PATH - Plan for Analyzing and Testing Hypotheses

Results of a Workshop to Design Retrospective Analyses

Draft

Bonneville Power Administration

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Results of a Workshop to Design Retrospective Analyses

DRAFT

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1.0 Introduction and Objectives

1.1 Background to PATH

This section provides background information for readers not familiar with PATH. Those who are familiar with the genesis and structure of PATH can skip directly to section 1.2.

For the past several years, the Bonneville Power Administration, the Northwest Power Planning Council, the National Marine Fisheries Service, and various state and tribal resource agencies have been attempting to work together to compare and enhance the models used by all of the agencies to evaluate management options intended to enhance recovery of depleted Columbia River Basin salmon stocks. Results from these model comparison activities and associated peer-review efforts illustrated that each modelling system has different strengths and weaknesses, several common patterns of model behaviour, and some significant differences. In 1994, an independent scientific review panel (coordinated by Dr. Larry Barnthouse of Oak Ridge National Laboratory) completed an interim report in which they concluded that there were three major differences between the modelling systems: 1) the distribution of survival over the life span; 2) the effect of flow on survival; and 3) the benefit of transportation. The panel felt that as long as these differences exist the models were going to give different answers in a fairly predictable fashion, providing conflicting advice to decision makers, and rendering further analysis of the details of model behaviour a relatively unproductive activity. The panel concluded that it would be more fruitful to focus on describing and attempting to resolve the fundamental issues, through hypothesis formulation and testing. This was the genesis of the Plan for Analyzing Testable Hypotheses (PATH).

The initial design of PATH[1] grew out of discussions among the peer review panel, and analytical/policy (ANCOOR/POCOMM) representatives within the major agencies dealing with Columbia River Salmon.[2] The primary objectives were originally defined as:

1. Determine the overall level of support for key alternative hypotheses based on existing information, providing guidance to management agencies. Propose other hypotheses and/or model improvements that are more consistent with the data.

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

---

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

[2] National Marine Fisheries Service (NMFS), Bonneville Power Administration (BPA), US Army Corps of Engineers (COE), Northwest Power Planning Council (NPPC), Washington Department of Fisheries and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), Idaho Department of Fish and Game (IDFG), Columbia River Inter-Tribal Fish Commission (CRITFC), Columbia Basin Fish and Wildlife Authority (CBFWA).

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

- define the management decisions that serve to focus analytical activities;
- bound the anadromous salmon ecosystem components that need to be considered;
- lay out alternative hypotheses for the functioning of these ecosystem components, in terms of the distribution of survival over the populations= life cycle and the life stage and population responses to management actions under different natural conditions;
- compile and analyse information to assess the level of support for alternative hypotheses;
- propose other hypotheses and/or model improvements supported by the weight of evidence from these analyses;
- identify knowledge and data gaps that could be filled through management experiments, research and monitoring, improving our ability to discriminate among competing hypotheses, and maximizing the rate of learning and clarity of decisions;
- provide guidance to the development of regional programs that would stabilize, ensure persistence, and eventually restore depressed salmon stocks to self-sustaining levels;
- implement model improvements so as to more defensively evaluate the likelihood of persistence and recovery of salmon stocks under alternative management scenarios; and
- provide a structure for an adaptive learning approach to development and implementation of a regional salmonid recovery program (i.e. iterative evaluation of results of research, monitoring, and adaptive management experiments; assessment of implications for alternative hypotheses and subsequent actions).

The logical framework developed in PATH will assist in management decisions concerning the Columbia Basin anadromous salmon ecosystem. The design of this framework will be driven by the management questions of interest, the alternative hypotheses relevant to these questions, and the data available to test these hypotheses. The purpose of the exercise is not to simply compare the existing belief systems embodied in the various models, though modelling will undoubtedly play a role. Instead, the hope is to lay out a framework without reference to existing models with the expectation that this will provide a novel foundation for learning and action. Ultimately, this should also lead to improved analytical tools.

Figure 1.1 provides an overview of the series of activities planned for PATH until October 1996, how they will interact with the needs of NPPC and NMFS, and the contributions generated to the ongoing coordination of quantitative analyses. Essentially, PATH consists of a series of workshops, analytical activities and reporting steps. These steps will be repeated several times**C**essentially successive orbits on an upward spiral towards greater understanding and better decision making. The activities throughout the year are being coordinated by a PATH Planning Group[3] that confers weekly. The PATH activities directly relate to a number of components in both the 1994 NPPC Fish and Wildlife Program, the NMFS Biological Opinion and the NMFS Proposed Recovery Plan.

[3] The PATH Planning Group includes David Marmorek (facilitator/coordinator), Jim Geiselman (operating agencies representative), Chris Toole (NMFS), Earl Weber (tribal fisheries representative), Howard Schaller (state fisheries representative), and Chip McConnaha (Northwest Power Planning Council).

1.2 Objectives and Structure of the Workshop

This report summarizes the first PATH workshop, held October 16 - 19 at Camp Cascade, Oregon. The first workshop took a retrospective look at the issues of importance for Columbia River salmonid stocks, developing hypotheses and analytical methods that could be applied to existing information. The objectives of the workshop are listed in Table 1.1, the agenda in Table 1.2, and the participants in Table 1.3. A considerable amount of material was assembled prior to the workshop, and is worth reading for those not already familiar with PATH (PATH Workshop 1 Information Package, ANCOOR (1995)). The information package summarizes work completed prior to the workshop on clarification of management decisions, development of hypothesis frameworks and sets of alternative hypotheses relevant to those management decisions, preliminary analyses for some hypotheses, data reconnaissance, and coordination with other entities conducting scientific investigations and management decision analyses.

The workshop was divided into three phases, as described on the agenda in Table 1.2: 1) a series of plenary presentations; 2) two concurrent subgroup meetings; and 3) a final plenary session to present and integrate the results of the subgroup meetings. Some ground rules were presented at the beginning of the workshop (Table 1.4), which were accepted by everyone, resulting in a constructive tone throughout the meeting. Participants at the workshop are to be congratulated for their energetic and creative efforts throughout the three days.

The two subgroups at the workshop had overlapping responsibilities. This structure was meant to provide an opportunity for independent thought by different groups of scientists to see what common themes and approaches emerged, and also to allow for complementary perspectives to come forward. Both groups discussed all three levels of hypotheses in the PATH framework (Table 1.5), and both discussed the hydrosystem at Level 3. However, because of the limited time available for discussions, the two groups were given different responsibilities for Level 3 hypotheses. Group A was asked to focus on hydrosystem, ocean and harvest issues; while Group B was asked to focus on hydrosystem, habitat and hatchery issues. The nature of the groups' discussions was such that Group A tended to delve deeper into statistical approaches, but not cover as wide a range of subjects. Group B, on the other hand, covered a much broader set of issues, but did not delve as deeply into statistical approaches.

Table 1.1 Objectives of the first PATH Workshop focusing on retrospective analyses.

- review hypotheses framework developed for meeting;
- develop specific approaches for testing stated hypotheses, and assess data currently available to apply these approaches (harmonize hypotheses, methods and data);
- develop approaches for testing both life-stage specific hypotheses and aggregate hypotheses encompassing the complete life cycle;
- work out methods of integrating results of hypothesis tests at different levels of analysis;
- **synthesize ideas into a Data Analysis Plan for retrospective analyses**;
- assign tasks, deliverables, and deadlines; and
- establish dates and protocol for exchange of preliminary results.

Table 1.2: Summary of workshop agenda.

Tuesday, October 17th

Morning

Introductions; PATH and Workshop 1 objectives; agenda; logistics (David Marmorek)
PATH and NMFS Management Decisions (Chris Toole)
NPPC Perspective (Chip McConnaha)
Tribal Fisheries Perspective (Earl Weber)
Independent Scientific Group (ISG) Activities and Perspectives (Jim Lichatowich)
Stocks of concern; Indicators of stock health (Marmorek)
Principles of Hypothesis Formulation; 3-Level Hypothesis Framework (Marmorek)
Level 1 and Level 2 Hypotheses (Chris Toole)
Overview of Preliminary Level 1 and 2 Analyses (Charlie Paulsen)

Afternoon

Overview of Preliminary Level 1 and 2 Analyses: Spatial/Temporal Contrasts in Trends (Howard Schaller)
Bayesian Framework for Level 2 Analyses (Rick Deriso)
Level 3 Hypotheses (David Marmorek)
Example of Level 3 Analysis: Flow, Migration Speed and Survival (Al Giorgi; Jim Anderson)
Example of Level 3 Analysis: Pre-spawning Survival (Charlie Petrosky)
Categorical Regression Trees for Fish Habitat Assessments (Danny Lee)

Evening Session

Cleveland 4 Seattle 0

Wednesday, October 18th

Charge to Subgroups

- develop analytical approaches and potential data sets for Level 1 & 2 hypotheses first, then address Level 3
- critical questions:
  - What statistical procedures, data sets, stock indicators?
  - How to break up historical period into time slices?
  - What sensitivity analyses to critical assumptions?
  - How to deal with challenges?
  - How will results provide useful input for key management decisions?
- work out logical sequence
- decide on compromises needed to hypotheses in view of data problems
- assess how level 1 and 2 should Abound@ results of level 3 (how to integrate results)
- keep track of weaknesses of current information and required research, monitoring, or experiments
- use of existing models
- input of retrospective analyses into development of adaptive management framework

Subgroup Discussions for remainder of day

Thursday, October 19th

Subgroup Presentations and Discussion (by level of hypotheses)
Bayesian Belief Networks as alternative to MLE/Bayesian Approach (Danny Lee)
Synthesis/assignment of Tasks

- work teams
- dates for delivery of work products
- means of data exchange
- scheduling of subsequent meetings

ADJOURN at 1:30 p.m.

Table 1.3: List of participants.

Agency/Group	Name	Subgroup
ODFW	Howard Schaller Ray Beamesderfer	A B
COE	Chris Pinney	A
CRITFC	Earl Weber	B
IDFG	Charlie Petrosky	B
BPA	Jim Geiselman	B
NMFS	Chris Toole Brian Brown Steve Smith John Williams	A B A B
NPPC NPPC - ISG NPPC - ISG	Chip McConnaha Jim Lichatowich Phil Mundy	A B B
WDFW	Tom Cooney Olaf Langness	A B
CBFWA	Paul Wilson	B
SRP	Larry Barnthouse	facilitator, B
ESSA	David Marmorek Dan Bouillon Ian Parnell	facilitator, A recorder, A recorder, B
	Rick Deriso	A
UC Davis	Lou Botsford	B
SFU	Randall Peterman	A
USFS	Danny Lee	B
PER	Charlie Paulsen	A
DCC	Al Giorgi	B
U.Wash.	Jim Anderson	A

Table 1.4: Workshop ground rules.

1. Wear two hats:
   a) Creative brainstorming to generate options.
   b) Critical thinking to select best ones.

2. Be hard on the problem, easy on people.

3. Not feasible to resolve decade-long disputes in 2 days.
   Is feasible to:
   a) clarify areas agreement / disagreement
   b) format to organize evidence for / against hypotheses
   c) design analyses to explore implications
   d) design novel approaches.

4. Open process share data, statistical routines, papers.

5. Design multiple approaches with collaborative teams; peer review internally and externally.

6. Focus on reduction in uncertainty, not winning argument for past position.

7. Iterative process try things and see what happens.

Table 1.5 Description of the three types of hypotheses considered in PATH. These three levels are a continuum: some hypotheses and associated analytical methods are intermediate between Levels 1 and 2; others bridge between Levels 2 and 3.

Level 1 Hypotheses

- exploratory analyses to explore differences in trends of standardized abundance, productivity, and associated variance in species, stocks and periods relevant to Snake River stocks.
- identify differences in trends among species/stocks, but do not propose mechanisms to explain those differences.
- may suggest L2/L3 hypotheses
- may Ascreen@ hypotheses; limit L2/3 possibilities

Example H: Snake River spring chinook stocks exhibit a different trend in productivity than other northwest Pacific stocks.

Level 2 Hypotheses

- explain trends in stock indicators in terms of spatial contrasts and temporal changes in:
  - a) survival during particular life history stages; or
  - b) pressure/stressor indicators associated with survival in one or more life history stages.
- do not propose specific mechanisms to explain life stage changes, but **must** provide inferences on where to focus management actions.
- two types of Level 2 hypotheses: 1) life stage composite hypotheses; and 2) life cycle aggregate hypotheses.

Example H: Changes in survival during juvenile and adult mainstem migration correspond to changes in overall productivity and abundance, while changes in survival during other life stages do not. (Life cycle aggregate hypothesis)

Level 3 Hypotheses

- explain life-stage specific mechanisms associated with observed trends, for each life history stage identified at Level 2 as closely associated with the population trends.
- for Snake River stocks, Level 3 hypotheses link directly to key management decisions.
- focus on the quantitative strength of hypothesized effects.

Example H: Decrease in water velocity during spring one mechanism to explain trend in juvenile mainstem survival; certain minimum flows required to maintain sufficient mainstem survival.

1.3 Structure of this Report

Rather than structuring this report to present workshop discussions in chronological order, we have organized it around PATH=s three levels of hypotheses (Table 1.5). The three sections which follow summarize the initial plenary, subgroup, and final plenary sessions for each level of hypotheses. The report is very much a Awork in progress,@ a snapshot of ideas that are continually evolving. In keeping with the ground rules of the workshop, the brainstorming process sometimes generated ideas which though not feasible themselves, were useful for generating other ideas that were. We have made some attempts to incorporate clarifications developed since the workshop, but have not attempted to include all of the advances made since the meeting.

The subgroup discussions have been synthesized into a structured format that facilitates moving forward. This structure includes several place holders for information which was not provided at the workshop but needs to be developed as workgroups think through hypotheses and analytical methods in more detail. Thus there are several gaps in the description of hypotheses, analytical approaches, data to be used, alternative outcomes of analyses, and implications of these analyses for management decisions. Though considerable progress was made at the workshop, it is important that these gaps be gradually filled within the workgroups carrying out specific tasks. The retrospective analyses need to be completed by early to mid February 1996, so that the draft report on Retrospective Analyses can be completed by the end of February, 1996.

For those readers interested only in the conclusions of the workshop and future tasks, please refer to Sections 2.3, 3.3, 4.3 and 5, which summarize the sets of tasks proposed for the next three months of work.

2.0 Level 1 Hypotheses

2.1 Level 1 Plenary Presentations and Discussions

Level 1 hypotheses represent exploratory analyses to determine if there are differences in trends of standardized abundance, productivity, and associated variance among a wide array of Pacific northwest species and stocks over a period that is relevant to the condition of Snake River stocks. Hypotheses at this level seek to identify differences, but they may suggest hypotheses which could be more formally tested with a more detailed analysis of component measurements at a Level 2 or 3 representation (e.g. marine survival separated out). They can also help to Ascreen@ hypotheses to reduce the number examined in detail. The Level 1 representation, though extremely simple, has the benefit that many more data sets can be employed to address a variety of questions.

This section summarizes plenary presentations dealing with Level 1 hypotheses and synthesizes comments made during and after these presentations. Chris Toole presented a summary of the PATH group=s vision of what Level 1 analyses represent. Charlie Paulsen presented the results of his preliminary analyses of escapement trends and correlations with climate and upwelling indices, time lagged escapement and number of dams. Howard Schaller presented preliminary results of analyses on run reconstructions for several chinook stocks upstream and downstream of the Snake River dams. These presentations often included both Level 1 and Level 2 material. Where appropriate we present Level 2 material in Section 3.1.

2.1.1 Level 1 hypotheses (Chris Toole)

Level 1 hypotheses explore possible differences in the trends of state indicators among populations: L1.1 consider all populations of interest; L1.2 classifies populations of interest by geographical region; L1.3 classifies populations of interest by geographical region and species; and L1.4 classifies populations of interest by geographic region , species, and life history characteristics. Table 2-1 provides examples of Level 1 classification variables.

