
PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Analytical Support-Path And Esa Biological Assessments

BPA project number: 9800100
Contract renewal date (mm/yyyy): 10/1999 **Multiple actions?**

Business name of agency, institution or organization requesting funding
Hinrichsen Environmental Services

Business acronym (if appropriate) HES

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NPPC Program Measure Number(s) which this project addresses
3.2C.1, 3.2C.2, 4.2A, 4.3A, 5.0A, 7.1A.1, 7.1E.1

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

Other planning document references

Snake River Salmon Recovery Plan: 2.1d2, 2.1.d3,2.11.a; Consideration of Ocean Conditions in the Columbia River Basin Fish and Wildlife Program Northwest Power Planning Council May 29, 1997: 2d.

Short description

Participate in PATH. Provide biological rationale for hypotheses, and develop and test model structures that identify key uncertainties in salmon life-cycle survival processes. Design alternative adaptive management experiments that maximize learning.

Target species

Spring Chinook, Fall Chinook, Steelhead, Sockeye

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 |
| <input checked="" type="checkbox"/> Anadromous fish <input type="checkbox"/> Resident fish <input type="checkbox"/> Wildlife | <input checked="" type="checkbox"/> Multi-year (milestone-based evaluation) <input type="checkbox"/> Watershed project evaluation | <input type="checkbox"/> Watershed councils/model watersheds <input checked="" type="checkbox"/> Information dissemination <input type="checkbox"/> Operation & maintenance <input type="checkbox"/> New construction <input checked="" type="checkbox"/> Research & monitoring <input type="checkbox"/> Implementation & management <input type="checkbox"/> Wildlife habitat acquisitions |

Section 3. Relationships to other Bonneville projects

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

| Project # | Project title/description |
|------------------|---|
| 9600600 | PATH-FACILITATION, TECH ASSISTANCE AND PEER REVIEW (umbrella project) |
| 9600800 | PATH (PLAN FOR ANALYZING AND TESTING HYPOTHESES) - PARTICIPATION |
| 9700200 | PATH -- UW TECHNICAL SUPPORT |
| 9601700 | TECHNICAL SUPPORT FOR PATH - CHAPMAN CONSULTING, INC.(NOW BIO...) |
| 9303701 | TECHNICAL ASSISTANCE WITH THE LIFE CYCLE MODEL |

Other dependent or critically-related projects

| Project # | Project title/description | Nature of relationship |
|------------------|----------------------------------|-------------------------------|
| | | |
| | | |
| | | |
| | | |

Section 4. Objectives, tasks and schedules

Past accomplishments

| Year | Accomplishment | Met biological objectives? |
|------|--|---|
| 1998 | co-authored Preliminary Decision Analysis Report on Snake River Spring/Summer Chinook [Marmorek and Peters (eds.)] in March 1998. Developed model structures rationale for the ocean-regime shift hypothesis for Appendix A . | Yes. Incorporated biological uncertainties in a decision support framework. |
| 1998 | Co-developed and refined fall chinook life-cycle model. | Yes. We were able to project fall chinook salmon populations and calculate probabilities of the populations meeting the NMFS survival and recovery standards. |
| 1998 | Reviewed and contributed extensively to the PATH Weight of Evidence report during May to August, 1998. Tested alternative post-hydrosystem mortality hypotheses with retrospective data. | Yes. We examined the level of support for alternative biological hypotheses using retrospective spawner-recruit analyses and passage model results. |
| 1998 | Conducted and documented numerous sensitivity analyses regarding harvest and drawdown for spring/summer chinook prospective model, testing how robust conclusions were to alternative assumptions. | Yes. We determined the sensitivities of important spring chinook population biology parameters (survivals, productivities, recovery probabilities) to various biological assumptions. |
| 1998 | Presented diagnostics for the spring/summer Delta version of the chinook life cycle model and wrote a report entitled "Influence of Exceptional Spawner-Recruit data of the John Day Middle Fork on the Delta Model Parameters." | Yes. Determined the influence of certain subsets of spawner-recruit data on the statistical inferences drawn on important spring/summer chinook population biology parameters. |
| 1998 | Test for correlation between extra mortality of naturally produced Snake River spring/summer chinook and hatchery releases. Co-authored a memo with C. Paulsen, June 12, 1998. | Yes. We quantified the level of covariation between hatchery releases and mortality of spring/summer chinook not accounted for by passage models. |
| 1998 | Described in detail the difficulties of working with an unbalanced design to determine and weight key uncertainties in the PATH decision support analysis. Co-authored a corresponding report with Charles Paulsen. | Yes. We assisted ESSA in achieving a balanced design for the spring/summer for the process of weighting alternative biological hypotheses. |
| 1998 | See accomplishments of umbrella | |

