Bonneville Power Administration
FY 2003 Provincial Project Review

PART 2. Narrative

Project ID: 35024

Title: Evaluating the sublethal impacts of current use pesticides on the environmental health of salmonids in the Columbia River Basin (Revised Proposal – Resubmitted March 7, 2003).

Section 9 of 10. Project description

This project proposal is directly tied to three other proposals submitted for review (35019, 35020, and 35048). Together these four proposals form a pilot program approach to a comprehensive status and effectiveness monitoring program for Columbia River basin salmonids and their habitat. This suite of proposals aims to implement the critical missing components (status monitoring, effectiveness monitoring and data management) of a regional Research, Monitoring and Evaluation program as called for in the 2000 NMFS FCRPS Biological Opinion (RPA Action Items 180, 181, 183 and 198). While all attempts to make each proposal a stand-alone project have been made, the four projects have been developed in concert to meet independent, yet closely related, RME needs of the FCRPS BiOp implementation plan.

a. Abstract

Project #35024, entitled "Evaluating the sublethal impacts of current use pesticides on the environmental health of salmonids in the Columbia River Basin" was submitted to the Mainstem/Systemwide Province in 2002 for funding consideration via the Northwest Power Planning Council's Fish and Wildlife Program. In October of 2002, the proposal was recommended as "Urgent" by the Columbia Basin Fish and Wildlife Authority (CBFWA). The following month, the proposal received a "Fund" recommendation from the Independent Science Review Panel (ISRP). More recently, the Bonneville Power Association (BPA) moved Project #35024 to the "Critical Needs" category, contingent on a revision of the original proposal to address water quality data needs under the BiOp RME Program. Reasonable and Prudent Alternative (RPA) Action 183 requires that water quality, a major habitat action, be assessed to obtain enough information for a complete evaluation at the five and eight-year check-in points (FCRPS BiOp page 9-170). At least two studies focusing on water quality within the Columbia River Basin must be implemented no later than 2003. To meet the information requirements mandated by RPA 183, Project #35024 was extensively revised and expanded. Both studies included under Task 1 in the original proposal (rapid phenotypic screens in zebrafish) were removed. The focus of this revised proposal was shifted from the Mainstem/Systemwide Province to water quality and habitat conditions in the Yakima subbasin (Columbia Plateau North Province) and the Wenatchee subbasin (Columbia

Cascade Province). Thus, the Middle Columbia Steelhead ESU (Yakima) and the Upper Columbia Steelhead and Spring Chinook ESUs (Wenatchee) are the new focus of the proposed research. The revised project has the following specific aims for FY03: 1) Select specific geographical locations within the Yakima and Wenatchee subbasins for water quality monitoring; 2) Identify and collect existing environmental data (chemical, physical, and biological) for selected monitoring sites from federal, state, tribal, and local agencies and entities; 3) Identify key data gaps specific to water quality, other major habitat characteristics, and salmonid abundance or productivity; 4) Develop GIS-based tools to integrate existing land use, environmental monitoring, and salmonid distribution data; 5) Develop life cycle models for spring chinook and steelhead in both basins; 6) Develop an experimental work plan that will address these data gaps and ultimately evaluate the importance of water quality for off-site habitat mitigation in the Yakima and Wenatchee subbasins. This work plan will be available for external review by the end of FY03, and will be implemented in FY04-FY07. In addition, new laboratory infrastructure for salmon health research will be developed. This will allow for the completion of the core components of Project #35024 (Task 2) – that is, the effects of common environmental contaminants on salmon physiology, behavior, survival, and migratory success – during the implementation of the new work plan. Given the emphasis on land use and watershed processes in the revised proposal, Dr. Tim Beechie (Acting Manager, Watershed Program, Northwest Fisheries Science Center) was added as a Co-Principal Investigator. To ensure the successful completion of FY03 specific aims, several additional Center scientists with expertise in stream geomorphology, salmon habitat assessment, salmon life cycle modeling, population biology, and GIS technology were included as contributing investigators for FY03.

b. Technical and/or scientific background

For a technical discussion of pesticides and degraded water quality throughout the Columbia River Basin, please refer to the original version of Project #35024 at: http://cbfwa.org/files/province/systemwide/projects/35024.htm. The scope of the revised proposal has been expanded to include several other classes of environmental contaminants that may limit the productivity of wild salmon populations in major tributaries to the Columbia River. The rationale for an expanded scope is provided below.

A central assumption of the 2000 FCRPS BiOp is that the negative impacts of the hydropower system on fish survival can be offset by mitigation of anthropogenic degradation of habitat in major tributaries to the Columbia River. Accordingly, the success of habitat recovery actions depends on a scientific understanding of which kinds of anthropogenic impacts place the greatest limits on salmonid productivity. Throughout the Pacific Northwest, it has been generally assumed that physical habitat characteristics are more important than water quality. Even where water quality is relatively degraded, such as in small streams in urban watersheds, habitat recovery efforts have almost exclusively focused on physical parameters – the restoration of normal stream flows, stream temperatures, substrate, off-channel habitat, large woody debris, and the like. However, in Seattle, where more than $26 million dollars have been spent to restore urban stream habitat since 1999, recent monitoring studies have documented widespread die-offs of adult coho returning to these streams to spawn. In the fall of 2002, almost 90% of returning females died prior to spawning in one restored stream. The cause is very likely to be pollutants contained in non-point source stormwater runoff (http://seattlepi.nwsource.com/local/107460_coho06.shtml). Two inferences can be drawn from these recent observations: 1) monitoring is a critical element of habitat recovery planning, and 2) plans that ignore water quality may fail to meet their recovery goals in river systems that receive significant loads of anthropogenic contaminants. This includes many of the major tributaries to the Columbia River, and especially the lower Yakima subbasin (e.g., Rinella et al., 1999).

RPA 183 seeks to ensure that water quality improvements meet their desired objectives; namely, increased natural production from off-site habitats. In addition to the targeted goals of RPA 183 is the need to evaluate whether water quality conditions in different tributaries may undermine off-site habitat recovery efforts. If they do, then the natural production of various ESA-listed salmonids may not increase to the extent that it offsets the impacts of hydrosystem operations in the mainstem of the Columbia River. However, there are some important conceptual disconnects between these two aims of RPA 183 and the indicators that have been selected as representative of water quality – i.e., pH, dissolved oxygen, nitrogen, phosphorous, and conductivity (Hillman and Giorgi, 2002).

First, "water quality" is too narrow a term to capture the mechanistic linkages that can occur between chemical habitat quality, salmon health, and the distribution or abundance of salmonids at different life history stages. Depending on their patterns of habitat use, salmon in the Columbia River Basin may be exposed to hundreds of different environmental contaminants. Some of these are dissolved in surface waters, others are in contaminated sediments, and still others can be transferred to salmon via the aquatic food chain. A focus on water quality alone will only capture a subset of these different exposure pathways. Consequently, the conceptual framework for this proposal will be on salmon health, and the ways in which different habitat characteristics (including water quality) might impair the physiology, growth, behavior, or survivorship of ESA-listed salmonids in ways that will ultimately limit natural production. This will allow us to make explicit comparisons between the physiological effects of certain physical habitat parameters (e.g., stream temperatures) and chemical habitat parameters (e.g., toxicants). These kinds of direct comparisons are essential because the ultimate goal of this intensive research project is to help natural resource managers prioritize recovery actions in off-site habitats that have mixed physical, biological, and chemical degradation.

