"What specific research needs to be done to change the degree of belief in the hypothesis that you have been asked to address? Specifically, what type of practical and feasible research is needed to reduce critical uncertainties affecting scientific advice to management?"

TOMPKINS & WHITEHOUSE (May 10): Data overviews

- Potential Analyses:
  - Cluster analysis survival & productivity
  - Gantt diagram timing & path of migration
- Identify commonalities, signals
- Identify gaps – monitoring, investigation
  - Data on life-history stage specific survival is very limited

- Environmental factors and data reviewed in relation to the 2007, 2008, and 2009 returns highlight the need for a move away from broad indicators, towards indicators that are Fraser specific in nature
- Temporal and spatial patterns of migration after lake exit are not well known – making it difficult to know where or when to focus in looking for causes

PATTERSON (May 10): En-route mortality upstream

- Support current research programs working on in-river mortality
  - long list of projects (DFO, Academia, NGO's, First Nations etc.)
- Multidisciplinary approach: Life stages are connected
  - Fish condition when they leave the ocean effects in-river survival (e.g. Energy/Disease)
  - Quality/Quantity of eggs deposited after migration likely affect subsequent freshwater survival
- Fisheries Management:

1. Improve estimates: Better post-season estimates of mortality for more accurate productivity estimates; Better predictions of in-river mortality (fishing vs. "natural" mortality (Sprout); stock specific; Biomarkers); Catch and release estimates (all gear types – best practices); Discard mortality estimates (short term and long term)

2. Build models: Predictive models for pre-spawn mortality; Climate change modelling for Productivity and Escapement Planning

3. Quantification of Intergenerational Effects in relation to population productivity

- Habitat Management
  1. Habitat protection of migration corridors
  2. Habitat mitigation projects to improve fish passage conditions

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SELBIE (May 10): Freshwater habitat

- Consideration of Uncertainty (fisheries & habitat data)
  - Estimate data quality
  - Estimate spatial & temporal representativeness
- Data Gaps in Monitoring & Research
  - Identify critical areas of poor data coverage
  - Identify essential monitoring
- Freshwater Synopsis & Future Research
  - Comment on state of knowledge on freshwater contributors to stock dynamics in Fraser sockeye
  - Suggest targeted studies addressing fundamental gaps in freshwater ecology of Fraser sockeye salmon (outmigration info, measures of spawner "quality")

THOMSON (May 10): Ocean physics

- We need to know where the fish are in time and space! If we are to truly link salmon survival to the widely varying marine conditions in which they are swimming, feeding, and spawning, we need *simultaneous* data defining the location (where and when) of the fish and their ambient environment.

- We need to conduct process oriented studies

BEAMISH (May 10): Factors inside Strait of Georgia

Future stock assessments of sockeye salmon should include a series of indices that identify the return as good, average or poor. Juvenile Pacific salmon abundance surveys provide one index of adult production.

An index of plankton production would also be useful in assessing adult production.

TRUDEL (May 10): Factors outside Strait of Georgia

1. Where and when do juvenile Harrison River sockeye leave the Strait of Georgia?
   ⇒ Acoustic tagging of juvenile sockeye salmon caught in the fall

2. Were Fraser River sockeye growing at an unusually low rate in 2007?
   ⇒ Otolith microstructure and early marine growth

3. Were juvenile Fraser River sockeye in poor condition in 2007?
   ⇒ Lipid analyses of archived samples

4. Are the three "Harrison River" juvenile sockeye salmon that we caught in Southeast Alaska in 2007 from Harrison Lake?
   ⇒ Freshwater age determination from otolith microstructure

5. Is there a correlation between Chilko survival and timing of N. plumchrus?

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FORD (May 10): Marine mammal predation

Pacific white-sided dolphin

- Opportunistic predator of schooling fish; Only cetacean in region with potential to consume significant numbers of out-migrating as well as returning adult sockeye
- **Further studies needed to define seasonal and geographic variation in diet**
- No evidence of substantial change in abundance or distribution over past decade
- Role in sockeye decline unknown

Stellar sea lion

- Salmonids a significant component of diet during summer, though proportion comprised of sockeye is unknown
- Increasing abundance likely associated with increasing predation rates on salmonids
- **Studies currently underway to identify proportion of different salmonid species in diet and amount consumed.**
- Role in sockeye decline unknown

- More data are needed on current seasonal diet of both species throughout coastal waters, especially on proportions of different salmonid species
- Diet information should be incorporated into energetic models to estimate consumption rates for each species

