Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal

Section 1. General administrative information

Path-Participation By State And Tribal Agencies

Bonneville project number, if an ongoing project 9600800

Business name of agency, institution or organization requesting funding
Oregon Department of Fish and Wildlife

Business acronym (if appropriate) ODFW

Proposal contact person or principal investigator:

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Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name
Columbia Basin Fish and Wildlife Authority	2501 SW 1st Ave.	Portland, OR 97207	Paul Wilson
Columbia River Inter-Tribal Fish Commission	729NE Oregon St. Suite 200	Portland, OR 97232	Earl Weber
Idaho Department of Fish and Game	600 South Walnut Box 25	Boise, Idaho 83707	Dr. Charlie Petrosky
Washington Department of Fish and Wildlife	2108 Grand Blvd	Vancouver, Wa 98661	Olaf Langness
US Fish and Wildlife Service	9317 Hwy. 99, Suite I	Vancouver, Wa 98665	Dr. Phaedra Budy

NPPC Program Measure Number(s) which this project addresses.
3.2.A, 3.2.F , 4.2a, 4.3, 7.1E

NMFS Biological Opinion Number(s) which this project addresses.

NMFS Hydrosystem BO RPA 13; RPA A17

Other planning document references.
NMFS Recovery Plan task 0.3.b and 2.11.b

Subbasin.
Columbia River Basinwide

Short description.
Test hypotheses underlying key salmon recovery management decisions, develop decision analysis to evaluate alternative management strategies, and assist in designing research, monitoring and adaptive management experiments.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction		Watershed
	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production	X	Population dynamics
*	Oceans/estuaries	*	Research	*	Ecosystems
*	Climate	X	Monitoring/eval.	*	Flow/survival
	Other	*	Resource mgmt		Fish disease
		*	Planning/admin.	*	Supplementation
			Enforcement		Wildlife habitat en-
			Acquisitions		hancement/restoration

Other keywords.
modeling, decision analysis, conservation biology

Section 3. Relationships to other Bonneville projects

Project #		Nature of relationship
9600600		work with planning group to develop specific PATH workplans and reports to be submitted to PATH peer review process, coordinate independent scientists work plan.
9203200	USFS modeling support	PATH scientific support
9303701	Simulation Modeling Participation C. Paulsen	PATH scientific support
9601700	Hydrosystem Work Particiption A. Giorgi	PATH scientific support

8910800	Modeling PATH/ BPA technical support J. Anderson	PATH scientific support
98	PATH Participation NMFS	PATH scientific support

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Retrospective Analysis (RA)	a	Snake River Sockeye salmon (RA)
1	RA	b	Finalize RA for spring/summer chinook (SPCH) fall chinook (FACH), and steelhead (STHD)
2	Prospective Analysis (PA)	a	STHD PA;completed, reviewed, and modified
2	PA	b	Incorporate additional management actions into STHD PA, update SPCH and FACH PAs
2	PA	c	Document biological rationale for alternative hypotheses for SPCH, FACH, and STHD
2	PA	d	Estimate the probabilities associated with alternative hypotheses
2	PA	e	Finalize PA for SPCH,FACH, and STHD. Relate to sockeye
2	PA	f	Incorporate PA findings into integrated species decision analysis
2	PA	g	Iterative evaluation of options
3	Decision Analyses (DA)	a	Estimate for STHD the needed improvement in life cycle survival
3	DA	b	Complete an integrated species DA
3	DA	c	Use integrated species DA to evaluate research, monitoring, and adaptive management experiments
4	Conclusions Document	a	Develop final conclusions document integrating across SPCH, FACH, and STHD. Relate to sockeye.
5	Adiministration and Planning		Coordinate PATH activities and administer subcontacts

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	11/1998	12/1998	10.00%
2	11/1998	5/1999	30.00%
3	11/1998	9/1999	45.00%
4	7/1999	10/99	10.00%
5	11/1998	10/1999	5.00%
			TOTAL 100.00%

Schedule constraints.
Schedule and objective are prioritized by needs for NMFS 1999 decision on the FCRPS Biological Opinion. The schedules may change due to the number of alternative management options that are fowarded for evaluation.

Completion date.
On going need for PATH to evaluate overall effects of management actions on salmon recovery.

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel	NRS4 10 mos, NRS3 6mos, NRS1 6mos, Manager 3 mos, Office Asst. 3mos	$107,342
Fringe benefits	41% of salary	$44,010
Supplies, materials, non-expendable property	Computer Software Miscellanous	$2,258
Operations & maintenance	Communications Computer Lease	$4,200
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		
PIT tags	# of tags:	
Travel	air fare, per diem, lodging, Mileage & Parking for workgroups and workshops	$4,425
Indirect costs	22.9%	$37,152
Subcontracts	CRITFC,CBFWA,IDFG, USFWS,WDFW	$498,750
Other		
TOTAL		$698,137

Outyear costs

Outyear costs	FY2000	FY01	FY02	FY03
Total budget	$698,200	$698,200	$710,000	$720,000
O&M as % of total				

Section 6. Abstract

The NMFS 1995-1998 Biological Opinion on operation of the Federal Columbia River Power System created a process called PATH--Plan for Analyzing and Testing Hypotheses. The PATH process was designed to clarify the nature of differences among salmon management models, and point the way towards helping to resolve them. The PATH process is intended to ensure that the region has the benefit of the best available scientific information in analyses supporting salmon recovery/rebuilding efforts, including: development of recovery plans for listed Endangered Species Act (ESA) salmon and steelhead populations; ESA section 7 consultations; and development of rebuilding programs under the Columbia Basin Fish and Wildlife Program. The first phase of PATH is retrospective and involves explicitly stating hypotheses about mortality over the life cycle, evaluating strengths and weaknesses of supporting evidence and testing those hypotheses which have significant management implications. Prospective analyses estimate the improvement needed in life cycle survival to achieve recovery objectives; forecast future stock responses for different management actions under the range of alternative hypotheses; document a biological rationale for each alternative hypothesis which can then be used in weighting in the formal decision analyses. The formal decision analyses assess the effects of different combinations of actions, to provide guidance to fishery management decision makers in an adaptive management framework. PATH's schedule and objectives are prioritized by needs for NMFS 1999 decision on the Biological Opinion. The PATH products are rigorously reviewed by an independent scientific review team.

Section 7. Project description

a. Technical and/or scientific background.

Salmon populations in the Columbia River Basin have been in decline since the early days of western settlement, with dramatic declines occurring in the last three decades. The annual production of the Snake River spring/summer chinook during the late 1800's was probably in excess of 1.5 million fish or 39% to 40% of all Columbia River spring/summer chinook (NMFS Biological Opinion, 1995). Today the population of Snake River spring/summer chinook is approximately 0.5% of its historic abundance, with approximately 1,800 spring/summer chinook returning to the Snake River. The story is similar for the Snake River fall chinook. From 1938, when Bonneville dam was completed, to 1950, the returns of Snake River fall chinook fell from approximately 72,000 to 29,000. Today, after completion of the Snake River dams approximately 350

Snake River fall chinook return. Such declines have led to both races of Snake River chinook being listed under the Endangered Species Act, though both have continued to decline since listing (NMFS, Proposed Recovery Plan for Snake River Salmon, 1995). Past efforts to halt the decline have been ineffective because 1) they didn't adequately reduce hydrosystem mortality; and 2) not all entities shared common objectives. A common adaptive management framework (analytical monitoring, evaluation and management assessment approach) for guiding research and monitoring activities and providing management advice for salmon population conservation and restoration, could have helped clarify these issues. The NMFS decision on the 1995 Biological Opinion for the FCRPS (hydrosystem) configuration and operations is slated for 1999. Therefore, there is an urgent need for coherent, defensible biological guidance to decision makers.

