PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Facilitation, Technical Assistance And Peer Review Of Path

BPA project number: 9600600
Contract renewal date (mm/yyyy): 11/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
ESSA Technologies Ltd.

Business acronym (if appropriate) ESSA

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
2.2H, 3.2.A, 3.2C, 3.2.F , 4.2a, 4.3, 7.1E

FWS/NMFS Biological Opinion Number(s) which this project addresses
NMFS Hydrosystem BO RPA 13; RPA A17

Other planning document references
Multi-Species Framework Briefing Nov. 1998: Analytical Approach page 21, NMFS Recovery Plan task 0.3.b and 2.11.b

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.

Target species
Columbia Basin salmon and steelhead

Section 2. Sorting and evaluation

Subbasin
Systemwide

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type

Mark one or more caucus	If your project fits either of these processes, mark one or both	Mark one or more categories
☒ Anadromous fish ☐ Resident fish ☐ Wildlife	☒ Multi-year (milestone-based evaluation) ☐ Watershed project evaluation	☐ Watershed councils/model watersheds ☐ Information dissemination ☐ Operation & maintenance ☐ New construction ☒ Research & monitoring ☒ Implementation & management ☐ Wildlife habitat acquisitions

Section 3. Relationships to other Bonneville projects

Umbrella / sub-proposal relationships. List umbrella project first.

Project #	Project title/description
20515	Mainstem Columbia River Umbrella Proposal (region umbrella)
9600600	Facilitation, Technical Assistance And Peer Review Of Path

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9803067	Technical Support for PATH - NMFS	PATH scientific support
9303701	Simulation Modeling Participation C. Paulsen	PATH scientific support
9600800	State, Tribal and U.S. Fish and Wildlife Participation in PATH	PATH scientific support
8910800	Modeling PATH/ BPA technical support Univ. of Washingto	PATH scientific support
9203200	USFS modeling support	PATH scientific support
9601700	Hydrosystem Work Particiption A. Giorgi	PATH scientific support

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1996	For Snake River salmon, clarified management decisions with senior personnel in the major management institutions	yes
1996	Developed hypothesis frameworks and sets of alternative hypotheses relevant to those management decisions	yes
1996	Performed data reconnaissance, acquisition and refinement prior to completion of retrospective analyses of specific hypotheses	yes
1997	For Snake River spring and summer chinook salmon, performed detailed retrospective analyses for hypotheses related to hydrosystem decisions, and the relevant hypotheses concerning climate, habitat, harvest and hatchery factors.	yes and continued work for other species

1997	Through a series of five workshops involving about 30 research scientists, planned retrospective analyses, developed tools for prospective analyses, and reviewed the results of these analyses and their implications for hydrosystem management decisions	yes, for Snake River spring, summer and fall chinook working on steelhead and chinook from other parts of the Columbia River basin
1997	Developed new analytical tools (Bayesian probabilistic approach) to assist in decision making framework	yes, for Snake River spring, summer and fall chinook working on steelhead and chinook from other parts of the Columbia River basin
1998	Performed and documented a Snake River Spring/summer chinook Decision Analysis for hydrosystem management alternatives	yes
1998	Produced and documented the weight of evidence for key alternative hypotheses which influence spring/summer decision analysis results	yes
1998	Scientific Review Panel (SRP) assigned weights to key alternative hypotheses and devloped recommendations for future PATH work	yes, for Snake River spring/ summer chinook
1998	Performed weighted decision analysis and compared to equally weighted case.	yes, for Snake River spring/ summer chinook
1998	Performed and documented a Snake River fall chinook Decision Analysis for hydrosystem management alternatives	yes, preliminary decision analysis without acompanying weight of evidence approach
1998	Assessed impacts of hydrosystem actions on Steelhead	yes, preliminary analysis using comparision with spring/summer chinook
1998	Coordinated PATH work with other regional groups such as the Corps' DREW (economic analysis) and Decision Process Coordinating Group	yes

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Determine the overall level of support for key alternative hypotheses, and propose other hypotheses and/or model improvements that are more consistent with existing data.	a	Complete and publish retrospective analyses for Upper Columbia chinook and steelhead stocks, to support NMFS Biological Opinion in March, 2000, and analyses of stock rebuilding plans proposed by Multi-species Framework. .
		b	Complete and publish retrospective analyses for Lower Columbia salmon and steelhead stocks, to support NMFS Biological Opinions and analyses of stock rebuilding plans proposed by Multi-species Framework.
2	Advise regulatory agencies on management actions to restore endangered salmon stocks to self-sustaining levels of abundance	a	Complete and publish follow-up work related to 1999 decision on Snake River chinook and steelhead.
		b	Complete and publish prospective and decision analyses for Upper Columbia, working with PUD's and other agencies.

		c	Complete and publish prospective and decision analyses for Lower Columbia salmon and steelhead stocks.
		d	Complete and publish prospective and decision analyses for Multi-species Framework.
3	Assess the ability to distinguish among competing hypotheses from future information, and advise agencies on research, monitoring, and adaptive management experiments that would maximize learning	a	Complete and publish detailed design of experimental management options for Snake River stocks involving hydro, harvest, habitat, and hatchery actions (4 H's), and detailed monitoring and evaluation programs
		b	Develop candidate experimental management options for Upper Columbia and Lower Columbia stocks, in response to tasks 2b and 2c (evaluate in FY2001).

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	11/1999	10/2000	firm foundation for objectives 2 and 3	published retrospective analyses	20.00%
2	11/1999	10/2000	biologically sound strategic decisions on Snake River, Lower and Upper Columbia River subregions, integrated across the 4 H's	published decision analyses	40.00%
3	11/1999	10/2000	experimental management plans to reduce uncertainties in meeting objective 2	published experimental management plans	40.00%
				Total	100.00%

Schedule constraints
Litigation among agencies. Unexpected delays in 1999 decision on Snake River. uncertain. Unexpected problems with run reconstructions and model development.

Completion date
Unclear. Many agencies (NMFS, NPPC, CoE) have identified an ongoing need for a coordinated, peer-reviewed, regional analytical work group.

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	ESSA staff: Marmorek, Peters, Parnell, Alexander	%47	210,000
Fringe benefits		%0	
Supplies, materials, non-expendable property		%0	
Operations & maintenance	Report production, communication, workshop facilities	%4	18,000
Capital acquisitions or improvements (e.g. land, buildings, major equip.)		%0	
NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel	for ESSA staff and subcontractors	%8	35,000
Indirect costs	subcontract administration	%4	16,000
Subcontractor	Dr. Larry Barnthouse	%4	19,000
Subcontractor	Dr. Mike Jones	%2	7,000
Subcontractor	Dr. Rick Deriso	%18	82,000
Subcontractor	Dr. Louis Botsford	%4	17,000
Subcontractor	Dr. Randall Peterman	%4	18,000
Subcontractor	Dr. Carl Walters	%2	7,000
Subcontractor	Drs. Jim Kitchell and Steve Carpenter	%2	7,000
Subcontractor	Dr. Saul Saila	%2	7,000
Subcontractor	Dr. Jeremy Collie	%2	7,000
Other		%0	
TOTAL BPA FY2000 BUDGET REQUEST			$450,000