Second, the emphasis on nitrogen, phosphorus, conductivity, and a few other conventional water quality parameters is exceptionally narrow. For example, juvenile steelhead foraging in the lower Yakima subbasin during summer months are likely to be exposed to complex mixtures of agrochemicals that are specifically designed to kill or regulate the growth of biological organisms. Many of these chemicals, and particularly the insecticides, are an ecological risk for aquatic insects that provide a prey base for steelhead during critical growth periods. Other pesticides can interfere with nervous system function in juvenile salmon, and thus behaviors that are critical for survival and migration (please see references in the original version of Project #35024). Still others are suspected endocrine disruptors that could potentially interfere with maturation and smoltification in salmonids (e.g., Moore and Waring, 1998). Juvenile steelhead in the lower Yakima are also exposed to DDTs and other organochlorines from the aquatic food chain. The DDTs are persistent pollutants that sorb to fine sediments, and they are transported to steelhead habitat via agricultural return flows. Wild steelhead may also have body burdens of PCBs (Rinella et al., 1999) that originate from maternal transfer or historically contaminated sites. Juvenile animals are also likely to be exposed to heavy metals, including copper. Copper is highly toxic to the salmon nervous system (Baldwin et al., 2003) and is widely used in the Yakima subbasin as a fungicide on agricultural crops and also as an algicide in irrigation canals – the majority of which eventually drain into the mainstem of the Yakima River. In addition, juvenile steelhead are likely to be exposed to polycyclic aromatic hydrocarbons (PAHs) that originate from highways, roads and other impervious surfaces that drain into river systems in the lower subbasin. The overall point is that any of these major classes of contaminants could be as important as phosphorus or the other conventional parameters in terms of limits on salmonid productivity (Waite and Carpenter, 2000). In the proposed study, we will be as inclusive as possible when evaluating chemical habitat quality. If environmental monitoring or toxicological data indicate that a certain class of contaminants is a risk for ESA-listed populations, then these chemicals will be considered in the implementation phase of this project.

Third, to our knowledge, there have been no projects funded by the Fish and Wildlife Program that specifically seek to improve water quality by controlling the point source or non-point source transport of toxicants to off-site salmon habitats. Therefore, action effectiveness monitoring of specific water quality improvements projects under RPA 183 is not possible at this time. It should be noted, however, that there have been numerous efforts at the state level to improve water quality in both the Yakima and Wenatchee sub-basins. For example, in the Yakima, the Roza-Sunnyside Board of Joint Control received a $10 million loan from the Washington State Department of Ecology in 1998 to help finance the implementation of on-farm best management practices to reduce sediment loading to surface waters via irrigation return flow (see project description at: http://www.ecy.wa.gov/programs/wq/nonpoint/success/success-roza_sunnyside.html#Purpose). In subsequent years, this effort has reduced sediment loading by as much as 95%. Other water quality improvement projects, including those funded by the Centennial Clean Water Program, are also underway. Therefore, there may be opportunities to conduct effectiveness monitoring for projects that have been implemented outside of the Fish and Wildlife Program.

Overall, there is little question that major water quality concerns, including the current use pesticides, have not been adequately addressed by the Fish and Wildlife Program. As monitoring efforts in urbanized streams have recently shown, degraded water quality can undermine large-scale habitat restoration efforts that run into the tens of millions of dollars or more (N.L. Scholz et al., unpublished results, data available upon request). It is therefore imperative that water quality monitoring studies be implemented as soon as possible in major tributaries to the Columbia River. This is particularly true for subbasins such as the Yakima that have well-documented water quality degradation (Rinella et al., 1999).

We are submitting a revised version of Project #35024 that will address key data gaps pertaining to water quality monitoring as mandated by RPA 183. The proposed experimental research will consist of two distinct yet interrelated studies – one in the Yakima subbasin, and the other in the Wenatchee. An intensive monitoring effort in both subbasins will provide side-by-side comparisons of physical and chemical habitat characteristics at multiple sites within each tributary. Since the primary sources of water pollution in both systems are agriculture and urban land use activities, we will focus on the major classes of contaminants that are widely associated with these forms of anthropogenic degradation. These are nutrients, pathogens, insecticides, herbicides, fungicides, heavy metals, PAHs, and the persistent organochlorines.

Several planning efforts will also be initiated in FY03. First, multiple monitoring locations will be selected within each of the two tributaries. Geographical differences in water quality and the use of different habitats by chinook and steelhead will be important considerations in site selection. Second, we will identify and collect existing environmental monitoring data for each tributary. For example, there are significant opportunities for data sharing (and thus cost savings) in the Yakima if we include monitoring sites that are part of the U.S. Geological Survey's National Water Quality Assessment Program (NAWQA). Third, we will identify and prioritize key information gaps with respect to water quality (or, more appropriately, salmon health) in the two tributaries. Fourth, we will develop new GIS capabilities to incorporate existing data for habitat quality and salmonid habitat use patterns into geospatial data layers. These GIS layers will be explicitly linked to life cycle models (see below) for the three ESA-listed ESUs that may be adversely affected by degraded water quality in the two subbasins. Fifth, life cycle models will be developed. These life cycle models will provide a foundation for theoretical and empirical comparisons of different habitat characteristics - physical parameters, conventional water quality parameters, and different classes of toxicants - and how these relate to salmonid abundance or productivity at different life history stages. Finally, we will develop a work plan for new environmental monitoring in the two study locations. This work plan will provide a basis for intensive RME research in both study areas in FY04-07. The work plan will be available for external review and approval by the end of FY03.

It is important to point out that significant uncertainties have already been identified with respect to the functional links that exist between contaminant exposure, salmon health, and the empirical data needed for life cycle models (see the description of Task 2 in the original version of Project #35024). For contaminants in general, and water quality in particular, there are two sides to the risk equation. The first is the risk of exposure, and the second is the risk of an adverse affect – in this case, harmful effects to individual animals (or their prey base) that may limit the productivity of wild populations. In the context of the RME program, documenting exposure is relatively straightforward: contaminants are measured directly in surface waters, sediments, or tissues in the course of field monitoring protocols. Even with an aggressive field monitoring design, drawing explicit, "cause and effect" inferences between contaminant exposures and fish health consequences, as called for in the 2000 FCRPS Biological Opinion will be of modest statistical power. Indeed, without new salmon-specific environmental health information (i.e., "adverse affect"), it may be very difficult to estimate risk for ESA-listed species in any context (Scholz and Collier, 2000). Consequently, we will support our habitat monitoring with new toxicological studies. We will use existing laboratory infrastructure at NWFSC to conduct these studies. We will also add some new infrastructure during the planning phase of FY03. Collectively, these laboratory studies will address key data gaps indentified in the workplan, and will be carried out in the implementation phase of this project (FY04-07).

c. Rationale and significance to regional programs

Since pesticides are a major water quality concern for Middle Columbia Steelhead in the Yakima subbasin and, to a lesser extent, Upper Columbia Steelhead and Spring Chinook in the Wenatchee subbasin, the rationale and significance for the original and revised versions of Project #35024 are the same. This includes RPA 39.

The focus of the revised project is much more broad than the original pesticide proposal. Moreover, the approach is more discretely tailored to the needs of the RME program. Specifically, the revised project is intended to directly address RME data needs for water quality under RPA 183 and Action 9 of the 2000 FCPRS BiOp.

d. Relationships to other projects

All of the pesticide-specific relationships to other projects that were identified in the original version of Project #35024 are the same. In addition, the proposed work will constitute intensive monitoring and evaluation studies of water quality and salmonid health in the Yakima and Wenatchee subbasins. Accordingly, establishing relationships between this project and other projects in these two tributaries is a key element of the FY03 planning phase. The objective is to identify existing sources of environmental monitoring and salmonid distribution data that we can incorporate into new GIS data layers and life cycle models, respectively. There is considerable potential for cost savings in both basins. For example, millions of dollars have been spent in recent years on surface water quality monitoring in the Yakima as part of the USGS NAWQA Program (http://or.water.usgs.gov/yakima/). For certain contaminants, the availability of these data may obviate the need for additional (and costly) surface water monitoring. In FY03, we will identify all relevant monitoring studies, past and present, in the Yakima and Wenatchee systems. These existing RME data sources will be specifically considered in the FY03 work plan.

e. Project history

N/A – this is a new proposal.

f. Proposal objectives, tasks and methods

Revisions to Proposal #35024

Project #35024 was not specifically developed as a RME proposal when it was initially submitted to the Mainstem/Systemwide Province in 2002. Certain studies in the original proposal (all of Task 1) were focused on rapid, high-throughput screens to generate new toxicological data for common pesticides. These studies were to be conducted using a surrogate species (the zebrafish, Danio rerio). Although new toxicological data for early life history stages of fish are badly needed, the use of zebrafish as a general model is not a good fit for the salmon-specific research objectives outlined by RPA 183. Therefore, Task 1 was removed from the revised project proposal.