| |
|---------------------|
| proposal (9600600). |
|---------------------|

Objectives and tasks

| Obj 1,2,3 | Objective | Task a,b,c | Task |
|----------------------|---|-----------------------|---|
| 1 | Refine existing models to evaluate the likelihood of persistence and recovery of salmon stocks under alternative management scenarios and alternative hypotheses. | a | Analyze the recently-discovered apparent effects of hyper-comensation in the spawner-recruit data. Determine whether these effects will influence the substantive inferences of our analysis. |
| | | b | Refine the the alpha life-cycle model (spring chinook) so that it provides a better fit to the data (AIC and BIC) using the alternative hypothesis that the lower river stocks serve as an adequate reference or "control" for Snake spring chinook stocks. |
| | | c | Provide rationale for climate affects on Upper Columbia salmon stocks. |
| 2 | Thoroughly test the refined models for important sensitivities, their qualitative behavior, and comparison with data unused in their calibration. | a | Provide model diagnostics showing the sensitivity of life cycle model and refined passage model parameter estimates and predictions to various subsets of the spawner-recruit data. |
| | | b | Test retrospective and prospective models against data unused in the calibration process. |
| | | c | Describe the qualitative behaviors of the models used. Do their dynamic behaviors reflect those observed in the natural spawning populations? |
| 3 | Use models to evaluate alternative adaptive management designs. | a | Participate in the design of adaptive management experiment. |
| | | b | Determine what data of opportunity exist to measure experimental outcomes (monitoring data). |
| | | c | Describe the possible confounding effects of ocean-climate regimes in design of management experiments. Develop a design that deals with this time-treatment interaction difficulty. |
| | | | |

Objective schedules and costs

| Obj # | Start date mm/yyyy | End date mm/yyyy | Measureable biological objective(s) | Milestone | FY2000 Cost % |
|-------|-----------------------|---------------------|--|--------------|------------------|
| 1 | 11/1999 | 7/2000 | Probabilities of persistence and jeopardy of salmon populations. | | 30.00% |
| 2 | 11/1999 | 7/2000 | | | 30.00% |
| 3 | 7/2000 | 10/2000 | | | 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): \$119,900

FY2000 budget by line item

| Item | Note | % of total | FY2000 |
|---|--|---------------|---------|
| Personnel | 1538 hours at \$80/hr | %98 | 123,040 |
| Fringe benefits | | %0 | |
| Supplies, materials, non- expendable property | | %0 | |
| Operations & maintenance | | %0 | |
| Capital acquisitions or improvements (e.g. land, buildings, major equip.) | | %0 | |
| NEPA costs | | %0 | |
| Construction-related support | | %0 | |
| PIT tags | # of tags: | %0 | |
| Travel | Workshop and meeting attendance for PATH. | %2 | 1,960 |
| Indirect costs | | %0 | |
| Subcontractor | | %0 | |

| | | | |
|--|--|----|------------------|
| Other | | %0 | |
| TOTAL BPA FY2000 BUDGET REQUEST | | | \$125,000 |

Cost sharing

| Organization | Item or service provided | % total project cost (incl. BPA) | Amount (\$) |
|---|---------------------------------|---|--------------------|
| | | %0 | |
| | | %0 | |
| | | %0 | |
| | | %0 | |
| Total project cost (including BPA portion) | | | \$125,000 |

Outyear costs

| | FY2001 | FY02 | FY03 | FY04 |
|---------------------|---------------|-------------|-------------|-------------|
| Total budget | \$130,000 | \$135,000 | \$140,000 | \$145,000 |

Section 6. References

| Watershed? | Reference |
|--------------------------|---|
| <input type="checkbox"/> | Belsey, D.A. 1991. Conditioning Diagnostics. J. Wiley & Sons, New York. |
| <input type="checkbox"/> | Belsley, D.A., E. Kuh, and R.E. Welsch. 1980. Regression Diagnostics. J. Wiley & Sons, New York. |
| <input type="checkbox"/> | Box, G.E.P, G.M. Jenkins, and G.C. Reinsel. 1994. Time Series Analysis. Third edition. Prentice Hall, Englewood Cliffs, New Jersey. |
| <input type="checkbox"/> | Brodeur, R. D., and Ware, D.M. 1992. Interannual and interdecadal changes in zooplankton biomass in the subarctic Pacific Ocean. Fish. Oceanogr. 1: 32-38. |
| <input type="checkbox"/> | Cook, R.D. and S. Weisberg. 1982. Residuals and Influence in Regression. Chapman and Hall, New York. |
| <input type="checkbox"/> | Francis, R.C., A.B. Hollowed, and W.S. Wooster. 1997. Effects of interdecadal climate variability on the oceanic ecosystems of the northeast Pacific. J. Climate, in press. |
| <input type="checkbox"/> | Friis-Christensen, E., and Lassen, K. 1991. Length of solar cycle: an indicator of solar activity closely associated with climate. Science 254:698-700. |
| <input type="checkbox"/> | Hare, S.R., N.J. Mantua, and R.C. Francis. 1998. Inverse production regimes: Alaska and West Coast pacific salmon. Fisheries, in press. |
| <input type="checkbox"/> | Hilborn, R. and C.J. Walters. 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty. Chapman & Hall, New York. |
| <input type="checkbox"/> | Hinrichsen, R. A. 1998. Influence of exceptional spawner-recruit data of the John Day Middle Fork on the Delta model parameters. PATH document. See http://www.cqs.washington.edu/~hinrich/PATH/INFLUENCE/abst_inf.html . |
| <input type="checkbox"/> | Mantua, J.N, S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A |

