**	**-**	**-**	**51%**	**40%**
Upper Georgia Strait	**Phillips**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**26%**[15]
	Quinsam	**-**	**-**	**-**	**-**	**-**	**-**	**41%**	**37%**
	Puntledge	**-**	**-**	**-**	**-**	**-**	**-**	**37%**	**42%**
	Big Qualicum	**-**	**-**	**-**	**-**	**-**	**-**	**44%**	**44%**
Lower Georgia Strait	**Cowichan**	**-**	**-**	**-**	**-**	**-**	**-**	**76%**	**62%**
WCVI	**Robertson**	**-**	**-**	**-**	**-**	**-**	**-**	**37%**	**35%**
Fraser Spring 4_2	**Nicola**	**-**	**-**	**-**	**-**	**-**	**-**	**27%**	**20%**
Fraser Spring 5_2	***None currently***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Fraser Summer 5_2	***None currently***	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Fraser Summer 4_1	**Lower Shuswap**	**-**	**-**	**-**	**-**	**-**	**-**	**50%**	**44%**
-	**Middle Shuswap**	**-**	**-**	**-**	**-**	**-**	**-**	**55%**[16]	**44%**
Fraser Fall 4_1	**Harrison**	**1.18**	**0.59**	**-50%**	**49%**	**27%**	**-45%**	**30%**	**28%**

[14] Estimates of Brood Year Exploitation Rate (BYER) and Calendar Year Exploitation Rate (CYER) exclude the youngest age classes (i.e. age-2 for ocean type stocks, and age-3, for stream type stocks). BYER is based on complete brood years (with the same input years as E_{MSY}) and thus is comparable to E_{MSY}. CYER can be estimated for incomplete brood years and can provide an early indication of recent changes in exploitation if it differs from BYER (though it is not in the same “currency” as BYER or E_{MSY}).
[15] Philips CYER is only based on 2014-2016.
[16] Middle Shuswap BYER is based on 2008 value only and CYER is based on 2014-2016.

Table 7. Escapement for indicator stocks relative to CTC-accepted escapement goals derived from stock-recruit analyses (S-R) or habitat-based estimates of S_{MSY} (estimated spawners required to produce maximum sustained yield, S_{MSY}; Parken et al. 2006) for Transboundary and BC management units. Note: in all cases there is significant uncertainty in the estimated S_{MSY} values and for most management units; the estimates are preliminary and require further review. Estimates of escapement include both hatchery and wild adult contributions, but exclude estimates of jacks.

Management Unit	**Stock**	**Escapement Goal**			**Escapement**[17]		
		Lower	**Upper**	**Type**	**Long-term AVG**	**Last 5 Years**	**2017**
Transboundary	Alsek	3,500	5,300	S_{MSY}	8,586 (1976-2017)	3,672	1,740
	Taku	19,000	36,000	S_{MSY}	36,140 (1975-2017)	18,304	8,754
	Stikine	14,000	28,000	S_{MSY}	24,635 (1976-2017)	15,997	7,206
Northern BC	Nass	10,000	15,000	S-R	17,344 (1977-2017)	11,411	4,984
	Kitsumkalum	8,621	-	S_{MSY}	13,764 (1984-2017)	10,225	4,943
Central BC	Atnarko	5,009	-	S_{MSY}	17,591 (1990-2017)	24,219	10,395
Upper Georgia Strait	*Aggregate*	-	-	-	-	-	-
Lower Georgia Strait	Cowichan	6,500	-	S-R	5,491 (1981-2017)	6,590	10,590[18]
WCVI	*Aggregate*	15,000	-	S_{MSY}	11,304 (1993-2017)	17,727	17,163
Fraser Spring 4_2	*Aggregate*	22,146	-	S_{MSY}	10,693 (1975-2017)	11,317	5,105
Fraser Spring 5_2	*Aggregate*	42,165	-	S_{MSY}	23,805 (1975-2017)	18,916	8,154
Fraser Summer 5_2	*Aggregate*	23,567	-	S_{MSY}	20,047 (1975-2017)	16,070	6,459
Fraser Summer 4_1	*Aggregate*	120,000	322,000	S_{MSY}	63,006 (1975-2017)	111,950	84,470
Fraser Fall 4_1	Harrison	75,100	98,500	S-R	94,958 (1984-2017)	52,056	29,799

[17] Although jacks can provide an indication of future abundance in situations where a sibling relationship exists, decreasing maturation trends have led to changes in the sibling relationships for some stocks (i.e., older ages consistently returning below that expected from the sibling regression relationship). Preliminary observations show that there are regional differences in the recent patterns of jack returns (i.e., Vancouver Island stocks generally show an increasing trend while Fraser River stocks show a decreasing trend).
[18] Excludes broodstock removals.

