SALISH SEA
MARINE SURVIVAL PROJECT

United States – Canada Science Retreat Report

2014

December 2-3, 2014
Lakeway Inn & Convention Center, Bellingham, WA

Attendees

United States

Alan Chapman (Lummi Nation)
Evelyn Brown (Lummi Nation)
Jed Moore (Nisqually Indian Tribes)
Barry Berejikian (NOAA)
Brian Beckman (NOAA)
Chris Harvey (NOAA)
Correigh Greene (NOAA)
Josh Chamberlin (NOAA)
Lyndal Johnson (NOAA)
Megan Moore (NOAA)
Mike Crewson (Tulalip Tribes)
Paul Hershberger (USGS)
Dave Beauchamp (UW/USGS)
Julie Keister (UW)
Madi Gamble (UW)
Wendi Ruef (UW)
Erik Neatherlin (WDFW)
Joe Anderson (WDFW)
Ken Warheit (WDFW)
Lance Campbell (WDFW)
Mara Zimmerman (WDFW)
Neala Kendall (WDFW)
Sandie O’Neill (WDFW)
Iris Kemp (LLTK)
Michael Schmidt (LLTK)

Canada

Kevin Pellet (BCCF)
Chrys Neville (DFO)
Dick Beamish (ret. DFO)
Ian Perry (DFO)
Jim Irvine (DFO)
Karia Kaukinen (DFO)
Marc Trudel (DFO)
Mel Sheng (DFO)
Robie MacDonald (DFO)
Sophie Johannessen (DFO)
Svein Vagle (DFO)
Terry Curran (ret. DFO)
Dave Priekshot (Independent)
Andrew Trites (UBC)
Austen Thomas (UBC)
Carl Walters (ret. UBC)
Nathan Furey (UBC)
Francis Juanes (UVic)
Ken Denman (UVic)
Peter Ross (Vancouver Aquarium)
Isobel Pearsall (PSF)

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Summary

U.S. and Canadian scientists convened for their second Salish Sea Marine Survival Project Retreat in December 2014. The objectives of the meeting were to:

1. Present and discuss the status of current research, implementation issues, lessons learned, and preliminary results and implications from 2014 research studies and sampling programs
2. Continue to work on research alignment between US (Puget Sound) and Canada (Strait of Georgia)
3. Discuss critical concerns about/gaps in the Project as a whole
4. Propose next steps, including ways to improve the Project: the science and the collaboration

Report of Initial Findings

Participating scientists presented on the status, implementation issues, lessons learned and preliminary results of over 20 distinct research activities associated with the Salish Sea Marine Survival Project. Most of the presentations focused on how approaches can be improved since the research is predominantly in progress. See the notes in body of this report for details. The early findings that were reported on are listed below:

Survival Trends

- A detailed Salish Sea-wide coho smolt-to-adult (marine) survival analysis confirms the more pronounced decline and limited recovery of marine survival in the Salish Sea vs Washington-British Columbia coast and lower Columbia River, and includes substantial within Salish Sea-basin variation in survival (years and basins) that may help elucidate the survival drivers. Detailed Chinook and steelhead marine survival analyses are underway. All will be correlated with ecosystem characteristics to help elucidate the drivers of salmon survival.

- An updated Strait of Georgia coho early marine survival index suggests a recent increase in coho outmigrant survival in years 2012 and 2013.

Outmigrant Behavior and Growth

- Cowichan Chinook outmigrant behavior (predominantly daytime outmigration), growth (.61mm/day) and size (67.5mm) was described. A review of current vs old (1976) data show that outmigrant size and timing offshore was similar, suggesting these aspects of the fish themselves have not changed since the period of higher survival.

Bottom-up Effects: Prey availability, changes to primary production and harmful algae

- Juvenile salmon, zooplankton, and physical data collection in Cowichan Bay all indicate incidents of algae blooms (*e.g., Noctiluca, Pseudo-nitzschia, Skeletonema*) that may be having negative effects directly on salmon or their prey and/or may be indicative of water quality issues affecting the abundance of key prey for salmon. Juvenile salmon were lethargic and had greater proportions of empty stomachs during *Pseudo-nitzschia* and S*keletonema* blooms; large, potentially harmful algal blooms were recorded in the oceanographic information; and *Noctiluca* blooms, while varying in intensity, were dominant during periods of late April through June as recorded in the zooplankton sampling.

- An assessment of qualitative (presence/absence) zooplankton data from Cherry Point, focused on years 1975-1988, included a large increase in ctenophores (comb jellies), a large decrease in barnacle cyprids (larvae), an increase in siphonophores, and decreases in crab megalopae and pelagic fish eggs. Although qualitative, this is a signal of a bottom-up shift in the food web over the time when salmon marine survival began declining in the Salish Sea.

Narrowing the field of what's driving juvenile steelhead mortality

- A reciprocal transplant study using acoustic telemetry, with Nisqually and Green River wild steelhead, illustrated that mortality is primarily a function of the lower river and marine migration pathway and distance traveled through Puget Sound, and not a result of source population or river (above the release location at river kilometer 19) condition. Mortality was highest from river mouth to the Admiralty Inlet acoustic receiver line (through South and Central Puget Sound) and much less in river and in the Strait of Juan de Fuca. Results of the study also show atypical behavior indicative of harbor seal (predator) movement.

Top-down effects: Predators, disease and contamination

- Predation has been identified as the most likely driver of direct juvenile steelhead mortality in Puget Sound; however, until now it hasn't been clear who the culprit is or whether or not increased predator abundance and targeting of steelhead is fundamentally why steelhead have declined (or whether fish or environmental conditions are ultimately a greater contributor to predation-based mortality). A literature review performed suggested that harbor seals and cormorants are the most likely culprits. An acoustic telemetry study of encounter rates between seals and steelhead illustrate a large number of encounters (e.g., 58% of the tagged Nisqually steelhead that made it to Central Puget Sound were detected by seals). None of the detections suggested a direct mortality by any of the harbor seals outfitted with receivers. However, the locations of several stationary tag detections, at or around harbor seal haul outs, suggest these tagged steelhead were eaten by seals and the tags deposited there. The encounter and tag deposition data are being used to establish estimates of seal predation rates on steelhead.

- Preliminary results from Cowichan harbor seal predation model estimates of consumption indicate that in 2012, 84,000 juvenile Chinook were eaten and 600 adult Chinookwere eaten. In 2013, 120,000 juvenile Chinook were eaten and 300 adults were eaten. To put these numbers in perspective, they would represent 8-14% and 25-87% of the juvenile hatchery releases for Cowichan and 20-25% and 3-9% of adult escapement for each respective year (however, this is just a representation as there are wild Chinook also entering the system, and Chinook from other watersheds, all that are being consumed by these seals).

- PSF completed testing of a new "seal beanie" Radio-frequency identification (RFID) reader that attaches to the head of seals and counts the number of RFID (aka. PIT) tagged juvenile fish the seal consumes. This invention will be implemented in a 2015 study of coho predation by harbor seals in the Strait of Georgia.

- An assessment of *Nanophyetus* in Puget Sound steelhead outmigrants indicates substantial parasite burdens in Green and Nisqually River populations, with the Nisqually population having higher burdens. Additional work is needed to determine the intensity of early-stage infection in the lower river and/or within two weeks of entering marine environment, since the early stages of the infection are when the steelhead are most vulnerable to either direct mortality, or indirectly by the disease affecting swimming performance and potentially predator avoidance. However, no *Nanophyetus* was found in Northern Puget Sound steelhead populations, and those populations also suffer from high early marine mortality (Snohomish and Skagit Rivers). Furthemore, *Nanophyetus* has been present at high intensities in South Puget Sound for some time, and it's not apparent that the parasite burdens have increased in correlation with declines in steelhead survival. Past literature is being investigated.

- A study of outmigrating Chinook and steelhead in Puget Sound suggest contaminants could be contributing to lower marine survival of populations from certain watersheds. Steelhead contaminant loads were generally below adverse effects thresholds, with the exception of PBDEs in steelhead captured in the lower river/estuary area of the Nisqually. Of greatest concern were levels of PBDEs in outmigrating Chinook in the lower Snohomish (high enough to alter thyroid production), and levels of PAHs, PCBs and PBDEs (above adverse effects thresholds to varying degrees) in the Green, Puyallup and Snohomish populations.

US-Canada Alignment

Scientist working together across the border or separately but on the same topic convened to discuss their approaches and progress, and discuss next steps in research. Per the alignment structure, the Project works toward aligning the Trend Analyses and Modeling, Bottom-up Sampling, and Data management and sharing while leaving individual bottom-up studies and top-down studies independent with cross-talk and collaboration occurring where it makes sense to do so.

Trend Analyses and Modeling

Survival Trends and Beyond – The US-Canada Coho Task Team completed their analysis of survival trends for hatchery and wild coho (manuscript in review). They will continue to progress down two avenues of investigation: 1) using Ricker midwater trawl data to understand early marine survival and behavioral differences during the early marine period in Puget Sound versus the Strait of Georgia, and 2) relating coho survival trends to ecosystem indicators. Steelhead survival trends have been analyzed for Puget Sound, and a US-Canadian Chinook Task Team has been established and is completing their analysis of hatchery survival trends.

Ecosystem Indicators/Data Catalog – Conference calls were held over the fall to establish a suite of common indicators for the entire Salish Sea. Hypotheses from both sides of the border were also compiled. These were presented and discussed at the meeting. Several additions and modifications were recommended and are listed in the Ecosystem Indicators/Data Catalog section in the body of this report. NOAA Fisheries is working to staff this effort, dependent upon pending funding. If funded, the data will be compiled and compared to the coho, Chinook and steelhead survival datasets. LLTK and PSF will continue to support aggregating data across the Salish Sea and facilitating the continued evolution of this work.

End-to-End Modeling Alignment - End-to-end modeling (ecosystem modeling, from physical characteristics through the biotic trophic levels) alignment is focused on concurrence around key information gaps/needs and associated output. Better establishing the NPZ (nutrient-phytoplankton-zooplankton) and bio-energetics for salmon feeding and growth are top priorities throughout the Salish Sea. Establishing ecosystem models is occurring in a slightly different fashion on both sides of the border. The Canadians are currently merging two existing models for the Strait of Georgia to establish links from circulation through to the salmon, prioritizing understanding effects on feeding behavior. The Americans are focused on acquiring funding to develop a full, end-to-end Atlantis ecosystem model of Puget Sound. In the interim, the Americans are using assessing physical data for input into the Salish Sea circulation model (MoSSea), and evaluating whether atmospheric and stratification datasets illustrate ecosystem change consistent with high and low marine survival periods of coho. They are also creating the basis for incorporating zooplankton data into circulation models.

