SALMONID RIVERS OBSERVATORY NETWORK (SaRON)

OF THE FLATHEAD LAKE BIOLOGICAL STATION
AND PARTNERS

Prepared by Jack A. Stanford, Program Leader
jack.stanford@umontana.edu
May 1, 2004
Revised November 9, 2004

The Flathead Lake Biological Station (FLBS) of The University of Montana (www.umt.edu/flbs) with the Wild Salmon Center (WSC) (www.wildsalmoncenter.org), Moscow State University (MGU) and other cooperators have assembled a multi-disciplinary team of scientists to document salmonid biodiversity and productivity, as controlled by natural and cultural processes, of a suite of pristine Pacific salmon river ecosystems (observatories). The research focuses on salmonid habitat requirements that appear to vary with life history stage and in relation to population structure. We believe that productivity of habitat is controlled by non-linear biophysical processes that create and maintain a dynamic or constantly **Shifting Habitat Mosaic** (SHM) throughout the river corridor from headwaters to the ocean. Human activities tend to reduce or dampen the variable nature of rivers in ways that should be predictable and, therefore, correctable given a robust understanding and modeling of salmon productivity and population dynamics in context of the SHM concept.

The program goals are: 1) to quantify biophysical processes producing the SHM and associated biodiversity in the observatory rivers, in context of influences on salmonid population structure and productivity; and, 2) to devise and promote a new conservation and management protocol for wild salmon rivers that is based on the SHM model.

The program is funded by the Gordon and Betty Moore Foundation (www. www.moore.org/) as a part of its Wild Salmon Ecosystems Initiative. The FLBS began the program in Kamchatka, Russia, in 2001 under a formal partnership with the WSC and MGU for work on the Kol and Utkholok Rivers. The Kamchatka work is conducted under the auspices of WSC and with logistical support of the WSC office in Petropavlosk as the Kamchatka Salmon Biodiversity Program (KSBP). In 2004 we began partnerships with the Yukon Delta National Wildlife Refuge of the US Fish and Wildlife Service (www.yukondelta.fws.gov/) for work on the Kwethluk River in Alaska and the Na'na'kila Institute (www.nanakila.ca) and Kitamaat Village Council for work on the Kitlope River in British Columbia, Canada. We expect to add another river to the observatory network during 2004-2005; the Stikine, Chickamen and Taku are being considered. We are proactively involving Federal, State, Province, Tribal, NGO and local entities with management or conservation interests in our sites and work. The Salmonid Rivers Observatory Network is planned for a 10-year period (2002 – 2012) to allow long-term measures of processes and responses. The initial 3-year funding period focuses on identification of observatory rivers, partnering, initial field measures and development of the SHM sampling protocol for cross-site comparisons.

Primary Objectives

- Document nonlinear ecological controls of Pacific salmon life history diversity and productivity as related to river-floodplain linkages for a suite of observatory rivers around the Pacific Rim, especially in context of marine-derived carbon, nitrogen and phosphorus subsidies within the shifting habitat mosaic that characterizes natural alluvial river systems.
- Compare/contrast results from the observatory rivers with the FLBS Biocomplexity and Microbial Observatory Programs funded by the US National Science Foundation that examine and model flux and transformation of carbon, nitrogen and phosphorus in relation to the shifting habitat mosaic on the Nyack Flood Plain of the Flathead River in Montana.
- Use research results to help partners and others foster an alternative salmon management and conservation paradigm that is based on habitat and food web dynamics in natural ecosystem context.

The research focuses on the mykizha (rainbow-steelhead, *Onchorynchus mykiss*) as an indicator of salmonid response to SHM variation between observatory rivers. Of the 12 species of anadromous salmonids on the Pacific Rim, steelhead have the most complex life history. Mykizha are similar to Atlantic salmon (*Salmo salar*) in exhibiting variable time in fresh water before migrating to sea (1 - 7 years), variable time at sea prior to maturation (1 - 5 years), variable distribution in salt water (estuarine to high seas anadromy) and strong proclivity to residualize or remain resident in freshwater but with considerable migratory behavior within the river system. We think that life history variation derives from environmental (ocean-estuary-freshwater) influences operating within genomic framework of the species and therefore responds to productivity and food web dynamics as mediated by the complex processes that drive the SHM. *Our general working hypothesis is that population structure and dynamics of the mykizha are robust indicators of general habitat conditions in freshwater and the ocean for all anadromous salmonid fishes as well as the attributes of riverine biodiversity that are associated with the relative complexity of the shifting habitat mosaic and marine nutrient subsidy of the observatory rivers.*

Observatory Rivers

- Kol River, Kamchatka, Russia – a clear water river (6^{th} order) on the west coast with tannic tundra tributaries on the coastal plain, including an adjacent tundra river, Kehkta, also being studied.