Cost sharing

Organization	Item or service provided	% total project cost (incl. BPA)	Amount ($)
		%0	
		%0	
		%0	
		%0	
Total project cost (including BPA portion)			$450,000

Outyear costs

	FY2001	FY02	FY03	FY04
Total budget	$450,000	$450,000	$450,000	$450,000

Section 6. References

Watershed?	Reference
☐	The following references are joint reports, with many individual scientific papers, as well as

	syntheses of the consensus (and disagreements) of PATH scientists on key issues. These references are available at: www/bpa.gov/Environment/PATH.
☐	
☐	Barnthouse, L. (ed.), J. Collie, B. Dennis, S. Saila, and C. Walters. 1996. PATH: First Scientific Review Panel Report. Prepared by ChemRisk Division, McLaren/Hart Environmental Engineering Co., Oak Ridge, TN.
☐	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
☐	Marmorek, D.P. and I. Parnell (eds.). 1995. 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 stocks. 89 pp. & Appendices
☐	Marmorek, D.R, I, Parnell, L. Barnthouse and D.R. Bouillon. 1995. PATH: Results of a Workshop to Design Retrospective Analyses. Prepared by ESSA Technologies Ltd. Vancouver, BC for BPA. 278 pp.
☐	Marmorek, D.R. (ed.)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.
☐	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. 30 pp.
☐	Marmorek, D.R. and C. Peters, editors. and 26 co-authors.1998a. Preliminary decision analysis report on Snake River spring/summer chinook, . Report compiled and edited by ESSA Technologies Ltd., Vancouver BC.
☐	Marmorek, D.R. and C. Peters, editors. 1998b. Weight of evidence report on Snake River spring/summer chinook. August 1998. Report compiled and edited by ESSA Technologies Ltd., Vancouver BC. 160 pp. + 360 pp. of Submissions by PATH scientists.
☐	Marmorek, D.R. and C. Peters, editors. and 31 co-authors. 1998c. PATH Final Report for Fiscal Year 1998. December 1998. Report compiled and edited by ESSA Technologies Ltd., Vancouver BC. 254 pp.
☐	Marmorek, D.R., C.N. Peters and I. Parnell (eds.), and 23 co-authors. 1998d. PATH: Retrospective and Prospective Analyses of Spring/Summer Chinook Reviewed in FY1997. 693 pp., including SRP Reviews.
☐	PATH Scientific Review Panel. (Drs. S. Carpenter, J.Collie, S. Saila, C. Walters). 1998. Conclusions and Recommendations from the PATH Weight of Evidence Workshop. September 8-10, 1998. Edited by C. Peters, I. Parnell, D. Marmorek, R. Gregory, T. Eppel.
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PART II - NARRATIVE

Section 7. Abstract

PATH (Plan for Analyzing and Testing Hypotheses) was created in the NMFS 1995-1998 Biological Opinion on operation of the FCRPS, and supports many goals in the 1994 Columbia Fish and Wildlife Program. PATH was created to test key hypotheses that underlie differences among salmon management models, and try to resolve them in support of regional management decisions on salmon recovery and

rebuilding. Since 1995, PATH has focussed on the 1999 FCRPS decision, but PATH has been asked to provide coordinated regional analytic support to other salmon management decisions. PATH's first objective is retrospective analyses: explicitly stating hypotheses about mortality over the life cycle; and evaluating the historical evidence for alternative hypotheses which have significant management implications. The second objective is prospective and decision analyses: estimating the improvement needed in life cycle survival to achieve recovery objectives; forecasting future stock responses for different management actions under a range of alternative hypotheses; and documenting a biological rationale for each alternative hypothesis to assign weights in formal decision analyses, that assess which actions are most robust to key uncertainties. The third objective addresses learning: evaluating how best to implement management actions so as to fulfill both conservation and learning objectives, and designing associated monitoring and evaluation activities. PATH's schedule and tasks are prioritized by the needs of regional groups (I.T., NWPPC) for decisions on the population recovery actions. PATH participants include scientists from federal, state and tribal entities, three independent scientists, and an independent facilitation team. PATH products are rigorously reviewed by an independent Scientific Review Panel.

Section 8. 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, USFWS, State and Tribal agencies, NWPPC). PATH has helped to define many areas of common agreement and is specifying the information or management experiments needed to resolve remaining key areas of disagreement. PATH's high quality retrospective analyses (Marmorek (ed.) 1996; Marmorek and Peters (eds.) 1996), prospective analyses (Marmorek and Peters (eds.)1998d), decision analyses (Marmorek and Peters 1998a, Marmorek, Peters and Parnell 1998c), and Weight of Evidence analyses (Marmorek and Peters 1998b) have built a foundation for evaluating recovery measures for Snake River salmon populations. 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. In addition, the experimental management approaches proposed by the Scientific Review Panel (1998) and elaborated on by PATH (Marmorek, Peters and Parnell 1998c) should assist in sculpting management options which both minimize risks to populations and maximize our ability to reduce uncertainties for key hypotheses. The PATH group has filled the role as a regionally coordinated analytical body for salmon and steelhead recovery measure evaluations.

PATH's progress through challenging scientific and institutional terrain has been assisted by independent facilitation, coordination and report preparation (ESSA Technologies Ltd.); the participation of three independent scientists with expertise in decision analysis, Bayesian statistics and conservation biology (Drs. Peterman, Deriso and Botsford); and an independent Scientific Review Panel (Drs. Barnthouse (coordinator), Carpenter, Collie, Kitchell, Saila and Walters). The contracts for other critically-related projects provide not only essential cross-institutional participation, but also critical technical expertise in stock run reconstructions; stock assessment; passage modeling; life cycle modeling; habitat, hatchery and harvest evaluations; and ocean/climate influences

b. 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) in 1992, 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.

Three different modeling systems have evolved to address recovery planning and rebuilding assessment for Columbia River salmon stocks. State and tribal fishery managers, federal fishery managers, federal hydropower operators and NWPPC reached consensus and implemented in 1992 a coordinated, peer reviewed effort to address the analytical needs of the region with respect to Columbia River salmon recovery and rebuilding. Reviews of the models and some of the analytical approaches were prepared by a scientific peer review panel (SRP) of academic experts funded by BPA during FY 1994 and 1995. One report from that effort recommended that model review and comparison should be focused on hypothesis formulation and testing to resolve crucial differences in assumptions and data interpretation.

The NMFS' 1995-1998 Biological Opinion on operation of the FCRPS (NMFS 1995) 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). Though initiated by written directives (i.e. the Scientific Review Panel, NMFS and NWPPC), the direction of PATH responds to periodic meetings with senior management and policy personnel in NMFS, BPA, NWPPC, WDF, ODFW, IDFG, US Fish and Wildlife Service (USFWS) and CRITFC.

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 (Objective 1), 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 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 benefit, 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).

The hypothesis and decision frameworks we developed and applied in PATH have provided a means of harnessing a wide array of information, prospective modeling tools and unpublished scientific knowledge to inform key management decisions (Objective 2). In particular, the decision analysis framework developed by PATH is an essential tool for rigorously evaluating alternative management strategies, and for explicitly and quantitatively assessing the effects of remaining uncertainties on the outcomes of these strategies. The decision analysis approach is providing the best possible support for informed management decisions under uncertainty.