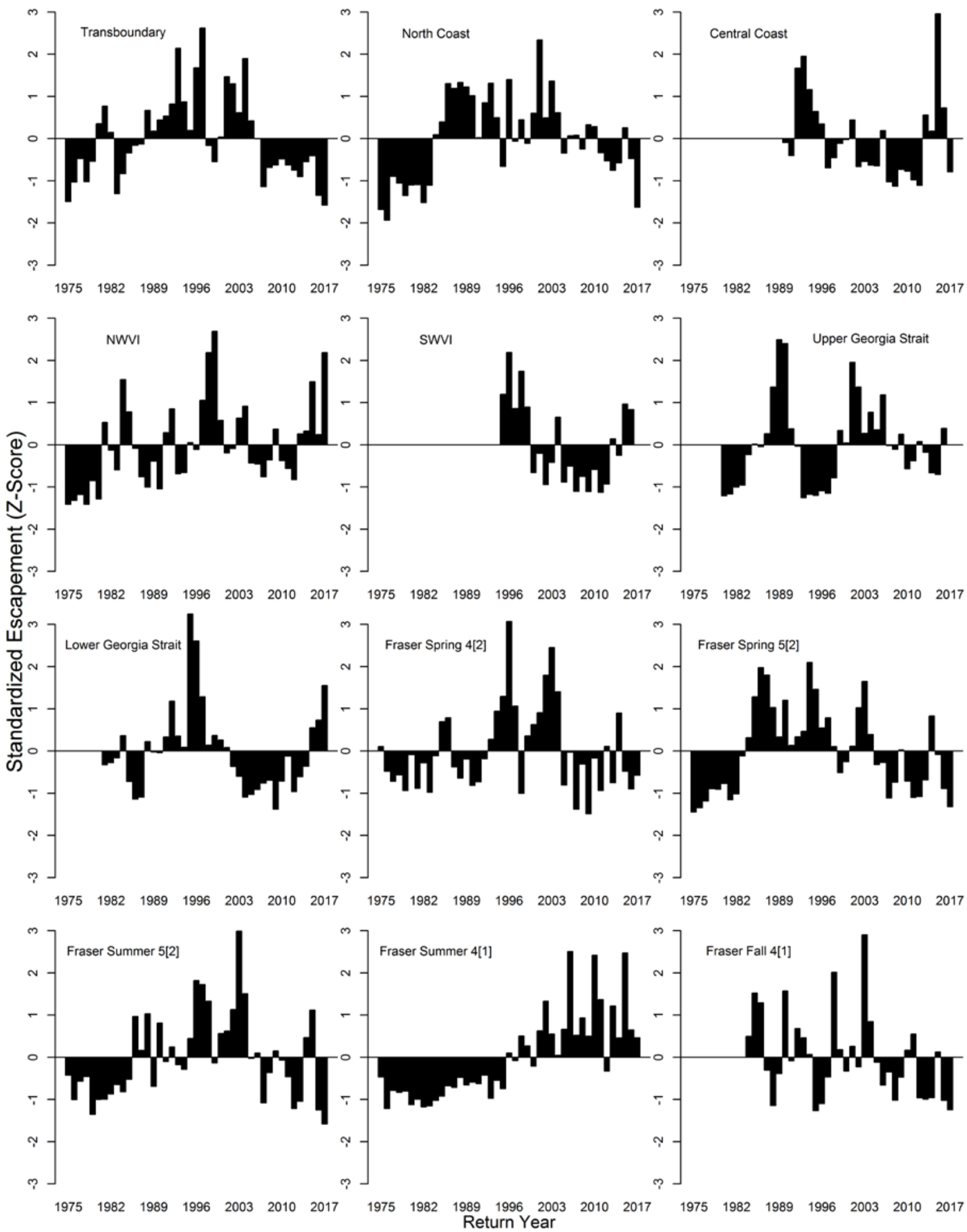

Figure 1. Trends in combined hatchery and natural escapement based on average deviations (Z-scores) for 12 Chinook management units, 1975-2017. Stocks included in the analysis are Transboundary: Alsek, Taku, Stikine; North Coast: Nass, Skeena, Kitsumkalum; Central Coast: Atnarko Total; NWVI: Artlish, Tahsis, Kaouk, Tahsish; SWVI: Megin, Moyeha, Bedwell; Upper Georgia Strait: Nimpkish, Salmon, Quinsam/Campbell; Lower Georgia Strait: Cowichan; Fraser aggregates for Spring 4_2, Spring 5_2, Summer 5_2 and Summer 4_1 and Fraser Fall 4_1: Harrison.