| | |
|--------------------------|--|
| | Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society. Vol. 78, No. 6, June 1997, p1069-1079. |
| <input type="checkbox"/> | Minobe, S. 1997. A 50-70 year climatic oscillation over the North Pacific and North America. Geophys. Res. Lett.. Volume 24. pages 683-686. |
| <input type="checkbox"/> | Murray, J.D. 1989. Mathematical Biology. Springer-Verlag, New York. |
| <input type="checkbox"/> | Northwest Power Planning Council. 1994. Columbia River Basin Fish and Wildlife Program. |
| <input type="checkbox"/> | Oregon Dept. of Fish and Wildlife and Washington Dept. of Fish and Wildlife. 1995. Status Report: Columbia River Fish Runs and Fisheries, 1938-1994. |
| <input type="checkbox"/> | PATH. 1998. Preliminary Decision Analysis Report on Spring/Summer Chinook. Edited by David Marmorek, and Calvin Peters, ESSA technologies. |
| <input type="checkbox"/> | PATH Scientific Review Panel 1998. Conclusions and recommendations from the PATH Weight of Evidence Workshop, September 8-10, Vancouver, B.C., Canada. |
| <input type="checkbox"/> | Pearcy, W.G. 1992. Ocean Ecology of North Pacific Salmonids. University of Washington Press. Seattle. |
| <input type="checkbox"/> | Polovina, J.J, G.T. Mitchum, and C.T. Evans. 1995. Decadal and basin-scale variation in mixed layer depth and the impact on biological production in the central and North Pacific, 1960-88. Deep-Sea Res., Volume 42:1701-1716. |
| <input type="checkbox"/> | Punt, A.E. and R. Hilborn. 1997. Fisheries stock assessment and decision analysis: the Bayesian approach. Reviews in Fish Biology and Fisheries, Volume 7: 35-63. |
| <input type="checkbox"/> | Roemmich, D., and McGowan, J. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267: 1324-1326. |
| <input type="checkbox"/> | Roemmich, D., and McGowan, J. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267: 1324-1326. |
| <input type="checkbox"/> | Schlesinger, M.E., and Ramankutty, N. 1994. An oscillation in the global climate system of period 65-70 years. Nature. 367:723-726. |
| <input type="checkbox"/> | Sugimoto, T. and K. Tadokoro. 1997. Interannual-interdecadal variations in zooplankton biomass, chlorophyll concentration and physical environment in the subarctic Pacific and Bering Sea. Fish. Oceanogr. 6:74-93. |
| <input type="checkbox"/> | Ware, D.M. 1995. A century and a half of change in climate of the NE Pacific. Fisheries Oceanography Vol. 4, No. 4, p267-277. |
| <input type="checkbox"/> | |

PART II - NARRATIVE

Section 7. Abstract

This is a sub-proposal of the umbrella proposal (9600600). As part of a large modeling effort underway through PATH, we will develop model structures that allow a large array of hypotheses to be included. We will include

alternative hypotheses on the role of climate variability in salmon and steelhead production, using historical productivities to estimate climate/ocean variability on the future success of index salmon and steelhead populations. We also bring a wide array of techniques to test the assumptions of the models used in the decision support -- a part of the modeling effort that has been lacking until recently. With our techniques, we seek further quantification of the uncertainties in the decision analysis. We ask two questions: (1) Are there exceptional data of low quality that are driving the performance of management alternatives? and (2) How well do the models predict data unused in their calibration? (3) What role does measurement error play in our substantive results? After identifying these key uncertainties, we apply the results to answer basic design adaptive management questions: How long should the experiment last (sample size)? On what schedule should the treatments proceed (e.g., off-on every other year)? How large a response is needed to deem the experiment a success (statistical power)? Most basically, how do we alter management schedules to derive the most useful information on key uncertainties?

Section 8. Project description

a. Technical and/or scientific background

This is a sub-proposal of the umbrella proposal (9600600)

Overall problem

The overall problem we address is the quantification of the effectiveness of management

decisions concerning anadromous salmonid ecosystems under uncertainty.

We develop

and implement life-cycle models that explore management questions of interest and the

alternative hypotheses relevant to these questions. We will also develop model structures necessary to incorporate a wide range of scientific hypotheses, provide peer review of model structures and their underlying data, and provide guidance on implementation. We also provide guidance on the use of models for design of management experiments.

Scientific review of literature (See umbrella proposal 9600600).

Adaptive management and decision support model evaluation

The need for consideration of alternative scientific hypotheses and model evaluation is crucial in PATH and other decision support endeavors. Punt and Hilborn (1997) summarize the steps involved in a decision analysis: (1) Identify hypotheses about population dynamics, (2) determine relative weight of evidence in their support, (3) identify alternative management actions, (4) evaluate the expected value of the performance measures, and (5) present the results to the decision maker. In order to

make scientific progress, we need alternative models representing different hypotheses on the states of nature. A too-narrow range of alternative hypotheses considered will produce overconfidence in the rankings of the effectiveness of management options (see PATH memo, Randall Peterman, May 31, 1997). During FYs 1997-1998 Hinrichsen worked with PATH to develop alternative model structures in the preliminary decision analysis document. The models developed were subsequently used in analysis of management decisions (see Preliminary Decision Analysis Report on Spring/Summer Chinook, PATH, 1998).

We will continue to evaluate the models in the iterative modeling process of PATH. Bayesian analysis is accomplished in many ways (Gelman et al., Bayesian Data Analysis, 1995). These are implemented to not be misled by models that do not fit reality and are sensitive to the arbitrary specification of model structures and probability distributions. We further evaluate models by identifying exceptional data that have large influence on important parameter estimates, and ultimately the ranking of management options (Belsley et al. 1980; Cook and Weisberg, 1982; Belsley 1991). During FYs 1997-1998, Hinrichsen conducted sensitivity analysis on the spring/summer chinook spawner-recruit model to detect exceptional data. Spawner-recruit data in the John Day Middle Fork were found to be highly influential on key parameter estimates and of questionable quality (see Preliminary Decision Analysis report on Spring/Summer Chinook, PATH document, 1998; Hinrichsen 1998). Distressingly little attention has been paid to model diagnostics. Because models are used prospectively, it is crucial to assess the ability of the models to predict outside the range of the data fit. These diagnostics are needed to improve our models and identify key uncertainties in the decision support analyses and in the design of experimental management.

