Proceedings of an Expert's Workshop on Columbia River and Hydro-system Impacts on Migration Success and Production Variations of Anadromous Salmon, Dec. 6-7, Portland Oregon.

Richard Bussanich[1], Kim Hyatt[2] and Howie Wright[1] (eds)

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1. Okanagan Nation Alliance ,
   #101-3535 Old Okanagan Highway, Westbank, BC, V4T 3L7
2. Fisheries and Oceans Canada, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7

Preface:

The three party (Okanagan Nation Alliance, ONA; BC-Ministry of Energy and Mines, BC-MEM; and Fisheries and Oceans Canada, DFO) Okanagan salmon oversight committee (OSOC) has initiated work to develop performance measures (PMs) for Columbia basin salmon of Canadian origin. The intent of the parties is to further understand the implications of Canadian water storage and release procedures for migrating salmon once they leave the Okanagan basin as smolts and migrate into the main-stem of the Columbia River as juveniles and returning adults. The oversight committee has been involved in developing PMs for Okanagan Sockeye Salmon with further consideration for other salmon that return to the Okanagan to follow.

To date, this collaborative work has identified some limiting factors for juvenile Sockeye life histories for fish returning to the Okanagan. However, a consistent, focused study design and assessment of Okanagan Sockeye Salmon during river main-stem and ocean portions of their life histories is lacking. With that, there are uncertainties related to the development of the PMs. In addition, several initiatives have been developed in the U.S. to understand juvenile survival and adult returns of salmon through the Columbia River hydro-system. These are the Comparative Survival Study (CSS) employed by U.S. Columbia Basin tribes, states and federal agencies (Marmorek et al, 2011; McCann et al, 2017), the comparative passage (COMPASS) model by NOAA Fisheries (Zabel et al 2008) and the Upper Columbia United Tribes development of a life-history based spreadsheet model. Although these models have been principally used to identify migration and life history outcomes that apply to Chinook and Steelhead salmon, they may have utility for current to future work to assess impacts of hydrosystem operation on Okanagan Sockeye Salmon.

Given the observations above, the OSOC agreed to sponsor a workshop of experts to discuss and compare existing scientific methods to assess juvenile sockeye survivals and if possible, smolt-to-adult returns as a measure of overall sockeye productivity. This effort will promote verifying and improving PM materials developed by the oversight committee. It will also serve to help finalize short papers on the PMs developed by OSOC that will then help inform in a broader, synthesis paper that uses a full life-history approach to provide a more balanced perspective on the relative influence of variations in migration success on annual variations in production exhibited by the Okanagan Sockeye population.

During the fall of 2017, the ONA assumed a lead role in organizing and then serving as moderators (Howie Wright, Richard Bussanich) for an expert's workshop on Okanagan Sockeye Salmon riverine migration success and Columbia River hydrosystem interactions. The workshop was held in Portland Oregon on Dec. 6-7th, 2017 and was attended by 15 experts (Appendix 2) invited from Canada and the United States. The intent of the current report is to provide brief summaries of: Key questions to be addressed, presentations provided by experts to address some of these questions, discussions from the workshop and suggestions for next steps to be considered by the OSOC.

Key Questions to be Addressed in the Workshop

Several key questions were posed for potential resolution by workshop participants. These were:

1. What are the survival/mortality rates during juvenile outmigrations, during estuarine/ocean residence through adult return and across the life cycle (smolt- to -adult)?
2. Are survival rates during outmigration correlated with mortality rates in subsequent life stages?
3. Which environmental factors best account for variation in survival rates at each life stage?

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Workshop Objectives:

1. Review current decision tools of Columba River Fish Passage with technical experts,
2. Consult with technical experts on sub-model components and their integration within broader life-history models,
3. Develop a common understanding of the key relationships between flow and Okanagan Sockeye life-history outcomes in the Columbia Basin
4. Decide on next steps for refining studies and models of migration success in the Columbia River and associated production outcomes for Okanagan Sockeye. .

Workshop Agenda:

Day 1 – Wednesday, December 6th

9:00 **Howie Wright**, ONA, Welcome, introductions, and overview of workshop

9:05 Michael McArthur, Alf Leake, and **Guy Martel,** BC Hydro, Okanagan Sockeye Committee, Columbia River Flows and Okanagan Sockeye.

10:05 **Rishi Sharma**, NWFSC NOAA Fisheries, Okanagan Sockeye: Assessing Alternative Hydro Strategies for a More Comprehensive Rebuilding Plan.

10:40 Break

10:45 **Brandon Chockley**, Fish Passage Center, Overview of Sockeye Juvenile Survivals and Smolt-to-Adult Return Rates from the Comparative Survival Study

11:45 **Jeff Fryer**, CRITFC, Comparative Upstream Sockeye Salmon Survivals in Columbia Basin – Highlights of Accords Project presentations.

12:40 Lunch Break

13:05 **Rich Zabel**, NWFSC NOAA Fisheries, Modeling Effects of Alternative Hydro-System Operations on Juvenile and Adult Return Rates.

13:55 **Stephen Smith**, UCUT, Life Cycle Modeling for Anadromous Fish Reintroduction Upstream of Chief Joseph and Grand Coulee Dams.

14:40 **Kim Hyatt** and **Scott Akenhead**, Exploring Natural and Human-Induced Cumulative Impacts on Production Variations of Okanagan Sockeye: A Sequential Life-History Event and Modeling Approach.

Day 2 – Thursday, December 7th

8:30-12:00 Group Discussion (facilitated by Howie Wright/Richard Bussanich) Discuss possible analyses to refine functional relationships for flows and fish, assign priorities, and discuss appropriate ways to aggregate Sockeye performance measures across space and time for Okanagan Sockeye Modeling.

Day 1 (6 December)

Welcome Message, by **Howie Wright**,

Provided a brief overview of the Okanagan Nation working with Canadian agencies since 1990s on fish-water management in the Okanagan Basin. In lieu of direct involvement in Canada-U.S. discussions of issues specific to Okanagan Sockeye and Columbia River Treaty Renewal, a three-party Okanagan Sockeye Oversight Committee (OSOC) involving ONA (Howie Wright, Jay Johnson), BC Province (BC Hydro: Heather Matthewes, Alf Leak, Michael McArthur; Ministry of Enery and Mines, Kathy Eichenberger, Kevin Conlin), Fisheries and Oceans Canada (DFO: Kim Hyatt, Heather Wood, Kylene Ennis), has been involved in reviewing relevant Okanagan salmon issues since 2012. Deliverables from this committee to date include development of key, Sockeye, life-history, performance metrics by BC Hydro, an ONA review of the BC Hydro Performance Metrics (PMs), and ongoing development by DFO of life-history elements for a future integrated model, (Freshwater and Oceans Cumulative Impact Model, FOCIM) to explain the basis for historic and future Sockeye production variations. The request

to the experts convened in the current workshop was to identify data gaps and possible additional work that might be undertaken to improve the PMs and help the Okanagan Sockeye Oversight Committee better assess potential management opportunities to sustain Okanagan Sockeye in the future. The Okanagan Salmon Literature Review has been revised by BCH with the points discussed at the June 18/2015 Committee meeting.