Table 2.1: Example of Level 1 classification variables.*

Geography	Species	Life history characteristics
Snake River	chinook	ocean type
Mid-Columbia	sockeye	stream type
Lower-Columbia	coho	ocean migration
Coastal	steelhead	migration timing
Other	etc	etc

* cells do not necessarily correspond by row.

Potential problems with level 1 analyses:

- meaning of Atrend;@
- inferences from correlations;
- non-linear trends; and
- quality and comparability of state indicator data.

Each of these problems were discussed in subgroups.

2.1.2 Overview of Preliminary Level 1 and Level 2 Analyses (Charlie Paulsen)

Charlie Paulsen summarized the analyses included in Section 8 (Sections 8.1, 8.2, 8.3, and 8.4) of the Information Package. The two main results of these analyses are:

- there are a wide variety of trends, many of which are closely correlated with Snake River stocks
- many trends are closely correlated with ocean conditions.

Charlie suggested that much of the level 2 analyses will look like the figures in Section 8 of the information package (e.g. Figures 8-3, 8-4, 8-7, and 8-12). New results not included in the Information Package were also presented and can be found in Appendix B.

Charlie could not find a consistent pattern between stock abundance, the spring upwelling index, and a climate index, the North Pacific Index (NPI) (see Table 2 in Appendix B). He suggested this lack of pattern may present a problem for upstream/downstream comparisons because the explicit assumption for these analyses is that ocean survival for upstream/downstream stocks is the same (for related discussion on this topic see Section 3.1.2.). Charlie noted that prior to 1948 there is no upwelling index data.

Comments on Charlie Paulsen's Presentation:

Implications of the lack of pattern:

- The lack of pattern may be due to only using escapement data. It would be preferable to have catch and recruitment data as well, so that ln(R/S) could be computed.
- The lack of pattern presents a problem not just for upstream/downstream comparisons, but for comparisons between neighbouring streams as well. (e.g. Imnaha/Marsh Ck). CONTRASTING VIEW: The lack of pattern simplifies level 2 MLE analyses. Since there are no confounding factors and one can assume everything behaves independently.

Methodology/Statistical considerations:

- Could there be an over-parameterization of the model? SAS only chooses four or five variables**C**the likelihood of getting one indicator significant is greater than the likelihood of getting four or five indicators significant.
- We must be careful in the interpretation of correlations**C**the Aocean@ indices are not truly ocean indicators, but really broad scale climatic factors. Which lags are truly due to ocean factors and which are not? Climatological work suggests there is a link between ocean and land conditions but the relationship, although statistically significant, is not terribly strong. How do we separate out the continental effect of ocean indicators? One possible method might be to use both types of indices in the same regression and see what=s chosen.
- The analysis is a low powered test of the hypothesis that there is covariation among stocks. If covariation does exist and we don=t consider it in Level 2 analyses, this will decrease the discriminating strength of Level 2 approaches.
- Enumeration methods affect both the mean and variance of escapement estimates. Tschaplinski and Hyatt (1991) compared several different enumeration techniques (Figure 2.1). Their work may be useful for assessing the effect of changes in enumeration methods, and filtering down the NMFS data set to acceptable time series.

Figure 2.1: Array of population estimates generated by various assessment techniques applied to Clemens Creek spawning grounds for Henderson Lake sockeye in 1989. Petersen mark-recapture estimates are provided with " 95% confidence limits. Source: Tschaplinski and Hyatt 1991.

2.1.3 Spatial/Temporal Contrasts in Stock Recruitment Patterns of Snake and Columbia River Spring/Summer Chinook Populations (Howard Schaller)

Howard Schaller presented results of analyses based on run reconstructions for several upstream and downstream Columbia and Snake River spring-summer chinook populations. The results provide insight spatial and temporal patterns of stock recruitment relationships. Howard passed out a draft manuscript (Petrosky *et al*, abstract Appendix D) with descriptions and standardized methods for the approach used in the analyses. The manuscript is currently an incomplete draft as the authors hope to include a number of Washington stocks in their analyses as well. Olaf Langness noted that Washington uses different enumeration methods (fish/mile rather than redd/mile), but other stocks could possibly be included (e.g. stocks for Wind River and the Klickitat between Bonneville and McNary). Upper-Columbia stocks which may be developed in the future are the

Methow, Entiat and Wenatchee. Data is hard to find because most Washington rivers are managed as fall chinook (this is also the case for Oregon).

For these run reconstructions, spawners equal the total number of females and males which produce recruits and are derived from redd counts expanded for fish/redd. Recruits to the Columbia River mouth are estimated based on redd counts scaled up to account for ocean and river harvest, upstream conversion rates, and pre-spawning mortality. Merely using spawner to spawner estimates would not take into consideration temporal variation in these three factors, particularly harvest and conversion rates. Upstream conversion rates are obtained from the Technical Advisory Committee (TAC). The complete list of assumptions used to estimate recruitment to the mouth of the Columbia is found in the manuscript document handed out at the workshop (Petrosky et al, abstract in Appendix D). Escapement data may be affected by changes in enumeration techniques and index areas.

Graphs of ln(R/S) vs S and Obs(R/S)/Pred(R/S) were displayed for the different stocks, broken up into three time periods: 1) Pre-1970; 2) 1970 - 1974 (Snake River dam construction); and 3) post - 1974. Productivity functions used to predict (R/S) were fitted to pre-1970 data. These graphs are presented in Appendix C.

Results:

- The productivity of Snake River spring-summer chinook declined and became more variable since Lower Snake River hydropower development.
- The productivity of John Day spring-summer chinook declined and became more variable since construction of the John Day dam, though there has been some recovery since the dam was screened.
- The historic productivity of South Fork Salmon River chinook, which suffered severe habitat degradation in the 1960s, was lower than in other Snake River populations.
- The pre-development productivity of most Snake River populations closely match recent productivity of the Warm Springs spring chinook, which have not been exposed to the same high levels of density-independent mortality.

General comments made by participants are summarized below.

Comments:

- Confidence intervals unavilable for redd counts; no good study has been done on this topic yet. It is important to know the relationship of redd counts to abundance because recruitment numbers are also based on redd counts. Some work is available comparing wier counts and redd counts for the Lemhi, Crooked and Upper Salmon rivers, which shows a good correspondence between these two measures (Charlie Petrosky, pers. comm.). On the Wenatchee, however, redd counts appear to underestimate abundance relative to dam counts, and redd counts are therefore not used for this river (C. Paulsen, pers. comm.)
- Estimating recruitment to the mouth of the Columbia may cause forward simulations of Poverty Flat stock to underestimate future stock sizes.
- Incidental harvest could be significant - high incidental mortality
- The John Day Dam was not screened until 1985/86. The turbines are on the south side of the Columbia River and chinook emigrating from the John Day cannot make it across the river away from the turbines.
- Poverty Flats showed no linear trend in ln(R/S) vs S during the historic period. This may be due to a major habitat impact in 1963/64 resulting from a rain on snow event which led to siltation and an unravelling of the system in 1964/65.Conditions for Poverty Creek are considered to be better now. Some people were suprised that ln(R/S) was not below the replacement line more often. It was pointed

out that recruitment was to the mouth of the Columbia and that replacement may be different at the spawning ground. There may be a bias in residuals around the stock-recruitment curve due to not knowing stock specific harvest rates)

2.2 Group Discussions

2.2.1 Group A Level 1 Discussions

Hypothesis L1.1 (Page 5-1 of PATH Workshop 1 book) states AThere has been a similar trend in the state indicators for anadromous salmonid species/stocks that spawn in a variety of geographical locations in the Pacific Northwest.@ Group A suggested replacing this hypothesis with AThere has been a *similar pattern of change* over *time* in *stock indicators* among *chinook* stocks across the Coast and Columbia River.@ The group discussed each of the components of this hypothesis:

1. *Similar Pattern of Change*
   The group agreed that the stocks should be classified by the pattern of change over time, and not purely their trend, so that temporal variability would be appropriately considered in the classification of stocks. It is important to consider not only the direction of change, but also the magnitude of change, and the distribution of those changes through time. We discussed several different ways of doing this (see Pattern Similarity below).

2. *Time*
   Over what time period should trends be calculated? It is difficult to specify time periods, as it is not at all clear whether one should begin at the time the first of the Snake dams were put in, or the last, or some other measure that reflects their expected influence. There are also potential confounding influences; the last dam was installed in 1976, and 1977 is considered to be the time of a shift in the ocean regime from cool/wet/high survival to warm/dry/low survival (Jim Anderson, pers. comm.). It is probably best not to use or exclude data based on years thought to be important for one reason or another (e.g. changes in dams or ocean conditions), but rather to use all reliable data and let the analyses reveal the anomolous years or time periods. We are missing pre-1976 chinook data from Canada, as Fisheries and Oceans Canada did not release these to the consultant (LGL) who compiled the Canadian data for the NMFS database. The quality of the pre-1976 chinook escapement estimates from BC is very poor, but D. Marmorek and H. Schaller will investigate further.

3. *Stock indicators*
   It is preferable to use ln(R/S) as a stock indicator, since it reflects survival, the population characteristic which one would expect to change in response to dam influences, other stressors and ocean conditions. Here AR@ refers to recruitment to the most downstream dam (Bonneville). Using AS@ alone has the potential problems of not incorporating the effects of harvest, the mortality experienced by salmon on their return upstream, and year-to-year variability in age structure. The measure of AR@ removes both the effects of harvest and losses as fish move upstream beyond the mouth of the Columbia River (above Bonneville), and directly accounts for age structure. The advantage of using AS@ alone is that a much larger data set is available for comparisons across streams (i.e. n. 100 for S instead of about 10 for ln(R/S)). It may be possible to expand the number of stocks with estimates of ln(R/S), through: 1) adding in area-specific harvest estimates; 2) using running averages of escapement as a crude substitute for the effects of age structure in the population; or 3) applying a weighting scheme for some stocks which roughly approximates the age structure. The subgroup concluded that both AS@ and ln(R/S) should be used, but that the analyses should be compared for the NMFS data set and the index stocks data (i.e. S_{NMFS} vs. S_{INDEX} vs. $\ln(R/S)_{INDEX}$).

4. *Chinook*

The group felt that prior to February 1995, there is only enough time to deal with chinook, and possibly (though not likely) steelhead. The best data set is for chinook, followed by steelhead. There are long time series of R/S data for sockeye in some systems, but others have nothing. The group agreed that the first priority is to filter the Big Eagle data set down to wild stocks only, since many of these supposedly Awild@ chinook escapement numbers have hatchery influence. The second priority is to evolve consistent measures of escapement within each time series, since changes in methods could create artificial trends. Consistency among time series is not necessary, but methods of escapement estimation should be documented. It is perhaps worth including the method as an explanatory categorical variable in regressions as a test of whether methods are important in inflencing the direction and magnitude of apparent trends, or the variation around that trend. The group suggested forming a Data Evaluation Working Group (DEW) consisting of Charlie Paulsen, Charlie Petrosky, Howard Schaller, Ray Beamesderfer, Olaf Langness, Tom Wainwright, and Robert Kope (NMFS).

Standardization of Stock Indicators

We agreed to standardize the spawning counts in two ways:

1. to assess changes in direction, compute $[(Y_i - \overline{Y}) / s]$, where s is the standard deviation, to standardize all of the measures to a normal distribution with mean=0 and variance=1; and
2. to assess changes in magnitude, normalize by $[(Y_i - \overline{Y}) / \overline{Y}]$, so that all time series would have the mean=1, but would differ in their variance.

Standardization would be done for both types of indicators, AS@ and ln(R/S).

Pattern Similarity

The main issues are: What stock attributes are of greatest interest? How should these attributes be compared to assess their similarity in space and time? The stock attribute of greatest interest is survival, best estimated by ln(R/S), to assess whether there are common trends or patterns in survival among stocks. Numbers of wild spawners, S, is also of interest, but is less preferred due to the confounding effects of harvesting. The group considered cluster analysis on time series data to be a worthwhile approach for comparing attributes, as well as simple trend regressions. The potential attributes of interest for clustering streams include:

a) ln(R/S) alone;
b) standardized S alone;
c) standardized S and ln (R/S) jointly; and
d) residuals from the regression of ln(R/S) vs S (a measure of the pattern of recruitment anomalies).

In addition to cluster analyses, the above attributes can also be used for analyses to compare trends in indicators in the upper Snake with other regions, as already completed for S by Charlie Paulsen and Charlie Petrosky for Spearman correlations with year (Section 8 of Workshop 1 handout). Three measures of change over time were considered: Spearman and Pearson correlations with year, and a simple measure of the % change (e.g. $Y_{1990-1995}$ vs. $Y_{1950-1955}$).
At the workshop, we considered two types of cluster analyses:

1. cluster analysis based on both Spearman and Pearson correlations, (i.e. clustering first those streams which had the highest correlations); and

2. for the spawning data only (not ln(R/S)) calculate the change in each year (i.e. y_2-y_1, y_3-y_2, etc.) creating about 30 first order differences. These would reflect the change in state, as opposed to the state itself. We would then performing a cluster analysis on the streams, each of which would have these thirty attributes.

Lou Botsford commented after the workshop:

> A problem with the correlation analysis proposed for the Level 1 analysis is that it will lump correlations on a variety of time scales. In particular, as proposed it will not differentiate between correlations that result from one series co-varying with another from year to year, and one series co-varying with another in a long-term, linear trend. The effect of long-term trends will be removed by the proposed first differencing, but the results are not easy to interpret biologically. I suggest that the correlations be computed between the series both with and without the linear trend removed. The cluster analyses could then be done on the correlations, the trends and the detrended correlations.

In addition, annual changes are hard to interpret in salmon populations, given their 4-year life cycle. Therefore, a post-workshop meeting on Nov. 16-17 concluded that the first differencing approach may not be necessary. The residuals approach described above will remove density dependence from the stocks, more effectively getting at the question of annual variation in survival above/below that expected. Trends in these residuals are of more relevance than the temporal pattern of residuals around a trend line.

Altogether there are 10 sets of analyses (2 stock indicators * 2 types of standardization * 2.5 types of similarity groupings) not including the variety of clustering algorithms. There is a need to standardize the clustering rules. It is proposed to play around with different methods, and see if a robust set of clusters emerge. For Level 2 analyses, a variety of multivariate approaches could be used on the clusters to assess what factors are correlated with the clustering pattern (e.g. ocean, dams, harvest). Group A briefly considered the use of category regression trees, as utilized by Danny Lee, but could not see how to use this given the fairly limited number of stocks and the fact that the dependent variables were not categorical in nature.

2.2.2 Group B Level 1 Discussions

Summary

Group B discussed the rationale for the Level 1 approach, the geographic scope for Level 1 analyses, the availability of data to test Level 1 hypotheses, and indicators of interest. While we outlined two analytical approaches, we did not finalize the hypotheses to be tested or the specific analytical methodology to be used. Group B proposed the formation of a Level 1 group to further define Level 1 hypotheses, pursue the acquisition of data and synthesis of information from studies, and to establish tests for the hypotheses. The following text is a synthesis of the comments and discussions from the Group B Level 1 workshop session, not necessarily in chronological order.

Rationale for Level 1 Analyses and Appropriate Scope

In general, Group B found it difficult to focus on the lower Level 1 questions and kept drifting towards preliminary Level 2 (high Level 1) analyses/questions. Several participants were keen to move on to the Level 3 management questions. We first defined the function of Level 1 questions. Level 1 analyses look at large scale comparisons between regions and species (Table 2.1). The scope of the Level 1 questions is broad because large-scale patterns provide a context within which to interpret finer-scale change. For example, changes in ocean conditions may amplify or offset human influences on stocks. Such an example was provided by Jim Anderson in his plenary presentation. He introduced the hypothesis that there may have been a masking of the effect of dams in the past by good ocean conditions. Conversely, dam impacts may be exacerbated with poor marine survival. This is one context which make Level 1 analyses relevant to Levels 2 and 3. Knowing ocean survival fluctuations can help to both Apartition the blame@ for historical changes and evaluate the potential

effectiveness of restoration efforts (i.e. will marine problems overwhelm future freshwater survival improvements?). We also use the Level 1 analyses to capture more fundamental ideas, even if they are obvious, so we can present the context of Columbia River changes to outside parties (i.e. other interest groups). Level 1 hypotheses move from a global outlook to focus on the Snake River and ask the question: AIs there something unique about the Snake River stocks?@

Table 2.1: Bound of the Level 1 hypotheses (from PATH Workshop document).

