PART I - ADMINISTRATIVE

Section 1. General administrative information

Title of project

Monitor And Evaluate Modeling Support

BPA project number: 8910800
Contract renewal date (mm/yyyy): 10/1999 ☐ **Multiple actions?**

Business name of agency, institution or organization requesting funding
University of Washington

Business acronym (if appropriate) UW

Proposal contact person or principal investigator:

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NPPC Program Measure Number(s) which this project addresses
3.2F.1, 3.3A.1, 4.3B, 4.3C, 5.2A7

FWS/NMFS Biological Opinion Number(s) which this project addresses
Program support & NMFS BO RPA A1; A13; A16; A17

Other planning document references
NMFS Proposed Recovery Plan Tasks 0.3.b; 2.1.d; 2.2.d; 2.11.b

Short description

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

Target species
Chinook and steelhead

Section 2. Sorting and evaluation

Subbasin

Evaluation Process Sort

CBFWA caucus	Special evaluation process	ISRP project type
Mark one or more	If your project fits either of these	Mark one or more categories

caucus	processes, mark one or both	
☒ 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
20537	Bonneville Power Administration Non-Discretionary Projects
8910800	Monitor and Evaluate Modeling Support

Other dependent or critically-related projects

Project #	Project title/description	Nature of relationship
9601700	Provide Technical Support in PATH - BioAnalysts Inc. (Giorgi)	CRiSP model output utilized by these groups in their analyses.
9600600	PATH Facilitation, Technical Assistance & Peer Review	CRiSP model output utilized by these groups in their analyses.
9600800	PATH-Participation by State & Tribal Agencies	CRiSP model output utilized by these groups in their analyses.
9800100	Analytical Support-PATH and ESA Biological Assessments - Hinrichsen	CRiSP model output utilized by these groups in their analyses.
9303701	Technical Assistance with Life Cycle Modeling - Paulsen Environmental	CRiSP model output utilized by these groups in their analyses.
9007800	Evaluate Predator Control and Provide Technical Support for PATH	Provides input for model development.
9601900	Second Tier data base for ecosystem focus	Data from this source are used for model calibration.
9700200	UW PATH support	Our specific tasks involve mainstem passage issues, effects of the ocean and estuary on survival, and harvest issues.
8910700	Statistical Support for Salmonid Studies	Information from this project is used to calibrate and validate the CRiSP models.
9105100	Monitoring & Evaluation Statistical Report (Dr. Skalski)	Cooperate with this group to produce CRiSP/Real-time outputs.

Section 4. Objectives, tasks and schedules

Past accomplishments

Year	Accomplishment	Met biological objectives?
1995	The Mainstem passage and Adult Harvest models, CRiSP.1 and CRiSP.2 were completed and calibrated.	

	Theory and calibration manuals were prepared. Participated in in-season database development. Began analyzing the impact of ocean conditions on smolt survival.	
1996	Revised and recalibrated CRiSP.1 and CRiSP.2. Successfully ported CRiSP.2 from Unix platform to Windows 95, making it more accessible to the public.	
	Revised manuals for both models. Expanded our in-season database that gave regional fisheries community real-time access to river and fish passage conditions through the World Wide Web.	
	Provided real-time projections of fish passage for various stocks at sites in the Snake and Columbia Rivers. Published daily predictions on the World Wide Web. Continued the impact of ocean analysis.	
1997	Improved DART web database. Completed manual update for CRiSP.2 through the on-line help. Released CRiSP.2 NT/Windows 95 and an alpha version of CRiSP.1 for NT/Windows 95.	
	Continued a combined effort between CRiSP and RealTime (developed under Dr. John Skalski) to provide real-time projections of fish passage for various stocks.	
	Implemented gas predictions for in-season management of the impacts of the hydrosystem on gas levels in the river on our web site.	
1998	Developed CRiSP1.6 to include gas mortality algorithm. Updated the survival calibration tool for the new version (1.6).	
	Updated in-season and post-season analyses.	
	Maintained and monitored Columbia Basin Research (CBR) web pages and answered requested information from the public as they are received.	

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Upgrade and link passage and harvest models	a	Update the juvenile passage model.
		b	Calibrate the adult upstream model.
		c	Update the CRiSP Harvest model.
		d	Develop JAVA-based control for model linkages.
2	IBM Tributary model	a	Convene a working group of modelers and biologists.
		b	Use the model to identify critical factors.
		c	Use the CIFSS model to examine the mechanisms and functional forms of the impacts of stream fertilization and spawner

			density on salmon productivity.
3	Process models	a	Vitality model.
		b	Growth model.
		c	Stream productivity.
4	CRiSP Realtime	a	Incorporate the adult passage model predictions into in-season predictions.
		b	Incorporate hatchery smolts into in-season predictions.
		c	Develop algorithms for passage stress.
		d	Maintain in-season prediction system.
		e	Prepare post-season analysis of system.
5	Modeling information exchange	a	Develop information exchange on web page.
		b	Solicit modeling groups for information in designing the web pages.
		c	Facilitate groups in developing and loading information.
		d	Hold work group meetings.

Objective schedules and costs

Obj #	Start date mm/yyyy	End date mm/yyyy	Measureable biological objective(s)	Milestone	FY2000 Cost %
1	10/2000	9/2001			30.00%
2	10/2000	9/2001			10.00%
3	10/2000	9/2001			15.00%
4	10/2000	9/2001			40.00%
5	10/2000	9/2001			5.00%
				Total	100.00%

Schedule constraints
Uncertainties of schedules from coordinated groups may cause schedule changes.