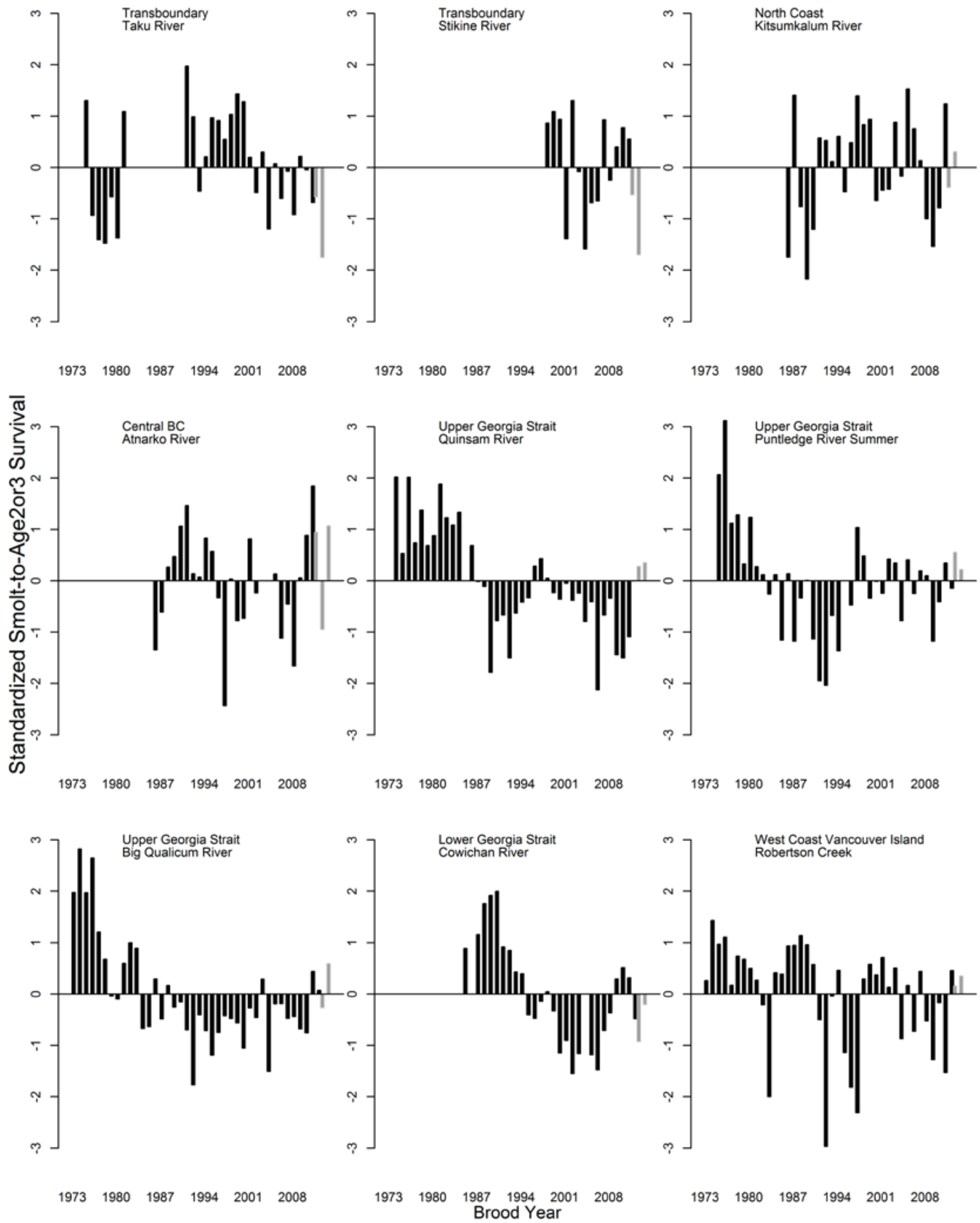

Figure 2a. Trends in brood year marine survival (commonly represented by cohort-based smolt to age-2 or -3 survival, CTC 2017b) estimated for nine CWT indicator stocks across Transboundary and BC rivers (excluding the Fraser River). Note: Estimates for incomplete broods are depicted by grey bars; these estimates are calculated using average maturation rate assumptions and are expected to change until fish have matured at all possible ages. 2015 brood year observations (which use model estimates for all but the age-2 class) have been excluded. Estimates include CWT recoveries from 2017. Data for each stock have been standardized by natural log transformation and scaled to a mean of zero and standard deviation of one.