Hypothesis L1.1	Comparison of all species/stocks
Hypothesis L1.2	Comparison of species/stocks spawning in different geographical regions
Hypothesis L1.3	Comparison of species spawning in different geographical regions
Hypothesis L1.4	Comparison of species with similar life history characteristics spawning in different geographical regions

We noted that preliminary analyses in Section 8.5 have already begun to explore Level 1.3 and 1.4 hypotheses. Charlie Petrosky has used the results of Charlie Paulsen's preliminary analyses and started grouping stocks by geographic area and life history type. So far, however, nothing has been done at the level of hypotheses 1.1 and 1.2.

Defining the Geographic Scope

To begin structuring the Level 1.1 and 1.2 analyses we had to bound the term APacific Northwest.@ To be more global in our outlook we decided to expand the spatial scale of stocks/species considered in Level 1.1 analyses to include those from Alaska to Oregon (including B.C.). The rationale for doing this is: 1) there appears to be a north-south pulsing in ocean productivity (Francis 1994); and 2) the Gulf of Alaska is a common feeding ground for some of the species and stocks. Measures of stock performance should include catch and escapement data as well as size-at-age. Stocks of interest should include coho, sockeye, chinook for both wild and hatchery stocks. We will need more data to encompass the larger geographic scope and number of species. Potential new sources of data are listed below.

Charlie Paulsen=s preliminary analysis limited the geographic scope based on availability of long time series. With the data he had, he looked first for natural stocks, then at mixed managed stocks. The criteria for selection was a long enough historical time series to go across the time periods of interest (approximately 10% of NMFS database stocks). He was also trying to match up with Ice Harbour dam counts. Other data for sockeye was too preliminary for use in his analyses. Additional sockeye and coho data could be used for further Level 1 analyses. He had problems finding stocks in B.C. (Canadian stocks) going back far enough due to a reticence by DFO to release poor quality data. Olaf Langness mentioned that additional data on coastal stocks along Washington and Oregon are probably ready now.

Additional Data Sources

Could we do anything different from what Charlie Paulsen did within the time available before February 1996? To expand the geographic scope of Level 1 analyses we require more data than we currently have.

Data exist for some stocks in Alaska and British Columbia. There are also studies available relating hatchery and wild stock characteristics to ocean conditions. Some potential sources mentioned by Phil Mundy are:

- Alaska - Bristol Bay: trends, variability in production as a function of ocean indicators
- Alaska - Cook Inlet: some, not much
- Alaska - Prince William Sound: Pink Salmon productivity related to zooplankton, oceanographic indicators
- Alaska - S.E. Alaska: a number of stocks with detailed escapement
- Alaska - Kodiak Island: salmon system (from early 20s, weir counts, age composition)
- British Columbia - Skeena River: sockeye escapements from the late 60s on.

As stated in the Information Package, Level 1.1 and 1.2 hypotheses are interested in all stocks, including hatchery stocks. Trends in escapement in hatchery stocks, however, may be strongly affected by year-to-year changes in hatchery operation. Most data available are for species of economic importance. Sockeye data are of interest in the Columbia system one sockeye stock is extinct and two are of concern.

Analytical Approaches for Level 1 Hypotheses

Group B considered two analytical approaches: 1) data acquisition and analysis; and 2) syntheses of existing studies. Each of these are described below.

Data Acquisition and Analyses

Data Available

- Paulsen's data set (NMFS Big Eagle database + BRWG data) now more complete for other species
- new NMFS data
- NMFS trend counts from southern California to the Washington/British Columbia border.
- PSC data geographic trends in PSC indicator stocks
- hatchery data
- Alaska Fish and Game Reports (see above)
- NMFS Coast Wide Status Reviews (not B.C., not Alaska) prepared for listing under ESA, lumped by ESU's (coho, sockeye, steelhead, chinook) not completed yet...
- CIS project
- British Columbia - PSC chinook technical committee
- CWT data from hatchery fish

Indicators of Interest

- size-at-age additional Level 1.1 hypotheses would look at size trends (e.g. Level 1.1c)
- age structure
- catch, catch + escapement
- ocean survivals estimated from CWT data for hatchery fish

Analytical Methodology

- For each data set compute linear trends (use linear trends: Pearson correlation with time, regression, other linear least square methods) and then perform statistical comparisons among different categories of stocks.
- Look at trends for different time periods, possibly using an incremental approach (e.g. 10 year steps).
- Use moving averages to take the noise out of redd counts prior to regressions.

There are many options, be selective to avoid problems.

Time Periods of Interest:

What are reasonable time periods to examine?

- Break out data by changes in oceanographic regime shifts. Francis and Hare, 1994 (see also Hare and Francis, 1995)documented these most clearly, also Ebbesmeyer et al. 1991.
- Before, during, after Snake project construction.
- Look for events affecting a wide geographic scale, for example after the completion of the Mica and Libby dams in 1973 there was a 40% decrease in flow in the Columbia. This is linked to changes in ocean salinity off the Oregon Coast.

Analytical Concerns:

- Future analyses should consider problems with the effective number of degrees of freedom, Charlie Paulsen ignored these in his preliminary work.
- There is a lack of clear hypothesis testing in the work to date.
- Should keep track of probability of fit.

Syntheses of Existing Studies

Even if data acquisition/analysis proves infeasible, much could be learned by a synthesis of previous analyses of the effects of ocean conditions on productivity:

- Brian Biggle=s work
- Alaska Fish and Game reports (see above)
- work by Francis, Ebbesmeyer (see above)
- Beamish and Bouillon (1993)

Comments and Concerns Arising From Level 1 Discussions

These comments are synthesized from concerns voiced throughout the Level 1 discussions indicating opposition or discomfort with the general group consensus. Due to time constraints these concerns were not pursued by the group in detail. These comments may be useful for prompting discussion of concerns in future working group sessions.

There was considerable discussion on the geographic scope. Some participants felt that expanding the geographic scope too far north will confuse things and lose the focus on Snake River stocks. Diverse trends among stocks in different regions may be difficult to explain. For example, what if another area without dams shares the same trends as the Columbia stocks? You wouldn't then say dams haven't had an effect in the Columbia because the other area did same thing without dams. Others felt that it was useful to know, for example, that ocean conditions show a decline in productivity along British Columbia, Washington, Oregon, but an increase in Alaska. Diving into the question of interactions between the freshwater and ocean environment requires specific hypotheses, as there are many complexities. For example, moving south to north you generally go from damaged freshwater habitat to more pristine freshwater habitat. The oceanographic effect also has a north-south axis., so there is a complex overlap of freshwater and ocean effects. The group was reminded that Level 1 was envisioned to simply see if there are large scale geographical patterns in temporal trends. That in itself is useful irrespective of freshwater/ocean interactions.

Other comments covered a variety of topics:

- preliminary analyses (Section 8 - PATH workshop document) show some selectivity in choice of species—was this too selective?

2.3 Analysis Plan and Tasks

Table 2.2 shows the Level 1 tasks agreed to in the Workshop 1 plenary session, and finalized by the PATH Planning Group.

Table 2.2: Level 1 tasks.

Task #	Description	Completion Date	People Responsible
Level 1 Hypotheses			
1.1	**H: There is a similar pattern of change over time in stock indicators among chinook stocks across the coast and Columbia River.**	951019 Oct. 19/95 (!)	
1.1.1a	Determine the sources of Canadian wild chinook data pre-1976 (contact Riddell or Hyatt at DFO, Nanaimo).	951103 Nov. 3/95	Marmorek, Schaller
1.1.1b	Organize a Data Evaluation Working Group (DEW Group) to determine which wild chinook stock time series are most reliable. Evaluate NMFS escapement data by classifying quality of escapement estimates, and document changing methods over time.	951129 Nov. 29/95 First Mtg.	DEW Group = Paulsen*, Petrosky, Schaller, Langness, Beamesderfer, Robert Kope, Tom Wainwright
1.1.1c	Complete evaluation of chinook data.	951222 Dec. 22/95	DEW Group
1.1.2a	Meet to discuss correlation / cluster / factor analysis approaches. [See **Task 2.2.3**]	951116 Nov. 16/17	Paulsen, Schaller, Marmorek*, Deriso, Botsford
1.1.2b	Prototype correlation / cluster analyses of time series in both NMFS database and set of index stocks with population reconstructions. Compare results using S_{NMFS}, S_{INDEX}, and $\ln(R/S_{INDEX})$. Also assess different standardizations, and clustering algorithms. Feed ideas on discrimination of clusters into **Task 2.1.2.**	951129 Nov. 29/95	Paulsen (NMFS data), Schaller (*, Index data), Botsford (review approach)
1.1.2c	Complete the correlation / cluster analyses of time series of NMFS chinook data and ln(R/S) data for index stocks.	960115 Jan. 15/96	Paulsen, Schaller*, Botsford
1.2	**Influence of climate on indicators of stock abundance for Pacific salmon as they might relate to survival of Columbia River chinook salmon.**	951019 Oct. 19/95 (!)	
1.2.1	Assemble/review existing studies on the relationship between stock indicators and climate ° generate possible integrative indicators for **Task 2.1.1b**	951129 Nov. 29/95	[Mundy], Anderson*, [Lichatowich], Peterman (pass on data), Bouillon
1.2.2	Carry out a broad-scale analysis of the influence of climate on wild and hatchery chinook and sockeye from Oregon to Alaska. Data from the PSC, Alaska Fish and Game, and Northern California.	960130 Jan.30/96 (if required)	[Mundy], Anderson*, [Lichatowich], Paulsen, Botsford

2.4 Implications of Analyses for Management Decisions and Other Levels of Analyses

Task 1 helps to place in an appropriate context the changes that have occurred in the Snake and Columbia River basins. It will provide an objective assessment of the similarities in the patterns of change over time among different groups of stocks. With the aid of higher level analyses, this will help managers to differentiate between

the patterns of change that may have been caused by human activities, and therefore potentially amenable to mitigative actions, and those activities which are the result of natural forces beyond human control. By generating different clusters of stocks that show similar past behaviour, the analyses under Task 1.1 will also potentially aid the design of adaptive management experiments, using the stock clusters as sources of Areplicates@ to which different treatments could be applied. Third, the Level 1 analyses provide a reference point for analyses at Levels 2 and 3. By determining which groups of stocks have shown similar past behaviour, the analyses in Task 1.1 set the stage for assessing the potential factors that result in one type of stock trend or another. Level 3 analyses of specific life stages must be consistent with the overall historical patterns observed in the Level 1 analyses.

Task 1.2 (the influences of climate on indicators of stock abundance) provides managers with an assessment of the systematic effects of climate over time and space. This allows managers to gain some perspective on when climatic effects may have undermined mitigation efforts, had no net effect, or helped to increase their effectiveness. Retrospective analyses of climate effects will help to set the stage for prospective analyses of climate influences on the effectiveness of future management actions. Changes in climate can affect survival during all life stages. Reviews of existing studies documenting the specific changes that have occurred in marine and freshwater environments during particular climatic regimes will help to focus attention on the life stages which were most likely affected at different time periods historically. This may provide some inferences on the likely future course of stock indicators under different climate regimes, and the potential effectiveness of different actions to restore salmon stocks.

3.0 Level 2 Hypotheses

3.1 Level 2 Plenary Presentations and Discussions

Level 2 hypotheses seek to explain trends in stock indicators (i.e. standardized abundance, productivity, or associated variance) in terms of spatial contrasts and temporal changes in: a) survival during particular life history stages; or b) pressure/stressor indicators associated with survival in one or more life history stages. Hypotheses at this level do not propose specific mechanisms to explain changes in survival during each life stage, but must potentially provide inferences on where to focus management actions. There are two types of Level 2 hypotheses: 1) life stage composite hypotheses; and 2) life cycle aggregate hypotheses. These two terms are explained in detail in the Information Package. The plenary presentations summarized below are informal discussions intended to clarify the rationale for the Level 2 approach and provide an opportunity to discuss preliminary results of the more complicated analytical methods already being used as well as potentially useful analytical methods.

3.1.1 Level 2 Life Stage Specific and Aggregate Life Cycle Hypotheses (Chris Toole)

Introduction:

Chris Toole summarized the Level 2 life stage specific and aggregate life cycle hypotheses in Section 5 of the Information package. Much of the group=s attention focused on the aggregate hypotheses summarized below in Table 3.1. Chris Toole pointed out that A and B do not represent even a small portion of the possible hypotheses. The PATH planning group requested submissions and A and B were the only two submitted. SP1 - all dams, SP2 - dams and other things; time periods of interest are determined by the underlying hypotheses. SP2 has many alternatives.

The listed hypotheses are examples, but they are also of primary significance and characterize the range of debate. A method to distinguish between these two hypotheses would be progress.

Table 3.1: Aggregate hypotheses.

A) L2.All.SP1 (Aall dam=s fault@)	**B) L2.All.SP2 (Anot all dam=s fault@)**
1950-1969 brood year (dam building) -no significant trends	1950 to 1966 brood years - trend related primarily to FSR and somewhat to JMC
1970 brood year to Present (Post dam era) -trend related to JMC, UP	1967 to 1979 brood years - trend related to FSR, JMC, EOS (harvest and hatchery effects), UP, PS
	1980 to present brood years - trend related to EOS, impacts in other life stages reduced to due habitat improvement, passage improvements, decreased hatchery output.

Time Periods:

Chris Toole discussed the rational for splitting time series into time periods.

The SP1 aggregate hypotheses propose that overall trends are the fault of the dams. The rationale for this is that: 1) though habitat and hatchery effects have affected some stocks, both affected and unaffected stocks have shown similar declines in productivity indicators; and 2) both ocean and freshwater harvest was far too low after 1969 to have caused observed declines. SP1 therefore looks at two time periods. The first time period (1950-1969) is prior to the completion of the last Snake River projects - the dam building era on the Snake River. No trends are expected during this time period. During the period 1950-1966 most dams were in place. The second period (1970-present) covers the period when all dams became operational - the post dam building era. While there were dams in place prior to 1969, the completion of the Snake River projects was the ›straw that broke the camel=s back.= Trends during this period are caused by dams and affect the JMC and UP life stages.

The SP2 aggregate hypothesis does not propose that dams are entirely responsible for trends, but rather that trends are due to the interaction of many factors. Trends prior to 1966 are primarily habitat related, with some JMC effects due to mainstem Columbia dams. During the period 1967-1979, trends are due to effects in all life stages; from 1980 on there is an improvement in stressor indicators, but populations are still dropping, so population are affected mostly by ocean conditions.

It was noted that there were significant anthropogenic effects prior to 1950, the analysis of SPA and SP2 will miss these.

Other Concerns:

Information package concerns are noted on pg. 5-6 and 5-7.

- one concern reiterated is delay in effects of stressors (e.g. lots of impacts outside of JMC which impact survival in JMC). These delays mean that: 1) patterns of change in one life stage=s survival cannot be ascribed primarily to stressors within that life stage; and 2) analyses relating stressors to overall escapement trends may be confounded by highly correlated stressors.
- what is the decision criteria when you assign probabilities to alternate hypotheses? (workshop2). Need to decide before you do an analysis to distinguish among competing alternatives what level of differentiated support is sufficient to choose one option over another.
- what is the relationship between L1 and L2? Does L1 constrain L2? We need to look at whole the life cycle and see if clear trends emerge.

3.1.2 Maximum Likelihood Estimates and Bayesian Analysis (Rick Deriso)

Rick Deriso summarized his MLE approach, described in Appendix D of the Info Package, and the results of preliminary tests of this approach.

Method:

Rick Deriso clarified some of the details of the MLE method:

Different indices have different variances. If you have multiple indices of adult abundance you would use all of them and not just choose the ›best= one.

