

# EPIDEMIOLOGICAL SURVIVAL METHOD

8910700

## SHORT DESCRIPTION:

Improve monitoring and evaluation capabilities by developing better measurement tools to estimate juvenile and adult survival. Develop statistical methods for PIT-tag release studies to determine survival rates and behavior of outmigrating smolts. Analyze tagging studies to determine survival relationships useful in improving mitigation.

## SPONSOR/CONTRACTOR: UW

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## SUB-CONTRACTORS:

N/A. No subcontractors on this project.

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## GOALS

### GENERAL:

Supports a healthy Columbia basin, Adaptive management (research or M&E)

### ANADROMOUS FISH:

Research, M&E

### NPPC PROGRAM MEASURE:

5.0F.5

### RELATION TO MEASURE:

Project develops the smolt survival estimates used to evaluate relationships between ambient conditions and survival. The Columbia River Basin Fish and Wildlife Program states that the relationship between spring and summer flow, velocity, and fish survival should receive highest priority in the region's research efforts.

### BIOLOGICAL OPINION ID:

NMFS Hydrosystem Operations Biological Opinion RPA 13f

### OTHER PLANNING DOCUMENTS:

Snake River Recovery Plan: 2.1.d.5

### TARGET STOCK

Snake River Basin Steelhead

Snake River Basin Chinook

### LIFE STAGE

Smolt and Adult

Smolt and Adult

### MGMT CODE (see below)

P

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## BACKGROUND

**Project is an office site only**

### HISTORY:

Project 8910700 was initiated in 1989 to develop the statistical theory and methods needed to analyze smolt and adult PIT-tag survival studies. The project developed the initial study designs for the National Marine Fisheries Service (NMFS/University of Washington (UW) Snake river survival studies of 1993-present (e.g. NMFS Project 9302900) . These ongoing efforts have produced statistical software (i.e., SURPH) for UNIX- and PC-based computers which are accessible to the Columbia Basin community via internet and the World Wide Web (WWW). Additional products include a comprehensive users manual for SURPH and software for sample size calculations.

As the Snake River survival studies have evolved, the numerical needs for new and more descriptive data analyses have also increased. This project continues to maintain existing analysis capabilities as well as add new data analysis features at program users' (e.g., NMFS) request. As the new 134.2 kHz frequency PIT tag decoder systems come on-line, the survival studies will be

extended to the joint analysis of survival of both downriver smolts and returning adults. The project has already developed some of the key statistical software to analyze this data. This projects stands ready to address new issues and questions the fisheries community wants to ask from PIT tagging investigations.

Specific accomplishments by year include:

1989: Developed theory to assess survival effects that result from ambient river conditions.

1990: Began software development for statistical analyses, and began statistical theory to assess individual covariate effects on survival.

1991: Demonstrated ability to simultaneously assess ambient effects and individual covariate effects.

1992: Extended computer software to include analysis of group and individual covariate effects. Proposed "strawman" design for development of PIT-tag facilities on Snake/Columbia River. Developed study plan for a Snake River survival study evaluation.

1993: Completed statistical software development of analysis package--final debugging of computer program, helped facilitate Snake River survival study, and conducted analysis of hatchery survival studies.

1994: Completed SURPH statistical software and dissemination of a users manual for statistical analysis of data.

1995: Produced a PC version of SURPH software and sample size program to design tag-release studies.

1996: Produced report on comparison of procedures for estimating confidence intervals and report demonstrating applications of SURPH.1 in release-recapture survival studies. Developed proper statistical model to estimate survival rates of fall chinook smolt taking into account residualization. Developed statistical methods for estimating season-wide survival.

1997: Improve statistical models and software for expanded survival experiments. Continue to support Columbia River survival studies. Investigate alternative approaches to estimate ocean survival rates. Develop software that appropriately incorporates migratory behavior traits of fall chinook in survival estimations. Continue research on repeated measures of smolt traits and survival; develop model for time-varying (updated) covariates; extract effects of smolt condition on in-river survival.

