PATH - Plan for Analyzing and Testing Hypotheses

Conclusions of FY96 Retrospective Analyses

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December 10, 1996

Status of this Document

The conclusions presented in this document represent our current consensus on the results of retrospective analyses completed in FY96 (Marmorek et al. 1996)[1], focusing on naturally-spawning spring-summer chinook (i.e. stream-type chinook that migrate back past Bonneville Dam in spring or summer). Readers interested in the details of these analyses should read the full report, which is available from the Bonneville Power Administration. This document has been reviewed by the PATH Scientific Review Panel (SRP), core PATH participants, and other interested scientists. We have spent a large amount of time and effort on compiling these conclusions and ensuring that they fairly represent the evidence obtained from retrospective analyses to date. This includes 2 days of discussion at a PATH workshop in early October, 14 hours of conference calls with the PATH Synthesis Group (people indicated with asterisks in the authorship list), reviews by the PATH SRP and others, and a 2-day meeting to assemble and synthesize all comments and proposed revisions. However, we acknowledge that these conclusions and their supporting evidence may change in the future as analyses are completed and extended. Indeed, many of these analyses are already underway. We intend to produce an update to this document in the early spring of 1997.

Objectives of PATH

PATH is 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. PATH s objectives are to:

1. Determine the level of support for key hypotheses based on existing information, and provide guidance to management agencies on the implications of these analyses for key management decisions [retrospective analyses]. Propose other hypotheses and/or model improvements that are more consistent with the data.

2. Assess the effects of alternative future management actions on salmon stocks, and the ability to distinguish among competing hypotheses from future information [prospective analyses]. Advise various institutions (NMFS, NPPC, BPA, USFW) on the consequences of alternative future management actions for salmon stocks, and the types of research, monitoring and adaptive management experiments which could maximize the rate of learning and clarify decisions.

Iteration within the PATH process occurs as this logical framework is revised over time in response to improvements in both information and analytical methods, and changing management questions. The framework is intended to provide guidance to the development of regional programs that would stabilize, ensure persistence, and eventually restore depressed salmon stocks to self-sustaining levels. It is also meant to provide a structure for an adaptive learning approach to development and implementation of a regional salmonid recovery program. PATH takes a whole life-cycle approach to developing this framework to encompass potential delayed effects of stressors or processes in one life stage on subsequent life stages.

Work in FY 96

In its first year of existence, PATH has already made considerable progress. Specific achievements include:

- clarification of management decisions with senior policy makers;
- development of hypotheses relevant to those decisions;
- considerable data reconnaissance, acquisition and refinement;
- detailed retrospective analyses related to hydrosystem, habitat and hatchery management decisions;
- three workshops and many technical meetings to help design approaches and review pilot

results;
- development of novel analytical tools to assist in decision making;
- recommendations for future research, monitoring and experimentation that arise out of the retrospective analyses;
- eight reports;
- presentations on PATH to the Implementation Team (IT), members of the NPPC, and the public; and
- meetings with the Research Review Group of the IT and the Independent Scientific Group (ISG; now the Independent Scientific Advisory Board) to coordinate our activities.

External peer reviews of PATH were conducted in March/96 and September/96, and have been both very helpful and consistently positive. In addition to advancing this work to the prospective domain, major goals for the next fiscal year are to complete similar analyses for fall chinook and begin to assemble data for steelhead. The current workplan does not include any analyses of Columbia River sockeye stocks.

Structure of this Document

The PATH Final Report on Retrospective Analyses is over 600 pages long, and consists of 13 chapters. To synthesize our results across chapters, we have developed a set of questions in the form of a flow chart (Figure 1). The first question, Do all stocks show a similar pattern of recent change in stock indicators? is important for understanding whether the trends in recent decades in endangered salmon stocks are affected by region-wide forces (e.g. climate), or stresses specific to those stocks. It is also of interest to understand the spatial scale of the observed patterns: basin (including all of the Columbia River and its tributaries); regions (portions of the Columbia such as the upper-Columbia, or tributaries to the Columbia such as the Snake River); or individual sub-basins (e.g. Middle Fork Salmon River and Grande Ronde River, each containing several index streams), and whether the different patterns that are observed correlate with geography or other obvious environmental characteristics.

The second question focuses on the nature of differences among stocks. We address two questions:

1) Have productivity and survival rates of spring chinook changed, and if so, when? (Question 2a)
2) Is the difference between productivity indices in pre-1970 and post-1974 periods the same for upstream and downstream stocks? (Question 2b)

The two time periods chosen for comparison were selected because a number of changes occurred in the 1970's. These changes include completion of 3 of the 4 lower Snake River Dams (Lower Monumental, Little Goose, and Lower Granite) and one lower Columbia River dam (John Day), concurrent declines in stock indicators (i.e. survival rates and productivity parameters), a shift from a cool/wet to a warm/dry oceanographic regime in the Northeastern Pacific Ocean around 1977, increases in production of hatchery fish, and changes in the seasonal distribution of flows in the Columbia River estuary. Stock groups were defined geographically[2]. Upstream stocks include 7 Snake River index stocks and 3 stocks that originate in the Upper Columbia River (above the confluence of the Columbia and Snake Rivers, including the Methow, Entiat, and Wenatchee Rivers). Downstream stocks are those that originate between the confluence of the Snake River and Bonneville Dam. Index stocks in this group include stocks from the John Day, Warm Springs, Klickitat, and Wind Rivers. The three John Day stocks were the only lower river stocks for which pre-1970 data were available.

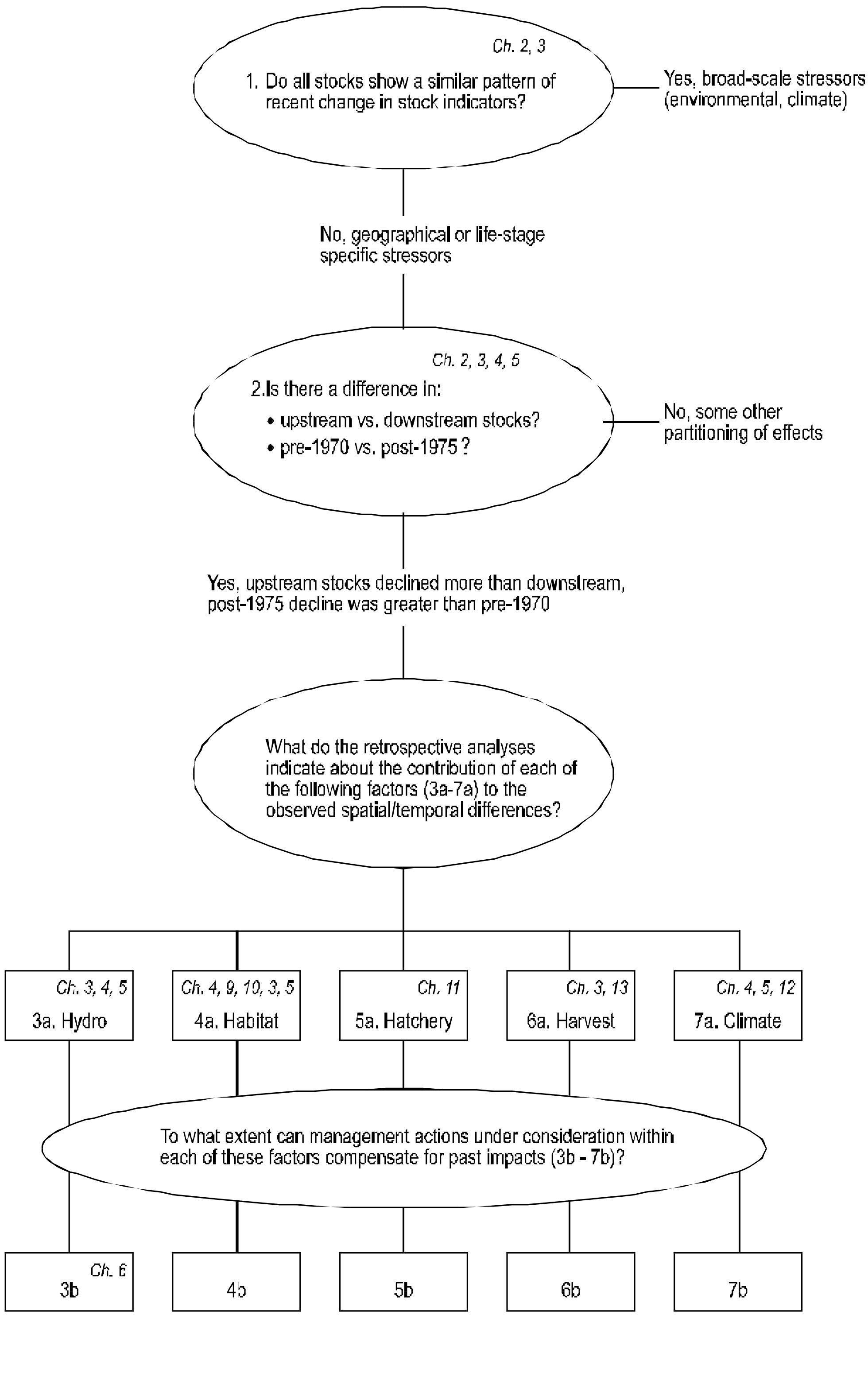

Figure 1: Framework for summarizing results and conclusions.