Core, Bottom-up Sampling Program (Salmon, Zooplankton, Physical)

US and Canadian sampling efforts continue to be well aligned. Protocol are shared for salmon and zooplankton monitoring, collection methods are aligned, and similar metrics are being collected. There are some differences in space and time in salmon sampling, with a longer nearshore collection effort in Puget Sound because the fish tend to disperse more slowly there. Utilizing the Ricker vessel in the Strait of Georgia and Puget Sound in July and September for offshore salmon sampling remains a top priority.

For zooplankton, vertical tows are being performed throughout the Salish Sea in a similar fashion. Sampling occurred at stations throughout Puget Sound in 2014 and will again in 2015. A limited effort was implemented in the Strait of Georgia, focused on Cowichan Bay and the existing DFO sampling sites. This will be expanded in 2015, sampling for 16-18 days at approximately 90 stations using the Citizen Science platform. Most stations will be CTD only, with secchi, phytoplankton, nutrients collected at about one quarter of the stations (priority stations). The aim is also to carry out vertical zooplankton tows from these priority stations for 3 or 4 of the citizen science vessels. Oblique tows have been implemented in Puget Sound to assess the salmon prey field; however, they have proven difficult off of the smaller vessels used in the distributed, multi-party approach implemented there. US collaborators continue to work on refining the oblique tow approach for Puget Sound, and Canadian collaborators will continue to assess whether oblique tows can be done in the Strait of Georgia.

Physical monitoring approaches are more distributed, with sampling inconsistently disbursed in space and time, on both sides of the border, relying on a mix of moorings, CTD casts, and ferry-mounted monitors. However, the physical data collected are generally comparable, with circulation models helping to expand these data and describe physical characteristics Salish Sea wide.

There are concerns about the lack of offshore salmon samples in late July through the end of August as that may be a critical part of the juvenile Chinook growth period. There are also concerns about consistency/quality of zooplankton sampling because a distributed approach using multiple collaborators/platforms is being applied; therefore, proper vessels and equipment, training and oversight are high priorities for success.

Top-down studies (Predators and contaminants)

The US and Canada have both pursued a technological solution to quantifying interactions between harbour seals and salmonids exhibiting poor marine survival. In Washington, steelhead were implanted with acoustic transmitters and seals were outfitted with transceivers to determine how often harbour seals detected juvenile steelhead during their outmigration. In BC, a development project was undertaken to create a head-mounted PIT tag scanner for harbour seals that could be used to quantify the number of PIT tagged salmon smolts consumed by pinnipeds. This coming April, 40,000 PIT-tagged hatchery coho will be released from Big Qualicum Hatchery in the Strait of Georgia, in conjunction with

20 seals receiving head-mounted PIT tag scanners. In addition to these novel technological approaches, both sides of the border are assessing traditional diet analysis approaches to quantify predation rates on juvenile salmonids. And, the US and Canadian predation projects may be converging on a predator diet analysis approach for predation quantification that combines traditional morphological identification of fish prey remains with modern genetic tools.

Data show that levels of persistent contaminants in the Salish Sea are problematic for salmon and their predators (humans, killer whales). Given the vast array of contaminants at play, the contaminants leads recommend focus on only a few of primary concern (e.g., PBDEs, PAHs, and microplastics). The group recommends a trans-boundary expert meeting to discuss Salish Sea issues and draw guidance from experts in non-Salish Sea locations.

Data Management and Sharing

The shared Project goal is to make ecosystem data assessed through this effort comparable across the Salish Sea and readily available and usable for a variety of analyses, with a life extending beyond this project. This is vital to project objectives such as establishing an ecosystem indicators program for salmon adult return forecasting. In the near-term, the focus will be on data-sharing among Salish Sea Marine Survival Project participants (via Basecamp). As datasets become more formalized, LLTK/PSF will create a project management site on Basecamp for everyone to access data. The shared approach for establishing long-term, useable data is to focus on back-end data needs, including data standardization to improve aggregation on a variety of platforms and automating data aggregation and quality control (QA/QC). LLTK continues to look to improve approaches to these back-end data needs. PSF continues to evolve the Strait of Georgia Date Centre as a central access point for Strait of Georgia data, and Puget Sound scientists continue to focus on established platforms such as NANOOS and NOAA's ecosystem indicators web site as data aggregators and access points for Puget Sound data.

Critical Concerns, Project Gaps and Affiliated Considerations

There was significant agreement that the current lack of manipulative experiments in the overall Project is a concern. Carl Walters believes that the critical mechanisms driving survival won't be fully revealed without some larger-scale manipulations such as removing specific predators of concern (e.g., disturbing specific haul outs) to test top-down effects, or manipulating hatchery releases (e.g., basin or inter-annual variation in releases) at a large scale to test responses. Participants responded that hatchery releases have changed: there have been significant reductions in production of hatchery fish, notably coho in the Strait of Georgia and steelhead in Puget Sound. Also, there have been significant increases in pink salmon, and the even/odd year pulses could help provide the basis for a natural experiment (to assess variation in environmental response). However, the appropriate environmental monitoring may have not occurred over this time period to elucidate mechanistic responses, and there may be too many confounding factors in such an uncontrolled natural experiment. Laboratory experiments, size and timing of hatchery releases, and comparing basins (e.g. South Puget Sound vs Whidbey, Hood Canal vs Puget Sound, etc.) and years (e.g. 2005 - low vs 2008 – high for coho) that have populations with contrasting growth (from Beauchamp, Chamberlin, Trudel and Neville work) and survival rates (marine survival trends) and substantial environmental and fish characteristics data are valuable approaches to consider.

There was also some concern that the Project structure discriminates between top-down and bottom-up effects as if they do not interrelate. Carl Walters used the example that rapid steelhead outmigration may be a response to limited food, and this behavior may make them more susceptible to predation. The group acknowledges this but notes that the structure is largely used for communications and organizational purposes, and that the studies do transit both top-down and bottom-up effects simultaneously where feasible. Along these lines, a better understanding of the relationship between food supply, consumption, and predator aversion was recommended.

Some participants believe that not enough has been done with existing data in order to determine how the ecosystem shifted between the 1980s and today, and that the retrospective work, such as that proposed via the Ecosystem Indicators and modeling components of this effort, should be prioritized. Indicators and modeling exercises will also help tell a more comprehensive story about the ecosystem and its effects on salmon, and to test and narrow down the number of hypotheses currently in play. However, there were concerns regarding how far correlations and modeling will take you given that the inability to appropriately weight potentially relevant factors (such as changing water quality vs increased predators) restricts honing in on the primary factors driving survival. Therefore, a combination of retrospective analyses, field studies and experimental work continues to be the recommended approach.

LLTK, PSF and participating scientists from both sides of the border will continue to emphasize these concerns and considerations when developing next steps in research.

Next Steps: Recommendations and Tasks

- **The group** agrees that experimental manipulations (both large-scale and localized) and comparative analyses of regions, populations or years with sharply contrasting dynamics are necessary to help elucidate the primary drivers of survival. But, manipulative experiments must be done in a manner that removes confounding influences.

- **The group** concluded that a list of tractable hypotheses should continue to be used as the primary basis for the research. Retrospective analyses and modeling should be emphasized to narrow the realm of factors driving survival; however, expect that this work will need to be paired with field assessments and experiments to determine exactly what factors are driving survival.

- Conceptual models, indicators exercises, and Ecopath with Ecosim modeling efforts are recommended as a way to: 1) increase communication among the various scientific disciplines involved, 2) test hypotheses, 3) develop and hone next steps in research, and evolving the narrative describing what the group thinks has happened to salmon and their Salish Sea ecosystem over the past 30 years.

    - **A trans-boundary workshop (led by Dave P. and Chris H.?)** was recommended to challenge a simple ecosystem model.

    - **Correigh G.** will follow up with researchers who suggested additional ecosystem indicators and/or had data in-hand for indicators (see Ecosystem Indicators/Data Catalog section on p. 20 for details). LLTK and PSF will work with Correigh and others to progress the Ecosystem Indicators work in 2015.

- **LLTK, PSF and their Technical and Steering Committees** will continue to work on evolving the narrative describing what the group thinks has happened to salmon and their Salish Sea ecosystem over the past 30 years.

- **The group** agrees that increased coordination is needed to create cohesion and align all activities towards the same goal. More communication between fish scientists and oceanographers is needed.

- Integrating data across the full Salish Sea remains high-priority. **LLTK/PSF** will create a high-level, all-access Basecamp project management site to house completed datasets. They will also continue to work with data management leads to progress the longer-term data handling approaches.

- **LLTK/PSF** will coordinate with the contaminants folks to arrange a trans-boundary expert meeting to discuss Salish Sea issues and draw guidance from experts in non-Salish Sea locations.

- **LLTK/PSF** will coordinate with zooplankton sampling PIs (Julie K., Ian P.) to arrange a retreat for sampling protocol discussions and taxonomic identification comparisons between US and Canadian groups.

- **Marc T.** and **Lance C.** will coordinate on reconstruction of growth histories over time using otoliths in Strait of Georgia and Puget Sound.

- **Neala K.** will follow up with **Correigh G.** to discuss results of steelhead survival correlations with ecosystem indicators and **Ken W.** to discuss including stock origin (e.g., Skamania fish in Puget Sound hatcheries) in steelhead models.

- **Julie K., Ian P.,** and **Iris K.** will coordinate on comparisons of Strait of Georgia and Strait of Juan de Fuca/Puget Sound zooplankton data (trend data, and current taxonomic identifications), and will continue discussing ways to address issues with distributed sampling efforts on small boats.

- A better understanding of the relationship between food supply, consumption, and predator aversion is recommended.
- Utilizing the Ricker vessel in the Strait of Georgia and Puget Sound in July and September for offshore salmon sampling remains a top priority.

Tuesday, Dec. 2: Report of Initial Findings

Salish Sea Coho Survival Study Results (Jim Irvine)

The Coho Task Team used cluster analyses, mixed effects models, and exponential decay models to explore patterns of spatial and temporal coherence in smolt survival rates of hatchery and wild coho populations within and outside of the Salish Sea. Survival patterns grouped regionally (Strait of Georgia, Puget Sound, Pacific Coast), and regional differences have changed over time. Salish Sea smolt survivals were higher than Pacific Coast populations in the 1970s and early 1980s. Survival in all regions declined in the late 1980s and 1990s. The survival decline for Salish Sea populations was more pronounced and these populations did not rebound from the decline, whereas the Pacific Coast populations did. Over the period of decline, smolt survivals were strongly correlated over a larger spatial scale than during the post-decline period. Hatchery smolts consistently had lower survival than wild smolts. One important conclusion is that the desired measurement scale for ecosystem indicators depends on temporal scales of interest. A manuscript describing this study is currently in revision.