#### **BIOLOGICAL RESULTS ACHIEVED:**

This project spearheaded the survival studies currently being conducted on the Snake/Columbia Rivers (1993-1995+). Monte Carlo investigations identified sensitivities of PIT-tag studies to violations of some assumptions and robustness to other assumptions paving the way for field trials. In conjunction with the National Marine Fisheries Service (NMFS), this study has helped to generate new biological understandings of the dynamics of smolt outmigration. These findings include:

1. Information on smolt travel time - survival relationships.
2. Information on river flow/temperature - survival relationships.
3. Comparisons of hatchery and wild chinook and steelhead smolt survival.
4. Comparison of smolt survival across 3 years and 2-4 river reaches.
5. Survival rates of upper Snake River hatchery releases.
6. Baseline survival data for comparison with potential mitigation practices in years to come.

These data have already influenced the choices of mitigation practices that might be attempted in the near future. Other aspects of the project are investigating the estimation of season-wide survival rates for the entire outmigration season.

#### **PROJECT REPORTS AND PAPERS:**

BPA Contract Reports:

DOE/BP-02341-1: Skalski, J. R., A. Hoffman, and S. G. Smith. 1993. Development of Survival Relationships Using Concomitant Variables Measured from Individual Smolt Implanted with PIT-tags. 1990-1992 Annual Report prepared for Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-2: Smith, S. G. and J. R. Skalski. 1994. SURPH.1 Manual: Statistical Survival Analysis of Fish and Wildlife Tagging Studies. Computer Software Manual prepared for Bonneville Power Administration, Portland, Oregon.

DOE/BP-02341-3: Center for Quantitative Science, School of Fisheries, University of Washington. 1996. Introduction to SURPH.1 Analysis of Release-Recapture Data for Survival Studies. Technical Report prepared for Bonneville Power Administration, Portland, Oregon.

Theses:

Smith, S. G. 1991. Assessing hazards in wild populations using auxiliary variables in tag-release models. Ph.D. dissertation. Univ. of Washington. Seattle, WA.

Hoffmann, A. 1993. Quantifying selection in wild populations using known-fate and mark-recapture designs. Ph.D. dissertation. Univ. of Washington. Seattle, WA.

Other Scientific Reports Produced for Publication:

Lowther, A. B. and J. R. Skalski. 1996. Monte-carlo comparison of confidence interval procedures for estimating survival in a release-recapture study, with applications to Snake River salmonids. Technical Report prepared for Bonneville Power Administration, Portland, Oregon (manuscript sent out for regional peer review).

Hoffmann, A., and J. R. Skalski. 1995. Inferential properties of an individual-based survival model using release-recapture data: Sample size, validity and power. *J. Appl. Stat.* 22:579-595.

Smith, S. G., and J. R. Skalski. 1995. Assessment of statistical significance of group covariate effects on survival using analysis of deviance of release-recapture data. *J. Appl. Ecol.* (Accepted).

Skalski, J. R. 1991. Initial "strawman" design for a 1992 Snake River survival study. Bonneville Power Administration, Portland, OR.

Skalski, J. R., and S. G. Smith. 1994. Risk assessment in avian toxicology using experimental and epidemiological approaches. In *Wildlife toxicology and population modelling: Integrated studies of agroecosystems*, pp.467 - 488. Lewis Publishers. Boca Raton, FL

Skalski, J. R., A. Hoffmann, and S. G. Smith. 1993. Testing the significance of individual-and cohort-level covariates in animal survival studies. EURING 92. In *Marked Individuals in the study of bird populations*, pp.9 - 28. S.D. Lebreton and P.M. North (Eds.). Birkhauser Verlag. Boston, MA.

Skalski, J. R. 1996. Estimating season-wide survival rates of outmigrating salmon smolt in the Snake River, Washington. *Can. J. Fish Aquat. Sci.* (submitted).

