Chapter 10
Trends in Upstream Spawning and Rearing Habitat

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10.1 Introduction

Anadromy requires multiple and connected habitat types for successful completion of a complex life history. Required habitats include freshwater streams and rivers, brackish estuaries, and the ocean. This chapter addresses primarily the freshwater habitat required for smolt production from the spawning and early rearing habitat to the first lower Snake River reservoir, Lower Granite. This same geographical delineation of freshwater habitat used by the fry through the smolt lifestages contains those components influential to the prespawning adults returning to natal grounds.

There exists a substantial amount of data from studies, surveys, and in the scientific literature on interactions among land use, habitat response, and changes in salmon survival that, when defragmented and synthesized, indicate that functional components of natal habitat essential to salmon survival have been pervasively degraded in Snake River watersheds that have history of land disturbance. This information includes work from within the basin that is extensive spatially and temporally, such as the work on pool loss over time (McIntosh 1995) and work that is more intensive geographically, such as the composite physical and biological data from the tributaries of the Middle Fork salmon River (discussed in Rhodes et al. 1994) and the Clearwater River (Espinosa et al., *in press*). Applicable information includes studies on the effects of various activities on habitat conditions; several works contain non-exhaustive overviews of this information (e.g., Geppert et al 1984, MacDonald and Ritland 1989, Meehan (ed.) 1991, Henjum et al. 1994, Rhodes et al. 1994, Murphy 1995). In aggregate, available information amply indicates that land use has degraded natal habitats in ways that have contributed to the reduction and suppression of salmon survival and production.

Rhodes et al. (1994) discusses degradation in FSR habitat prior to, during, and after the construction of lower Snake River dams. The report documents that existing watershed conditions and land uses have maintained or exacerbated degraded conditions up to the present. The rate and geographical extent of FSR habitat quality declines were great prior to the construction period of the lower Snake River dams, potentially establishing a less variable landscape equilibrium condition, at least for the highly erodable Idaho batholith geome, historically used for chinook salmon spawning, rearing, and overwintering. Since this period does not coincide with most of the time series data collected for use in stock recruitment and productivity relationships, cause and effect determinations for salmonid early life stage response remain highly uncertain, severely restricting predictive evaluations for scaling habitat contributions to restoring chinook salmon stock numbers back as far as pre-European settlement. Potential mechanisms for a net decrease in FSR survival since lower Snake River dam completion in 1975 may include: overall decreases in Snake River basin habitat quality in tributary spawning/rearing and over-wintering areas (e.g., sedimentation, loss of pools or instream cover, increased temperatures); or environmental fluctuation or climatic regime shifts (e.g., drought, warming cycle, severe winter conditions). A decrease in FSR survival after 1975 might be considered evidence for an overall decrease in habitat quality, or simply the repeat occurrence of unfavorable environmental conditions, such as low flow precipitated by drought (Petrosky and Schaller 1996). Increased hatchery releases in the basin to mitigate for hydropower effects might also act to decrease average survival from spawner to smolt, if hatchery fish produced less viable progeny in the wild, or through

increased localized competition for space and resources (Petrsoky and Schaller 1996). Evidence of decreased FSR survival could also be attributed to depensatory survival mechanisms (BRWG 1994), which are possible at the low spawning escapements experienced by many Snake River populations.
Tributary production studies to directly address FSR hypotheses are lacking or limited in terms of number of years and streams covered. FSR life stage survival estimates are available for a limited number of streams and years. Available estimates include egg-to-migrant survival for the Lemhi River for 1965-1973 brood years (Bjornn 1978) and Lookingglass Creek for 1965-69 brood years (Burke 1993); and egg-to-parr and parr-to-smolt survival for the upper Salmon River for 1987-91 brood years (Kiefer and Lockhart 1994). PIT-tag studies by NMFS, ODFW, and IDFG provide parr survival data from natal areas to Lower Granite Dam. These estimates cover more geographical area than the FSR, including the free-flowing Snake River reach to the head of the reservoir, as well as Lower Granite reservoir. A more complete and longer time series of early life stage survival and anthropogenically modified landscape data, dating to before construction of the Federal Columbia River Power System (FCRPS) would be desirable to rigorously evaluate hypotheses concerning FSR survival responses through historical periods (as early as pre-European settlement). The current data limitations highly restrict the ability to gauge the true potential of chinook salmon recovery attributed to any independent or correlated compensation between the lower Snake River mainstem passage and FSR habitat.