The retrospective analysis and Weight of Evidence process completed by PATH have made considerable progress in reducing both the magnitude and number of remaining uncertainties and their magnitude. Despite considerable progress, much uncertainty remains. Forecasts of future results of management actions are uncertain due to complex ecological responses to human and natural disturbances, variability over space and time, and incomplete knowledge of these ecosystems. These uncertainties create biological risk in our predictions of management actions, which have economic and social consequences. Using the existence of remaining uncertainties as a rationale for maintaining status quo management, is an approach that has an extremely low likelihood of achieving population recovery goals. The decision analysis approach under taken by PATH explicitly and quantitatively considers the implications of uncertainties, so as to provide the support to informed management decisions. A further improvement on the decision analysis approach taken to date is to choose those actions that will achieve a given recovery objective, as well as learn something to improve future management. This is called experimental or adaptive management, which is addressed under Objective 3.

As stated above, PATH's previous accomplishments provide a concrete foundation for designing adaptive management programs and coordinating research initiatives (Objective 3). While PATH scientists have recommended several specific research, monitoring and evaluation approaches to resolving critical uncertainties (Marmorek and Peters 1996), work on objective 3 was postponed in FY98 given the high priority assigned to objective 2. 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 (SRP 1998). The best experimental management approach to resolving uncertainty is called “active adaptive management” (Walters 1986). The design of this experimental management framework is already in progress (Marmorek, Peters, and Parnell 1998c): 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. Work in FY99 will rigorously assess the value of additional information from research studies, monitoring, and adaptive management experiments. This will help incorporate learning as a criterion for the 1999 FCRPS decision, and provide a scientific basis for assisting in prioritizing expenditures for conserving and restoring these populations given limited financial resources. The specific objectives for experimental management (EM) work in FY99 are to:

1. Clarify the EM approach the SRP has recommended.
2. Describe EM options as variations to proposed hydrosystem actions.
3. More detailed description of EM options with review, input from SRP, I.T., NPPC.
4. Develop tools (modifying models, developing simpler models, comparing simpler models to existing ones) for quickly evaluating EM options.
5. Evaluate proposed actions with/without EM options in terms of risk to the stocks versus amount of learning possible.
6. Evaluate proposed actions with/without EM options across populations (e.g. spring/summer and fall chinook).
7. Using results from EM evaluation, develop a research, monitoring, and evaluation plan to support the 1999 decision.

Work on Experimental Management in FY2000 will build on the progress made on these objectives in FY99.

PATH work would continue at a high level of intensity through the year 2002 for three reasons. First, after the 1999 decision, there will remain considerable uncertainty with respect to the response of the Columbia River and Snake River fisheries populations to the 1999 decisions. Assessment of these responses will require thoughtful design of region-wide research, monitoring and evaluation programs *with a quantitative focus;* and an interagency analytical team that is able to provide informed evaluation of new information, integrating new data with the historical information. The retrospective analyses and formal decision analyses completed by PATH will provide a foundation for such work. In addition , the PATH group’s broad approach will provide much insight on the post-1999 interpretation of new information (e.g. survival studies, spawner-recruit estimates, oceanographic information, transportation studies detailed project-specific evaluations). Second, there will be a need to integrate the assessment of the other H’s (habitat, hatchery, harvest) with the post-1999 evaluations. Continued development of an operational means to implement adaptive management is a high priority for the region, as stressed in the 1994 Fish and Wildlife Program. The tools developed by PATH are an excellent foundation for the region to quantitatively explore the implications of different adaptive management strategies, not only in hydrosystem operations, but also in the realm of harvest, habitat and hatchery activities. Third, PATH is seen as a critical element of the Multi-Species Framework, whose development is being led by the Northwest Power Planning Council. The framework documents developed by the NPPC mention two key roles that PATH could play: providing quantitative, population-based analyses of specific policy alternatives; and assessing the overall feasibility of alternative visions.

Funding for 2003 and 2004 assumes a continuing need for a coordinated, regional analytical work group, with peer-reviewed products, as expressed by the Implementation Team and other groups.

c. Relationships to other projects

Increasing the returns and diversity of salmon and steelhead populations to the Columbia River basin relies on activities throughout the subasins, mainstem cooridors, estuary, and ocean. The PATH project is a coordinated and consistent approach to technical analyses supporting salmon rebuilding and recovery efforts over the life-cycle; it provides a formal process to efficiently utilize and focus regional technical expertise on such analyses. The project is intergrated on a programatic level through the PATH facilitation contract with ESSA Technologies, which also provides subcontracts for specialized technical expertise and independent peer review. (ESSA has provided the umbrella proposal for PATH work in FY2000.) The PATH Planning Group (ESSA and six representatives of the operating agencies, states and tribes, NMFS and the NWPPC) coordinates the activities of 25-30 scientists working on analyses of salmon rebuilding and recovery alternatives.

PATH involves cooperation among scientists from NMFS, BPA, U.Washington, NPPC, ODFW, IDFG, WDFW, CRITFC, USFS, USFWS, CBFWA, USACE; consultants to BPA (Paulsen Environmental Research, BioAnalysts Inc., Richard Hinrichsen), as well as three independent scientists from academic and research institutions (Simon Fraser University, UC Davis, and Inter-American Tropical Tuna Commission). In addition, independent peer review is provided by scientists associated with UBC, U. Rhode Island, and U. Wisconsin), coordinated by Dr. Larry Barnthouse of LWB Environmental Services. Collaboration occurs through workshops, meetings, workgroups, cooperative planning, joint reports, and scientific review. The contracts for other critically-related projects (see section 3) not only provide essential cross-institutional participation, but also critical technical expertise in stock run reconstructions; stock assessment; passage modeling; life cycle modeling; habitat, hatchery and harvest evaluations; and ocean/climate influences. The cross-institutional composition of PATH work groups on these topics, together with the participation of independent scientists, ensures rigorous internal peer review. It also provides better integration of decision making among management agencies through a clear framework for decision analysis and adaptive management experiments. The integration of these projects by the umbrella facilitation project and the independent scientific review by the SRP have been key to the past sucesses and acceptance of PATH products.

In addition, the Independent Scientific Advisory Board has participated in PATH since its inception (Phil Mundy, Dan Goodman, Chuck Coutant, and Chip McConnaha). Close cooperation and dialogue with the ISAB is very important to PATH. It ensures that the broader, conceptual framework developed by the ISG in the Return to the River report guides the structure of PATH's technical analyses, and clarifies some of the processes excluded from PATH's analyses due to difficulties in quantification (e.g. life history diversity). PATH in turn provides the ISAB with rigorous analyses of hypotheses.

PATH will also be coordinated with US vs Oregon Columbia River Management Plan activities and the Mid-Columbia Habitat Conservation processes. PATH has recently been asked to assist federal agencies and the Mid-Columbia PUD's in developing tools and approaches for the FY2000 Biological Opinion on Mid-Columbia chinook and steelhead.