Climate and salmon ecosystems

Widespread ecological changes related to interdecadal climate variations in the Pacific have been observed in this century. Dramatic shifts in many marine and terrestrial ecological variables in western North America coincided with changes in the physical environment in the late 1970s. This array of rapid and widespread changes is known as the 1977 climate regime shift. The 1977 regime shift is not unique in the climate record or in the record of North Pacific salmon production. Signatures of other regime shifts are

evident in the Pacific basin ecological systems starting in the 1700s (1925 and 1947 in this century). (See Mantua et al. 1997, Minobe 1997). Among salmon species shown to have interdecadal variability were Alaskan sockeye, Alaskan pink salmon, Columbia River spring chinook, and Washington-Oregon-California (WOC) coho. While the climate regime from 1977-present favored Alaskan salmon production, it was associated with decreased production of West Coast salmon stocks south of Alaska (Hare et al. 1997, Pearcy 1992). The marine ecological response to regime shifts may start with the plankton at the base of the food chain and work its way up to top-level predators such as salmon (Francis et al. 1997). After the 1977 regime shift, there was a zooplankton biomass increase and a re-distribution around the Subarctic gyre, creating favorable feeding conditions for migrant salmon smolts (Brodeur and Ware 1992, Sugimotoa and Tadokoro 1997). Conversely, off the West Coast, there was a dramatic decrease in zooplankton production due to stratification of the California Current waters and loss of advective products from the westwind drift (Roemmich and McGowan, 1995). This relatively barren ocean environment was unfavorable for West Coast smolts (Hare et al. 1997).

b. Rationale and significance to Regional Programs

(See umbrella proposal 9600600)

Decision support. (see umbrella proposal 9600600).

Consideration of Climate in Adaptive Management. The need for including ocean and climate effects in management decisions has been made law and is now included in several planning documents. On September 12, 1996, Congress enacted the first and only amendment to the Northwest Power Act of 1980. Section (4)(h)(10)(D)(vi) of the Act, they instructed the NWPPC to "consider the impact of ocean conditions on fish and wildlife populations" in making its recommendations to Bonneville regarding projects to be funded. In response to this, NWPPC concluded "ocean conditions have their most direct impact on anadromous fish populations, such as salmon and steelhead," and directed the region to "integrate current scientific knowledge regarding biological impacts of ocean conditions with the regional fish and wildlife planning and management." (See action 2.D, "Consideration of Ocean Conditions in the Columbia River Basin Fish and Wildlife Program," NWPPC, May 29, 1997). The proposed recovery plan for Snake River Salmon also called for investigation of the influence of ocean conditions on salmon

production (see task number 4.8d, "Proposed Recovery Plan for Snake River Salmon," NMFS, March 1995).

Benefits to FWP: Our work provides quantification of key uncertainties surrounding climate variability and salmon and steelhead production. It also provides a vehicle for including climate in management decisions as mandated by law and as recommended by NWPPC. Consideration of an ocean/climate regime shift will be important in the design of adaptive management experiments. How do we implement an experiment so that, if it occurs, it is not confounded with other effects we intend to measure?

Our model development and implementation follows these basic steps:
(a) Improve existing model and/or develop new models to better evaluate the likelihood of persistence and recovery of salmon and steelhead stocks under alternative management scenarios and for use in monitoring adaptive management experiments. (b) Emphasize implications for management decisions on endangered or threatened salmon populations of the Columbia River Basin. (c) Provide guidance to management agencies (particularly NPPC and Implementation Team) based on these outputs in written format and through oral presentations. (d) Propose alternative hypotheses and/or model improvements that are more consistent with the data. (e) Develop refined models that incorporate what has been learned from the retrospective analyses and model checking procedures for use in adaptive management experiments and design.

Benefits to FWP: Quantification of key uncertainties regarding model structures and exceptional data used in their calibration. Testing of models employed for decision support and the design and implementation of adaptive management experiments.

c. Relationships to other projects

(see umbrella proposal 9600600)
James Anderson's and colleagues' participation in PATH 8910800 CRiSP Modeling. Al Giorgi's hydrosystem work participation in PATH 9601700 Technical Support for Path Chapman Consulting, Inc. (now Bioanalysts, Inc.) Paulsen's simulation modeling participation in PATH 9303701 Technical Assistance With the Life Cycle Model. U.S. Forest Service for quantitative habitat assessments (Danny Lee) participation in PATH 9203200 Life-cycle Model Development and Application, and Analysis of Fish-habitat

Relationships. ESSA for PATH, Facilitation, Tech Assistance & Peer Review-work with planning group to develop specific PATH workplans and reports to be submitted to PATH peer review process. PATH 9600600 (umbrella).

Cooperation

Through PATH, Hinrichsen currently cooperates with scientists from NMFS, BPA, NPPC, ODFW, IDFG, WDFW, CRITFC, USFS, CBFWA, and CORPS, as well as from a number of academic and research institutions (U. Washington, 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). In addition, the Independent Scientific Group (ISG) has participated in PATH since its inception (Phil Mundy, Jim Lichatowich, Chip McConnaha, and Chuck Coutant). Close cooperation with the ISG is very important to our work.