The investigations in Task 2, which address the impacts of degraded water quality on salmonid health and performance, were retained. These salmon health studies will be revised and expanded during the planning phase of FY03. The justification for expansion is that pesticides are only one of the major classes of anthropogenic stressors that must be considered by RME water quality studies in the Yakima and Wenatchee subbasins (Rinella et al., 1999). Laboratory and field studies on other classes of contaminants will be included, as appropriate, in the revised project work plan.

In addition to water quality investigations, there is a need for new field research that will meet RPA 183 data requirements for evaluating other aspects of off-site habitat quality in the two different tributaries. This includes (but is not limited to) data for geomorphological indicators, water temperature, sediment, channel structure, flow, riparian structure, and the abundance of macroinvertebrates. One of the overarching goals of our revised proposal is to compare the relative importance of water quality with these other habitat characteristics at multiple sites within each of the two study areas. A direct, side-by-side comparison will be necessary to identify which determinants of "salmon habitat quality" place the greatest limits on salmonid productivity in watersheds with mixed physical, biological, and chemical degradation.

FY03 Objective

The primary objective in FY03 (planning phase) is to develop an integrated work plan for understanding and monitoring the mechanisms by which contaminants alter salmonid population (or meta-population) performance in the Yakima and Wenatchee River sub-basins. The ultimate objective of the complete FY04-07 project (implementation phase) is to evaluate the importance of water quality for off-site mitigation in the Yakima and Wenatchee sub-basins, and specifically to assess how water quality degradation might affect salmon population performance, including adult migration and homing, juvenile survival, life history diversity, and spatial structure of populations and meta-populations. Thus, the work plan developed in FY03 will cover the three main objectives of the implementation phase of this project:

1) experiments and field monitoring to examine effects of water quality on salmonid fitness and survival,
2) field monitoring and mapping of environmental conditions in space and time, and
3) modeling effects on salmon populations.

The experimental studies provide a basic understanding of how different water quality parameters affect individual salmonids (e.g., habitat use, growth, or survival). Estimating how these parameters affect populations then requires mapping environmental conditions in space and time, and modeling their effects on populations via life cycle and meta-population models. The specific aims of the FY03 task include:

1) Select specific geographical locations within the Yakima and Wenatchee subbasins for water quality monitoring;
2) Identify and collect existing environmental data (chemical, physical, and biological) for selected monitoring sites from federal, state, tribal, and local agencies and entities;
3) Identify key data gaps specific to water quality, other major habitat characteristics, and salmonid abundance or productivity;
4) Develop GIS-based tools to integrate existing land use and environmental monitoring data;
5) Develop life cycle models for spring chinook and steelhead in these basins;
6) Develop an experimental work plan that will address these data gaps and ultimately evaluate the importance of water quality for off-site habitat mitigation in the Yakima and Wenatchee subbasins.

It should be emphasized that the revised version of Project #35024 is, first and foremost, a monitoring and evaluation proposal. This reflects an assumption that real empirical data supersede modeled data for the purposes of recovery planning. The primary objective is therefore to identify and obtain existing monitoring data and, where necessary, collect new data for habitat conditions, fish health, and salmonid abundance at each monitoring location. Since we cannot monitor continuously throughout each tributary, we will use GIS-based technologies and fate and transport models to infer habitat conditions in unmonitored locations. Moreover, we will use life cycle models to integrate cumulative effects across the different life history stages of ESA-listed species that use degraded habitats for different periods of time. Our specific aims and their associated methods for this FY03 task are described in more detail below.

Specific aim 1. Identify monitoring locations.

We will first evaluate existing water quality monitoring locations (e.g., NAWQA study sites in the Yakima) for their suitability as reference or treatment sites, considering such site attributes as channel slope, stream discharge, elevation, and watershed characteristics. To the extent possible, we expect existing sites to form the backbone of the monitoring network. We will establish supplemental sites to fill out the spatial distribution of monitored sites and take advantage of the gradient of land uses and water quality conditions in the Wenatchee and Yakima tributaries. The final suite of monitored sites will, to the extent possible, be stratified by physical and biological characteristics in order to provide some degree of control over those variables and increase the probability of detecting differences in water quality and its influence on the stream ecosystems and salmonids. Within each stratum, we will identify replicate sites with varying treatment levels (i.e., land uses). The final sample design will be strongly influenced by the remaining specific aims listed below, especially # 3 which identifies important data gaps that must be filled in order to estimate the future effectiveness of water quality improvement efforts in these two basins.

Key Investigators: Beechie, Pess, Pollock, and Scholz.

Specific aim 2. Identify and collect existing environmental data (chemical, physical, and biological) for selected monitoring sites from federal, state, tribal, and local agencies and entities.

In terms of water quality, the lower Yakima is one of most heavily impacted basins in the western United States. There are many sources of water pollution, and many different entities have conducted at least some forms of environmental monitoring over the years. There are also water quality concerns in the Wenatchee, but baseline conditions are not as well understood as for the Yakima. One of the major reasons for this is the selection of the Yakima subbasin as a study unit for the USGS National Water Quality Assessment Program. For years, USGS investigators have conducted synoptic and fixed-site sampling for pesticides, nutrients, bacteria, metals and other trace elements, and persistent organic pollutants such as the DDTs (for a partial summary of NAWQA publications, see http://or.water.usgs.gov/yakima/). In addition, the Washington State Department of Ecology has developed Total Maximum Daily Loads (TMDLs) for suspended sediments and DDTs in the lower Yakima River, temperature in the Teanaway, and suspended sediments and pesticides in the upper Yakima River. There are relatively extensive sets of environmental monitoring associated with these TMDLs (see www.ecy.wa.gov/programs/wq/tmdl/watershed/yakima_wq/wq_assessments.html). Also, a Watershed Management Plan for the Yakima River Basin was recently developed by the Yakima River Basin Watershed Planning Unit and the Tri-County Water Resources Agency and finalized in January of 2003 (available at http://www.co.yakima.wa.us/tricnty/). This watershed plan was formulated, in part, from a water quality monitoring plan, a prioritized list of water quality research projects for temperature, bacteria, dissolved oxygen, and nutrients, and a surface water quality strategy for the Yakima River Basin. Overall, there are many good sources of existing monitoring data for metals (WDOE, 2000), dissolved pesticides (Ebbert and Embrey, 2002; Foster et al., 1993), biological indicators (Cuffney et al., 1997; Leland, 1995), and other important habitat parameters.

Available data sets also include digital elevation models (DEM), lithology, soils, land use and land cover, land ownership, hydrography, various climate parameters (air temperature, dew point temperature, precipitation, wind, solar radiation, humidity, cloud cover, evapotranspiration, etc.), stream gauge measurements, weather station measurements, snow pack, diversions and dams, and road networks (StreamNet 2001; ICBEMP 1999; USGS 1999; Daly et al. 1994).

In the planning phase of FY03, we will acquire existing tabular and geospatial data for the Yakima and Wenatchee tributaries. We will assess the quality and appropriate uses of each data set, and ensure that various data sets will be useful for out-year analyses during the implementation phase of the project.

Key Investigators: Beechie, Feist, Fullerton, Pess, Pollock, and Scholz.

Specific aim 3. Identify key data gaps specific to water quality, other major habitat characteristics, and salmonid abundance or productivity.

Important data gaps that we will identify fall into three broad categories: (1) missing data types at active monitoring sites, (2) important sampling locations that are currently not monitored for specific environmental conditions, and (3) missing parameters for life-cycle models. Addressing the first class of data gaps ensures that a minimum set of environmental parameters is monitored consistently at key sampling locations. New data for the second class is needed to ensure that we have an adequate spatial distribution of monitoring sites for core habitat parameters. To this end, we will identify where we need increased numbers of reference or treatment sites, improved spatial distribution of reference or treatment sites, or improved pairing of reference and treatment sites in terms of environmental parameters we intend to control as much as possible in the study design (e.g., channel slope, discharge, etc.). To address the third class of data gaps, we will identify important parameters that will be needed to run the life cycle models but have not been previously measured. For example, we may need to establish empirical connections between mixtures of insecticides in surface waters, aquatic insect abundance, and growth rates for juvenile steelhead or chinook in contaminated habitats. Missing or poorly understood parameters will be identified, and we will design new research projects to fill these data gaps during the implementation phase of the project.