One thing usually not estimable are the λ=s (the ratios of the variances for the different indices); these usually must be specified externally and are better estimated via a sensitivity analysis. The user specifies the ratios of variances; the model estimates one of the variances.

The output are posterior probability distributions for parameters of interest (e.g. in-river mortality).

(OH - in river mortality estimations)
(OH Year effect (delta parameters)

Testing:

The only way to see if something works is to set up a dummy data set and run analyses using these data, then modify assumptions and do the analyses again. You repeat this process until you understand the behaviour of the estimation procedure. The next step is to run Monte Carlo analyses with real data.

Some test results are presented in Appendix D of the Information Package, running over ten simulated years for six simulated stocks (two down-river, two mid-river, two up-river). Estimates fluctuate around the true values. Bayesian posteriors would show a wide band. Rick also simulated a sinusoidal year effect and tested how well the framework detected it.

Results indicate that: 1) year effects in recruitment (e.g. due to ocean conditions) can affect the estimates of passage mortality (the two parameters m and ε can trade off against each other); and 2) there is a need to do a sensitivity analysis of the effects of assumed measurement errors (i.e. variance ratios (λ)).

We need more lower river stocks to improve the resolution of parameter estimates.

Parameters:

Participants discussed how the various estimated parameters should be incorporated. The main output of this approach is probability distributions for m, a, b, and ε (where b is the habitat factor (Ricker carrying capacity), a is the production factor, m is the in-river passage mortality, and ε is a pure process error term).

It was noted that parameters may covary. For example, the ›a= and ›b= parameters often covary - the estimates are not independent. Each stock has its own ›b= term which represents habitat (carrying capacity), but does not vary with time (changing b with time and space over parametizes the model). If habitat is constantly degrading (carrying capacity is constantly declining) in upstream areas but not in downstream areas, the effect would show up in the ›m= term rather than ›b.= If habitat degradation appears in each stock in a given year, this would show up in the ›year= effect of the ›a= term (see Information Package Appendix D, pg 2 for a description of the year effect and its inclusion in the ›a= term). Sporadic habitat effects in space and time will probably get picked up in the residual variation (ε). This points out the need for careful testing of the method beforehand to aid in the interpretation of results obtained using real data. The success of the MLE method depends on not having ocean or carrying capacity effects that are very different between upstream and downstream stocks, so that one passage mortality effect (m) is distinguishable. One question raised was whether the recruitment should be estimated in the MLE or calculated beforehand (e.g. as in Petrosky et al (1995) report on index stockCsee Appendix D). This needs to be clarified by the MLE group.

While the example in Appendix D of the information package illustrates the inclusion of ›year= effects for the ›a= parameter, you can change which variable you want to have ›year= effects on, or have year effects on more than one parameter. However, as you increase the number of parameters with both space and time indices you make estimation more difficult to do and to interpret. It=s better to start with a simple structure so that you know what the method is doing.

During discussion an example of the inclusion of an ocean factor in the ›a: term was given: $a_{i,t} = (B_i * E_t) + a + \delta_t + \varepsilon_{i,t}$: where B is a regression coefficient and E is the environmental factor. However, this structure could lead to a confounding of the year effect (δ_t). It would be better to see if δ_t is a function of environmental factors outside the MLE framework. These supplementary analyses are the best possible link between Level 1 climate analyses and the Level 2 MLE framework.

Use of probability distributions of m for Prospective analyses:

The MLE method would generate probability distributions for life stage mortality (m) and how it might change over time. These probability distributions could then be linked to a forward simulation model and used to calculate returns to some pristine level (for which the endpoint must be specified).This is a key point of interest for prospective analyses in PATH workshop 2. Additionally, policy makers are very interested in the survival improvements required to restore stocks, and where these survival improvements should occur (i.e. which life stage).

3.1.3 Bayesian Belief Network (Danny Lee)

At the closing plenary session (Thursday, October 19) Danny Lee presented a possible way to link retrospective to prospective analyses. This method would modify of a Bayesian viability analyses model to pull together information from different sources. For example, the stochastic life cycle model (SLCM) has been recast in a Bayesian framework**C**a Bayesian Belief Network consisting of the following:

1) a causal network - the linkage between different components of the SLCM model;
2) belief vectors - to assign likelihood or probability to a range of parameters; and
3) probability distribution graphs for stock indicators of interest.

The network is Atrained@ to generate the probability distributions by running millions of Monte Carlo analyses to simulate the range of possible combinations of inputs. The same theory could be used in reverse to estimate parameters from data on stock indicators. Such an approach may be a stock specific way to apportion survival over different life history stages. Danny Lee agreed to write up some ideas on this approach.

3.2 Group Discussions

3.2.1 Group A Level 2 Discussions

Group A examined the Level 2 hypotheses on page 5-4 and 5-5 of the PATH Workshop 1 Information Package. The group proposed a slightly different representation of these hypotheses, namely:

> *Coastal, lower Columbia River, upper Columbia River, and upper Snake River salmon stocks have different distributions of survival over their life cycle.*

We want to assess whether there are differences in survival among these areas, and whether these differences are attributable to the presence of dams. Two different approaches were considered:

1. a multivariate analysis approach, such as multiple regression, which could use both AS@ and ln(R/S) as dependent variables and a variety of independent variables including number of dams, ocean data, harvest, and development industries; and

2. the Bayesian Maximum Likelihood Approach, outlined by Rick Deriso in Appendix D of the Workshop 1 Information Package..

The reason for converging to these two approaches is that the group felt there were not sufficient measures of survival for each life history stage to directly assess the relative changes in survival.

Multivariate Analysis Approach

Hypothesis: Trends in stock indicators are related to environmental stressors associated with one or more life history stages.

Relevance to Management Decisions:

The purpose of this analysis would be to demonstrate the relative influence of different types of stressors on changes in numbers of salmon over time. By describing the temporal changes in independent variables one may be able to infer which stressors may have had the greatest influence at different times historically. Charlie Paulsen suggested that a model of this type could assist NMFS in providing a rationale for restricting certain land use activities. There was some skepticism on the relevance of this analysis to management decisions. Chris Toole pointed out that it is not a high priority for NMFS to determine which habitat stressors are having the greatest effect on stocks, as both good and bad stocks are in decline. Even though this technique has the potential for showing the relative importance of different stressors, this is of less priority to NMFS than assessing some of the issues in the operation of the hydro system.

Analytical Approach:

The first approach discussed by the group was a multiple regression, using escapement and ln(R/S) as dependent variables, and a number of independent variables (ocean conditions, mining, dams, grazing, forestry, irrigation). Alternatives to this approach include the use of factor analysis, where each of the factors would be a combination of variables such as an ocean index, or index of land use change. Factor analysis and principle components analyses have the advantage that each of the factors are independent from one another. However if the factors or components incorporate mixtures of independent variables from different spheres (e.g. ocean and land use variables), they are very difficult to interpret. The cluster analysis approach described in Section 2.2.1 (clustering streams with similar patterns of escapements or recruits per spawner) could also feed into the multivariate approach. A variety of methods (discriminant analysis, principle components analysis) could be used to ascertain which factors best explain (in a statistical sense) the results of the cluster analyses.

Data to be Used:

It was agreed that prior to engaging in the major effort of documenting different types of stressors over time, we should first work on filtering down the number of stocks considered in the analysis, as described in Section 2.2.1 (i.e. removing hatchery influenced stocks and those with inconsistent methods of escapement estimation). There are a number of people who could be helpful in documenting the stressor variables:

- Danny Lee and Charlie Petrosky;
- Kim Jones of the Oregon Department of Fish and Wildlife Habitat Unit;
- EPA's Environmental Monitoring and Assessment Program (EMAP), Aquatic Program (Steve Paulsen, EPA Corvallis Laboratory);
- USGS National Water Quality Assessment Program (NAWQA) (Mark Munn, USGS, Tacoma, WA); and
- numerous groups who have oceanographic data (NMFS - data supplied by Chris Toole, Stephen Hare, Dan Ware (Pacific Biological Station, Nanaimo), Professor Ebbesmeyer (UW), Jim Anderson, and Dan Cayan (Scripps).

It was agreed that it made the most sense to conduct this analysis first in a prototype manner on the data sets for which we have immediate information, namely the Snake River, and lower to mid Columbia stocks. The report by Petrosky et al. (October 1995, see Appendix D) on spawner-recruit relationships has some useful histories of land development and habitat use in each of the basins. Documenting the history of land use over time, perhaps in a tabular form which shows changes over time in various land uses (e.g. mining, dams, grazing, forestry, irrigation), would provide a clear description that could be used for both the multiple regression and other multivariate approaches.

Potential Problems:

Potential technical problems with this type of approach include

- the difficulty in quantifying temporal changes in some stressor variables
- a lack of consideration of measurement error;
- not enough contrast in the key independent variables of interest (e.g. all the Snake River stocks would have dams in them for the last 20 years);
- with enough variables included in enough multiple regressions, some things will create significant correlations even though they have no causal connection;
- any regression approach will create co-linearity problems, such that one cannot uniquely attribute some of the variance in the dependent variable to variation in the independent variables;
- though the problem of co-linearity among independent variables could be partly dealt with through principle components analysis, there may also be difficulties interpreting what each of the components represent; and
- as a result of the above problems, considerable difficulty in drawing clear management inferences.

Next Steps:

1. prepare a clear proposal of the sequence of steps that would be completed (Charlie Paulsen);
2. conduct a reconnaissance of the data available on an extensive basis as well as for a smaller data set;
3. complete a prototype application on the smaller data set (i.e. index stocks); and
4. expand the prototype to a larger data set (filtered NMFS data set).

Bayesian Approach Using Maximum Likelihood Estimation (MLE)

Hypothesis: Distribution of in-river mortality of spring/summer chinook show a different magnitude and trend among lower Columbia, Snake River, and upper Columbia stocks.

The intent of this approach would be to estimate the probability distributions of in-river survival through space and time. As this is a Bayesian approach, one does not really specify an hypothesis for acceptance/rejection but rather looks at distributions of parameters of interest and the relative level of support.

Relevance to Management Decisions:

The Bayesian/MLE approach offers the potential for elucidating the most likely changes in passage mortality and other stock parameters (e.g. production, carrying capacity, annual recruitment variation) over time. The probability distributions of these parameters can be used for a number of purposes that are relevant to management: 1) upstream/downstream comparisons to show whether there are consistent differences in passage

survival between stocks that travel through a different number of dams; 2) assessment of factors which appear to influence all stocks in certain years, potentially relating to ocean regime shifts or changes in terrestrial climate; 3) a comparison of the predictions made by competing passage models (CRISP and FLUSH) vs. the most likely estimates for passage mortality; and 4) a general framework for assessing the value of new information in distinguishing among competing aggregate hypotheses.

Analytical Approach:

The MLE method estimates the incremental mortality due to downstream passage (m), by comparing upstream stocks with downstream stocks. It also estimates stock-recruitment parameters (a,b), Ayear effects@ on productivity that affect all stocks (δ), and changes in other sources of mortality (ε) (see Appendix D in Workshop 1 Information Package and Section 3.1 summary of Rick Deriso=s plenary presentation). One can use these estimates to examine the temporal and spatial changes in parameter distributions as functions of other factors (e.g. dams, climate). It was agreed to begin with the simplest model and then move to more complex models which consider separate year effects and separate stock effects.

Data to be Used:

There are some challenges in finding enough chinook of the same life history type to do the upstream/downstream comparisons. Spring/summer chinook are not separated from fall chinook in many coastal stock enumerations, and are not as common in downstream areas due to a scarcity of suitable stable habitat for rearing. Using hatchery spring/summer stocks would lead to confounding influences because of disease and variation in fish survival with the age of the hatchery, making this approach ill advised. There are, however, a small number of downstream stocks which could form a sufficient basis for comparison with the large number of upstream Snake River stocks. The group made the following conclusions with respect to stock groupings:

- The upstream Snake River stocks, which pass through eight dams, include the Minam, Imnaha, Marsh Creek, Bear Valley, Sulfur, Poverty Flats, and Johnson Creek. Though there are other upstream stocks which could have their data assessed (Losteen, Catherine Creek, Wenaha, and Upper Grand Ronde), these were considered to be of a lower priority than the lower Columbia stocks.
- The highest priority is to complete the reconstructions for the downstream stocks: Deschutes Warm Springs stock (extending the time series from 1975 backwards to 1969), Wind (back to 1970s), and Klickitat (back to 1960s). Reconstructions have already been completed for John Day (see Appendix C). The John Day stock goes through three dams, the Deschutes stock goes through two dams, and the Wind and the Klickitat stocks through only one dam. Depending on how stocks are grouped, we therefore have between two and four downstream stocks with Asimilar@ passage mortality for comparison with upstream stocks. (The Cowlitz and Kalama streams were also considered, but are not usable due to hatchery influence.)
- The John Day is an awkard Acontrol stock.@ It goes through the John Day (built 1968), Dalles (1957) and Bonneville (1938) dams. To include John Day as a downstream control stock, the analysis would need to exclude the 1969-1982 brood years, which were after dam construction but prior to installation of screens.
- The Wenatchee and Methow (mid- Columbia stocks) go through seven and nine dams respectively, and would also be of interest for spring chinook, though lower in priority than the downstream stocks. There is not much work remaining to complete the reconstructions for these stocks.
- These upstream-downstream data sets would also be of value for the more traditional upstream/ downstream comparison approach recommended by Group B.

The group agreed to put a priority on spring and summer chinook, as the Snake River fall chinook represent only one stock, with poor pre-dam data and a heavy influence of hatcheries. Fall chinook comparisons are possible for the mid-Columbia stocks. There are three mid Columbia fall chinook stocks (Hanford Reach (4

dams); Wenatchee (7 dams); Methow and Okanogan (9 dams)) which could be compared to two downstream stocks (Lewis River (0 dams), Deschutes River (2 dams)). The data for mid-Columbia fall chinooks are good to excellent, though the run reconstructions need to be reviewed to ensure harvest is considered appropriately. Though there are at least 3B4 fall chinook coastal stocks in Washington, these stocks have the problem that they do not share the same estuary as Columbia River stocks, resulting in a potential confounding of passage and estuary effects. Coastal stocks would need to back out harvest rates, which are about 40 percent for fall chinook.

In terms of tasks, the seven upstream stocks plus the mid to lower Columbia stocks can be used immediately in both the multivariate and Bayesian approaches. By the end of November it should be possible to include the Wenatchee, Methow, Wind, Klickitat and extended Warm Springs data sets in prototype analyses.

Potential Problems:

A potential problem with the analysis can occur if there are systematic up-river/down-river differences over time in ocean survival or productivity. If this occurs, it would confound the effects of the dams. Snake River spring chinook have *generally* similar ocean distributions, as they are all seldom found north of Vancouver Island. The Washington coastal fall chinook are quite distinct, being found as far north as northern British Columbia and southeast Alaska. Most of the group felt that though the Level 1 analyses completed by Charlie Paulsen did show differences in the ocean indicators most highly correlated with escapements, it did not constitute sufficient evidence that the *ocean distributions* and *ocean survivals* were substantially different. If all stocks differ somewhat in ocean survivals or productivity, this is not necessarily a problem (i.e. the variation gets assigned to ε in the framework). If there are systematic upstream-downstream differences however, there is a risk that the m parameter might incorrectly pick up some of this variation. Estimation of stock-specific productivities (a_i, where i=stock) using pre-1970 data (i.e. assuming m=0) is one way around this problem, but this approach has the risk that the mean year effect (δ) might get assigned to the a_i estimates.

A second potential problem is that the method will not detect all of the survival effects of the dams is on the estuarine conditions below Bonneville, since both upstream and downstream stocks would experience these effects. The method would only detect any supplementary effect of estuarine conditions on upstream stocks as compared to downstream ones (presumably due to weakened condition of the fish).