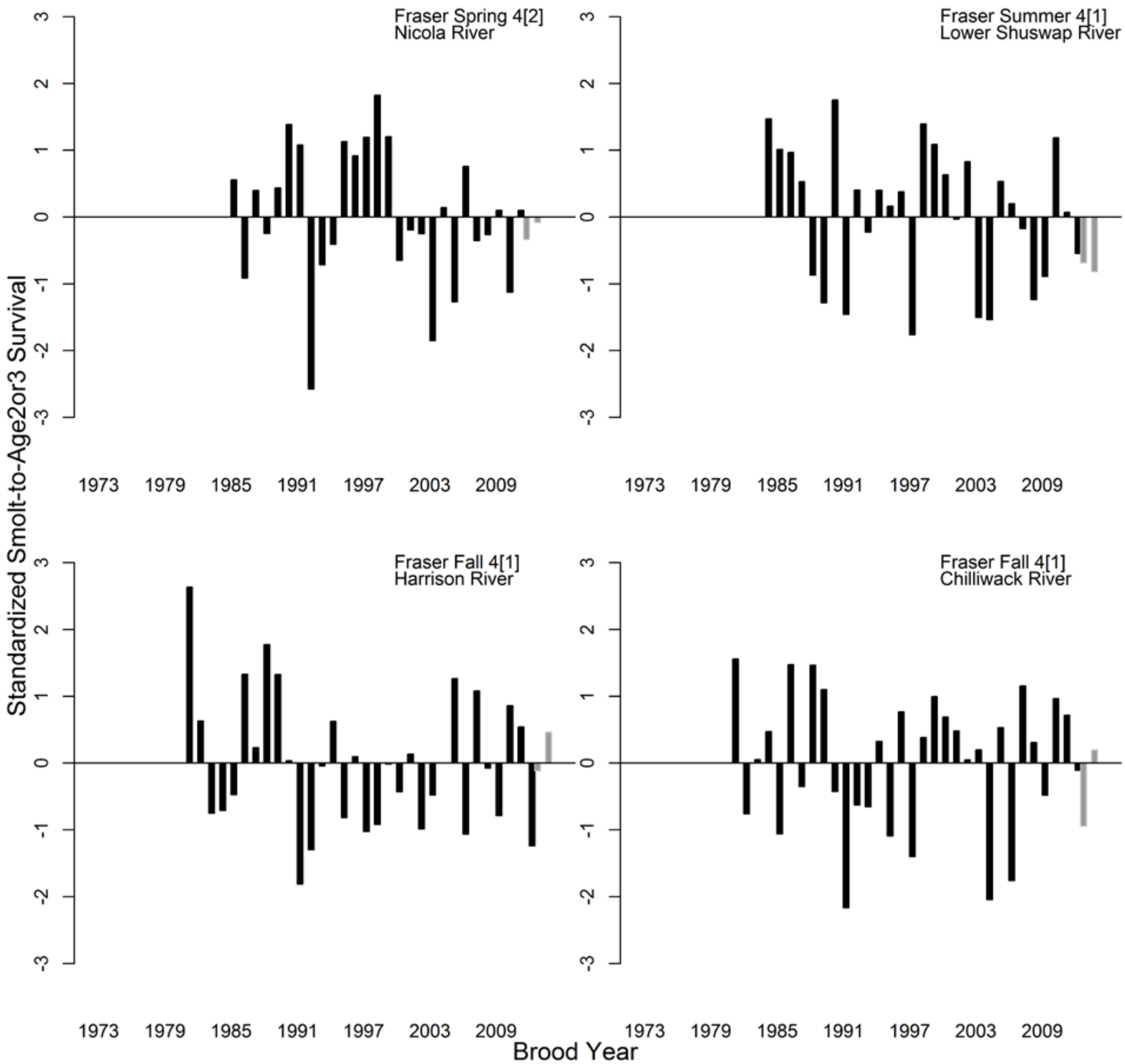

Figure 2b. Trends in brood year marine survival (commonly represented by cohort smolt to age-2 or -3 survival, CTC 2017b) estimated for four CWT indicator stocks from the Fraser River. Note: Estimates for incomplete broods are depicted by grey bars; these estimates are calculated using average maturation rate assumptions and are expected to change until fish have matured at all possible ages. 2015 brood year observations (which use model estimates for all but the age-2 class) have been excluded. Estimates include CWT recoveries from 2017. Data for each stock have been standardized by natural log transformation and scaled to a mean of zero and standard deviation of one.