Modeling and experimental management analyses are only as good as the data on which they're based. PATH relies on the continuation of numerous data collection activities throughout the

Columbia River basin. These activities include many BPA funded activities such as: Smolt Monitoring program, Northern Pikeminow program and predator control assessment, Comparative Survival Studies, NMFS Reach Survival studies, Spawning Escapement Enumeration projects, Coded-Wire-Tag (CWT) marking and recovery. These activities also rely on data collected through Pacific Salmon Treaty activities (CWT mark and recovery, and escapement enumeration), US Army Corp projects (dam counts, transportation experiments), and US vs Oregon-Columbia River Fish Management Plan activities.

d. Project history (for ongoing projects)

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 (Marmorek (ed) 1996);

- six workshops, each involving about 30 research scientists, to plan retrospective, prospective, and decision analyses, review results, 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 and fall chinook stocks; a 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); and a Weight of Evidence process to assess the relative likelihood of key alternative hypotheses.

- 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 (Marmorek and Peters (eds) 1996)

- a decision analysis report (Marmorek and Peters 1998a) on spring/summer chinook which tested the decision analysis method formulated over the last two years, provided decision makers with our preliminary insights into the range of population responses to alternative management decisions, explained the biological rationale for alternative hypotheses, and evaluated the relative importance of different uncertainties in affecting outcomes of alternative management decisions.

- A Weight of Evidence process and report (Marmorek and Peters 1998b) on spring/summer chinook which: rigorously identified the effects of key uncertainties on management outcomes; and assessed the evidence for and against alternative hypotheses for these key uncertainties. The Weight of Evidence report, and the other 2500 pages of PATH reports reviewed by the SRP over the last two years, were used by the SRP to assign weights to key alternative hypotheses using expert judgement (SRP 1998). In the end, the mean SRP weights produced results very similar to weighing all hypotheses equally (Marmorek, Peters and Parnell 1998c), but nevertheless provided an extra measure of rigour to the analysis.

- Revised Decision Analysis for Snake River spring/summer chinook, Preliminary Decision Analysis for Snake River fall chinook, qualitative assessment of the effects of actions on Snake River steelhead, and preliminary work on sockeye salmon (Marmorek and Peters 1998c).

- 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 , state fish and wildlife commisions, and the public; meetings with the Decision Process Coordinating Group of the IT; and meeting with the Independent Scientific Group (now the Independent Scientific Advisory Board) to coordinate our activities.

The past costs for the umbrella contract to ESSA Technologies were $450,000 for FY96, $450,000 for FY97, $490,692 for FY98 (increased by $40,000 for Weight of Evidence process), and $450,000 for 1999. Costs of other critically-related PATH contracts listed in Section 3 are given within each contract.

e. Proposal objectives

Objectives

PATH's primary objectives were originally defined as:

1. Determine the overall level of support for key alternative hypotheses based on existing information (Retrospective analyses). Propose other hypotheses and/or model improvements that are more consistent with the data.

   Sub-objectives for Objective 1:

- 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;
- publish retrospective findings in peer-reviewed reports and journal articles;
    - propose other hypotheses and/or model improvements supported by the weight of evidence of these analyses;

2. Advise regulatory agencies on management actions to restore endangered salmon stocks to self-sustaining levels of abundance.

   Sub-objectives for Objective 2:

    - define the management decisions that serve to focus analytical activities;

- improve existing models 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 the development of regional programs that would stabilize, ensure persistence of, and eventually restore depressed salmon stocks to self-sustaining levels;

3. 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]

   Sub-objectives for Objective 3:
   - 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 results of research, monitoring, and adaptive management experiments; assess implications of alternative hypotheses on subsequent actions).

Products in FY2000:

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.

<u>Objective 1:</u>

Specific tasks for FY2000 retrospective analyses are:

a. Complete and publish retrospective analyses for Upper Columbia chinook and steelhead stocks, to support NMFS Biological Opinion in March, 2000, and analyses of stock rebuilding plans proposed by the Multi-species Framework.

b. Complete and publish retrospective analyses for Lower Columbia salmon and steelhead stocks, to support NMFS Biological Opinions and analyses of stock rebuilding plans proposed by the Multi-species Framework.

Both these tasks will involve working with scientists beyond the existing PATH group (e.g. within the Mid-Columbia Coordinating Committee). We see these tasks as an opportunity for "technology transfer" of the PATH process to other subregions and entities. Since the scope of these tasks will depend on an evaluation of data for these subregions, and further definition of the

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

range of actions to be assessed (to be completed in FY99), it is not yet possible to specify the appropriate level of complexity of models. As the Multi-species Framework is still in the formative stage of defining broad goals, it is not possible to specify what specific analyses will be required in FY2000.

<u>Objective 2:</u>

Specific FY2000 tasks for prospective / decision analyses are:

a. Complete and publish follow-up work related to 1999 decision on Snake River chinook and steelhead.

b. Complete and publish prospective and decision analyses for Upper Columbia, working with PUD's and other agencies.

c. Complete and publish prospective and decision analyses for Lower Columbia salmon and steelhead stocks.

d. Complete and publish prospective and decision analyses for Multi-species Framework.

The 1999 decision on the Snake River hydrosystem will determine the level of effort required for task 2a. We anticipate that further analyses of options may be required before a large committment is made by the region and Congress. Tasks b and c are driven by NMFS Biological Opinions required in FY2000. Task d recognizes the need for a rigorous evaluation of the feasibilty of the visions and policy options proposed in the Multi-Species Framework.

<u>Objective 3:</u>

Future oriented evaluations of research, monitoring and experimental management options will form a major part of PATH's proposed work in FY2000, specifically:

a. Complete and publish detailed design of experimental management options for Snake River stocks involving hydro, harvest, habitat, and hatchery actions (4 H's), and detailed monitoring and evaluation programs.

b. Develop candidate experimental management options for Upper Columbia and Lower Columbia stocks, in response to tasks 2b and 2c (evaluate in FY2001).

The purpose of experimental management is to proceed with management actions in a manner designed to maximize the rate of learning about key uncertainties, while at the same time meeting survival and recovery objectives for salmon and steelhead populations throughout the Columbia River basin. Under objective 3a, we will evaluate experimental management options across populations (e.g. spring/summer, fall chinook, and steelhead in the Columbia River basin), and then develop a research, monitoring, and evaluation plan to support the 1999 decision. The structure of task 3b will depend on the outcome of tasks 2b and 2c, and therefore cannot be specified at this time.

For task 3a, PATH will provide guidance on what type of management experiments are worth pursuing through three steps: 1) define ability of experimental management options to reach population rebuilding goals and what it is we want to learn; 2) assess what we can learn from continued monitoring, retrospective analyses, and / or research (i.e. methods other than experimental management); and 3) contrast this with what we can learn using an active experimental management approach. That is, PATH will explicitly document why reducing uncertainty about a particular hypothesis requires an active adaptive management approach, why further large management perturbations to the ecosystem are required, and why more passive approaches to learning are not adequate or pose a high level of risk to the populations. We anticipate that the tools developed in FY99 to evaluate experimental management options (see section 8b) will be extremely useful in FY2000 for both tasks 3a and 3b.

f. 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 ,Kitchell, and Carpenter).