Another component of this project was to update the Strait of Georgia early marine survival model. Dave P. and Chrys N. reported that, according to the updated model, early marine survival increased in 2012-2013 to estimates comparable to survivals from 2000-2001. There is noise around estimating Puget Sound coho contribution to the Strait of Georgia, since those estimates are based on only a small number of recovered CWTs.

The Coho Task Team's recommended next steps are to develop an early marine survival index for Puget Sound to compare to that used in the Strait of Georgia, identify appropriate ecosystem indicators for analysis, evaluate biological data and life history characteristics, and compare the relative role of freshwater versus saltwater effects to overall survival.

- The exponential decay approach has been used in other studies of salmon species; the team chose to use this analysis so they could compare spatial correlations in coho to other species.

- **Julie K.** asks how much effort it would take to update the survival time series for subsequent years. **Jim I.** says it would depend on the user's familiarity with RMIS (coded wire tag database). Generating survival estimates is fairly easy; however, to obtain information from various agencies and hatchery programs to filter the data (to e.g., remove diseased release groups) can be difficult.

- **Dave P.** asks, from a management perspective, at what time and area scale can we make meaningful interventions? Most responses will likely be over the short-term, which is difficult to assess.

- **Carl W.** asks whether any stocks in the analysis were strong outliers.

    - For example, Tenderfoot coho have consistently lower survival than other stocks. **Jim I.** answers that Tenderfoot was not included in this particular dataset; however, the interior Fraser stock has lower survivals also. This may be because the measurements of smolts and adults occur further upriver than for other stocks, so there is added freshwater mortality.

    - The model included 3+ stocks per year, and there was variation in patterns. For example, Inch Cr and Chilliwack stocks were consistently different. However it is difficult to determine whether that variation reflects real stock differences, or whether it reflects differences in assessment (terminal fisheries, etc.). Jim I. does not recall any stocks that had consistently higher survival rates in this analysis.

- **Dick B.** notes that we don't yet understand behavioral differences between Puget Sound coho (outmigrate early August) and Strait of Georgia coho (high mortality in Strait of Georgia between mid-July and mid-September). Coho stocks are reasonably well-mixed in the Strait of Georgia in July. Is this also true for Puget Sound?

    - The Coho Team will be discussing investigation of early marine survival and behavior in the Salish Sea as a next step of their work.

    - **Carl W.** says that data shows coho leave Strait of Georgia and move offshore as soon as they can to avoid predators, and suggests that since Puget Sound is all nearshore that coho are leaving early to escape from haul-outs and predation.

- **Mel S.** noticed an inverse relationship between post-smolt hatchery production and survival rates in east coast Vancouver Island hatcheries, possibly due to limited marine capacity. **Jim I**. says that while there are ways to experimentally test this (changing release sizes and times), it is very complicated to get approval/cooperation.

Cowichan Studies

In-river RST, snorkel surveys, and PIT tagging work (Mel Sheng, Kevin Pellet)

Snorkel surveys showed a maximum of ~15 chinook per habitat/site. Fry clustered mid-day and dispersed at night; over time, fry moved further from shore and into high-velocity areas.

Fish were tagged with CWTs and released 40 km upstream to test assumptions about migration rate and mortality. Results were inconclusive due to low recaptures and poor trap efficiency; however, data suggested fairly low survival (25%). This study will be continued next year and changes will be made to improve trap efficiency and recaptures. Another next step will be calculating survival to adulthood for tagged fish.

Wild fish (~2000) and hatchery fish (~1800) were PIT-tagged to assess the feasibility of tracking PIT tags in the Cowichan, track usage of different freshwater habitats, and monitor adult returns for freshwater and saltwater survival rates. A tag retention and mortality study with hatchery fish resulted in 5% tagging rejection or mortality. Detection efficiencies in the side channel were 90-97% and detection efficiencies in the mainstem were ~10%. Most detections in side channels and mainstem were during mid-day, indicating that outmigration occurs during daylight. Growth rates for recaptured individuals were 0.61 mm/day and wild fish emigrated around 67.5 mm. Recruitment into side channels appeared to happen at pre-tagging sizes (<60 mm); none of the tagged fish moved into side channels. Residence time in side channels was low; wild fish stayed 5-10 days and hatchery fish only a few hours. Very few fish were detected in the estuary.

Catch rates for marine tagging (beach seines, purse seines, micro trolls) were highest in May and June. The size distributions of fish caught with beach seines versus purse seines were significantly different. Only 55-65% of the fish caught just outside Cowichan Bay were of Cowichan origin.

- **Mara Z.** is concerned that amalgamation of size groups may confound tag retention/mortality and survival rate results. **Kevin P.** says that the data can be broken out by size.

- **Mara Z.** asks whether CWT data from river mouth and upriver was compared. **Mel S.** says yes; there were large differences in survival and possible density-dependent factors that drove in-river mortality.

- **Michael S.** asks, given the low catch rates in the estuary and marine environments, how confident are mortality rates beyond the river? **Kevin P.** says they assume close to zero recaptures in marine environments, so scanning returning adults is critical to get marine mortality estimates.

Oceanographic observations (Svein Vagle)

Coordination of oceanographic sampling has been planned through a variety of efforts. DFO performs CTD, rosette, nutrients, and net sampling through Strait of Georgia periodically. Eddy Carmack does seasonal sampling and has been developing a citizen science sampling program with small boats, which take weekly oceanographic samples.

Cowichan Bay stations were sampled in 2013 (10 stations) and 2014 (11 stations; the additional is further from the Bay). The small boats sampling these stations are captained by scientists/fishers who have some prior experience. They do small CTDs, net tows for zooplankton, and nutrient sampling in surface water and 20 m water depth. They try to sample the same part of the tidal cycle each time to minimize tidal influence. Additionally, 3 moorings were placed into the system to monitor variability: 2 within Cowichan Bay and 1 at a reference site. These were installed mid-June 2014 and will remain there until late-2015.

Results show temporal and spatial variability in chlorophyll fluorescence, and possibly a detectable harmful algal bloom signal. Preliminary data from the moorings also show high variability in the system, as well as Heterosigma bloom signals and zooplankton diel vertical migration.

A next step for this project is to finalize coordination of the citizen science effort, which will add another 90 stations to provide coverage of the full Strait of Georgia. Evidence suggests that there are multiple water masses with different physical properties in the Strait; these water masses need to be regularly sampled to understand their dynamics and relationships to biological factors.

- **Carl W.** thinks that the diurnal data from the moorings is very important, since fish behavior varies diurnally. He asks whether fish sampling is also coordinated on a diurnal schedule.

    - **Marc T.** says that micro trolling is done over tidal cycles, but time-of-day could be analyzed and time is controlled for a very short duration. The same is not true for purse seining, since it takes a couple hours just to sort the fish. Stable isotopes for integrated values of diet contents are also valuable information.

- **Chrys N.** notes that the guts have not emptied over the time between feeding and sampling. One of Carol Cooper's diet metrics is an index of digestion.

- **Dick B.** asks whether crepuscular/night sampling should be happening as a coordinated program instead of opportunistically.

    - **Marc T.** thinks a coordinated program to sample at night would not be worth the extra effort. With the daytime data we have now, aggregated diet explains 65% of variability already.

- **Dave B.** comments that, in Puget Sound, invertebrate-feeding fish are feeding during daylight. There is some indication that daylight piscivory also occurs (based on acoustically-tagged coho). The dusk/night-time purse seines in Puget Sound this year had very low capture rates for piscivorous fish. However, Dave does think capturing the transition to piscivory requires some effort towards dusk/night sampling.

Zooplankton (Ian Perry)

Weekly zooplankton sampling was done in Cowichan Bay, concurrent with oceanographic sampling. In 2013, a larger-mesh NorPac net was used and, in 2014, a smaller mesh ring net. The difference in nets may affect variation between years, although the amount of *Noctiluca* and low filtering rates indicate that small zooplankton were captured in both years. In 2014, a depth sensor and flowmeter were used; neither had been used in 2013. Most tows were vertical, and were intended to sample the whole water column. Small boat station-keeping was poor, so actual sampling locations were inconsistent.

The major lessons learned were that effective sampling requires 1) depth sensors, 2) better logs and station-keeping, 3) flowmeters and 4) crab pot-pullers or some other mechanized way to haul nets. Hand-hauling was too difficult to maintain speed and consistency. There is concern about expanding this sampling through the citizen science program.

Preliminary data show that in 2013 there were lower abundances and less overall biomass in May. This was the period when freshwater input was high. Taxonomic composition varied seasonally. Composition was similar along a west-to-east transect in Cowichan Bay, but amounts? Numbers? of taxa differed by location. Decapod larvae, euphausiid larvae, *Noctiluca*, and fish larvae all had fairly consistent patterns among sites. Preliminary 2014 data had similar but less strong patterns to 2013.

Between-year comparisons showed that taxonomic diversity was similar but composition was different: about half of the most common taxa were different between years. There was much more *Noctiluca* caught in 2014, and more small taxa and fewer big taxa (e.g., jellyfish) caught overall in 2014. Larger animals tended to be more abundant in April and June of both years, while *Noctiluca* was abundant in late-April, early-May, and June.

- **Evelyn B.** asks how to deal with increased variability at high abundances and biomasses when modeling food availability. **Ian P.** says it would depend on several factors: for example, whether fish are prey-selective or employ a simple size-based approach (literature suggests both), and prey escape/capture behaviors.

- **Ken D.** suggests beginning sampling prior to April. **Ian P.** agrees this should be discussed; their sampling start dates were intended to match with fish outmigration.

- **Julie K.** thinks the differences in size and taxa caught between 2013 and 2014 are due to the different mesh sizes of the two nets used. Also, the size metric shown was taxa length – Julie points out that a 1 mm long but narrow zooplankter could slip through larger mesh. **Ian P.** says they plan to use the smaller-size mesh consistently in future sampling.

- **Dave B.** says that the U.S. team is doing vertical integrated tows and oblique tows in the upper water column to capture prey field information for planktivorous fish. **Ian P.** says the debate will continue for the Canada team; sampling the full water column includes the zooplankton in the prey field, and oblique tows are not feasible for small boats. Also, if fish are feeding in the crepuscular period, that prey information would be captured with full water column daytime tows but not oblique daytime tows. **Dave B.** says that vertical tows dilute the upper water column data.