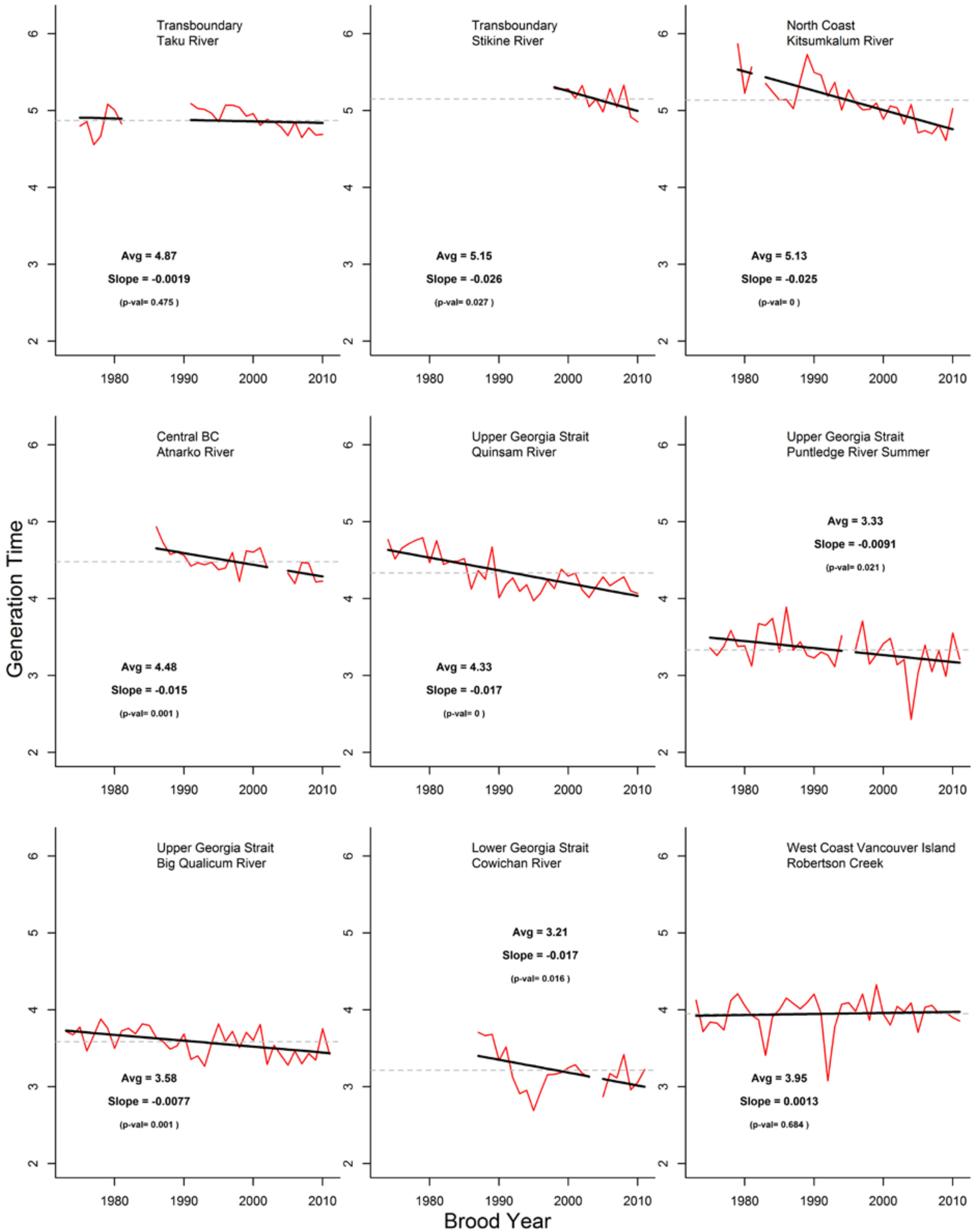

Figure 3a. Observed changes in average generation time for Transboundary and (non-Fraser) BC CWT indicator stocks in the absence of fishing. Calculated values are based on CWT recoveries up to and including 2016. Slope value estimates the rate of change in average generation time over the time series. P-val provides a statistical measure of the probability the slope is significantly different from zero.