Petrosky and Schaller (1996; Chapter 9) suggest that no significant change occurred in the relationship of ln(smolts/spawner) versus spawner during the 1962 to 1982 and 1990 to 1993 time series, especially not a change of the magnitude observed in adult-to-adult productivity (Schaller et al. 1996, Chapter 3). Paulsen (1996; Chapter 4) suggests that a relationship between FSR landscape or flow-related variables and recruitment may exist. Ultimately, this chapter must assess the potential and magnitude of mitigation actions upon FSR habitat contribution on improving Snake River basin salmon egg-to-smolt production contributing to stock recovery and/or the ability of the FSR habitat to compensate for declining production attributed to hydroelectric development, harvest, and hatchery mitigation practices.

The scope of this chapter focuses on the freshwater habitat required for smolt production from the spawning and early rearing habitat to the first lower Snake River reservoir, Lower Granite. To address stock responses useful for PATH evaluations, the scope is very descriptive, including the synthesis of temporal and spatial information, and theoretical considerations, on freshwater habitat and corresponding stock responses for the interior Columbia basin habitats.

Objectives of this chapter are: 1) bringing the available data to bear on the influences of good habitat versus bad habitat components and distribution on index stock recruitment indicating descriptive trends and describing possible covariants that correlate with the habitat quality rating classifications; 2) description of trends in freshwater spawning and rearing (FSR) habitat conditions, based on available evidence; 3) describe how these trends have affected juvenile salmon survival, based on available information; 4) evaluate the available evidence for formulating retrospective hypotheses of FSR habitat contribution to Columbia River basin spring, summer, and fall chinook salmon declines; 5) develop an analytical framework for testing hypotheses, including an assessment of strengths, weaknesses, and probable resolution of these analyses including obstacles to such work; and 6) present a Decision/Hypothesis Tree for organizing outcomes of probabilistic evaluation of the hypotheses testing process that can be revised or reformulated for guiding habitat management that accounts for the low reversibility of habitat degradation and uncertainty regarding protection/restoration approaches.

The geographical bounds of interest for this evaluation include the freshwater spawning and rearing habitat (FSR), which overlaps with habitat components important for prespawning (PS) adults migrating upstream. It remains generally apparent that the assumption that persists throughout the Northwest Pacific region is that those habitat component qualities that are productive for downstream migrants should also be adequate to maintain upstream migrating spawner viability. Although many habitat variables overlap in importance to both life stages, like migratory river flow, further evaluation based upon synthesis of lifestage response monitoring may indicate that some landscape variables may be more significant to PS than to FSR, i.e., pool depth, tributary temperature, and substrate size versus fine sediment delivery, stream and migratory river temperature, and cobble embeddedness. Additionally, the region generally accepts that density-independent effects are the overriding influential limitation upon the declining Snake River basin salmon stocks where adult escapement has acted to limit adequate seeding of the spawning population (BRWG 1994, Petrosky and Schaller 1996). Although a localized segment of habitat may not express the optimal productive level of its potential, one should not expect any density-dependent effects acting upon the population productivity if the adult spawner escapement is too depauperate resulting from mainstem hydro development passage. Although spawner escapement would logically have a spawner response on the number of smolts that could be produced, localized habitat quality could have a limiting effect upon one of the presmolt lifestages, thus acting to stabilize the outmigrating smolt recruitment abundance through some strictly localized density-dependent adjusted carrying capacity response. To address these questions FSR is further delineated into spawning and early rearing (S/ER), downstream rearing (DR), and overwintering (OW) habitats.