Skalski, J. R., S. G. Smith, R. N. Iwamoto, J. G. Williams, and A. Hoffmann. 1996. Use of PIT-tags to Estimate Survival of Migrant Juvenile Salmonids in the Snake and Columbia Rivers. *Can. J. Fish. Aquat. Sci.* (submitted).

Skalski, J.R. 1996. Regression of abundance estimates from mark-recapture surveys against environmental covariates. *Can. J. Fish. Aquat. Sci.* 53:196-204.

Other Related Joint Contributions:

Skalski, J.R., P.R. Mundy and W.E. McConnaha. 1989. Suggested work plan for flow/water budget smolt survival evaluation. Submitted to the ad hoc committee on Mainstem Passage Research, Northwest Power Planning Council, June 1, 1989.

Dauble, D.D., J. Skalski, A. Hoffman, and A.E. Giorgi. 1993. Evaluation and application of statistical methods for estimating smolt survival. Pacific Northwest Laboratory, University of Washington and Don Chapman Consultants, Inc. Technical Report (DOE/BP-62611-1) to Bonneville Power Administration.

**ADAPTIVE MANAGEMENT IMPLICATIONS:**

Both the Northwest Power Planning Council's Fish and Wildlife Program and the National Marine Fisheries Service (NMFS) 1995 Hydrosystem Operations Biological Opinion call for implementation of reliable monitoring and evaluation of mitigation actions within the Columbia River Basin in support of an adopted adaptive management framework. With respect to evaluating actions associated with hydropower operations, three performance measures have been repeatedly identified as being instructive; smolt mitigation speed, smolt survival through the hydroelectric complex, and subsequent survival to adulthood. Activities of

this project strive to address these performance measures in an adaptive management framework by:

1. Assessing the accuracy and precision of such performance measures.
2. Identifying any deficiencies in estimation procedures.
3. Identification and/or development of analytical approaches to improve the statistical integrity of such estimates.
4. Examining the relationships between these performance measures and a variety of predictor variables that can affect salmon survival, particularly as associated with conditions encountered during their seaward migration.

This project promotes adaptive management by providing the statistical underpinnings to ongoing smolt survival studies being conducted by NMFS on the Snake/Columbia Rivers. Data generated by these studies are being used to monitor outmigration success, provide baseline information to evaluate future mitigation measures, update Columbia River models (i.e., CRiSP) and investigate river management decisions such as flow augmentation and spill programs.

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## **PURPOSE AND METHODS**

### **SPECIFIC MEASUREABLE OBJECTIVES:**

1997 Improve statistical models and software for expanded survival experiments. Continue to support Columbia River survival studies. Investigate alternative approaches to estimate ocean survival rates. Develop software that appropriately incorporates migratory behavior traits of fall chinook in survival estimations. Continue research on repeated measures of smolt traits and survival; develop model for time-varying (updated) covariates; extract effects of smolt condition on in-river survival.

1998 Continue to support Columbia River survival studies. Develop, maintain and provide software to routinely test assumptions of survival studies. Respond to major user group needs for improved analysis of survival studies. Complete research on repeated measures of smolt traits and survival.

### **CRITICAL UNCERTAINTIES:**

There will always be some uncertainties inherent to survival estimation. Project strives to develop, incorporate and apply the best statistical models and methodologies into the design, implementation and analyses of Columbia River Basin survival experiments.

### **BIOLOGICAL NEED:**

Hatchery managers and fisheries managers need to know how alternative rearing practices, water management practices, and mitigation activities affect smolt outmigration success. This project has helped develop survival studies that provide accurate and precise estimates of survival unaffected by uncertainties in FGE, spill and collection efficiency that here to now have confounded other attempts at quantifying smolt survival.