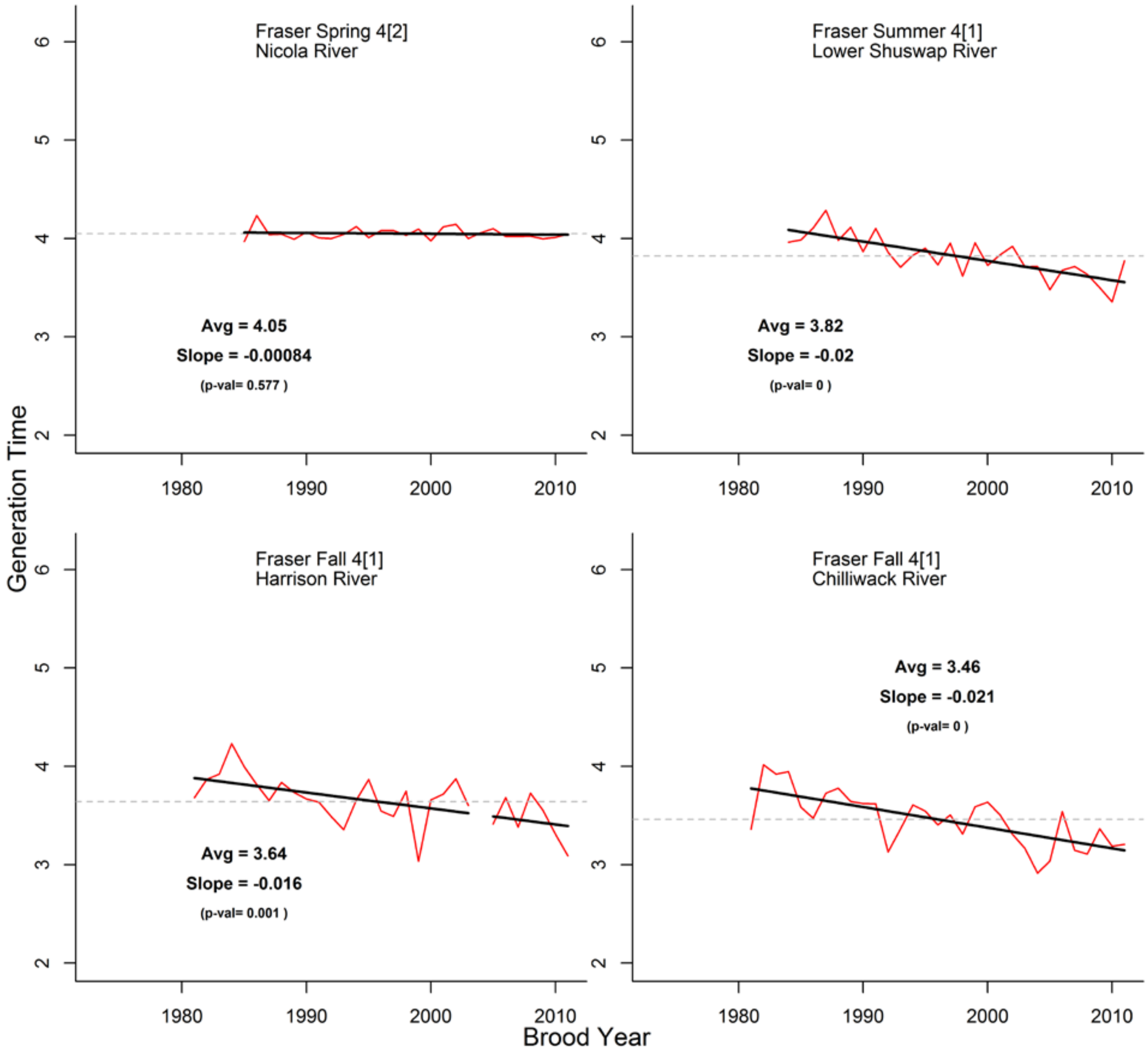

Figure 3b. Observed changes in average generation time for Fraser River CWT indicator stocks, in the absence of fishing, brood years 1980-2011. Calculated values are based on CWT recoveries up to and including 2016. Slope value estimates the rate of change in average generation time over the time series. P-val provides a statistical measure of the probability the slope is significantly different from zero.