Next Steps:

The following are the next steps for the Bayesian approach:

1. continue the S-R reconstructions (Howard Schaller, Olaf Langness, Charlie Petrosky);
2. further develop the Bayesian prototype framework using the seven upper Snake stocks, John Day, and Warm Springs data (Rick Deriso);
3. convene a meeting to discuss the measurement errors in AS@ and AR@ (meeting held in mid November), including information comparing redd counts and weir counts from the Imnaha, Lemhi, Warm Springs, and Looking Glass Year streams;
4. review the complete structure of the Bayesian framework;
5. consider how to incorporate environmental stressors into the MLE approach (Charlie Paulsen, Rick Deriso);
6. complete a summary table of the brood age structure so that the proper maturation schedule can be incorporated into the model (Howard Schaller, Charlie Petrosky); and
7. add in pre-spawning, smolt survival information.

The main products of the Bayesian analysis would be:

1. The distribution of Am@ and other survival (ε) over time for each spring/summer chinook stock group (i.e. lower Columbia, Snake River, upper Columbia). This would include the latent effect of dam mortality throughout the life of the salmon (see Figure 3.1). The duration of estimates of m depends on data availability; they would certainly extend back to 1970. Pre-1970 calculations depend on the availability of data for downstream stocks.
2. Comparisons of these distributions of Am@ (#1) with predictions from CRISP and FLUSH.
3. Distributions of other spring chinook stock parameters over space and time to elucidate consistent year and stock effects (a,b of Ricker curve, or parameters from a power curve which is easier to estimate).
4. Possibly a similar approach for fall chinook, especially for the mid-Columbia stocks.

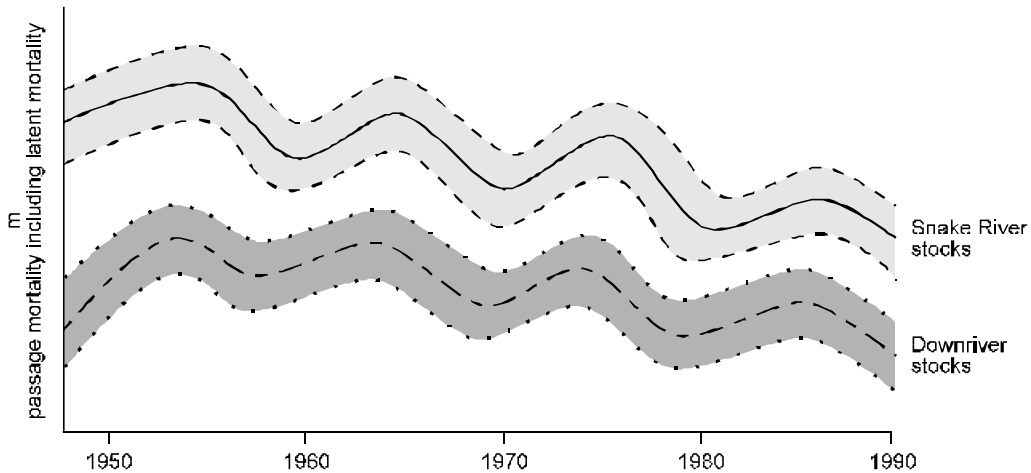

Figure 3.1: Example of output of MLE analyses. Dashed and dotted lines (---, ...) indicate 95% confidence intervals about estimates for Am@ for upstream and downriver stocks respectively. CRISP and FLUSH estimates for Am@ could be overlaid on this graph. Box and Whisker plots could also be used to illustrate changing statistical distributions over time.

3.2.2 Group B Level 2 Discussions

What=s the Point of Level 2 Analyses?

At Level 2 we identify the life stages most responsible for historical changes in overall survival (i.e. partitioning survival by life stage and time). Level 3 then looks at the mechanisms driving such changes. Once we established that there was some utility to Level 2 we began thinking of how we could explore Level 2 questions. The group spent more time on the general strategic approach to hypotheses, than the details of statistical methods.

What Data is There That is Specific to Particular Life Stages?

Table 3.1 summarizes the data available for each of these different life history stages identified in the PATH planning documents. Data are discontinuous, however, with many gaps in the historical record. Run reconstructions are required to provide multiple reference stocks for upstream/ downstream comparisons.

Table 3.1: PATH life history stages and data specific to those stages.

Life History Stage	Data Particular to Life History Stage
Freshwater spawning and rearing (FSR)	C redd counts C carcass studies (age structure) C parr density C smolt counts
Juvenile Migration Corridor (JMC)	C smolt counts (dams, traps) C tagging (PIT tags, earlier tagging studies)
Estuarine and Ocean Survival (EOS)	C harvest C tag returns
Upstream passage (UP)	C harvest (tributary, mainstem) C adult dam counts (upstream conversion) C tag returns
Prespawning survival (PS)	C harvest estimates C tag returns

What Analytical Methods Can We Use for Level 2 Analyses?

General

- C Charlie Petrosky=s Level 3 pre-spawning survival work may provide some useful information for Level 2 analyses
- C look for stocks similar in all but one life stage and compare observed R/S to that predicted, using redd counts
- C look at two areas with similar habitat characteristics and compare downstream indices (e.g. Warm Springs, John Day North Fork, Middle Fork)
- C use Paulsen=s multiple regression approach (PATH Workshop document Section 8) and include other stressor indicators that have not yet been developed. These stressor indicators could include the number of irrigation diversions, number of miles of timber roads, number of dams, etc. Paulsen did use dams in his analyses.

Aggregate Hypothesis: Stock Indices Approach

The main approach suggested is to compare upstream index stocks with downstream stocks (spring and fall chinook) and look for changes in production estimates (e.g Petrosky et al, 1995 - plenary presentation plus draft manuscript). Other information could be used to corroborate inferences drawn from upstream/downstream comparisons (e.g. upriver stocks other than Snake River; upstream passage and harvest rate components, inferential data (pre-spawning survival); egg-to-smolt: wild escapement index combined with index of smolts to the upper dam, juvenile survival estimates from tagging information, adult survival). These data could also be used in MLE models and for testing aggregate hypotheses. For upstream and downstream comparisons it is desirable to have more downstream stocks to avoid skewed comparisons. Currently we have run reconstructions for several upstream stocks but only two downstream stocksCGrande and Warm Springs. We need to have multiple reference stocks.
A possible complicating factor is that ocean conditions may not affect all stocks equally (perhaps Paul Wilson=s hypothesis can help resolve this). What if upstream and downstream stocks go to different places in the ocean?. We don=t know much about the first 3-4 months in the ocean. The upstream and downstream stocks diverge

upon leaving the Columbia River mouth, and there are differences in the timing of entering salt water for the lower to mid Columbia index stocks.

Aggregate Hypotheses: The Stressor Approach

Another potential way to test Level 2 aggregate hypotheses is by using stressor indicators for stressors known or assumed to affect portions of the fish life history. This approach could be useful when there is little or no life history data available. (see PATH Workshop document, pages 5-6 and 5-7). Stressors can be environmental or anthropogenic in origin including such things as, water temperature, flow, winter temperature, ocean index, snow pack, irrigation, land use, harvest, dams, and hatchery releases.

One possible analytical approach is to correlate stressor indicators with stock performance indices (e.g. irrigation diversions vs stock escapement numbers, or grazing units vs trends of spawning stock escapement). An example of a conclusion which might be drawn from this type of analysis is A30% of differences in stock performance may be attributed to grazing@ (though this correlation could be entirely coincidentalC*see cautions in Section 2.2.1*). It may be difficult to discern specific effects because individual stressors can affect more than one life history stage (PATH Workshop document Table 5-2). We must define the spatial resolution at which to conduct such analyses. For example, when looking at habitat there are spawning and rearing habitat issues, juvenile migration corridor habitat issues, and estuary habitat issues. For each of these habitat types stocks could be grouped or individual stocks could be used.

We must also figure out on which stage of the life cycle to focus, determine what the biggest problems are for that particular life stage, and decide on the stock performance indicator of interest. For example, what affects the Warm Springs stock? The issue boils down to whether one is using this procedure to test *a priori* hypotheses, or to generate hypotheses. Danny Lee=s work (see Plenary presentations) may already suggest which variables are important or what data are available. A general comment was that this approach seems more like a Level 3 analysis. Jim Geisleman will write up the stressor work in more detail.

Summary of Analytical Approaches for Level 2

1. Temporal trends for individual stocks (by life stage (Table 3.1), and aggregate trends).
2. Comparison of trends for different stocks/subbasins, particular time frames.
3. Correlations of stock status indicators with stressor indicators.
4. Retrospective Synthetic Modelling would be an extension of the MLE/Bayesian methods of Rick Deriso using more data than redd count/recruitment expansions. Once Rick=s part is working, we could try putting in other data series to see if they improve predictions or make no difference.

Other Level 2 Hypotheses

Other hypotheses discussed during the group meeting have been placed in the framework suggested in Section 6 of the PATH Workshop document even though the discussions did not necessarily follow this structure. Framing the information in this manner will help to facilitate further thoughts about hypotheses and methods of testing them. The text comes from both the Group B discussions and comments and suggestions made during the closing plenary session on Thursday, October 19.

Hypothesis B1 is a carry over from our Level 1 discussions. It was proposed by Paul Wilson as a high Level 1 hypothesis, but because it deals with trends in the late marine survival of spring chinook it fit better in the Level 2 framework. Hypothesis B2 is a rephrasing of the Level 2 life stage hypothesis derived for the Juvenile Migration corridor. Hypothesis B3 is also a life stage hypothesis. Hypothesis B4 is really an approach to examining all Level 2 aggregate hypotheses. Hypothesis B5 arose during closing plenary discussions and is related to B3.

Level 2 Hypothesis B1:
Hypothesis: Stable Maturity Schedule Hypothesis (Paul Wilson): Trends in late ocean survival can be estimated from shifts in age structure of the spawning stock.
Level: 2:: Estuarine/ocean survival life stage
Analytical approach: C calculate age composition of spawners; expand to age composition of fish entering the river using differential harvest and in-river mortality between years. C examine trends within stocks; compare across stocks C examine relative survival between years; survival as a function of growth rate C methodology from Prince William Sound Study; linked impact hypothesis structure (Phil Mundy)
Data to be used: C carcass surveys
Alternative outcomes and implications for management decisions: not discussed
Potential Problems: C analysis assumes no harvest until in river (good assumption for Spring chinook) C trends in late ocean survival. don=t get first year, the most pronounced effects on salmon are during the first few months of ocean residence C if you don=t see a shift in age structure, it doesn=t tell you that there wasn=t one in an earlier age.

Level 2 Hypothesis B2:
Hypothesis: Downward trends in Snake River stocks are caused primarily by hydrosystem impacts (e.g. PATH Workshop 1 Information Package p. 5-4, L2.JMC1.a)
Level 2: Juvenile migration corridor life stage
Analytical approach:
Data to be used:
Alternative outcomes and implications for management decisions:
Potential Problems:

Level 2 Hypothesis B3:
Hypothesis: Trends in stock indicators are related to trends in survival during the freshwater spawning and rearing stage (L2.FSR1.a)
Level 2: Freshwater spawning and rearing life stage
Analytical approach: C relate escapement and smolt production measured at dams to the size of the spawning stock estimated from redd counts C look at trends within basins C make comparisons within basins (e.g Mid-Columbia vs Snake)
Data to be used: C wild escapement index (sightings at last dam), spring chinook**C**estimates of how many are getting to the spawning ground C wild smolt index (counts at uppermost dam)**C**aggregate for the upper Snake system**C**Raymond data (pre-1980s years best, during 80s didn=t know what was wild and what was hatchery, made assumptions). Perhaps use data prior to 1975, and in more recent years use tagged fish. C published indices of wild smolts C redd counts C adults in/ parr out C subyearling smolt PIT tagging
Alternative outcomes and implications for management decisions: not discussed
Potential Problems: C perhaps create a database for input from others**C**footnote tables C how do you relate to stock performance? Is pattern consistent within years? Relate the size of the parent stocks to smolts produced at dams (size of stocks that produced smolts) and look for changes over time. C ...where habitat hasn=t changes there is a trend. C Environmental noise: good for one time series, bad for another time series, could mess up conclusions relative to anthropogenic conditions**C**freezing, scouring, nutrient load

Level 2 Hypothesis B4:

Hypothesis:

L2.ALL.SP1

- there is no significant trend in population state indicators between 1950B1969 brood years
- there is a significant population trend from 1970 brood year to the present
- the trend in survival during JMC and UP explain most of the trend in population state indictors from 1970 brood year to the present
- changes in survival during FSR, EOS, and PS cannot explain the trend in population state indictors from 1970 brood year to present

L2.ALL.SP2

- there may or may not be a significant trend in population state indicators during the period affecting the 1950B1969 brood years (no *a priori* hypothesis; may propose some after level 1 analyses).
- The trend from the 1970 brood year to the present is explained by different factors for the period affecting the 1970 to approximately 1980 brood year to the present.
- if a population trend is present during the period prior to the 1970 brood year, it is related to trends in FSR, JMC, UP, and PS survival but not EOS
- during the 1970s, the trend in survival during FSR, JMC, EOS, UP, and PS together explain most of the trend in population state indicators (all of relatively similar importance)
- During the 1980s, the trend in survival during EOS explains most of the trend in population state indicators

Level 2: aggregate

Analytical approach:

- compare trends in production estimates for stocks in Snake River basin vs down river stocks
- for spring, fall chinook
- could compare to MLE approach (both use upstream / downstream comparisons)

Data to be used:

- need multiple reference stocks
- trends in upstream passage rates
- trends in harvest rates
- any other stock health indicators for which at least partial time series of data are available.

Alternative outcomes and implications for management decisions:

Potential Problems:

Level 2 Hypothesis B5: Charlie Petrosky

Hypothesis:

Trends in stock indicators are related to trends in survival during the freshwater spawning and rearing stage (L2.FSR1.a)

Level 2: Freshwater Spawning and Rearing Life Stage

Analytical Approach:

Derive the linear relationship for historical Wild Smolt Index data as a function of historical Wild Escapement Index data, then plot new Wild Smolt Index data and Wild Escapement Index data on the same graph. Deviations from the historical Smolts vs Escapement line may indicate changes.

Data to be used:

Wild Escapement Index:
- from 1962 to present
- estimate of total harvest
- used to calculate terminal harvest rate
- data is used in upstream conversion factor (aggregate run, hatchery + wild)
- dates back to the first Ice Harbour dam counts
- index adjusted by terminal harvest prior to 1978,
- data for recent years from US, Oregon, Technical Committee

Wild Smolt Index:
historic data:
- late 1960s (1967-1975) mostly wild smolts, consists of estimates of smolts arriving at uppermost dam

Recent data:
- 3 years of recent data since adipose clip program introduced in 1994.
- scale pattern analysis by ODFW extends data back through 93, 92, 91

Alternative outcomes and implications for management decisions: not discussed

Potential Problems:
- The analysis assumes a linear relationship with negative slope for Wild Smolt to Wild Escapement, the wild smolt index may have a different relationship to wild escapement than hypothesized.
- An estimate of possible bias in the Wild Smolt Index could be made by taking collection efficiency into consideration (Jim Anderson).
- could put wild smolt index into MLE, data gaps are okay, wouldn=t want to bias data by filling in gaps, however could do with gaps and with gaps filled in to test sensitivity of the MLE analysis.
- must assume wild smolt index is proportional to sum of all areas above the uppermost dam.
- changes could be due to events independent of the river system (e.g depensatory effects - predation -or environmental conditions.

Comments and Concerns Expressed During Level 2 Discussions

- Can the importance of survival trends for different life stages be determined using limited measures such as adult returns which incorporate everything?
- Many of the available data are indices, how do you get the actual survival rate?
- How do you make spatial and temporal inferences? Can=t separate out effects if there are habitat impacts all the way through both geographic areas (upstream and downstream).
- What about incremental impacts?
- How do you isolate ocean effects when using one type of data?
- How do you isolate survival by life stage using one type of data?
- Mixed information: should use informed judgement C narrowing ranges of survival may or may not be useful.

Future Work

Establish workgroups for specific analyses (i.e. life-cycle aggregate hypotheses, analyses of stressors).

3.3 Analyses Plan and Tasks

Table 3.2 shows the Level 2 tasks agreed to in the Workshop 1 plenary session, and finalized by the PATH Planning Group.