Okanagan Sockeye Committee, Title: Columbia River Flows and Okanagan Sockeye. Presentation (**Presenter**): Michael McArthur, Alf Leake, and **Guy Martel,** BC Hydro,

Project boundaries were defined and included the area between the terminal spawning area in a Canadian portion of the Okanagan River (near Oliver, BC) downstream to Rock Island Dam, WA, USA. Sockeye biological performance measures were outlined, with a focus on smolt and adult migration timing, and temperatures. Univariate relationships for flow and water travel time, smolt survival and water travel time were summarized from surrogate species (Chinook and Steelhead). General overview of historical studies illustrated:

1. Columbia River flows have a limited but measureable influence on Sockeye smolt survival, i.e., greater discharge -> decreased travel time -> increased survival (R^2: 24),

2. Adult migration is delayed by high flows (R^2:0.25), and

3. Adult exposure to high temperatures (>21 ^{o} C, Okanagan River by 7 July) decreases successful migration to reach the terminal spawning area.

Sockeye smolt outmigration along with the overall viability of the Okanagan Sockeye Population need to be addressed plus a method of ranking uncertainty and noise, given recent events such as: the 2001 Drought (associated with low, in-river survival of smolts), 2010 Testalinden earthen-dam breach (associated with reduced Okanagan fry-to-smolt survival), 2014 Wanapum Dam structural failure (associated with fishway blockage and emergency remediation measures), the 2015 Drought and June-July record breaking Columbia main-stem, water temperatures (associated with >90% *en route* loss of Columbia River adult Sockeye during migration).

The Oversight Committee and BC Hydro analysis identified the following uncertainties and ranking of their relative importance in limiting Okanagan Sockeye production as warranting additional attention:

- Additional data regarding smolt survival upstream of Rock Island Dam and downstream of John Day,

- Smolt survival influence of fish passage and operational interactions (e.g. at John Day and reservoir),
- Total dissolved gas trauma (unknown),
- Descaling impacts on fish viability (associated with mortality),
- Predation (unknown),
- Influence of ocean conditions on smolt-to-adult survival variations (initial ocean-entry year survival),
- Other factors affecting adult return.

Next steps, use the current workshop to inform the development of an Okanagan Sockeye SAR metric, address uncertainties and information gaps.

Questions & Responses:

<Q1> (JH) Was disease considered as a factor specific to sockeye as they migrated through the system? Chuck Peven report suggested decaling an associated variable with disease (KH). Two issues with descaling are magnitude of immediate losses and then subsequent losses from disease, have not been investigated in a systematic way. This needs to be done. Anecdotal evidence from laboratory work with kokanee and sockeye suggests even minor scale losses and abrasion will often be followed by fungal and bacterial infections and mortality. Frequency and extent of regenerated scales on returning adults relative to frequency and extent of scale loss on seaward migrating smolts may suggest impact. Could be a Doctoral Theses. (JF) Descaling has been crudely monitored, evidence of >20% descaling suggests mortality within a week. (JH) (KH/RB) PBS-ONA completed an epidemiological study (Kyle Garver and Carl Ribble), reviewing 10year data series of adult sockeye returning to Okanagan, to assess health conditions of Okanagan sockeye, no indication that IHN prevalence in returning adults is associated with any mass mortalities in either adults or subsequent juveniles observed to date. Adult fish are clearly carriers but are not predictors of disease outbreaks. <Q> (RZ) Do we see injury from sea-lion predation on late migrant sockeye? Not a large enough sample to notice, more noticeable for Chinook.

<Q2> (KH) Question of descaling impact, needs to be framed for relevance to the Sockeye population i.e. it's not certain whether descaling is simply an issue for fish using bypass structures at dams or if descaling results represent the broader population of migrating fish (KH) Results could be confounded due to sampling method and bypass locations. Sampling fish between dams rather than just at bypass structures could be used to determine extent to which samples taken at bypass structures are representative (e.g. for descaling incidence, species, size etc…) of the smolt populations at large. Discussion of optional gear types followed: 1. RST or incline plane traps, if higher velocities permit/site characteristics, 2. Floating Fyke nets, 3. Purse seining (Review 1990s focus of TGP study using purse seining techniques, if data available). Sampling standardized gear in a couple of locations, as each dam is unique, but gear used to

collect fish would be standardized to avoid bias (e.g. species, size, condition, debris). <BC> FPC responsible for sampling at bypasses including traps in river (e.g. Salmon River) and issues collecting fish. Logistics can be complex for middle river sampling (especially during high flow years), a good idea but is it practical? For example, NOAA Lower Columbia PIT-Trawl low encounter rates <KH> Sampling on the main-stem, Fraser River (Mahoney et al, 2013) has proven techniques.

Action Item: Data improvement of standardized smolt survival index, re: descaling from bypass structures, Pilot representative sampling in mid-reservoir locations between a minimum of two dams, using standard gears, to assess impact of descaling of smolts, to assess project by project impacts.

Action Item: Howie to circulate Literature Review of the known published data relating to Okanagan sockeye life history and passage issues in the US portion of the Columbia River.

Action Item: Rich to circulate Epidemiology Report, Ribble, C, and T. Stitt. 2016. Okanagan River Sockeye Epidemiology Report. Prepared by Center for Coastal Health for Okanagan Nation Alliance and Fisheries and Oceans Canada, PBS. p 48.

Action Item: Kim to locate and circulate description of gear used for sampling smolts in the Fraser River mainstem.

Okanagan Sockeye: Assessing Alternative Hydro Strategies for a More Comprehensive Rebuilding Plan. Presented by Rishi Sharma, NWFSC NOAA Fisheries (Views expressed by presenter and not agency).

Overarching goal is to quantify or build relationships on survival using independent or multivariate analysis of flows across projects and external estimates of survival for some upper Columbia sockeye/chinook populations. Documenting this and some minimal spill requirements across dams/reservoirs will guide the constituents to their ultimate goal of how much should be spilled to optimize smolt survival during passage through the projects or reservoirs.

The implicit assumptions of an analysis examining water travel time, distance and its effects on survival are derived from the following logic:

a) Water flow and spill of dams influence travel time for fish moving through the Canadian and US Columbia River systems.

b) These in turn influence survival using a relationship indicating exponential decrease in survival as travel time increases (i.e. $Survival = \alpha * e^{-\beta * Travel\ time}$, where alpha is max

survival and decreases at the rate of beta over time, with some theoretical minimum survival through a project (between dams is the project).

c) Overall survival is a product across all projects through the entire Columbia River hydropower system.