Key Investigators: Beechie, Greene, Feist, and Scholz.

Specific aim 4. Develop GIS-based tools to integrate existing land use and environmental monitoring data.

Mapping environmental conditions in space and time requires site-specific field data from a limited number of sites, combined with GIS-based tools for extrapolating that data to the remaining landscape and stream network. Field data will be based on a combination of existing data and data gathered during the course of this study. This will include RME data for physical, chemical, and biological habitat characteristics as well as salmonid distribution and abundance data. GIS-based tools for mapping environmental conditions throughout the stream network will be based on existing software and models. Thus, this task focuses on evaluating existing watershed models, and identifying those that will be useful for the implementations phase of this project. The U.S. Geological Survey, U.S. Environmental Protection Agency, and the U.S. Department of Agriculture have a wide variety of such models. Most require existing geospatial datalayers of climate (air temperature, precipitation, etc.), evapotranspiration, land use and land cover (urban, agriculture, etc.), digital elevation models (DEM), hydrology, and soils/lithology. Environmental monitoring data (primarily) and GIS modeled data (secondarily) will be used to estimate patterns of exposure to different environmental contaminants as a function of space, time, and species-specific patterns of habitat utilization in the Yakima and Wenatchee subbasins. We will take full advantage of the spatially explicit network capability of existing watershed models in order to create 2D maps of water quality degradation in each catchment.

Key Investigators: Beechie, Feist, and Pess.

Specific aim 5. Develop life cycle models.

Despite considerable interest in the effects of water quality and habitat changes on salmon populations, most research in these areas is still inferential, where observed changes in physiological performance, behavior, or density are extrapolated to the scale of natural populations. How changes in water quality influence key demographic parameters such as mortality, fecundity, and dispersal rate are still poorly understood. Moreover, water pollution and other forms of anthropogenic habitat modification can have variable effects on salmonid populations, depending upon their residency in freshwater habitats impacted by these changes (Pess et al. 2002a&b). For example, degraded water quality may pose a greater cumulative risk for threatened and endangered steelhead in the Yakima and Wenatchee, respectively, because these species smolt at age 2 vs. age 1 for spring chinook in the Wenatchee. Our goal here is to develop life cycle models for these different species to quantify the relative impacts of physical, biological, and chemical habitat changes on populations and meta-populations.

The most simple life-cycle models determine the population consequences of particular anthropogenic impacts by evaluating their direct effects on mortality using population matrices (e.g., Kareiva et al. 2000; Caswell 2001). These types of models do not readily integrate the health or behavioral performance of salmonids, and they can potentially underestimate the sublethal effects of anthropogenic impacts if these effects lead to indirect mortality. A few examples of sublethal impacts include increased vulnerability to predation (Scholz et al., 2000; Kruzynski and Birtwell, 1994), increased susceptibility to disease (Arkoosh et al., 2001), or reduced growth leading to lower marine survival (Zabel and Williams, 2002).

An alternate way to integrate individual variability is to track frequency distributions of individual characteristics such as body size and residency at multiple life stages. Allometric relationships (e.g., McGurk, 1996), growth models (Hayes et al., 2000), and other life history summation techniques (Stearns, 1992) can be used to evaluate how ontogenetic changes in individual animals can influence population parameters. These techniques provide a way to integrate the direct effects of contaminants on salmonid health as well as indirect effects on aquatic ecosystems and, in particular, the availability and abundance of prey taxa.

We will construct life-cycle models for steelhead in the Yakima and Wenatchee subbasins and spring chinook salmon in the Wenatchee. Steelhead and spring chinook in both tributaries are characterized by extended residency (at least one year) in streams (Myers et al., 1997; Busby et al., 1996). To parameterize the models, we will use data obtained from existing sources as well as new empirical data derived from monitoring studies and experimental manipulations in the laboratory and the field. We will use standard sensitivity analysis (Caswell, 2001) to examine the degree to which changes in individual and population parameters affect demographic endpoints such as abundance or recruitment rate.

In addition, matrix models of individual spawning populations can be linked via metapopulation models to examine the impacts of degraded water quality on ESA-listed steelhead and chinook. For example, sublethal exposures to pesticides can disrupt adult homing behavior (Scholz et al., 2000). Exposure to contaminants could therefore increase rates of straying among spawning populations, which could lead to increased gene flow among wild and hatchery populations. We will use spatially explicit metapopulation models to evaluate the relationships between degraded water quality and gene flow (Hanski and Gilpin, 1997) within and among different spawning populations in the Yakima and Wenatchee sub-basins (see Task 2 in the original version of Project #35024).

Key Investigators: Greene, Feist, and Jordan.

Specific aim 6. Develop the FY04-07 work plan

The work plan will have three basic elements: (1) experiments, field studies, and monitoring protocols, (2) mapping of environmental attributes, and (3) evaluation of contaminant effects on populations or meta-populations. Experiments will test specific hypotheses of water quality effects on salmon fitness, survival, and movements. These will include a combination of laboratory experiments, experiments in artificial stream channels, and field experiments. The aim of each experiment will be to test specific hypotheses of water quality effects on salmonid growth, survival, migration, or reproductive success. Field monitoring of environmental conditions will primarily focus on data needed to map environmental conditions in space and time. Sample designs will focus on understanding differences in habitat and water quality attributes among land uses, as well as spatial (i.e., downstream) and temporal trends in those attributes. Laboratory experiments and field studies will:

1. address specific, testable hypothesized relationships among land uses and water quality (and fish responses where possible),
2. have detailed study designs capitalizing on a gradient of land uses (i.e., sampling both "control" and "treatment" sites), and
3. describe the use of standard protocols for all measured parameters.

Mapping environmental conditions in space and time is a critical element of interpreting the effects of contaminants at the population level. In essence, the map describes the environment that drives life-cycle models and alters population dynamics and performance. The population models integrate results from the other three elements into an assessment of water quality effects on population (or meta-population) performance.

Key Investigators: Beechie, Greene, Feist, Fullerton, and Scholz.

g. Facilities and equipment

All facilities and equipment associated with Task 1 (zebrafish developmental screens) in the initial version of Project #35025 have been removed. The original request for supplies and equipment to support the studies in Task 2 (relating sublethal toxicity in salmonids to population endpoints) is the same. One of our goals for FY03 is to build laboratory infrastructure to support salmon health studies during the implementation phase of this project (FY04-07). These will include anatomical analyses, physiological recordings, behavioral observations, and other laboratory investigations. Thus, there will be a one-time purchase of laboratory equipment in FY03. In addition, there will be a purchase of computers and software in FY03 to support GIS analyses, and software (e.g., Matlab) to support life cycle modeling.

h. References

Arkoosh, M.R., E. Clemons, P. Huffman, and A.N. Kagley. 2001. Increased susceptibility of juvenile Chinook salmon to vibriosis after exposure to chlorinated and aromatic compounds found in contaminated urban estuaries. Journal of Aquatic Animal Health, 13:257-268.

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz, 2003. Sublethal effects of copper on coho salmon: impacts on non-overlapping receptor populations in the periperhal olfactory nervous system. Environmental Toxicology and Chemistry. *In press.*

Busby, P.J., Wainwright, T.C., Bryant, G.J., Bierheimer, L.J., Waples, R.S., Waknitz, F.W., and Lagomarsino, I.V. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-27.

Caswell, H. 2001. Matric Population Models: Construction, Analysis, and Interpretation. Sinauer Associates, Inc. Sunderland, Massachusetts.

Cuffney, T.F., Meador, M.R., Porter, S.D., and Gurtz, M.E. 1997. Distribution of fish, benthic invertebrate, and algal communities in relation to physical and chemical conditions, Yakima River Basin, Washington, 1990: U.S. Geological Survey Water-Resources Investigations Report 96-4280, 94 p.

Daly, C., R. P. Neilson, and D. L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. J. Appl. Meteor. 33:140-158.

Ebbert, J.C. and Embrey, S.S., 2002. Pesticides in surface water of the Yakima River Basin, Washington, 1999-2000--Their occurrence and an assessment of factors affecting concentrations and loads: U.S. Geological Survey Water-Resources Investigations Report 01-4211, 49 p.

