SALMON RECOVERY SCIENCE REVIEW PANEL

Report for the meeting held
December 15-17, 2003
Southwest Fisheries Science Center
National Marine Fisheries Service
Santa Cruz, California

This introductory material (pp. i-iii) is available on the RSRP web site, but as an aid to the reader we are now including it with individual reports.

Robert T. Paine	**University of Washington, chair**
Ransom A. Myers	**Dalhousie University**
Frances C. James	**Florida State University**
Russell Lande	**University of California – San Diego**
Simon Levin	**Princeton University**
William Murdoch	**University of California – Santa Barbara**
Beth Sanderson	**NOAA Fisheries liaison RSRP report coordinator**

Recovery Science Review Panel

The Recovery Science Review Panel (RSRP) was convened by NOAA Fisheries to guide the scientific and technical aspects of recovery planning for listed salmon and steelhead species throughout the West Coast. The panel consists of six highly qualified and independent scientists who perform the following functions:

1. Review core principles and elements of the recovery planning process being developed by NOAA Fisheries.
2. Ensure that well accepted and consistent ecological and evolutionary principles form the basis for all recovery efforts.
3. Review processes and products of all Technical Recovery Teams for scientific credibility and to ensure consistent application of core principles across ESUs and recovery domains.
4. Oversee peer review for all recovery plans and appropriate substantial intermediate products.

The panel meets three to four times annually, submitting a written review of issues and documents discussed following each meeting.

Expertise of Panel Members

Panel members have all been involved in local, national, and international activities. They have served on numerous National Research Council committees and have published many papers in prestigious scientific journals.

Dr. Robert T. Paine (chair), University of Washington

- *Field of expertise*: Marine community ecology, complex ecological interactions, natural history
- *Awards*: National Academy of Sciences member; Robert H. MacArthur award recipient from the Ecological Society of America; Tansley Award from the British Ecological Society; Sewall Wright Award from the American Society of Naturalists; Eminent Ecologist Award from the Ecological Society of America
- *Scientific leadership*: Member of multiple National Research Council committees, editorial boards, past president of Ecological Society of America
- *Research*: About 100 scientific publications

Dr. Ransom A. Myers, Dalhousie University

- *Field of expertise*: Ecology, Conservation, and Management of Marine Animals, Modeling and Statistical Ecology, Population dynamics
- *Awards*: The Great Auk Lectureship (1999), Awarded first Killam Chair in Ocean Studies, Dalhousie University (1996)
- *Scientific leadership:* Member of Science Advisory Boards for Sierra Club of Canada (2003), Oceana (2003), and Atlantic Policy Congress (2000), Member of Board of Directors: The International Oceans Institute of Canada (2000) and Natural Resource Modelling Association (1994-1999). Asked to testify at the U.S. Senate Commerce Committee Hearing on Overfishing (2003) and the House of Commons (Canada) Standing Committee on Fisheries and Oceans (2003)
- *Research*: More than 110 scientific publications.

Dr. Frances C. James, Florida State University

- *Field of expertise*: Conservation biology, population ecology, systematics, ornithology

- *Awards*: Eminent Ecologist Award from the Ecological Society of America; leadership and dedicated service awards from the American Institute of Biological Sciences
- *Scientific leadership*: Participant on National Research Council panels; service on many editorial boards; Board of Governors for The Nature Conservancy; past president of the American Institute of Biological Sciences; scientific advisor for national, state, and local activities
- *Research*: More than 105 scientific articles published

Dr. Russell Lande, University of California-San Diego

- *Field of expertise*: Evolution and population genetics, management and preservation of endangered species, conservation and theoretical ecology
- *Awards*: Sewall Wright Award from the American Society of Naturalists; Guggenheim Foundation; MacArthur Foundation; Fellow of the American Academy of Arts and Sciences
- *Scientific Leadership*: President of the Society for the Study of Evolution; International recognition; developed scientific criteria for classifying endangered species adopted by the International Union for Conservation of Nature and Natural Resources (IUCN)
- *Research*: More than 116 scientific publications

Dr. Simon Levin, Princeton University

- *Field of expertise*: Theoretical and mathematical ecology, evolutionary ecology, complex ecological systems
- *Awards*: National Academy of Sciences member; Robert H. MacArthur award recipient from the Ecological Society of America; Statistical Ecologist Award from the International Association for Ecology; Distinguished Service Award from the Ecological Society of America; Guggenheim Fellowship; Fellow, American Academy of Arts and Sciences; Fellow, American Philosophical Society; Okubo Prize, Society for Mathematical Biology and Japanese Society for Theoretical Biology; Heineken Environmental Prize, Netherlands Academy of Science.
- *Scientific leadership*: Member of many National Research Council committees; Science Board, Santa Fe Institute; Committee of Concerned Scientists; Past President, Ecological Society of America; Society for Mathematical Biology; Technical Advisory Council, BP-Amoco
- *Research*: More than 300 technical publications