10.1.1 Lower Columbia River Habitat

Studies performed under Lower Columbia River Bi-State Program (Tetra Tech, 1996) concluded there is strong evidence that fish and wildlife in the lower Columbia River basin (below Bonneville dam) are being exposed, via water, sediments, and prey, to harmful levels of heavy metals, organochlorine pesticides, dioxins and furans, and other organic compounds. The report further concludes that the use of the river for migratory fish such as salmon has been seriously limited by loss of and degradation of habitat. This is particularly true in the estuary, where dredging, filling, diking, and channeling have resulted in the loss of over half of the tidal swamp and marsh areas since 1870. Most recently the Columbia River basin has been graded “water quality limited” by the U.S. Environmental Protection Agency. The use of the lower river by wildlife and for fishing is listed as not supported. The river is occasionally unsafe for water sports.

The growing population of the lower Columbia River has had increasing impacts on the river through industrial, agricultural, forestry, commercial, and residential uses. The Lower Columbia River Bi-State Report identified a total of 54 point sources discharging directly to the lower Columbia. The sources included 19 municipal wastewater treatment plants, 3 fish hatcheries, and 32 major industrial dischargers. Industrial dischargers included three aluminum, six chemical, six pulp and paper, eight seafood, and six wood products facilities. In addition to these plants there are seventeen hazardous waste and Superfund sites and eighteen landfills within one mile of the river. Quantitative information on pollution discharges from these facilities is very limited or unknown. Data for non-point source pollution from surface water runoff, combined sewer overflows, and accidental spills are even more limited.

The potential for uptake of toxic chemicals by down-stream migrant salmon and the adverse effect on the immunocompetence of juvenile salmon is well documented in the literature (McCain et al., 1990; Arkoosh et al., 1991; Arkoosh et al., 1994; Stein et al., 1995). Studies in the Fraser River have also shown a higher susceptibility to predation after exposure to fungicides (Kruynski and Britwell, 1994).

The relative significance of the pollution effects and habitat degradation on salmon in the lower Columbia River requires additional research and scientific assessment. Similar pollution problems from extensive industrial and agricultural development and habitat degradation in the mainstem Columbia River above Bonneville dam and in the Snake River also have the potential for significant adverse effects on salmon and require additional research and assessment.

10.2 Methods

10.2.1 Retrospective Hypothesis Formulation and Testing

Hypotheses were identified for the Retrospective Analysis based upon the objective of formulating a more complete description of FSR habitat quantity and quality distribution for lower Snake, mid-Columbia, and lower Columbia River index stocks. Supporting empirical evidence for negative, stabilizing, and positive responses were then sought to identify explanatory methodologies to test the more uncertain low level or stock specific hypotheses related to FSR condition effects on productivity and recruitment. A preliminary set of Prospective hypotheses were also identified based upon various degrees of management questions for ESU persistence proposed throughout several regional planning forums. Prospective hypotheses can be refined based upon the results and acquired knowledge gained from the Retrospective evaluation.

10.2.2 FSR Habitat Condition Description

Lee et al. (1996) performed a broad-scale assessment survey on a number of historical landscape variable changes across the Columbia River Basin that have influenced aquatic habitat conditions, ecological integrity, and contributed to declines in fish population distribution and persistence. The cumulative effects of many of these changes are readily apparent in the distributions and status of naturally reproducing anadromous salmonids. The information provided by Lee et al. (1996) lends further support to a scientific view that is emphasized repeatedly in the literature: habitat change is pervasive and at times can be dramatic, impacts are not evenly distributed across the landscape, and high-quality areas remain that are capable of supporting anadromous spawners at near-historical levels. A couple caveats to this statement would be: 1) “Near-historical” levels of spawner abundance estimates are temporally dependent on favored “year” groupings and may or may not be estimated recovery levels. For example, the Proposed Draft Recovery Plan (NMFS 1995), like the PATH Hydro Subgroup analyses in Chapter 6, favor the 1964-67 estimates of smolt survival, smolt-to-adult return, and adult escapement as numerical basis for defining recovery criteria. Obviously, the FSR habitat conditions and the Snake and Columbia River hydrosystem configuration present during the 1964-67 time frame did not produce chinook or sockeye salmon escapement or recruitment that would have been produced prior to Bonneville Dam construction in 1938, or pre-European settlement. 2) Spatially, the areal extent of high-quality spawning habitat may suffice for “near-historical”, or recovery, levels of spawners, but the limiting factor may be the lower quality or measured quantity of lower quality rearing and/or overwintering habitat that could act to reduce presmolt abundance.