Overall Conclusions from Review of McArthur and Leake (2015)

Based on the fairly simplistic analysis the following can be concluded:

- Interactions with other variables and travel time and distance are important and cannot be discounted.
- Hence the analysis presented for purposes of this project is overly simplistic and probably ignores key variables that are important to survival by project.
- Insufficient contrast and variability in both observations of the derived variable (survival) and predictor (independent) variables makes the results based on these data inconclusive.
- Increasing the power of this data and predictability should probably use Snake River sockeye populations (if data exist) and extrapolate to these populations.
- Effects of reservoir management in the Canadian and Grand Coulee complex could have significant impact of reducing Water Travel Time for the upper river populations and some model scenarios examining this and its effect on survival should be explored.

The key points that are determined from Sharma's review of the McArthur and Leake (2015) report are the following:

1) There is insufficient contrast in pit-tag data as of 2014 to come up with meaningful relationships between flow, spill and Sockeye survival during passage through the Columbia River. For example, some data suggest increased WTT association with increased survival (though that relationship is insignificant); the relationship is based on a questionable arc-sine transformation of observations, is most certainly spurious as increased WTT and survival should exhibit a negative association (Zabel et. al. 2008).

As suggested in Zabel et. al. (2008), the response model proposed should be:

$$-\ln(Sg,s)=(\alpha 0+\alpha 1Flow+\alpha 2Temp+\alpha 3Temp2+\alpha 4Spill)d+(\beta 0+\beta 1Flow+\beta 2Temp+\beta 3Temp2+\beta 4Spill)t+\varepsilon g,s \text{ (eq. 1)}$$

We realize the data requirements for Eq. 1 are not easily available, using multivariate data to examine this is important, and examination of interactions is also important.

One might supplement the current juvenile Sockeye dataset with observations from Snake River stocks to provide adequate contrast and use derived relationships in this case.

2) The data examined isolated spill effects on a reservoir/dam basis without adequate contrast in the data. Variations between individual dams show very low contrast in the survival (predicted) versus the response variable (CV~0.2).

3) A key point that may be missed from this entire analysis is the effect of storage and spill in Canadian Reservoirs on the movement of sockeye smolts for the Okanagan and upper Columbia locations. No data is presented here on that, and the evidence that spill affects survival indicates marginal if any effect, hence the conclusion drawn is that spill does not have a positive effect on survival, and can in some cases may negatively impact survival. I think this is extremely misleading and the data presented here are rather inconclusive given limited sample sizes and insufficient contrast.

4) As such, BC Hydro's Mica Dam (Kinbasket Reservoir), Keenleyside Dam (Arrow Lakes Reservoir) and the U.S. Grand Coulee Dam (Lake Roosevelt) on the Columbia River should hypothetically have a positive benefit if water were released from these reservoirs to reduce water travel time for sockeye smolts, and theoretically improve survival; contrary to the data presented here. Interactions with other variable such as temperature and flow are also missing from this analysis and need to be examined at some point.

A review of an Okanagan Chinook Population Viability Analysis (PVA) was outlined, as a first step towards establishing management scenarios, i.e. hydro system, hatchery program, and harvest strategy changes in relation to Sockeye survival, productivity, or capacity. PVA analysis could provide projections of the Sockeye population trajectory over time.

Questions & Responses:

(JH) We have run climate scenario's when modeling viability, anticipating a reduction in carrying capacity. Thus 'buffering' this risk, you would need to build a trend in the model to assess climate scenario's. (CB) Be careful if considering use Snake stock as a surrogate, given its' extremely weak stock status; <Q> (CB) is the existing data set a reflection of the reality of the hydro system in terms of lack of variability? (KH) the time series is short and the sample size low, thus sampling power low, a later presentation will show a larger range of catastrophic survival events that drive greater variability in Okanagan Sockeye survival and production.

Overview of Sockeye Juvenile Survivals and Smolt-to-Adult Return Rates from the Comparative Survival Study Presented **by Brandon Chockley**, Fish Passage Center.

The U.S. Comparative Survival Study (CSS) Oversight Committee contributed to the preparation of a retrospective synthesis of the methods and results to date on Sockeye in the

Columbia Basin. The study methods, results and conclusions are based on pit-tag, monitoring efforts since 1998 for the Snake River, and since 2013 for the Okanagan and Wenatchee stocks. The Passive Integrated Transponder (PIT) data used in the CSS are analyzed retrospectively, incorporating all juvenile and adult recovery data available for the period 1998 through 2015. The retrospective summary analyzed the available PIT-tag data within and across-years, assessing the effects of migration routes, environmental conditions and migration timing on survival rates of smolts in specific river-reaches and Smolt-to-Adult Return rates (SAR). These analyses improve our understanding of survival rates and the effects of various environmental conditions and management actions on those rates.

Synopsis:

- FPC generate survival estimates for all tag groups (of which Okanagan is an Indicator Stock), reviewed by agencies, comments considered in entirety, revisions generated, final report to BPA prior to November, each year. Data reported at this workshop will be in the final report for 2017.
- Juvenile sockeye survival data based PIT-detections at bypass structures for six groups of fish including: (1) Upper Columbia - Hatchery and Wild tagged at Rock Island Dam (1998-2017), (2) 'Wild" Osoyoos consisting of wild-origin Osoyoos plus some Skaha hatchery-origin fish (2013-2017), (3) Wild Wenatchee River Sockeye (2014-2017), and Snake River Groups comprised of: (4) Hatchery + Wild Snake River Sockeye (1998-2017), (5) Sawtooth Hatchery (2009-2015, discontinued) and (6) Springfield Hatchery (2015-2017). The latter is the principal source of hatchery-origin Sockeye in the Snake River system from which 50,000 juvenile sockeye are now tagged per year, on a continued basis.
- Hatchery and Wild Sockeye Tagged at RIS (1998-2017), exhibited survival-data anomalies in 2003 (inoperable bypass), and 2014 (Wanapum drawdown operation).
- Wild Okanagan (2013-2017) and Wild Wenatchee (2014-2017) juvenile survival from their respective release sites to McNary were similar for both populations (0.25-0.55)
- Juvenile Snake group survival observations reflected: shifts in production output from different hatcheries over the past few years, influences from water quality issues (TGBT, and issue with transportation trucks), water quality very alkaline (at Spingfield Hatchery). Water quality issues at Springfield required adaptive changes to program and resulted in no estimate for 2017. All future Snake estimates to be derived from Springfield group; survival from Lower Granite to McNary observed from 0.27 to 0.88. Plan for 2018 represents new release strategies; some reared at Sawtooth, acclimate at Sawtooth, direct releases, acclimated in trucks with water from various water sources. Analyses on in-river survival rates indicate that improvements of in-river survival can be achieved through management actions that reduce the water travel time or increase the average percent spilled for Snake River sockeye in the Lower Granite to McNary reach. The effectiveness of these actions varies over the migration season.