Dr. William Murdoch, University of California Santa Barbara

- *Field of expertise*: Theoretical and experimental ecology, population ecology
- *Awards*: Robert H. MacArthur award recipient from the Ecological Society of America; President's Award from the American Society of Naturalists; Guggenheim Fellowship; elected American Academy of Arts and Sciences
- *Scientific leadership*: Founder of National Center for Ecological Analysis and Synthesis; Director of Coastal California Commission 10-year study; scientific advisory panel member for the Habitat Conservation Plan for the California marbled murrelet
- *Research*: More than 125 scientific publications

Dr. Beth Sanderson

- NOAA Fisheries liaison to the Recovery Science Review Panel
- Recovery Science Review Panel report coordinator

RECOVERY SCIENCE REVIEW PANEL (RSRP)

Southwest Fisheries Science Center, Santa Cruz, California

December 15–17, 2003

I. Overview

A full committee (James, Lande, Levin, Myers, Murdoch and Paine) met in Santa Cruz, certainly for the last time with the above membership. James, Levin, Murdoch and Paine will rotate off; the replacements have been determined. Our agenda is appended (Appendix A).

As noted in our previous evaluations of the challenges of salmon restoration in California, the handicap of very few time-series assessments of stock abundance is not easily overcome. When coupled to a different climate and with most species at the southern end of their geographic distribution, salmon recovery science requires development of and focus on different techniques than those characterizing recovery programs and TRT actions in the Pacific Northwest. It is clearly premature for the RSRP to advise nascent TRTs. Therefore in this report we focus on a variety of developing technologies and issues; no central or unifying theme predominates. In this report, we discuss the potential utility of a broad commitment to otolith geochemistry, the problem of how to manage anadromous and resident phases in the steelhead/rainbow trout complex, and the value of developing the concept of a habitat's "intrinsic potential". We also extend our previous comments on defining population structure and monitoring.

External Review Report, September 2003

The RSRP asked for and was provided with copies of the 2003 external review of the Southwest Fisheries Science Center. Our assessment is that the authors' conclusions accurately portray the strengths of the Southwest Science Center. Its general overview commented favorably on the balance of scientific endeavors, outreach to both the local and the scientific community, and a balance in staff composition and age structure. It suggested, and we agree, that Scott Creek be developed as a long-term research site. This relatively small, local, privately owned facility has on-going research on coho and steelhead. The studies there allow evaluation of competition between wild and hatchery adult fish as they return together. The external review also noted the absence of salmonid data as "…clearly a barrier to thoughtful recovery plans…." We concur. We had identified this challenge in our earlier (March 2002) analysis of salmonid recovery plans in California. We now note, below, with satisfaction that there has been subsequent progress in developing databases vital to recovery planning for salmon ESUs.

II. Population Structure and Life History Diversity

Genetics, Resident/Anadromous O. mykiss*, and Reintroductions*

Empirical research on salmonids at the Southwest Fisheries Science Center (SWFSC) focuses on impressive high-tech approaches to the analysis of population structure, using molecular genetics and otolith micro-chemistry (NMFS SWFSC 2003). These approaches have begun to produce data that should prove quite useful in understanding the evolutionary history and current genetic and demographic structure of populations, which will be important in restoration efforts.

A significant feature of many stocks of *Oncorhynchus mykiss* on the west coast is the coexistence of anadromous steelhead and resident rainbow trout. Under natural conditions such populations often experience two-way gene flow.[1] In addition, artificial barriers to migration have produced many resident populations that are closed to immigration and gene flow, or have resulted in one-way gene flow out of resident populations. In some cases habitat destruction and alteration have extirpated the anadromous component of the population system. Recently land-locked resident populations, which sometimes still produce anadromous forms with some frequency, could be used to reintroduce and successfully establish self-sustaining anadromous populations. The potential success of restoring anadromous populations from existing resident stocks depends critically on the current fitness in the ocean of anadromous forms produced by resident populations and on the quantitative genetic variation available for life-history evolution that remains in these resident populations.