All available habitat condition indices or data useful in compiling a standardized index and then testing stock response to habitat quality has not been synthesized to date. To date, attempts have been made to only evaluate the State designated and EA methods. Contributing data sources that will be included in future evaluations include Idaho Department of Fish and Game (IDFG) parr density monitoring for juvenile anadromous and resident salmonids for 1985-1995 that can be compared with Northwest Power Planning Council (NPPC) habitat ratings from subbasin planning, as well as the USFS-INT land use classes.

The initial habitat condition descriptive analysis approach that was adopted is based upon the individual State representatives classification of Idaho, Oregon, and Washington stocks for which run reconstructions have been completed into three habitat quality classes based upon degree of human management activity and impact within three life stage areas per index stock (rearing; spawning/early rearing [SER], downstream rearing [DR], and over-wintering [OW]). Within the State classifications based upon subjective estimates of degree of land use disturbance, there are some measures of bad habitat integrated with and assumed as good habitat in the aggregate stream estimates, especially within and between SER, DR, and OW (e.g. John Day run reconstructions have been disaggregated into the Mainstem, Middle Fork, and North Fork/Granite Creek stocks that are indexed separately, whereas the subjective rankings for the corresponding habitats were estimated as aggregated). The John Day subbasin has a geographically arranged mixture of land use disturbances resulting in potential hierarchical effects upon the different life stages of annual broods produced in the spawning habitat, including fragmented as well as overlapping effects. The State delineations were aggregated over all potential spring chinook habitat where it was assumed that inclusion of subbasin or subwatershed specific delineated geomorph conditions were not originally considered in determining ratings, such as contamination sources, erodability, and other similar variables.

The ratings were delineated on the subwatershed unit maps of USFS/BLM Interior Columbia Basin Ecosystem Management Project's Eastside Assessment (EA) provided by personnel from the USFS Inter-Mountain Research Station (USFS-INT). USFS-INT personnel would use the three quality classes per stock delineated by the States and correlate to 6th code physical variables catalogued in the EA database. USFS-INT queried and compared EA parameters to correlate and verify similarities and difference between State and EA rating estimates, then choose one or several of the habitat ratings as a predictive variable for developing predictive models to assess whether EA data matches the subjective perceptions of the habitat condition raters. Potential dependent and independent variables based upon data derived indices was identified, such as road density in units of miles/square mile. The USFS-INT team would assess for the delineated index stocks initially, then scale up to the aggregate using the greater reliability and geographical coverage of the EA database. It is difficult to get time series data related to human impacts. Available time series data is related to natural successional and/or biological processes.

USFS-INT Data

The Forest Service and BLM data compiled by USFS-INT is course based on information collected at the reach, drainage, or subwatershed level. Little resolution can be gained to extrapolate or compress to the watershed level. USFS-INT has performed extrapolation of landscape variables with some elements of change. Road information is not characterized into condition level categories (logging skid roads and state highways are treated the same), although densities by variables such as slope and aspect do give intrinsic information from which condition class level can be derived. Some limited time series analyses could be done, but would likely not add much useful evaluation information.

Overton (pers. comm., 1996) indicated that in the pool frequency data some historical estimates are available for short time series (e.g. 1938-1942 vs recent). All information is in GIS. Stream habitat attributes are referenced to reaches. USFS-INT does have good detailed information about certain geographical reach areas, such as Yankee Fork, Herd Creek, Rapid River, and Boulder Creek. Rapid river vs Boulder Creek (harvest) could be compared with inferences made about effects of land use. For Yankee Fork there may be some data from the Tribes, like summer parr densities from snorkel counts of subsampled habitat units.