PATH has made very significant progress in building constructive working relationships among scientists from agencies with different perspectives (i.e. BPA, NMFS, USACE, State and Tribal agencies, NWPPC). PATH has helped to define many areas of common agreement and is specifying the information or experiments needed to resolve remaining key areas of disagreement. The high quality retrospective analyses (Marmorek et al. 1996; Marmorek and Peters 1996) cooperatively generated and the PATH prospective analyses (Marmorek and Peters 1997), is beginning to identify biological performance measures such as improvements in survival over the salmon life-cycle and smolt to adult return rates (SARs) which are need to achieve population recovery goals. This PATH work and the conceptual foundation provided by the ISG in their Return to the River report, will together strengthen the scientific basis for the difficult and urgent decisions that must be made for salmon conservation and recovery.

b. Proposal objectives.

The goal of this project is to have the Fishery Agencies and Tribes (CBFWF, CRITFC, IDFG, ODFW, USFWS and WDFW), through ODFW, provide their best available scientific methods and data to be applied to analyses of the PATH process with respect to salmon and steelhead recovery and rebuilding in a coordinated regional effort that maximizes the effective use of limited staff resources.

PATH grew out of reviews by the Scientific Review Panel, and a series of meetings with Regional Analytical Coordination Group (ANCOOR) and senior personnel in NMFS, BPA ,USACE, NWPPC, IDFG, WDFW, ODFW, and CRITFC. The primary objectives were originally defined as:

1. Determine the overall level of support for key alternative hypotheses based on existing information (the greater the number and diversity of confirming observations, the more probable the hypothesis). Use these results to provide guidance to management agencies. Propose other hypotheses and/or model improvements that are more consistent with the data.

2. Assess the ability to distinguish among competing hypotheses from future information. Advise various institutions on research, monitoring and adaptive management experiments which would maximize the rate of learning and clarify decisions.[1]

Further thinking has led to an evolution in PATH's objectives and the means of achieving them. PATH is an iterative process of defining and testing a logical framework of hypotheses relating to the Columbia River anadromous salmonid ecosystem, while moving towards stock recovery and rebuilding. Iteration within the PATH process should occur as this logical framework is revised over time in response to improvements in both information and analytical methods. The overall objectives of the PATH effort are:

- define the management decisions that serve to focus analytical activities;
- bound the anadromous salmonid ecosystem components under consideration;
- explicitly define alternative hypotheses and implications for the functioning of ecosystem components, in terms of the distribution of survival over the populations' life-cycle, and the life stage and population responses to management actions under different natural conditions;
- compile and analyze information to assess the level of support for alternative hypotheses (component, composite, and aggregate hypotheses);
- propose other hypotheses and/or model improvements supported by the weight of evidence of these analyses;
- provide guidance to the development of regional programs that would stabilize, ensure persistence of, and eventually restore depressed salmon stocks to self-sustaining levels;
- improve existing model and/or develop new models to better evaluate the likelihood of persistence and recovery of salmon and steelhead stocks (i.e. assess conservation risk) under alternative management scenarios;
- provide guidance to managers on the strategic implications of hypotheses tests for key management decisions, and for the design of research, monitoring and adaptive management experiments that maximize the rate of learning and clarity of decisions; and
- provide a structure for an adaptive learning approach to development and implementation of a regional salmonid recovery program (i.e. iterative evaluation of

[1] Barnthouse, L.W. and D. Marmorek; April 5, 1995. A new direction for Columbia River Basin Salmonid Model Evaluation and Use.

results of research, monitoring, and adaptive management experiments; assess implications of alternative hypotheses on subsequent actions).

The logical framework developed in PATH will assist in management decisions concerning the Columbia Basin anadromous salmonid ecosystem. The design of this framework is driven by the management questions of interest, the alternative hypotheses relevant to these questions, and the data available to test these hypotheses. The purpose of the exercise is not to simply compare the existing belief systems embodied in the various models, though modeling plays a large role. Instead, the framework that is laid out is not limited to existing models. Ultimately, this should also lead to improvements in analytical tools.

FY 1999 Objectives and Tasks:

1. RETROSPECTIVE ANALYSIS: Publish peer-reviewed reports demonstrating the overall level of support for key alternative hypotheses with implications for management decisions on endangered or threatened salmon populations of the Columbia River Basin. Provide guidance to management agencies (particularly NWPPC and Implementation Team) based on these outputs in written format and through oral presentations. Propose other hypotheses and/or model improvements that are more consistent with the data. Develop improved models that incorporated what has been learned from the retrospective analyses.

Through FY98, retrospective analyses should be completed for spring/summer chinook, fall chinook and steelhead. The tasks for FY99 retrospective analysis are:

a. Complete a retrospective analysis and peer reviewed report for Snake River sockeye which draws parallels to the completed retrospective conclusions for spring/summer chinook, fall chinook and steelhead.
b. Update and finalize retrospective analysis for spring/summer chinook, fall chinook and steelhead.

2. PROSPECTIVE ANALYSIS: PATH "prospective" analyses attempt to evaluate the ability of alternative management actions to restore depressed populations of spring/summer chinook stocks. These prospective analyses are based on results of the retrospective analyses, and are using this information in two different but complementary ways to assess alternative management actions. The first approach is a weight-of-evidence approach, which synthesizes existing information around specific questions in the decision-making process. This approach was applied in Chapter 6 of the FY96 Retrospective Report, which developed a flowchart of key questions to consider when making decisions about the hydropower system and compiled available evidence to answer those questions. The second phase to prospective analyses is a Bayesian modeling approach, which systematically forecasts the outcomes of management actions under several alternative hypotheses (about biological mechanisms linking actions to outcomes). The prospective

analysis incorporates what has been learned from the retrospective analyses. Through FY 98, preliminary prospective analysis should be completed for spring/summer chinook and fall chinook . During FY 99, there are seven tasks concerned with Snake River fall chinook and steelhead prospective analyses, and an integrated prospective analysis for spring/summer chinook, fall chinook, and steelhead:

a. Complete prospective analyses for steelhead and submit for review. Modify the methods used in the steelhead prospective analysis, based on comments from the SRP and ISAB.

b. Incorporate additional management actions (proposed by the IT) into the steelhead prospective analysis, and update the spring/summer chinook and fall chinook prospective analyses for additional management actions.

c. Document the biological rationale for alternative hypotheses.

d. Estimate the probabilities associated with alternative hypotheses, based on the full suite of available empirical information and expert elicitation.

e. Finalize steelhead, fall chinook and spring/summer chinook prospective analysis report. Identify similarities and differences in response to management actions for sockeye.

f. Incorporate the findings of the prospective analyses on spring/summer chinook, fall chinook and steelhead into an integrated species decision analysis.

g. After initial prospective findings of integrated analysis, provide analysis of alternative management options for the region. The evaluation of options will be an iterative process between fishery managers and the PATH working group.