- Fish Travel Time Model: Lower fish-travel times were associated with faster water-travel times during juvenile migration and for the Rock Island group, fish travel-time was the most influential factor in survival (i.e. faster FTT, higher survival of juvenile sockeye).
- Daily Survival Model (DSM): proportion of spill was the most influential factor relative to instantaneous mortality versus water transit time or temperature.
- Taken together, results from the two models (FTT+DSM) account for 20% of the observed variability of in-river survival (R^2= 0.2).
- For Snake stocks, influence of their rearing facility was the most important variable in controlling subsequent survivals during smolt migration.
- Long time series of observations for Snake River juvenile Sockeye enabled examination of associations between environmental factors (seasonality, temperature, spill or pit/power house, surface passage structures and water transit time) with respect to fish travel time and mortality rates.
- Stronger relationship for *fish travel time* of Snake Sockeye (H&W; R^2 =0.64) to McNary compared to RIS Sockeye, among years (H&W; R^2=0.31).
- Stronger relationship for *instantaneous mortality* of Snake Sockeye (H&W; R^2 =0.43) to McNary compared to RIS Sockeye, among years (H&W; R^2=0.21).
- Stronger relationship for *in river survival* of Snake Sockeye (H&W; R^2 =0.64) to McNary compared to RIS Sockeye, among years (H&W; R^2=0.29).
- Overall SARs for RIS Wenatchee + Okanagan Sockeye (RIS-BOA, mean 2.37%) fell short of the Northwest Power and Conservation Council (NPCC) goal for SARs (i.e. 2% minimum, 4% average for recovery; 5 of 15 years).
- Overall SARs for Wenatchee Sockeye (McN-BOA, mean 1.9 %) fell short of the Northwest Power and Conservation Council SAR objectives for that population (i.e. 2% minimum, 4% average for recovery; 1 of 2 years).
- Overall SARs for Okanagan Sockeye (RRE-BOA, mean 3.8 %) roughly met the Northwest Power and Conservation Council SAR objectives (2% minimum, 4% average for recovery; 2 of 3 years).
- Average survival varied greatly between hatcheries-of-origin in the Snake River program where SARS averaged 0.6% for Sawtooth, and 2.5% for Oxbow.
- Upper Columbia RIS juvenile Sockeye appear to have higher SARs than Snake River sockeye.
- None of the 2015 Snake River PIT releases have been detected as returning adults to date.

Action: Increase PIT array stations for smolt program between Wells and terminal areas, to improve detection efficiency and reduce variance around survival estimates at mid-Columbia dams.

Questions & Responses:

<Q> RZ Do we know the standard errors on the juvenile survival estimates. (JC) Fish Passage Annual Reports would include specific estimates of these for various release groups.

(JH) In terms of contrast, 2001 was an extreme drought and low water year, for SE analysis. Low survival from Snake population that year.

(KH) In terms of "Okanagan Wild+Hatchery Aggregate" Skaha hatchery-origin fish have constituted no more than 10% of the aggregate of seaward migrating smolts.

<Q> (SS) Where were Okanagan PIT tags released? (JC) In Osoyoos and Skaha. (RB) A single year of capture, tag and release at Skaha, the remaining years, mixtures of hatchery-origin fish reared in Skaha Lake and wild-origin fish reared in Osoyoos lake were captured, tagged and released at Osoyoos Lake, (JC). The goal has been to pit-tag 5,000 fish per year, for decent SAR estimate.

(JC) This data presented today will be made available via FPC website end of December, 2017

(JC) Clarification for Upper Columbia smolt tagged prior to 2013, from Wenatchee would be nearly all hatchery origin, from 2013 onwards, the only hatchery component is Skaha tag group.

(JC) Clarification, we don't have a PIT power-house metric for Upper Columbia smolt passage, only the Snake. When the models for Snake were initially developed there as a metric for proportion of the smolt population influenced by average spill and surface spill but a metrics based simply on proportion spill was viewed as inadequate, which drove us to develop a PIT Powerhouse metric that interacts with spill to influence fish passage. i.e. more spill lowers the proportion of PIT passage through the powerhouse. It's a cumulative estimate of probabilities. We have not developed these metrics for each dam on the Upper Columbia. In the Upper Columbia case, we estimate the proportion of fish affected by spill that occurs when we 'think' the fish are at the structure.

<Q> (SA) What variables do you think we are missing, from viewing the residuals? Position of fish relative to sunlight? Densities of Predators? (JC) Steve Haeseker's FPC talks, often comment on which direction do we think the fish are facing? When moving downstream – for CH/ST tendency is to be facing upstream which means swimming upstream which could result in the passage delays we observe relative to model predictions. The Ho for sockeye, is that these fish are adapted for lakes, they may be different in swimming behaviour during passage through the reservoirs. Thus WTT didn't suggest as much variability for Sockeye, these fish may move through fast, facing downstream, active swimmers? (HW) Concurred that behavioral interactions need further investigation (e.g. Fraser River study (Chilko) underwater video

observations of 'milling' behaviour during smolt outmigration in response to lighting conditions).

Comparative Upstream Sockeye Salmon Survivals in Columbia Basin – Highlights of Accords Project. Presented by Jeff Fryer, CRITFC.

Empirical data for Columbia River adult sockeye was summarized for the development of hypotheses of what is limiting the survival of Okanagan and Wenatchee populations. Multi-year studies have involved monitoring the fish, the environment, and effects of actions that may be taken to improve the sockeye's environment and survival chances.

Synopsis:

- Historical context: In the 1990s the aggregate sockeye stock composition was 60% Okanagan, whereas today we observe 80% Okanagan; transition of harvest from the 1980s to current show a decrease in harvest rates from 39% to 24%, with an increase in allocation among First Nations (from 63 to 79%) in Canada, recreational fisheries (from 0% to 21%) in the U.S.and Canada, and a reduction of U.S. commercial catches (from 37% to < 1%) to facilitate protection and recovery of ESA listed, Redfish Lake Sockeye in Idaho.
- Improvements for stock monitoring include: continuous operation of a permanent PIT array (1 array in 2009) at Okanagan Channel (re-engineered, double array in 2017), upstream of Osoyoos Lake, testing systems at various dams (e.g. Zozel Dam, McIntyre Dam), and installation of permanent station (1 array 2017). Complementary testing of survival using Acoustic biotelemetry has been implemented to inform distribution and fate of adults, since 2009.
- With nearly ten years of PIT data (tagged at Bonneville), specific years from 2015 (2% to Okanagan vs 8% Wenatchee) and 2016 (28% to Okanagan vs 21% Wenatchee) provided contrast for adult survival and fate. Weekly survival of adult sockeye decreases sharply from Statistical Week 28 onwards.
- While 2015 was catastrophic for adult sockeye recruitment, evidence from 2012 migration study outlined 209,000 missing sockeye that could not be accounted for in terms of either final escapement or harvest. Records show that annual, losses (i.e. not accounted for as either catch or escapement) have ranged from 40% to 76%, among years.
- Outlined the unusual levels of straying of Okanagan PIT fish under the highly anomalous environmental conditions experienced in 2015 (i.e., Deschute River (n=3), Methow River (n=3), and Entiat River (n=1).