- **Dave P.** comments that some literature suggests that well over 50% of primary production is eaten by microzooplankton and becoming food not available to fish. Higher temperatures can be associated with larger portions of microzooplankton. Is there capacity in the Cowichan to measure how much energy is available to fish? **Ian P.** says that this is not currently being measured but there are potential ways to do so: sample microzooplankton, or take chemical measurements of secondary productivity. A PhD thesis from UVic suggested that variability in secondary production and trophic transfer efficiency is high.

Nearshore juvenile salmon studies, fish and bird predation, HABs (Marc Trudel, Chrys Neville)

Beach seines, purse seines, micro trolling, and midwater trawls were used to sample Cowichan Bay and Strait of Georgia (Ricker survey). Chinook were about 2.5% of the catches, and there was no significant change in species catch over time. Dominant prey items 2010-13 in the estuary and bay were gammarid amphipods, insects, and crab larvae. Insects and crab larvae were especially common in bay areas. The dominant prey items in juvenile chinook are consistently decapods followed by insects, and prey items are eaten in different proportions by unmarked versus marked chinook.

There were similar growth trajectories observed in microtrolling and purse seine samples. IGF-1 results showed heterogeneous growth within the Strait of Georgia and generally lower growth in the Gulf Islands. There were more empty stomachs during bloom events of *Pseudo-nitzschia* and *Skeletonema*. Stock covariation suggests effects within the Strait of Georgia rather than in nearshore environment.

No fish predators were recovered in Cowichan Bay. Bird surveys found high numbers, but whether those birds actually predated on salmon and, if so, how much, is unknown.

Next steps for this work include expansion to other areas in the Strait and continued discussions about appropriate sampling depths and frequencies.

- **Carl W.** asks for more details on growth rates. **Marc T.** says IGF-1 is a hormone that reflects growth over 4-7 days. It is a short-term metric, not an estimate for the full growth season. It is unknown how the growth estimate from micro troll and purse seine samples (1 mm/day) varies year-to-year for a specific stock or for other stocks in the region.

- **Mara Z.** asks how much growth occurs prior to marine entry for these fall chinook. In Puget Sound, bimodal outmigrations are common: small subyearlings that have not grown in the river versus large subyearlings that spent time rearing in freshwater. This freshwater growth element likely contributes to marine survival. **Marc T.** plans to use otoliths to reconstruct growth histories for specific fish. He will collaborate with Lance C.

- **Mara Z.** asks whether size variation influences IGF-1 and whether freshwater life history contributes to those patterns. **Brian B.** answers yes, and chinook IGF-1 data are complicated. Data needs to be analyzed on a stock-specific basis.

Seal predation (Andrew Trites)

Harbor seal scats from log booms in Cowichan Bay show that their April-July diets are dominated by Pacific herring (~50% of diet), followed by pollock, hake, salmon, and other species. August-November diets contain less herring and more salmon. Hard parts and DNA evidence from 2012 show contributions from chinook, coho, sockeye, pink, and chum. Adult hard parts in diets peaked in November. Juvenile bones were observed from May through October. Chinook hard parts in diets peaked in July. Similar patterns were observed in 2013, though there was no peak in adult hard parts and chinook peaked earlier (May).

Preliminary results from model estimates of consumption indicate that in 2012, 84,000 juveniles were eaten and 600 adults were eaten. In 2013, 120,000 juvenile Chinook were eaten and 300 adults were eaten. To put these numbers in perspective, they would represent 8-14% and 25-87% of the juvenile hatchery releases for Cowichan and 20-25% and 3-9% of adult escapement for each respective year (however, this is just a representation as there are wild Chinook also entering the system, and Chinook from other watersheds, all that are being consumed by these seals).

Next steps will be to add data from 2014 samples to database, integrate data with salmon assessments, and plan tagging studies to identify where and when fish are caught. Andrew and Austen are working on novel technology: seals with PIT tag readers will detect when PIT tagged fish are eaten.

- **Correigh G.** suggests that these data indicate seals are largely opportunistic predators. Do they seem to catch fish proportional to the fish species' abundance? **Andrew T.** says we need to know more about the prey base to judge. There does appear to be selection for herring and hake.

- **Correigh G.** asks how much of the wild fish outmigration would this estimated consumption represent. **Mel S.** says that 30% of adult returns are hatchery fish; his assumption is that the juvenile population is similarly 30% hatchery.

- **Neala K.** asks whether there are steelhead in the Cowichan. **Chrys N.** says yes, at very low abundances. **Austen T.** says that at the molecular marker used for some tests, steelhead and coho are indistinguishable and therefore are lumped in the results. Other data that do not lump these species detect steelhead at very low rates.

- **Frances J.** asks whether stock is detectable. **Austen T.** says not yet – there have been discussions on getting it from scat DNA analysis, but it is very difficult to parse out stock with metasamples.

- **Dick B.** thinks that these data indicate predation is not occurring in Cowichan Bay. There are no hake or pollock in Cowichan Bay, yet the seal diets include high amounts of hake. **Andrew T.** says that identifying where the fish get eaten is a next step.

- **Marc T.** asks how juveniles are separated from adults in the model estimation. **Austen T.** says that for the rough estimation, any datapoint that occurred in the juvenile window was assigned as a juvenile. The next step will get closer to an actual number. The rationale for doing this is that the earlier DNA peak (May) and lack of any hard parts peak in 2013 indicate that the May juveniles consumed were smaller and bones were digested.

- **Jim I.** asks whether it is feasible to look at diet on a scat-by-scat basis to identify individual variation. **Andrew T.** says that cluster analyses can show which species are in single scats. However, tracking individual animals is more difficult.

- **Mel S.** asks whether CWTs show up in scats. **Austen T.** says that the colleague doing hard part analysis has not noted any CWTs, but he is not sure what her sieve mesh size is.

    - **Chrys N.** suggests wanding samples before sieving them. Also, if otoliths are recovered in hard part analysis, the ones from hatchery fish are thermally marked.

    - **Andrew T.** says that if they are provided a wand they could wand scat on booms.

- **Mel S.** notes that they observed a population of 40-60 seals coming into the river during adult chinook return. The return was male-saturated, indicating that seals were targeting females. **Austen T.** says that qPCR techniques are currently in development to detect amounts of males versus females in samples.

- **Carl W.** says that in order to explain the total mortality of smolts entering Strait of Georgia, juveniles would have to be at least 10% of the diet over the whole Strait. Because these results are lower than that, he suggests seal predation is not that important.

Microbe screening (Karia Kaukinen)

Kristi Miller's group is conducting a large, four-phase project to collect samples, identify when and where pathogens are present, identify which microbes are harmful and show how these factors affect salmon. They are currently identifying pathogens using wild and hatchery collections, as well as aquaculture samples as healthy comparisons.

Infection appears to increase risk of predation. One study took sockeye from auklets returning to nests to feed young and found that the sockeye that were preyed upon had higher microbe diversity and higher loads than sockeye caught in trawls.

- **Julie K.** asks whether the sockeye study is the first/best evidence of predators removing weaker fish, and whether the results are only applicable to the specific microbe studied. **Marc T.** says that this is one of few methods of getting whole dead fish from predators. Birds systematically selected smaller and poorer-condition fish compared to trawls. It is unknown what implications there are for recruitment; one possibility is that culling by predators reduces disease transmission.

- **Julie K.** asks whether this method can be applied to gut content of other predators. **Karia K.** says that it can be used for any template but groundtruthing is required in order to exclude good/healthy microbial flora.

Puget Sound Critical Growth

Approach and status of critical growth study (Dave Beauchamp, Josh Chamberlin)

This project uses size-selective mortality to identify critical periods of growth and survival and associated life stages and habitats. Samples were collected at in-river, estuary, marine nearshore, and marine offshore sites. Previous research showed that CWT chinook size in July was positively correlated with marine survival.

Catches showed temporal pulses for each basin. Scale samples were used to back-calculate growth of known-origin juveniles. There is some question whether modality needs to be tracked within specific stocks or whether the general population is sufficient. The ultimate comparison will be with returning adults. In Nisqually, chinook guts contained insects in estuary and nearshore sites and crab larvae at offshore sites.

Next steps are to complete scale and gut analyses for other watersheds and species. Then use bioenergetics modeling to estimate consumption. Refining collaborations and coordination took a lot of time; progress towards simplification has been made. Two missing pieces are sampling in August and September, and depth-stratified sampling.

- **Carl W.** asks whether there is confidence that circulus count is age-dependent and independent of feeding. **Dave B.** says that, based on Gulf of Alaska pink salmon, a circulus is laid down every few days and this is not affected by growth rates.
    - **Lance C.** says that circuli count in other species can be quite variable, and can be decoupled from time. For chinook salmon coming out of the Columbia, a single circulus is deposited over every two weeks to 30 days. Circuli counts also change as a function of growth.
    - **Dave B.** says that they are using circulus counts as a benchmark of growth and, when it is done on specific known-origin fish, that accounts for variability. So far, they are seeing good modality for known-origin fish.
- **Mara Z.** asks how multiple stocks are accounted for; the further from the smolt trap, the more likely a sample contains multiple stocks.
    - **Dave B.** says they are following larger release groups to the extent possible, but also seeing whether pooling stocks changes the results.

- **Madi G.** explains that the slide Dave B. showed with modalities for groups represented a specific release group versus a pooled group, and much greater variation was observed in the pooled group.
- **Josh C.** notes that a subset of samples will also be analyzed for genetics.
- **Dave B.** notes that otoliths are being archived for all samples.

- **Dave P.** asks whether competitive interactions will be analyzed; Ruggerone suggested interactions between pink and chinook salmon, and millions of pinks are returning to Nisqually recently. **Dave B.** says that previous analyses showed that herring were the most important competitor, eating much more prey than chinook and pink salmon combined.

Assessment of qualitative WDFW zooplankton dataset (Iris Kemp)

This dataset consists of qualitative (largely presence/absence) zooplankton samples collected with short horizontal tows in nearshore regions close to herring spawning grounds in Puget Sound. The dataset spans 1974-1994 but is spatially and temporally patchy. The best candidate for zooplankton trend analysis was Cherry Point, which was consistently sampled weekly in April-June, 1975-1988.

There was interannual and seasonal variation in Cherry Point zooplankton community composition. Ordinations showed a cyclical pattern over the decade, with more recent years (1986-1988) driven by ctenophores whereas early years (1975-1977) were driven by barnacle cyprids and more strongly separated from the rest of the time series. Logistic regressions of specific taxon presence/absence over time showed statistically significant trends for many taxa. Notable trends included a large increase in ctenophores, a large decrease in barnacle cyprids, an increase in siphonophores, and decreases in crab megalopae and pelagic fish eggs.