Opportunities for relationships exist for several non-BPA funded projects for ocean/climate effects:

The U.S. Global Ocean Ecosystems Dynamics (U.S. GLOBEC) is a research program organized by oceanographers and fisheries scientists of the National Science Foundation (NSF), and the Coastal Ocean Program (COP) and the National Marine Fisheries Service (NMFS) divisions of the National Oceanic and Atmospheric Administration (NOAA).

The program has a goal of understanding how physical processes influence marine ecosystems, to predict the response of the ecosystem to climate change.

The Pacific Northwest Coastal Ecosystem Regional Study (PNCERS) is a joint interdisciplinary effort of the Oregon Coastal Management Program, the Oregon and Washington Sea Grant Programs, and the NMFS Northwest Fisheries Science Center. The goal of the PNCERS program is to improve the understanding of natural variability and anthropogenic factors on coastal ecosystems that support Pacific salmon, and to translate that understanding into improved management of resources and activities that affect coastal ecosystems.

d. Project history (for ongoing projects)

Project History

The project (number 9800100) began FY98 on October 19, 1997. The cost of FY98 work was \$99,580. The objectives for the project were outlined in a

work plan. The work plan identified six different general tasks: (1) Spring/Summer chinook analysis, (2) Fall Chinook Analysis, (3) Steelhead Analysis (not yet implemented), (4) Spring/Summer PIT tag analysis (ongoing with Charlie Paulsen -- 9303701) (5) Prospective Modeling (6) Additional Tasks.

Results Achieved in FY 1998:

Task 1. Spring/Summer chinook analysis. Developed alternative model structures (the alpha model) for use in retrospective and prospective modeling. Developed and documented alternative hypotheses for inclusion in decision support analysis. Co-authored PATH preliminary decision analysis report (PATH 1998). Described in detail the alpha life-cycle model and the regime shift hypothesis. Provided the rationale for the regime shift hypothesis and presented supporting data and literature review. Tested various extra mortality hypotheses: climate regime shift, BKD, and hydro-related extra mortality hypotheses using retrospective modeling results. Documented results (Hinrichsen and Paulsen 1998a) Conducted sensitivity analyses on the retrospective delta model. Discovered a small subset of data that drove the high in-river mortality estimate, high per-dam mortality estimate, and the high estimate of intrinsic productivity of the Snake stocks (Hinrichsen 1998). Compiled and ran the Fortran version of the retrospective delta model and compared it to output from a statistical program (S-PLUS). S-PLUS confirmed the maximum likelihood estimates attained using the Fortran version.

Task 2. Fall Chinook analysis. Developed an alternative model structure for treating the potential effects of a climate regime shift on the Snake River fall chinook stocks. Demonstrated a need to estimate the ratio post-Bonneville survivals of in-river and transported fish outside of the spawner-recruit model. Tested various retrospective models based on AIC and BIC. Compiled and tested version of the retrospective Fall Chinook model presented in FORTRAN by Rick Deriso. Detected and corrected an input error in the original program.

Task 4. Spring/Summer Pit-tag analysis. Reviewed and discussed in detail with C. Paulsen the methods for analyzing over-wintering survival of spring/summer chinook in various subbasins Paulsen produced a report " Snake River Chinook Parr-Smolt Survival and Habitat Quality Indices."

Task 5. Prospective Analyses. Developed pseudo code and variable dictionary for segments of the Fortran Bayesian Simulation Model, which projects spring/summer chinook recruitment. Conducted sensitivity analysis of the probabilities for spring/summer chinook actions to meet the jeopardy standards. Described the difficulties of working with an unbalanced design to determine critical uncertainties (hypotheses) in the PATH decision support

analysis. Worked closely with ESSA and Charlie Paulsen to resolve the difficulties posed (Hinrichsen and Paulsen 1998b). Discovered a bias in the way the hydro-related extra mortality hypothesis was framed mathematically. It described a positive relationship between passage survival and post-Bonneville survival of in-river fish, when none really existed in the retrospective data (Hinrichsen and Paulsen, 1998a). Developed and implemented a spring/summer chinook harvest alternative that showed that certain management alternatives could achieve the 48-year recovery standard by reducing harvest (applying the mean scientific review panel's weightings on the leading uncertainties.)

Reports for FY 1998

PATH. 1998. Preliminary Decision Analysis Report on Spring/Summer Chinook.

Hinrichsen, R. A. 1998. Influence of Exceptional Spawner-Recruit data of the John Day Middle Fork on the Delta Model Parameters. PATH memo.

Hinrichsen, R. A. and C. Paulsen. 1998a. Testing the Hydro-Related Extra Mortality Hypothesis. Technical report submitted to PATH. Incorporated into PATH Weight of Evidence Report Appendix (submission 3). June 10, 1988.

Hinrichsen, R.A. and C. Paulsen. 1998b. Weighting and sensitivity analysis difficulties with an unbalanced design. PATH memo submitted April 29, 1998.

Paulsen, C. and R. A. Hinrichsen. 1998. Hatchery Hypothesis: Variation in releases of Snake River hatchery spring/summer chinook is associated with variation in extra mortality of naturally produced Snake River spring/summer chinook. PATH memo. June 12, 1998.