3. DECISION ANALYSES: Publish peer-reviewed reports and journal articles that use a number of analytical approaches that explicitly account for uncertainty (e.g., Baysian statistics, formal decision analysis) to project the range of possible future states of salmon populations under different management actions. A related objective is to apply these analytical approaches to assess the ability of adaptive management experiments to distinguish among competing hypotheses from future information. In generating these outputs we will gradually evolve a quantitative adaptive management framework for development of a regional salmonid recovery program. Advise various institutions (e.g., IDFG, ODFW, NMFS, NPPC, USFWS, WDFW, and Columbia River treaty tribes) on research, monitoring and adaptive management experiments, which would optimize the rate of learning and clarify decisions for maximizing the likelihood of recovery. Integrate the future information from basin wide research, monitoring, and adaptive management experiments in a quantitative framework to provide ongoing, coordinated and peer-reviewed management advise.

The FY 99 goals for the decision analyses are as follows:

a. Estimate for steelhead the improvement in life cycle survival required to reach survival, recovery, and rebuilding objectives and the uncertainty associated with these estimates. These survival improvements can be expressed as Biological Objectives, consistent with the 1994 NWPPC Fish and Wildlife Program. To develop goals for rebuilding, decisions will need to be made on which stocks are included.

b. Complete an integrated species decision analysis. Build on the formal decision analysis developed in FY98 for spring/summer chinook and fall chinook, which provides a common framework (integrating across spring/summer chinook, fall chinook and steelhead) for incorporating alternative management action packages. The decision analysis permits the calculation of the expected value of various performance measures (e.g. probability of survival, probability of recovery, expected rates of learning), given a number of different hypotheses about key processes and life history stages, and their associated probabilities. Incorporate the probabilities associated from alternative hypotheses (from tasks 2d and 2f) into the decision analysis. We have defined a suite of performance measures, some of which could be used on an annual basis to optimize the likelihood of reaching survival improvement objectives. The development of a suite of performance measures will involve interaction with Decision Process Coordinating Group and the Independent Scientific Advisory Board (ISAB). Development of a set of action packages for the decision analysis will involve interaction with both the IT as well as other entities. Analyze and report on the integration of recommended management actions for the spring/summer chinook, fall chinook, sockeye, and steelhead. This analysis would identify conflicts and complements in the proposed action plans, and identify means by which research, evaluation, and monitoring actions can be streamlined to address multiple species of concern.

c. The decision analysis approach (integrated for species) will also be used to evaluate research, monitoring and adaptive management experiments. Adaptive management experiments involve evaluating the tradeoffs between optimizing learning while maximizing the likelihood of population survival and recovery goals. Learning can be represented in the decision analysis by changes in the probabilities of alternative hypotheses. This analysis of the benefits of different management and research directions would be linked to ongoing research, monitoring and evaluation programs, to assess whether or how existing activities could be modified to better answer key uncertainties, and also to suggest new activities which could be added to those already planned. Integrate research monitoring and evaluation findings with the RRG in development of a regional research, monitoring, and evaluation plan.

4. CONCLUSIONS DOCUMENT: Summarize the retrospective, prospective and decision analyses in a format that can be used by regional fishery management decision makers. The tasks for FY-99:

a. Develop a final conclusions document intergrating across spring/summer chinook, fall chinook, and steelhead that summarizes the findings of the retrospective analyses, prospective analyses, and decision analyses. In additon, identify similarities and differences in response to management actions for sockeye in this report. This report should specifically address the evidence for and against competing hypotheses.

c. Rationale and significance to Regional Programs.

Snake River spring/summer and fall chinook, steelhead, and sockeye populations have declined dramatically since completion of the Federal Columbia River Power System (FCRPS). Spring/summer and fall chinook are listed as threatened under the Endangered Species Act (ESA), and sockeye are listed as endangered. ESA listings are pending for steelhead in the Snake and upper Columbia rivers. Under the ESA, the National Marine Fisheries Service (NMFS) is charged with developing and implementing management plans to ensure survival and recovery of the listed salmon populations.

For the past several years the BPA, the NWPPC, the NMFS, and various state and tribal resource agencies have been attempting to work together to compare and enhance the models used by all of the agencies to evaluate management actions intended to recover depleted Columbia River Basin salmon stocks. Results from previous model comparison and peer-review efforts indicated that the models operate with different interpretations or hypotheses regarding the survival rates at different stages of the salmon life cycle, and result in disparate management advice.

The NMFS' 1995-1998 Biological Opinion on operation of the FCRPS created a process called PATH--Plan for Analyzing and Testing Hypotheses. The PATH process was designed to clarify the nature of the differences among the models and point the way towards helping to resolve them (Marmorek and Parnell 1995). The region has a continuing need to consider analytical results in decision making in a number of areas, including: the development of specific recovery plans for listed salmon and steelhead stocks; the Endangered Species Act mandated Section 7 consultation process; and, the development of rebuilding programs under the NWPPC Fish and Wildlife Program (see sec. 2.2-4 Strategy for Salmon Vol. II). The region has and will continue to benefit significantly in these areas from a coordinated and consistent approach to technical analyses supporting salmon rebuilding and recovery efforts. In recognition of the need, the NWPPC (Ibid., Sec. 7.3) has called for "....a process to provide for continuing review, coordination and development of analytical tools to assist decision making, facilitate program evaluation and identify critical uncertainties." The PATH process is intended to ensure that the region has the benefit of the use of best available scientific methods and information in the analyses supporting salmon recovery/rebuilding efforts.

The first phase of PATH is retrospective, and involves explicitly stating hypotheses about the distribution of mortality over the life cycle, evaluating strengths and weaknesses of supporting evidence, and testing those alternative hypotheses which have significant

management implications. Hypotheses are organized within PATH by anthropogenic (habitat, harvest, hatcheries and hydropower) and environmental (climatic/oceanographic) factors. The hypothesis and decision frameworks we developed and applied in PATH have provided a means of harnessing a wide array of information, analytical tools and unpublished scientific knowledge towards key management decisions. The analyses have clearly confirmed patterns of spatial and temporal change in spring-summer chinook stocks, which not only elucidate the most likely causes of recent declines, but also lay the groundwork for grouping stocks for future adaptive management experiments. By bridging across different types of data sets and studies (e.g. migration corridor survival, transportation effectiveness, spawner-smolt survival, spawner-recruit survival, climate and ocean indicators, land use and hatchery indicators), PATH has generated a higher level understanding of how to integrate across life history stages and spheres of management action (hydro, hatchery, habitat, harvest). This provides a concrete foundation for designing adaptive management programs and coordinating research initiatives. PATH scientists have recommended several research, monitoring and evaluation approaches to resolving critical uncertainties (e.g. assessing the magnitude of delayed mortality of both transported and in-river migrants). In addition, by rigorously assessing the value of additional information from research studies, monitoring, and adaptive management experiments, PATH will provide a scientific basis for assisting in prioritizing expenditures for conserving and restoring these populations given limited financial resources. The design of this adaptive management framework is already in progress: it is being driven by the management questions of interest, the alternative hypotheses relevant to these questions and the data available to test these hypotheses. In FY 1998 PATH is conducting a workshop on experimental management options. The PATH scientific review panel has recommended that in light of the major uncertainties that are difficult to resolve with current information, we focus attention on experimental management options which vary management actions over time and space in a deliberate attempt to test key hypotheses pertaining to response of fish populations.