- **Mark T.** recommended comparing the zooplankton data to relevant salmon marine survival trends.
- **Jim I.** recommended comparing these data to Dave Mackas' data via working with Ian Perry.

Approach and status of zooplankton sampling (Julie Keister)

The Puget Sound zooplankton sampling program is a distributed approach by a variety of groups (agencies, universities, tribes, non-profits) at sites throughout Puget Sound. Spatial coverage was generally good, aside from South Hood Canal, which no groups were able to sample. Sites were sampled every other week, from April through September. At each site, groups performed one vertical single-ring tow (full water column or 200 m) and three oblique bongo tows at 30 m water depth over varying bottom depths (25 m, 50 m, 75 m). This sampling design will be simplified over time, as the data reveal which sites are most informative.

Because this was a new sampling activity for many groups, with new protocols and gear, start-up was the most difficult part of the process. There were assorted other group-specific issues. Julie's group is assessing data quality as part of the project. The quality of vertical net sampling is generally good. The quality of oblique net sampling is not as good. Lack of depth sensor use was a big issue. Small boats had a difficult time doing oblique tows.

Lessons learned through the first year of this program were that use of depth sensors must be stressed as critical, and that groups would benefit from early and repeated training and quality assessments. The next step for this project is to discuss program adaptations to address issues. This sampling program will continue in 2015.

- **Chrys N.** asks what constitutes a "small" boat. **Julie K.** says it depends on several factors (e.g., horsepower). **Jed M.** says the Nisqually boat is 24 ft with a single outboard motor and a pot-puller. The oblique bongos swing the boat around in the water if they are not careful. **Julie K.** comments that the Nisqually samples are pretty good quality, but only because Jed and the Nisqually crew put in lots of effort.

- **Ian P.** asks whether single-ring nets could be used instead of bongos. **Julie K.** says that Cheryl Morgan (Oregon) did a single-ring/double-ring comparison and found that bongos were much more efficient at catching the zooplankton in which we are interested. Smaller nets mean that we would miss a lot. Additionally, while catchability indices can be developed, they vary substantially by species. The decision for 2015 was to sample fewer locations with bongos if groups could not make them work.

- **Ian P.** says a concern for Canadian samplers is using formalin with untrained crews. **Julie K.**'s samplers are using gloves and dispenser bottles that make it difficult to spill much formalin.

Status of ORCA buoy upgrades and data accessibility (Wendi Reuf)

The ORCA buoy program is a data resource for efforts like the Salish Sea Marine Survival Project. They have six autonomous profiling moorings across Puget Sound, which take up to 12 profiles per day during summer and have taken over 80,000 profiles since 2000.These moorings are solar- and battery-powered and have a standard CTD package. Depending on data needs, sensors can be added to measure nitrate concentrations, currents, transmissivity, PAR, etc. Some moorings also have recently upgraded weather stations. All buoys follow industry standards and all data are available online.

Next steps are to finish deploying weather stations and adding pH monitoring capability to buoys. There will also be sampling cruises in Puget Sound basins in the upcoming year.

Otolith Analyses (Lance Campbell)

Lance C. wrote a proposal to do a study on successful salmon life histories, based on returning adults' scales and otoliths. Otoliths can be used to determine whether juvenile chinook life histories vary by geographic area within Puget Sound. Scales can be used to assess the age and growth of Puget Sound, Washington coast, and Columbia River samples across time. The goal of this study is to build a map of life histories in Puget Sound, across coastal Washington/Oregon, and into Canada where data are available.

Currently, samples are available from Nooksack, Skagit, Snohomish, Cedar, and Nisqually. Otoliths form in eyed eggs, so a laser transect of an otolith can give a maternal signal and full record of the fish's life prior to catch. The size of the otolith is related to the size of the fish, which gives the ability to back-calculate size at any chemical change (e.g., transition to saltwater). Typically, Sr:Ca ratios are used to identify freshwater-saltwater migration, since Sr is found in high concentrations in ocean water and low concentrations in freshwater.

- **Marc T.** has had issues with West Coast Vancouver Island chinook where back-calculated model estimates of ocean entry size did not match observed micro-measurements. **Lance C.** will follow up with Marc separately. Lab experiments suggest fairly good accuracy, but Lance advises caution with size specificity beyond categories like small/medium/large fish.

- **Dave P.** asks whether unmarked hatchery fish are a concern. **Lance C.** says yes, that is one issue.

- **Carl W.** notes a dip in Sr:Ca ratios after saltwater entry. **Lance C.** explains that the relationship between salinity and Sr incorporation is not linear; Sr reaches a maximum at certain salinities. There is also a size effect to Sr incorporation, where larger fish are better able to exclude Sr.

- **Correigh G.** comments that there have been efforts to differentiate local habitats with isotopes. **Lance C.** says that elemental chemistry studies are promising, but fail when talking about freshwater portions of estuaries (e.g., Skagit); different fry life history types may have different mortality rates, but that can't be parsed out from adult samples.

Puget Sound Chinook and Steelhead Toxic Contaminants Analyses (Sandie O'Neill)

Contaminants may reduce health and productivity of salmon and/or their prey supply. Chinook are most likely to be affected, due to their life history in Puget Sound. Some areas of Puget Sound are highly urbanized; urbanization includes physical habitat degradation and also chemical toxic inputs. Effects of contaminants may worsen with climate change and warmer water temperatures.

Previous research developed a series of adverse effects thresholds for a few common contaminants. The current work encompasses sampling throughout Puget Sound to evaluate contaminant levels in outmigrant chinook and steelhead, predict likely effects, and identify contaminant sources.

In general, steelhead outmigrants had lower levels of contaminants than chinook, and were below adverse effects thresholds. The exception was for PBDEs in the lower Nisqually River. PBDEs may be an issue for Nisqually steelhead if low lipid levels during outmigration exacerbate their effects.

In contrast, there was evidence to suggest that contaminants could affect early marine survival of chinook. PAH levels were high enough in marine nearshore areas to affect growth of 20% of Snohomish chinook and 50% of Green/Duwamish chinook. PCB concentrations increase as fish move into marine waters. In marine waters, 100% of Green/Duwamish chinook were affected, 10% of Snohomish chinook were affected, and 10% of Puyallup chinook were affected. PBDE concentrations were high enough to significantly affect 100% of Snohomish chinook in the lower river (high enough to alter thyroid hormone production), and adversely affect 10% of Green/Duwamish chinook. The high PBDE levels in the Snohomish river were likely due to the presence of a wastewater treatment plant near the sampling site.

The next steps for this study are to complete analysis of offshore midwater trawl samples. Fairly high contaminant levels are expected for these fish; based on herring data, the Puget Sound food chain for salmon is contaminated. Additional analyses of biological metrics like condition factor and lipid levels are needed. Further steps would be to do trend analysis of chemical contaminants and model exposure effects on chinook marine survival.

- **Correigh G.** asks whether calculating biomagnification from returning adults is possible. **Sandie O.** says that most contaminants get picked up in the areas where fish are growing. For adults, most contaminants are from saltwater. About 30% of chinook outmigrants become resident in Puget Sound, and they have high contaminant levels.

- **Sophie J.** asks whether contaminants were measured in fish upstream of wastewater treatment plants. In the Strait of Georgia, ~60% of PBDEs are from wastewater treatment plants. **Sandie O.** says this would be a desired future analysis in Puget Sound (pending funding). **Mike C.** comments there are a number of inputs of wastewater, especially in the Snohomish and Puyallup Rivers.

- **Chrys N.** asks whether fish with higher concentrations of contaminants die and the survivors tend to have lower contaminants. **Sandie O.** says it is possible, but sample sizes are too low to determine how much of the population is dropping out from river to marine waters. Also, if there is continual exposure in marine waters, fish will continue to pick contaminants up as they outmigrate. If contaminant levels are high enough to affect behavior, this may contribute to predation events.

- **Evelyn B.** notes that post-Exxon Valdez, impairment in reproduction was observed for salmon. Do contaminants in Puget Sound cause similar issues? **Lyndal J.** says some studies show salmon spawning behavior issues near wastewater treatment plants and reproductive issues in English sole, but for the most part adult salmon reproduction has not been studied with respect to contaminant levels.

- **Francis J.** asks whether assessment of microplastics is being done for Puget Sound, since that work is beginning in Canada. **Sandie O.** thinks that a worst-case/best-case scenario approach would be a good way to begin addressing the issue; microplastics were not included in the current contaminant study.

Puget Sound Steelhead Research

Genetics update (Ken Warheit)

Ken is working with acoustically tagged smolts (survivors vs non-survivors) and comparing RAD sequence results with existing genetic linkage maps to look for relationships between survival and SNP allelic differences and/or genomic architecture. Samples are ready for processing; there has been some delay due to equipment breakages.

- **Marc T.** asks whether Ken is doing parental SNP tagging to see if there is specific linkages to parents. **Ken W.** says that no genetic analyses have been done on these samples before, but he can look for relationships at some level (as a covariate in the analysis).

Survival correlations with life-history and ecosystem characteristics (Neala Kendall)

This study looked at steelhead trends across time and regions (Puget Sound, Strait of Juan de Fuca, WA coast, Columbia River) and related smolt survival trends with fish characteristics and environmental variables. Very little Canadian data on steelhead were available for this study, and the U.S. data prior to 1994 requires additional QA/QC.

Steelhead smolt survival has declined over time and remains low. Puget Sound survivals have been lower than coastal and Columbia River stocks since the 1990s. Within Puget Sound, South Puget Sound and Hood Canal stocks have the lowest survivals. Mixed effects models using data from 1994 onwards show that some years are significantly different than others, and that Puget Sound and Strait of Juan de Fuca stocks are significantly different from each other and from coastal and Columbia River stocks.

Preliminary results on regressions relating environmental variables to survival show that early spring upwelling index is most important to explaining data from all regions combined. Using data from only Puget Sound and weighting by how much time the fish spends in a particular Puget Sound basin, herring spawner abundance is positively correlated with steelhead smolt survivals. Seal abundance increases over the same time period as steelhead survival declines.

- **Correigh G.** asks for more detail on indicator relationships. **Neala K.** will follow up with him.

- **Ken W.** asks whether fish from both segregated and integrated hatchery programs were included. Further, is stock origin (e.g., Skamania fish in Puget Sound hatcheries) considered as a covariate? **Neala K.** says that segregated and integrated programs were both included, and that is significant in models. Stock origin has not been included; **Neala K.** will follow up with Ken W.