PATH activities in FY96, 97, 98 culminated in the completion of a series of documents, which summarizes the findings of retrospective, prospective, decision and weight of evidence analyses. These documents represent 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 and the relative effectiveness of management alternatives. These documents have been supplemented by a series of presentations to the NPPC, the Implementation Team, State and Tribal fish and wildlife commissions, 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 (www/bpa.gov/Environment/PATH).

Approach for Retrospective Analyses (Objective 1):

1. Identify the key uncertainties that affect management questions.
2. Compile historical data relevant to key uncertainties and assess its quality.
3. Based on data availability, decide on a set of retrospective analyses test alternative hypotheses about key uncertainties. Specific techniques used here include classical statistical techniques for hypothesis testing, maximum likelihood estimation, and synthesis of information around key questions.
4. Summarize peer-reviewed retrospective analyses in a conclusions document. Conclusions documents represent the consensus view of PATH scientists on the major conclusions from retrospective analyses, the relative degree of certainty in those conclusions, the relative strength of underlying evidence, and information that would be needed to increase the degree of certainty in conclusions.
5. Propose other hypotheses and/or model improvements that are more consistent with the data. Develop improved models that incorporate what has been learned from the retrospective analyses.

These methods will be applied to Upper Columbia and Lower Columbia stocks in FY2000, as outlined in tasks 1a and 1b.

Approach for Prospective/Decision Analyses (Objective 2):

1. 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.

2. 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 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 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 involves

interaction with the Multi-species Framework, Research Review Group and the Independent Scientific Advisory Board (ISAB). Development of a set of action packages for decision analyses involves interaction with the Implementation Team as well as other entities (e.g. the PUD's for Mid-Columbia work).

Approach for Experimental Management (Objective 3):

Methods for approaching experimental management are described in Chapter 6 of Marmorek, Peters and Parnell (1998c). In brief, the development of experimental management options involves consultation, a recognition of tradeoffs, and intensive design work. Each of these are briefly described below.

Consultation. The selection of experimental options is an iterative process and will require input from many people. First, initial experimental recommendations need to be reviewed and filtered by the Regional Forum Implementation Team and other decision-making groups such as the Northwest Power Planning Council. Second, economic workgroups (e.g. the Drawdown Regional Economic Workgroup (DREW)) may wish to explore the economic costs and benefits of particular experimental options. Third, PATH cannot deal with the logistic complexities associated with changes that may be required in specific management sectors of the Columbia Basin ecosystem. When PATH has developed a set of potential experimental actions, we must consult with managers in these areas to refine and plan these actions. For example, if PATH decides that changing hatcheries or harvest policies is an acceptable experimental action (from a conservation and learning perspective), then hatchery operators and harvest managers must be involved in the detailed planning of how to do this.

Tradeoffs between learning and conservation. The region and PATH must work together to consider the relative benefits of experimental and non-experimental actions for learning and conservation, and also consider what experimental design is appropriate and/or legal under the requirements of the *Endangered Species Act*. The most informative management experiments are those that will provide the greatest contrast between treatments. However, such experiments might also increase the risk of extinction for stocks already at high risk. Thus, PATH must consider tradeoffs between learning and conservation.

Design. The monitoring program used to track management indicators is a crucial component of experimental management. What variables are monitored, the frequency at which they are sampled, and the spatial and temporal resolution of data collection determines what size of effect managers will be able to detect, and how long it will take to detect it. Thus when evaluating any experimental option, PATH must estimate how long it will take to observe responses if they exist. Larger perturbations mean less time to observe effects, but these may increase risk to stocks.

Past work has helped develop the methods PATH needs to assess other stocks. Prospective analyses were completed in FY97 and FY98 for Snake River spring-summer chinook, with further sensitivity analyses to be completed in FY99. Retrospective and initial prospective/decision analyses were completed for Snake River fall chinook and steelhead in FY98, to be finalized in FY99. Experimental management work for Snake River spring-summer chinook will be initiated in FY99. Prospective modeling, decision analysis, and experimental management design work integrating all three species will be undertaken in FY99 and FY2000. These techniques will then be applied to Lower and Upper Columbia steelhead and salmon populations in FY2000. In FY2000, we will also initiate integrating decision analysis and experimental management activities for Snake, Upper and Lower Columbia River anadromous salmonid populations, in conjunction with the Multi-Species Framework assessments in FY99 and FY2000.

This work would continue through the year 2004 focusing on integrating these analyses and decision tools over many of the salmon populations in the Columbia River basin. This is the period during which many critical management decisions and assessments of those decisions must be made.

g. Facilities and equipment

The project is primarily located at the following: NMFS, Portland and Seattle; BPA, Portland; CBFWA, Portland; CRITFC, Portland; IDFG, Boise; ODFW, Portland; USFWS, Vancouver; and WDFW, Vancouver. ESSA Technologies is located in Vancouver, British Columbia. Several BPA consultants are located in the Seattle area (Drs. Anderson, Hinrichsen, Zabel, Giorgi), while Dr. Paulsen is in the Portland area. In addition, numerous technical work sessions are required, occasionally with outside technical experts to complete contract tasks. Periodically, PATH participants will need to consult and meet with field and research staff, and attend related workshops and conferences. Some PATH participants participate in Multi-species framework meetings, Decision Process Coordinating Group meetings, IT meetings, Pacific Salmon Treaty meetings, and activities to provide input from the PATH process. Also, PATH participants periodically present findings to scientific associations.

h. Budget

The budget for work in FY2000 is based on the time allocations for work in FY99. Though the tasks will change somewhat in FY2000, the time allocations should remain about the same, since the same basic tasks will be required, that is:

1) facilitation of workshops and technical meetings;
2) coordination of PATH tasks, with the PATH Planning Group;
3) technical analyses on behalf of PATH, particularly related to decision analyses;
4) writing, production and distribution of PATH reports;
5) presentation of PATH results; and
6) administration of subcontracts to the SRP (4 SRP members, SRP coordinator);
7) administration of subcontracts for the 3 independent scientists in PATH.

Time allocations and roles for the listed personnel are as follows:

Personnel	**Roles**	**# days**
D. Marmorek	lead facilitator and coordinator, writing, presentations	99
C. Peters	decision analysis, technical analysis, writing	170
I. Parnell	experimental management, technical analysis, writing	99
C. Alexander	technical analysis, writing	10
C. Pinkham	research assistant	20
M. Jones	salmonid habitat specialist	10
R. Deriso	Bayesian statistics and life cycle modeling expertise	75
R. Peterman	decision analysis and fisheries population dynamics expertise	21
L. Botsford	conservation biology and ocean impacts on salmon	21
L. Barnthouse	coordinator of SRP	20

SRP (C. Walters, J. Collie, S. Saila, S. Carpenter / J. Kitchell)	peer review of PATH products	9 each (total of 36)
TOTAL DAYS		581

The total fees for the above personnel comes to $382,465. Disbursements include travel and expenses for attendance at workshops and technical meetings by the above scientists ($35,000), report production ($6,000), workshop facility costs ($3,000), communications ($7,000) and subcontract administration ($16,536; 10% of all subcontracted fees). Total of fees plus disbursements is $450,001.