d. Project history

PATH began in 1995. In 1993 and 1994, funding was provided to facilitate cooperative efforts by the BPA, the NWPPC, the NMFS, IDFG, ODFW and WDFW and the CRITFC and their member tribes to compare and enhance the simulation models they use to evaluate Columbia River salmon management options. Results from these model comparison activities and associated peer-review efforts showed that each modeling system has different strengths and weaknesses, several common patterns of model behavior, and some significant differences. In 1994, an independent scientific review panel (coordinated by Dr. Larry Barnthouse, then of Oakridge National Laboratory) completed an interim report in which they concluded that there were three major differences between modeling systems: 1) the distribution of survival over the life span; 2) the effect of flow on juvenile salmon survival; and 3) the benefit of transporting juvenile salmon around hydroelectric dams. The panel felt that as long as these differences exist the models were going to give different answers in a fairly predictable fashion. This would result in conflicting advice to decision makers and would make

further analysis of details of model behavior relatively unproductive. The panel concluded that it would be more fruitful to focus on describing and attempting to resolve the fundamental issues, through hypothesis formulation and testing (applying Bayesian and other approaches). The 1995 NMFS Biological Opinion on operation of the federal Columbia River Power System (pg. 124, Rec. 17) stated that "The BPA shall participate with NMFS in activities to coordinate the regional passage and life cycle models and to test the hypotheses underlying those models." NMFS noted that the emphasis should shift to analyses that test the different assumptions underlying the models, rather than refining our understanding of how the models are different. NMFS concurred with the recommendation of the Scientific Review Panel (SRP) to conduct an analysis of alternative hypotheses, and worked with BPA to ensure that this work was funded out of the dollars dedicated to actions arising out of the Biological Opinion. This was the genesis of the Plan for Analyzing and Testing Hypotheses (PATH). Critical to the success of PATH are three components: 1) facilitation and funding of the interagency scientific working groups, 2) specialized expertise in Bayesian statistics, multivariate analysis, and Columbia Basin salmon stock assessment and population dynamics; and 3) external, independent peer review.

In the 3 years of its existence, PATH has already made considerable progress. Specific achievements include:

- clarification of management decisions with senior personnel in the major institutions;

- development of hypothesis frameworks and sets of alternative hypotheses relevant to management decisions;

- considerable data reconnaissance, acquisition and refinement prior to completion of retrospective analyses of specific hypotheses;

- detailed retrospective analyses for hypotheses related to hydrosystem, habitat, hatchery and harvest management decisions;

- five workshops, each involving about 30 research scientists, to plan retrospective and prospective analyses, review the results of preliminary analyses and assess their implications for management decisions;

- a series of technical meetings of task work groups to advance progress on specific retrospective analyses;

- novel development and/or application of analytical tools to assist in decision making

1. three-level hypothesis framework

2. decision trees for hydrosystem, habitat and hatchery management decisions

3. a Bayesian maximum likelihood estimation (MLE) framework to evaluate ability of different models to predict stock-recruitment patterns

4. several different statistical analyses (cluster analyses, multiple regression, analysis of variance and covariance) to assess patterns implied by spatial and temporal contrasts in stock-recruitment

5. a method for evaluating survival trends in the freshwater spawning and rearing life stage

6. prospective analyses for determining the required improvements in the chinook salmon life cycle survival needed for achieving recovery goals

7. development of a Bayesian population model to be used to simulate the implications of habitat, harvest, hatchery, and hydro management actions for survival and recovery of listed Snake River spring/summer chinook stocks

8. a preliminary formal decision analysis to assess through a variety of performance measures the effects of different combinations of actions in each of the four H's (hydrosystem, hatcheries, habitat, harvest]

- numerous reports (see below)

- a 30-page Conclusions Document synthesizing the major findings from the 620-page Final Report on Retrospective Analyses for FY96, including outstanding information needs necessary to resolve major uncertainties

- Decision analysis report on spring/summer chinook which tests the decision analysis formulated over the last two years, provides decision makers with our preliminary insights into the range of population responses to alternative management decisions, provides biological rationale for alternative hypotheses, and characterizes the magnitude of uncertainties and demonstrates their relative importance in affecting outcomes of alternative management decisions.

- a set of presentations on progress by PATH participants to the Implementation Team (IT) Committee on PATH and other IT representatives; members of the NPPC and the public; meetings with the Research Review Group(RRG) of the IT; and meeting with the Independent Scientific Group (now the Independent Scientific Advisory Board) to coordinate our activities.

The past costs for this project were $498,598 for 1996, $606,381 for 1997, $633,331 for 1998.

e. Methods.

PATH consists of an iterative series of workshops, analytical activities and reporting steps to test key hypotheses underlying management decisions, coordinated by an interagency PATH Planning Group. (The PATH Planning Group includes the PATH facilitator, David Marmorek (ESSA Technologies); H. Schaller, ODFW (representing the State fishery agencies); J. Geiselman, BPA (representing the power system operating agencies); C. McConnaha, NPPC; E. Weber, CRITFC; and C. Toole, NMFS.) The workshops and reports force participants to complete tasks, and provide for fruitful exchange, feedback and internal peer review. Both a core set of 25 PATH participants, and an extended set of 15 - 20 occasional participants, provide input to analytical activities. Interaction with the Implementation Team for the Draft Recovery Plan and NPPC helps to prioritize major goals.

Iteration within the PATH process occurs as the logical framework of hypotheses is revised over time in response to improvements in both information and analytical methods. This framework is intended to:

1. compile and analyze information to assess the level of support for alternative hypotheses relevant to key management decisions, identifying knowledge and data gaps that could be filled through management experiments, research and monitoring;
2. provide guidance to the development of regional programs that would stabilize, ensure persistence, and eventually restore depressed salmon stocks to self-sustaining levels; and
3. provide a structure for an adaptive learning approach to development and implementation of a regional salmonid recovery program.

The overall PATH process has five features to ensure high quality outputs: 1) fisheries scientists from the participating agencies; 2) active participation of three internationally recognized independent fisheries scientists in PATH workshops and technical meetings (Drs. Peterman, Deriso and Botsford); 3) the formation of interagency work groups to address specific topics, which ensures strong internal review of all work products; 4)

overall coordination, mediation and integration by the PATH facilitator; and 5) external review by the Scientific Review Panel (Drs. Walters, Collie, Saila and Dennis).

PATH activities in FY96 culminated in the completion of a Conclusions Document, which summarizes the findings of retrospective analyses. This document represents the consensus view of PATH participants on what the data and analyses completed thus far say about probable reasons for the decline in abundance of Snake River spring/summer chinook. This document has been supplemented by a series of presentations to the NPPC, the Implementation Team, and the public. Summary outputs and quarterly presentations are an integral part of the PATH process and are an important means of communication between PATH and interested groups in the region. PATH products are also available on the BPA-maintained www site.