Nanophyetus assessment (Paul Hershberger)

Nanophyetus is the most likely pathogen that could produce observed epidemiological patterns in Puget Sound steelhead. Saltwater pathogens are unlikely to result in mortality within the 2 week window that steelhead are in Puget Sound. *Nanophyetus* is a flatworm with a complex life history cycle; its intermediate snail host is the determinant of *Nanophyetus* presence in a watershed. Steelhead in five Puget Sound watersheds were sampled at hatcheries, traps, estuary/nearshore areas, and offshore marine areas.

No *Nanophyetus* was observed in Skagit or Snohomish hatchery and wild steelhead, though 3 *Nano*-positive wild steelhead were recovered in Whidbey Basin marine waters (Skagit fish, which were likely infected at low intensities in the lower river estuary). *Nanophyetus* was also not observed in Tahuya wild steelhead; however another parasite (*Neascus*) was present.

Wild and hatchery steelhead from Green and Nisqually Rivers were positive for *Nanophyetus*. All Soos Cr hatchery fish had extremely high levels. *Nanophyetus* is a known problem at the Soos Cr hatchery, and a portion of those fish were moved to other hatcheries in 2014 to try to avoid infection. The other hatcheries (Icy Cr and Flaming Geyser) had low intensities of *Nanophyetus*. Prevalence in Green fish increased as the fish moved downstream/offshore. Fish in the Nisqually estuary had the highest prevalence and intensity than fish in the river or offshore. Overall, infection prevalence and intensity was higher in wild Nisqually fish than Green fish.

The literature indicates that exposure to 300 cercaria can result in 50% mortality within a day. The observed exposure levels in the estuary were higher than 300 cercaria in a matter of days. An additional observation from this study was that all fish infected with *Nanophyetus* had low condition factors (uninfected fish had a range of high to low condition factors).

A saltwater challenge was performed at Marrowstone lab, and no mortality occurred. However, **Paul H.** recommends repeating this experiment with newly infected fish. The Soos Cr fish used in this study had been infected for a while, and the early stage of infection (in this case, within the estuary) is the most dangerous for the fish.

- **Jim I.** asks whether *Nanophyetus* has increased over the period of steelhead decline: are snails becoming more abundant? Potentially related to urbanization? Also, does *Nanophyetus* die in the ocean?
    - **Paul H.** explains that infections are established in freshwater and estuaries. Not all fish die; those that survive bring back *Nanophyetus* to the freshwater to complete its life cycle. Adult returns can also be re-infected in the estuary/river.
    - There are no good data over time on *Nanophyetus* or snail abundance in Puget Sound.
- **Sandie O.** asks to what degree other species are affected. **Paul H.** says that chinook, coho, and steelhead are most susceptible.
- **Lance O.** suggests that managing snail populations may be something to consider.
- **Mike C.** comments that *Nanophyetus* infection does not explain high mortalities in Hood Canal or Whidbey Basin steelhead. **Paul H.** agrees that it is not a smoking gun, but also recommends caution in expanding results from one system to others. For example, Tahuya (Hood Canal) fish were not infected, but Skokomish (Hood Canal; not included in this study) is known to be heavily infected with *Nanophyetus*.

Reciprocal transplant (Megan Moore)

This work builds upon previous acoustic tagging studies which indicated high mortality occurring within the two weeks that steelhead spent outmigrating through Puget Sound. The objectives of this study was to separate effects of population and location on survival (i.e., whether survival is determined by environmental factors or by intrinsic characteristics of populations), identify mortality hotspots, improve survival estimates, and decrease confounding variables. Survival estimates were improved by using more acoustic receivers per line and more lines for increased resolution of mortality locations.

Steelhead smolts from the Nisqually and Green Rivers were tagged and released at home and away locations at river mile 19. Nisqually fish were much larger at tagging and had a higher proportion of 2-year old fish than the Green population. The average travel time for all fish was about two weeks. Best-fit models for mark-recapture survival analysis included segment and release date, but not release location or population.

Smolts had high survival within both rivers, but overall survival through Puget Sound was low. The highest mortality rates were in the first marine segment of travel for both populations at both release locations. The probability of survival was higher at the beginning of the outmigration period (early release date) than later.

Typical steelhead spent about 14 hours in the estuary. However, a few outliers spent lots of time in the estuary. These outliers traveled back and forth, generally on tidal cycles (detections upriver at high tide and in estuary at low tide), and were never detected on other receivers in Puget Sound. This back-and-forth tidal pattern is a typical behavior of harbor seals, suggesting these fish may have been eaten. The longest duration of this behavior was 20-25 days.

- **Austen T.** thinks that it seems improbable that a tag would stay in a harbor seal for 25 days (unless they re-ingest it). Passage rates for hard parts in harbor seals are about two weeks, with some variability based on size and shape of the hard part.

Dinner bell, harbor seal encounter rates (Barry Berejikian)

This study was paired with the reciprocal transplant study; its objectives were to quantify encounters between steelhead and seals and investigate the evidence for predation. Instrument packs were deployed onto the backs of 12 harbor seals (7 from Admiralty Inlet, 5 from Central Puget Sound) and 11 packs were recovered. These packs included GPS units, time-depth recorders, Vemco receivers, and VHF transmitters. All data are timestamped. The acoustic tags implanted in steelhead can be picked up by receivers from about 50 m away; this short range means that detections were fairly unlikely. To detect a steelhead, the seal would have to be underwater and within 50 m of the individual tag.

Seals detected 44 steelhead tags total. Most detections were by Central Puget Sound seals for fish coming out of the Nisqually. Admiralty seals only detected 7 tags. Based on mortality rates from release locations, there would have been ~140 steelhead alive in Central Puget Sound and ~60 fish alive in Admiralty Inlet. One seal detected 30 steelhead; of those, 13 survived. Steelhead detected by 2+ seals were not detected at later lines. All surviving steelhead smolts passed the Admiralty/Juan de Fuca lines by June 10. However, tag detections occurred throughout the full summer. Examination of single tags that remained in Puget Sound past the outmigration period showed some tags that appeared to be stationary at haul-out sites, and several tags that had a mysterious behavior where the tag moved too quickly to be within a steelhead and did this for 3 months (too long to stay in predator's digestive tract).

Literature has suggested a "dinner bell effect" where the pinging of the tags attracts predators to the fish. To test this, delayed tags (tags which didn't start pinging until 10 days after implantation into the fish) were compared with continuous tags (tags which pinged from implantation onwards). Most (~70%) of the delayed tags stayed silent through the Central Puget Sound line (highest steelhead mortality occurred prior to this line), and 85% turned on before hitting the Admiralty/Juan de Fuca lines. The numbers of survivors with delayed and continuous tags were comparable, indicating that tag pinging did not affect survival.

This study allowed identification of the fate of 34% of tags. Next steps could include sampling haul-out locations and other pooping sites (seals and seabirds) for tags, scat sampling and genetic analysis, and mobile tracking. **Barry B.** has a draft sampling plan for next steps; he thinks that it would allow us to understand the fate of up to 80% of tags.

- **Carl W.** used a VR28 to actively search for tags with Mike Melnychuk in Strait of Georgia. They found tags scattered along migration routes and hypothesized that these tags were eaten but not pooped at haul-outs. **Carl W.** also thinks that tags get stuck in seal digestive systems, although **Austen T.** remains skeptical that tags could be stuck for multiple weeks.

- **Sandie O.** asks whether tag detection distances were groundtruthed. **Barry B.** says that informal testing showed a 0-50 m range, although in a few cases detections could occur up to 100 m away. The seals could also hear each other with greater power.

- **Barry B.** says that a few of the tags detected over the summer may indicate the possibility of residence – random pings here and there. Some tags were only detected near Atlantic salmon net pens.

Wednesday, Dec. 3: Alignment Activities

Overview of 2015 and Beyond Marine Survival Project Research (Isobel Pearsall, Michael Schmidt)

The Canadians are currently evaluating proposals for the next round of research. Ian Perry is leading the (proposed) bottom-up activities, which include the citizen science sampling program, remote sensing to measure phytoplankton blooms over time, and ichthyoplankton and forage fish sampling. The citizen science program will involve 9 vessels, sampling over 16-18 days at approximately 90 stations throughout the Strait of Georgia. Most stations sampled will be CTD only, and secchi, phytoplankton, nutrients will collected at one quarter of the stations (priority stations). The aim is also to carry out vertical zooplankton tows from these priority stations for 3 or 4 of the citizen science vessels. All volunteers will watch a training video and will be trained by an IOS technician. Wireless CTDs and tablet apps will transmit data to Ocean Networks Canada.

Expansion from Cowichan Bay is planned for 2015. Marc Trudel will lead the juvenile salmon studies. UBC scientists proposed steelhead and sockeye acoustic telemetry studies. Other proposed studies included investigations into seal, fish, and bird predation, harmful algal blooms, contaminants and microplastics, and marine habitat (eelgrass, kelp).

The U.S. team will continue fish and zooplankton sampling in 2015 on a similar scale as in 2014. Steelhead studies have been funded through the state, which is on a biennial budget. The next study period for steelhead will therefore be 2016. Additional studies in 2016 include retrospective analyses of chinook survival, ecosystem indicators, otolith and scale analyses, and further development of end-to-end modeling.

Discuss Overall Concerns, Program Gaps, Needed Research

Manipulations, Experiments, and Mechanistic Linkages

- **Carl W.** feels strongly that the Salish Sea Marine Survival Project will fail unless experimental manipulation studies become a focus. Current work attempts to measure growth, predation rates, etc. more precisely, but even accurate measurements will not explain mechanisms. Carl suggests manipulation of hatchery releases and predators (e.g., deterrents at seal haul-out sites).
    - **Barry B.** agrees, and reminds the group that one of the primary recommendations of the Advisory Panel in 2012 was to do large-scale manipulations.
    - **Dave B.** comments that there is value in added precision; identifying particular life-stages of concern indicates where/when to focus effort.
- **Dave P.** says that there is an ongoing manipulation right now, with massive pulses of pink salmon every other year. The opportunity to look at pink years versus non-pink years is an obvious natural experiment.
    - **Barry B.** thinks that the pink salmon experiment has occurred already (reinvasion of Puget Sound) and that time period needs to be examined.

- **Francis J.** notes that laboratory experiments can also be useful to assess mechanisms. Past conditions can be artificially recreated and predicted future conditions can be created. This allows testing of cause and effect in a controlled system.

- **Carl W.** thinks the key to understanding is to manipulate factors not known to be correlated with ecosystem changes. Figure out experimental sequences to break up correlations to prevent confounding effects. For example, any experiment designed with even-odd years will be confounded by pink salmon.

- **Andrew T.** suggests comparative analyses of systems with contrasting dynamics as a natural experiment. He asks for examples of contrasting systems with regards to salmon survival.