- Utkholok River, Kamchatka, Russia – a tannic, tundra river (5^{th} order) on the west coast; adjacent to two smaller study rivers, the Kvachina and Snatylvayam, also tannic, that are being studied in less detail.

- Kwethluk, Alaska, USA – a tannic, tundra tributary (6^{th} order?) of the Kuskokwim within the Yukon Delta National Wildlife Refuge; has a fish weir operated by the US Fish and Wildlife Service.

- Skeena, British Columbia, Canada – a very large (8th order) river in central BC; study focuses on a large floodplain reach near Terrace, B.C.

- Kitlope, British Columbia, Canada – glacially turbid river (6th order?) in the coastal rainforest area; entirely included in the Kitlope Conservation Area.

  Except for the Skeena, these rivers are within formal protected areas and are essentially intact ecologically, and management of the salmon runs is focused on production of wild fish.

The FLBS and WSC have established research/conservation camps at the Kol and Utkholok Rivers in Kamchatka, Russia, in cooperation with Moscow State University and other Russian scientific and management interests. Program researchers live in these camps. Long-term data collection on the Kamchatka Rivers began in 2001 and the camps are considered permanent. In Alaska we operate a mobile field camp with the US Fish and Wildlife Service on the Kwethluk River near Bethel, Alaska. The Na'na'kila Institute and Haisla First Nation are cooperators on operation of a similar camp on the Kitlope with a home base in Terrace, B.C. that also facilitates synoptic work on the Skeena. FLBS is working with Ecotrust Canada and other NGOs to develop a future, similar operation on one or a few other pristine rivers in Canada and Alaska.

Cross-Site Comparisons: Data Collection Protocol

1. River and estuary habitat complexity

FLBS has pioneered the use of remote sensing to classify quantity of river habitat using imagery from satellite (QUICKBIRD multispectral) and aircraft (AISA-hyperspectral; infared) platforms. Most of the catchment and estuary (only the lower portion of the Skeena) are imaged at least annually and a stratified random sampling procedure is used to select stream segments on each river system for detailed habitat classification and assessment using a suite of on-the-ground measures including:

- position of habitat type (GPS)
- description of habitat type (position relative to main channel, vegetation, depth, velocity) at various river flows
- temperature (point measures and recording thermisters)
- substratum size (point measures and automated image analysis)
- species-specific standing crops (dead and live trees, forbes, grasses, benthic algae, aquatic plants, fish and invertebrates from direct measures)
- production (abundance, growth rates) of fish.

Typology of habitats is being developed from analysis of these variables in relation to accuracy of image classification.

2. Routine biophysical variables in time series

A suite of variables are collected in continuous time series for cross-site comparison. In the case of the North American rivers, some of the data (e.g., run timing and escapement of salmon) are obtained from local observing stations operated by others.

Variable	Frequency of Collection	Method
Precipitation	Daily, year around	NOAA-type collector, manual measurement
Air temperature	Hourly, year around	NOAA temperature loggers
Water temperature	Hourly, year around	Vemco temperature loggers
River stage and discharge	Hourly, year around	Pressure transducer and data logger; calibrated by stage-Q relation from x-sec measures of velocity with ADP
Water turbidity,color, sp cond., DO	Daily, year around	Electronic meters
Adult fish passage (escapement biomass) by species –	Daily – weekly	Nonlethal enumeration at weirs or with DIDSON or other sonar or direct observation;
River insect biomass by species of flying adult stage	Weekly integrated samples	Light and pitfall traps; sweeping
River benthos biomass	Spring, Summer, Fall	Unit area kick net samples
Juvenile fish biomass passage by species	Daily-weekly	Fyke nets, screw traps and/or sonar: non-lethal counts
Habitat-specific fish standing crop biomass and behavior; juveniles and spawners	Daily-weekly	Underwater video and non-lethal electrofishing and observation by snorkeling.
Food web linkage	Spring, Summer, Fall	stable isotopes analysis of food web components

3. Specific routine measures of mykizha

This indicator species is examined in greater detail than in the routine monitoring including the following measures taken in time series:

- habitat use by life history stage (video, electrofishing)
- life history analyses from scales (non-lethal sampling)
- population structure from micro satellite dna analysis (non-lethal sampling)
- life history and maternal origin from otoliths (20 lethal samples per life history type and habitat type)
- physiological condition from lipid analysis (same 20 lethal samples)
- food web linkage from stable isotopes (same 20 lethal samples)

4. Focused studies

We are conducting a number of more detailed studies of floodplain ecology at the observatory rivers as foci for graduate thesis programs. Our objective is to train new scientists/managers/conservationists with a holistic, process view of salmon ecosystems, in contrast to the prevailing fish-centric view. These studies amplify particularly pressing questions or hypotheses about the linkages between floodplain habitat complexity (SHM) and population-level biodiversity of salmonid fishes and other biota.

Focused studies were initiated in 2004 and involve U.S., Canadian and Russian graduate students. Students assist the PIs in developing proposals for the National Science Foundation and other funders to leverage the investment by Moore and increase utilization of observatory sites. The graduate students live full time at the field sites and assist with the routine data collection as well as conduct these focused cross-site comparisons.

Brief descriptions of the focused studies are provided here with the understanding that detailed work plans are either already developed or in progress by the program team.

<u>Empirical and modeled analyses of *O. mykiss* life history variation</u>

We must fully understand the various growth, survival and reproductive traits associated with the array of life history types of O. mykiss per river system (anadromous, resident and variants). The routine analysis of *O. mykiss* samples described above provide much of the required information (juvenile otolith, stable isotope, lipids and length-frequency analyses, adult samples for fecundity, and life history analyses of scales and otoliths). However, additional, concentrated sampling will be required, including collections of juvenile *O. mykiss* in freshwater rearing areas throughout the summer and fall growing season and during the smolt outmigration in late May and early June to obtain samples for analysis of patterns of size and growth. Smolt samples will also be analyzed to determine sex ratio to evaluate if sex ratio at time of smolting is different from the sex ratio of returning anadromous adults in order to clarify the life history period at which the skew in the sex ratio of anadromous adults first occurs. Spawning areas will be surveyed starting in mid-May to observe spawning activity and determine the extent to which anadromous and nonanadromous phenotypes interact on the spawning grounds. The fecundity of adults sampled lethally in the fall (both resident and anadromous) will be measured to improve the sample size that has been obtained over the past two years. Most of these field studies will be complemented by the genetic analysis of the samples collected.

Analyses and modeling of the data will allow differences between life history types at key points in the life cycles to be identified. Identification of these differences will enable important trade-offs between the adoption of anadromous and nonanadromous life histories to be determined and the magnitude of these trade-offs estimated. Such information can be expected to improve our understanding of such critical issues as the determinants of anadromy and the relationship of habitat complexity and variation to life history diversity in salmonids.

Interspecific food web and behavioral relations of salmonid juvenile by habitat type

We intend to quantify behavioral interactions, especially interspecific competition for food and space, by the various salmonid species that are found in shallow water habitats within the flood plains of these rivers. A related objective is to determine if habitat selectivity by particular salmon species exists and natural how disconnection floodplain habitats may or may not influence behavioral patterns and growth in relation to food supply and predation. In 2003 at Kol, we also observed that certain species of leaf cutting moth larvae were very abundant. The moths were consuming the tall forb under story (shallamanik) of the streamside forests. These moth larvae were a primary forage item for juvenile fishes during periods of river flooding, suggesting a strong linkage between forest growth as enhanced by marine nutrients from salmon runs (see next) and energetics of the fishes in shallow near shore habitats. This research will describe these interactions in the context of riparian control on fish abundance and growth and marine nutrient cycling. These analyses will be done synoptically at all the sites to using the same methods.

Marine nutrient subsidy of floodplain soils and riparian tree growth

Riparian trees at the study sites should contain the legacy of salmon runs into these rivers. The problem involves isolating the marine nutrient signal by relating nitrogen isotope ratios in the tree cross section to tree growth by year and understanding availability of marine nitrogen in soils and groundwater. The current belief is that most of the marine nutrients reach the floodplain forest by bears and other animals carrying the salmon from the river into the riparia. However, hyporheic flow (recharge of floodplain aquifers with river water) likely is orders of magnitude more important because ground water flow is the hydrologic process that allows riparian trees to exist along rivers. Moreover, we have observed salmon carcasses by the tons entrained in the riparian forests after flooding. While some of the data needed to support these ideas, especially the relative strength of the marine N signal in relation to salmonid total run size, will be forthcoming from the time series measures above, focused cross site study of soil processing of marine nutrients and tree uptake and growth is required to fully resolve this issue.