Foster, G.D., Gates, P.M., Foreman, W.T., McKenzie, S.W., and Rinella, F.A. 1993. Determination of dissolved-phase pesticides in surface water from the Yakima River basin, Washington, using the Goulden large-sample extractor and gas chromatography/mass spectrometry: Environmental Science and Technology, 27:1911-1917.

Hanski, I.A. and M.E. Gilpin. 1997. Metapopulation biology: ecology, genetics, and evolution. Academic Press, San Diego, CA, USA.

Hayes, J.W., Stark, J.D., Shearer, K.A. 2000. Development and test of a whole-lifetime foraging and bioenergetics growth model for drift-feeding brown trout. Transactions of the American Fisheries Society 129 (2): 315-332.

Hillman, T. W. and Giorgi, A. E. 2002. Monitoring Protocols: Effectiveness Monitoring of Physical/Environmental Indicators in Tributary Habitats. At: http://www.efw.bpa.gov/cgi-bin/FW/welcome.cgi?ViewMode=External

ICBEMP (Interior Columbia Basin Ecosystem Management Project) Spatial Data. 1999. Portland, OR: ICBEMP, October 1999. [July 1999]. URL: <http://www.icbemp.gov/>.

Kareiva, P., M. Marvier and M. McClure. 2000. Recovery and management options for spring/summer chinook salmon in the Columbia River basin. Science 290:977-979.

Kruzynski, G.M. and Birtwell, I.K. 1994. A predation bioassay to quantify the ecological significance of sublethal responses of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to the antisapstain fungicide TCMTB. Can. J. Fish. Aquat. Sci. 51:1780-1790.

Leland, H.V. 1995. Distribution of phytobenthos in the Yakima River basin, Washington, in relation to geology, land use, and other environmental factors. Canadian Journal of Fisheries and Aquatic Sciences, 52:1108-1129.

McGurk, M.D. 1996. Allometry of marine mortality of Pacific salmon. Fishery Bulletin 94:77-88.

Moore, A. and Waring, C.P. 1998. Mechanistic effects of a triazine pesticide on reproductive endocrine function in mature male Atlantic salmon (*Salmo salar* L.) parr. Pest. Biochem. Physiol. 62:41-50.

Myers, J.M., Kope, R.G., Bryant, G.J., Teel, D., Lierheimer L.J., Wainwright, T.C., Grant, W.S., Waknitz, F.W., Neely, K., Lindley, S.T., and Waples. R.S. 1997. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-35.

Pess, G.R., D.R. Montgomery, R.E. Bilby, E.A. Steel, B.E. Feist, and H.M. Greenberg. 2002a. Correlation of landscape characteristics and land use on coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Washington State, USA. Canadian Journal of Aquatic and Fisheries Science. 59:613-623.

Pess, G.R., Montgomery, D.R., Beechie, T.J., and Holsinger, L. 2002b. Anthropogenic alterations to the biogeography of salmon in Puget Sound. Pages 129-154 in D. Montgomery, S. Bolton, and D. Booth, eds., Restoration of Puget Sound Rivers, University of Washington Press, Seattle, WA.

Rinella, J.F., McKenzie, S.W., Crawford, J.K., Foreman, W.T., Fuhrer, G.J., and Morace, J.L. 1999. Surface water quality assessment of the Yakima River Basin, Washington – Distribution of pesticides and other organic compounds in water, sediment, and aquatic biota, 1987-1991. U.S. Geological Survey Water Supply Paper 2354-B, 180p.

Scholz, N.L. and Collier, T.K. 2000. Endangered salmon and probabilistic risk assessments for organophosphate pesticides. SETAC Globe 1:32-33.

Scholz, N.L., Truelove, N., French, B., Berejikian, B., Quinn, T., Casillas, E., and Collier, T.K. 2000. Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha).* Canadian Journal of Fisheries and Aquatic Sciences, 57:1911-1918.

Stearns, S.C. 1992. The evolution of life histories. Oxford University Press, Oxford England.

StreamNet Spatial Data. 2001. Current anadromous salmon distribution at a 1:100,000 scale, all species. Pacific States Marine Fisheries Commission,Gladstone, OR. At: http://www.streamnet.org/.

USGS (United States Geological Survey) Spatial Data. 1999. Washington Land Cover Data Set. Sioux Falls, SD USA: USGS NLCD, June 1999. Available at http://www.cr.usgs.gov/programs/lccp/nationallandcover.html.

Waite, I.R. and Carpenter, K.D. 2000. Associations among fish assemblage structure and environmental variables in Willamette Basin streams, Oregon. Trans. Am. Fish. Soc. 129:754-770.

Washington State Department of Ecology (WDOE). 2002. Concentrations of 303(d) listed metals in the upper Yakima River. Publication No. 00-03-024, available online at http://www.wa.gov.ecology/biblio/003024.html.

Zabel, R.W. and J.G. Williams. 2002. Selective mortality in Chinook salmon: what is the role of human disturbance? Ecological Applications 12:173-183.

Section 10 of 10. Key personnel

The core, salmon-specific elements of Project #35024 (Task 2, as submitted to the Mainstem/Systemwide Province in 2002) will be incorporated into the RME work plan that will be completed by the end of FY03. The work plan, in turn, will provide the basis for the monitoring and evaluation phase of the revised proposal. NWFSC scientists that were originally identified for the different studies under Task 2 are included as key personnel below. Some investigators (Scholz, Baldwin, and Feist) will be actively involved in the RME planning phase of the FY03 effort. Others (Berejikian, Dittman, and Jordan) will be involved in the implementation of the work plan in FY04-07.

To meet the RME requirements for habitat monitoring under RPA 183, additional investigators from the Watershed Program at the NWFSC were added to the revised proposal. This includes Timothy Beechie, the acting manager of the Watershed Program, as a Co-Principal Investigator along with Nathaniel Scholz (Ecotoxicology and Environmental Fish Health Program and original project sponsor). Additional Watershed staff (Fullerton, Greene, Pess, and Pollock) will contribute to the work plan and other FY03 specific aims.

We anticipate an intensive period of data acquisition in the remainder of FY03 for both the Yakima and Wenatchee subbasins. Accordingly, we will hire two new interns via the Oak Ridge Science and Education (ORISE) program to contact various agencies and collect existing environmental monitoring data. In addition, a Biological Science Technician from the Ecotox Program will work full time for the remainder of FY03 to establish laboratory infrastructure for salmon health research.

Key personnel are listed below:

Nathaniel Scholz	Research Zoologist	Principal Investigator
Timothy Beechie	Research Fisheries Biologist	Co-Principal Investigator
David Baldwin	NRC Postdoctoral Associate	Contributing Investigator
Barry Berejikian	Research Fisheries Biologist	"
Andrew Dittman	Research Fisheries Biologist	"
Blake Feist	Spatial Ecologist	"
Aimee Fullerton	Research Fisheries Biologist	"
Correigh Greene	Research Biologist	"
Christopher Jordan	Mathematical Population Biologist	"
George Pess	Research Biologist	"
Michael Pollock	Research Fisheries Biologist	"

Nathaniel L. Scholz, Principal Investigator (0.25 FTE for FY03)

Education:

- Ph.D., Zoology, University of Washington, Seattle, WA, 1997.
- M.A., Biology, Boston University Marine Program, Woods Hole, MA, 1991.
- B.A., Marine Biology with Distinction, Boston University, Boston, MA, 1991.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division, Montlake Facility. Previous employment: National Research Council Postdoctoral Associate, National Academies of Science and Engineering (1998-1999).

Position: Research Zoologist, Team Leader (Fish Neurobiology and Development), Ecotoxicology and Environmental Fish Health Program. NMFS employee since 1999.

Present assignment: Dr. Scholz supervises a research laboratory at the NWFSC (three postdoctoral associates, one doctoral student, two ORISE interns, and four research scientists) that is currently investigating the effects of environmental contaminants on Pacific salmon and marine fish, with an emphasis on species that are listed as threatened or endangered under the ESA.