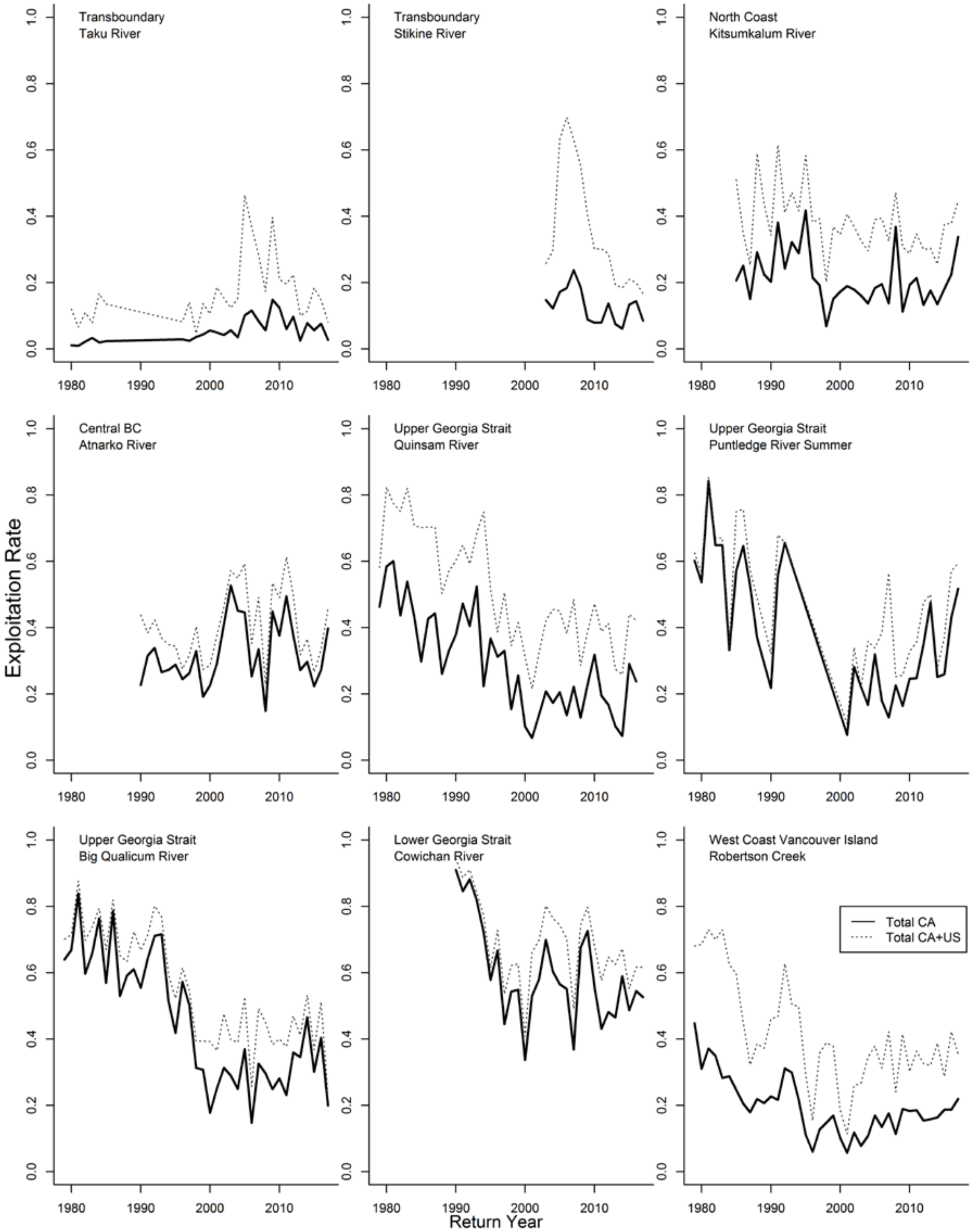

Figure 4a. Trends in total annual simple calendar year exploitation rate for Transboundary and (non-Fraser) BC Chinook CWT indicator stocks. The exploitation rate represents total mortality (i.e., includes estimated incidental mortality from releases as well as landed catch). The estimates exclude youngest age fish and have been adjusted for age-specific adult equivalency. For the Robertson Creek Hatchery stock, estimates are based on pre-terminal fisheries only as terminal fisheries targeting the hatchery returns in Alberni Inlet are not representative of terminal impacts on natural stocks in the WCVI region.