Completion date
2004

Section 5. Budget

FY99 project budget (BPA obligated):

FY2000 budget by line item

Item	Note	% of total	FY2000
Personnel	Direct Salary	%51	209,305
Fringe benefits	Standard UW benefit rates	%11	47,130
Supplies, materials, non-expendable property		%3	10,486
Operations & maintenance		%5	18,874
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	Office Lease & minor equip. upgrade	%6	25,751

NEPA costs		%0	
Construction-related support		%0	
PIT tags	# of tags:	%0	
Travel		%1	3,900
Indirect costs	26% of Modified Total Direct Costs	%19	79,221
Subcontractor	Lang, Railsback & Associates	%4	15,000
Other	Tuition fees	%0	1,633
		TOTAL BPA FY2000 BUDGET REQUEST	$411,300

Cost sharing

Organization	**Item or service provided**	**% total project cost (incl. BPA)**	**Amount ($)**
		%0	
		%0	
		%0	
		%0	
		Total project cost (including BPA portion)	$411,300

Outyear costs

	FY2001	**FY02**	**FY03**	**FY04**
Total budget	$411,300	$411,300	$411,300	$411,300

Section 6. References

Watershed?	**Reference**
☐	
☐	Zabel, R.W., J.J. Anderson, and P.A. Shaw. 1998. A multiple reach model describing the migratory behavior of Snake River yearling chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences: 55:658-667.
☐	Zabel, R. and J.J. Anderson. 1997. A model of the travel time of migrating juvenile salmon, with an application to Snake River spring chinook salmon. North American Journal of Fisheries Management, 17:93-100.
☐	Anderson, J.J. (in press) Decadal climate cycles and declining Columbia River salmon. In Proceedings of the Sustainable Fisheries Conference, Victoria, B.C," ed. E. Knudsen. American Fisheries Society Special publication no. 2x. Bethesda, MD
☐	Anderson, J.J. A vitality based model relating stressors and environmental properties to organism survival . Accepted by Ecological Monographs, 1998.
☐	Anderson, J.J. 1996. Review of the influence of climate on salmon. In 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.
☐	Anderson, J.J. , J. Hayes, P. Shaw and R. Zabel. 1996, Columbia River Salmon Passage Model CRiSP1.5: theory, Calibration and Validation. School of Fisheries University of Washington. 220 pages.
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PART II - NARRATIVE

Section 7. Abstract

This proposal addresses the need to evaluate fish and wildlife rebuilding strategies with computer/analytical models shared and developed regionally (FWP Section 3.2F). In Objective 1, we will work with regional entities to adapt existing life stage models/analyses into a multi-species ecosystem framework. In Objective 2, we will model in-season hydrosystem operations impacts on fish passage.

These tools help the FWP in making decisions that optimize fish recovery under uncertainty. The Objectives address retrospective, prospective, and in-season analyses of actions.

Objectives 1, 2, 3 use existing models of fish migration, ocean survival, harvest and spawning developed regionally from simple spawner-recruit population and passage models to complex individual based models of small-scale interactions of fish with the environment. Model development involves mathematical formulation, calibration, sensitivity analyses, and validation where possible.

Objective 4 applies a real-time web-based tracking system linking juvenile and adult river passage with hydrosystem operations and water quality. The system predicts wild fish interaction with stressors (hatchery fish, temperature, gas supersaturation, and estuary conditions).

Objective 5 develops web-based information exchange among modeling groups.

The modeling systems give FWP managers tools to evaluate actions within a season and over the long term. The effectiveness of the ecosystem modeling efforts (Objectives 1, 2 and 3) will be evaluated by the ability of the models to identify critical issues and uncertainties through validation of model predictions in an adaptive and experimental management mode. In-season predictions (Objective 4) are evaluated by comparing pre- and within-season passage predictions to post-season results.

Section 8. Project description

a. Technical and/or scientific background

Columbia River salmon populations have been declining over the past century as a result of human use of the river and its resources including harvesting of the salmon, construction of dams, logging, water withdrawals for irrigating and municipal uses and other purposes. The annual catch of Columbia and Snake River chinook exceeded 25 million pounds at the turn of the century. Today the population is approximately 0.5% of that historical abundance. With the construction of the hydrosystem beginning in 1950, a series of mitigation efforts have been implemented to maintain the salmon runs. The original efforts involved installing adult bypass ladders on the mainstem of the hydrosystem dams and construction of hatcheries as mitigation for the dams that permanently blocked spawning grounds in the upper reaches of the Columbia and Snake Rivers. With the completion of the Snake River hydrosystem in 1976, efforts to improve fish survival include barging them down river, use of bypass screens on dams, flow augmentation and spill. These efforts were unable to maintain the runs, which resulted in listing of some stocks under the Endangered Species Act (ESA). Currently, recovery efforts include re-evaluating current programs and seeking new approaches.

This re-evaluation is difficult because of the need to identify both anthropocentric and natural environmental changes. One approach has been to develop mathematical and statistical models that address specific life-stage elements and the interaction of these stages in a life-cycle model. Such models are useful for choosing actions when there are conflicting issues such as when differing actions (that may be mutually exclusive) have different benefits to fish and other competing Columbia/Snake Basin resources. Models then become tools to quantitatively evaluate the benefits and trade-offs of different actions and assess their significance in light of the inherent levels of uncertainty. Although much of this work is done within the constructs of PATH there is a need outside of PATH to address specific issues related to non-fish users of Columbia/Snake Basin resources and to begin the development of concepts and models that will eventually be used in a regional assessment framework such as PATH or the Multi-Species framework.

The goal of the UW/CBR research is to participate in the development, calibration and validation of mechanistic based models to assist the scientifically-based management of the Columbia/Snake River fisheries and other resources. These models must be accessible and usable by scientists, hydrosystem and fish managers and the public so the basis for the decisions and the implications of the decisions can be reviewed and understood by all stakeholders. The UW project has developed these types of models for eight years to aid management of the river system. Significant past accomplishments include: CRiSP1, CRiSP2, DART, and CRiSP/Real Time.

The CRiSP1 (Columbia River Salmon Passage) Model is a smolt passage model (currently in version 6) that simulates the downstream migration and survival of smolts. Factors affecting passage include flow, temperature, dam operations, spill and gas bubble disease. The model is stochastic, incorporating measures of variability and uncertainty into survival predictions, and is calibrated with data from dam passage and predator consumption studies. It also incorporates biologically significant factors such as fish migration behavior (Zabel and Anderson 1997; Zabel et al. 1998). It has been validated against survival and travel time studies conducted between 1966 and 1998. The manual and model can be obtained on the World Wide Web (www.cqs.washington.edu/crisp/crisp.html).

The CRiSP2 (CRiSP Harvest) Model simulates the harvest of 30 chinook salmon stocks by 25 fisheries over an extended time horizon. The geographic range covered by the model extends from Southeast Alaska to the Oregon coast. Ten stocks and two fisheries from the Columbia River basin are included in the model. This is freely distributed software. The model for Windows 95 can be obtained from the World Wide Web (www.cqs.washington.edu/crisp/crisp2pc.html). The user-friendly computer model has been extended to include the ocean migrations of salmon making it useful for evaluating harvest policies that selectively target strong hatchery stocks and minimize the harvest on ESA stocks.