Section 9. Key personnel

David R. Marmorek

Birthdate: **December 6, 1952**
Citizenship: **Canadian**

Post-Secondary Education

M.Sc. Zoology, University of British Columbia, 1983. Thesis topic: Effects of lake acidification on zooplankton community structure and phytoplankton-zooplankton interactions: an experimental approach. 397 pp.

B.E.S. (Honors), Man-Environment Studies and Mathematics, First class honors, University of Waterloo, 1975.

Professional Experience

1993 – now **Director,** ESSA Technologies Ltd.
1991 – now **Adjunct Professor,** School of Resource and Environment Management, Simon Fraser University.
1983 – 1993 **Director,** ESSA Environmental and Social Systems Analysts Ltd.
1981 - 1983 **Systems Ecologist,** ESSA Environmental and Social Systems Analysts Ltd.
1975 - 1978 **Applied Ecologist/Urban Planner,** Proctor and Redfern Ltd.

Relevant Experience and Publications

Over 20 years of experience as an aquatic ecologist, modeller and workshop facilitator, including:

- - used maximum likelihood estimation models and decision analysis to assess the impacts of power plant water withdrawals on Hudson River fish species (1992-1996)
- - coordinated and facilitated PATH: an interagency group of fisheries modellers, policy advisors and peer reviewers in a series of analyses of Columbia River salmon stocks (1993-present)
- - served as modeller, facilitator and data analyst developing regional models of aquatic effects of acidic deposition with a focus on fisheries and other aquatic biota in Eastern Canada (1984-1995)
- - major contributor and coordinator of the 1990 NAPAP Integrated Assessment. Responsibilities included critical analysis and synthesis of studies of impacts of acid deposition on aquatic systems, simulation modelling, and coordination of a team of 15 scientists and modellers (1987-1990).

Marmorek, D.R., G. Lacroix, J. Korman, I. Parnell, and W.D. Watt. 1998. Modelling the effects of acidification on Atlantic salmon: a simple model of stream chemistry. Can. J. Fish. Aquat. Sci. 55(9): 2117-2126.

Korman, J., D.R. Marmorek, G. Lacroix, P.G. Amiro, J.A. Ritter, W.D. Watt, R.E. Cutting, D.C.E. Robinson. 1994. Development and evaluation of a biological model to assess regional scale effects of acidification on Atlantic salmon. Can. J. Fish. Aquat. Sci. 51:662-680.

Marmorek, D.R. and J. Korman. 1993. The use of zooplankton in a biomonitoring program to detect lake acidification and recovery. Water, Air, and Soil Pollution 69: 223-241.

Marmorek, D.R., M.L. Jones, C.K. Minns, and F.C. Elder. 1990. Assessing the potential extent of damage to inland lakes in eastern Canada due to acidic deposition. I. Development and evaluation of a simple "site" model. Can. J. Fish. Aquat. Sci. 47: 55-66.

Thornton, K., D. Marmorek, P. Ryan, K. Heltcher, and D. Robinson. 1990. Methods for projecting future changes in surface water acid-base chemistry. State-of Science/Technology Report 14. Prepared for National Acid Precipitation Assessment Program. 271 pp.

Marmorek, D.R., D.P. Bernard, C.H.R. Wedeles, G.D. Sutherland, J.A. Malanchuk, and W.E. Fallon. 1989. A protocol for determining lake acidification pathways. Wat. Air and Soil Poll. 44: 235-257.

Calvin N. Peters

Birthdate: **April 26, 1967**
Citizenship: **Canadian**

Post Secondary Education

- **Masters of Resource Management**, Simon Fraser University, Burnaby, B.C. 1996
  Interdisciplinary training in integrated environmental management, specialization in policy analysis and quantitative approaches to decision-making in fisheries management
- **B.Sc. Ecology**, Simon Fraser University, Burnaby, B.C. 1992.
  (Specialization in evolutionary and behavioural ecology)
- **Diploma of Technology (Honors), B.C. Institute of Technology (1988)**
  Professional training in financial management, capital budgeting and financing, and computer systems analysis, design, and programming.

Professional Experience

1996- (Sept-)	**Systems Ecologist**, ESSA Technologies Ltd., Vancouver, BC. Responsibilities include: proposal preparation, workshop facilitation, data analysis, ecological modelling, statistical and decision analysis, and report writing.
Jan. 01/96- Aug. 31/96	**Research Assistant**, Simon Fraser University, Burnaby, BC. (Contract position with Dr. Randall Peterman)
1994-1995	**Recreational Fisheries Policy Analyst**, Fisheries Branch, B.C. Ministry of Environment, Lands, and Parks

Mr. Peters carries out much of the detailed analytical work in PATH, in consultation with other PATH members. Calvin Peters is highly skilled at integrating the biological, economic, and social components of environmental problems into comprehensive solutions. Mr. Peters has an interdisciplinary background in computer systems, financial management, ecology, and natural resource management. He specializes in quantitative and analytical tools for the development and evaluation of environmental policy and practices. Mr. Peters has applied his skills with the B.C. Ministry of Environment, where he developed a decision-making framework for lake stocking policy in the management of B.C. freshwater fisheries, and with the B.C. Ministry of Forests, where he assisted in the development and delivery of a workshop on quantitative approaches to decision-making for Ministry staff. He has considerable expertise in analytical and technical writing, and has prepared technical documents for a Royal Society of Canada expert panel on Global Change and Canadian Marine Fisheries while doing post-graduate research at Simon Fraser University. Since joining ESSA in the fall of 1996, Mr. Peters has been leading the application of decision analysis to endangered Columbia River salmon stocks. He has also helped develop designs and working modules for fish simulation tools. He has received numerous academic awards.

Publications and Reports

Peterman, R.M., C. Peters. S Frederick and C. Robb. (in press). Benefits of taking uncertainties into account when making decisions in fisheries management: Example applications of Bayesian decision analysis. In: T. Pitcher (ed.). Reinventing Fisheries Management: Proceedings of a Symposium held February, 1996.

Peterman, R.M. and C. Peters. 1998. Decision analysis: Taking uncertainties into account in forest resource management. In: V. Sit and B. Taylor (eds.). Adaptive Management of Forest Resources. B.C. Ministry of Forests Technical Report. Handbook No. 42.

Peters, C.N., D.R. Marmorek, and T.M. Webb. 1997. Design of FFIP Management Model: Summary of FFIP Meetings held December 5,6, 1996 and February 5, 1997 at University of British Columbia. Prepared by ESSA Technologies Ltd., Vancouver, BC for Integrated Resource Management Section, Research Branch, BC Ministry of Forests, Victoria, BC, 28 pp. and appendices.