A potentially useful indirect method for a more resolute description of specific life stage habitat effects, such as OW was suggested by Horan (pers. comm., 1996). Trends in resident fish, such as bull trout, could be related as surrogates to anadromous trends (i.e., monitor resident salmonid responses on temporal timeframes for which environmental and population data exists in habitat locales where anadromous salmonids have not recently been found or anadromous salmonid data has not been collected, but anadromous salmonids may exist). Land use management agencies can typically monitor resident populations better because they are present year-around in some lifestage, at least more likely when sampling has occurred. The use of resident salmonid data may also be applicable and needed to address comments presented by Carl Walters on the evaluation of direct population performance measures, thus avoiding total effort concentrated on cataloguing measures of physical attribute changes and subjectively contriving some weak cause and effect relationship. It is well known that population response specific experimentation and resolute monitoring data for anadromous fish is typically lacking and often tightly constrains these Level 3 types of evaluations.

One deterrent identified by Reiman was that USFS-INT or the USFS Districts/Supervisor Offices/Region Offices probably do not have any more resolute time series data collected on resident freshwater species than on overlapping anadromous species. They do have broader distribution data. For example, *freshwater production information* that characterizes stream flow during the fall season relative to production gives inferences about access to habitat relating to distribution. USFS data provides information on broad area, such as patterns of occurrence in a particular setting. This allows one to say, "if we move in this direction with development we may get this kind of habitat structure". Trends can be anticipated, where numbers are much more difficult to identify.

10.2.3 Stock Recruit Relationships

This section accepts the hypothesis that land use management has had some degree of effect on anadromous salmon, supported by a wealth of empirical evidence reviewed in the Case Studies in Appendix 5. The central hypothesis to test for the Retrospective Analysis is how important is spawning and rearing habitat to stock productivity and persistence at the natal and aggregate scales. Stock/recruit analyses should provide a scientific base for the Prospective Analyses to address if efforts to improve and/or protect habitat aid in the recovery of depressed populations while considering other life stage mortality variables upon these fish.

Some caution is warranted because simplified stock and recruitment equations can not be considered to be complete descriptions of the expected spawner abundance from a given array of management actions or proposed activities over a long time series, because the strengths of the year-classes constituting future escapement will be variable. To the extent that these variations are highly correlated to environmental factors (e.g. temperature, food supply for young-of-year), and are independent of the abundance of the parent stock, stock/recruitment estimates may be of relatively less importance than expected by some analysts for the purpose of characterizing freshwater habitat contributions to Snake River Basin (SRB) salmon stock decline. The actual value of the spawner abundance in some future year will depend on measurable landscape variables, such as the water temperature in the preceding spawning, rearing, and/or overwintering periods, but the advantages and disadvantages of changing management activities upon other lifestages may be slightly altered contributing to the difficulty in the ability to measure.

The possible effects on recruitment of changes in the parent stock may be more critical. If, over the range likely to be observed, smaller stocks will produce proportionally smaller recruitment on the average, and more direct mortality sources on adults and/or stochastic catastrophic events can cause interannual disaster to the stock, thus reducing spawning stock that could cause cascading lower recruitment given time. This is not a typically measured trend in salmon fisheries or consistent with their evolutionary strategy. The high fecundity of most nonsalmonid species typically results in correspondingly high average mortality between egg production and spawning. If the interannual spawning escapement is reduced appreciably, quite a small reduction in this mortality through some density-dependent factor may result in about the same number of juvenile recruits. Literature suggests that competition between young fish, predation, or interference from adults can result in a lower recruitment from very robust stocks. Evolutionarily this is logical for Pacific salmon, where damage to previous spawning by later spawners appears to be an important factor in causing the greatest recruitment to occur at less than maximum adult stock size. Salmon also provide the clearest decreases in recruitment at low adult densities, probably in part because their fecundity is lower than most other fish species. In general the stock-recruit relationship is not well defined for over one-half of the stocks comprising the Snake River spring/summer chinook ESU aggregate. Although, it can often be a reasonable assumption that moderate changes in spawning stock caused by changes in management practices will not cause significant changes in recruitment, the appraisal of any stock's productivity and persistence should include some consideration of whether recruitment is likely to be affected.