The third set of questions consists of two parts:

a) What do the retrospective analyses indicate about the contribution of each of five factors (hydro, habitat, hatchery, harvest and climate) to the observed spatial and temporal differences? Note that analyses to date refer primarily to freshwater spawning and rearing habitat. However, we acknowledge that effects in other habitats, such as the estuary, may be common factors that affect the temporal pattern of change in both upstream/downstream stocks.

b) To what extent can management actions under consideration within each of these factors compensate for past impacts? We have only begun to address this question seriously for hydrosystem management actions, and expect to provide more insights during the next year s work. For the hydrosystem, we address four questions:

   1) Can **transportation of fish to below Bonneville Dam** compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration? (Question 3b(i))
   2) Can **modifications to in-river passage**, other than drawdown, compensate for the effect of the hydro system on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration? (Question 3b(ii))
   3) Can a **combination of transportation under some conditions and in-river passage under other conditions** compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration, if **improvements to transportation and modifications to in-river passage, other than drawdown,** are made? (Question 3b(iii))
   4) Can **drawdowns to spillway crest or natural river level** compensate for the effect of the hydro system on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration? (Question 3b(iv))

Answers to the questions in Figure 1 are presented by summarizing our overall conclusions to date, the evidence for these conclusions, and the information required to address remaining uncertainties. There are varying amounts of uncertainty surrounding both the conclusions and the individual pieces of evidence. The degree of scientific consensus associated with the evidence is indicated in most cases by a star system :

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

This approach was successfully applied to a broad range of impacts in the final report to the U.S. Congress on the National Acid Precipitation Assessment Program.[3] The degree of uncertainty in the conclusions is indicated verbally in the text of the conclusion by stating whether there is low confidence , reasonable confidence , or high confidence in the conclusion. The degree of confidence in a conclusion is determined by the strength of the evidence on which it is based. For example, conclusions in which there is reasonable or high confidence require strong empirical support (i.e. evidence with 3 or 4 stars). Where our analyses allow for alternative hypotheses, we have described those alternatives and their supporting evidence.

Information needs for each conclusion summarize what is required to reduce the uncertainty in that conclusion and its underlying evidence, addressing both data and conceptual gaps (e.g. absence of hypothesized mechanisms) that prevent a full understanding and rigorous quantitative description of the relationships between natural and human-induced stressors and salmon populations. For each information need, we also provide a rough estimate of when this information might be available given the constraints on either collecting or analyzing relevant data. In some cases, research designs that will generate this information have already been identified. **Information needs that are marked with P in the margin are tasks that PATH will carry out in its FY97 Work Plan.** PATH has only begun to explore alternative research designs. The development of these designs, including the design and implementation of an adaptive management framework, remains one of the major objectives of PATH.

Question 1

Do all wild yearling-migrant spring/summer chinook salmon stocks above Bonneville Dam show a similar pattern of change in stock indicators since the late 1950s?

Overall Conclusions

1.1 Although all stocks have declined somewhat since the late 1950's, we conclude with high confidence that these stocks do not all have the same long-term trends in number of spawners (S) or recruits (R) per spawner (R/S: # of adults returning to the mouth of the Columbia River per spawner in the parent generation[4])

1.2 We conclude with reasonable confidence that stocks originating from the Salmon River sub-basin and from the upper-Columbia sub-basin show steeper patterns of decline since the late 1950's than do stocks originating from the lower Columbia sub-basin. Patterns of decline are similar within the Salmon River stock group and within the upper-Columbia stock group. Patterns of decline are not similar within the lower river stocks. In addition, the lower river stocks show a decline that is less steep than the upstream stocks.

1.3 We conclude with reasonable confidence that year-to-year fluctuations about the trends are strongly similar within the Salmon River, Oregon tributaries of the Snake River, and Upper Columbia River sub-basins. In addition, there are many similarities across sub-basins.

Since sub-basins differ in trends in number of spawners and R/S, long term declines were more likely associated with factors affecting stocks which originate in those sub-basins, rather than some common factor affecting all monitored stocks within the Columbia Basin. Year-to-year changes about these trends, however, showed some similarities among both upper and lower river stocks, suggesting that some common environmental forces may have been operating.

Note on Spawner and Recruit Data

There is uncertainty and variability in the expansion of redd counts to spawners and recruits. Further review of the expansions of redd counts to Spawner and Recruit estimates should be completed in FY97, including the effects of uncertainty and potential bias on analyses. This review may lead to changes in the conclusions presented herein, or their associated levels of confidence.

Evidence for Conclusion 1.1:

Correlation and cluster analyses of spawning escapement (ln(R/S)) from 16 stocks (Ch. 2; Botsford (1996)) suggest that:

> The five spring-summer chinook index stocks within the Salmon River sub-basin covary significantly. The three upper-Columbia River index stocks also covary significantly with one another. Both of these groups of stocks are distinct from those within other sub-basins (Botsford 1996 Tab. 2). (***)

Analysis of Covariance tests for differences in productivity (measured as the intercept in the relationship of ln(R/S) versus S) between the pre-1970 and post-1974 periods were significant for 12 out of 14 index stocks. The two exceptions were the Poverty Flat (on the Snake River) and Middle Fork John Day stocks (Ch. 3 Tab. 3-4). (**)

Evidence for Conclusion 1.2:

Analyses of stock-recruitment data (where recruits are the number of adults returning to the mouth of the Columbia River) for upstream and downstream index stocks indicate that:

The survival rate (measured as ln[(observed R/S)/(predicted R/S)]) of upstream stocks show different long-term trends than downstream stocks (Ch. 3, Figs 28, 29, 30). (**)

Evidence for Conclusion 1.3:

Correlation and cluster analyses of spawning escapement (ln(R/S)) from 16 stocks (Ch. 2; Botsford (1996)) suggest that:

In terms of rapid variability about trends, many stocks throughout the interior Columbia River basin covary significantly (Botsford 1996 Tab. 4). (***)

The Wind River and Warm Springs River stocks each show unique patterns of year-to-year variability, different from all other stocks (Botsford 1996, Tab. 4 and p. 8). (***)

The three John Day River stocks show distinct patterns of short-term (year-to-year) variability from one another (Botsford 1996 Tab. 4). (***)

There are some intriguing similarities among stocks from different regions in their year-to-year variability. For example, the North Fork of the John Day River and the Klickitat River both covary significantly with the Salmon River stocks (Botsford 1996 Tab. 4). (***)

Information Needs

P The analysis should be extended to stream-type chinook salmon stocks outside the Columbia River Basin to better assess the geographic scale at which stocks covary (<1 year to collect additional data and complete analyses).

P The analysis should also extend to Columbia River ocean-type chinook salmon and steelhead and hatchery stocks of these species and areas, although some analyses (e.g. discriminant analysis) may not be possible because of the small number of stocks. Data for these stocks may be obtained by reconstructing runs for more stocks or by using S_{t+T}/S_t as an index of recruitment (where T is based on the appropriate maturity schedule). Caution should be used in applying S_{t+T}/S_t when harvest rates vary, particularly for ocean-type chinook. The estimated time before this information is available will depend on availability of data.

Question 2a

Have productivity and survival rates of spring chinook stocks changed, and if so, when?

Overall Conclusions

We conclude with a high degree of confidence that the stock productivity and survival rate of the aggregate of spring chinook stocks have decreased over time, especially between the pre-1970 and post-1974 periods.

Evidence

Estimates of productivity (i.e. Ricker 'a' parameter) for each decade for the aggregate of natural-spawning spring chinook stocks (from above Bonneville Dam) show similar values for the 1940s, 1950s, and 1960s ('a ' = 1.8 - 1.98), but then a large and significant decrease in the 1970s ('a' = 0.63) and 1980s ('a' = 0.37) (Ch. 3, Tab. 9). Survival rate indices for the aggregate of spring stocks that reflect survival rate deviations from those defined by the best-fit Ricker curve (i.e. *ln[(observed R/S) / (predicted R/S)])* are also lower beginning in the 1970s than in the previous period (Ch. 3, Tab. 7 and Figs. 28 and 29).