### **HYPOTHESIS TO BE TESTED:**

Ho1: The statistical theory and software developed by this effort will not improve the region's ability to test survival relationships and research hypotheses to address critical uncertainties in the Columbia River Fish and Wildlife Program. If rejected, alternate hypothesis is statistical theory and software developed by this effort will improve the region's ability to test survival relationships and research hypotheses to address critical uncertainties in the Columbia River Fish and Wildlife Program.

### **ALTERNATIVE APPROACHES:**

The models and statistical methodologies employed in the current NMFS/UW survival studies were determined appropriate by an independent scientific peer review conducted under the auspices of the Northwest Power Planning Council in 1995. No other rigorous approaches have been formerly recommended for implementation or made available for consideration.

### **JUSTIFICATION FOR PLANNING:**

This project focuses on improving the monitoring and evaluation capabilities of the Columbia River Fish and Wildlife Program. Understanding of factors affecting smolt survival has been crucial to deciding mitigative actions regarding drawdown, gas bubble abatement, bypass and surface collector development, and transportation.

### **METHODS:**

Estimation of smolt and adult survival rates based on maximum likelihood methods, generalized linear models, and analysis of deviance. Confidence interval estimation of survival parameters based on multiple procedures including normal theory, nonparametric bootstrap methods, and profile likelihood techniques.

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## PLANNED ACTIVITIES

### SCHEDULE:

**Planning Phase**            **Start** 1989                            **End** Indefinitely                            **Subcontractor** No

**Task** Analyze Columbia River Basin tagging studies to determine survival relationships useful in improving mitigation.

**Planning Phase**            **Start** 1989                            **End** Indefinitely                            **Subcontractor** No

**Task** Develop statistical methods for PIT-tag release studies to determine survival rates and behavior of outmigrating smolts in the Columbia River Basin: In 1997 improve statistical models and software for expanded survival studies.

**Implementation Phase**   **Start** 1989                            **End** Indefinitely                            **Subcontractor** No

**Task** In 1998 Provide software to routinely test assumptions of survival studies. Develop guidance to design seasonwide survival studies and experiments. Analyze Columbia River Basin tagging studies to determine survival relationships useful in improving mitigation: In 1997 Conduct research on repeated measures of smolt traits and survival; develop model for time-varying (updated) covariates; extract effects of smolt condition on in-river survival. In 1998 continue research on repeated measures of smolt traits.

**Implementation Phase**   **Start** 1989                            **End** Indefinitely                            **Subcontractor** No

**Task** Further development of SURPH software for fall chinook smolt survival studies. In 1998 Provide software to routinely test assumptions of survival studies. Develop guidance to design seasonwide survival studies and experiments.

**Implementation Phase**   **Start** 1989                            **End** Indefinitely                            **Subcontractor** No

**Task** Improve Columbia River Basin monitoring and evaluation capabilities by developing better measurement tools to estimate juvenile and adult survival: In 1997 continue to support Columbia River survival studies. Investigate alternative approaches to estimate ocean survival rates.

In 1998 respond to major user group needs for improve analysis of survival studies.

**O&M Phase**                **Start** 1993                            **End** Indefinitely                            **Subcontractor** No

**Task** Maintenance of SURPH Software

### PROJECT COMPLETION DATE:

N/A

### CONSTRAINTS OR FACTORS THAT MAY CAUSE SCHEDULE OR BUDGET CHANGES:

Changes in the marking programs could impact survival research and the scheduled analyses of these tagging studies to determine survival relationships.

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## OUTCOMES, MONITORING AND EVALUATION

### SUMMARY OF EXPECTED OUTCOMES

#### Expected performance of target population or quality change in land area affected:

Publicly accessible and user-friendly statistical software has been developed and is being used to analyze Columbia-Snake River survival studies since 1993. Ongoing efforts are expanding capabilities of extracting information on survival relationships and providing robust point and interval estimates. Software provides powerful computing environment to assess smolt survival relationships.

#### Present utilization and conservation potential of target population or area:

ESA-listed and non-listed stocks presently utilize the entire migration corridor during outmigration.