Some of the technical methods used to date in PATH were summarized in Section 2 on historical information. PATH uses a weight-of-evidence approach to hypothesis testing, looking for consistency across all available evidence, and the sensitivity of conclusions to the weights assigned to different data sources and analytical results. The retrospective analyses provide the foundation for prospective analyses. The FY98 goals for the prospective analyses are as follows:

P1. Estimate the improvement in life cycle survival required to reach various salmon objectives (survival, recovery, rebuilding) and the uncertainty associated with these estimates, using a Bayesian modeling approach that incorporates all uncertainties and compare results with existing stochastic life-cycle models (ELCM and SLCM). These survival improvements can be expressed as Biological Objectives, consistent with the 1994 NPPC Fish and Wildlife Program. To develop goals for rebuilding, decisions will need to be made on which stocks are included. For survival and recovery goals these are clearly related to stocks listed under the *Endangered Species Act*. (This task nearly complete for Snake River spring-summer chinook as of Jan. 30/97).

P2. Develop a formal decision analysis framework, which provides a common tool for incorporating alternative management action packages, alternative states of nature (with their respective posterior probabilities based on retrospective analyses), and a variety of performance measures. The decision analysis framework will permit the calculation of the expected value of various performance measures (e.g. probably of survival, probability of recovery, expected rates of learning), given a number of different hypotheses about key processes, and their associated probabilities. In some cases (e.g. hydro) these probabilities may be computed from retrospective analyses, whereas in other cases (habitat, hatcheries) they may need to be more subjectively assigned (although bounded by inferences of empirical stock performance). The development of a suite of performance measures will involve interaction with the RRG

and ISAB. Development of a set of action packages for the decision analysis will involve interaction with the IT as well as other entities. A modular set of interacting software tools is expected to evolve within this task to permit all PATH investigators to flexibly explore the implications of alternative model formulations. This modular framework would include the output from different passage models; tests of this output against both stock-recruitment, SARs, passage survival, and transportation studies (using an MLE framework to estimate Bayesian posterior probabilities); and a decision analysis tool to generate expected values of different performance measures given the model output and associated probabilities.

P3. Use of the decision analysis approach and other methods to assess the rate of learning associated with alternative sets of management actions, research and monitoring activities, and adaptive management experiments. This analysis of the benefits of different management and research directions would be linked to ongoing research, monitoring and evaluation programs, guide management decisions to minimize risks to extremely depressed populations, to assess how existing activities could be modified to better answer key uncertainties, and also to suggest new activities which could be added to those already planned. A component of this objective is to define performance measures to optimize the likelihood of reaching survival improvement objectives.

Tasks P1 and P2 were completed in FY97 for spring-summer chinook. Retrospective analysis for fall chinook and steelhead will be completed in FY98, though more qualitative assessments will certainly occur in FY98. Experimental management work for spring-summer chinook will be initiated in FY98. Prospective modeling and decision analyses for fall chinook and steelhead will be completed in FY99. Prospective modeling, decision analysis, and experimental management design work intergrating all three species will be undertaken in FY99.

This work would continue through the year 2003 focusing on integrating these analyses and decision tools over many of the salmon populations in the Columbia River basin. This is the period where many critical management decisions and assessments of those decisions must be made.

f. Facilities and equipment.

The project is primarily located at the following: CBFWF, Portland; CRITFC, Portland; IDFG, Boise; ODFW, Portland; USFWS, Vancouver; and WDFW, Vancouver. The Fishery Agencies and Tribal (FAT) staff shall participate in meetings of the PATH, ANCOOR and policy group in various locations. In addition, numerous technical work sessions will be required with technical representatives of FAT, Facilitator, other ANCOOR member organizations, and outside technical experts to complete contract

tasks. Periodically, FAT ANCOOR representatives will need to consult and meet with their department field and research staff and attend related workshops and conferences. Some FAT members will participate in RRG meetings, Decision Process Coordinating Group meetings, IT meetings, and activities to provide input from the PATH process.

g. References.

Barnthouse, L. (ed.), J. Collie, B. Dennis, S. Saila, and C. Walters. 1996. Plan for Analyzing and Testing Hypotheses (PATH): First Scientific Review Panel Report. Prepared by ChemRisk Division, McLaren/Hart Environmental Engineering Co., Oak Ridge, TN for Bonneville Power Administration, Portland, OR, 20 pp.

Barnthouse, L. (ed.), J. Collie, B. Dennis, S. Saila, and C. Walters. 1997. Plan for Analyzing and Testing Hypotheses (PATH): Second Scientific Review Panel Report. Prepared by ChemRisk Division, McLaren/Hart Environmental Engineering Co., Oak Ridge, TN for Bonneville Power Administration, Portland, OR, 20 pp.

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Langness, O. P. and H. A Schaller. 1996. Contrasting Stock-Recruitment, Harvest, and Upstream Passage Survival Patterns of the Columbia River Stream-Type Chinook Populations. Draft Chapter 13 in: Plan for Analyzing and Testing Hypotheses (PATH),Retrospective Analysis.

Marmorek, D.P. and I. Parnell (eds.). 1995. Plan for Analyzing and Testing Hypotheses (PATH): Information package for Workshop 1 - Design of retrospective analyses to test key hypotheses of importance to management decisions on endangered and threatened Columbia River salmon stocks. Prepared by ESSA Technologies Ltd., Vancouver, BC with contributions from ANCOOR (Analytical Coordination Working Group) and Dr. R. Deriso, 88 pp. and appendices.

Marmorek, D.R, I, Parnell, L. Barnthouse and D.R. Bouillon. 1995. PATH - Plan for Analyzing and Testing Hypotheses. Results of a Workshop to Design Retrospective Analyses. Prepared by ESSA Technologies Ltd. Vancouver, BC for Bonneville Power Administration, Portland, 71 pp. and appendices.

Marmorek, D.R. (ed.)., J.J. Anderson, L. Bashan, D. Bouillon, T. Cooney, R. Deriso, P. Dygert, L. Garrett, A. Giorgi, O.P. Langness, D. Lee, C. McConnaha, I. Parnell, C.M. Paulsen, C. Peters, C.E. Petrosky, C. Pinney, H.A. Schaller, C. Toole, E. Weber, P.

Wilson, and R.W. Zabel. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C. 620 pp. Chapters 3, 5, and 9 are about to be submitted to Canadian Journal of Fisheries and Aquatic Sciences.

Marmorek, D. and C. Peters (editors) and 24 co-authors. 1996. PATH - Plan for Analyzing and Testing Hypotheses. Conclusions of FY 96 Retrospective Analyses. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. December 10, 1996

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PATH Hydro Workgroup, Data Subcommittee. May 1997. Draft Review of survival and travel time estimates for yearling chinook salmon through various reaches in the Snake and Columbia system.

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Peters C. and D. Marmorek. 1996. Detailed notes from PATH Workshop 3, Wenatchee, Washington (October 7-11, 1996). Prepared by ESSA Technologies Ltd., Vancouver, BC for Bonneville Power Administration, Portland, OR, 24 pp.

Petrosky, C.E., H.A. Schaller and R.C.P. Beamesderfer. 1995. Spawner-recruit relationships for spring and summer chinook populations in several Columbia and Snake River subbasins. Draft prepared for PATH Workshop 1

Petrosky, C.E. and H.A. Schaller. 1996. Evaluation of survival trends in the freshwater spawning and rearing life stage for Snake River spring/summer chinook. Chapter 9.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Petrosky, C. 1997. Steelhead data reconnaisance and run reconstruction. Progress Report for PATH Workshop 5. October 20-23, 1997. 5 p. plus tables and figures.