- Of the 24 acoustic tagged sockeye tracked to the cold water refugia at the junction of the Similkameen and Okanagan rivers in 2015, only 5 made it upstream to spawn. Results also indicated that the earliest migrating fish in 2015 experienced the best chances of surviving to reach the terminal spawning area near Oliver, BC.

Questions & Responses:

<Q> (CP) What do we know of pinniped impacts to sockeye? Do we see injuries for early or late runs? (JF) Chinook and Steelhead study, but unknown for Sockeye, would be interesting to take a closer look at sockeye injuries.

A relevant paper outlining methods is: G.P. Naughton, M.L. Keefer, T.S. Clabough, M.A. Jepson, S.R. Lee, C.A. Peery, and C.C. Caudill. 2011 Influence of pinniped-caused injuries on the survival of adult Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*) in the Columbia River basin. Can J. Aquat. Sci. (68): 1615-1624.

<Q> (SS) Is the Skaha population timing earlier? (JF) Skaha fish arrive somewhat earlier at Bonneville, but arrival at Wells appears to be a lot earlier. We are seeing a 'U'-shaped distribution, with much faster travel and earlier arrivals at Wells Dam. Note that both Skaha and Osoyoos lakes provide coldwater refugia for pre-spawning Sockeye but the quality of the refugium in Skaha Lake is superior to that in Osoyoos Lake where the latter becomes hypoxic from mid-depths to bottom in late summer In terms of historical observations, there is some evidence from early 1920's fish scale analysis to suggest an early May run may have returned to the Upper Columbia, plus Okanagan Nation elders speak of the existence of early vs late run timing groups of Sockeye.

Modeling Effects of Alternative Hydro-System Operations on Juvenile and Adult Return Rates. Presented **by Rich Zabel**, NWFSC NOAA Fisheries.

The Comprehensive Passage (COMPASS) Model was developed as a tool for investigating the passage experience of migrating juvenile salmon and steelhead under various environmental conditions and management scenarios (Zabel et al. 2008, COMPASS 2008). COMPASS was reviewed by the independent science advisory board (ISAB) in 2008 and has been used to inform a variety of management decisions concerning juvenile salmon since then using life-cycle modeling to build population viability metrics.

COMPASS contains physical descriptions of the Snake and Columbia Rivers and their main tributaries, which include spatial representations of widths, depths, and elevations to allow water volume and water velocity calculations. The hydroelectric dams in the system are also

represented and algorithms are used to route flow through the set of alternate passage routes unique to the configurations at each dam. This allows the impact of dam operations such as spill and surface collector operation on salmon smolts to be accounted for on daily or finer time steps.

Flow is input at the river headwaters or at the dams (geometry, water levels), either as measured observations or as predictions from hydrological models. Other possible environmental inputs include temperature, turbidity, and dissolved gas. COMPASS can also take spill proportions as inputs and can account for changes in surface weir volumes and operation schedules. Schedules and rates of smolt transportation on barges are also included, where warranted, as inputs for operation of collector dams.

COMPASS contains a set of biological models developed to determine: arrival timing at the head of the hydropower system, reservoir travel time, reservoir and dam survival, and dam passage routing for various species. These models were all fitted to observed data and are functions of the set of variables describing environmental conditions and dam operations that are available to COMPASS. When combined together, COMPASS sub-models allow predictions of the passage experience and survival consequences of smolt "releases" through the system to the Bonneville Dam tailrace. Predictions of timing distributions for smolt arrival at Bonneville Dam are subsequently used as inputs into models for smolt-to-adult returns (SAR).

Since the most recent documentation of COMPASS (Zabel et al. 2008; COMPASS 2008), there have been several updates to the sub-models and to the general functionality of the COMPASS model. The following is a brief list of changes:

- Updated the data used to calibrate the travel time and reservoir survival components of the model to the 1998-2015 interval.
- Updated the data for the dam passage routing models (spill efficiency and fish guidance efficiency) to the 1998-2013 interval. Also made changes to passage models to better account for observation uncertainty.
- Updated estimates of route-specific survival for dams on the Snake and lower Columbia Rivers. These estimates come from experiments on fish implanted with radio tags or acoustic tags.
- Changed the structure of the reservoir survival models. We use a hierarchical modeling format where random effects for unknown survival probabilities follow beta distributions, and the observed survival (Cormack-Jolly-Seber estimates) follow lognormal distributions, conditional on latent random survival effects. This structure allows a more accurate decomposition of the uncertainty.
- Added component to the reservoir survival models that allows predator density and smolt density to affect survival through a functional response.
- Updated models that predict dissolved gas supersaturation based on flow, spill, and temperature.

- Added models for passage at dams on the Upper Columbia River. These include route specific survival and functions for passage route probabilities. There are also have travel time and survival models for fish originating in the Upper Columbia.
- More time steps have been added to the reservoir passage model (up to 16 per day) to allow more accurate travel time calculations.

Eight management scenarios were presented for Upper Columbia Chinook and Upper Columbia Steelhead for Columbia River Treaty. The life-cycle modeling (LCM) is part of a proposed adaptive management strategy for evaluating alternative salmonid recovery actions in the Columbia River Basin. The LCM report builds on previous reports, which were reviewed most recently by the ISAB in 2013 (ISAB 2013-5). The latter report describes ongoing efforts to model the numerous factors affecting salmon and steelhead in the Columbia River Basin. Life-cycle modeling remains a significant challenge because of the complexity of the wide-ranging life histories of these fish and the many locations where fish are affected by human activities and the changing environment.

The Bonneville Power Administration (BPA) generated the scenarios using their hydrological model, HYDSIM. Most of the managed flow comes from Canada, very little from US. The big question is amount of spill. This model accurately accounts for power generation and spill and associated hydrology in the hydropower system and outputs daily predictions of flow, spill, and reservoir elevation associated with each dam. This was done for a data set of 80 water years representing headwater inputs for the years 1929-2008. These water inputs are applied to the operation rules determined by each scenario in HYDSIM. We used the daily flow, spill, and reservoir elevation values predicted by the HYDSIM model for the 80 water years for each scenario as inputs to COMPASS.