PATH 1998. Path Weight of Evidence Report, August 11, 1998.

Adaptive Management Implications (See umbrella 9600600).

e. Proposal objectives

See umbrella proposal 9600600 for overarching objectives.

Objective 1 (9800100)*Refine existing models to evaluate the likelihood of persistence and recovery of salmon stocks under alternative management scenarios and alternative hypotheses.* (Sub-objective of objectives 1 and 2 in umbrella proposal 9600600.)

Goals. Refine life-cycle models to consider over-compensation and depensation more fully. Refine alpha life-cycle model so that it has better AIC and BIC fits. Accumulate evidence for and against influences of a climate regime shift on salmon and steelhead populations. Publish findings in PATH weight-of-evidence, decision analysis, and final reports.

Hypothesis. We will test the hypothesis that there is significant hyper-compensation (or depensation) in the salmon stocks. We will measure the significance by using a spawner-recruit curve that allows for depensation and hyper-compensation. The fit of the model will be determined by the AIC and BIC.

Hypothesis. The alpha life-cycle model will fit the spawner-recruit data better if it is allowed to have year-specific common year effects for the Snake River spawner-recruit data. We will test this hypothesis by comparing AIC and BIC of the current version of the model to the AIC and BIC of the alternative alpha model.

Hypothesis. We will test the hypothesis that there are significant relationships between climate indicators (such as the pacific decadal oscillation index) and salmon and steelhead production at the time scales known to be important in ocean processes. Needed to test these hypotheses are production data, which may include spawner-recruit data or catch data extending from the present to before 1947, and preferably, the 1925 climate regime shift.

Objective 2 (9800100). *Thoroughly test the refined models for important sensitivities, their qualitative behavior, and comparison with data unused in their calibration.* (Sub-objective of objectives 1 and 2 umbrella proposal 9600600.)

Goals. Provide model diagnostics showing sensitivity of life cycle models to exceptional data. Test retrospective and prospective models against data unused in the calibration process. Describe in detail the qualitative behaviors of the models used. Publish findings in PATH weight-of-evidence, decision analysis, and final FY2000 reports.

Hypothesis. We will test the hypothesis that substantive inferences of the life cycle models are influenced by exceptional data or multicollinearity. We will measure the sensitivity of model parameters to exceptional data using Cook's distance and condition indices (tests for multicollinearity). The models and decision analysis will be updated based on the findings.

Hypothesis. We will test the hypothesis that qualitative behavior of the modeled populations is inconsistent with the true spawner-recruit dynamics of salmon. This involves a qualitative test based on how the generated spawner-recruit data fit the past observations of spawner-recruit dynamics. We will also determine whether the Ricker spawner-recruit model dynamics lie within the single stable point, limit cycle, or chaotic regime.

Objective 3. *Use models to evaluate alternative adaptive management designs.* (Sub-objective of objective 3 umbrella proposal 9600600)

Goals. Determine the suitable duration and schedule of the experiments, and the responses necessary for statistical and biological significance. Determine what monitoring data need to be incorporated in the management experiments. Publish findings in PATH weight-of-evidence, decision analysis, and final FY2000 reports.

Hypothesis. We will test the hypothesis that the expected value of perfect information is worth proceeding with adaptive management experiments. This is a crucial step in the six-step adaptive policy design. Our preliminary work suggest that perfect information would be invaluable for management

decisions since the performance of management decisions relative to one another depends on scientific uncertainties.

f. Methods

The over-arching scope and approach of PATH are identified in proposal 9600600. The proposed data and methodology are outlined below.

Objective 1. Refine existing models to evaluate the likelihood of persistence and recovery of salmon stocks under alternative management scenarios and alternative hypotheses.

Task 1.a. Analyze the recently-discovered apparent effects of hyper-compensation in the spawner-recruit data. Determine whether these effects will influence the substantive inferences of our analysis. Current analysis of the spawner-recruit data has proceeded using a model that assumes that hyper-compensation (more compensation than expected at low spawner numbers) is not present in the data. However, our preliminary analyses show clearly that a model with hyper-compensation is preferred by the AIC and BIC model fit criteria. The stock-recruit relationship we will use in this analysis is a modified form of the Ricker model suggested by Rick Deriso ($R=S^p * \exp(a-bS)$). Where depensation exists when $p>1$, and hyper-compensation, when $p < 1$ ($p=0$ is the standard Ricker-model case). We will fit this model to the spring chinook and fall chinook data and determine what value of p is favored by minimizing the sum of the squared error between the modeled and actual recruits. We will determine if adding the extra parameter is justified in terms of AIC and BIC. If the model is favored, we will use it to project forward the salmon populations and see if it influences the substantive results (the ability of actions to meet the jeopardy standards set by NMFS).

Task 1.b. Refine the alpha life-cycle model (spring chinook) so that it provides a better fit to the data (AIC and BIC) using the alternative hypothesis that the lower river stocks serve as an adequate reference or "control" for Snake spring chinook stocks. The current version of the alpha life-cycle model for spring chinook salmon provides a relatively poor fit of the data, but has the compensating merit of few parameters. We will reformulate the alpha life-cycle model by allowing year effects to be estimated retrospectively. We will determine the strength of the relationship between the year effects and flow, then use the relationship for forward projections of the model. We will compare the AIC and BIC of the alternative model formulation. We will determine whether this alternative formulation affects the substantive inferences of the model (i.e., the probability that various actions meet the "survival" [actually persistence] and jeopardy standards.) We will also use the AIC and BIC to judge how well this form of the model fits the upper Columbia spring chinook spawner-recruit data.