Schaller, H.A., C.E. Petrosky and O.P. Langness. 1996. Contrasts in stock recruitment patterns of Snake and Columbia River spring/summer chinook populations. Chapter 3.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Toole, C., A. Giorgi, E. Weber, , W. McConnaha, and anonymous. 1996. Hydro Decision Pathway and Review of Existing Information. Chapter 6.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Weber, E., P. Wilson, H. Schaller, R. Beamesderfer and C. Petrosky. 1997. Internal PATH Review of Williams, Matthews and Myers. 1997. The Columbia River hydrosystem: does it limit recovery of Snake River spring/summer chinook salmon? PATH document, submitted June 1997. 19 p. plus tables and figures.

Wilson, P. and anonymous authors. 1996. PATH: Hatchery Impacts. Chapter 11.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Wilson, P., E. Weber, C. Petrosky and H. Schaller. 1997. Draft proposed general framework for prospective modeling with detailed examples for one hypothesis about delayed mortality. PATH document, submitted August 1, 1997.

Wilson, P. and H. Schaller. August 1997. Passage and prospective model linkage. PATH progress report.

Section 8. Relationships to other projects

PATH currently involves cooperation among scientists from NMFS, BPA, U.Washington, NPPC, ODFW, IDFG, WDFW, CRITFC, USFS, USFWS, CBFWA, USACE, as well as from a number of independent representatives from academic and research institutions (Simon Fraser University, UC Davis, UBC, U. Rhode Island, U. Idaho, Inter-American Tropical Tuna Commission) and private firms (ESSA Technologies, Paulsen Environmental Research, Don Chapman Consultants). Collaboration occurs through workshops, meetings, workgroups, cooperative planning, joint reports, and scientific review. In addition, the Independent Scientific Group has participated in PATH since its inception (Phil Mundy, Jim Lichatowich, Chip McConnaha, and recently Chuck Coutant). Close cooperation with the ISAB is very important to PATH. PATH provides a formal process to efficiently utilize and focus the regional technical expertise. The PATH work will also be coordinated with US vs Oregon Columbia river Management Plan activities and the Mid- Columbia Habitat Conservation processes. The PATH project provides better integration of decision making among management agencies through a clear framework for decision analysis and adaptive management experiments. The PATH project directly links and coordinates the work of 7 Bonneville fish and wildlife program projects (identified in section 3 of the proposal).

Section 9. Key personnel

Name: Howard Schaller
Title: Biometrics Program Leader NRS4
Project Position: Principle Investigator and technical representative for Oregon
FTE: .83 FTE (1780 hrs)
Education:
B.S., Biology, York College, City University of New York (1975)
M.S., Marine Science, C.W. Post Center, Long Island University (1980)
Ph. D., Oceanography (Fisheries), Old Dominion University (1984)
Current Employer: Oregon Department of Fish and Wildlife 1990-Present. Biometrics Program Leader in the Interjurisdictional Fisheries Management Program Primary Duties: develop analytical models and statistical procedures to assess, monitor, and describe factors limiting naturally produced fish populations. These analytical techniques incorporate and integrate ecology, conservation biology, and population dynamics principles using probabilistic approaches. Participate in an inter-agency modeling and hypotheses testing technical team for Columbia River Basin salmon recovery and rebuilding activities. Develop proposals and/or oversee a number of projects including: multi-state agency and tribal participation in PATH process; the lower Snake River Compensation Plan: chinook salmon population viability assessment; StreamNet data base project; and hatchery spring chinook PIT tag mark-recapture survival assessment.
Previous Employment: August 1990. Senior Fisheries Scientist for the Columbia River Inter-Tribal Fish Commission (CRITFC), Portland, Oregon. Primary Duties: Co-Chair of the Pacific Salmon Commission's (PSC) Chinook Technical Committee. Responsible for developing analyses to evaluate the impacts of long and short-term coastwide fishing proposals on the coastwide chinook salmon rebuilding program. August 1982 - April 1984. Co-principal investigator for the Prince William Sound (PWS) Salmon Management Study. Employed by the Department of Oceanography, Old Dominion University, Norfolk, Virginia.
Description of expertise: 15 years experience in modeling salmon population dynamics and assessing rebuilding and recovery programs. Developing analytical models and statistical procedures to assess, monitor, and describe factors limiting naturally produced fish populations.
Recent Publications:
Chinook Technical Committee. 1985-1990. Pacific Salmon Commission Joint Chinook Technical Committee Annual Reports 1985-1990. PSC Vancouver, B.C.

Debrot, A, H. Schaller, and M. Matylewich. 1989. Estimates of sustainable exploitation rates for Columbia River landlocked White Sturgeon: Evaluating the importance of a maximum size limit. Columbia River Inter-Tribal Fish Commission Technical Report 89-4.

Petrosky, C. and H. Schaller. 1992. A comparison of productivities for Snake River and lower Columbia River spring and summer chinook stocks. American Fisheries Societies 1992 Northwest Pacific Chinook and Coho Workshop Proceedings.

Petrosky, C.E. and H.A. Schaller. 1996. Evaluation of survival trends in the freshwater spawning and rearing life stage for Snake River spring/summer chinook. Chapter 9.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996

Schaller, H. A, C. E. Petrosky, and O. P. Langness. 1997. Contrasts in stock-recruitment patterns of Snake and Columbia River spring and summer chinook salmon (Oncorhynchus tshawytscha) populations. in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996

Name: Charles E. Petrosky

Title: Fisheries Staff Biologist
Project position: Technical representative for IDFG
FTE: Fisheries Staff Biologist, full time, 12 months (2080 hours)

Education

Ph.D. 1984. University of Idaho. Fishery Resources (Supporting Field - Applied Statistics)
M.S. 1973. University of Minnesota. Fisheries (Minor - Entomology)
B.S. 1970. University of Minnesota. Fisheries

Current Employer

Idaho Department of Fish and Game

Current Responsibilities

Provide technical and analytical support to IDFG Fisheries Bureau on anadromous fisheries management issues. Participate in Columbia Basin interagency modeling and analysis of salmon recovery and rebuilding management alternatives. Current process is Plan for Analyzing and Testing Hypotheses--PATH. Specific areas include: spring chinook spawner-recruit analyses, temporal/spatial patterns of productivity and survival rates, freshwater spawning-rearing habitat, steelhead smolt-to-adult survival rate estimation, passage modeling, retrospective analyses, prospective analyses, decision analyses.

Previous Employment

Idaho Department of Fish and Game, Boise, ID
1987-present, Fisheries Staff Biologist: technical, analytical support on salmon recovery
1985-87, Sr. Fisheries Research Biologist: salmon and steelhead natural production studies
University of Washington, Fisheries Research Institute, Grand Coulee, WA
1976-79, Fishery Biologist: fisheries and limnology studies, Banks Lake and Lake Roosevelt
Ichthyological Associates, Pottstown, PA
1973-75, Research Biologist: ecological impact studies

Expertise

stock assessment, salmon biology, freshwater habitat, mainstem passage impacts to fish

Selected Publications

Petrosky, C.E. and H.A. Schaller. 1996. Evaluation of productivity and survival rate trends in the freshwater spawning and rearing life stage for Snake River spring and summer chinook. Chapter 9 in: Marmorek, D.R. and 21 co-authors. 1996. Plan for Analyzing and Testing Hypotheses (PATH): final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies, Ltd., Vancouver, B.C.