We constructed average population arrival distributions at Lower Granite Dam for the combined population of each species at large (combined hatchery and wild, tagged and untagged) based on historical data. We used relationships from regression models of median arrival date on median April-June flow to shift the average population distribution in response to predicted flows. This allowed arrival timing at Lower Granite Dam to vary with water year as a function of flow. These predicted population distributions were used as smolt release profiles in COMPASS, where each water year had the same number of fish released.

We ran the COMPASS model for each of the 80 water years for each scenario. We produced separate results for Snake River, spring-summer Chinook and steelhead. We collected several summary measures of passage experience for each year, including in-river survival from Lower Granite Dam to Bonneville Dam, proportion of fish transported, average travel time between Lower Granite Dam and Bonneville Dam, and SAR for combined transported and in-river migrants.

The results from the management scenarios show that the scenarios with increased spill had small effects on in-river survival. The increased spill resulted in shorter predicted travel times and smaller predicted proportions of fish transported. Faster travel times will get fish to the estuary sooner. There is an optimal time window for arrival at the estuary, with too early or late arrivals resulting in lower SAR's! The SAR relationships differ for transported and in-river fish, so the amount and timing of transportation will affect overall combined SAR's.

Model improvements continue to predict the effects of alternative operations of Snake and Columbia River dams on salmon survival rates, expressed both within the hydrosystem and as latent effects which may occur outside the hydrosystem. Accordingly, the model has the following capabilities: 1) realistically simulate survival and travel time through the hydrosystem under variable river conditions; 2) produce results in agreement with available data, particularly PIT-tag data; 3) allow users to simulate the effects of alternative management actions; 4) operate on sub-seasonal time steps; 5) produce an estimate of uncertainty associated with model results; 6) estimate hydrosystem-related effects that may occur outside of the hydrosystem. (http://www.cbr.washington.edu/analysis/compass)

Synopsis of COMPASS Model Results to Date:

- Evidence suggests later arriving juveniles to Bonneville show a decreasing trend of return rate as adults,
- Upper Columbia (UC) survivals show 'weak' relationship with spill relationships, not as responsive to spill as the Lower Columbia stocks (Snake),
- UC temperature stronger relationship evident,
- UC-FTT decreases with increasing flows, relationship evident,
- While in-river survival relationship is 'weak', there is a strong relationship with SARs and flows, as a consequence of arrival timing distributions,
- Biggest benefit from flow, with earlier run timing, getting past BON by a certain date. System-wide need to get them past Bonneville to see the best results,
- 4%-10% improvement in SAR response from various CRT scenarios run to date. E1 Scenarios is a Salmon Naturalized flows,
- Proposition of a block design, are there a post-Bonneville benefits to increased Spill, increase spill vs current spill block design to minimize yearly variability.
- Increased spill, during drought, low water years, shows a noticeably higher response in SAR. (E5 scenario), with similar results exhibited by both Chinook and Steelhead.
- In-river fish survive better than transported fish, but trade-off gains from % population from transport relatively better later in the season. So, transport doesn't start until May 1st, where benefits appear to be: Steelhead highest, then Chinook, and jury still out for sockeye.

- Plan to run future climate change scenarios, to show stream temperature and survival interaction impacts on SARs.

Action Item: Next iteration of models will provide greater coherence and integration among the modeling efforts, so that they may begin to address key questions for Columbia River Sockeye populations, discussions to date include a Snake River Sockeye Compass Model.

Questions & Responses:

<Q> (KH) Can we do runs of the model to test impacts of a pre-hydrosystem, free-flowing river on earlier, sea-entry timing and associated SARs? Yes, developed for a dam breach scenario. <Q> If we enable sea-entry five weeks earlier, do we have empirical data? No, this gets into the overall trade-off if we transport too early fish are not physiologically/size ready to show better smolt condition, thus mortality.

(RZ) 2001 spill result observations have not been used in the models because hydrosytem operators would never repeat the decisions made in 2001 which were associated with very loss molt survival, i.e. not relevant to the current time series. 2005 first BiOp for spill rules. (BH) 2001 the electrical market was an anomaly in terms of Canada selling electricity. (JC) 2005 was mostly no spill year, and 2007 was shaping up to a no spill year, but the technical advisory team intervened given discussions with ISAB.

(SS) When we get these drought years, we need to think about flow and spill so that Bonneville doesn't need to declare emergency status.

<Q> (CB) Does sufficient data onsmolt travel times and survival at McNary to really do a COMPASS model version for Sockeye? (RZ) To do a full model, probably not, but we could use surrogates, or build a simpler version of the COMPASS model, i.e. alter passage route (use Spring Chinook). We could do some sort of model – based on the management questions asked. (JC) Current PIT observations on Sockeye are limited for estimating probability distributions. (RZ) McNary to Bon observations continue to be low from Trawl sampling in the Columbia estuary to obtain pit-tagged smolts. Results have broad confidence intervals for Chinook and Steelhead and sockeye would be even worse. In addition, sockeye survival is based on growth and foraging principally on zooplankton at lower trophic levels than Chinook or Steelhead, and survivals may tend to be more regionally focussed than in the case of Steelhead or Chinook i.e., Sockeye relationship to PDO variations may be different.

<Q> (CP) Was there one dam that had a greater impact of delay than others? And comments on Predation levels? (RZ) No, with respect to dams. Bird predation is captured in the COMPASS

model, in 2001 Steelhead, huge bird predation mostly PIT tagged, we do have bird management scenarios in specific reaches (i.e. Icicle).

Life Cycle Modeling for Anadromous Fish Reintroduction Upstream of Chief Joseph and Grand Coulee Dams. Presented by Stephen Smith, UCUT.

The tribal agencies are interested in improving their understanding of existing life cycle models and obtaining recommendations on how to proceed with model development for anadromous salmon reintroduction upstream of Chief Joseph and Grand Coulee dams (+ Canadian Dams). Management controls for Anadromous Fish Reintroduction Upstream of Chief Joseph and Grand Coulee salmon can be grouped into four broad categories: (1) improving production; (2) improving downstream passage of smolts; (3) reducing harvest; and (4) improving upstream passage of returning adults. Current modeling efforts to analyze recovery strategies include Expert Opinion and meta-data analysis from Columbia River Biological Opinion papers, plus information gained from recent monitoring programs at high head dams throughout the Pacific Northwest.