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GARVER (May 10): Diseases

- Impact of enzootic diseases are unclear
  - Long term affects on growth, reproduction, and survival?
- Insufficient fish health data to predict what, if any, role disease has played in long term declines of Fraser sockeye
- Determine prevalence and abundance of pathogens in Fraser River sockeye
  - Comprehensive health assessment for multiple stocks throughout the life cycle, particularly marine phase.
- Better understand the relationship between infection and disease, especially the role of unfavorable environmental conditions
- Model disease impacts into fisheries models

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HARGREAVES (May 10): Sea lice

- Establish inter-annual variations in sea lice levels for juvenile sockeye in Strait of Georgia
  - Related studies in the Broughton Archipelago showed significant interannual variation in sea lice on wild juvenile salmon
- Establish inter-annual variations of infections with bacteria, virus or other parasites
  - Diseases other than those caused by sea lice may be significant determinants of sockeye health and survival
  - Sea lice may increase the risk of other diseases in juvenile sockeye
- Determine lethal and other impacts of sea lice on individual sockeye salmon in controlled laboratory experiments
  - Use protocols and methods already developed for the study of sea lice effects on juvenile pink and chum salmon
- Integrate and analyse health data from farmed and wild salmon in the Strait of Georgia and elsewhere to obtain a global assessment of pathogen dynamics
  - Establish an ecosystem-based perspective of sea lice ecology that includes wild and farmed hosts, multiple lice species and hydrodynamic modelling
  - Will provide a rational basis for establishing trigger levels on cultured stock

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MILLER (May 10): Genomic indicator

- Identify an infectious agent associated with the Viral signature
    - Develop a molecular marker and expand screening
- Establish whether prevalence has shifted over time during the decline, whether there is a correlation with recruitment/escapement, and impact of environmental conditions
- Challenge studies to determine whether the virus causes mortality directly or simply weakens fish and how it is transmitted
- Confirm behavioural impact of virally-infected fish in more years/samples
- Establish whether stocks that are doing well (e.g. Harrison) are also affected as well as prevalence in sockeye outside the Fraser River
- Establish effects on other salmonid species, in hatcheries versus wild fish, and in Atlantic salmon
- Identify potential mitigation measures to control infection-levels or viral-mediated mortality in the wild

IRVINE (May 10): Harmful algae blooms

Establish a proper monitoring program:

- Include areas away from salmon aquaculture operations, where there are few or no HAB data
- Include areas known to be important to outmigrating juvenile & returning adult salmon
- Examine diel patterns of distribution
- Isolate & culture harmful algae to fully identify these species, assess harmful levels, & develop non-microscopic methods of HAB detection (Major NOAA-sponsored project just beginning in Puget Sound)

Monitoring proposal developed with budget estimates

Spring 2010 was cool, but if May is hot, focused sampling recommended

[1]Adapted/expanded from unpublished March 2010 report prepared for J. R. Irvine by Nicky Haigh, Harmful Algae Monitoring Program (HAMP), VIU, Nanaimo

BEACHAM (May 10): Non-PST catch of Fraser sockeye

1. Spatial and temporal trends in adult recruits? No information available from non PST fisheries
2. Direct or indirect evidence? Rearing in non PST fishery areas, need to pass through areas where fisheries are conducted. Sample immature bycatch in Aleutian Island fisheries.
3. Specific research? Sampling of commercial fisheries in Alaska, to provide background for future PST negotiations.
4. Management action? Shape fisheries to reduce exploitation of Fraser sockeye.

Synthesis Workshop (May 28)

- Dick Beamish: Need more research to determine where sockeye go (when)
- Clarification of terminology (and consistent use): "productivity", "marine survival", "marine productivity", "decline", age notations, etc.
- Need data to able to partition freshwater effects (lake from river) and those from marine effects (not presently collected)
- Jim Irvine: More rigorous data analyses can be done (time series analyses, cross-spectral analyses, etc.)
- Stewart Johnson: Need more research on differences between "lake-type" vs. "river-type" sockeye (with respect to all hypotheses)
- Rick Thomson: "phase shift" idea (stationary process, variability stays the same, but timing shifts; step changes rather than gradual ones)
- Need sea lice data from fish farms (due Dec 2009, still not received?); consider direct AND indirect effects of sea lice; data from Discovery Islands
- Correlation in marine survival/productivity with other species sharing habitat & timing: herring/sardines, stickleback, Island Scallops data, eulachon(?), hake
- Predation: need more data on sea birds, squid, lamprey
- Patterson/Selbie: Spawning/incubation habitat still needs to be looked at in greater detail (land use, pine beetle, etc.)
- Forecasting: break down forecasts by regime type, more emphasis on estimate intervals rather than single point estimates