#### Assumed historic status of utilization and conservation potential:

N/A

**Long term expected utilization and conservation potential for target population or habitat:**

The recovery of ESA-listed and non-listed stocks.

**Contribution toward long-term goal:**

Improved methodologies and analytical capabilities to conduct research on survival process of wild and hatchery chinook and steelhead during outmigration through the FCRPS. Eventually improved analysis capability to evaluate survival rates of returning PIT tagged adult salmon and steelhead. Resulting improved monitoring and evaluation capabilities will assist in-season river management in optimizing operational and fish passage strategies to maximize survival through the FCRPS.

**Indirect biological or environmental changes:**

Findings from analyses of survival studies could influence mitigation activities to recover stocks.

**Physical products:**

This project has produced the statistical theory, software, and analysis package which provides the scientific basis for the ongoing Snake/Columbia River survival studies conducted by NMFS-CZES since migration year 1993.

**Environmental attributes affected by the project:**

Survival information collected through application of the methodologies and analytical products developed through this project could result in changes in the operations of the FCRPS e.g. timing, duration and pattern of flow augmentation and other operations of the FCRPS.

**Changes assumed or expected for affected environmental attributes:**

Changes in ambient river conditions e.g. flow, water velocity, water temperature.

**Measure of attribute changes:**

N/A

**Assessment of effects on project outcomes of critical uncertainty:**

This project has performed self-evaluations and solicited independent peer review of the statistical models, methodologies, underlying assumptions and results of the survival studies.

**Information products:**

Project provides capabilities to estimate smolt survival of spring and fall chinook and steelhead along with assessing survival relationships. Project has been successfully accomplishing this mission since 1993.

**Coordination outcomes:**

The transfer and coordination of information and products produced by this project has occurred throughout the history of the project. The transfer of information and products by year include:

1989: Developed theory to assess survival effects that result from ambient river conditions.

1990: Began software development for statistical analyses, and began statistical theory to assess individual-covariate effects on survival.

1991: Demonstrated ability to simultaneously assess ambient effects and individual-covariate effects on survival.

1992: Extended computer software to include analysis of group and individual-covariate effects, proposed "strawman" design for development of PIT-tag facilities on Snake-Columbia River, and developed study plan for a Snake River survival study evaluation.

1993: Completed statistical software development of analysis package - final debugging of computer program, helped facilitate Snake River survival study, and conducted analysis of hatchery survival studies.

1994: Completed SURPH statistical software, dissemination of a user's manual for statistical analysis of data.

1995: Produced a PC version of SURPH software and sample size program to design tag-release studies.

1996: Developed alternate confidence interval estimators for survival, new model for fall chinook smolt, and statistical methods for estimating season-wide survival.

## MONITORING APPROACH

The ultimate outcome, increased passage survival through the FCRPS, depends upon the effectiveness of these survival measurement tools to monitor outmigration success, investigate river management decisions and to provide baseline information to evaluate future mitigation options. The ultimate evaluation of these products will come from annual post-season evaluations performed by the contractor, direct users of the products e.g. NMFS, independent scientific peer reviews, and possibly from other regional entities involved in survival studies, including the Fish Passage Center.

### Provisions to monitor population status or habitat quality:

This contract develops and supports analytical tools that provide the ability to estimate survival for PIT tagged releases of listed and non-listed salmon and steelhead stocks as they migrate through the FCRPS.

### Data analysis and evaluation:

Estimation of smolt and adult survival rates based on maximum likelihood methods, generalized linear models, and analysis of deviance. Confidence interval estimation of survival parameters based on multiple procedures including normal theory, nonparametric bootstrap methods, and profile likelihood techniques.

### Information feed back to management decisions:

By technical reports, scientific publications, and public presentations.

### Critical uncertainties affecting project's outcomes:

N/A

## EVALUATION

The theory to use PIT-tags to estimate smolt survival has been translated into action by NMFS since 1993 and more recently in proposals by the Columbia Basin Fish and Wildlife Authority (CBFWA).