DART (Data Access in Real Time) is a World Wide Web based interactive data resource designed for research and management purposes relating to the Columbia Basin salmon populations and river environment. Both up-to-date and historic data since 1962 are accessible on-line. DART focuses on the Columbia Basin dams and fish passage. Detailed information is brought in daily from federal, state and tribal databases to provide a comprehensive information tool. DART generates user-specified data files which can be saved to a user's personal directory in a variety of formats designed to be compatible with most spreadsheet programs. In addition, DART has graphing capabilities which allow for the visual comparison of multiple variables on one plot. These output formats are available for data resources related to fish passage, PIT tags and the river environment.

The in-season forecaster is a composite model, known as CRiSP/RealTime, that predicts the arrival distributions and fraction transported at downriver projects - Little Goose, Lower Monumental, Ice Harbor, and McNary Dams. The system was developed jointly with other BPA Projects 8910700 and 9105100. Predictive runs from 1996 through 1998 were made weekly and published on World Wide Web pages. The model system takes as inputs fish releases, generated by RealTime, and flow and spill forecasts from BPA. The latter are also used to project temperature and gas profiles in the river. The model also simulates exposures of fish to gas and temperature and the survival rates of fish through the hydrosystem.

An adult upstream migration model has been developed which simulates the impacts of dam operations, flows, and temperature on upstream migration of adult salmon. The model incorporates the river environment and dam operation components from the CRiSP downstream passage model but has separate algorithms to describe upstream migration. The main components of the model are reservoir passage, dam passage route and delay, dam fallback, mortality, migratory route and straying, and harvest. The data structure is designed to be compatible with the chinook harvest model being developed by NMFS and University of Washington Columbia Basin Research (CBR) scientists.

The effects of water temperature on timing and size of emergence of fry from redds has been developed, showing that spawning choices for spring and fall chinook can be optimized by matching egg growth dynamics to river temperature patterns (Beer 1996; Beer and Anderson 1997; Beer, in press).

These models developed in the CRiSP project represent mechanistic formulations of critical life stages of salmon and their interactions with human activities including harvest, the hydrosystem, and tributary flows. With adoption of an ecosystem focus, there is a need to further develop and integrate the available life-stage models. A central focus of the work in the PATH project under the umbrella of Project 9600600 has been on identifying components of mortality in each life stage under assumptions of the Ricker spawner-recruit model, which has a two parameter, log-linear pattern of recruits-per-spawner against spawner. An ecosystem approach must move beyond this simplified approach to evaluate the trade-off of the different actions on the different fish stocks and species.

To address ecosystem processes and take actions that have an ecosystem impact the region will need to identify important factors, identify their structural and mathematical relationships within an ecosystem context, and characterize the significance of the uncertainty of these elements in issues of fish recovery. An example of an ecosystem issue is identifying the suitability of habitat for fall and spring chinook spawning. Studies in the upper Columbia indicate that the habitats of the two life-history types are disjoint in space and time within the same river system. Our initial work (Beer and Anderson, 1997) indicates that the timing and success of egg emergence should depend on when spawning occurs, and the temperature and flow history over the redds. Because spring and fall chinook spawn at different times with different size eggs, they respond differently to the temperature profile in their habitat. As a result, it appears that when and where each life history type spawns is optimized for their survival at emergence. If the temperature or flow regime of the habitat is altered by climatic or anthropogenic, the result may have different effects on spring and fall chinook. Only a mechanistic ecosystem approach can have a chance of evaluating the impacts of actions on multiple species at this level. The current approach to life-history analysis using a two-parameter Ricker curve is inadequate to resolve these issues.

Our approach will be to develop the models with different levels of detail in stages. The first stage is to connect existing life stage models for river migration with the harvest models and work on spawning, egg growth and emergence. These are known as “p-state” models that define the probability of a population surviving to the next life-history stage. Using sensitivity analysis, the models can be evaluated independently or connected in order to identify the importance of a particular action on either a specific life stage or the complete life history.

The second stage is to develop an individual based model (IBM). Here the small-scale dynamics and interactions of individual fish with their predators and the local physical environment are modeled and tracked over time using time steps relevant to the daily changes experienced by the fish. To take this approach, we use the SWARM modeling environment, a multi-agent software platform for the simulation of complex adaptive systems developed in the 1990s at the Santa Fe Institute (www.santafe.edu/projects/swarm). A prototype model has been developed to investigate smolt-predator interactions in a drawn-down Snake River reservoir. It involves defining the bioenergetics and behavior of the smolts and their prey and how these interactions are altered by physical changes in the environment including temperature, velocity distributions and sediment types.

Both the p-state models and the IBM models are useful for developing an ecosystem management perspective that will be needed to identify where specific actions can restore the river system to a more normative state.

b. Rationale and significance to Regional Programs

Both the Council Fish and Wildlife Program (FWP) and the NMFS 1998 Supplemental Biological Opinion (SBO) indicate a need to develop and assess regional strategies to rebuild fish and wildlife populations through the use of credible and understandable analytical tools. SBO Section III-5 indicates the need to fund a regionally-coordinated analysis through forums such as PATH and to fully coordinate with the ongoing PATH process to evaluate the effects of the proposed actions in the context of species-level biological requirements over the life-history of the fish. NMFS will apply PATH analyses to recommendations on the Snake River and the mid- and lower Columbia River. The FWP section 3.2F identified that computer models are essential in the framework to provide a means to align program measures to survival targets and rebuilding schedules and targets. The tools developed will contribute to the legitimate scientific debate on the differences and approaches for modeling the system. Past experience indicates that debates can not be easily resolved, nor the priorities easily set for what constitutes important avenues of research and development of the models. The research will help clarify differences in approaches and promote a more thorough understanding of uncertainties in ecosystem function. Overtime, this will facilitate the development of a unified approach.