    - **Mara Z.** says Hood Canal coho trends are different from the rest of Hood Canal. South Sound has had stronger declines than elsewhere. Nooksack coho trends are more similar to Strait of Georgia trends than to Puget Sound.

    - **Barry B.** notes that Hood Canal steelhead appear to have different behavior and survival (to the bridge) than other Puget Sound steelhead; however, this is a regional signal and not a stock-specific signal.

    - **Carl W.** says that there used to be large differences in survival between Fraser River and East Coast Vancouver Island stocks. Fraser fish in general survive better.

- **Carl W.** thinks localized experiments could produce good information. For example, there was a case in Strait of Georgia where the hatchery water was accidentally chlorinated and 80% of the smolts died. The return of the survivors (reared at low densities and released at large sizes) was the highest ever measured in a hatchery program.

    - **Mel S.** notes that there have been a few localized hatchery experiments. However, changes in hatchery practices are difficult. There is strong pushback from sports fishermen.

    - **Mike C.** points out that hatchery practice changes affect tribal fishermen also. We have retrospective coho and chinook data, and can use those to look at hatchery practice changes over time for specific stocks. Additionally, steelhead hatchery closures in Puget Sound this year provided some opportunity to draw inferences.

Retrospective Questions

- **Jim I.** would like to see more retrospective analyses documenting how the system has changed over the past several decades. Lots of money has been spent on fieldwork, but relatively little money has gone to retrospective work (scale/otolith analyses, historical samples, ocean conditions across decades).

    - **Carl W.** says that the Ecopath with Ecosim (EwE) model simulations they have done aggregated various trend data; the results showed that trends in survival could be explained through variation in ocean conditions or through predators, depending on how the model is weighted. In order to determine how much weighting is appropriate for each component of the ecosystem and to begin to understand mechanistic interactions, manipulations are required.

- **Sophie J.** comments that they have published oceanographic time series for all available data.
- **Neala K.** agrees that further retrospective studies are needed. Basic data compilation and story-building is lacking, at least in Puget Sound.

- **Chrys N.** comments that distribution and timing for many species in Strait of Georgia has changed: salmon, juvenile herring, pollock (which have been showing up in recent catches but have not been in the Strait for years). Some of the largest trawl catches used to be at the south end of Vancouver Island, but nowadays catches there are smaller or nothing. We need to look at multiple species and focus on time periods during which changes are actually occurring.

- **Carl W.** notes that the vertical organization of the salmon community has changed over time in the Strait of Georgia. In the 1970s, anglers fished for resident coho at the surface. Over the period of decline, anglers observed that birds and herring disappeared, and they switched to fishing for coho and chinook with downriggers – catching them at much deeper depths.
  - **Julie K.** asks whether the change in vertical distribution could have been driven by fishing pressures. **Carl W.** doesn't think so, since anglers had fished at the surface for half a century prior.
  - **Jim I.** has noticed the disappearance of herring balls over the year. Anglers' anecdotal information should be documented.

Other Issues

- **Carl W.** thinks it is fundamentally incorrect to categorize top-down effects and bottom-up effects separately. They are intimately linked; for example, foraging is controlled by both food supply and predation.
  - **Dick B.** says that the top-down/bottom-up concept is an artificial construct for organizational purposes, to enable communication between oceanographers and fish scientists. **Michael S.** agrees; the distinction is solely a way to facilitate conversation.

- **Dick B.** notes that studies in Cowichan Bay may not reflect typical estuary dynamics, because Cowichan Bay is highly altered. Studies in 2014 observed predators outside of Cowichan Bay but not inside, indicating different dynamics. Additionally, we need to remember that the ecosystem we observe now is different from the ecosystem 50 years ago.

- **Dick B.** thinks that there is not enough integration of studies and information between Puget Sound and the Strait of Georgia. He recommends a US-CA task team composed of scientists with different skills.

- **Carl W.** says that the assumption that more food availability translates to better growth is not true. If there is twice the food supply, a juvenile salmon will not eat twice as much; it will just spend more time hiding. When food supply is low, a juvenile salmon will not spend more time feeding and being exposed to predators; it will move on to a different area. Coho smolt size is similar across streams, even when food supply is different. They do not translate available food into growth; they translate it into survival.

  - **Dave B.** says that the balance between risk aversion and growth shifts when juvenile salmon move into marine waters such that growth rates are maximized. In marine waters, salmon display more risky behavior.

  - **Carl W.** disagrees, and says that predation risk is minimized in marine waters as well as in freshwater systems. Models of zooplankton supply predict more growth variation than is actually observed in marine systems.

- **Evelyn B.** thinks that identifying the spatial and temporal scales at which fish are responding is an important issue that is not addressed in current project efforts.

- **Barry B.** comments that a few years ago, the conclusion was that we have to first understand salmon ecology before concluding anything about hatchery effects. This contrasts with the current discussion, which posits that we have to manipulate hatcheries to understand hatchery-wild interactions before we can understand the ecology. **Carl W.** says this issue is chicken-and-egg.

- **Jim I.** recommends increased modeling efforts for two reasons: 1) communication: talking about the ecosystem as a whole and 2) the original EwE models need to be updated to include information we have learned over the past few years.

  - **Dave P.** thinks the value of models is for thought experiments and exercises, and to help develop manipulation experiments. For some species, like lingcod, fishing can explain trends without any environmental factors. However, there are lots of changes and issues that make it difficult to define what is driving salmon trends over time.

- **Dave B.** says an ongoing gap in the current juvenile salmon sampling in Puget Sound is that urbanized watersheds (Duwamish, Puyallup) were not included due to expense.

- **Michael S.** asks the group how to progress towards presenting the science in a holistic manner and creating a storyline.

  - **Chris H.** recommends revisiting the conceptual model for Puget Sound (or creating one for the entire Salish Sea) and using it as a central organizing tool to integrate the science and develop a narrative.

  - **Brian B.** suggests a salmon model similar to Correigh G.'s model for the Skagit. **Correigh G.** notes that population modelers would have concerns about simulating food changes.

  - **Dave P.** suggests that EwE models can be helpful in building a narrative, and predicting the effects of potential actions. EwE is capable of simulation exercises of management, stakeholders, and scientist actions.

  - **Carl W.** says that the Canadian Steering Committee is supposed to do the broader thinking about the project's narrative. **Michael S.** says the issue is how to functionally integrate the Strait of Georgia and Puget Sound into a full Salish Sea narrative, since each side of the border is organized differently.

Ecosystem Indicators/Data Catalog

Correigh G. presents a compiled list of indicators, in the context of high-graded Salish Sea Marine Survival Project hypotheses.

Available/Recommended Trend Data

- **Karia K.** notes that a 7-year dataset of parasite/pathogen loads will be available after phase 2 of their microbe screening project.

- **Peter R.** suggests also including long-term watershed datasets (e.g., pollution/wastewater releases, agricultural runoff/fertilizer use patterns, human population sizes, impervious surface area). This may help fill gaps in ultimate drivers.

- **Neala K.** suggests including additional non-salmon species (lingcod, pacific cod, etc.) to reflect the community assemblage. (Sidenote: Among and within year data on herring abundance over time would also be helpful)

- **Sandie O.** says there is contaminant trend data for a small number of species. Long-term contaminant trends can also be developed with sediment core samples.

- **Ken W.** suggests connecting with geographers who study land-use change in the Salish Sea. **Correigh G.** says there is a program trying to track land modifications within Puget Sound. However, development and land-use change may be different in Strait of Georgia.

- **Lance C.** notes that there are age data for salmon; the otolith analysis proposal suggests outmigrant growth as an indicator. Some collections are older than the 1970s.

- **Dave B.** would like to include turbidity trends and light increases in the night environment, since these could affect predation. **Francis J.** suggests noise levels in the environment also.

- **Dave P.** suggests synthesizing basin-specific airport wind datasets.

- **Correigh G.** suggests ways to expand time series for primary production: satellite data and/or geoduck shells.

    - **Dave P.** says that satellite data does not reflect the full water column (the amount which it does depends on water clarity), and may not adequately measure primary productivity. **Correigh G.** thinks looking at standardized anomalies may still be valuable. **Isobel P.** notes that there is a proposal to assess satellite data for the Strait of Georgia.

    - **Julie K.** notes that it is very difficult to get good satellite data across the whole of Puget Sound because of land contamination. **Correigh G.** says that there are scientists currently working to address the bleed-in to land in these datasets; a standardized anomaly might account for this also.

    - **Chris H.** suggests costing out the effort to synthesize these data.

  - Geoducks live 30-50 years and their shells can document environmental conditions via growth rings. Acetate peels from collected geoducks are archived by WDFW and PBS, so there is good opportunity for cross-border collaboration. These data would need to be standardized to account for local variability in productivity.

- **Other suggestions from the preceding conference call on Nov 18**
  - Additional sources of data on how the salmon community and overall species assemblage has changed over time may be valuable. For example, fishermen report that salmon have shifted to occupying deeper depths in the water column over the past decades.
  - Continue to compare and standardize datasets across the Salish Sea. Which exist in Strait of Georgia vs Puget Sound and are they comparable?
  - Compare algorithms and outcomes used for assessing Strait of Georgia and Puget Sound.
  - Compare JEMS, mid-basin Strait of Georgia, West Coast Vancouver Island, and Newport zooplankton data to see if species compositions are similar or different.
  - Compare herring data for Strait of Georgia vs. Puget Sound

Process Recommendations

- **Peter R.** suggests explicitly dividing anthropogenic stresses versus natural stresses, since this affects the conversation about mitigation and management.
  - **Dave B.** disagrees; human impacts are entwined with natural stresses, so it is more beneficial to use an integrative approach. **Peter R.** thinks that it depends on the goals of the exercise: if a goal is to affect management actions, managers will need distinction.
  - **Mike C.** notes that an indicator that predicts salmon survival well is still valuable, even if management actions cannot affect it.
- **Mara Z.** suggests discussion over the applicability of these indicators to the full Salish Sea versus individual basins (Puget Sound/Strait of Georgia). The current list is based on elements called out in research plans and does not indicate whether factors are differentially important across basins.
  - **Correigh G.** agrees that a synthesis of oceanographic indicator data across the Salish Sea is needed.
- **Jim I.** says that indicators need to be related temporally and spatially to the questions that each hypothesis is trying to answer; are we trying to explain the initial survival declines? Conditions now versus then? Interannual variability within the current oceanographic regime?
- **Peter R.** says that oceanographic and biological production indicators are helpful for forecasting but may not inform freshwater or early marine survival issues without additional information on habitat.