Adaptation of a natural population to two environments, with both resident and anadromous components of the population, bears a close resemblance to evolutionary processes involved with gene flow between hatchery and wild anadromous populations of both coho and chinook salmon (Myers et al. 2004). When barriers to immigration (partially) isolate a resident population, it undergoes an evolutionary process similar to the -adaptation that occurs in a hatchery population with limited immigration from the wild-spawning population. This inevitably involves increased fitness for survival and reproduction in the resident environment and decreased fitness for ocean survival. Such life-history tradeoffs that can be described in terms of genotype-environment interactions or negative genetic correlations of fitness (or some components of fitness) among related genotypes developing in different environments (e.g. Via 1984a, 1984b, Via and Lande 1985).

Observations from a resident population of *O. mykiss* created in 1926 by artificial introduction into an Alaskan lake show that this population still produces an appreciable frequency of anadromous forms. Thses forms, however, have greatly reduced marine

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J. Ruzycki and M. Flesher, [affiliation/address/date] pers. comm.

C. Garza [affiliation/address/date] pers. comm.

survival, only one-fourth to one-fifth as high as that from the anadromous population (Thrower and Joyce 2003). Parallel experiments with anadromous × resident hybrids suggest that these effects are most likely due to adaptation of the resident population to survival in freshwater rather than to past inbreeding of the population (Thrower and Joyce 2003, Thrower et al. in press). These studies are near the stage at which it would be possible to estimate quantitative genetic variation for life-history parameters relevant to the possibility of using a resident population to restore an extinct or endangered anadromous population. We were informed that his work is likely to be stopped due to lack of funding from the agency. This is extremely unfortunate given that such information is critically important to assess the utility of historically land-locked resident populations for restoring extinct or endangered anadromous runs.

Two reasons can be suggested why it is desirable to restore self-sustaining anadromous populations of steelhead where they have been previously depleted or extirpated, while maintaining the associated resident populations of rainbow trout:

1. Increasing the number and geographic range of local anadromous populations will increase ESU viability by increasing total population size and increasing the diversity of local adaptations both of which improve the resilience of the ESU to local and regional environmental perturbations (McElhany et al. 2000); increasing the number and density of local populations also reduces the risk of metapopulation-level Allee effects (Lande et al. 1998).
2. Life-history diversity provided by resident populations can help to buffer the ESU against risks of depletion or extirpation of anadromous populations during periods of poor ocean conditions and/or anthropogenic threats.

We therefore recommend that NMFS place priority on continuing molecular and quantitative genetic studies and ecological experiments on resident populations of *O. mykiss* with different levels and histories of gene flow from anadromous populations, including historically land-locked populations (Thrower and Joyce 2003), throughout the range of the species. It is also important that state agencies curtail their current practice of widespread introduction and stocking of non-local stocks of rainbow trout into rivers and lakes, to conform with current limitations on translocations of anadromous stocks.

Otolith Geochemistry

Fish, including salmonid, otoliths are rapidly gaining recognition as “natural tags,” capable of identifying natal environments, duration of fresh and salt water residency, migration routes, etc. (Campana and Thorrold 2001, Thresher 1999). The otoliths themselves are aragonite concretions in fish inner ears, secreted continuously during the individual’s life, and are relatively insoluble and therefore permanent. These daily increments thus can be treated as a biological clock. Their analysis potentially provides a chronology of life history events independent of but entirely complementary to stock genetic analyses. The analyses are hardly infallible and are probably in their scientific infancy (Thresher 1999). Linking otolith biochronology to their recorded geochemistry promises new insights into such fundamental questions of salmonid biology as straying of hatchery fish, geographic origin of unmarked wild fish, chronological changes in juvenile environment (e.g., relative duration of the freshwater and estuarine stages of known-origin Chinook salmon), and the important issue of whether known rainbow and steelhead crosses have or can develop an oceanic phase.

The last issue is perhaps the most immediate. Steelhead salmon and rainbow trout are conspecific. They interbreed: steelhead are anadromous (A), and in California and elsewhere are known to be locally extinct, threatened, or endangered. Hatchery supplementation exists. Rainbow trout are resident (R), non-anadromous, and often abundant fish with actively supplemented distributions and abundances. Otolith microgeochemistry offers the potential to track the fate of A × R crosses in both fresh and salt waters. Further, the relative contributions of R to A gene pools, and vice versa, classified by stock or drainage system, should be possible. Distinctive otolith chemical signatures will permit discrimination of unmarked hatchery and wild fish.