The Columbia Basin Research (CBR) project provides essential modeling capabilities for the region to explore alternative hypotheses that effect future harvest policy, management of tributary habitat, and both smolt and adult river passage. Specifically, Objectives 1, 2, and 3 involve the adaptation and development of models to address ecosystem-level concerns including the impacts of the physical environment on life-history stages, and further exploration of factors that limit stock recovery in hydrosystem mitigation programs. The work will take a multi-species approach for several life history stages including harvest, stream habitats and river passage in order to integrate FWP elements into a more unified framework. This is a “work-in-progress” of several steps that are ongoing and under development. First, biological and physical research on life stage interactions, developed by individual FWP projects, provide the conceptual and descriptive information from which the mathematical framework of an ecosystem modeling system is developed. In this aspect the models define and link concepts from different projects into a common framework.

Second, model parameters are set or calibrated using information from a variety of projects across differing temporal and spatial scales. For example, a model could use information on the river environment and the distribution of fish within the environment, thus integrating in a meaningful way information from different, independent projects.

Third, an ecosystem model integrates and orders the significance of information over small and large-scale focuses. For example, within CriSP1, the significance of fish guidance at a dam is put in context of total hydrosystem passage and the resulting model output of river survival can be compared and validated against system survival studies. Thus, the model provides a way to compare the significance and accuracy of data collected at differing temporal and spatial scales.

Finally, the ecosystem model is used to evaluate the importance of individual projects, data, and management actions to stock recovery.

Objective 4 involves in-season predictions of smolt and adult river passage and the exposure of these fish to stressors during passage. This capability, provided across the World Wide Web, gives managers and the public up-to-date information on fish passage. The multi-factored real-time predictions include the interactions of species interactions, hatchery and wild fish interactions, and the effect of exposure to water quality anomalies and estuary conditions. This real-time tool is a natural and logical way to actively manage system operations. It meets a significant number of the goals of the FWP including:

1) multi-species management (the tool can track smolts and adults of steelhead, fall and spring chinook of both wild and hatchery origin)

2) an ecosystem perspective (concomitant with fish passage river flows, temperatures, TDG and dam operations are modeled and the interaction with the target species are predicted)

3) regionally coordinated (the real-time system uses real-time information from the Army Corps, the Fish Passage Center and Pacific States Marine Fish Commission)

4) accessible to the public (all information is available through the World Wide Web).

Objective 5 addresses the need to coordinate analytical methods in the region. The development of a center for regional biological analyses (FWP 3.2F1) is problematic because of the decentralization of analytical expertise across a four-state region and beyond. Irrespective of the ultimate fate of a physical center, there is an immediate need to improve the information exchange among modelers.

A web-based information exchange is a cost-effective and productive way to create a virtual analysis center. In 1994 when the FWP was developed, a virtual center could not exist because modern data management tools and broad access to the World Wide Web did not exist. With current and future web capabilities, a virtual center for the region may become a model for other fields.

c. Relationships to other projects

This project will provide a framework in which to synthesize information from the FWP field studies which are evaluating ecosystem interactions including spawning factors, flow/survival relationship, and estuary dynamics. Because of the modeling aspects of the project, it will integrate field programs, individual life-stage modeling efforts, and regional analyses such as PATH.

To address issues of mainstem survival and migration, we have developed a close working relationship with several project from NMFS including “Monitoring of smolt Migration of wild Snake River spring/summer chinook” (Project 9102800), and “Avian predation on juvenile salmonids in the lower Columbia river” (Project 9702400). Other projects that provide data for model calibration and comparison include the PIT tag studies (Projects 8712702 and 9102800).

For the development of ecosystems models that focus on the tributary and mainstem spawning habitats, the project will use information from the supplementation projects including the Idaho Supplementation Studies (Projects 8909800, 8909801, 8909802, and 8909803), and the Steelhead Supplementation study (Project 9005500). The extensive early life-history and productivity studies (Project 9202604) will provide valuable information on the abundance, migration patterns, survival and life history strategies exhibited by spring chinook juvenile. Studies of spawning habitat models (Project 9105) and models of the habitat (Project 9203200) are available and will be of value in developing the conceptual/mathematical framework for spawning in an ecosystem perspective.

In furthering the ecosystem framework, the behavioral and physiological aspects of salmon must be considered. In this area, valuable information on smolt conditions has been collected in Project 8740100 and in various anadromous fish projects funded by the Army Corps.

In developing individual based models of ecosystem function, we will work with a team at the Department of Mathematics at Humboldt State University. The team is developing the California Individual-based Fish Simulation System (CIFSS) which is a system for building, testing, calibrating and using individual-based models of fish populations and multi-species fish communities (http://weasel.cnrs.humboldt.edu/~simsys).

The models and analysis conducted by CBR are actively used in PATH analyses, which are referenced under the umbrella Project 9600600.

The web-based modeling center will involve the cooperation with regional modeling groups. Projects that have immediate use of the facility involve the ecosystem modeling groups mentioned above. Several of these groups have been contacted and see the value of a web based information system.

d. Project history (for ongoing projects)

The UW monitoring and evaluation modeling support is a continuing project that was initiated in 1989. Major past accomplishments are outlined below.

1989-1991:

CRiSP.0 based on FISHPASS the BPA smolt passage model

CRiSP1.1 released -first version of the CRiSP 1 model

Published model on vitality-based organism survival

CRiSP training workshops held

Publications: Anderson (1991a, 1991b), Swartzman (1991)

1992:

CRiSP1 passage model with capabilities to run monte carlo simulations, mortality from supersaturation, calibrated for spring and fall chinook and steelhead

Total dissolved gas and mortality modeling

Workstations installed at 6 agencies in the regions

Translated the Stochastic Life Cycle model developed by RFF into a UNIX version with a graphical user interface

Participated in the System Operation Review (SOR)

Developed a flow archive data set accessible through the internet

Training workshops were held for 25 regional scientists

Publications: Anderson (1992)

1993:

Workstations provided to region

Two model training workshops were held

Training workshops

Participated in the System Operation Review (SOR)

CRiSP2 harvest modeling project initiated (later becomes CRiSP Harvest)

CRiSP1.4 released with manual

Publications: Anderson (1993a, 1993b)

1994:

CRiSP 1.5.1 released

CRiSP2 released

Second Tier database system on-line with hydro operations, water quality information, and fish passage information on-line for user

World Wide Web page developed providing on-line access to the database through graphical interface and real-time predictions of in-season fish migration

Publications: Anderson (1994), Hinrichsen (1994), Zabel (1994)