Information Needs

P Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

P Use different time periods from 1939 - 1990 in applying the Analyses of Covariance in Chapter 3 to evaluate more precisely when changes in stock indicators occurred (<1 year).

The decrease in productivity and survival rates starting in the 1970s suggests that future analyses should focus on hypotheses relevant to that period.

Continue stock identification program at Bonneville Dam, and expand to Lower Granite Dam to get better data on age structure and stock composition.

Question 2b

Is the difference between productivity indices in pre-1970 and post-1974 periods the same for upstream and downstream stocks?

Overall Conclusions

2b1. We conclude with a reasonable degree of confidence that the stock productivity (defined below) decreased between the pre-1970 and post-1974 periods more in the upstream than in the downstream stocks.

2b2. We conclude with a high degree of confidence that the survival rate index (defined below) decreased more between the pre-1970 and post-1974 period in the upstream than in the downstream stocks.

2b3. We conclude with a high degree of confidence that the variability in survival rate index increased for the Snake River stocks in the post-1974 period compared to the pre-1970 period.

2b4. We conclude with a reasonable degree of confidence that the variability in the survival rate index did ***not*** *increase between pre-1970s and post-1974 periods for the Upper Columbia River stocks (above the confluence of the Snake River) and for the lower Columbia River stocks.*

2b5. We conclude with a reasonable degree of confidence that the estimates of productivity became more uncertain in the post-1974 period for most of the upstream stocks, due to wider variation in (R/S) ratios. This uncertainty did not increase for the downstream stocks.

Evidence

Analyses of stock-recruitment data for upstream and downstream index stocks indicate that:

Productivity (measured as the Ricker a parameter in the ln(Recruits/Spawner) versus Spawner relationship[5]) declined more from the pre-1970 period to the post-1974 period in the upstream stocks than in the downstream stocks (Ch. 3, p. 15). Tests justified the assumption that the Ricker $ parameters for each stock were the same in both time periods (Chap 3, Tab. 4, Equation 3-2). (***)

A survival rate index, measured as ln[(observed R/S) / (predicted R/S)], also declined significantly more from the pre-1970 period to the post-1974 period in upstream than in downstream stocks (Ch. 3, p. 15-16, Tabs. 7 and 8). (***)

Variability in the survival rate index increased more in the post-1974 period for Snake River stocks than in all other index stocks (Ch. 3, Fig. 28). (**)

Productivity (Ricker a parameter) of upstream chinook stocks declined abruptly, beginning around 1970 (Ch. 3, Tab. 9). Survival rate decreased for the upstream stocks between 1960 and 1990 (Ch. 3, Figs. 28 and 29), but not for the downstream stocks (Ch. 3, Fig. 30). Productivity remained fairly stable for the aggregate spring chinook stocks above Bonneville from about 1930 to 1970 (Ch. 3, Tab. 9) and survival rate remained fairly stable from about 1950 to 1970 (Ch. 3, Figs. 29 and 30). (***)

For conclusion 2b5, standard errors on estimates of the Ricker 'a' parameter were larger for all upstream stocks in the post-1974 period than in the pre-1970 period, except for Bear Valley/Elk and Johnson stocks (Ch. 3, Figs. 25, 26). This pattern did not hold as clearly for the downstream stocks (Ch.3, Fig. 27). (**)

Information Needs

P Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

P If possible, data for other downstream stocks (e.g. McKenzie River in the Willamette basin and coastal North Umpqua spring-run) should be included to strengthen some of the conclusions about geographical differences (<1 year). However, caution should be used when comparing these stocks to above-Bonneville spring-summer stream type stocks, as the McKenzie and N. Umpqua stocks have different juvenile life histories and ocean distributions from the above-Bonneville stocks. Similar analyses should be done for fall chinook (<1 year) and possibly steelhead (< 2 years), although the quantity and quality of population data for these stocks is poorer than for spring-summer chinook.

To enhance future analyses, full spawning ground monitoring (redd counts, age structure, hatchery percentages) of all spring-summer index stocks should be maintained, and expanded to include additional index stocks.

Question 3a

What do the retrospective analyses indicate about the contribution of the ***hydrosystem*** *to observed spatial/temporal differences in stock indicators?*

Conclusion 3a.1

We are highly confident that the differences (identified in Question 2) in stream-type chinook indicators of productivity and survival rates between upstream (Snake River sub-basins) and downstream (lower-Columbia sub-basin) stocks are coincident in space and time with development of the hydrosystem.

We are reasonably confident that on a decadal scale, the differences (identified in Question 2) in stream-type chinook indicators of productivity and survival rates between upstream (Upper Columbia sub-basins; i.e. Methow, Entiat, and Wenatchee) and downstream (lower-Columbia sub-basin) stocks are coincident in space and time with development of the hydrosystem.

We have low confidence that on a finer time scale, changes in productivity and survival of upper Columbia stocks (Methow, Entiat, and Wenatchee) are coincident with an increase in the total number of dams through which these fish migrate.

Evidence

Between the 1953-69 period and the post-1970 period, there was a larger increase in the **average** number of dams encountered by the Snake and upper-Columbia stream-type chinook stocks than for the lower river stocks (Ch. 3, Fig. 6C, Ch. 4, p. 16-17, Tabs. 4.1 and 4.6). (****)

There was a significant decrease in the water velocity and an increase in water velocity variability encountered by Snake River stream-type chinook stocks after 1970 (Ch. 3 Fig. 6d). (***)

Conclusion 3a.2

We are reasonably confident that the aggregate effects of the hydrosystem have contributed to reduced survival rates of Snake River stocks (from spawners to adults returning to the mouth of the Columbia River), during the post-1974 period, as compared to the pre-1970 period. Hydrosystem effects include both direct (e.g. turbine mortality) and indirect effects (e.g. delayed mortality, due to such mechanisms as changes in estuary arrival times).

Evidence

Maximum likelihood estimation (MLE) analyses were completed using upstream/downstream stock comparisons for Snake River stocks (Ch.5). A detailed MLE analysis has not yet been completed for Upper Columbia stocks (Methow, Entiat, and Wenatchee). These analyses show that after removing common effects affecting the year-to-year patterns in all stocks, and differences in productivity among stocks, the remaining differences between Snake River and downstream stocks in their recruitment to the mouth of the Columbia River are consistent with the following *hydrosystem impact hypotheses* (**):

> The 1952 to 1970 brood years of Snake River stocks passed through 2-7 dams, consistent with the hypothesis that there was a 40-84% reduction in recruitment (respectively; average= 65%)[6] associated with the hydrosystem. Down-river stocks passed through 1-3 dams, consistent with the hypothesis that there was a 23-54% reduction in recruitment (respectively) associated with the hydrosystem (average for stocks passing through 2 dams was 40%) (Ch. 5, Tables 5-4 and 5-5).
>
> The 1975 to 1990 brood years of Snake River stocks either passed through or were transported around 8 dams. This is consistent with the hypothesis that there was an 89% reduction in recruitment of Snake River stocks associated with the hydrosystem[7]. Down-river stocks passed through up to 3 dams, consistent with the hypothesis that there was up to a 54% reduction in recruitment of these stocks associated with the hydrosystem (Ch. 5, Tables 5-4 and 5-5).

One of the main mechanisms by which dams can affect salmon is by reducing water velocity. As indicated above in Conclusion 3a1, there was a significant decrease in water velocity and an increase in water velocity variability encountered by Snake River stream-type chinook stocks after 1970 (Chap. 3, Fig. 6d). Between 1970 and 1990, upstream stocks experienced greater reductions in brood year recruitment when outmigration water velocities were slower (Ch. 5, Fig. 5-5). Low to negligible reductions in recruitment occurred for 6 brood years 1970, 1973, 1980-1983, five of which had water velocities faster than the average for that period (Ch. 5, Figure 5-6). (**) This statistical association does not imply that average water velocity is the sole factor responsible for increased mortality; many other factors are believed to be important. The hydrosystem also changed conditions within the estuary, including flow and the arrival times of both in-river and transported fish.