Previous research/expertise: Dr. Scholz's expertise is in the areas of developmental biology, neurobiology, and animal behavior. His broad interests are in the emerging discipline of conservation medicine, and the application of biomedical research techniques to problems in conservation biology. His postdoctoral research focused on the impacts of pesticides on the neurobiology and behavior of chinook salmon. His doctoral research explored biochemical and physiological mechanisms of cell-cell signaling in the nervous system, and he studied the behavioral ecology of marine animals for his masters.

Five Relevant Publications:

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz, 2003. Sublethal effects of copper on coho salmon: impacts on non-overlapping receptor populations in the periperhal olfactory nervous system. Environmental Toxicology and Chemistry. *In press.*

Scholz, N.L., J.S. Labenia, J. de Vente, K. Graubard, and M.F. Goy, 2002. Expression of nitric oxide synthase and nitric oxide-sensitive guanylate cyclase in the crustacean cardiac ganglion. Journal of Comparative Neurology, 454:158-167.

Scholz, N.L. 2001. NO/cGMP signaling and the flexible organization of motor behavior in crustaceans. American Zoologist. 41:156-167.

Scholz, N.L., J. de Vente, J.W. Truman, and K. Graubard. 2001. Neural network partitioning by NO and cGMP. Journal of Neuroscience, 21:1610-1618.

Scholz, N.L., N. Truelove, B. French, B. Berejikian, T. Quinn, E. Casillas, and T.K. Collier. 2000. Diazinon disrupts antipredator and homing behaviors in chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences, 57:1911-1918.

Timothy J. Beechie, Co-Principal Investigator (0.17 FTE for FY03)

Education:

- Ph.D., Forestry, University of Washington, Seattle, WA, 1998.
- M.S., Fisheries, University of Washington, Seattle, WA, 1990.
- B.S., Geology, University of Washington, Seattle, WA, 1983.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division, Montlake Facility. Previous employment: Skagit System Cooperative, La Conner, WA. (1990-1999).

Position: Research Fishery Biologist, Science Coordinator, Watershed Program. NMFS employee since 1999.

Present assignment: Dr. Beechie is currently Science Coordinator and Acting Program Manager for the Watershed Program, Northwest Fisheries Science Center.

Previous research/expertise: Dr. Beechie has worked in fisheries resource management since 1985, beginning with assessments of fish populations in West African lakes. His previous research in the Pacific Northwest includes the natural development of landscapes and salmon habitat, influences of land uses on stream morphology and ecosystems, recovery of stream habitat from landslide impacts or removal of riparian forests, and the development of process-based habitat restoration strategies. He is currently studying the formation and evolution of floodplain habitats, impacts of sediment supply changes on aquatic habitats, and impacts of land uses and dam removal on dynamics of floodplain ecosystems.

Five Relevant Publications:

Beechie, T.J., C.N. Veldhuisen, D.E. Schuett-Hames, P. DeVries, R.H. Conrad, E.M. Beamer. Accepted. Monitoring treatments to reduce sediment and hydrologic effects from roads. In P.Roni, editor. Methods for monitoring stream and watershed restoration.

Beechie, T.J., G. Pess, E. Beamer, G. Lucchetti, and R.E. Bilby. 2002. Roles of watershed assessment in recovery planning for salmon. Pages 194-225 in D. Montgomery, S. Bolton, and D. Booth, editors, Restoration of Puget Sound Rivers, University of Washington Press, Seattle.

Beechie, T.J. 2001. Empirical predictors of annual bed load travel distance, and implications for salmonid habitat restoration and protection. Earth Surface Processes and Landforms 26:1025-1034.

Beechie, T.J, G. Pess, P Kennard, R.E. Bilby, and S Bolton. 2000. Modeling recovery rates and pathways for woody debris recruitment in northwestern Washington streams. North American Journal of Fisheries Management 20:436–452.

Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. Fisheries 24(4):6-15.

David H. Baldwin, Contributing Investigator (0.58 FTE for FY03)

Education:

- Ph.D., Zoology, University of Washington, Seattle, WA, 2000.
- B.A., Biology, Reed College, Portland, OR, 1986.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division.

Position: National Research Council Postdoctoral Associate, Ecotoxicology and Environmental Fish Health Program (Fish Neurobiology and Development).

Present assignment: Member of the Fish Neurobiology and Development Team. Dr. Baldwin's primary responsibility is establishing and performing electrophysiological recordings from the salmon olfactory system.

Previous research/expertise: Dr. Baldwin is a neurophysiologist whose research has focused on sensory physiology and behavior. His graduate research dealt with the role of specific visual pathways in the behavior of the fruit fly, *Drosophila melanogaster*. These experiments involved genetic manipulation, electrophysiological recording, and behavioral testing. His additional skills include immunocytochemistry, image analysis, and computer programming.

Five Relevant Publications:

Baldwin, D.H., J.F. Sandahl, J.S. Labenia, and N.L. Scholz, 2003. Sublethal effects of copper on coho salmon: impacts on non-overlapping receptor populations in the periperhal olfactory nervous system. Environmental Toxicology and Chemistry. *In press.*

Nakamura, M., Baldwin, D.H., Hannaford, S., Palka, J., and Montell, C. 2002. Defective proboscis extension response (DPR), a member of the Ig superfamily required for the gustatory response to salt. Journal of Neuroscience, 22:3463-3472.

Christie, A.E., D.H. Baldwin, E. Marder, and K. Graubard. 1997. Organization of the stomatogastric neuropil of the crab, *Cancer borealis*, as revealed by modulator immunocytochemistry. Cell and Tissue Research, 288: 135-148.

Christie, A.E., D. Baldwin, G. Turrigiano, K. Graubard, and E. Marder. 1995. Immunocytochemical localization of multiple cholecystokinin-like peptides in the stomatogastric nervous system of the crab *Cancer borealis*. Journal of Experimental Biology, 198:263-271.

Baldwin, D.H. and K. Graubard. 1995. Distribution of fine neurites of stomatogastric neurons of the crab *Cancer borealis*: evidence for a structured neuropil. Journal of Comparative Neurology, 356:355-367.

Barry A. Berejikian, Contributing Investigator (Implementation Phase)

Education:

- Ph.D., Fisheries Science, University of Washington, Seattle, WA, 1995.
- M.S., Fisheries Science, University of Washington, Seattle, WA, 1992.
- B.S., Fisheries Science, California Polytechnic State University, San Luis Obispo, CA., 1990.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Resource Enhancement & Utilization Technologies Division, Manchester Research Station.

Position: Fisheries Research Biologist, Team Leader (Behavioral Ecology). NMFS employee since 1994.

Present assignment: Project Leader of the BPA funded Assessment of Captive Broodstock Technologies Project (93-056). Dr. Berejikian's responsibilities include identifying the effects of captive rearing on adult reproductive behavior and success. Dr. Berejikian is also a Principal Investigator on the "NATURES" project, evaluating the effects environmental parameters on the behavioral attributes of salmonids, including anti-predator behavior.

Previous research/expertise: Dr. Berejikian is a behavioral ecologist. His graduate research dealt with juvenile steelhead behavior and predator-prey interactions. He is an expert in quantifying Pacific salmon breeding behavior and success and juvenile behavioral ecology of salmonids. He has published numerous papers and is regularly invited to speak at national and international meetings.

Five Relevant Publications:

Berejikian, B. A., E. P. Tezak, and S. L. Schroder. 2001. Reproductive behavior and breeding success of captively reared chinook salmon (*Oncorhynchus tshawytscha*). N. Am. J. Fish. Manage. 21:255-260.

Berejikian, B. A., E. P. Tezak, L. Park, S. L. Schroder, E. P. Beall, and E. LaHood. 2001. Male dominance and spawning behavior of captively reared and wild coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 58: 804-810.

Berejikian, B. A., E. P. Tezak, and A. L. LaRae. 2000. Female mate choice and spawning behavior of chinook salmon (*Oncorhynchus tshawytscha*) under experimental conditions. J. Fish. Biol. 57: 647-661.

Berejikian, B. A., R. J. F. Smith, E. P. Tezak, S. L. Schroder, and C. M. Knudsen. 1999. Chemical alarm signals and complex hatchery rearing habitats affect anti-predator behavior and survival of chinook salmon (*Oncorhynchus tshawytscha*) juveniles. Can. J. Fish. Aquat. Sci. 56: 830-838.