1995:

DART (Data Access in Real-Time) was implemented on the World Wide Web

3 workstations were provided to regional agencies

28 regional scientists were trained in modeling workshops

Publications: Anderson (1995), Swartzman (1995)

1996:

Revised and recalibrated CRiSP1 and CRiSP2

Revised manuals for both models

Provided real-time projections of fish passage for various stocks in the Snake & Columbia Rivers

Publications: Beer (1996), Hyun (1996), Norris (1996)

1997:

CRiSP2 (Harvest) released on the World Wide Web

Implemented gas predictions for in-season management of the impacts of the hydrosystem on gas levels in the river

Publications: Anderson (1997) Beer and Anderson (1997), Lubetkin (1997), Zabel and Anderson (1997)

1998:

Updated in-season and post-season analyses

CRiSP1 total dissolved gas predictions implemented on World Wide Web

Publications: Anderson (1998), Zabel, Anderson and Shaw (1998)

1999:

CRiSP1.6 released through the World Wide Web includes temperature predictions, modeling of TDG with horizontal and longitudinal distribution

Publications: Anderson (1999a), Anderson (1999b), Helu and Anderson (1999), Beer and Anderson (in preparation)

e. Proposal objectives

Objective 1. Upgrade and link passage and harvest models: We will continue to upgrade, calibrate and validate the passage models for smolts and adults and the multi-species harvest model being developed for selective stock management of chinook. These models will be linked allowing managers to evaluate the relative benefits of stock recovery measures from harvest and river actions.

Objective 2. IBM tributary model: We will develop an individual based model of the early life history stages of salmon from eggs to smolts. This model will focus on defining the interaction of small-scale interactions of river hydraulics and environment with the bioenergetics and behavior of salmon and their predators. This model will incorporate existing information from several sources: 1) field studies being conducted by the Army Corps of Engineers as part of the drawdown studies, 2) supplementation and tributary life-history studies of the FWP, and 3) literature-based information on bioenergetics and fish behavior. The model will provide an experimental framework in which to explore the limiting factors controlling early life-history recruitment.

Objective 3. Process models: We will continue to develop and evaluate simplified models describing the important ecosystem processes that affect the survival through a specific life stage. Examples include the vitality survival model that characterizes the effects of cumulative stressors on fish survival (Anderson, in press), and a dynamic model characterizing the impacts of stream fertilization and non-linear density interactions on early life history recruitment and fish growth (Beer and Anderson 1997, Beer in preparation). These process models become algorithms within a ecosystem models that link the physical environment and the fish over one or more life-history stages. The process models will be published in journals and incorporated into the evolving life stage ecosystem models.

Objective 4. CRiSP/Real-time fish passage: Our real-time web-based passage prediction models will be improved and maintained during the passage of adult and juvenile river passage seasons. The modeling system links juvenile and adult river passage models with hydrosystem operations and water quality models. The system will provide across-the-web pre- and within season predictions of the percent passage of wild fish during migrations and make predictions of the cumulative and daily exposure to stressors during migration. Stressors that will be modeled and tracked include hatchery/wild fish interaction, temperature, gas supersaturation, and estuary conditions. The Real-time system will provide managers with detailed information and predictions on the hydrosystem environment juvenile and adult fish experience during their river passage including run timing and survival.

Objective 5. Information exchange among modeling groups: A significant number of modeling efforts are being conducted in the Columbia/Snake River community, including models of salmon over various life stages, resident fish, avians, physical models of river sediments and hydraulics, and physical and biological models of the terrestrial habitats. To help the development of a regional ecosystem management framework, a modeling information exchange web page will be established to increase the communication between the diverse biological and physical model groups whose efforts will be the foundation of future ecosystem models. Through the exchange process, modelers will be able share papers, data sets, and models. The page will be interactive and provide users a discussion format to identify common needs and synergistic efforts, establish common data sets, programming conventions and output and display protocols. The exchange process will be nonhierarchical and distributed through the capabilities of the World Wide Web.

f. Methods

Objective 1. Upgrade and link passage and harvest models.

Task a. Update the juvenile passage model. CRiSP1 will be updated in terms of model functionality, calibration and validation. New information emerging from the studies on fish behavior in tailrace and forebays from Army Corps studies of dam passage will be integrated into the model. Information on the impacts of estuary bird predation will be incorporated with the assistance of scientists on Project 9702400. A smolt growth function developed in 1998 and implemented in 1999 will be further calibrated and validated with the PIT Tag studies from Projects 8712702 and 9102800. A simplified form of the passage model developed in 1998/9 will also be calibrated with the updated PIT tag information. Calibration of fish travel time and survival will be accomplished with multi-reach PIT tag information and a computer search algorithm. The basic method was developed in Zabel et al. (1998).

Task b. Calibrate the adult upstream model. This will be calibrated with the results of the adult radio tagging studies being conducted by the University of Idaho under funding from the Army Corps of Engineers. Adult travel time calibration will use the calibration system noted in Task a.

Task c. Update the CRiSP Harvest model. The multi-species multi-stock salmon harvest model developed by CBR with NMFS funding will be updated with the modifications and calibrations being developed by a joint ESSA/CBR project funded by the Pacific Salmon Commission.

Task d. Develop JAVA-based control for model linkages. The updated and calibrated CRiSP Harvest model will be linked with the upstream and downstream passage models by a model control module that we will develop in the JAVA programming language. In this manner, the models, either as individual elements or as a linked set, will be executable across the World Wide Web.

Objective 2. Develop IBM tributary model.

To model the small-scale dynamics of individual fish from spawning through the early life stages the California Individual-based Fish Simulation System (CIFSS) will be used (Railsback et al. 1999). The model system is developed and maintained by a consortium through Humboldt State University in California (http://weasel.cnrs.humboldt.edu/~simsys).

Task a. Convene a working group of modelers and biologists involved in modeling predator/prey interactions in stream. The group will exchange information on the most recent work on the CIFSS models and other applications of the SWARM modeling system. This will include researchers at Colorado State University, Humboldt State University, University of Washington, US. Geological Survey, and University of California at Davis plus researchers in the FWP with interest in the IBM modeling. This working group will update and calibrate the CIFSS model for application in the Columbia/Snake River system.