Synopsis:

- Phase 1 Reintroduction – US habitat assessment, donor stock assessment, re-introduction risk assessment, review of high head dam fish passage facilities, and life-cycle modeling for distribution to tribal and indigenous-fisheries management agencies in early 2018.
- Simple, Life-cycle modeling to inform Columbia River Treaty discussions, potential salmon translocations and reconnaissance-level program.
- Early base-line model development by DJWA, and parameterization nearly completed for Summer Chinook (Chief Joe Scenario; exclude 10J Spring Chinook listed). Future intent is to include Sockeye, to baselines, as follows (Chief Joe, only, Chief Joe and Grand Coulee, US plus Arrow, Brilliant, and Waneta, US and Brilliant only, and US and Arrow only.
- Scenario variants: with and without passage facilities (juveniles), at various levels of artificial propagation.
- Sensitivity Analysis will contribute to evaluation of reintroduction and translocation options and strategies, to identify key uncertainties; research and facility needs, and provide data to move program forward in Phase 2.
- Consulting firm DJWA has developed a simple spreadsheet model that encompasses all of the major life history stages of summer run chinook salmon to refine assumptions and define an overall solution for prioritization of key facilities to facilitate anadromous salmon reintroductions above Chief Joseph Dam (e.g. initial model runs use 1000 adult fish from capture below Chief Joe, for outplant above Chief Joe to create various outputs).

Questions & Responses:

<Q> (GM) What consideration was provided for resident species which could include bass and kokanee, how were interactions and impacts of these resident fish taken into account? (SS) Survival estimate parameters are adjusted as model inputs to reflect potential interactions, but this has been "flagged" as one of the key uncertainties for initial fry-to-smolt output. We are researching based on empirical results from other programs, and this may be an important piece of future research. Until we introduce fish into these new environments, we won't know the interaction with the fish community.

(SS) Trials involving translocating adults above Grand Coulee in the short term will inform future research (i.e., 1000 adults). To create natural product would be of interest.

<Q> (JH) Will the paper documenting DJWA model results be peer reviewed? (SS) When it is submitted to the Northwest Power and Conservation Council, a decision will be made, but it is not a complex model, as rich observational data doesn't exist, but the intent is to learn through design and doing.

<Q> (JH) Where is the data input derived from? (SS) Data from CSS and NOAA output estimates with a reasonable range of driving parameter values.

<Q> (JH) Is climate change considered in the model? (SS) The climate modeling that others are generating can be inserted into the survival parameter values used to drive the model. (KH) the benefit is the transparency and simplicity of this model tool, compared to COMPASS.

Exploring Natural and Human-Induced Cumulative Impacts on Production Variations of Okanagan Sockeye: A Sequential Life-History Event and Modeling Approach. Presented by **Kim Hyatt** and **Scott Akenhead**, Fisheries and Oceans Canada, Pacific Biological Station.

Synopsis:

- Our objectives include: (1) identification of historic trends and current state of Okanagan sockeye salmon, (2) describing a sequential freshwater-to-ocean, life-history approach to assess natural & human impacts on Ok-sockeye, (3) providing comments on lessons learned to date from our research on cumulative impact effects (e.g. role of density-dependent vs density-independent drivers) and (4) defining an integrated assessment approach to determine cumulative-impact interactions & outcomes for Okanagan Sockeye interactions with natural and human-induced drivers.

- Okanagan Sockeye return trends 1969-2005 exhibit high variability followed by a roughly 7-fold increase in adult returns between 2008 and 2017; Pre-season forecasts of Columbia Sockeye return variations based largely on sibling models are useful to managers, but don't imply we understand the underlying processes controlling return variations exhibited by this population. Historical trends show huge interannual return variations which raise questions about factors controlling Sockeye production. Multiscale assessments (geographical and temporal) are critical to refining our understanding of the origins of these large production variations,
- Fish Water Model Tool (Hyatt et al, 2015) sub-models identify both density independent and density dependent mechanisms that drive production variations for Okanagan Sockeye from the egg-to-smolt stage in freshwater. The FWMT model is a coupled set of four biophysical sub-models of key relationships (among climate/hydrology, fish, water and property) that interact with a fifth water management "rules" sub-model used to predict the consequences of water management decisions for fish and other water users. based on
- Review of historic data that drive FWMT outputs indicate that most Okanagan Sockeye production is likely to be lost during years of either extreme flood (e.g. 1997) or drought (e.g. 1930). Naturally occurring events that drive density-independent Sockeye losses as extreme as these are roughly a 1 in 70-year occurrence.
- Human-induced, density-independent losses also occur. For example, in 2010 an earthen dam failure on a tributary of the Okanagan River (Testalinden Creek) appears to have suppressed Osoyoos Sockeye smolt production below expected outputs for 3-5 years.
- Fisheries management decisions also result in significant density-dependent impacts on Okanagan Sockeye production. For example reductions in harvest and subsequent increases in terminal area spawner abundance have been associated a roughly 5-fold increase in Sockeye smolts and associated adult production within the most recent decade.
- Our modeling work indicates that when taken together, interactions among density-dependent and density-independent mechanisms may increase or reduce production dramatically within intervals of less than a decade due to cumulative impact interactions.
- We are interested in extending our work to model freshwater and ocean cumulative impact analysis to include Columbia River smolt migration effects and smolt-to-adult ocean effects.

  We are currently investigating whether uncalibrated, historic Sockeye smolt passage data obtained at various dams can be calibrated based on independent annual abundance estimates of Okanagan smolt production from acoustic and trawl surveys in addition to the use of newly developed PIT data on passage rates and success from one dam to the next.
- These data are being used to build a fish-and-water transit time model based on individual PIT data (using a daily time step, from one dam to next dam, using advection principles). Model processes are documented in R, and we see significant opportunities for productive collaborations with US (e.g. to account for observed 'anomalies' in data

series e.g. appearance of count saturation in annual smolt abundance values at John Day); to document protocols of hydrosystem operations at various dams). This model of fish transit is similar to elements within COMPASS but run within a Bayesian hierarchical model framework.

- We have demonstrated in previous work (Hyatt and Luedke 1999) that a two state ocean model for smolt survival at the time of sea entry (i.e. "warm ocean" = below-average survival; "cold ocean"= above-average survival), is sufficient to forecast production surges and collapses of Barkley Sound Sockeye on the southwest coast of Vancouver Island. The utility of using this model to forecast returns has been verified repeatedly during the past two decades (Hyatt et al. 2016). Both Okanagan and Barkley Sockeye smolts make sea entry into the northern California Current system and both exhibit similar production surges in La Nina years, and production crashes in El Nino years and the basis for these is now sufficiently well understood to inform smolt-to-adult production outcomes in a future cumulative life-history event model.

Questions & Responses:

<Q> (SS) Are low egg-to-fry survivals (i.e. mean of 4%) typical of Sockeye populations? (KH)Yes. Eight systems with more than 30 years of data are the basis for a biostandard, of eggs-to-smolts of ~ 4%, (minimum 0.1%, maximum 21%), for river and lake populations.

<Q> (JH) When did flood occur? (KH) typically in May-June driven by the meltwater freshet. During the 1997 record, snow-pack summer flows ran at 30-40 cms right into the fall. The most recent Okanagan flood occurred with rain-on-snow events in late spring 2017. Analysis is ongoing to review egg-set response to this the coming spring.