Task 1.c. Provide rationale for climate effects on Upper Columbia salmon stocks. Test for a relationship between productivity (Recruits/Spawners) and climate indices (such as the Pacific Decadal Oscillation index). We will test for variation in productivities, ideally described by $\log(\text{Recruits/Spawners})$ for spawner-recruit data,

coincident with changes in ocean production regimes at various time scales: El Nino/Southern Oscillation (7 years), Bidecadal Oscillation (~20 years), and the Pacific Interdecadal Oscillation (~60 years). The data we use is the ENSO (El Nino/Southern Oscillation index and the Pacific Interdecadal Oscillation index (PDO)). We will use the methods of spectral analysis, time series analysis, and where appropriate intervention analysis. Where spawner-recruit data are not available, we will test catch data for variation at these various time scales and changes coincident with known changes in ocean/climate indices. We will test for significant changes in production corresponding to outmigration years 1977 (switch to warm/dry regime) and, if possible 1925 (shift to cold/wet regime). The length of the historical record will dictate the sample size.

Objective 2. Thoroughly test the refined models for important sensitivities, their qualitative behavior, and comparison with data unused in their calibration. This objective concerns the iterative process of model selection, which is defined below (Box et al. 1994): (i) Postulate general class of models. (ii) Identify model to be tentatively entertained. (iii) Estimate parameter in tentatively entertained model. (iv) Diagnostic checking (is the model adequate?) If not, go to (ii). (v) Use model prospectively in decision analysis. It can be difficult to decide whether the model is adequate, but there are many diagnostic tests available. In the tasks below, we identify diagnostics that have recently proven useful in PATH and entertain others that should be employed.

Task 2.a. Provide model diagnostics showing the sensitivity of model results to various subsets of data. This task is part of the iterative process of model building which must be implemented with each proposed model and is a part that has, until recently, been largely neglected in PATH (Hinrichsen 1998). Techniques for detecting exceptional observations (Cook's distance, for example), will be employed in the retrospective analyses (Cook and Weisberg 1982, Belsley et al. 1980; Belsley 1991). The quality of observations of high influence will be scrutinized carefully, and possibly down-weighted or removed if necessary.

Task 2.b. Test retrospective and prospective models against data unused in the calibration process. This task is part of the iterative process of model building, and falls within the realm of model validation. The techniques utilizing these types of data in validation are fairly well known. For a simple model test, we will withhold data in the calibration of the models, then simply run the models prospectively exactly as done with the full data set present and determine how well it predicts the data withheld. There is also opportunity to compare the life-cycle model estimates of survival through the hydrosystem to PIT-TAG data. This analysis will be explored by Paulsen (9303701).

Task 2.c. Describe the qualitative behaviors of the models used. Do their dynamic behaviors reflect those observed in the natural spawning populations? The Ricker model currently employed for the Snake River stock-recruit relationship results in *chaotic* population dynamics for pre-dam levels of productivity. This is the results of some rather high (pre-dam) Ricker-a parameters (> 3.0) estimated for the Snake index stocks and high upstream adult survival rates (See Murray [1989] which discusses how chaos occurs in discrete population models). Are chaotic dynamics of a salmon population reasonable? And if not, is it a defect that influences the substantive inferences of the life cycle models? We will test whether substantive inferences are effected by using dynamic population models that are stable at high productivity. Our decision-support analyses indicate that all management alternatives explored are extremely optimistic compared to current levels of spawner numbers. This occurs because the improvement in system-wide survival, which includes the survival of transported fish, is assumed to improve *dramatically* for each of the alternatives. For example, using the FLUSH passage model and using the BKD extra mortality hypothesis, actions A1, A2, and A3 are calculated to increase the productivity (Ricker-a) of the stocks (from the brood year 1975-1990 average) by an average of 0.34, 0.31, and 1.13, for actions A1, A2, and A3, respectively. We will implement a strategy that is status quo for comparison, the case where management strategies actually fail to improve system survival.

Objective 3. Use models to evaluate alternative adaptive management designs.

Task 3.a Participate in design of an adaptive management experiment. (See umbrella 9600600 for review of methodology). This is part of a difficult design problem that will need to go through an iterative PATH process, involving methodology outlined in Walters (1986) and Hilborn and Walters (1992). Given a set of feasible experiments, we can use the models, along with past spawner-recruit data to determine the level of response (in R/S) necessary to conclude that the experiment was a success. This necessarily involves the modeling process in which natural environmental variation is modeled directly. Otherwise, we will be less able to determine whether a "response" is due to the experiment, or due to background variation in the environment. The designing of a management experiment Walters (1986) is six-step process: (1) Identification of alternative stock response hypotheses. (2) Assessment of whether further steps are necessary by estimating the expected value of perfect information. (3) Development of models for future learning about hypotheses. (4) Identification of adaptive policy options. (5) Development of performance criteria for comparing actions. (6) Formal comparison of options using tools of statistical decision analysis. Some of these steps have been undertaken in the previous decision-analysis and weight-of-evidence exercises of PATH, but other difficult design issues have yet to be addressed. (See umbrella proposal 9600600 "design" under f. methods)

Task 3.b. Determine what data of opportunity exist to measure experimental outcomes (monitoring data). Once the management experiment was underway, we would continue to monitor the spawner-recruit data to determine the response of the test. The auxiliary data we collect will be a function of the experimental policy implemented. For example, PIT-TAG data would be useful only as long as fish collectors were still in operation at the

dams. Policies that turn off fish collection will necessarily rule out PIT-TAG data. Spawner-recruit data will be available regardless of experimental policy.