Table 3.2: Level 2 tasks.

Task #	Description	Completion Date	People Responsible
Level 2 Hypotheses			
2.1	**Multivariate Analyses to explain stressors correlated with patterns of change in stock indicators.**	951019 Oct. 19/95 (!)	
2.1.1a	Form the Environmental Stressor Working Group (ESWG). DEW Group (see Task 1.1.1 above) will meet Nov. 29 to filter down NMFS data set to a reliable set. First ESWG mtg. Nov. 30/95 to decide potential data for environmental stressors. Data sources include Emlen study, Lee, Petrosky, Kim Jones (ODFW Habitat), EMAP, USGS, climate data (S. Hare, D. Ware, C. Ebbesmeyer, J. Anderson, D. Cayan (Scripps)).	951130 Nov. 30/95 Meeting	ESWG = Beamsderfer, Lee, Petrosky, Paulsen*, Geiselman, Langness, [Randy Tweeten (NMFS)], [John Rhoades (CRITFC)]
2.1.1b	ESWG completes data reconnaissance, building on **Task 1.2.1**. ESWG will document land use (viz. mines, dams, grazing, irrigation, forestry) history in a standardized way for use in both the regression analysis and the MLE-Bayesian analysis.	960115 Jan. 15/96	ESWG
2.1.2a	Develop prototype multivariate analysis approach and apply to a small data set, building on **Task 1.1.2b** (clustering approaches). Techniques may include regression	960115 Jan. 15/96	Paulsen*, Petrosky, Schaller, Botsford,

Task #	Description	Completion Date	People Responsible
	/ factor / discriminant analysis.		Deriso+, Lee+, Peterman+
2.1.2b	Apply prototype approach to the larger data set.	960215 Feb. 15/96	ESWG (Paulsen*) + Schaller, Botsford, Deriso+, Lee+, Peterman+
2.2	**Maximum Likelihood Estimation (MLE) / Bayesian approach to estimate population parameters, compare hypotheses.**	951019 Oct. 19/95 (!)	
2.2.1	Complete S-R reconstructions, focussing on downstream spring summer stocks first (Wind, Klickitat, *Cowlitz*, N. Fork Lewis, *Kalama*, extending Warm Springs back to 1969), then Upper Columbia (Wenatchee, Methow). {Streams in *italics* may not be usable due to hatchery influence}. Summary table of brood age structure.	951116 Nov. 16/95	Langness, Schaller, Petrosky*, Paulsen
2.2.2	Further develop prototype model using 7 Snake R., John Day and Warm Springs	951116 Nov. 16/95	Deriso
2.2.3	Meet to discuss measurement errors in S, R; complete framework structure; assess how to add in env. stressors; add in pre-spawning and smolt survival info. Also discuss topics listed in **Task 1.1.2a**	951116 Nov.16&17/95	Deriso, Schaller, Petrosky, Paulsen, Marmorek*
2.2.4	Spawner to smolt survival calculations (1967-75 versus 1990s)	951116 Nov. 16/95	Petrosky, Giorgi
2.2.5	Estimate the shifts in age structure of age 3, 4, and 5 fish to determine trends in late ocean survival.	951116 Nov. 16/95	Wilson
2.2.6	Explore the use of SLCM Bayesian belief network to assess the distribution of survival over life stages based on various data sources. Circulate ideas by Nov. 16/95 and prepare examples for the February workshop.	951116 Nov. 16/95 Ideas circulated	Lee, Deriso
2.2.7	Complete MLE analysis	960115 Jan. 15/96	Deriso, Schaller, Petrosky, Paulsen, Marmorek*
2.2.8	Develop examples of the use of SLCM Bayesian belief network for Retrospective Analysis report	960215 Feb. 15/96	Lee

3.4 Implications of Analyses for Management Decisions and Other Levels of Analyses

The multivariate analyses described under Task 2.1 potentially provide managers with some assessment of the relative importance of different stressors in determining stock trends. However, methodological problems associated with this approach mean that conclusions drawn from these analyses need to be very carefully thought through.

Task 2.1 offers the possibility of generating indices for prediction of changes in salmon stocks for different classes of stressors (e.g. ocean conditions, freshwater spawning and rearing habitat, estuarine habitat). These

indices, combining a number of different measures, could potentially be used in the future to improve the prediction of stock trajectories. Task 2.1 will also provide the databases and methodologies for examining specific causes of changes in particular life stages under Level 3 hypotheses. Multivariate analyses are often very useful for generating hypotheses, perhaps more so than testing them.

Task 2.2 (the MLE/Bayesian approach) provides an objective means of estimating the probability of different aggregate hypotheses or combinations of survival changes over time. This will permit an assessment of the degree to which different passage model predictions (i.e. CRISP, FLUSH, PAM) show historical predictions that are consistent with the most likely passage survivals. The Bayesian framework will also permit an assessment of systematic changes over time in other portions of the life-cycle (e.g. as a result of climate changes), and can help to identify similarities/differences in the passage survival, productivity, and carrying capacity of different stocks over time. Perhaps most importantly, this task can potentially demonstrate the level of contrast between upstream and downstream stocks during various time periods (i.e. relative to the timing of various dams and other human activities with differential effects on upstream and downstream passage survival.

By rigorously accounting for the uncertainties in measurements of stocks during different life stages, and the aggregate consequences of these uncertainties for the prediction of parameters of interest (e.g. passage mortality), this task will allow for an examination of the length of time and amount of effort required to improve the discrimination among competing aggregate hypotheses. This will help (though perhaps be rather sobering) in adjusting managers' expectations of the rate of learning that is feasible over the next decade, and thus the amount of reduction in uncertainty in various key management decisions. The MLE/Bayesian approach can therefore serve as one important technical component of an adaptive management approach in the Columbia River Basin. Prospective simulation experiments with the MLE framework could be used to help design monitoring and experimental programs that would increase the rate of learning and ability to discriminate among competing hypotheses. Task 2.2 can also potentially reveal the historical time periods with the greatest divergence in predictions of passage models. This may help to provide a more detailed understanding of the functional relationships which drive differences in model performance, and the underlying hypotheses which require the most research.

The framework developed under Task 2.2 could be used to assess the likelihood of different hypotheses developed under Level 3. For example, a Level 3 analysis may suggest that climatic changes during the late 1970s and 1980s seriously reduced ocean survival. This hypothesis could be incorporated as a prediction into the Level 2 framework to see if it improves the fit to historical escapement measures. Since historical data has gaps spatially, temporally, and by life stage, the retrospective analyses under Task 2.2 may have some serious limitations. Identification of critical gaps will be an important benefit of the analyses.

4.0 Level 3 Hypotheses

4.1 Level 3 Plenary Presentations and Discussions

Level 3 hypotheses seek to explain the life-stage specific mechanisms associated with observed trends, for each life history stage identified at Level 2 as most closely associated with the population trends. For listed Snake River stocks, Level 3 hypotheses link directly to key management decisions. Since the key management questions relate to the degree of various effects (e.g. changes in survival with increased flow) rather than whether or not an effect occurs, Level 3 hypotheses need to focus on the quantitative strength of hypothesized effects. The Level 3 plenary presentations were informal discussions of preliminary analyses, not completed pieces of work. The purpose here is to provide a brief summary of the presentations.

Following the plenary discussions, Level 3 responsibilities were allocated to the two subgroups: Subgroup A was asked to focus on hydrosystem, harvest and ocean conditions; Subgroup B was asked to focus on hydrosystem, habitat, and hatcheries. The results of the Subgroup discussions are found in Sections 4.2.1 and 4.2.2.

4.1.1 Synthesis of Evidence for Level 3 Hypotheses

There is a requirement for structured syntheses of evidence for and against particular hypotheses. Al Giorgi presented one approach for doing this for a level three hypothesis concerned with flow, migration speed and survival (Appendix E). Earl Weber distributed an alternative approach that he prepared with the assistance of Paul Wilson (Appendix F). Regardless of the format used, it was recommended that the content of these two documents need to be merged, together with the evidence summarized in Williams and Matthews (in press, see Appendix G). Further discussion of the appropriate format for these syntheses occurred in the subgroups and is summarized in Section 4.2.

4.1.2 An Approach to Testing Level 3 Hypothesis on Survival and Travel Time (J.J. Anderson)

Jim Anderson presented his approach to testing a Level 3 hypothesis on the relationship between survival and travel time. He first assembled different data on fish travel time. These data came from passage/transport experiments, brand marks, PIT tag recovery, and radio tracking. He then calibrated the CRiSP model to these data for some years and predicted travel time very successfully for other years. He also compared predicted survival against measured survival. This is discussed in more detail in his workshop handout (Appendix H).

Jim Anderson found that in the low survival years of 1973 and 1977, the juvenile fish velocity vs Julian day relationship (usually curvilinear) remained linear with a slope of less than 1. In 73/77 smolts apparently did not respond to flow the way they did in other years. Several alternative hypotheses were discussed by the group: 1) fish may not have received the signal that causes them to change their velocity with time; instead, fish moved slowly (relative to the river) and suffered more mortality; 2) physiologically poor condition, perhaps due to overwintering conditions; and 3) dams were operated unusually in low flow years (at night when smolts usually move through dams, the utilities cut back on flow which prevented fish from passing through dams as efficiently as normally).

It was agreed that the dam mortalities assumed for these conditions should be included in Table 2 of Jim Anderson=s handout (Appendix **H**). Jim reported that he did not adjust the dam mortalities while conducting this analysis.

There was some concern over potential bias in the analyses...

Bias potential - trimming the tail -- Earl, please explain.

The analyses used data from very different data sets (e.g. freeze brands, individual PIT tags), it may be worthwhile to compare data for several years and conditions to see if there is any bias. Al Giorgi mentioned that the NMFS has made PIT tag/freeze brand comparisons and while there was a higher recovery rate for PIT tags there was no bias in calculated migration speeds

Jim Anderson also presented an interesting figure showing an apparently strong relationship between the PNI (a Pacific Northwest climate index) and chinook harvest (Figure 3 in Appendix H). He suggested there may have been a masking of hydrosystem effects during good ocean conditions and a possible confounding of dam effects post-1976 due to worsening ocean conditions. He raised the question: can we separate the climate signal from the dam conditions? There were several comments on the chinook harvest:

1. seasonal restrictions on fishing (i.e. reduced fishing effort) could be the primary reason for harvest declines;
2. freshwater effects are masked, there was enormous fisheries development when spring-summer chinook were the major catch (1800s-1920s);
3. overfishing: troll fishing was increasing while in-river harvest declined, restrictions on troll fishing were slow to come; and
4. hatchery production in the mid-1960s could explain the slower fishing decline during this era.

It was suggested that the PNI index be compared to time series with stock and recruitment data (e.g. those available for spring-summer chinook stocks, both within the Snake River and elsewhere).

4.1.3 Analysis of Prespawning Survival (Charlie Petrosky)

Charlie Petrosky presented results of his analyses using existing information to assess trends in prespawning survival. Details can be found in Appendix I. He created three indices to assess different components of prespawning survival. The first index (PROP1) estimates the proportion of total (hatchery + wild) spring-summer chinook counted at the uppermost dam that were accounted for in Snake River tributaries and harvest. PROP1= [(hatchery weirs)+(sports harvest)+(2 * redd counts)]/[uppermost dam counts]. The PROP1 index correlates positively with year ($r=0.68$, $p<0.01$).

The second index (PROP2) estimates the survival of unharvested wild chinook from the uppermost dam to the spawning ground: PROP2 = [(2 * standard redd counts)] / [(wild run size)* (1 - HRwild)], where HRwild = wild harvest. Charlie used 2*redd counts as a consistent index of spawners even though redd counts tend to underestimate spawners. PROP2 index shows a weak, slight positive trend ($r=0.31$, $p=0.08$). There may be year effects, especially in years of high abundance.

Participants had the following comments on these results:

- could it be that we are not seeing the full impact of decline because we index the best areas of the basins, and the population shrinks into these major areas, while disappearing from other rivers?
- This analysis assesses what happens from the uppermost dam to the spawning grounds. One could also compare counts at Ice Harbour and Upper dam to see if there is such an effect. This is quite easily done, since the run reconstruction accounts for dam effects.

The third index (PROP3) estimated the proportion of females that were greater than 25% spawned. The PROP3 index showed no indication of a decreasing trend over the years ($r=0.07$, $p=0.75$)

- must consider the removal rate of carcasses due to being washed downstream or bears (in areas where there are lots of bears you don=t find many carcasses).

4.1.4 Fish Habitat Assessment (Danny Lee)

The Forest Service is moving towards larger-scale ecosystem assessments, an approach that began with the Spotted Owl assessment. USFS wants to know about the habitat containing these species, the spatial distribution of the species in the available habitat, and where to find this habitat in the larger landscape. The eastside assessment includes Oregon and Washington State east of the Cascades plus the rest of the Columbia River Basin (PACFISH). The purpose was to get information on the distribution and status of fishes in this area with respect to:

1. key salmonids (7 key species): bull trout; westslope cutthroat trout; yellowstone cutthroat trout; red eared trout; steelhead; ocean type chinook; stream type chinook;
2. fish communities and assemblages; and
3. sensitive native species

The landscape was divided up using the EPA River Reach System, which divides the nation into a series of watersheds. There are 167 4th code watersheds, 2500 5th code watersheds and 7500 6th code watersheds.

Species status information was collected and classified into six categories: A- Absent; PD - Present, depressed; PS - Present, strong; PM - Present, migration corridor; PU - Present, unknown; U - Unknown status. A variety of potential predictor variables were used in the analyses. The predictor variables (about 25 of them) fell into one of the following three groups: physiographic/geophysical (e.g. drainage density); vegetation indices; and ownership and management (e.g. road density class).

A novel method (categorical regression tree (CART)) was used to classify each of the seven key species into status categories based on the predictor variables. To analyse the data he looked for simple models where Prob(status) = fn(predictor variable). A dichotomous key or tree is generated, with a predictor variable at each node, and a status category at the end of each branch. The predictor variables split up the histogram of streams by status category. The ideal result is one predictor variable that will separate out the categories in the histogram. An example was given for bull trout where the histogram of categorical variables was run through the tree and split according to four possible responses. The histogram was first split according to whether trout were absent or present, then if present whether the populations were depressed or strong. In general, some variables which split these categories up also tend to apply to most of the species (e.g. air temp is a useful predictor).

In another example using stream type chinook, the procedure failed to identify strong localities because there was nothing unique about where they were strong as opposed to where they were depressed. The small number of sites (eight) may have reduced the discriminatory power of the predictor variables (i.e. not enough contrast). However, all eight were pulled together**C**the right variable may have set them apart. A result like this might be found if a species is usually absent from where it should be strong, as would be the case with anadromous fish.

Danny Lee does not know of anyone else doing this kind of work. A draft report is currently out for blind peer review.

Possible Application to PATH

If information on index stocks= habitat classification in the past were provided using expert judgement, then Danny Lee=s method could be a more objective/quantitative approach for assessment of habitat impacts over time. For example, there has been discussion about performing trend analyses on habitat indicators at both Level 1 and Level 2. How would these indicators be chosen *a priori*? One method might be to use analyses based on Danny Lee=s CART methodology. This would allow selection of habitat indicators in a more objective and structured manner than by merely making guesses at indicators and then running multiple regressions. When the habitat indicators which are the best predictors of fish abundance have fallen out, historical data could then be collected on those indicators (if such data exist).

There are several challenges to this approach. One possible drawback might be the tautological process of finding the indicators to include in the first place. As we saw in Danny Lee=s presentation, the methodology grouped chinook stocks although they were classified wrongly. He suggested that if the right variable were selected the grouping might have been correct. Obviously spending the time finding the ›right= variable may be too time consuming for this phase of the PATH process and searching for the variable that classifies Acorrectly@ is not defensible unless validated independently. Second, it may be that after finding the variable which best groups fish according to their current status, data on this variable may not be available as a time series. Third, changes in scale can affect the significance of explanatory variables (eg fish production is highly correlated with the morphoedaphic index (MEI) over the broad range of lakes, but when the most oligotrophic fraction are examined there is no relationship). Fourth, the small number of discrete classes for his indicators of stock abundance may not provide sufficient resolution for the hypotheses tests of interest.