### Incorporating new information regarding uncertainties:

Scientific peer review both formally and informally.

### Increasing public awareness of F&W activities:

The smolt survival studies have high visibility. Presentations and publications are increasing public awareness.

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## RELATIONSHIPS

### RELATED BPA PROJECT

9008000 Columbia Basin PIT-Tag Information System [PSMFC]

9102900 Identification of the Spawning, Rearing, and Migratory Requirements of Fall Chinook Salmon in the Columbia River Basin [USFWS]

### RELATIONSHIP

The high quality PIT tag data provided through Project 9008000 is critical to the successful implementation of this effort. This project produces data queries tailored to PTAGIS to extract PIT-tag information to analyze survival data in various formats covering the multiple river reaches, years of release, and origins of tag releases. These data queries are necessary prerequisites to using PIT-tag data in survival estimation.

Project 9102900 utilizes the statistical models and computer software (e.g. SURPH) for survival estimation developed, enhanced and maintained by this project.

9302900 Survival Estimates for the Passage of Juvenile Salmon and Steelhead Through Snake River Dams and Reservoirs [NMFS/CZES]

This BPA project provides direct technical and analysis support of the NMFS field studies of project 9302900. Specifically, this project responds to NMFS requests to enhance survival estimation capabilities incorporated in program SURPH (Survival Under Proportional Hazards). This project also responds to community requests to NMFS to investigate alternative ways of analyzing and interpreting the tagging data.

**RELATED NON-BPA PROJECT**

U.S. Army Corps of Engineers AFEP Research Program (FY97 implementation anticipated)

**RELATIONSHIP**

This Corps project will analyze capture probability information collected in 1993-95 to extract fish guidance efficiency (FGE) and spill efficiency relationships.

**OPPORTUNITIES FOR COOPERATION:**

The project has been cooperating with other fisheries agencies, council, and other forums to investigate smolt survival processes, including:

1. National Marine Fisheries Service.
2. Various state hatchery managers.
3. Council/NMFS ISG/ISAB Expert Panels.
4. PATH groups.

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**COSTS AND FTE**

**1997 Planned:** \$150,888

**FUTURE FUNDING NEEDS:**

<u>FY</u>	<u>\$ NEED</u>	<u>% PLAN</u>	<u>% IMPLEMENT</u>	<u>% O AND M</u>
1998	\$180,000	5%	80%	15%
1999	\$200,000	5%	80%	15%
2000	\$200,000	5%	80%	15%
2001	\$200,000	5%	80%	15%
2002	\$0			

**PAST OBLIGATIONS (incl. 1997 if done):**

<u>FY</u>	<u>OBLIGATED</u>
1989	\$99,999
1991	\$127,871
1992	\$130,656
1993	\$197,060
1994	\$168,011
1995	\$164,725
1996	\$169,952
1997	\$150,888

TOTAL: \$1,209,162

Note: Data are past obligations, or amounts committed by year, not amounts billed. Does not include data for related projects.

**OTHER NON-FINANCIAL SUPPORTERS:**

Technical collaboration with NMFS and Army Corps of Engineers. PIT tag data provided by PTAGIS.

**LONGER TERM COSTS:**

Project is anticipated to continue in some form beyond 2002 as part of a fixed-base monitoring and evaluation program. The level of costs is likely to be dependent on the continuing need of analytical support to Columbia River Basin system survival studies and decision and analysis tools for program evaluation. The estimated annual cost is \$200,000.

Most of the costs would be for continued implementation. Planning costs would be minimal and costs for operation and maintenance would be dependent on the need to maintain developed software tools and analysis systems.

**1997 OVERHEAD PERCENT:** 27.3%

**HOW DOES PERCENTAGE APPLY TO DIRECT COSTS:**

On all direct costs except the following; equipment over \$2K, lease, and graduate student operating fees.

**SUBCONTRACTOR FTE:** 0 FTE

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