The presentations by Rachael Johnson and Chris Donahoe clearly identified the potential of otolith chemistry and micromorphology to reveal features of salmonid biology that must be understood if they are to be managed effectively, or when or where attempts are made to restore endangered stocks. We encourage the Center both to continue these lab-based investigations and in particular to couple them with manipulative field studies. The RSRP committee further suggested that for certain fish the otoliths (left and right) be subjected to identical isotopic and morphological analyses be carried out to check on the level of intra-individual homogeneity. The suggestion was made that "doping" of carefully selected hatcheries could produce unambiguous isotopic signatures, thereby increasing the certainty of source. Alternatively, because of the expense of these analyses, efforts to develop the analytical utility of other fish structures (e.g., fin rays) should be continued.

III. Intrinsic Potential

TRTs that don't have estimates of past abundances for their ESUs are faced with estimating them from records of past harvest, such as from old cannery records, or developing even more indirect methods. At the meeting, Gordon Reeves (USDA Forest Service, Corvallis, Oregon) described progress with one such method undertaken in the Coastal Landscape Analysis and Modeling Study (CLAMS) to estimate the "intrinsic potential" (IP) of a stream or watershed to support fish. IP is defined as the geometric mean of suitability values (which range from 0 to 1) based on the channel gradient, valley constraint, and mean annual discharge for stream reaches on the order of 50-200 m in length. Reeves's example was based on digital topographic data for two large basins (Tillamook Bay and Nestucca River) in coastal Oregon. Because there are known links between where steelhead (*Oncorhynchus mykiss*) and coho salmon (*O. kisutch*) thrive and topographic features, it is possible to use topographic information to estimate the attribute IP separately for the two species. Steelhead thrive where stream gradients are high; by contrast, coho salmon use slower water in marshy wide valleys. High IP values can indicate where there is the greatest potential for conservation benefit. The addition of another data layer for land ownership adjacent to high IP areas showed that high IP values for steelhead are mostly adjacent to public forestry land, whereas high IP values for coho salmon are mostly adjacent to private agricultural and urban land.

Several TRTs have begun to use this methodology to estimate past abundances and to identify priority areas for either protection or restoration. Those TRT's working on coho salmon in Oregon are using IP results with increasing confidence due to the apparent concordance of predictions with other population estimates. The incorporation of information from analyses of water temperature allows some improvements because it can help eliminate areas that are probably too warm for juvenile salmon during the summer. TRTs in Oregon and northern California are using IP results as proxies for population size in simple models that predict potential demographic connections between populations as a measure of population independence. The Central Valley TRT has used the steelhead IP model, but mostly as an exploratory tool. The South Central-Southern California TRT also has the steelhead IP at its disposal. The North-Central California Coast TRT has applied a version of IP for chinook salmon to predict potential habitat along the coast and hopes to soon have a GIS database with information on the distribution of the coastal chinook evolutionarily significant unit (ESU). Overall, the TRTs are finding the IP approach to be a useful new analytical tool. Our only comment is that indices such as IP that involve the multiplication of variables presume tradeoffs among them, so it is prudent to watch out for the possible loss of relevant information in their construction.

IV. Monitoring

Review of Survey Design For Estimating the Abundance and Trends of Salmon in Rivers

Review of Survey Design For Estimating the Abundance and Trends of Salmon in Rivers

- **a.** A noticeable deficiency in ongoing research is the paucity of quantitative genetic studies of life-history characters and basic ecological approaches to field monitoring of population sizes and trends and their relation to environmental factors. This is reflected in the continuing paucity of population data, which has severely hampered restoration planning. The SWFSC has engaged the California Department of Fish and Game (CDFG) in collaboratively designing a monitoring program to collect population data necessary for effective recovery planning and evaluation of population and ESU status. Because this is a central problem that needs to be solved, we urge the two agencies to make sure that data collection begins in the very near future and is done according to a rigorous sampling design. If for some reason CDFG is not in a position to carry out the sampling, we urge SWFSC to investigate urgently alternative ways of obtaining these essential data.
- **b.** Bruce MacFarlane reported that the ecology of juvenile salmon in California is probably severely negatively affected by the joint effects of dredging, chemical pollution, changes in zooplankton, and the presence of exotic species, both in the freshwater delta confluence of the San Joachin and Sacramento Rivers and in the estuary of San Francisco Bay. The poor health of both freshwater and salt marshes is reflected in poor growth in juvenile salmon generally. Further work to clarify what resources are different in Scott Lagoon, where juvenile salmon grow better, would be useful.
- **c.** George Watters explained that data from archival tags on chinook that record the depth and water temperature that the fish are experiencing in the ocean can be summarized to characterize “essential fish habitat”. Such relationships, along with data on predation and ocean productivity, are contributing to state/space models that account for the fitness and maturity of fish returning to fresh water.