An alternative explanation for observed upstream-downstream differences in recruitment patterns is that some non-hydro mortality factor (e.g. ocean mortality) differentially affected upstream/downstream river stocks in a large enough way to coincide with and account for the estimated mortality attributed above to the hydrosystem.There is strong evidence for common year/climate effects that affect all index stocks recruitment (Ch. 5, Fig. 5-2). Though it is clear that survival patterns vary among stocks on both decadal and year-to-year time scales (Ch. 2, 4, 5), there are differences of opinion in the level of evidence for systematic, regional differences in ocean distribution or mortality between upstream and downstream stocks. Other factors may have contributed to upstream/downstream differences, but their coincidence in space and time with changing recruitment patterns has not yet been investigated.

Conclusion 3a.3

We are reasonably confident that the hydrosystem has contributed to decreased juvenile survival in the downstream corridor for Snake River stocks in the post-1974 period.

Evidence

Juvenile tagging studies indicate:

Survival from the area of the head of Lower Granite (LGR) pool to Ice Harbor (IHR) pool (96 miles) declined from the pre-1970 period to the post-1974 period (from Ch. 6, p. 30-31) (**):

Brood Years	Ave. surv LGR to IHR
1964-1966:	95%[8]
1974-1982:	55%[9]
1991-1994:	73%[10]

There are various differences among these three time periods. First, the middle period is longer and therefore likely encompasses a wider range of environmental conditions. Also, the proportion of hatchery fish in the population increased through time. (Ch. 3, Fig. 6a).

Estimates of per-mile survival in free-flowing reaches of the Snake River based on recent pit-tag data suggest that survival over the Lower Granite to Ice Harbor reach in the absence of dams would remain comparable to the 1964-1966 period. (**) (Ch. 6, p. 6-30).

Adult upstream passage

Retrospective analyses have not been completed for adult upstream passage, but are planned for inclusion in FY97. The following data will be used in PATH retrospective analyses of adult passage:

1. Estimated upstream conversion rates

2. Adult radiotracking data

Information Needs (for all of question 3a, also relevant to question 3b)

It is critical to maintain and expand the monitoring of index stock spawning and recruitment throughout the Basin, and expand to other species (i.e. fall chinook and steelhead). Multiple surveys over time and area should be maintained to estimate the errors associated with peak redd counts.

We also need to develop a system-wide, ecosystem approach to estimating migratory corridor juvenile survival rates of upstream and downstream stocks through tagging experiments of both hatchery and wild fish. The data should be collected over a number of years to include a wide range of environmental conditions. The ability to make these estimates from tagging data is currently constrained by the limited collection opportunities in the JMC for downstream stocks (those that enter the mainstem below John Day Dam), and by the small number of adults that survive to adulthood. These juvenile survival rates should be compared to estimates of the spawner to recruit survival rates of both up-river and down-river, stream type stocks. Both juvenile and spawner-recruit survival rates should be compared to hydrosystem, fish condition, and river/estuarine indices (e.g. conditions in estuary, timing of arrival of different stocks to the estuary, spill, temperature, flow, water transit time, % transported) to better elucidate the reasons for year-to-year variation in survival rates (>10 years to collect data).

P Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

P Use CRiSP and FLUSH to explore hypotheses about delayed mortality and compare to MLE and other data (i.e. PIT-tag passage survival estimates, SAR estimates) (<1 year).

P Attempt to explain year-to-year variation in delayed mortality as functions of climate and other variables (<1 year).

P Clarify dip in net dam passage mortality from the Snake River sub-basins to John Day Dam in early 1980's (<1 year).

P Estimate net dam passage mortality for upper-Columbia stocks (Methow, Entiat, and Wenatchee) and compare to downstream and upstream estimates (i.e. perform MLE analyses for these stocks; <1 year).

P Various tasks to assess the degree of association between habitat, hatchery, climate changes, and changes in recruitment (see Information Needs under sections 4a, 5a, and 7a).

Question 4a

What do the retrospective analyses indicate about the contribution of ***habitat changes*** *to the difference in upstream vs downstream stocks and between pre-1970 vs post-1974 conditions?*

Conclusion 4a1

We conclude with reasonable confidence that habitat degradation affected many Columbia River salmon stocks before 1975. Such past changes may still be affecting some stocks, though the habitat of other index stocks remains in high quality condition.

Evidence

Descriptions of historic land use activities (Ch. 10, Appendix 5; Beamesderfer et al. 1996). (***)

Conclusion 4a2

Though changes in the quantity and quality of freshwater spawning and rearing (FSR) and pre-spawning (PS) habitat may have contributed to production declines in some index streams, we conclude with reasonable confidence that changes in adult-to-smolt survival (presumably related to the quantity and quality of FSR habitat) do not appear to be of a great enough magnitude <u>*alone*</u> *to explain the post-1974 decline in spring and summer chinook index stocks.*

We have not yet examined upstream-downstream differences in habitat, but intend to do so.

Evidence

FSR productivity and survival of the aggregate of Snake River index spring/summer chinook stocks, as inferred from ln(smolts/spawner) vs spawners, does not appear to have declined since hydrosystem completion (Ch. 9, p. 11). Tests of FSR survival had adequate statistical power to detect declines in spawner-to-smolt survival of > 25%. Therefore, declines in spawner-to-smolt survival (presumably due to declines in quantity and quality of FSR habitat) must have been less than 25%, which is well below the magnitude of observed declines in spawner-to-adult recruit survival rates (e.g. ln(R/S)). (***)

Observed changes in patterns of survival rates (e.g. ln(R/S)) over time are similar among stocks in different habitat conditions (Ch. 3). (**)

Changes to physical habitat within the index sub-basins (i.e. losses of quality pools, temperature increases, point-source discharges) throughout the Snake River Basin that are known to be associated with reduced survival and production of riverine salmonids occurred primarily before 1975 (Ch. 9, p. 2). (**)

Life history and PIT tag studies suggest that mortality during FSR is habitat-specific (Ch. 10, p. 14, 15). (***)

Information Needs

The conclusion applies primarily to the index spring/summer chinook stocks for the time period for which runs can be reconstructed. However, the aggregate, long-term impacts of the degradation on the productivity of the basin as a whole are unknown.

Determine whether the changes in productivity among index populations are representative of the response in populations across the available spectrum of FSR and PS habitat conditions (i.e. pristine to degraded). Habitat contrasts within regions and sub-basins will provide the best tests of habitat quality effects. This may be done using PIT-tag and radio-telemetry studies in ranked quality habitats surveyed under standardized indices or variables (2-3 years).

- Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

- Identify habitat changes in the migratory corridor that are not related to the hydrosystem and their potential effects on observed differences between upstream and downstream stocks (duration depends on availability of data).

- Identify changes in the estuarine habitat and their potential effects on temporal patterns in observed declines of both upstream and downstream stocks (duration depends on availability of data).

- Derive rules for systematically assigning habitat ratings to index stocks and to currently unoccupied habitats that are known to have produced chinook in the past (<1 year).

P Compare changes in Ricker alphas (from Ch. 5) over time among stocks with different habitat ratings (include other stocks beyond index stocks) to estimate effects of habitat on productivity (<1 year).

P Use the parr density data base to measure differences between good and bad habitats (<1 year).

P Examine other habitat models (e.g. from ISG report) and case studies (<1 year).

P Continue analysis of parr-to-smolt PIT tag data in relation to habitat conditions (<1 year; already started in Ch. 10 Appendix 4).

P Extend analyses in Chapter 4 to assess statistical association between ln(R/S) and land use data (<1 year)

Question 5a

What do the retrospective analyses indicate about the contribution of artificial propagation to the observed spatial/temporal differences?

Overall Conclusions

Preliminary results suggest that artificial propagation of spring/summer chinook has not significantly contributed to declines in wild populations of spring/summer chinook in upstream areas (Snake and upper Columbia River) between pre-1970 and post-1974 periods.

These results, which must be considered highly tentative given the limited amount of data analysis completed to date, imply that the hatchery programs have not been a major cause of the continued decline of endangered spring/summer chinook stocks in the Columbia River.

Evidence

Declines in the productivity and abundance of the listed Snake River chinook stocks preceded the initiation of most Snake River hatcheries (Ch. 3, p. 5; Ch. 11 Imnaha River analysis). (**)
Lower Columbia naturally-spawning spring/summer chinook stocks (e.g. Klickitat, Warm Springs), which have been influenced by artificial propagation for a longer period of time than Snake River stocks, have not exhibited declines in productivity and abundance of the same magnitude as Snake River stocks (Ch. 3, p. 7). (**)

Interaction between wild fish and hatchery fish during mainstem smolt migration is likely greater for listed Snake River stocks than for downstream stocks because of increased contact between fish during barging and dam passage. The resulting opportunities for disease transmission and competition could adversely affect smolts originating in the Snake River basin. (*)

Information Needs

P Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

P Complete/extend multiple regression analysis in Chapter 11 (<1 year):
  - C add additional stocks and species
  - C analytical refinements (e.g. correction for autocorrelation bias)

- C add other hatchery production variables (e.g. number, method, and timing of releases, number of releases per spawner)

P The MLE approach in Chapter 5 could be modified to incorporate hatchery data to test hypotheses about hatchery impacts (< 2 years). Since many hatchery programs were instituted in response to declines in populations, there will be some confounding between hatchery effects and hydro effects. However, there may be some opportunity for partitioning these effects.