Petrosky, C.E. and H.A. Schaller. 1992. A comparison of productivities for Snake River and Lower Columbia River spring and summer chinook stocks. Proceedings of Salmon Management in the 21st Century: Recovering Stocks in Decline. 1992 Northeast Pacific Chinook and Coho Workshop. American Fisheries Society, Idaho Chapter, Boise, ID.

Petrosky, C.E. and T.C. Bjornn. 1988. Responses of wild rainbow (*Salmo gairdneri*) and cutthroat trout *(S. clarki*) to stocked rainbow trout in fertile and infertile streams. Canadian Journal of Fisheries and Aquatic Sciences. 45(12): 2087-2105.

Schaller, H.A., C.E.Petrosky and O.P. Langness 1996. Contrasts in stock recruitment patterns of Snake and Columbia River spring and summer chinook populations. Chapter 3 in: Marmorek, D.R. and 21 co-authors. 1996. Plan for Analyzing and Testing Hypotheses (PATH): final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies, Ltd., Vancouver, B.C.

Weber, E., P. Wilson, H. Schaller, R.Beamesderfer and C.Petrosky. 1996. Internal PATH Review of Williams, Matthews and Myers. 1997. The Columbia River Hydropower System: Does It Limit Recovery of Spring/Summer Chinook Salmon? DRAFT Review Comments, 6/97.

Name: Paul H. Wilson
Title: Biometrician / Modeler
Project Position: CBFWA technical assistance
FTE/hours: .90 FTE/ 1872 hours

Degrees Earned: (May 1983) B.A. in Environmental Science, University of Virginia. *Graduate work*: (1989-1992) Completed course work for M.S. at School of Fisheries, University of Washington. 1989-1990 Egtvedt Entering Scholar Award Recipient

Current Employer: (1993 to present) Columbia Basin Fish and Wildlife Foundation

Current Responsibilities: Work with multi-agency analytical team that evaluates multi-faceted recovery and rebuilding strategies for Snake River chinook salmon populations . CBFWF Technical Representative to the Plan for Analyzing and Testing Hypotheses (PATH) Project. Study Oversight and Analysis Committee member for the Comparative Survival Rate Study of Hatchery PIT Tagged Chinook Project under the Smolt Monitoring Program..

Recent Previous Employment: (Fall 1992) Teaching Assistant, QSCI/FISH 456 (Fish Population Dynamics) Univ. of Washington, Seattle. (1990-92) Assistant Environmental Analyst Seattle City Light, Environmental Affairs Division, Seattle WA.

Description of expertise: Seven years experience in modeling salmon population dynamics, including population genetics. Five years experience in modeling management strategies for salmon recovery, including developing and updating juvenile passage and life-cycle models. Experienced in programming in several structured programming languages. Monitored and described compliance of major hydroelectric project with fisheries provisions of license agreement, managed development of database application to automate flow compliance of agreement. Wrote research reports of environmental impacts of proposed hydrosystem projects.

Relevant Publications or Job Completions:

Marmorek, D.R. and C. Peters, editors. 1997. Preliminary decision analysis report on spring/summer chinook, 2nd Draft. PATH document, December 19, 1997.

Weber, E., P. Wilson, H. Schaller, R. Beamesderfer, and C. Petrosky. 1997. Internal PATH Review of Williams, Matthews and Myers: The Columbia River hydropower system: Does it limit recovery of spring/summer chinook salmon? Draft review comments. Submitted June, 1997. 18 p. plus figures.

Marmorek, D. and C. Peters (editors) and 24 co-authors. 1996. PATH - Plan for Analyzing and Testing Hypotheses. Conclusions of FY 96 Retrospective Analyses. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. December 10, 1996.

Marmorek, D.R. (editor) and 21 co-authors. 1996. Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Name: Olaf Paul Langness
Title: Fish Biologist 3
Project Position: WDFW technical representative
FTE/hours: 1.00 FTE/ 2,240 hours

Degrees Earned: (Dec. 1975) Bachelor of Science in Fisheries, College of Fisheries, University of Washington, Seattle, Washington. (Dec. 1985) Master of Science in Systems Management (Systems Technology), Institute of Safety and Systems Management, University of Southern California, Los Angeles, California (Yokosuka Campus, Japan). *Additional graduate work*: (June 1986 - April 1987) Post-Baccalaureate candidate for Systems Science Ph.D. Program, Portland State University, Portland, Oregon. (March - May 1987) Admitted to Doctor of Public Administration Program, School of Public Administration, University of Southern California, Los Angeles, California (Sacramento Public Affairs Center, Sacramento, California).

Certification Status: None related to fisheries.

Current Employer: Washington Department of Fish and Wildlife, Fish Biologist 3 (ANCOOR/PATH and CSS/Hatchery PIT Tag Projects; special assignments) February 1993 - Present; and, Fish Biologist 2 (Fall Chinook Harvest Management) July 1991- January 1993.

Current Responsibilities: (90 %) WDFW Technical Representative to the Regional Analytical Coordination Work Group (ANCOOR)/ PATH Project. (8 %) Study Oversight and Analysis Committee member for the Comparative Survival Rate Study of Hatchery PIT Tagged Chinook Project under the Smolt Monitoring Program. (2 %) Other duties as assigned (conduct other fisheries management analyses, supervise/participate in other research-monitoring-evaluation projects, etc.).

Recent Previous Employment: Confederated Tribes of the Colville Reservation, Fish and Wildlife Department, Fish Biologist 1 (Off-Reservation Biologist) June 1989- July 1991; and, Temporary Fisheries Specialist (System/Subbasin Planner) June 1988 – June 1989. U.S. Army Corps of Engineers, Walla Walla District, Raceway Biological Technician Fisheries [GS-5] (Juvenile Salmonid Transportation Program) March – June 1988.

Description of expertise: Ten years working in the Columbia River Basin for federal, state, and tribal agencies doing salmon life-cycle and passage modeling, harvest management, system and subbasin planning, and transporting juvenile salmonids.

Relevant Publications or Job Completions:

Schaller, H.A., C. E. Petrosky, and O. P. Langness. 1997. Contrasts in Stock-Recruitment Patterns of Snake and Columbia River Spring and Summer Chinook Populations. Chapter 3 in, Plan for Analyzing and Testing Hypotheses (PATH) Final Report on Retrospective Analyses for Fiscal Year 1996 (David Marmorek, ed.). ESSA Technologies, Vancouver, BC, Canada. 75p.

Langness, O. P. and H.A. Schaller. 1997. Contrasting Stock-Recruitment, Harvest, and Upstream Passage Survival Patterns of the Columbia River Stream-type Chinook Populations. Draft Chapter 13 for the Plan for Analyzing and Testing Hypotheses (PATH) Final Report on Retrospective Analyses for Fiscal Year 1996 (David Marmorek, ed.). ESSA Tech.,Vancouver, BC, Can. 41p.