- **Evelyn B.** cautions that the baseline data used in modeling exercises must be carefully assessed, and error corrections should be included. The calculations Evelyn has done have produced estimates different from survival model estimates, because there are errors associated with outmigrant abundance, hatchery releases, etc. that are not corrected for in current models. There is underreporting of tag error and of fishery catches. Reporting rates have decreased over time.
  - **Dick B.** agrees; he doesn't believe survival rates calculated from CWT data, and no one puts error estimations on those interpretations.
  - **Mara Z.** says that lower marine survival results in lower CWT recoveries, which results in higher error in the survival estimate. For the coho study, all US data were CWTs from systems with creek-spanning weirs. Those estimates are very confident. **Jim I.** says the CA coho data were largely data-generated estimates of exploitation and survival using CWT data, and they spend several weeks checking data quality with individual hatcheries. Data quality was documented in the database as much as possible.
  - **Chrys N.** says they verify RMIS data with hatcheries, and the bigger issue is the survival disparity between hatchery and wild fish. Forecasting models assume that there is no hatchery/wild survival difference.
  - **Evelyn B.** says, anecdotally, hatchery reports and RMIS records do not agree in many cases. Dave P. agrees.

Breakout Sessions

Coho Task Team

The next steps for the coho marine survival work will progress down two avenues of investigation: 1) using Ricker midwater trawl data to understand early marine survival and behavioral differences during the early marine period in Puget Sound versus the Strait of Georgia and 2) relating coho survival trends to ecosystem indicators and strengthening the US-CA collaboration on ecosystem indicator work.

End-to-end modeling alignment

End-to-end modeling (ecosystem modeling, from physical characteristics through the biotic trophic levels) alignment is focused on concurrence around key information gaps/needs and associated output. At the 2013 US-Canada Retreat, the scientists concluded that better establishing the NPZ (nutrient-phytoplankton-zooplankton) component of ecosystem models is a critical need. At this 2014 retreat, the modelers agreed that the bio-energetics modeling being led by Dave Beauchamp and Marc Trudel is also critical to informing the greater ecosystem modeling effort. The US and Canadian scientists also continued to discuss the utility of using simple ecosystem models and a spatial life-history model (e.g., an elasticity analysis) in the near term for identifying data gaps.

Regarding current activities, the US scientists are framing an Atlantis ecosystem model and have proposals in place for funding. They are also working on analyzing basic datasets with an existing MoSSea, Salish Sea model, such as stratification, to see if there has been significant environmental change between now and the time period when salmon survival was higher, and working toward establishing the NPZ component to better inform the future Atlantis model. The Canadian scientists are simulating the migration and feeding of juvenile salmon from the Southern Strait of Georgia out through the northern passages to the Pacific Ocean (evaluating sensitivity to seasonal timing and year-to-year differences). This is being done by connecting two models by adding modules in each: 1) a ROMS model of Strait of Georgia circulation and the planktonic food web developed by Angelica Pena (an IBM module will be added); 2) Mike Foreman has an FVCOM model of the Discovery Archipelago – circulation + an Individual Based Model 'IBM' model, currently used to study the spread of viruses between aquaculture farms (a food web module will be added). These projects are longer-term, and there is good US-CA alignment in goals.

Bottom-up Sampling (Juvenile Salmon, Zooplankton, Physical Monitoring)

The juvenile salmon group agreed to determine whether Chinook and coho stocks are showing different growth and survival patterns as this will be valuable in assessing contrasting environments. In terms of US-CA coordination, juvenile salmon sampling is fairly well-aligned. There is more nearshore work in Puget Sound, since stocks appear to disperse more slowly than in Strait of Georgia. The Ricker will do midwater trawls in the Strait of Georgia every July and September for the foreseeable future. The Ricker can likely come down to Puget Sound on fall surveys, but July is difficult to do. If a trawler (e.g., Viking Storm or Frosti) could be chartered for Puget Sound, there is a CA net the US scientists can borrow. **Dave B.** remains concerned about the lack of offshore samples in the latter portion of the growth period (post-July), and that the purse seine cannot sample deeper in the water column.

The zooplankton group discussed training and consistency concerns for dispersed sampling programs. They would like to compare the JEMS station data to Strait of Georgia data. Also, they recommend comparing taxonomic identifications between US and CA groups as soon as possible. The US scientists will coordinate vertical tow and oblique tow sampling for 2015. The CA scientists will definitely do vertical tows, and are discussing oblique tows. The different types of tows capture similar information, but in a different way. There is potential for better correlations with oblique tows, if they can be sampled consistently well. However, it remains to be seen which tow-type is a better metric.

Physical monitoring approaches are more distributed, with sampling inconsistently disbursed in space and time, on both sides of the border, relying on a cadre of moorings, CTD casts, and ferry data. However, the physical data collected are generally comparable, with circulation models helping to expand these data and describe physical characteristics Salish Sea wide.

Top-down studies (Predators and contaminants)

The US and Canada have both pursued a technological solution to quantifying interactions between harbour seals and salmonids exhibiting poor marine survival. In Washington, steelhead were implanted with acoustic transmitters and seals were outfitted with transceivers to determine how often harbour seals detected juvenile steelhead during their outmigration. In BC, a development project was undertaken to create a head-mounted PIT tag scanner for harbour seals that could be used to quantify the number of PIT tagged salmon smolts consumed by pinnipeds. . This coming April, 40,000 PIT-tagged hatchery coho will be released from Big Qualicum Hatchery in the Strait of Georgia, in conjunction with 20 seals receiving head-mounted PIT tag scanners. In addition to these novel technological approaches, both sides of the border are assessing traditional diet analysis approaches to quantify predation rates on juvenile salmonids. In Canada, three important salmon bearing estuaries were targeted for two years of intensive harbour seal scat sampling, and a genetic diet analysis tool was developed to determine the species and life stage of salmon consumed by seals. The seal diet percentages generated from this effort are being integrated with bioenergetic and demographic information to estimate numbers of smolts consumed by the seal population. Similarly, the US is considering a multi-predator scat sampling design to determine the impacts of pinniped and seabird predators, informed by an extensive literature review that identified which species are probable steelhead predators. The US and Canadian predation projects may be converging on a predator diet analysis approach for predation quantification that combines traditional morphological identification of fish prey remains with modern genetic tools.

Data show that levels of persistent contaminants in the Salish Sea are problematic for salmon and their predators (humans, killer whales). Sediments can provide a good record of contamination over time and space, and provide opportunities to model food webs in terms of contaminants. Addressing these issues in a trans-boundary way is complicated; the group suggests paring down the list of concerns to focus on only a few (e.g., PBDEs, PAHs, and microplastics). Microplastics have not been studied in Puget Sound, but in Strait of Georgia they are found in zooplankton. The group recommends a trans-boundary expert meeting to discuss Salish Sea issues and draw guidance from experts in non-Salish Sea locations.

Data Sharing Plan and Updates

The shared Project goal is to make ecosystem data assessed through this effort comparable across the Salish Sea and readily available and usable for a variety of analyses, with a life extending beyond this project. This is vital to project objectives such as establishing and ecosystem indicators program for salmon adult return forecasting. In the near-term, the focus will be on data-sharing among Salish Sea Marine Survival Project participants (via Basecamp). As datasets become more formalized, LLTK/PSF will create a project management site on Basecamp for everyone to access data. The shared approach for establishing long-term, useable data is to focus on back-end data needs, including data standardization to improve aggregation on a variety of platforms and automating data aggregation and quality control (QA/QC). LLTK is looking to improve approaches to these back-end data needs. PSF continues to evolve the Strait of Georgia Date Centre as a central access point for Strait of Georgia data, and Puget Sound scientists continue to focus on established platforms such as NANOOS and NOAA's ecosystem indicators web site as access points for Puget Sound data.

Terry C. presented the Strait of Georgia Data Centre (sogdatacentre.ca), which is a central data repository for the Strait of Georgia marine ecosystem. It complies with international data management standards and an open access policy. The user can search metadata via browser, access data, and interactively map location data. The database automatically harvests metadata. Data can be output in a variety of formats.

SOG Data Centre current content includes data from BC Marine Conservation Analysis, Levings manuscripts and Excel spreadsheets, zooplankton biomass 1990-2010, benthic biota and geology samples, and Capital Regional District benthic invertebrate samples. Content in development include CODIS, OSD archive (CTD data), lighthouse data, Strait of Georgia literature, Pacific Biological Station data.

Collaboration Status and Suggestions

- **Dave P.** recommends a trans-boundary workshop to challenge a simple ecosystem model with different ideas. This would facilitate the next level of modeling and designing experimental studies.

- **Peter R.** says that much of the discussion thus far has focused on models and other quantitative approaches. However, qualitative information is important too – for example, there is a distinction between quantity and quality of prey sources. At the end of the day, what does a healthy ecosystem for salmon look like?

    - **Marc T.** says that prey quality is being assessed over the short-term (how amount/type of lipids affect growth) and eventually the long-term (how changes in prey quality affect returns).

    - **Dave P.** says that EwE was created to look at predator-prey dynamics. It is less useful for assessing contaminants, etc. From a broader perspective, current models sum all populations in a single model. However, it is becoming apparent that specific stocks and basins behave differently, and spatially explicit modeling is necessary.

- **Austen T.** asks whether a modeling framework exists which can accommodate synergistic effects of stressors on mortality.

    - **Ken W.** says there is a conceptual model called fitness windows, which may be a starting point.

    - **Karia K.** says that their project is assessing co-occurring microbes and challenges.

    - **Marc T.** points out that there are a huge number of factors and potential interactions that could affect salmon, and that we are not yet able to construct models with biologically realistic parameters. Marc thinks that starting from tractable hypotheses is more feasible. If data does not align with hypothesis predictions, reject that hypothesis. Contrasts and fluctuations are necessary to begin to weed out hypotheses and direct research (covariation must be minimized).

- **Sandie O.** says that her group plans to calculate the proportion of Puget Sound chinook that may be impacted by contaminants (with the caveat that there are lots of assumptions involved); she will provide those data to incorporate into EwE simulations.

- **Dave P.** points out that the one consistent and powerful correlation in models is that human impacts matter; the species people like to fish decline or vanish. The timescale needed for recovery from overfishing is variable and unknown for many species. **Chrys N.** comments that these correlations may reflect indirect or direct linkages, depending on the species.

- **Marc T.** recommends coordination of more discussion between fish scientists and oceanographers. All activities must be aligned towards the same goal. On the Canadian side, there needs to be more effort to create cohesion.

- **Andrew T.** comments that the SSMSP must lead to an understanding of declines and management recommendations. We must create a tangible product. Andrew (speaking for Carl W. and Dick B.) recommends being more proactive and experimental; take risky actions and see what happens.