P Many of the specific hypotheses discussed in Chapter 11, section 1, which allude to possible mechanisms for hatchery effects on wild populations, require further examination. In many cases, empirical/statistical analyses may not be possible because of inadequate data for the specific stocks of concern. Instead, conclusions and data will have to be drawn from a thorough review of available literature. Data from outside the Columbia Basin should be obtained from published sources only (<2 years).

P An alternative approach to direct comparisons between wild and hatchery R/S would be to compare the observed survival rate (ln(R/S)) for hatchery fish to that predicted from the stock-recruitment relationship for the stock in question using both wild and hatchery spawners (<2 years).

Question 6a

*What do the retrospective analyses indicate about the contribution of **harvest** to the observed spatial/temporal differences in stock indicators?*

Overall Conclusion

Chapter 13 (which is incomplete) contains the retrospective analyses of harvest effects and has not yet been subjected to internal and external review. The authors of that chapter have an interim conclusion with a reasonable degree of confidence that harvest has not significantly contributed to declines in index upstream (Snake and Upper Columbia Rivers) stream-type chinook stocks between the pre-1970 and post-1974 periods.

Evidence (all from Chapter 13, which was incomplete at the time of editing the Conclusions Document)

Freshwater harvest rates (mainstem and tributary) were reduced from annual averages of approximately 54% between 1950 and 1970 to less than 8% for 1975-1995 for spring chinook. For summer chinook, freshwater harvest rates were reduced from annual averages of approximately 32% between 1950 and 1970 to 3% between 1975 and 1995 (Ch. 13). (***)

Ocean harvest rates for upstream stream-type spring and summer chinook salmon are estimated to be less than 5% and possibly less than 1% for the post-1974 period (Ch. 13). (**)

The decline in ln(Recruit/Spawner) and ln(Spawner/Spawner) and in survival rate indices are coincident with a substantial decline in harvest rates. Coincident trends are contrary to the hypothesis that harvest is a major contributing factor to the decline in productivity and survival rate indices for upstream stream-type chinook between the pre-1970 and post-1974 periods (Ch. 13). (***)

Information Needs

P Review spawner-recruit estimates (see Note on Spawner and Recruit Data under Question 1; <1 year).

P The Harvest workgroup will supply information needs once their retrospective analyses are completed.

Question 7a

What do the retrospective analyses indicate about the contribution of ocean conditions and terrestrial climate to observed spatial/temporal differences in stock indicators?

Overall Conclusions

7a.1 We conclude with reasonable confidence that stocks differ in their degree of statistical association with selected indicators of ocean conditions and terrestrial climate, but there are no consistent differences in response between upstream/downstream stocks.

Certain environmental stressors are associated with spawner to recruit survival (ln(Recruits/Spawner)) for some stocks and not for others. In particular upstream/downstream stocks show systematic differences in their associations with drought and ocean indicators. Although this suggests that the effects of both ocean and local climatic conditions differ between sub-basins, the relative contribution of these effects to observed upstream/downstream differences in stock indicators is unclear.

7a.2 We conclude with reasonable confidence that climatic conditions have contributed to observed differences in stock indicators between the pre-1970 and post-1974 periods.

There is evidence from published literature that an abrupt shift in ocean conditions in the North Pacific ocean in 1976 has affected salmon populations throughout the North Pacific. In general, southern populations have been negatively affected by this change, while northern populations have been positively affected. This implies that ocean conditions have contributed to temporal patterns in stock indicators of Snake River and lower Columbia spring/summer chinook stocks. Ocean conditions may amplify the effects of other stressors on these stocks, and continued poor ocean conditions may reduce any positive results of measures that reduce the impacts of these stressors.

Evidence for conclusion 7a.1

Analyses of stock-recruitment data do not show differences between Snake River and downstream stocks that are significant:

Models in which ocean survival was assumed to differ systematically between Snake River and downstream stocks do not provide a significantly better fit to stock-recruitment patterns than models in which ocean survival was assumed to be constant for all stocks (Ch. 5, p. 18). (***)

Correlation analyses of year effects estimated from stock-recruitment data indicate that:

Year effects (effects that were assumed to reflect common factors affecting survival of all stocks, including ocean conditions) were not associated with either the North Pacific Index (NPI; an index of ocean conditions in the North Pacific) or the May upwelling index (Ch. 5, p. 17). (***)

Regression analyses of survival rates (measured as ln(recruits/spawner)) indicate that:

The patterns of statistical association between the NPI and survival rates of upstream and downstream stocks are complex. Upper-Columbia and John Day stocks generally showed more association with NPI than other lower Columbia or Snake River stocks (Ch. 4, p. 16, Tab. 4.6). The John Day consistently shows either a positive relationship or no relationship to the NPI in the 2nd and 3rd ocean winter (Ch.

4, Tab. 4.6). However, with some regression models, none of the stocks showed any relationship to the NPI in the 1st ocean winter or to the upwelling index (Ch. 4, Tabs. 4.2a, 4.2b, and 4.4b). (**)

The patterns of statistical association between survival rates and upwelling indicators are also complex. Survival rates of lower Columbia stocks showed a stronger degree of association with the May upwelling index than upstream stocks (Ch. 4, p. 16, Tab. 4.6). However, adding the upwelling index as a covariate for all downstream stocks (as a single group) in the MLE analysis did not affect the MLE. Furthermore, there was no correlation between upwelling indices from different months (e.g. between May upwelling and June upwelling), suggesting that these indices did not reflect the strong temporal signal in upwelling conditions that would indicate a possible mechanism for observed associations between survival rates and upwelling indicators (Deriso, unpubl. analysis). Work by Hinrichsen et al. (cited in Ch. 12) suggests that the timing of the spring transition in winds (associated with a change from downwelling to upwelling conditions), rather than its strength in any one month, may have more effect on smolt to adult survival. (**)

Survival rates for most upstream spring-summer stocks decreased under May-September drought conditions, while downstream stocks and Snake River summer chinook stocks showed no significant association with this factor (Ch. 4, p. 16, Tab. 4.6). (**)

Evidence for conclusion 7a.2

Analyses of stock-recruitment data indicate that:

Year effects on recruitment (effects that were assumed to reflect common factors affecting survival of all stocks, including ocean conditions) were generally positive for the 1952-1968 brood years and negative for 1970-1989 brood years (Ch. 5, p. 13). (***)

Correlation analyses of year effects estimated from stock-recruitment data indicate that:

Sockeye salmon from Bristol Bay, Alaska, had higher survival rates in years when there were positive year effects than in years when there were negative year effects (Deriso and Peterman, unpubl. analysis, cited in Ch. 5, p. 17). (***)

Reviews of previous studies (Chapter 12) suggest that:

Many populations of marine fish, including Pacific salmon, have experienced major and persistent changes since the mid-1970's. Salmon catches in the northern portion of the Pacific Ocean (off northern B.C. and Alaska) have increased, while catches of southern populations (off Washington, Oregon, and California) have decreased (Ch. 12, p. 2-3). (***)

There was a major shift in oceanographic conditions in the North Pacific ocean between 1976 and 1977 (Ch. 12, p. 1). (***)

The shift in ocean conditions in 1976 was characterized by a change in current patterns along the west coast of North America. The effect of this change was to lower productivity of coastal waters in the southern portion of the west coast (off Washington and Oregon), and increase productivity off northern B.C. and Alaska (Ch. 12, p. 3-4). (**)

Catches of Columbia River spring chinook (which depend on fishing effort, catchability, etc. as well as on recruitment) were inversely correlated with the Pacific Northwest Index (PNI), a composite index of freshwater and marine climate patterns in the Pacific Northwest (Ch. 12, p. 6). (**)

Information Needs

See Information Needs under question 3a.

- P Test for correlations between Chapter 5 year-effects and PNI, flow, water of origin, timing of spring transition relative to arrival times, and other environmental variables (<1 year).

- P Test for statistical associations between survival rate indices and other environmental variables (extension of Chapter 4, with a priori hypotheses) (<1 year).