Ian J. Parnell

Birthdate: **March 11, 1961**
Citizenship: **Canadian**

Post Secondary Education

- *Masters of Resource Management*, ***Simon Fraser University, expected 1999***
- *B.Sc. (Honors) Ecology*, ***Simon Fraser University, 1990.***

Professional Experience

Position	Date	Department/Division	Institution or Company
Systems Ecologist	1998	Fisheries and Aquatic	ESSA Technologies Ltd.,
Research Associate	1997/98	Fisheries and Aquatic	ESSA Technologies Ltd.,
Graduate Researcher	1997/98	Fisheries Management	Simon Fraser University,
Systems Ecologist/Research	1992/96	Fisheries and Aquatic	ESSA Technologies Ltd.,

Mr. Parnell has worked at ESSA as a full time employee and research associate for over six years. He has been involved with PATH since its inception. He recently completed an educational leave of absence to work on his Masters degree. His graduate research is focused on methods, such as decision analysis, for explicitly incorporating biological uncertainty and economic value in the design of management experiments. At ESSA, Mr. Parnell applies his expertise to the ecological and technical analysis of fisheries management problems. This includes the evaluation of the hydrosystem and habitat impacts on fish, bounding environmental impact assessments, and evaluating the statistical performance of environmental monitoring programs. He is experience as a programmer, modeler, and data analyst is invaluable in this area. This experience includes work on simulation models to: assess the impacts of forest management on salmon habitat in coastal streams (FFIP; Fish Forestry Interaction Project); explore the effects of acidification on atlantic salmon (ASRAM; Atlantic Salmon Regional Acidification Model); predict stream chemistry for juvenile atlantic salmon (TSTM; Time Series Translation Model, Marmorek *et al*. 1998); and assess the potential effects of acid precipitation on watersheds in Northern Thailand using MAGIC (Model of Acidification of Catchments).

Selected Publications and Reports

Marmorek, D.R., C. N. Peters, and I. Parnell (eds.). 1998. Plan for Analyzing and Testing Hypotheses (PATH): Final report for Fiscal Year 1998. Prepared by ESSA Technologies Ltd., Vancouver, BC, 254 pp. and appendices.

Marmorek, D.R., G.L. Lacroix, J. Korman, I. Parnell, and W.D. Watt. 1998. Assessing the impact of acidification on Atlantic salmon (*Salmo salar*): a simple model of stream chemistry. *Canadian Journal of Fisheries and Aquatic Sciences* 55:2117-2126.

Parnell, I. and G. Lang. 1998. Statistical power analysis of the Theodosia River water quality monitoring program. Prepared for the British Columbia Ministry of Environment, Lands and Parks. Prepared by Klohn-Crippen Consultants Ltd.

Clint A.D. Alexander

Birthdate: **April 6, 1972**
Citizenship: **Canadian**

Post Secondary Education

- X **Master of Resource and Environmental Management**, Simon Fraser University, Burnaby, BC, 1995-1999.
- X **B.Sc. (Ecology and Environmental Biology),** The University of BC, Vancouver, BC, 1991-1995.
- X **First Year Science,** Okanagan University College, Kelowna, BC, 1990-1991.

Professional Experience

1997 -present **Systems Ecologist**, ESSA Technologies Ltd. As a member of the aquatic ecosystems, fisheries and environmental monitoring group specializing in quantitative methods, responsibilities include:

- X design / development of computer simulation models and other decision support tools;
- X evaluation of sampling (e.g. creel surveys) and experimental designs;
- X development and assessment of appropriate research methods;
- X conducting statistical analyses (using Bayesian, classical and Bootstrap methods);
- X statistical power analysis, decision and risk analysis; technical writing
- X identification of new research areas, proposal writing; coordination of workshops.

1996 -1997 **Principal Researcher (contract position),** Canadian Department of Fisheries and Oceans, Burnaby, BC. Design of simulation model to assess the performance and risks of alternative spawning escapement and in-river allocation policies for Fraser River sockeye.

1996 **Teaching Assistant and Research Assistant (Ecology; Toxicology),** School of Resource and Environmental Management, SFU, (Sept.-Dec.) Burnaby, BC.

1995 **Research Assistant / Technician 2,** The University of British Columbia Fisheries Centre, Vancouver, BC. Fisheries modelling.

Publications and Reports

Alexander, C.A.D. (Masters thesis - *in prep.*). Contradictory data and the application of the precautionary approach: a case study for setting escapement targets for Stuart River sockeye salmon (*Oncorhynchus nerka*), British Columbia.

Alexander, C.A.D. 1998. 1998 Native catch estimates on the lower Fraser River. Prepared by ESSA Technologies Ltd., Vancouver, BC. For the Canadian Department of Fisheries and Oceans, Fraser River Division, New Westminster BC., 52 pp.

Alexander, C.A.D, T.M. Webb, and D.R. Marmorek. 1998. The Fish Forestry Interaction Project - Management Model (FFIP-MM): Preliminary Model Description and and Application to Carnation Creek, British Columbia. Prepared by ESSA Technologies Ltd., Vancouver, BC, and Lookfar Solutions, Tofino, BC. 50 pp.

Alexander, C.A.D. and D.R. Marmorek. 1998. The Nechako Fisheries Conservation Program (NFCP): The Last 10 Years and the Next 10 Years. Report on a workshop held February 24th and 25th, Vancouver, British Columbia, Canada. Prepared by ESSA Technologies Ltd., Vancouver, BC. 65 pp.

Alexander, C.A.D. 1995. Computer simulations examining the contribution of ocean currents and pre-migration temperature responses on sockeye salmon return timing. Paper presented at the American Fisheries Society North Pacific International Chapter annual meeting, held April 5 - 7, Vancouver, BC, page 14 of program.

Summary Professional Vitae
Richard B. Deriso

c/o Scripps Institution of Oceanography
La Jolla, CA 92093
Research Associate, ESSA Technologies Ltd.

Formal Education

- Ph.D. in Biomathematics (Quantitative Ecology) 1978, University of Washington
- M.S. in Mathematics 1975, University of Florida
- B.S. in Industrial Engineering 1972, Auburn University

Academic Honors

Tau Beta Pi, Pi Alpha Mu (scholastic honor societies)
1981 W.F. Thompson Award from American Institute of Fishery Research Biologists for publication (Deriso, 1980 CJAFS).

Major Research Interests

- Fisheries Population Dynamics
- Quantitative Ecology
- applied mathematics, statistics

Recent Professional Experience

- Chief Scientist of the Tuna-Billfish Program, Inter-American Tropical Tuna Commission, 1988-present.
- Associate Adjunct Professor, Scripps, Institution of Oceanography, UCSD, 1990-present.
- Affiliate Associate Professor of Fisheries, University of Washington, 1987-present; 1982-1986, Assistant Professor.
- Scientific and Statistical Committee member, Western Pacific Management Council, 1993-present.
- Population Dynamicist, International Pacific Halibut Commission, Seattle, WA, 1980-1988.
- Visiting Research Assistant Professor, Marine Sciences, University of North Carolina at Chapel Hill, 1979-1980.
- Consultant to several agencies and institutions, including US Minerals Management Service, Exxon, ESSA Ltd., Australian Department of Primary Industry, Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, University of Alaska at Juneau, Applied Biomathematics Inc., Living Marine Resource Inc., National Marine Fisheries Service, North Carolina Sea Grant Program, and US Environmental Protection Agency.

Other Professional Activities

- Over 30 seminars given at various universities, agencies, and conferences.
- Taught several graduate courses, including:
  - FISH 557 course (Theoretical Models of Exploited Animal Populations, University of Washington),
  - QSCI 598 (Decision analysis for exploited populations, University of Washington),

- ♦ SIO 276 (Quantitative theory of populations and communities, Scripps Institution of Oceanography, with G. Sugihara).