Berejikian, B. A. 1995. The effects of hatchery and wild ancestry and experience on the relative ability of steelhead trout fry (*Oncorhynchus mykiss*) to avoid a benthic predator. Can. J. Fish. Aquat. Sci. 52: 2076-2082.

Andrew H. Dittman, Contributing Investigator (Implementation Phase)

Education:

- Ph.D., Fisheries/Pharmacology, University of Washington, Seattle, WA, 1994.
- B.A., Biochemistry, Dartmouth College, Hanover, NH, 1982.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Resource Enhancement & Utilization Technologies Division.

Position: Fisheries Research Biologist, Behavioral Ecology/Integrative Fish Biology, NMFS employee since 2000.

Present assignment: Principal Investigator for the Imprinting/Homing components of the BPA funded Assessment of Captive Broodstock Technologies Project (93-056). Dr. Dittman's responsibilities include development of rearing and reintroduction strategies to minimize straying in captively reared salmon populations.

Previous research/expertise: Dr. Dittman is an integrative biologist whose research focuses on olfactory physiology and olfactory–mediated behaviors in fishes. The focus of his current research is olfactory imprinting and homing in salmon. His graduate research dealt with behavioral and biochemical mechanisms involved in olfactory imprinting and homing. His post-doctoral research focused on the endocrine control of maturation and migratory behavior in salmon and the molecular physiology of fish olfaction. He is an expert in a wide range of techniques from field-based behavior to molecular biology. He has published numerous papers and is regularly invited to speak at national and international meetings.

Five Relevant Publications:

Speca, D. J., D. M. Lin, P. W. Sorensen, E. I. Isacoff, J. Ngai, and A. H. Dittman. 1999. Functional identification of a goldfish odorant receptor. Neuron, 23:487-498.

Nevitt, G. A, and A. H. Dittman. 1998. A new model for olfactory imprinting in salmon. Integrative Biology, 1:215-223.

Dittman, A. H., T. P. Quinn, G.A. Nevitt, B. Hacker, and D. R. Storm. 1997. Sensitization of olfactory guanylyl cyclase to a specific odorant in coho salmon. Neuron, 19:381-389.

Dittman, A. H., T. P. Quinn, and G. A. Nevitt. 1996. Timing of imprinting to natural and artificial odors by coho salmon (*Oncorhynchus kisutch*). Canadian Journal of Fisheries and Aquatic Sciences, 53:434-442.

Dittman, A. H. and T. P. Quinn. 1996. Pacific salmon homing: mechanisms and ecological basis. Journal of Experimental Biology, 199:83-91.

Blake E. Feist, Contributing Investigator (0.04 FTE for FY03)

Education:

- Ph.D., Fisheries Science, University of Washington, Seattle, WA, 1999.
- M.S., Fisheries Science, University of Washington, Seattle, WA, 1991.
- B.S., Zoology, University of Wisconsin, Madison, WI., 1986.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division, Watershed Program.

Position: Statistician (Biology), NMFS employee since 1999.

Present assignment: Dr. Feist is responsible for designing and participating in research that examines the relationship between Pacific salmon fitness and survival, and terrestrial/estuarine habitat type and condition. He uses a landscape scale approach for building spatial models for most of his research, and also studies the effects of differing spatio-temporal scales on ecosystems.

Previous research/expertise: Dr. Feist is a spatial ecologist, with extensive experience in basic ecology, ethology, neurobiochemistry, and biology. His doctoral research focused on the spatio-temporal dynamics of the invasion of a non-indigenous aquatic plant in Pacific Northwest estuaries. His master's research examined the impact of industrial noise on the estuarine ecology of juvenile Pacific salmon. He has published his research in the peer-reviewed literature and is frequently invited to present at scientific symposia. In addition, he has given numerous guest lectures at the University of Washington, on topics ranging from spatial ecology to GIS technology.

Five Relevant Publications:

Feist, B.E., E.A. Steel, G.R. Pess, and R.E. Bilby. 2003. The influence of scale on salmon habitat restoration priorities. Animal Conservation. In press.

Feist, B.E. and E.O. Box, 2002. Vegetation and ecosystem mapping. In: Encyclopedia of Science and Technology, 9th Edition, Volume 19. McGraw-Hill publishers, New York, NY.

Levin, P.S., S. Achord, B.E. Feist, and R.W. Zabel. 2002. Non-indigenous brook trout and the demise of Pacific salmon: a forgotten threat? Proceedings of the Royal Society of London – Biology. 269:1663-1670.

Pess, G.R., D.R. Montgomery, R.E. Bilby, E.A. Steel, B.E. Feist, and H.M. Greenberg. 2002. Correlation of landscape characteristics and land use on coho salmon (*Oncorhynchus kisutch*) abundance, Snohomish River, Washington State, USA. Canadian Journal of Aquatic and Fisheries Science. 59:613-623.

Feist, B.E., and C. A. Simenstad. 2000. Expansion rates and recruitment frequency of exotic smooth cordgrass, *Spartina alterniflora* (Loisel), colonizing unvegetated littoral flats in Willapa Bay, Washington. Estuaries. 23(2):267-274.

Aimee H. Fullerton, Contributing Investigator (0.08 FTE for FY03)

Education:

- M.S., Aquatic Ecology, University of Notre Dame, Notre Dame, IN, 1998.
- B.S., Biology, Ohio State University, Columbus, OH, 1994.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division, Montlake Facility.

Position: Fisheries Research Biologist, Watershed Program. NMFS employee since 2002.

Present assignment: Ms. Fullerton works on the integration of research (largely involving freshwater habitat) conducted by the Watershed Program with recovery planning conducted for each evolutionarily significant unit by NMFS-appointed Technical Recovery Teams, watershed groups, and others.

Previous research/expertise: Ms. Fullerton previously worked on aquatic nongame and endangered wildlife issues with the North Carolina Wildlife Resources Commission (1998 to 2002), with special focus on crayfishes. Her thesis research at Notre Dame focused on interactions between a nonindigenous fish and the invaded ecosystem. Her research at Ohio State investigated factors controlling overwinter survival of largemouth bass.

Five Relevant Publications:

Kolar, C.S., A.H. Fullerton, K.M. Martin, and G.A. Lamberti. 2002. Influence among zebra mussel shells, invertebrate prey, and Eurasian ruffe or yellow perch. Journal of Great Lakes Research 28(4): 664-673.

Fullerton, A.H. and B.T. Watson. 2001. New distributional records for two nonindigenous and one native crayfish in North Carolina. The Journal of the Elisha Mitchell Scientific Society 117:66-70.

Fullerton, A.H., G.A. Lamberti, D.M. Lodge, and F.W. Goetz. 2000. Potential for resource competition between Eurasian ruffe (Gymnocephalus cernuus) and yellow perch (Perca flavescens): growth and RNA responses in laboratory experiments. Transactions of the American Fisheries Society 129:1387-1395.

Fullerton, A.H., J.E. Garvey, R.A. Wright, and R.A. Stein. 2000. Overwinter growth and survival of largemouth bass: interactions among size, food, origin, and winter severity. Transactions of the American Fisheries Society 129:1-12.

Fullerton, A.H., G.A. Lamberti, D.M. Lodge, and M.B. Berg. 1998. Prey preferences of Eurasian ruffe and yellow perch: comparison of laboratory results with composition of Great Lakes benthos. Journal of Great Lakes Research 24:319-328.

Correigh M. Greene, Contributing Investigator (0.27 FTE for FY03)

Education

Ph.D. 2001. Animal Behavior, University of California Davis.
M.S. 1995. Wildlife Ecology and Management, University of Michigan.
B.S. 1992. Environmental Studies and Biopsychology, Tufts University.

Employer

NOAA Fisheries, Northwest Fisheries Science Center, Environmental Conservation Division, Montlake Facility. Previous employment: National Research Council Postdoctoral Associate, National Academies of Science and Engineering (2001-2002).

Position

Research Biologist, Team Leader (Fish-Habitat Relationships), Watersheds Program.