Preamble to Questions 3b-7b

A reasonable objective for management of hydro, habitat, harvest, and hatcheries in the Snake and Columbia River basin is that these activities should result in survival rates that allow persistence and recovery of listed Snake River spring/summer chinook salmon. One goal of the PATH prospective analysis is to determine the survival rate over the entire life cycle that is necessary to achieve recovery of these stocks. Determining this overall survival rate is a prerequisite for determining the improvement in overall or life-stage specific survival, relative to current survival rates, that is needed for persistence and recovery. When the magnitude of these needed improvements is known, the effectiveness of management actions within each of these human activities in providing these improvements can be assessed (planned for FY97). Therefore, determining the overall survival goal is an important step in answering questions 3b-6b, To what extent can management actions within each area of human activity (hydrosystem, habitat, hatchery, and harvest) compensate for past impacts on listed Snake River spring/summer chinook? .

PATH prospective analyses to determine the overall survival rate necessary for persistence and recovery will not be completed until the spring of 1997. We will attempt to structure the quantitative prospective analyses to partition the effects of human-induced mortality factors and climate, based on a Bayesian approach to uncertainty that builds on the retrospective analyses in Chapter 5 and the use of formal decision analyses. In the meantime, the PATH hydro working group has proposed an interim smolt-to-adult return (SAR) survival goal of 2-6%[11], which includes: (1) direct mortality of smolts and adults passing through the Federal Columbia River Power System (FCRPS) that are caused by the hydro effects; (2) any smolt mortality caused by other human factors that are expressed within or below the FCRPS (e.g. pollution, smolt condition related to habitat quality and hatchery effects); (3) mortality below Bonneville and in the ocean resulting from delayed effects of smolt passage through the FCRPS; (4) natural ocean and estuarine mortality; (5) disease; and (6) ocean and in-river harvest.

PATH has only started to address question 3b (hydro management actions to compensate for past impacts) in any detail. However, questions 4b-6b will also be addressed by prospective analyses in FY97. In the conclusions for question 3b that follow, we emphasize that these conclusions are based on the interim survival goal, and are subject to change once the SAR goal has been established by the PATH prospective analyses.

Question 3b

Questions 3b(i) - 3b(iv) are adapted from the Chapter 6 decision tree (Marmorek et al. 1996, pages 6-4 to 6-8)[12]. The decision tree is more complex than the questions presented in this summary, with most questions being contingent upon the conclusions reached for previous questions. The Chapter 6 decision tree organized long-term management options hierarchically, starting from the present hydro configuration and moving to those requiring major structural changes. The structure of the formal decision analysis planned for FY97 involves a concurrent examination of options. The interested reader is urged to review the more detailed Chapter 6 summary on pages 6-9 through 6-22.

Questions 3b(i) - 3b(iv) were evaluated relative to two survival goals. The PATH Hydro Work Group has suggested an interim goal of survival approximating that which occurred during the 1960s for juvenile salmon migrating from Lewiston (near the head of the Lower Granite pool) to below Bonneville Dam. This approach corresponds to the temporal survival pattern described in Question 2. The working group estimated the passage survival goal at 50-70%, in combination with an (unknown) delayed mortality rate that is no higher than that which occurred during the late 1960s. The working group also evaluated survival relative to the interim 2-6% smolt-to-adult return (SAR) survival goal, described in the Preamble above, which applies to various sources of human-induced and natural mortality in addition to hydro mortality.

Question 3b(i)

*Can **transportation of fish to below Bonneville Dam** compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration?*

Overall Conclusions

> *Survival to the point of release appears high enough to exceed the interim smolt passage survival goal (50-70% from LGR pool to below BON, with delayed mortality no greater than that which occured during the late 1960s). However, there is uncertainty regarding the magnitude of delayed effects. Therefore, available information and analyses are presently insufficient to answer this question.*

Based on higher returns of transported fish than in-river migrants in most studies, transportation appears to at least partially compensate for hydropower system effects. Further, based on the percentage of the outmigration that can be collected at upstream dams and their apparent direct survival to the point of release below the hydropower system, transportation has the potential to fully compensate for the hydropower system, if delayed mortality to transported fish does not exceed levels that occurred in the 1960s. However, recent transportation of 50-65% of migrants has not halted the decline of upstream stocks as described in Question 2. This could result from: (1) low survival of transported fish due to delayed mortality; (2) adequate survival of transported fish, but an inability to collect a sufficient percentage of the run; (3) mortality associated with factors not directly related to the hydropower system; or (4) some combination of these factors.

Sub-conclusion 1:

> *Available evidence suggests that the survival of transported fish to the point of barge release is sufficient to meet the goal. Opportunities for increasing survival to the point of barge release are limited because survival is so high.*

Evidence:

Enumeration of carcasses of juveniles in trucks and barges has not been formally conducted. The group generally agrees with casual observations that the survival of transported fish from truck/barge loading to the point of release is high (approximately 96-98%) (Ch. 6, p. 32-33).

Sub-conclusion 2:

> *There are varying interpretations of the available evidence regarding whether or not the SAR of transported fish is sufficient to meet the survival goal. This uncertainty results from a lack of explicit*

estimates of the survival of wild transported fish in most years and differences in interpretation of indirect evidence (listed below).

There is also uncertainty with regard to the prospect of increasing transport survival, because the mechanisms which could cause hydro-related delayed mortality, and where such mechanisms are expressed, are unknown. Thus, we cannot evaluate whether or not any of four identified transportation measures (Ch. 6, p. 39-40) will be able to reduce hypothesized delayed transportation mortality.

Evidence suggesting that delayed mortality is too high:

Adult returns from 1983-1990 transport experiments, adjusted to emulate SAR of wild spring chinook, indicate average survival of transported fish was 1.32%, compared to 2.53% for a downstream (untransported) stock (Warm Springs River, above only two dams). If the two stocks are exposed to similar estuarine and ocean conditions, then the lower transport survival would indicate considerable delayed mortality given the presumed low mortality in the barge. Differences could not be explained by differences in adult upstream mortality. Only in one of seven years (1990) did the adjusted transport SAR exceed the lower bound of the interim 2-6% SAR goal, which is based on survival of the Snake River stock in the mid-1960s (Ch. 6, p. 37; Appendix 7). The combined SAR for transported and non-transported wild fish was likely less in most years than the SAR for transported fish alone.

Note: Transport survival experiments were not designed to estimate absolute smolt-to-adult survival rates, just to compare relative survival of experimental groups. Experimental fish were not collected in proportion to the run at large and may not represent returns of all transported fish. Some adjustment factors were not available on an annual basis, so were assumed to apply in all years.

In the MLE analysis (Ch. 5), passage models which assume a high, constant transport survival over the complete life cycle (e.g. 74%; CRiSP T2) did not match 21-year upstream/downstream stock-recruitment patterns as well as passage models which assume lower survival of transported fish (e.g. 21-48%; CRiSP T1; FLUSH T1 and T2) (Ch. 5, p. 15-16).

Previous studies on the effects of collection, transport, and release on the health of juvenile salmon suggest that transported fish are stressed but usually recover within a few days. During the recovery period their vulnerability to other sources of mortality such as predation and disease may be increased (Ch. 6, p. 34); however, explicit links between these mechanisms and delayed mortality caused by transportation have yet to be identified.

Evidence suggesting that delayed mortality is not too high:

The only transport study that actually estimated SAR of **wild** transported fish and attempted to collect fish in proportion to the run at large (1990) indicated that survival was >2%, and higher than that of the Warm Springs stock. This suggests that wild transported fish reached the lower end of the acceptable range of survival, at least during one year (Ch. 6, p. 33; Appendix 7).

Note: The high value in 1990 was not necessarily related to experimental procedures unique to that year, which allowed estimation of survival of wild transported fish. In addition, 1990 was also the year of highest survival for mixed wild/hatchery transported fish, suggesting that high transport survival is a relatively infrequent occurrence.

Radio-tag data for transported fish and in-river migrants suggests that delayed effects of transportation are minimal to the upper end of the estuary, relative to delayed effects for in-river migrants (Ch. 6, p. 35-36). However, lack of an effect in this stanza of their life cycle does not preclude delayed mortality occurring during a later period, such as the lower estuary or early ocean transition.

Note: The failure to detect differences in survival between Bonneville and the estuary suggests that any delayed mortality expressed in this river section is the same for transported and untransported fish. However, the usefulness of this comparison for evaluating delayed effects is questionable since the sample sizes were small, the in-river group was handled and tagged at Bonneville Dam, the in-river fish probably were not of Snake River origin, and the detections only provide a minimum estimate of survival.