- Served on several committees and working groups, including groups with ICES, FAO, NAS, and NRC. Currently co-chairman, NRC Committee on Fish Stock Assessment Methods.

Publications and Reports

Over 40 publications and reports, including:

- Deriso, R.B. 1978. Non-linear age-structured models for seasonally breeding populations. Ph.D. dissertation, University of Washington, 159 pp.
- Deriso, R.B. ;1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 42: 268-282.
- Deriso, R.B., T.J. Quinn II, and P.R. Neal. 1985. Catch-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42: 815-824.
- Deriso, R.B., R.G. Punsly, and W.H. Bayliff. 1991. A Markov movement model of yellowfin tuna in the Eastern Pacific Ocean and some analyses for international management. Fish. Res. 11: 375:395.

Randall M. Peterman

B.Sc. (Biological Sciences, University of California at Davis).
Ph.D. (Zoology, University of British Columbia)
Professor, School of Resource and Environmental Management

Dr. Randall Peterman is a population ecologist who specialized in quantitative methods to improve fisheries management. His research interests include the application of simulation modeling, statistical power analysis, Bayesian statistics, and decision analysis to problems in resource management. Some of his research applies these methods to the design of monitoring programs. He is also developing quantitative techniques for ecological risk assessment and for detecting the effect of climate change on fish productivity.

Dr. Peterman and his graduate students also work on methods to deal with uncertainties effectively, for example:

- Peterman, R.M. 1990. Statistical power analysis can improve fisheries research and management. Can. J. Fish. Aquat. Sci. 47:2.
- Robb, C.A. and R.M. Peterman. 1998. Application of Bayesian decision analysis to management of a sockeye salmon fishery. Can. J. Fish. Aquat. Sci. (in press).
- Frederick, S.W. and R.M. Peterman. 1995. Closing fisheries harvest policies: when does uncertainty matter? Can. J. Fish. Aquat. Sci. 52:291.

Dr. Peterman also co-authored "Principles of the conservation of wild living resources", in 1996 Ecological Applications (6:338) and "Precautionary Approach to Fisheries, Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions", 1995, Food and Agriculture Organization (FAO) of the United Nations, Fisheries Technical Paper No. 350/1.

Peer recognition for his research in fisheries management includes the 1990 J.C. Stevenson Award for "…creative research on the cutting edge of an aquatic discipline." Also, in 1992, Peterman and his graduate student, M. McAllister, received a citation for the most significant paper in the North American J. of Fisheries Management for their paper, "Experimental design in the management of fisheries: a review", (NAJFM 12:1). In 1994, he and two of his graduate students received the W.F. Thompson Award from the American Institute of Fisheries Research Biologists for the best student publication, the paper in the 1992 Can. J. Fish. Aquat. Sci. (49:1294).

Dr. Peterman won an Excellence in Teaching Award from Simon Fraser University in 1990 and a University Research Professorship in 1990-91. He has served on several professional committees in Canada and the U.S. and is currently co-chair of a panel on Canadian Marine Fisheries for the Canadian Global Change Program of the Royal Society of Canada.

Dr. Peterman teaches Applied Population and Community Ecology (REM 611), Current Topics in Fisheries Management (REM 613), and Risk Assessment and Decision Analysis for Management of Natural Resources (REM 625).

CURRICULUM VITAE

Michael L. Jones

Dr. Jones is leading the PATH workgroups responsible for assessing the impacts of habitat change and hatchery activities on endangered chinook and steelhead populations.

Education

B.Sc.(Honours), Zoology, University of British Columbia, 1977
Ph.D. Zoology, University of British Columbia,1986

Professional Experience

- Associate Professor, Great Lakes Fisheries, Michigan State University
- Honourary Conjunct Professor, Watershed Ecosystems Program,Trent University, 1991-present
- Research Scientist-in-Charge, Great Lakes Salmonid Unit, Aquatic Ecosystems Research Section, Ontario Ministry of Natural Resources, 1988-present.
- Director and partner, ESSA Environmental and Social Systems Analysts Ltd., 1983-1988.
- Systems Ecologist and Manager, ESSA Ltd., Toronto Office, 1981-1988
- Lecturer, Institute for Environmental Studies, University of Toronto, 1983-1989

Professional Affiliations

Past Chairman, Board of Technical Experts, Great Lakes Fishery Commission
Director, International Association for Great Lakes Research

Selected Publications

Jones, M.L., and nine coauthors. 1996. Limitations to lake trout (*Salvelinus namaycush*) rehabilitation in the Great Lakes imposed by biotic interactions occurring at early life stages. Journal of Great Lakes Research *in press*

Jones, M.L., R. G. Randall, D. B. Hayes, W. Dunlop, J. Imhof, G. Lacroix, and N. Ward. 1996. Assessing the ecological effects of habitat change: moving beyond productive capacity. Can. J. Fish. Aquat. Sci. 53: (Suppl. 1): *in press.*

Stoneman, C. L., and M.L. Jones. 1996. A simple method to classify stream thermal stability using single observations of daily maximum water and air temperature. N. Amer. J. Fish. Manage. *accepted.*

Stoneman, C. L., M.L. Jones, and L. W. Stanfield. 1996. Habitat suitability assessment models for southern Ontario trout streams. Model development and evaluation. Can. Manus. Rep. Fish. Aquat. Sci. 2345: 45 pp.

Jones, M.L., and J. D. Stockwell. 1995. A rapid assessment procedure for the enumeration of salmonine populations in streams. N. Amer. J. Fish. Manage. 15:551-562.

Jones, M.L., J.F. Koonce, and R. O'Gorman. 1993. Sustainability of hatchery dependent salmonine fisheries in Lake Ontario: the conflict between predator demand and prey supply. Trans. Amer. Fish. Soc. 122(5):1002-1018.

Rand, P.S., D.J. Stewart, P.W. Seelbach, M.L. Jones, and L.R. Wedge. 1993. Modeling steelhead trout population energetics in Lakes Michigan and Ontario. Trans. Amer. Fish. Soc. 122(5):977-1001.

Jones, M.L. and L. Stanfield. 1993. Effects of exotic juvenile salmonines on growth and survival of juvenile Atlantic salmon (*Salmo salar*) in a Lake Ontario tributary. p. 71-79 in R.J. Gibson and R.E. Cutting (ed). Production of juvenile Atlantic salmon, *Salmo salar*, in natural waters. Can. Spec. Publ. Fish. Aquatic. Sci. 118.

Jones, M.L., C.K. Minns, D.R. Marmorek, and K.J. Heltcher. 1991. Assessing the potential extent of damage to inland lakes in eastern Canada due to acidic deposition. IV. Uncertainty analysis of a regional model. Can. J. Fish. Aquat. Sci. 48:599-606.

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 presentations 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. Presentations on PATH have been made at the American Fisheries Society (Monterey, August 1997), and a Special Forum on Adaptive Management (Ontario, Canada; October 1998). In addition, some PATH analyses have been submitted for publication in the Canadian Journal of Fisheries and Aquatic Sciences.

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 and FY2000. The results of experimental management work should translate into better design of monitoring programs and evaluation tools. In addition, PATH intends to work with other groups (e.g. the Mid-Columbia Coordinating Commitee) to pass on our methods and process.

Congratulations!