Here we review methods that are being used and proposed for the estimation of the abundance of spawning salmon, salmon parr, and habitat quality in rivers in Oregon (Stevens 1997, 2002). The objectives are twofold: to describe the status of the measured variables, and to describe their trend over time.

The proposed design-based Horvitz-Thompson estimator estimator makes minimal reliance on model assumptions. We find that the use of this estimator is reasonable for the design, and is statistically appropriate.

The sampling design described in Stevens (2002) is spatially balanced, in the sense that it takes into account that the sampling in streams occurs in a 2-dimensional landscape. The design explicitly takes into account the 3-year life cycle for female coho that occurs for almost all females in the Oregon and Washington rivers. That is, each site is sampled in multiples of 3 years. The design call for 25% of the sampling to be done at sites that are sampled every year, 25% of the sampling to be done at sites that are sampled every 3 years, 25% of the sampling to be done at sites that are sampled every 9 years, and 25% of the sampling to be done at sites that are sampled every 27 years. According to this protocol, 50% of the sampling is done at 9 or 27-year interval. The longer-term surveys (9 and 27 years) will not be very useful for trend estimation, which is one of the prime uses that will be made of these data. The design might be better served by putting more effort in the sites that are sampled more frequently, i.e. perhaps by using 50%, 30%, 15%, 5% allocation.

We are concerned that the proposed sampling design will not best serve the estimation of ocean survival. For ocean survival, the number of smolts that go to sea and subsequent returns need to be estimated. This estimation is best done by combining return rates from specific sites, to take into account the large site-to-site variability. In the proposed sampling design, this can only be done with the 25% of sites sampled every year.

Finally, there is a large amount of data that could be used to estimate the spatial scale of recruitment and survival variability in rivers and in the sea. The meta-analysis by Myers et al. (1997) showed that the spatial scale of recruitment in rivers is usually very small, i.e. in-river survival was not correlated for distances larger than 50 kilometers. However, the authors found that at-sea survival had a much larger spatial scale. It would be useful to carry out such an analysis with existing data before implementing new sampling designs.

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Appendix A

Recovery Science Review Panel Meeting Agenda

15-17 December 2003, Santa Cruz Lab 15 December 2003

9:00 – 9:15 Welcome, logistics, overview of meeting – Churchill Grimes

Theme: SCL research and data collection to support recovery science in California

9:15 – 9:45 Studies on the ocean and estuarine ecology of juvenile salmon (Bruce MacFarlane)

9:45 – 10:15 Ocean variability and salmon dynamics (George Watters)

10:15 – 10:30 Determining production sources, spatial structure & population dynamics of chinook salmon using otolith microchemistry and microstructure (Rachel Johnson)

10:30 – 10:45 Break

10:45 – 11:15 Comparative Life History Studies of Wild and Hatchery Salmonids (Sean Hayes)

11:15 – 11:45 Population genetics of California salmonids – Carlos Garza

11:45– 12:00 Coastal Monitoring Project – David Boughton

12:00 – 1:00 Lunch

Theme: TRT review and progress: focus on SCL TRTs

1:00 – 1:15 General overview of TRT progress and status

1:15 – 2:00 Modeling Intrinsic Potential for Salmonid Habitat – Gordie Reeves

2:00 – 2:45 Population structure of coastal salmonids – Eric Bjorkstedt

2:45 – 3:00 Break

3:00 – 3:45 Population structure and viability: Central Valley – Steve Lindley

4:00 – 5:00 General discussion (TRT Chairs' meeting ?)

Social Hour and Dinner

16 December 2003

Theme: Connectivity between resident and anadromous salmonids (with a focus on O. mykiss) and implications for risk and recovery

9:00 – 9:30 Overview: resident-anadromous O. mykiss – Pete Adams

9:30 – 10:15 Review : resident-anadromous links in Oncorhynchus – Chris Donohoe

10:15 – 10:30 Break

10:30 – 11:15 Relationships among life history forms of O. mykiss using microchemistry (Chris Donohoe)

11:15 – 12:00 Effects of 70 Years of Freshwater Sequestration on Survival, Growth, Early Maturation and Smolting in a Stock of Anadromous Rainbow Trout (Oncorhynchus mykiss) from Southeast Alaska – Frank Thrower

12:00 – 1:00 Lunch

1:00 – 1:45 O. mykiss life-history investigations in Northeast Oregon – Jim Ruczycki

1:45 – 2:30 Genetic studies of resident-anadromous linkages – Carlos Garza

2:30 – 2:45

Break 2:45 – 4:00

General discussion 4:00 – 5:00 RSRP discussion & drafting report.

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9:00 – end: RSRP discussion & drafting report.