Sub-conclusion 3:

Available evidence suggests that the proportion of fish transported can be significantly increased above current levels. Whether the future collection rate will be sufficient to achieve the smolt passage survival goal (50-70%) for the entire wild smolt population also depends on the combined mortality incurred by both transported and in-river migrants.

Evidence

Calculations based on estimates of fish guidance efficiency, turbine survival, and reservoir survival suggest that collection rates are expected to be significantly higher than recent rates when planned improvements in the system are implemented in 1997, assuming that collection is maximized (Ch. 6, p. 42; Appendix 2).

If bypass efficiencies achieved at Wells Dam can be realized at Lower Granite Dam, then the proportion of the population collected for transport can be increased substantially over current levels (Ch. 6, p. 44-45). However, differences in configuration of Wells and LGR dams suggest that it will be difficult to achieve similar efficiencies with surface collection.
Since mortality associated with the collection and release of transported smolts appears to be low, there is little room for improving direct survival. However, if hypothesized delayed effects are associated with those processes, there may be an opportunity to improve survival through to returning adult (Ch. 6, p. 39-40).

Information Needs for Question 3b(i)

- Further PATH analyses to better quantify the amount of delayed mortality for both transported and in-river fish (see Question 3a and end of question 3b) (<1 year).

- Use CRiSP and FLUSH to explore hypotheses about delayed mortality and compare to MLE and other data (i.e. PIT-tag passage survival estimates, SAR estimates) (<1 year).

  Estimate smolt to adult survival rate (SAR) for transported wild fish to determine if SAR rates are significantly different than the interim SAR goal of 2-6% (< 1 year using existing data; <5 years using results of ongoing studies; 5-10 years with data from new studies). Compare % transported with adult returns.

  Alternatively, comparisons of wild transported fish survival with that of other reference populations (downstream wild stocks) in the Basin may be more instructive than trying to interpret a performance measure (absolute value of an SAR) that reflects various effects in addition to hydro. In this regard, reference populations should be similar to the transported populations in all respects, except their exposure to transport. Departures from this assumption require careful consideration when making inferences. (<5 years if data exists; 5-10 years if data does not exist).

  Determine whether LGR-BON passage survival of 50-70%, coupled with delayed mortality no greater than that which occurred in the 1960s, is necessary and sufficient to achieve survival and recovery of Snake River spring/summer chinook salmon. Make a similar determination for the 2-6% SAR goal.

Formally estimate the direct mortality associated with collection and transport through release. Though collection mortality has been estimated within juvenile facilities at the dams for many years, estimates of survival in trucks and barges are subjective and based on casual observations (<5 years).

Conduct field and lab evaluations of possible mechanisms leading to hypothesized delayed mortality, including susceptibility of barged and trucked smolts to fish, bird, and mammal predation following release and to disease and impaired saltwater adaptation relative to non-transported migrants (5-10 years for lab experiments, >10 years for field). Purpose would be to determine if specific mitigation actions could reduce any delayed mortality caused by specific mechanisms.

Formally estimate the straying rate associated with transported fish in comparison to the straying rate of in-river migrants. (5-10 years).

Estimate Transport/Control Ratio and in-river survival concurrently over a number of years with a range of environmental conditions (5-10 years). Acquire estimates for wild and hatchery fish and compare. If equivalent, it may be possible to rely on hatchery fish as experimental fish in future studies that estimate TCR and in-river survival. Also compare the absolute values of the SAR for wild and hatchery fish. If these are related proportionately, it may be possible to rely on hatchery fish for this performance measure as well.

Determine the effectiveness of the following measures currently being considered within the region, in reducing hypothesized delayed mortality: a) direct-loading transported fish; b) improving barge release mechanisms or strategies; c) improving collection facilities (e.g. new separator at LGR); and d) installing surface collectors at one or more Snake River dams (>10 years).
Determine the efficiency of current and future devices for collecting fish for transport (<5 years for current, 5-10 years for prototypes).

Studies have been conducted since 1990 which should provide additional estimates of transport survival of wild fish (within 1 year).

Question 3b(ii)

*Can **modifications to in-river passage**, other than drawdown, compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration?*

Overall conclusions

It is unlikely that current and proposed in-river passage measures will achieve the interim smolt passage survival goal of 50-70%, with delayed mortality no higher than that which occurred during the 1960s.

Even under the most favourable conditions, current passage measures are not sufficient to maintain juvenile survival rates of upstream stocks at the interim smolt passage survival goal. Delayed mortality is unknown, but unless delayed mortality is **much** lower than in the 1960s, this conclusion would be reinforced. Improvements to the current system may increase survival rates, but such improvements are not likely to increase survival rates sufficiently to meet the full range of the passage goal.

***Evidence* (all from Chapter 6)**

PIT-tag reach mark-recapture studies, expanded to estimate survival through eight projects, indicate that:

Average per-project survival rates have ranged from 87-92% from 1993-1996, corresponding to an average system survival (unweighted expansion to 8 dams and reservoirs) of 33-51%. Similar estimates of system survival are obtained when project survivals are weighted by fish travel time through each reservoir (p. 46).

Estimated system survival rates ranged from 40-50% in 1995 and 1996, when in-river operations were designed to provide the best possible conditions for in-river migrants (p. 46).

Estimated system survival rates ranged from 33-36% in 1993 and 1994 (p. 46)

Analyses of Transport/Control Ratio and smolt-adult return data suggest that delayed mortality effects on in-river migrants are higher than transported fish in some years and lower in others (p. 36-37).

Our assessment of the performance of existing and proposed measures for increasing dam and reservoir passage survival suggest that:

Dam Passage Effects - Proposed operations and structural modifications, other than drawdown, may increase dam passage survival rates by a maximum of approximately 2 percent per dam above current levels, which is not sufficient to achieve the full range of the survival goal (p. 57).

Reservoir Effects - Opportunities for improving direct survival through reservoirs are minimal (p. 65).

Information Needs for Question 3b(ii)

Extend the range of smolt survival studies to provide estimates to at least John Day Dam, or preferably Bonneville Dam. These studies should be conducted over a number of years to determine a range of survival estimates under a variety of environmental conditions (5-10 years).

Determine the magnitude of delayed effects associated with in river passage measures. One opportunity may be to compare the SARs among groups characterized by different passage histories as smolts. (>10 years).

Obtain concurrent estimates of passage through all dam passage routes, possibly using PIT-tag mark/recovery techniques (5-10 years).

Monitor and evaluate the change in smolt survival resulting from the implementation of measures such as gas abatement systems, surface bypass systems, improved turbine designs, and extended-length screens (5-10 years).

Continue to monitor the abundance and other demographic characteristics (such as size and age structure)of predators in reservoirs, primarily to determine harvest rates and to estimate changes in smolt predation mortality resulting from the squawfish removal program (<5 years).

Determine the extent, if any, to which migrational delay reduces early ocean survival. Quantify the potential gains associated with proposed mitigation actions intended to minimize migrational delay (5-10 years).

Question 3b(iii)

Can a ***combination of transportation under some conditions and in-river passage under other conditions*** *compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration, if* ***improvements to transportation and modifications to in-river passage, other than drawdown,*** *are made?*

Overall conclusion

A combination of transportation and in-river passage measures is unlikely to increase survival rates to target levels, unless either measure, by itself, could accomplish the same.

If the conditions that favored transportation and in-river passage were complementary (e.g. high flow years favored in-river, low flow years favored transportation), then a hybrid strategy might be appropriate. However, it appears that both approaches are likely to have poorer survival in low flow years than in high flow years.

This approach would most likely be implemented as a "spread-the-risk" policy if uncertainties about survival associated with other measures could not be resolved. If properly constructed, a hybrid operation could be implemented as an adaptive management experiment that helps to reduce uncertainty.

Evidence

See evidence in questions 3b(i) and 3b(ii).

Available evidence suggests that in-river survival increases with mean annual flow (Ch. 6, p. 61-65) and transport survival **may** increase with mean annual flow (Ch. 5, p. 15-17).

Information Needs for Question 3b(iii)

See Information Needs under questions 3b(i) and 3b(ii).

Question 3b(iv)

Can ***drawdowns to spillway crest or natural river level*** *compensate for the effect of the hydrosystem on juvenile survival rates of Snake River spring/summer chinook salmon during their downstream migration?*

Overall conclusions

Drawdown of 3-4 Snake River dams to natural river level should compensate for hydro effects through that reach and yield overall juvenile survival from Lower Granite to Bonneville of 50-70% (our interim goal). However, we have not yet evaluated whether resultant smolt-to-adult return rates would attain our target of 2-6%.