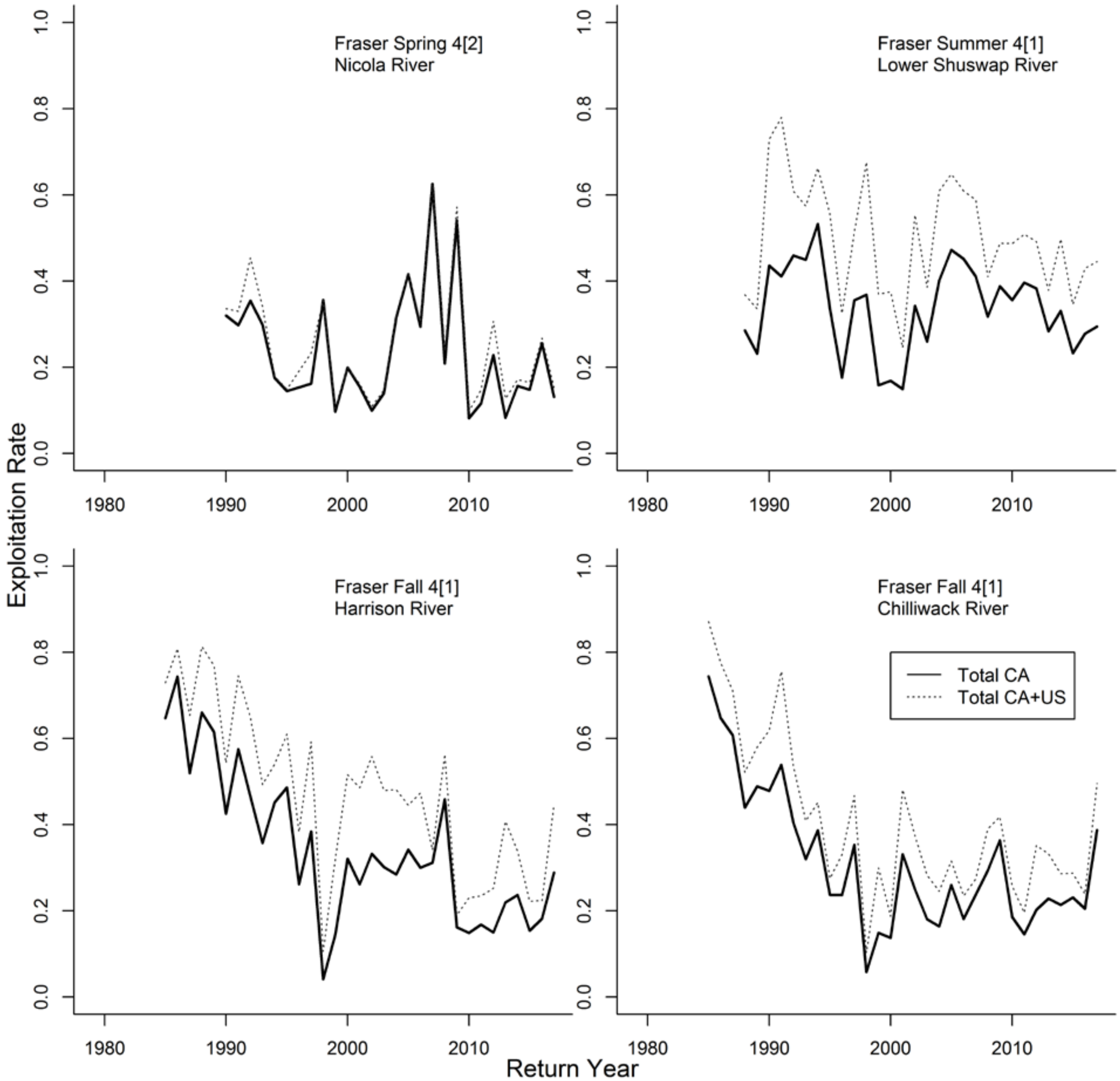

Figure 4b. Trends in total annual simple calendar year exploitation rate for Fraser River Chinook CWT indicator stocks. The exploitation rate represents total mortality (i.e., includes estimated incidental mortality from releases as well as landed catch). The estimates exclude youngest age fish and have been adjusted for age-specific adult equivalency.

Appendix

Table A-1. Unrevised (original) Table 5: estimates of calendar year annual exploitation rates (2011-2016) for Transboundary and BC Chinook management units relative to historic levels (1980-1989) provided in previous SR version. In the original (unrevised) Table 5, estimates from modelled outputs from the Chinook Technical Committee coast-wide model were provided for Transboundary, Fraser Spring 5_2 and Fraser Summer 5_2.stocks. The unrevised Table 5 estimates included youngest age fish (i.e., age-2 for ocean-type stocks, and age-3 for stream-type stocks), and escapement strays. Table A-1 is included ***as a comparison only*** *to illustrate the revisions in the updated Table 5 above.*

Management Unit	CWT Indicator Stock / Model Stock	Average ER 1980-89	Average ER 2011-2016	% Change
Transboundary	***CTC Model Output***	***24%***	***39%***	**66%**
Northern BC	**Kitsumkalum River**	**46%**	**35%**	**-23%**
Central BC	**Atnarko River**	**n/a**	**40%**	**n/a**
Inner South Coast	**Cowichan River**	**79%**	**55%**	**-30%**
	Big Qualicum Hatchery	**76%**	**43%**	**-43%**
	Puntledge Hatchery	**66%**	**37%**	**-43%**
	Quinsam Hatchery	**73%**	**38%**	**-48%**
WCVI	**Robertson Creek Hatchery**	**56%**	**35%**	**-37%**
Fraser Spring 4_2	**Nicola River**	**33%**	**18%**	**-44%**
Fraser Spring 5_2	***CTC Model Output***	***36%***	***26%***	***-28%***
Fraser Summer 5_2	***CTC Model Output***	***51%***	***35%***	***-31%***
Fraser Summer 4_1	**Lower Shuswap River**	**37%**	**42%**	**16%**
	Mid Shuswap	**n/a**	**46%**	**n/a**
Fraser Fall 4_1	**Harrison River**	**73%**	**24%**	**-67%**

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