Strong interactors in river nutrient cycling

We have observed amphipods, probably of estuarine origin, are very abundant at Utkhology-Kvachina-Snatolveyem and other rivers. We think that scuds are the primary consumers of salmon carcasses and thus strong interactors in cycling of marine nutrients. However, our work at Kol suggests that scuds are not very important there. Carcasses at Kol appear to be entrained in riparian vegetation and predominately consumed by blow flies and birds. Hence, we must conduct detailed study of carcass consumer ecology in the various habitat types and in relation to trophic structure. We envision experimental study of trophic structure and aquatic productivity in relation to carcass decomposition with and without scuds and other consumers.

5. Data and informatics management

The FLBS operates a sophisticated data management and archival system that uses a SQL server platform and serves the research team and outreach functions through a secure web site. Program participants view sampling sites as superimposed on a spatially explicit image of the observatory rivers. They can "drill-down" through data bases contained for each sampling site by simple click functions. Several other search modes are available and an upload or download protocol guides data entry and retrieval, but quality controls retrieval in context of researcher intellectual property.

Data bases in the system currently include:

- *Activity logs*—this is the daily record of activities in the field by the research teams, including descriptions of river conditions, weather and ecology.
- *Weather*—air temperature, rain, snow, etc
- *River and tributary stage, discharge*—data from the pressure transducers by hour and including the discharge calibration data from the ADP (stage;Q relation).
- *River and tributary temperatures and chemistry via field sensors*—this includes data from Vemco temperature loggers, measures with YSI temperature, conductivity and dissolved oxygen meters.
- *River and tributary chemistry from laboratory analysis*—this includes nutrient content (N, P and C variables) from field samples.
- *River and tributary biophysical data for SHM analysis and modeling* — all raw and analyzed data obtained to date. A sample number or data array number references files of results of analyses described above, including location of collection in latitude, longitude, life stage designation, morphometrics, scale image and data, otolith image and data, life cycle analysis results, otolith interpretations, tissue analysis results (stable isotopes, lipid content), tree core data, vegetation and habitat classification metrics, depth, velocity, substratum size and other physical data.
- *Remote sensing imagery* – data files containing hyperspectral and infared data and associated ground truth information, such as positions of large trees, structures, ATV tracks, stable channel reaches and various uniform plant patches.
- *Other digital images* – mainly digital photos of river structures or biota.

In all cases, metadata is included with the empirical data. Metadata is information about data, such as who sampled, who did analysis by what method and when, various notes and so on for each measure. The FLBS data manager sends data bases back to the researchers if the metadata or the actual measures are incomplete or thought to contain errors. Data are only filed in the data management system when completed.

The data management system contains all data, including a library of scientific papers published including all previous papers from the KSP and a separate library of papers relevant to the program (key references) derived from literature and data searches.

Primary Outcomes

- The main products of the research are scientific publications that substantially increase understanding of the ecology of salmon and salmon river ecosystems. These are listed on the FLBS web site and electronic copies are available where permitted by copyrights.

- Detailed habitat classifications in spatially explicit formats in time series are being produced for distribution to management and conservation partners.

- The FLBS internet-based informatics system is being developed initially for sharing of data among the program team and partners. This information will be opened to the general public as various aspects of the study are published. Partner organizations should benefit directly in their own work by following our lead in spatially explicit data management.

- The program team and partners will produce a general protocol for conservation of salmon rivers based on the SHM model as synthesized from information collected from the suite of observatory rivers.