Task b. Identify critical factors using the model. A study and sensitivity analysis using the model will be developed with the goal of identifying critical physical and biological features that affect 1) the creation of spawning grounds and 2) egg to smolt survival in tributaries and drawn down reservoirs. A paper will be written describing the findings with reference to evaluating drawdown actions and fish supplementation.

Task c. Use the CIFSS model. The CIFSS model deals with spawning as well as emergence and survival of fry and will be used to examine 1) the mechanisms of potential spawner-recruit relationships, 2) the function forms of density-dependent survival issues and 3) the effect of stream fertilization. This task is coupled with the Objective 3, which will develop individual components of the CIFSS model. A paper will be published on mechanisms and functional forms of the impacts of stream fertilization and spawner density on salmon productivity.

Objective 3. Process models.

A number of processes important in an ecosystem context will be modeled and the results published. These mechanistic models are needed for the eventual development of ecosystem models that consider the interactions of a larger variety of species in the system. Several potential modeling tasks are identified below, others will be addressed as needed.

Task a. Vitality model. Controversy on the effect of cumulative stress on smolts in passage has lead to differing hypotheses on river passage survival. The existing empirical models are inappropriate for addressing the issue which needs to examine survival at a mechanistic level. To this end, a vitality-based model is appropriate (Anderson in press). The vitality model will be fit to PIT tag estimates of survival through the river system using the multi-reach fitting algorithm developed at CBR for fitting models to PIT tag data. The results characterizing the effects of cumulative stress on fish survival, will be published in a paper and the model included in the CRiSP1 passage model.

Task b. Growth model. The growth of fall chinook as they migrate through the hydrosystem and the impacts of growth and size on survival have been documented from evaluations of PIT tag interrogation records and over 30,000 PIT tag recovery records which have associated growth information. The contributions of feeding rate and temperature to the observed growth have been resolved using the Wisconsin Bioenergetic model equations. In this task, this work will be updated with the most recent results and work begun to identify the contributions of reservoir temperatures to optimize growth and survival of fall chinook. The results will be incorporated into the CRiSP1 passage model and a paper prepared on the effects of temperature on fall chinook growth.

Task c. Stream productivity. Considerable research has emerged on the importance of stream fertilization with the carcasses of adult salmon (the most recent work was presented a the 1998 ASF conference in Anchorage). The results of current and historical work will be reviewed and the implications to spawner–recruit curve forms will be explored. Mechanistic model forms will be developed for inclusion in the CIFSS model.

Objective 4. CRiSP/Realtime maintenance and development.

The web based pre- and in-season projections of smolt passage and predictions of water quality conditions are an operational service provided by CBR (http://www.cqs.washington.edu/inseason).

Task a. Incorporate the adult passage model predictions into in-season predictions.

Task b. Incorporate hatchery smolts into in-season predictions.

Task c. Develop algorithms for passage stress based on the temporal and spatial intersection of wild fish (smolts and adults) with hatchery fish, gas supersaturation and temperature levels.

Task d. Maintain in-season prediction system.

Task e. Prepare post-season analysis of system.

Objective 5. Information exchange among modeling groups.

The development of a web-based information exchange capability has the following tasks.

Task a. Develop an information exchange web page. This will use the existing web tools developed at CBR. The concept is to have an umbrella page under which other groups maintain their own project pages with CBR assistance.

Task b. Solicit modeling groups to provide information in designing of the web pages.

Task c. Facilitate groups in developing and loading information to their own web pages.

Task d. Hold work-group meetings.

g. Facilities and equipment

The CRiSP project is conducted at the University of Washington off-campus. This project involves maintenance of a library, computer facilities, and databases. The whole operational system is well integrated to adequately perform the job at the Columbia Basin Research facility. Minor replacement of computer hardware and upgrading of software is anticipated, but no major high-cost equipment will be needed.

h. Budget

Salary and benefits rates are computed based on several categories of staff involved.

Supplies include software and miscellaneous hardware computer supplies.

Operations and Maintenance include local & long distance phone, publications, software licenses & support, internet cost, equipment insurance & repairs, postage, freight, and photocopy.

Travel is projected for meetings in Portland and other regional areas. A trip to present results of the project at national meeting is included.

Indirect Costs are computed based on Modified Total Direct Costs times 26%. This off-campus rate is provided by the UW grant/contract services and is anticipated to remain unchanged until year 2002.

Section 9. Key personnel

Curriculum Vitae

James J. Anderson
Columbia Basin Research, University of Washington
1325 – 4th Ave., Suite 1820, Seattle, WA 98101
Phone: 206-543-4772; Fax: 206-616-7452
Email: jim@fish.washington.edu

Associate Professor (WOT)

Fisheries Research Institute and Center for Quantitative Science in Forestry, Fisheries and Wildlife
College of Ocean and Fisheries Sciences

Teaching Activities:

Graduate course in modeling organism dynamics (QSCI 551)
Graduate course in Ecosystem models (QSCI 550)

Students Receiving Degrees: Three in M.S. Fisheries, Two in M.S. Quantitative Ecology & Resource Management, and Two in Ph.D. Quantitative Ecology & Resource Management.

Current Research Projects:

Bonneville Power Administration (Funding level: $6+ million): Developing computer models for management of Columbia River hydroelectric and fisheries agencies.

U.S. Army Corps of Engineers (Funding level: $1+ million): Developing analysis and computer models for the impact of gas bubble disease on migrating salmon.

National Marine Fisheries Service (Funding level: over $500K):

1) Studying mortality processes of juvenile salmon in tributaries
2) Developing a multi-species multi-regional salmon harvest model

Honors and Awards:

1) Research Faculty Fellowship, College of Ocean and Fishery Sciences 1985, 1989.
2) Special Recognition for participation in the U. S. Fish and Wildlife Service Fish Passageways and Division Structures course in 1990.
3) Nomination for Computerworld Smithsonian Awards in programming for the CRiSP computer model College of Ocean and Fishery Sciences Distinguished Research Award, 1996.

Professional Activities: Consulting; Expert Testimony on Fish Migration and Dam Passage; Guest Speaker

Selected recent publications from over 45 publications and reports include:

Anderson, J.J. 1998 (in press). Decadal Climate and Declining Columbia River Salmon. Proceedings of the Sustainable Fisheries Conference, Victoria B.C., Canada. Eric Knudsen, Editor. American Fisheries Society special publication no. 2x. Bethesda, MD.