Snake River spillway crest drawdown was not analyzed because it no longer appears to be a management option being considered by the region. It appears to be too risky a venture because it requires major structural reconfiguration of juvenile and adult passage facilities. The efficiency and safety of the new devices cannot be guaranteed.

A John Day spillway crest drawdown may have a greater potential for increasing reservoir survival than Snake River spillway crest drawdowns, due to the greater reduction in reservoir volume that *would occur. However, the workgroup could not reach agreement on the likelihood that potential survival improvements due to increased reservoir velocity and rearing habitat would outweigh the risks associated with potential increased dam passage mortality of juveniles and adults. We did not have time to complete a thorough analysis of this option.*

Evidence **(all from Chapter 6)**

Review of previous SCS analyses and the 1995 NMFS Biological Opinion suggest that:

Risks associated with increased dam passage mortality resulting from drawdown of Snake River projects to spillway crest are significant and may outweigh potential improvements in reservoir survival (p. 66-67).

Risks associated with increased dam passage mortality resulting from drawdown of John Day Dam to spillway crest may or may not outweigh potential improvements in reservoir survival (p. 67)

Comparison of juvenile survival rates in the Snake River during historical periods when one dam was in place to those in recent periods when 4 dams were in place suggests that:

Natural river drawdown of three or four Snake River projects would substantially increase survival of juvenile migrants and possibly of adults returning upstream to spawning areas (p. 68).

Information Needs for Question 3b(iv)

Information needs associated with these measures are extensive, but the PATH Hydro work group has not yet had time to identify and evaluate them.

Information needs that are relevant to all of Question 3b

P Estimate magnitude of delayed mortality of transported and non-transported fish after 1975 using Chapter 6 estimates of per dam mortality estimates and Chapter 5 estimates of per dam reduction in recruitment (<1 year).

P Reconcile Chapter 6 survival targets with Chapter 5 estimates of net dam passage mortality from the Snake River sub-basins to John Day dam (:) (<1 year).

P Develop new versions of CRiSP and FLUSH that incorporate hypotheses about delayed mortality and compare to MLE (<1 year).

P Attempt to explain year-to-year variation in delayed mortality as functions of climate and other variables (<1 year).

P Finish Chapter 6 retrospective tasks (<1 year).

PATH tasks under question 3a are also relevant to question 3b.

Question 4b

To what extent can ***habitat*** *management actions compensate for past impacts?*

Overall Conclusions

We are reasonably confident that habitat management actions alone in spawning and rearing habitat cannot significantly compensate for productivity declines in the index stocks that have occurred since 1975.

The productivity of salmon stocks in areas with intensive land-use impacts could be significantly increased through improved habitat management, if survival through other life history stages is increased. However, the recovery time will vary with the severity and type of habitat degradation. There is little room for improvement in spawning and rearing habitat for stocks in wilderness areas.

We have not yet analyzed the roles of mainstem migratory corridor and estuarine habitat.

Evidence

Productivity of the index stocks has declined since 1975, even though habitat quality in most spawning and rearing areas remains medium to high. (**)

Information Needs

P Compare Recruit/Spawner indices and densities of juvenile salmon, steelhead, and resident fish among streams from different habitat quality classes within regions to index responses in good and poor habitat.

P Develop alternative experimental designs to assess the effects of habitat restoration activities on Recruits/ Spawner and other stock indicators.

Question 5b

To what extent can ***hatchery*** *management actions compensate for past impacts?*

Overall Conclusions

We cannot draw conclusions on the answer to this question because of the preliminary and incomplete state of the analyses of hatchery data.

Evidence

The mean value of a survival index (ln(R/S)) for two stocks subjected to hatchery supplementation (Warm Springs, Imnaha) was significantly higher for wild fish than hatchery fish in one case (Warm Springs) and not significantly different in the second case (Ch. 11, p. 27). However, the Warm Springs naturally-spawning stock exhibits higher survival and productivity levels than the listed stocks, and the relevance of these results to listed stocks is uncertain. (*)

Information Needs

Incorporate results of current supplementation and captive brood stock studies (e.g. IDFG Idaho Supplementation Study, NMFS/BPA Snake River Genetic M&E program) (5-10 years).

See information needs for Question 5a.

Question 6b

To what extent can harvest actions compensate for past impacts?

Overall Conclusions

We chose not to address this question now because Ch. 13 is preliminary and internal / external reviews are not yet complete. We anticipate answers to this question in early 1997.

Question 7b

To what extent does the development of hydrosystem, habitat, hatchery, and harvest management actions need to consider future climatic conditions?

Overall Conclusions

Based on the conclusions in question 7a that climate can affect stock indicators, we conclude with reasonable confidence that changes in climatic conditions can affect the ability of management actions in the 4 H s (hydro, habitat, hatchery, and harvest) to compensate for past impacts. Therefore, development of management actions in the 4 H s should consider the implications of a range of future climatic conditions.

Endnotes

1. Marmorek, D.R. (ed.), J.J. Anderson, L. Basham, D. Bouillon, T. Cooney, R. Deriso, P. Dygert, L. Garrett, A. Giorgi, O.P. Langness, D. Lee, C. McConnaha, I. Parnell, C.M. Paulsen, C. Peters, C.E. Petrosky, C. Pinney, H.A. Schaller, C. Toole, E. Weber, P. Wilson, and R.W. Zabel. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C. 620 pp.

2.

	Index Stock	Brood years with Spawner-Recruit Data
Upstream stocks	Minam (Snake R.)	1954-1990
	Imnaha (Snake R.)	1949-1950, 1952-1990
	Bear Valley/Elk (Snake R.)	1957-1990
	Poverty Flat (Snake R.)	1957-1990
	Johnson (Snake R.)	1957-1990
	Sulphur (Snake R.)	1957-1990
	Marsh (Snake R.)	1957-1990
	Methow (Upper Columbia R.)	1960-1990
	Entiat (Upper Columbia R.)	1955-1990
	Wenatchee (Upper Columbia R.)	1958-1990
Downstream stocks	John Day (3 stocks)	1959-1990
	Warm Springs	1969-1990
	Klickitat	1966-1990
	Wind River	1970-1990

3. NAPAP. 1991. The U.S. National Acid Precipitation Assessment Program. 1990 Integrated Assessment Report. 520 pp.

4. Several variations on this index (R/S) were used in the analysis pertaining to Question 1 (e.g. S, S detrended, S_{t+4}/S_4,S_{t+4}/S_4 detrended, ln(R/S), ln(R/S) detrended).

5. The Ricker a parameter is the intercept of the linear relationship between ln(Recruits/Spawner) and the number of Spawners (see Ch. 3 Equation 3-2 for this relationship). The Ricker $ parameter is the slope. Tab. 3-4 refers to the intercept and slope, rather than Ricker a and Ricker $.

6. Average of 65% for 4 dams: average dam instantaneous mortality rate before 1970 (x) =0.26; $1\text{-}e^{-(0.26)4} = 0.65$ (Ch. 5, Tab. 5-5).

7. x(as above) = 0.26; : (net dam passage mortality from the Snake River sub-basins to John Day dam) = 1.4; $1\text{-}e^{-[(0.26)3+1.4]} = 0.89$ (Ch. 5, Tab. 5-4, model 1).

8. 0.99952 survival per mile through 96 unimpounded miles.

9. 0.82 survival per project through 3 projects.

10. 0.90 survival per project through 3 projects.

11. The interim smolt-to-adult survival goal is based on:
    1) Estimates of survival of Snake River chinook from smolt (at the uppermost dam they encountered) to adult return (at Ice Harbor Dam, adjusted for in-river harvest below that point) during the 1960s, when stocks were believed to be healthy
    2) Warm Springs SARs, from the mouth of the Warm Springs River during out migration to the mouth of the Deschutes River for returning adults, during a period in which the stock was believed to be healthy

3) SARs that would be necessary to replace spawning stock, given historical estimates of spawner-smolt survival (from spawning grounds to Lower Granite Dam) and adult to spawner survival (from Lower Granite Dam to spawning grounds).

Details are provided in Ch. 6. Further analyses are needed to determine the necessity and sufficiency of a 2-6% SAR for Snake River spring/summer chinook survival and recovery.

12.

Question in Conclusions Document	Question from Ch. 6 decision tree in Marmorek et al. 1996
Question 3b(i)	Questions 1.1, 1.2, 1.3, and 1.4
Subconclusion 1	Questions 1.1.A and 1.2
Subconclusion 2	Questions 1.1.B and 1.2
Subconclusion 3	Questions 1.3 and 1.4
Question 3b(ii)	Questions 1.5 and 1.6
Question 3b(iii)	Questions 1.7, 1.8, and 1.9
Question 3b(iv)	Question 2.1