<Q> (BH) How can we improve forecasting of FWMT? (BH) NOAA looking at atmospheric rivers to improve forecasting methods.

(JF) recent PIT tag information showed that May 15th run timing date to separate Wenatchee vs Osoyoos smolts did not apply (i.e. usually the latter migrate after Wenatchee but separation has been poor in some recent years), plus different migration rates, and survival rates.

(RZ) We are working on models to assess correlations between freshwater and marine survival variations, one life stage to the next. This is the next evolution of our modeling.

<Q> RS Can you predict when there is a phase shift? (KH) To some extent, as ENSO events (i.e. La Ninas or El Ninos) develop two to three years before a surge or decline in adult stock production which allows some adaptive responses by managers. (RS) We need to use foresight to learn from how the system works.

End of Day Dialogue Guidance for Day 2 program:

Developing a version of the COMPASS model for Okanagan Sockeye and testing its' utility through closer collaboration among interested "parties.

Rishi Sharma notes there is sufficient data, to populate a PVA model, parameterize the UCUT model, and build some form of COMPASS model

Day 2 Discussion

Kim's Comments:

1. Options to continue with: Sockeye Compass Model, UCUT Model built for communication/purpose, parameterize model with OK sockeye data (reconstructed + current data; 30+ years)
2. Encourage partnerships US-CAN, parameters from Ok-FWMT/Skaha Experiment could be shared with the Upper Columbia United Tribes (UCUT) ad hoc modelling group.

3. Provides a reminder that results from Skaha Experimental Program of Sockeye reintroduction represents empirical results to inform future Salmon reintroduction program(s) in upper portions of the Columbia basin. There are also results from Sockeye salmon introductions into several Ak-BC lakes (e.g. 25 plus initiative sponsored by the Pacific Salmon Commission for introducing hatchery-origin Sockeye fry into Tuya, Tahltan and Tatsamenie lakes (Hyatt, K. D., K. Mathias, D. P. Rankin, D. McQueen, B. Mercer and P. Milligan. 2005. Evaluation of hatchery versus wild sockeye salmon fry growth and survival in two British Columbia lakes. N.Am.J.Fish.Mgt. 25: 745-762).

Rishi Comments:

1. Develop a simple Population Viability analysis approach, then fine tune management to, improve Stage Survival?
2. Potential exists to develop a Sockeye version of the Compass Model as suggested earlier by Rich Zabel.
3. Reflected on two escapement goals – interim management goal at PR.
4. Where does CRT fit into all this? KH: Canada's current position is to move towards assessing potential impacts of CRT either historically or in future on existing Columbia basin salmon stocks of Canadian origin. By contrast, Canada and DFO do not have a clear position regarding the execution of work to re-establish extirpated salmon stocks in the upper Columbia. Currently an ordering of priorities.

Howie Comments:

1. Concur with the advice to partition FW and Marine survival effects and with integration of Compass for running and informing CRT scenarios. There would be value in further development of integrated Sockeye salmon performance metrics to inform future CRT discussions. To do so would require establishing an experts sub-group from both Canada and the U.S (agency, tribal and First Nations participants) to share data and build performance measure models.
2. There would be value in increasing sampling plan coordination between US-Canada entities to improve transboundary salmon stock assessment and management;
3. The suggestion of designing sampling programs between some dams to obtain juvenile salmon that may be more representative of populations of migrants has merit;

Rich Comments

1. Day was productive to see data; 2015 a good learning year.
2. Caution to discuss model vs model one better than the other.

Steve S Comments

1. Take advantage of lake rearing habitats and future reintroduction opportunities, rather than focus solely on existing Okanagan Sockeye.
2. Can we look at harvest management to encourage better escapement?
3. Within the context of CRT renewal develop a focus on big storage to offset drought years that are especially problematic for juvenile salmon losses; avoid any arrangements that would make matters in drought years in particular?

Jeff F Comments

1. There is a need to identify options that might be implemented to avoid the catastrophic losses of adult Sockeye salmon that accompanied anomalous environmental conditions in the Columbia River in the summer of 2015.

Guy M.

1. Data gaps? Optimal physiological conditions were a key question that came out of today's talk; clearly there's a need to refine our knowledge of swimming behaviour by juvenile salmon migrating within variable flow conditions in the Columbia River?

Bob Heinith

1. Better forecasting of salmon returns, environmental conditions and coordination of both fish and water management between US and Canada are all desirable;

2. Gap – trying to create a peaking hydrograph? What is this flow going to assist? Uncertainties? Interactions re: productivity response, ..missing food web in reservoirs.

Keith Kutchins

1. Install an Upper Columbia PIT array because increasing number of PIT arrays will improve statistical reliability (e.g. lower SE) on juvenile salmon survival estimates.
2. Reminder of points made during Brandon's discussion.

Christine /Jeff F

1. Synthesis of Active Radio/Acoustic Tag studies, comparing sockeye to steelhead.
2. Improve detection at Zozel.

Cedar Morton

1. It will be important to consider the impacts of future introductions of salmon into freshwater lake and river ecosystems from which they have been absent for the better part of almost 90 years – there are many management implications associated with impact of introductions of salmon on resident fish, other species, and other services.
2. Questions will arise as to what are the trade-offs, where or when will they occur, and who will be impacted.

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Appendix 1: Attendees

Attended Wed Dec 6	Attended Thur Dec 7	Name	Agency	Contact Info
X		Bob Heinith	CRITFC	bheinith@comcast.net
X	X	Brandon Chokley	FPC	bchockley@fpc.org
X	X	Casey Baldwin	CCT	Casey.Baldwin@colvilletribes.com
X	X	Cedar Morton	ESSA	cmorton@essa.com
X	X	Christine Petersen	BPA	chpetersen@bpa.gov
X	X	Conor Giogi	Spokane	conor.giorgi@SpokaneTribe.com
X	X	Guy Martel	BC Hydro	Guy.Martel@bchydro.com
X	X	Howie Wright	ONA	HWright@syilx.org
X	X	Jeff Fryer	CRITFC	fryj@critfc.org
X		Jim Heffernan	CRITFC	hefj@critfc.org
X	X	Keith Kutchins	UCUT	keith@ucut-nsn.org
X	X	Kevin Conlin	Rapporteur for BC (MEM)	'Kevin Conlin' <kevinrconlin@gmail.com>
X	X	Kim Hyatt	Fisheries and Oceans Canada	Kim.Hyatt@dfo-mpo.gc.ca
X		Rich Zabel	NFSC-NOAA	rich.zabel@noaa.gov
X	X	Richard Bussanich	ONA	rbussanich@syilx.org
X	X	Rishi Sharma	NOAA	rishi.sharma@noaa.gov
X	X	Scott Akenhead	Fisheries and Oceans Canada	Scott@s4s.com
X	X	Steve Smith	UCUT	huntersmith@canby.com>