Anderson, J.J. A vitality based model relating stressors and environmental properties to organism survival. Accepted by to Ecological Monographs in 1998.

Helu, S.L., J.J. Anderson, D.B. Sampson. 1998. An individual-based boat fishery model can generate fishery stability. Natural Resource Modeling. (In press)

Zabel, R.W., J.J. Anderson, and P.A. Shaw. 1998. A multiple reach model describing the migratory behavior of Snake River yearling chinook salmon (Oncorhynchus tshawystscha). Canadian Journal of Fisheries and Aquatic Sciences: 55:658-667.

Curriculum Vitae

Richard William Zabel
Columbia Basin Research, University of Washington
Phone: 206-685-1132

Education

B.S. (with honors and distinction), in Botany, The University of Michigan, Ann Arbor, 1983.
M.S., in Plant Biology, The University of Michigan, Ann Arbor, 1988.
Ph.D., in Quantitative Ecology and Resource Management, The University of Washington, Seattle, 1994.

Recent Employment and Research Experience

July 1997 - present: Research Consultant, Columbia Basin Research, School of Fisheries, University of Washington. Research on salmon survival issues including participation in PATH process.

January 1995 - June 1997: Post Doctoral Research Associate, School of Fisheries, University of Washington. Work with Professor James Anderson developing and calibrating models of salmonid migration.

March 1994 - December 1994: Research Consultant, The Center for Quantitative Science, University of Washington.

Responsibilities

Develop models of juvenile and adult migration in the Columbia River system. Perform data analysis to calibrate models for predictive purposes. Participate in regional forums that analyze salmon survival issues and make recommendations for measures to recover endangered stocks. Write papers for publication in scientific publications.

Publications in refereed journals, conference proceedings, and dissertation

Zabel, R.W. and J.J. Anderson. 1997. A model of the travel time of migrating juvenile salmon, with an application to Snake River spring chinook salmon. North American Journal of Fisheries Management, 17:93-100.

Zabel, R.W., J.J. Anderson, and P.A. Shaw. 1998. A multiple reach model describing the migratory behavior of Snake River yearling chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 55: 658-667.

Zabel, R.W., J.J. Anderson, and J.A. Hayes. 1998. Calibration and validation of the Columbia River Salmon Passage (CRiSP) Model. In E. L. Brannon and W.C. Kinsel Editors, Proceedings of the Columbia River Anadromous Salmonid Rehabilitation and Passage Symposium, June5-7, 1995. Aquaculture Research Institute, University of Idaho.

Zabel, R. W. 1994. Spatial and Temporal Models of Migrating Juvenile Salmon with Applications. Ph.D. dissertation, University of Washington, Seattle.

Curriculum Vitae

James Grant Norris
Columbia Basin Research, University of Washington
Phone: 360-385-4486
Email: jnorris@olympus.net

Education

1989 PhD Fisheries University of Washington, Seattle, WA
1972 MS Fisheries University of Alaska, Fairbanks, AK
1968 BS Mathematics University of California, Davis, CA

Work Experience

AUG 1992 - PRESENT: Fishery Research Consultant, Columbia Basin Research,University of Washington, Seattle, WA. Coordinate development of mathematical harvest models for Pacific salmon stocks, with emphasis on Columbia River stocks. Research includes estimating ocean harvest rates and residence proportions from coded-wire-tag data. Projects are funded by Bonneville Power Administration and the National Marine Fisheries Service.

APR 1989 - PRESENT: Marine Resource Consultants, Port Townsend, WA.
Provided scientific analysis of various harvest issues to fishery management agencies. Developed underwater videographic mapping system for nearshore marine habitats. The mapping system has been applied throughout Puget Sound and Willapa Bay and was awarded Honorable Mention in the 1997 Applications Contest sponsored by GPS World Magazine.

SEP 1986 - MAR 1989: Graduate Research, School of Fisheries, University of Washington. Analyzed harvesting strategies for sablefish fishery off the coasts of Washington, Oregon, and California. Included linear programming analysis of multi-species/multi-gear fisheries, yield per recruit analysis (with reproductive considerations) for sablefish stocks, and development of methods for incorporating political objectives in fishery models.

National Committees and Panels: Member of the 1997 Environmental Protection Agency (EPA) Peer Review Panel for the Experimental Program to Stimulate Competitive Research (EPSCoR). Reviewed 37 research proposals for scientific merit in a national competition for EPA research funds.

Selected Publications

Norris, J. G. (in press) Defining equivalent harvest rate reduction policies for endangered Pacific salmon stocks. Presented at Towards Sustainable Fisheries: Balancing Conservation and Use of Salmon and Steelhead in the Pacific Northwest. Victoria, BC. April, 1996. Published as a special publication of the American Fisheries Society.

Norris, J. G. 1991. Summary of chinook salmon bycatches in the BSAI and GOA groundfish fisheries: Jan. 1, 1991 - Nov. 10, 1991. Submitted to the North Pacific Fishery Management Council, Anchorage, AK.

Norris, J. G. 1991. Further perspectives on yield per recruit analysis and biological reference points. Can. J. Fish. Aquat. Sci. 48: 2533-2542.

W. Nicholas Beer

Columbia Basin Research, Box 358218, University of Washington
Seattle, WA 98195, Phone: (206) 221-3708 nick@cqs.washington.edu

Education:

M.S. 1996. Quantitative Ecology and Resource Management, University of Washington.

1990. Harvard University, Graduate School of Education. Visiting scholar on fellowship from Outward Bound USA.

B.A. 1983. Environmental Studies, University of Vermont.

Current Employment:

Research Consultant Columbia Basin Research,
University of Washington, Box 358218, Seattle, WA 98195

Responsible for juvenile salmon growth analysis. Writing and publication of research findings. GIS data management and analysis.

Recent Employment:

Research Assistant / System Analyst/Programmer I/II 9/92-3/97
Center for Quantitative Science, University of Washington, Box 358218, Seattle, WA 98195

Technical Writer / Software tester, Alki Software 9/ 91-5/92
300 Queen Anne Ave. N., Suite 410, Seattle, WA 98109

Expertise:

Statistical and mathematical modeling skills including use and application of mechanistic and stochastic models, 5 years experience in GIS analysis and AML programming using ARC-INFO including spatial/analytic problem solving and data conversion management; UNIX, C, S+, Perl, AML and JavaScript programming; advanced training in ecological dynamics. Technical writing and editing in academia and private sector.