Program Science Team

Professor (Dr.) Jack Stanford, Program leader – FLBS Director and Professor – Ecosystem processes

Dr. Xanthippe Augerot, Co-Program Leader – Wild Salmon Center Science Director and FLBS Affiliated Scientist – Geopolitics of salmon management and science

Academician (Prof, Dr.) Dmitry S. Pavlov, Co-Program Leader - Head, Ichthyology Department, Moscow State University (MGU) and FLBS Affiliated Professor – Ecology of Fishes

Professor (Dr.) Richard Hauer – FLBS Professor – Habitat assessment and image acquisition

Dr. Mark Lorang – FLBS Assistant Professor – Physical process measurement/modeling

Dr. John Kimball – FLBS Associate Professor – Ecosystem modeling

Bonnie K. Ellis – FLBS Senior Scientist – Microbial ecology, food web analysis; sampling quality assurance and oversight

Dr. Fred Allendorf –UM Professor – Salmonid population genetic analyses

Dr. Ksenia Savvaitova – MGU Professor of Ichthyology and FLBS Affiliated Scientist – Taxonomy and ecology of fishes, especially charrs

Dr. Kirill Kuzishchin –MGU Associate Professor and FLBS Affiliated Scientist – Life history variation from scale analyses, Kol camp science operations supervisor and science coordinator for all Kamchatka work (we propose that starting in 2005, Kuzishchin will coordinate cross-site comparisons at all the observatory rivers)

Dr. Marina Gruzdeva – MGU Scientist and FLBS Affiliated Scientist – Salmonid life history and productivity analyses and Utkholok camp supervisor

Dr. Jason Mouw – FLBS Senior Scientist – Riparian ecology; liaison to Alaska Fish and Game Department

Dr. Chris Zimmerman – Affiliated (USGS) Assistant Professor – Life history variation from otolith analyses

Dr. Peter Rand – Affiliated (WSC) Assistant Professor – Fish population dynamics (sonar applications) and liaison to State of the Salmon Program (WSC, Ecotrust)

Ms. Kathy Knudsen – Affiliated (UM) Scientist – salmonid genetics laboratory operations

Ms. Diane Whited – FLBS Scientist – GIS and remote sensing leader

Mr. Phil Matson – FLBS Scientist – GIS and remote sensing processes

Mr. Don Schenck – FLBS Scientist – data and informatics manager

Mr. Jim Craft – FLBS Scientist – Synoptic sampling coordinator for B.C. and Alaska

Mr. Jeremy Nigon – FLBS Scientist – computer and LAN operations

Ms. Kristin Olson – FLBS Scientist – analytical chemistry laboratory operations

Dr. Bob Newell – FLBS Scientist – aquatic invertebrate taxonomy and SaRON reference collection curator

Mr. Jake Chaffin – FLBS Scientist – Kwethluk River science supervisor

Graduate Students: Michael Morris (FLBS: MDN cycling); Michelle Anderson (FLBS: juvenile salmonid ecology), Nick Gayeski (FLBS: *O. mykiss* population models), Aaron Hill (FLBS: Kitlope food web studies); an additional FLBS and two or three Russian students to be added in by the end of 2004. CVs available at www.umt.edu/flbs.

Partners: Wild Salmon Center (Xan Augerot, Andrei Klimenko), Ecotrust (Ed Backus), Moscow State University (Dmitry Pavlov, Ksenia Savvaitova, Russian Co-PIs for Kamchatka research), Na'na'kila Institute (Kevin Dobbin); Ecotrust Canada (Gerald Amos). U.S. Geological Survey, Anchorage (Chris Zimmerman); Wild Salmonid Genetics Laboratory of The University of Montana (Fred Allendorf, Kathy Knudsen); Alaska Fish and Game (Jason Mouw); U.S. Fish and Wildlife Service, Bethel Alaska (Mike Rearden).

Kitlope/Skeena Field Crew (2004)

Aaron Hill – Lead Scientist and FLBS Graduate Student
Candice Wilson – Assistant Scientist and UNBC Environmental Studies Student (Haisla First Nation representative)
Rachel Wilkinson – Volunteer Assistant (UM Graduate, Ecology)

Kwethluk Field Crew (2004)

Jake Chaffin – Lead Scientist and FLBS Staff Scientist
Tyler Tappenbeck – Assistant Scientist (UM student)
FWS staff

Kol Field Crew (2004)

Kirill Kuzishchin – Kamchatka Science Coordinator and Kol Supervisor
Alexander Malsev – Assistant Scientist, MGU PhD student
Mike Morris – Assistant Scientist, FLBS PhD student
Michelle Anderson – Assistant Scientist, FLBS PhD student
Edick Goldza - Outfitter
Staff

Utkholok Field Crew (2004)

Marina Gruzdeva – Supervisor
Elizaveta Maslova – Assistant Scientist and MGU Student
Pavel Kirillov – MGU Scientist
Nick Gayeski – Assistant Scientist, FLBS PhD Student
Audrey Thompson – Volunteer Assistant Scientist
WSC-PK Staff