Task 3.c. Describe the possible confounding effects of ocean-climate regimes in design of management experiments. Develop a design to deal with this difficulty. A major difficulty in using planned experiments in our case (where we have spatial replication and "control" or reference populations), is time-treatment interaction. If, for example the management policy seems to work at first for the upriver (treatment stocks), then declines without a corresponding decline in the lower river stocks ("control" stocks), we have a difficulty in interpreting the results. One might argue that the experiment was not a failure, and that the reason the lower river stocks did not decline was that they were less sensitive to temporary environmental change (i.e., they were not really an adequate control group). Scientific designs to handle this case is a staircase design. The two designs outlined by the scientific review panel (SRP) were (PATH Scientific Review Panel, 1998):

- (1) Incremental alternative: implement the cheapest action first and monitor effects, then progressively more costly ones.
- (2) "Reverse staircase" alternative: Implement all actions at once, then turn dams, hatcheries of transportation back on one at a time.

In the case of a climate regime shift occurring during the experiment (we can detect a regime shift a few years after it has occurred), it will not be a concern *as long as the lower river stocks (the control stocks), have the same response to the climate regime shift as the upriver stocks.* Otherwise, the shift could easily be attributed to the management alternative (hatchery interaction reduction for Snake stocks, for example). Thus it will be important to design the experiment in such a way that it does not rely on the lower stocks as a control (this is an assumption that needs testing). This is a specific case of the time-treatment interaction which needs to be addressed through an appropriate design. We will explore the use of staircase designs to address this difficulty.

g. Facilities and equipment

The facility for conducting the research will be the offices of Hinrichsen Environmental Services, Seattle, Washington. Hinrichsen has acquired the necessary Internet access, statistical software, and word processing software to complete the work and communicate with other researchers on related projects. No special equipment purchases will be necessary to complete the work.

h. Budget

Total Budget: 125,000. This represents ~\$5,000 increase over the FY 1999 budget. The work on PATH has required a great investment in time, including increased work load,

planning and conducting analyses, model development, computer programming, and reviewing and contributing to PATH documents. Greater work loads predicted for FY2000 when design of adaptive management experiments is expected. For personnel, the cost is \$123,040 for FY2000. The rate of \$80/hour is a reasonable consulting rate, and the estimated number of hours, 1,538 (~84% of full-time), is expected based on past work loads in PATH. The travel budget of \$1960.00 expenses have amounted to 6 trips per year at a cost of about \$300+ each. Giving a total travel expense of about \$1,800+.

Section 9. Key personnel

Richard A. Hinrichsen, Principal Investigator, 1,538 hours (~84% FTE)

Duties on project

Hinrichsen will plan and implement the model development and evaluation, and develop alternative hypotheses for decision analysis.

Resume

Education. Doctor of Philosophy (Ph.D.), Quantitative Ecology & Resource Management, University of Washington, Seattle, Washington, December 1994; Master of Science (M.S.), Mathematical Sciences, Clemson University, Clemson, South Carolina, June 1987; Bachelor of Science (B.S.), Mathematics, Central Washington University, Ellensburg, Washington, June 1985.

Current Employer: Self-employed

Current Responsibilities: Resource modeling, development of alternative hypotheses, model development and testing, development of management experiments.

Recent Previous Employment: University of Washington, Research Consultant, January 1995-October 1997.

Expertise: Hinrichsen has evaluated and designed models of salmon survival for the past 9 years, beginning with the evaluation of FISHPASS in 1988 and the development of a passage model used for the Biological Opinion and Biological Assessment published annually by the Bonneville Power Administration (BPA) and the National Marine Fisheries Service (NMFS) in the early '90s. His expertise in the area of statistics has been particularly useful in the development and testing of models used in decision support. He has also published papers in the area of climate variability in the eastern Pacific. He

excels in written communication and is editor-in-chief of the international Shad Journal.

Recent and Relevant publications.

Hinrichsen, R. A. 1998. Influence of Exceptional Spawner-Recruit data of the John Day Middle Fork on the Delta Model Parameters. PATH document. See http://www.cqs.washington.edu/~hinrich/PATH/INFLUENCE/abst_inf.html.

PATH. 1998. Preliminary Decision Analysis Report on Spring/Summer Chinook. Edited by David Marmorek, and Calvin Peters, ESSA technologies.

Hinrichsen, R.A., J.J. Anderson, G.M. Matthews and C.C. Ebbesmeyer. 1998. Assessment of the effects of the ocean and river environment on the survival of Snake River stream-type chinook salmon. Bonneville Power Administration Report. (In Review) Portland, Oregon. USA.

Ingraham, W.J., C.C. Ebbesmeyer, and R.A. Hinrichsen. 1998. Sea surface drift and tree rings signal imminent decadal shift of northeastern Pacific subarctic water movement. EOS. Volume 79, No. 6, page 197.

Anderson, J.J. and R.A. Hinrichsen. 1997. A suite of alternative hypotheses using a passage model in a Bayesian approach. Path Memo. June 1997.

Section 10. Information/technology transfer

(Replace this text with your response in paragraph form)

Congratulations!