Publications:

Beer, W. N. (in press) Comparison of mechanistic and empirical methods for modeling embryo and alevin development in chinook salmon. Progressive Fish Culturist.

Beer, W. N. and J. J. Anderson, 1997. Modeling the growth of salmonid embryos, Journal of Theoretical Biology.

Beer, W. N., 1996. A growth model for larval salmon with application to field and laboratory observations of chinook salmon. Master's thesis, University of Washington, Seattle, WA.

Wissmar, R., and W. N. Beer, 1994. Distribution of fish and stream habitats and influences of watershed conditions, Beckler River, Washington. Fisheries Research Institute, University of Washington, 98195.

David H. Salinger

Columbia Basin Research, Box 358218, University of Washington
Seattle, WA 98195
Phone: (206) 616-7449; Email: salinger@cqs.washington.edu

Education:

Ph.D. 1997. Applied Mathematics, University of Washington.
Specializations: Stochastic and deterministic optimization, mathematical modeling.
Dissertation title: "A Splitting Algorithm for Multistage Stochastic Programming with Application to Hydropower Scheduling." Work included algorithm development, implementation for a large scale (200,000 variable) test problem and theoretical results on optimality and convergence.
Pertinent course-work: Math Ecology(3), Numerical Analysis(3), Optimization(6).

M.A. 1987. Mathematics, Pennsylvania State University
Specializations: Applied Mathematics, Geophysics, Fluid Flow.

B.A. 1984. Mathematics/Geology (dual major), State University of New York at Oneonta.

Current Employment:

Research Consultant Columbia Basin Research, University of Washington, Seattle. Responsibilities: Have primary responsibility for development and coding of optimization routines for calibration of salmon passage model to data. Provide mathematical support for modeling projects and in the development of methodologies.

Recent Employment:

Research Assistant / Teaching Assistant 9/90-6/97
Dept. of Applied Mathematics, University of Washington, Seattle, WA 98195.

Expertise:

Optimization techniques including methods for calibration of models to data as well as methods for large scale stochastic and deterministic optimization; mathematical modeling including ecological and hydrosystem modeling; Numerical analysis and mathematical problem solving techniques; Unix, C programming.

Publications:

Salinger, D. H. and Rockafellar, R.T. (submitted) Dynamic Splitting: An Algorithm for Deterministic and Stochastic Multiperiod Optimization. SIAM J. Optimization.

Salinger, D. H. 1997 A Splitting Algorithm for Multistage Stochastic Programming with Application to Hydropower Scheduling. Doctoral thesis, University of Washington, Seattle, WA.

Matthew P. Moore

Columbia Basin Research, Box 358218, University of Washington
Seattle, WA 98195

EXPERIENCE:

- Senior Computer Specialist, University of Washington, Seattle, WA, 4/97 - Present. Worked with one other engineer and numerous domain experts in the School of Fisheries to maintain and expand two multi-platform computational applications in natural resource modeling. These applications allow graphical entry of physical and biological environmental data and graphical display of simulation results. Greatly improved the multi-platform GUI and added several features in the platform-independent simulation engine. Win32, Solaris, RogueWave Zapp & Tools.h++, Visual C++ 5.0.
- Senior Computer Specialist, University of Washington, Seattle, WA, 8/95 – 4/97. Worked with three other engineers in the Dept. of Bioengineering to maintain and expand a multi-platform computational application in pharmacokinetic analysis. This application allows graphical entry of a biological compartmental model, graphical display of simulation results, and automatic fitting of model parameters to data. Greatly improved the Windows GUI, added numerous features in the platform-independent UI engine, maintained the Windows Setup program and help file, and fixed countless bugs. Win32 SDK, MFC, Visual C++ 4.0.
- Software Design Engineer in Test, contract at Microsoft Corp, Redmond, WA, 11/93 - 6/95. Developed, adapted, and supported test software for window management and kernel components of Windows 95. Found many bugs. Windows 95 SDK, Visual C++ 2.1, 80x86 Assembler.
- Software Engineer, Microstar Laboratories, Bellevue, WA, 2/93 - 10/93. Developed parts of a Windows 3.1 front end program for smart data acquisition boards. My contribution included several complex windows, configuration storage, online help support, and the installation disk. MS/DOS, Windows 3.1 SDK, Borland C++, IDE, and OWL.
- Senior Software Engineer, John Fluke Manufacturing Co, Everett, WA, 10/89 - 1/93. Developed Windows 3.1 application code, including several complex interactive windows and DLLs. Added Boundary Scan test support, maintained ROM emulation software, and added new Am29000 microprocessor support to a large Windows-based board test system. On another board test system, maintained and expanded ROM emulation pod firmware, and developed processor support for 680x0, 80x86, and R3000. UNIX, MS/DOS, Windows 3.1 SDK, C, 680x0, 80x86, R3000, Am29000 Assemblers.

EDUCATION:

- MS in Computer Science, University of California, Santa Cruz, 1989. Thesis: "A Flexible Object Animation System". Extensive implementation of computer animation systems based on physical modeling, using advanced numerical techniques and high-performance workstations. UNIX, C, Silicon Graphics.
- BA in Operational Mathematics, University of Rochester, 1976. GPA 3.55. Seven advanced courses in Computer Science, GPA in that field 4.00. Independent research in computer vision.

PUBLICATIONS:

- "Collision Detection and Response for Computer Animation", Matthew Moore and Jane Wilhelms, SIGGRAPH 1988 Conference Proceedings.
- "Interactive Control for Computer Graphics Simulation of Articulated Figures", Jane Wilhelms, Matthew Moore, and Robert Skinner, the Visual Computer, Dec 1988.

Section 10. Information/technology transfer

The project maintains an extensive web page providing all models and databases (www.cqs.washington.edu). The page is heavily used in the community with over ten thousand accesses per week from several hundred unique hosts. The increase in usage has been linearly increasing over a three year period. The web site contains a web-based access to an extensive second-tier database of river and fish passage information which is updated daily and extends back to 1962. The page also contains real-time in season projections of juvenile and adult passage information. The fish passage models and harvest models can also be downloaded from the site.

Congratulations!