4.2 Group Discussions

4.2.1 Group A Level 3 Discussions (Dave, Dan)

The group felt that the efforts by Al Giorgi and Earl Weber/Paul Wilson to synthesize information on various hypotheses was a good start. The group felt that it was worthwhile developing a consensus document using a variety of categories of evidence, perhaps those employed by the Intergovernmental Panel on Climate Change (1990) report. Before these syntheses take place, there has to be some agreement on the specific wording of the hypotheses for which information is being synthesized. Therefore the first step is to begin with these existing documents and work out a logical hierarchy of hypotheses stemming from the decision frameworks included in the PATH workshop report in Figures 5.1 and 5.2 or others under development. These syntheses of evidence should involve some ISG members, and also be subject to an internal peer review process. The syntheses should represent all points of view fairly and critically evaluate methods and assumptions. With respect to flow survival relationships, the syntheses should incorporate in a concise way the summaries of Čada, NPPC discussions of flow survival, the ISG conceptual model of passage survival (when available), and the work by Jim Anderson in synthesizing the different types of data available for assessing flow transit time relationships. Later on, the group discussed specific analyses with respect to flow-fish transit time, and flow-survival sensitivity analyses. These are summarized below.

Syntheses of Evidence

There are a number of options for how to organize syntheses of evidence. Randall Peterman recommended the format shown in Figure 4.1. A key issue to be decided is how to rate the strength of evidence. Following the workshop, we reviewed a number of different approaches. The IPPC (1990) executive summary used the following classification methods:

1. we are certain of the following...;

2. we calculate with confidence that...;
3. based on current model results we predict...;
4. there are many uncertainties in our predictions particularly with regard to the timing magnitude and regional patterns of climate change, due to our incomplete understanding...;
5. our judgement is that...; and
6. to improve our predictive capability, we need....

The final report of the National Acid Precipitation Assessment Program (NAPAP 1991) used a system with five categories:

- o unsupported hypothesis
- **i** best judgement**C**low confidence
- **i i** best judgement**C**limited confidence
- **i i i** reasonable confidence
- **i i i i** high confidence

The star system was used for three purposes: 1) answers to specific management questions; 2) validity of hypotheses; and 3) confidence associated with model outputs. Appendix J includes some examples of how this approach was applied. The NAPAP document used a weight-of-evidence approach, similar to that recommended for Level 3 syntheses. Appendix J includes a table summarizing the advantages and disadvantages of different types of evidence. Such a table could also be compiled for the Columbia.

Hypothesis:	**Members of Group:**

Category of Strength of Evidence	**Description of Evidence:**

Unresolved Uncertainties	**Information and type of experiment needed to resolve that uncertainty (for workshop # 2)**

Figure 4.1: Standardized format for syntheses of evidence. There are a number of options for how to categorize the strength of evidence (see text).

Neither of the above two systems seems quite appropriate for the syntheses envisioned for PATH hypotheses, though the NAPAP strengths and weaknesses table (Appendix J) suggests that it may be worthwhile to consider rating the types of evidence available. The following is proposed for consideration.

Model projections could be rated according to:

M1. Validated and well accepted.

M2. Consistent with some historical data, but disputed; alternative models also consistent.

M3. Theoretically reasonable, but unvalidated.

Field data could be rated as:

F1. Consistent, reliable, relevant measurements from several locations and time periods (e.g. flow).

F2. Small number of locations or time periods, but high relevance and low measurement error.

F3. Small number of locations or time periods, high relevance, but moderate to high measurement error.

F4. Small number of locations or time periods, very indirect measure, and moderate to high measurement error.

The summaries of evidence should also recognize the conclusions of previous literature syntheses.

Retrospective Analyses

The group considered four sets of retrospective analyses:

1. A comparison of data sets and relationships describing how fish transit time varies with flow. This would compare the work done by the University of Washington (Anderson, Zabel, and others) with work done by the States and Tribes.

2. A sensitivity analysis would be completed to look at how estimates of fish survival change based on the uncertainty in past data describing levels of debris, turbine mortality, spill, and transportation. Uncertainty around certain data points could be incorporated into the functions derived from such estimates. Some of the members of Group A were sceptical that much progress

could be made in this area, given how much attention past data sets have already received. It was pointed out that we need to be very careful in distinguishing between estimates of survival for reservoirs, reaches, the estuary (for which there are few survival estimates), and whole life cycle estimates.

3. Use the MLE / Bayesian approach to assess the level of support for alternative aggregate hypotheses based on: i) strong flow survival relationships, and ii) weak flow survival relationships. This involves putting the CRISP and FLUSH estimates for Rick Deriso=s Am@ parameter into the MLE model and computing the Bayes factors for each model. This is essentially the ratio of the sums of squares for each of the two models (model estimates minus maximum likelihood estimates, squared). It was noted that the calculated Am@ factors will need to incorporate transportation assumptions and these assumptions should be explicitly defined for each estimate. Ideally, the estimates for Am@ would incorporate the maximum number of identical data inputs (e.g. FGEs, turbine survival, spill efficiency, spill caps, powerhouse elevations, predator control assumptions) (See Table 4 of ANCOOR 1995 Section 7 Comparison Report). Though some key assumptions will clearly be different between the two models (i.e. at the core of the issues being disputed), interpretation will be easier if the number of different assumptions can be reduced.

4. Exploration of the hypothesis that changes in the flow regime have resulted in changes in estuarine conditions (salinity, productivity) and survival. This would involve documenting the changes in seasonal flow patterns, synthesis of the Ebbesmeyer data on changes in salinity, and analysis of the changes in survival of transported fish according to their release time (3B5 years of data, J. Anderson, pers. comm.).

Though Group A was not charged with making research recommendations, the discussion under item 4 above led to a consensus that putting PIT tag-detectors at the Bonneville dam would help to clarify the actual passage survival. Similarly monitoring of a downstream control stock such as Lewis River would help to assess the issue of delayed mortality.

4.2.2 Group B Level 3 Discussions: Hydrosystem, Habitat and Hatcheries

After some initial skepticism (AWhat can this group do with existing data that hasn=t already been doneCespecially for downstream passage data?@) the group considered various hypotheses, syntheses of evidence, and possible new analyses for hydrosystem, habitat and hatchery issues. In addition to these retrospective analyses, it is important to examine new work that may contribute to particular hypotheses (e.g. NMFS in-river survival study, NMFS transportation study), either directly or by suggesting different analytical approaches to historical information.

Hydrosystem

- Summarize the evidence for and against transportation, flow, flow/survival in the manner used by Al Giorgi (see plenary presentation, plenary handouts).
- Use format similar to Earl Weber=s Level 3 handout from the opening plenary session. Such tables would be useful for a retrospective approach to summarize and categorize existing evidence, ideas, and hypotheses. The Earl Weber hypotheses need to be refined, they appear to roll too many things up together.

The following tables summarize hydrosystem hypotheses discussions in a consistent structure. As with the Level 2 hypotheses, there are many gaps, since the workshop discussions did not cover all issues. These tables can serve as a template for tackling the missing issues.

Hypothesis 3.B1: Null passage hypothesis (Mundy=s Conjecture)
Hypothesis: All routes of passage are equal with respect to juvenile survival.
Level 3: Hydrosystem
Analytical approach: Test: frequency histogram of recaptures of PIT tags at McNary dam**C**catalogue # Fish seen 0 times, once, twice, thrice. The probability of being seen three times is low if all passage pathways are equal. Can develop the expected frequency distribution, and compare to observed distributions.
Data to be used: 86/87 and 94/95 McNary PIT tag data (must know the collection efficiency) NMFS survival estimates for different reaches and passage conditions (smolt survival)
Alternative outcomes and implications for management decisions:
Potential Problems: ›No-shows= could be interpreted as being spilled down river, but perhaps there is a high mortality and that is why they are not being seen.

Hypothesis 3.B2: Transportation Retrospective
Hypothesis: Transportation has helped to mitigate the rate of decline of stocks (alternatively**C**transportation has prevented stocks from going extinct).
Level 3: Hydrosystem
Analytical approach: One possible approach would be to examine trends in the productivity of mid-Columbia stocks versus those of the Snake River stocks. When transportation began on the Snake River, the mid-Columbia did not have transportation. Many of the mid-Columbia populations also go through many dams (e.g. the viable Okanagan sockeye pass through 9 dams). Look at a sister system during the same time frame, noting differences in productivity trends vs. presence / absence of transportation.
Data to be used: no new data to analyse
Alternative outcomes and implications for management decisions:
Potential Problems Comment: Phil Mundy: average survival of transported spring chinook is higher than those not transported, but this is flow dependent. Transportation did help slow the decline of spring chinook.

The subgroup also briefly discussed what a definitive prospective transport experiment might be. One proposed experiment tests the hydrosystem mainstem passage hypothesis: transportation affects the ability of fish to find their way home. The experimental/analytical approach would be to PIT tag all hatchery fish, then at LGR transport 50% and leave the rest in-river. Then assess the number reaching downstream dam; number reaching

hatchery. The data to be used analyses would be parr, smolt and adult PIT tag data collected at dams and hatcheries and during harvest. Potential problems are: the manifold bypass effects; the fact that transport competes with other forms of passage; to transport or not is the issue, another is the uncertainty about when to transport. For example with an FGE of 70% transportation does not have much of an effect. There is lots of uncertainty about the Transport Benefit Ratio (TBR) for spring chinook. Phil Mundy is currently writing something on this subject (available at the end of October 1995, currently being peer reviewed by John Williams).

Hydrosystem Comments:

- flow augmentation can not change a low flow year into a high flow year; management question is how to best use water for flow augmentation

Habitat

The habitat hypotheses are presented below in the same format. The group discussed some possible measures of stressors and habitat quality or condition:

- water diversion
- irrigated acres
- roads/ha
- grazing units/months
- stream pool glide indices
- pollution
- wetland
- agri chemical volumes
- human population density

Hypothesis 3.B5:
Hypothesis: Habitat declines lead to stock declines.
Level 3: Habitat
Analytical approach: Break data into time periods: 1. mid-1800s to present time period 2. 1950s to 1969 3. 1970 to 1974 brood years 4. 1975 to modern era 5. 1980 to modern era Comparison of 1940s and 1970s stream data
Data to be used: initial stream inventory in the 1940s streams measured in the 1970s pre-diversion stock data for disturbed vs undisturbed watersheds catch data

Alternative outcomes and implications for management decisions:
Potential Problems: C Why define a time period up front? C Lots of data reconnaissance required. C How do we define and quantify land use patterns? C Historical stream surveys were done from horseback (ride by and count pools etc). C Not much historic land cover data, only have models of what historical land cover was thought to be.

Hypothesis 3.B6:
Hypothesis: Improvement in habitat has lead to an increase in stock indices.
Level 3: Habitat
Analytical approach:
Data to be used: C run reconstruction of the Wenatchee stock C comparative analyses of mid-Columbia versus Snake River performance
Alternative outcomes and implications for management decisions:
Potential Problems:

Habitat Comments:

- C habitat is the whole watershed, not just stream bed
- C dewatering has been a problem since long before dams (1910 water rights)
- C the effects of fine sediment on the egg-to-emergence stage, data for this is almost anecdotal, lots of independent research efforts have been synthesized (request that Earl Weber circulate this paper or summary of it to the group)
- C look at the habitat relationships of other non-impacted systems, for example coastal systemsCpools, woody debris dynamics
- C look at the Freshwater Spawning and Rearing life stageCat least at rearing habitat, develop an aggregate habitat index
- C for the estuarine portion of the Estuarine and Ocean life stage the impacts started in 1910 with dyking in the Portland area (estimated 35% reduction of available habitat in the Portland areaCare profiles for the Portland area available?)
- C we don=t have affected versus unaffected Columbia River time series to work with
- C assign teams to improve Level 3 habitat hypotheses and to define data and analyses needs

Hatcheries

Hatcheries are used in two ways:

1. Augmentation: to improve harvest
2. Supplementation: conservation of genetic material. Wild fish are taken out of the natural habitat. Their offspring spend part of life cycle in a hatchery and after release return to spawn as native fish. There is gene flow between the hatchery-raised and wild fish.

Effects of hatcheries on wild fish are different for different stocks but in general:

- lowered genetic fitness**C**the primary concern (e.g. coastal coho)
- competition for carrying capacity (e.g. rearing streams)
- domestication selection (crossing)
- non target harvest - management effect
- predation by hatchery smolts on smaller wild smolts
- disease transfer (e.g. during transportation)
- effects of mixed stock management

Evidence exists that hatchery fish are different from wild fish:

1. total survival for hatchery fish is different (egg-to-adult survival, higher smolt to adult survival for hatchery fish than wild)
2. allozyme diversity is different between hatchery and wild fish
3. discernable phenotypic differences

The lower Snake has federally required augmentation for listed stocks. Augmentation and supplementation have different effects on the wild stocks and should be analysed separately.

Hatchery Hypotheses

The following hypotheses were taken from the group B discussions of Level 3 hatchery issues. They are not necessarily presented in the order in which they were discussed.

Hypothesis 3.B7:
Hypothesis: Hatchery augmentation has adverse affects on wild populations.
Level 3: Hatcheries
Analytical approach: 1. qualitative evidence (e.g. Al Giorgi=s synthesis method, see plenary handouts) 2. changes in wild stock composition 3. population trends in areas augmented versus those not 4. quantify the % of stocks of interest affected by hatcheries

5. quantify trends in the % of stocks affected by hatcheries 6. spatial distribution and trendsCuse a procedure like the East Cascade Assessment to quantify where hatchery fish have been introduced 7. impact in other areas relevant to genetic effects (e.g. allozyme diversity, morphology) 8. effects of competition in rearing streams
Data to be used: C Rapid River C Upper South Fork, Imnaha (more supplementation), maybe four or five stocks are hatchery influenced, several are not influenced C Redd River (part of the Clearwater). C retrospective studies (e.g. Jim Lichatowich (CEA). They identified data, looked at the cumulative impacts of the Columbia basin hatchery system, and concluded that it virtually impossible to identify the impact). Hatchery Effects reportCKramer and Associates (mentioned by Earl Weber). three studies which look at changes in wild stock composition with respect to hatchery influence mentioned by Phil Mundy C Section 10 permits C East Cascade Assessment (Danny Lee)C10% of streams not affected by hatcheries C Milo Adkinson=s population genetics model C studies which look at changes in wild stock composition with respect to hatchery influence (e.g. influence of crossing on fitness of offspring, Chilcot steelhead, Macintyre and Reisenbach). C existing literature summaries
Alternative outcomes and implications for management decisions:
Potential Problems: Rapid River - affected by irrigation and harvest

General Comments

Use the results to construct decision trees (as on p5-9, 5-10 of the PATH Workshop document) linking refined Level 3 hypotheses to management decisions. Fig 5-1: There are other possible decision frameworksC1) accept it; 2) test it with existing data; 3) test it with future data (next workshop).

Next Steps

Form scoping groups for hydrosystem, hatcheries and habitat, each group with members from across the range of agencies, to develop decision trees (as on pages 5-9 and 5-10 of PATH Workshop document) and then develop/refine the Level 3 hypotheses associated with these decisions. For any given testable hypothesis, there are three possible courses of action: 1) accept it; 2) test it with existing data; or 3) test with future data (next workshop).

4.3 Analyses Plan and Tasks

Table 4.1 shows the Level 3 tasks agreed to in the Workshop 1 plenary session, and finalized by the PATH Planning Group.

Table 4.1: Level 3 tasks.