Present Assignment

Dr. Greene's general research interests concern how individual behavior influences population dynamics and distribution, and how knowledge of behavior might aid in conservation. He is currently studying biological habitat relationships, habitat selection, and life history variability of salmonid populations. His methods combine matrix modeling efforts, statistical analyses of time series population data, and empirical studies of ecology and behavior of juvenile salmon.

Previous Research/Expertise

Dr. Greene's expertise is in the areas of population biology and animal behavior. His postdoctoral work focused on developing a habitat-specific life cycle model of chinook salmon. His masters and Ph.D research involved studies of habitat use and habitat selection in a number of different wildlife species, including great gray owls and western fence lizards.

Five Relevant publications

Greene, C.M. In press. Habitat selection reduces extinction of populations subject to Allee effects. Theoretical Population Biology.

Rabin, L.A. and C.M. Greene. 2002. Changes to Acoustic Communication Systems in Human-Altered Environments. Journal of Comparative Psychology, 116: 137-141.

Howell, J.A., G.C. Brooks, M.Semenoff-Irving, and C.M. Greene. 2002. Population dynamics of tule elk at Point Reyes National Seashore, California. Journal of Wildlife Management, 66: 478-490.

Greene, C.M. and J.A. Stamps. 2001. Habitat selection at low population densities. Ecology, 82:2091-2100.

Greene, C.M., J.A. Umbanhowar, M. Mangel, and T. Caro. 1998. Animal breeding systems, hunter selectivity, and consumptive use in wildlife conservation. Pages 271-305 *in* T.M. Caro, ed., Behavioral Ecology and Conservation Biology, Oxford University Press, Oxford.

Chris Jordan, Contributing Investigator (Implementation Phase)

Education:
- Ph.D., Zoology, University of Washington, Seattle, WA, 1994.
- B.A., Biology with honors, University of Chicago, Chicago, Illinois, 1985.

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division and Cumulative Risk Initiative.

Position: Operations Research Analyst (Mathematical Population Biologist). NMFS employee since 1999.

Present assignment: Population risk assessment modeling, spatial population dynamical modeling and basic population processes exploration with historical data sets. In addition, leading the development of a region wide monitoring and evaluation program for anadromous salmonid population status and recovery action effectiveness.

Previous research/expertise:

• Research Assistant Professor	Washington State Univ., Pullman	1999 - present
• Assistant Professor	University of Colorado, Boulder	1995 - 1999
• Research Associate	University of Chicago, Chicago	1994 - 1995

Training and research experience includes mathematical modeling of populations and physiological processes and experimental approaches to neurobiological bases of behavior, fluid dynamics and population processes.

Five Relevant Publications:

Jordan, C.E. 2001. A predictive mathematical model to simulate swimming in the medicinal leech *Hirudo medicinalis*. J. Theor. Biol. *In review*.

McClure, M. M., B. L. Sanderson, E. E. Holmes, and C. E. Jordan. 2001. A large-scale, multi-species risk assessment: Anadromous salmon in the Columbia River Basin. Ecol. Apps. *In review*.

Jordan, C.E. 1998. Scale effects in the kinematics and dynamics of swimming leeches. Can. J. Zool., 76(10):1869-1877.

Steinberg, E.K. and C.E. Jordan. 1997. Using genetics to learn about the ecology of threatened species: the allure and the illusion of measuring genetic structure in natural populations. In: Conservation Biology. eds, P. Fiedler and P. Kareiva. Chapman Hall, New York.

Jordan, C.E. 1996. Coupling internal and external mechanics to predict swimming behavior: a general approach? Amer. Zool. 36:710-722.

George R. Pess, Contributing Investigator (0.08 FTE for FY03)

Education:

- M.S. Forest Science, Yale University, New Haven, CT 1992.
- A.B. Economics and Environmental Studies, Bowdoin College, Brunswick, ME 1987

Employer: National Marine Fisheries Service, Northwest Fisheries Science Center, Environmental Conservation Division, Watershed Program. Seattle, WA. Previous employment: The Tulalip Tribes, Natural Resources Department. Marysville, WA. 1993-1998.

Position: Research Biologist, Team Leader (Restoration), NMFS employee since 1998.

Present assignment: George has worked in the fisheries science and management field since 1989. His primary research interest during that time has been the examination of natural and land-use effects on salmon habitat and production. George has conducted research on historic and current land use impacts on salmon habitat and production, the influence of wood in forested stream channels, the development of a wood recruitment model to determine the relative influence of forestry activities, and what role watershed analysis plays in ecosystem management. He is currently studying how salmon respond to log jam placement in large river systems, the effects of large flood events on salmon spawning success, and how landscape characteristics and land use affect salmon abundance.

Five relevant publications:

Benda, L.. Poff, D., Miller, T., Dunne, G. Reeves, G. Pess, and M. Pollock. In review. Network disturbance theory: landscape and river organization of environmental variance. Bioscience.

Pess G.R., D.R. Montgomery, R.E. Bilby, E.A. Steel, B.E. Feist, and H.M. Greenberg. 2002. Influence of landscape characteristics and land use on coho salmon (*Oncorhynchus kisutch*) abundance in the Snohomish River, Washington State, USA. Canadian Journal of Fisheries and Aquatic Sciences 59:613-623

Pess, G.R., D.R. Montgomery, T.J. Beechie, and L. Holsinger. 2002. Anthropogenic alterations to the biogeography of salmon in Puget Sound. Pages 129-154 in D. Montgomery, S. Bolton, and D. Booth, eds., Restoration of Puget Sound Rivers, University of Washington Press, Seattle, WA.

Montgomery D.R., E.M. Beamer, G.R. Pess, and T.P. Quinn. 1999. Channel type and salmonid spawning distribution and abundance. Canadian Journal of Fisheries and Aquatic Science. 56: 377-387

Montgomery, D.R., R.D. Smith, K.M. Schmidt, and G.R. Pess. 1995. Pool Spacing in Forest Channels. Water Resources Research. 31: 1097-1105.

Michael M. Pollock, Contributing Investigator (0.15 FTE for FY03)

Education:
- Ph.D., Ecosystems Analysis, College of Forest Resources, University of Washington, Seattle, WA, 1995.
- B.S., Biochemistry, California State University, Arcata, CA, 1986.

Employer: NOAA Fisheries, Northwest Fisheries Science Center, Environmental Conservation Division, Watershed Program.

Position: Fisheries Biologist. NOAA Fisheries employee since 1999.

Present assignment: Dr. Pollock supervises a research group at the NWFSC that is currently working with the Washington State Department of Natural Resources monitoring the effects of timber harvest on instream habitat.

Previous research/expertise: Dr. Pollock's expertise is in the areas of watershed processes and riparian ecology. His doctoral research explored relationships between effects of disturbance and environmental variation on patterns of biological diversity in floodplain systems. He has published manuscripts on biodiversity, riparian ecology and the relations between beaver habitat and coho salmon production, and is regularly invited to speak at regional and national meetings.

Five Relevant Publications:

Pollock, M.M., T.J. Beechie, S. Chan and R. Bigley. 2003. Monitoring and evaluating riparian restoration efforts. Chapter 3 *In* Methods for monitoring stream and watershed restoration. American Fisheries Society, Bethesda, MD.

Pollock, M.M. and T.J. Beechie. 2001. Effectiveness monitoring of instream habitat on Washington State Department of Natural Resources trust lands. Washington State Department of Natural Resources, Olympia, Washington.

Pollock, M. M. 1998. Biodiversity. Pages 430-452 *in* R.E. Bilby and R. J. Naiman, editors. Ecology and management of streams and rivers in the Pacific Northwest coastal ecoregion. Springer-Verlag, New York.

Pollock, M. M., R. J. Naiman, and T. A. Hanley. 1998. Predicting plant species richness in forested and emergent wetlands - A test of biodiversity theory. Ecology 79:94-105.

Pollock, M. M., R. J. Naiman, H. E. Erickson, C. A. Johnston, J. Pastor, and G. Pinay. 1994. Beaver as engineers: Influences on biotic and abiotic characteristics of drainage basins. Pages 117-126 *in* C. G. Jones and J. H. Lawton, editors. Linking species to ecosystems. Chapman & Hall, New York.