Beamesderfer, R.C.P., H.A. Schaller, M.P. Zimmerman, C.E. Petrosky, O.P. Langness, and L. LaVoy. 1997. Spawner-Recruit Data for Spring and Summer Chinook Salmon Populations in Idaho, Oregon, and Washington. July 1, 1997 Review Draft for the PATH Project. 83p + 152p.

Giorgi, A., C. Paulsen, O. Langness, J. Anderson, L. LaVoy, and C. Peven. 1996. Analysis of Passage Alternatives to Improve Smolt Survival for Ocean-type Summer Chinook in the Mid-Columbia Basin. Report to the Mid-Columbia Habitat Conservation Plan Technical Committee, April 2, 1996. 19p + 77p.

Columbia Basin Fish and Wildlife Authority. 1990. Integrated System Plan for Salmon and Steelhead Production in the Columbia River Basin. Northwest Power Planning Council Report 90-12. 449p.

Name: Earl Weber
Title: Fisheries Scientist
Project Position: CRITFC technical representative
FTE Hours: 2080

Education: B.S. in Fisheries Management, The Ohio State University, 1975
M.S. in Fisheries Biology, The Ohio State University, 1977

Current Employer: Columbia River Inter-Tribal Fish Commission
Current Responsibilities: Serve as scientific representative for four treaty tribes in PATH process.

Previous Employment: For ten years prior to my employment at the Commission I was employed with the National Marine Fisheries Service in La Jolla California where I studied the biology and population dynamics of tunas and billfishes worldwide.

Expertise: My current and previous position have required the ability to develop and use mathematical computer models that simulate the life cycles and dynamics of various fish populations. Specifically, I was one of the developers of a system of models that simulate the mainstem passage of salmon stocks through the Columbia and Snake River hydropower system. I have also been involved with several generations of life cycle models that simulate Columbia Basin salmonids.

Recent Publications:

Marmorek, D. and C. Peters (editors) and 24 co-authors. 1996. PATH - Plan for Analyzing and Testing Hypotheses. Conclusions of FY 96 Retrospective Analyses. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. December 10, 1996.

Marmorek, D.R. (editor) and 21 co-authors. 1996. Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Toole, C., A. Giorgi, E. Weber, , W. McConnaha, and anonymous. 1996. Hydro Decision Pathway and Review of Existing Information. Chapter 6.0 in: Plan for Analyzing and Testing Hypotheses (PATH). Final Report on Retrospective Analyses for Fiscal Year 1996. Prepared by ESSA Technologies Ltd., Vancouver, B.C. for Bonneville Power Administration, Portland, OR. September, 10, 1996.

Weber, E., P. Wilson, H. Schaller, R. Beamesderfer and C. Petrosky. 1997. Internal PATH Review of Williams, Matthews and Myers. 1997. The Columbia River hydrosystem: does it limit recovery of Snake River spring/summer chinook salmon? PATH document, submitted June 1997. 19 p. plus tables and figures.

Wilson, P., E. Weber, C. Petrosky and H. Schaller. 1997. Draft proposed general framework for prospective modeling with detailed examples for one hypothesis about delayed mortality. PATH document, submitted August 1, 1997.

Name: Phaedra Budy
Title: Quantitative Fishery Biologist GS 11/1
Project Position: USFWS technical assistance
Salary 0.5 FTE, 130 days

EDUCATION: Ph.D. Aquatic Ecology, Utah State University. Dissertation: Adding nutrients to enhance growth and production of endangered sockeye salmon: Trophic transfer in an oligotrophic lake. Chris Luecke- major advisor
Bachelor of Science- University of California, Davis. June 1991 Independent Major in Limnology P.Moyle and C.R. Goldman- advisors.

EMPLOYMENT:1997-present. Quantitative Fishery Biologist. 50% time on the Analytical Work Groupof the Chinook Technical Team (CTC), Pacific Salmon Commission (PSC), 50% time on Plan for Analyzing and Testing Hypotheses (PATH) analyses. Analytical work for the CTC includes annual exploitation analyses based on coded-wire tag data, stock escapement rebuilding assessment, development of abundance based management techniques for PSC fisheries and related analyses, and overall model improvement and evaluation. Current PATH projects include review of PATH prospective analysis for spring/summer chinook, and other associated PATH reports. Direct PATH involvement in retrospective and prospective analyses for fall chinook includes estimating ocean harvest for wild stocks of fall chinook, for run rconstruction and life cycle modeling. A time series of ocean exploitation rates going back to 1977 was completed using the available coded-wire tag data and the models and techniques associated with the (CTC) 1996 Annual Exploitation Analysis; the time series is now being extended beyond the coded-wire tag data back to 1965 using historical data on fishing effort and landed catch.
1996-1997 Utah State University/ Colorado State University/ Puerto Rico LTER - Postdoctoral position, Atyad shrimp population dynamics and conservation genetics. In combination with: Assistant Program Chair for Ecological Society of America-1997.
1992-6 Utah State University, Department of Fisheries and Wildlife, Research Assistant-Ph.D. 1991 Tahoe Research Group, U.C.Davis, Post Graduate Researcher. Duties included sampling nearshore fish distribution and habitat availability/ preference. Hydroacoustic fish assessment. Fish stomach content analysis. Data maintenance, analysis, and presentation. Report writing.
1991-93 Basin Strategies: Planning and Consulting Services. Environmental Assessment, Pier Relocation and Expansion Projects. Describe fish habitat, littoral substratum

composition, and any impacts on the fish community. Propose fish restoration sites and mitigative measures.

PUBLICATIONS

Budy, P. C. Luecke, and W. A. Wurtsbaugh. Adding nutrients to enhance growth and production of endangered sockeye salmon: Trophic transfer in an oligotrophic lake. Transactions of the American Fisheries Society, in press, 1998.

Budy, P. C. Luecke, and W. A. Wurtsbaugh. The effects of whole-lake fertilization on the productivity of an oligotrophic nursery lake for endangered salmon. Ecology,in press, 1998.

Luecke, C., W. Wurtsbaugh, P. Budy, and G. Steinhart. 1995. Simulated growth and production of endangered Snake River sockeye salmon: Assessing management strategies for nursery lakes. Fisheries 26(6):18-25.

Budy, P.Chris Luecke, Wayne Wurtsbaugh, and Howard Gross. 1995. Limnology of Sawtooth Valley Lakes with respect to potential growth of juvenile Snake River sockeye salmon. Northwest Science 69(2):133-150.

Budy, P., Chris Luecke, Wayne Wurtsbaugh, and Howard Gross. 1994. Effects of nutrientenhancement on juvenile sockeye salmon growth. Lake and Reservoir Management, 9(1):140-145.

Section 10. Information/technology transfer

Once peer reviews are complete, PATH reports are distributed directly to fisheries managers and the interested public. In addition, the PATH planning group has made five presentation to the NPPC (including members of the public), bimonthly presentations to the Implementation Team, and individual presentations to the ISAB, NMFS, U.S. Army Corps of Engineer Public Round Table, and the Executive Committee. In addition, four PATH analyses are almost ready to be submitted for publication in the Canadian Journal of Fisheries and Aquatic Sciences, who are interested in concentrating these results in a single journal.

The tools being developed and improved by PATH, particularly the decision analysis tools, will have tremendous benefits to the region over the next few decades. These will be demonstrated to fish managers, with training provided, in FY99.