Task #	Description	Completion Date	People Responsible
Level 3 Hypotheses			

Task #	Description	Completion Date	People Responsible
3.1	**Hydrosystem Group (HG) Hypotheses Development**	951019 Oct. 19/95 (!)	
3.1.1	HG group meet to develop/refine: 1) decision trees for flow augmentation, drawdown, transportation and spill (Figs. 5-1 and 5-2 in PATH workshop doc); 2) hierarchy of hypotheses that follow from these decision trees. Follow principles in PATH Workshop 1 binder (page 4-18).	951109 Nov. 9/95 Meeting	HG group: Toole*, Giorgi, Weber, Williams, Wilson, Geiselman
3.1.2a	Full HG meet to review decision tree and hypotheses developed in 3.1.1. Agree on structure, responsibilities for synthesis of evidence for/against hypotheses. Build on Weber/Wilson and Giorgi papers distributed at Camp Cascade. Develop groups of 2-3 people to work on parts of problem.	951128 Nov. 28/95 Meeting	HG: {Giorgi, Weber, Williams, Toole*, Wilson}+ {Mundy, Anderson, McConnaha, Pinney, one ISG member (?)} + {Fred Olney, Dave Ward (ODFW), Gene Matthews - transportn.}
3.1.2b	Interim product circulated to larger PATH group.	960115 Jan. 15/96	HG
3.1.2c	Version for Draft Retrospective Report	960215 Feb. 15/96	HG
3.1.3	Compare relationships for the flow / transit time data sets. Provide input to **Task 3.1.2b.**	960115 Jan. 15/96	Wilson*, Weber, Steve Smith, Zabel, Giorgi, Berggren
3.1.4a	Conduct a sensitivity analysis for mainstem passage survival.	960130 Jan. 30/96	Wilson*, Weber, Steve Smith, Zabel, Giorgi, Berggren
3.1.4b	Sensitivity analysis for transportation and fish survival.	960130 Jan. 30/96	Wilson, Weber*, Giorgi, Anderson
3.1.5	Develop CRISP / FLUSH estimates for ›m: into the MLE model and compute Bayes factors. Maximize agreement on model inputs; use same definition for ›m.: Time periods of primary interest are 1971-1990, for spring/summer chinook. If analysis worthwhile and temperature info available, also do 1950-70 (by Dec. 22/95).	951130 Nov. 30/95	D. Askren*, J. Hayes, Wilson, Weber, Al Giorgi (historical Corps data), Deriso+
3.1.6a	Form CHAMEO group - Changes in Habitat in Migration corridor, Estuary and Ocean (does not include effects on mainstem spawning and rearing habitat - under **Task 3.2**). Define hypotheses linked to decision trees developed in **Tasks 3.1.1 and 3.1.2a.**	951130 Nov. 30/95 Meeting	McConnaha*, Heinricksen, [Francis+], Lee, Petrosky, Geiselman, Pinney, [Bob Emmett, NMFS]
3.1.6b	Compile evidence for and against hypotheses. Also complete analyses comparing flow changes to estuary changes using flow, salinity, and survival of transported fish. The group will meet Nov. 30/95 to carry out this, and other work. Feed indicators into multivariate analyses **(Task 2.1).**	960115 Jan. 15/96	McConnaha*, Heinricksen, [Francis+] , Lee, Petrosky, Geiselman, Pinney, [Bob Emmett, NMFS]
3.1.7	Compare the relative survival of salmon via different passage routes (if required).	960115 Jan. 15/96	Mundy, S. Smith*
3.2	**Form CHASPR group - Hypotheses re Changes in**	951019	

Task #	Description	Completion Date	People Responsible
	Habitat for Spawning and Rearing	Oct. 19/95 (!)	
3.2.1	Definition of hypotheses for spawning and rearing habitat {includes mainstem spawning and rearing habitat}, linked to management decisions.	951215 Dec. 15/95	Lee, Petrosky*, Geiselman, Paulsen, Beamsderfer, Tweeeten, Rhoades
3.2.2	Synthesis of evidence for/against hypotheses regarding spawning and rearing habitat. Link with **Tasks 2.1.1a and 2.1.1b.**	960130 Jan. 30/95	Lee, Petrosky*, Geiselman, Paulsen, Beamsderfer, Tweeten, Rhoades
3.3	**Form HATCHY group - Hatchery Hypotheses.**	951019	
3.3.1	Develop hypotheses regarding hatchery impacts, linked to management decisions.	960109 Jan. 9/96	Mundy or Weber, Wilson*, Geiselman + _____, Steve P. Smith, one person from WDFW, C. Pinney, L. Botsford, Chair of PAC (Production. Advisory Committee)
3.3.2	Synthesize information for/against hypotheses regarding hatchery impacts.	960215 Feb. 15/96	Mundy or Weber, Wilson*, Geiselman + _____, Steve P. Smith, one person from WDFW, C. Pinney, L. Botsford.
3.4	**Form HARVHY group - Harvest Hypotheses.**	951019 Oct. 19/95	
3.4.1	Develop hypotheses regarding harvest impacts, linked to management decisions.	960109 Jan. 9/96	Tom Cooney*, Peter Dygert, J. Norris, Schaller, Mike Matylewich, Chair of TAC [D. Swartz or T. Roth], J. Geiselman
3.4.2	Harvest work group - organize evidence for/against hypotheses.	960215 Feb. 15/96	Tom Cooney*, Peter Dygert, J. Norris, Schaller, Mike Matylewich, Chair of TAC [D. Swartz or T. Roth], J. Geiselman
3.5	Develop a process to evolve new aggregate hypotheses from advances made in Levels 1, 2 and 3.	951222 Dec. 22/95	Marmorek*, Cooney, Deriso, Anderson

4.4 Implications of Analyses for Management Decisions and Other Levels of Analyses

The Level 3 analyses are most closely tied to key management decisions. The working groups dealing with each of the four Hs (Hydro system, Habitat, Hatcheries, Harvest) will be developing hypotheses based on the suite of management actions that are possible within each of these domains. The Hydro system group, due to the large amount of work that has gone into this problem, is developing a detailed decision tree to guide the definition of hypotheses and analyses. This decision tree in itself is of interest to managers. More importantly it provides a foundation for linking analyses and hypotheses directly to decisions. The organization of evidence for each of these hypotheses will provide managers with a concise summary, showing the large number of areas in which there is substantial agreement, as well as the areas where the evidence is insufficient to reach a consensus. These latter areas are clearly the ones that serve as potential candidates for future research and monitoring studies. Thus these syntheses are a foundation for the development of research and monitoring designs to improve future learning at the second PATH workshop.

As mentioned in Section 4.4, Level 3 analyses of particular life stages can potentially be embedded into the Level 2 MLE framework to assess the aggregate life cycle consequences of particular hypotheses. It may turn out that the Level 2 framework suggests that more than one competing hypothesis are equally plausible given historical information. The syntheses of evidence conducted under Level 3 can provide additional information that must be weighed together with the Level 2 results to assess the overall likelihood of particular hypotheses.

Some of the tasks under Level 3 will provide qualitative syntheses of existing information. Other tasks (e.g. the sensitivity analyses under Task 3.1) provide a more quantitative assessment of the implications of historical uncertainties in survival estimates. These analyses can potentially lay the ground work for assessing how much monitoring and experimentation would be required to overcome these historical data gaps and uncertainties.

5.0 Synthesis of Tasks and Schedule

Figure 5.1 pulls together all of the tasks described in the previous three sections in the form of a Gantt chart, showing the timing and some of the linkages among activities. This chart is continually being revised, both to break down tasks into smaller components and to reschedule them based on changing priorities. For example, the descriptions of management decisions (as sets of actions or decision trees) developed by Level 3 work groups under Tasks 3.1.1 (hydrosystem), 3.2.1 (spawning and rearing habitat), 3.3.1 (hatcheries), and 3.4.1 (harvest) are seen as being particularly valuable to the policy group, and will probably happen sooner than indicated, though the latter three decision descriptions will not be in as much detail as for the hydrosystem.

Figure 5.1: Gantt chart.

6.0 Preliminary Outline Feb. 29th Report and Other Assignments

Table 6.1 presents a suggested structure for the Draft Report on Retrospective Analyses, to be synthesized by ESSA by February 29th, 1996. It mirrors the general structure of tasks described in this workshop report, and will draw some material both from this report and the Workshop 1 Information Package. However, we propose that the report be written in a concise form much closer to a collection of peer reviewed journal articles. This will facilitate outside peer review, and hopefully eventual publication. Authors and dates for draft material to be sent to ESSA are indicated below; the authors will presumably revise the content as their analyses develop, but the consistent format shown below is strongly recommended. The structure needs to be reviewed, priorized, and perhaps consolidated (e.g. parts of section 6.0 could be folded into the appropriate Level 3 syntheses).

The draft report will be reviewed by all participants, discussed at the March workshop on Prospective Analyses, and also reviewed by a set of outside peer reviewers. The Final Report on Retrospective Analyses will be completed by the end of April, 1996.

Table 6.1: Proposed structure for the Draft Report on Retrospective Analyses, with primary authors and contributors indicated.

Retrospective Analysis Report Sections	**Authors (*Lead*)**	**Due Date**
1.0 Introduction 1.1 Objectives of PATH and Retrospective Analyses 1.2 3-Level Hypothesis Framework 1.3 Structure of this Report	***Marmorek***	960215
2.0 Level 1 The Snake River in the Context of Broad Scale Patterns of Change in Stock Indicators 2.1 Hypotheses - similar pattern of change over time in stock indicators...(task 1.1) - influence of climate (task 1.2) 2.2 Methods - selection of stock attributes, cluster analyses, correlations, regressions, time trends, literature review - data used: large NMFS data set, smaller data set with run reconstructions to compare S and ln(R/S), climate data 2.3 Results Cluster and Trend Analyses - large scale patterns from NMFS data - results from smaller Columbia River data set Influence of Climate - summary of results from other studies on influence of climate; analytical results from this study 2.4 Discussion - implications for management decisions; other levels of analysis	***Paulsen*** Schaller Anderson Bouillon Botsford	960215
3.0 Level 1 Spatial/Temporal Patterns of Change in Spawner-Recruit Relationships Within the Columbia River Basin 3.1 Hypotheses - similar stock-recruitment relationships over space and time in spring chinook (extension of Howard=s Camp Cascade presentation) 3.2 Methods	***Schaller*** ***Petrosky*** Paulsen	960130

Retrospective Analysis Report Sections	**Authors (*Lead*)**	**Due Date**
3.3 Results 3.4 Discussion - implications for management decisions; other levels of analysis		
4.0 Level 2 Stressors and Life History Stages Correlated with Patterns of Change in Stock Indicators: a Multivariate Analysis Approach 4.1 Hypotheses 4.2 Methods - discriminant analysis, multiple regression (perhaps using results from MLE estimates as well as basic data) 4.3 Results 4.4 Discussion	***Paulsen*** Giorgi Petrosky Langness Geiselman Botsford	960215
5.0 Level 2 Changes in Passage Mortality and Stock Production: A Bayesian Approach Using Maximum Likelihood Estimation 5.1 Hypotheses - alternative aggregate hypotheses (e.g. those implied by CRISP and FLUSH) 5.2 Methods - MLE framework; upstream-downstream assumptions; Bayesian approach for assessing relative likelihood of CRISP and FLUSH 5.3 Results 5.4 Discussion - implications for alternative hypotheses; management decisions;	***Deriso*** ***Marmorek*** Schaller Paulsen Petrosky Weber Wilson Anderson	960215
6.0 Level 2 Retrospective Analyses of Life Stage Survival Data 6.1 Hypotheses - trends in freshwater spawning and rearing survival; late ocean survival; (as per section 3.2.2 - Other Hypotheses); pre-spawning survival (Charlie Petrosky's plenary presentation) 6.2 Methods 6.3 Results 6.4 Discussion	***Wilson*** Petrosky Giorgi	
7.0 Level 3 A Structured Synthesis of Evidence Concerning Key Hypotheses in the Columbia River Hydrosystem (Tasks 3.1.1 and 3.1.2) 7.1 Decision Framework 7.2 Hypotheses 7.3 Methods - describe synthesis approach, ranking of evidence 7.4 Results 7.5 Discussion	***Giorgi*** ***Weber*** Toole Williams Wilson Pinney Geiselman	960215
8.0 Level 3 Quantitative Exploration of Alternative Hydrosystem Hypotheses 8.1 Hypotheses - Flow:transit time relationships (Task 3.1.3); mainstem passage survival (3.1.4a); transportation and fish survival (3.1.4b); migration corridor habitat (task 3.1.6); alternative passage routes (task 3.1.7) 8.2 Methods - sensitivity analyses 8.3 Results 8.4 Discussion	***Wilson*** Smith Weber Zabel McConnaha Pinney	960201
9.0 Level 3 A Structured Synthesis of Evidence Concerning Changes in Spawning and Rearing Habitat (Task 3.2)	***Petrosky*** Lee	960130

Retrospective Analysis Report Sections	**Authors (*Lead*)**	**Due Date**
9.1 Decision Framework 9.2 Hypotheses 9.3 Methods 9.4 Results 9.5 Discussion	Paulsen Geiselman Beamsderfer Tweeten Rhoades	
10.0 Level 3 A Structured Synthesis of Evidence Concerning Effects of Hatcheries (Task 3.3) 10.1 Decision Framework 10.2 Hypotheses 10.3 Methods 10.4 Results 10.5 Discussion	***Wilson*** Mundy Weber Smith Pinney PAC	960215
11.0 Level 3 A Structured Synthesis of Evidence Concerning Effects of Hatcheries (Task 3.4) 11.1 Decision Framework 11.2 Hypotheses 11.3 Methods 11.4 Results 11.5 Discussion	***Cooney*** Dygert Norris Schaller Matylewich TAC	960215

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Appendix A: Table of Workshop Participants

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Appendix B: Preliminary Level 1 and 2 Analyses

Charlie Paulsen=s Handout - Section 2.1

Figures 1 and 2 look to see whether the ability of the predictor variables to predict escapement varied with the length of the time series. Some people wondered whether this kind of regression analysis is only effective for relatively short time periods, but that the independent variables could not explain longer time series. The slight non-significant downward trend indicates that shorter time series tended to have a slightly higher adjusted R^2, but several longer time series also showed Arespectable@ R^2 values.

Table 1: Regression coefficients for variables included in significant multiple regressions. The magnitude of the coefficients varies greatly in response to the several orders of magnitude variation in spawning escapements.

Table 2: Pattern of significant trends for a subset of the stocks included in the larger table Cthese are possible indicator stocks distributed throughout the watershed. The table includes the different indices and lags used: -1 indicates a signifcant downward trend, 1 indicates a significant upward trend with the index and lag which the column represents. There does not appear to be any systematic pattern in the indices which were selected, or particular indices that are consistently chosen. See section 2.1 of report.

Appendix C: Contrasts in Stock Recruitment Patterns of Snake and Columbia River Spring/Summer Chinook Populations

Howard Schaller Presentation Handout - Section 2.1

Appendix D: Title Page and Abstract From: Spawner - Recruit Relationships for Spring and Summer Chinook Salmon Populations in Several Columbia amd Snake River Subbasins

C.E. Petrosky, H.A. Schaller and R.C.P. Beamesderfer.
Incomplete Draft Manuscript. 115 pgs.
(Howard Schaller handout - Section 2.1)

Appendix E: An Approach For Analyzing A Level Three Hypothesis: Flow/Migration Speed/Survival

Draft. Al Giorgi. (Al Giorgi handout - Section 4.1)

Appendix F: Level 3 Hypotheses: A Draft Approach Toward Presenting Arguments and Evidence

Prepared by STFA. (Earl Webber/Paul Wilson handout - Section 4.1)

Appendix G: Title Page and Abstract From: A Review of Flow/Survival Relationships For Spring/summer Chinook Salmon From the Snake River Basin

29 pages. by John Williams and G.M. Matthews , Draft Manuscript, in press. (John Williams handout - Section 4.1)

Appendix H: An Approach to Testing Level 3 Hypothesis on Survival and Travel Time

Prepared by J.J. Anderson (Jim Anderson handout - Section 4.1)

Appendix I: Level 3 Example - Prespawning Survival

(Charlie Petrosky handout - Section 4.1)

Appendix J: Excerpt from The U.S. National Acid Precipitation Assessment Program, 1990 Integrated Assessment Report. Star Ranking System