Two analyses are proposed: First, consider the draft manager oriented paper by Lee and Rieman (1996; Appendix 1). They utilized the Stochastic Life Cycle Model (SLCM) to evaluate the response of varying habitat quantity (parr carrying capacity) with relation to mainstem survival and habitat quality. A wider range of passage survival (<20% to 60%) with larger variances that would be consistent with BRWG (1994) and Deriso et al. (1996) *mu* estimates should be examined. Second, **to be completed** is incorporation of Paulsen (1996, Chapter 4) including a sensitivity analysis consistent with the FSR Decision/Hypothesis tree. This analysis would vary Ricker's alpha and beta to gauge the significance or contribution of each variant's influence on stock productivity in SER, DR, and OW. An added iteration may incorporate the suggestion of Petrosky and Schaller (1996; Chapter 9) to develop an alternate production function other than Ricker's to evaluate alternative hypotheses for depensation of small populations.

10.2.4 Wild Parr PIT-tag Analysis

NMFS analyzed data collected from their wild parr PIT-tag studies by year and stream for correlation with habitat quality classifications. Achord and Sandford (1996) examined spill-adjusted PIT-tag detection rates at Snake and Columbia River dams of wild spring/summer chinook salmon smolts from the Snake River Basin that were PIT-tagged the previous year as parr (Appendix 4). They compared detection rates with the distance traveled to the first dam (Lower Granite) from the tagging/release sites of the parr, between years, and to an assigned stream condition/habitat from the tagging/release sites. They assumed that detection rates at dams were an indication of the relative survival of fish from different streams with different habitat quality to the dams. Probability of detection was not constant for all groups of fish as originally assumed. Achord and Standford (1996) assume that the differences in detection rates were related to differences in spill rates at the dam.

10.2.5 SER/ DR/ OW Habitat Decision Tree

To better organize our developing knowledge on FSR habitat contribution to ESU stock productivity and efficiently use that knowledge to educate management decisions, a Decision/Hypothesis Tree was developed based on the probabilistic decision analyses approach described by Peterman (PATH Workshop II, Ka-Nee-Tah Lodge, Oregon, 16-19 April 1996). Such a tree is best utilized as an hypothesis tree for management direction linking the Retrospective descriptive analyses with the Prospective hypotheses analysis. The most useful form of decision tree would be one developed within a risk assessment framework aimed at identifying what response variables or characteristics lead to persistence and recovery versus simplified restoration of physical landscape attributes to some desired successional stage. In addition, what would be beneficial for scientifically based direction for State management decision groups would be the couching of the Decision/Hypothesis Tree in terms describing change in survival and/or productivity to build wild and natural stocks to estimated viable levels managers desire, and will a preferred path or set of actions get us there?

Review of decision framework for the EA indicated that the EA process was designed to be technically based in nature and have little influence over the decision process of the land use management agencies. The Federal land use management agency's decision framework is not useful or appropriate for the PATH objectives of organizing hypothesis testing or risk management evaluations. The EA provides base line standards to follow in absence of site specific information. The aquatic conservation strategy is to apply to all Forest Plans incorporating the new or revised standards and guides that would be followed during future land use activities under the management direction of very limited risk to endangered species.

The EA Aquatics Team used predictive modeling in evaluation of alternatives, e.g. where fish would and would not prosper based upon where roads were allowed to be constructed. No formal risk assessment models were developed or used. Spatial allocations on land, restrictions to be in place, and landscape were used to predict in-stream habitat and from that infer about populations response. No probabilities of risk could be generated because they used imprecise statements. They formalized and used 13 selection criteria questions to guide discussions about concept/alternative evaluation and recommendation (Appendix 2). An attempt will be made to apply the EA guiding question in Appendix 2 to current land management for SER/DR/OW habitats for the index stocks in the Snake, upper Columbia, and lower Columbia Rivers, to help characterize and contrast the different populations from differing subbasins (Petrosky, Schaller, and Langness comments on DRAFT Chapter 10).

10.2.6 Test of Persistence Being Independent of Current Time Series Habitat Condition

Beamesderfer, Lee, and Rieman intend to explore comparisons of patterns of persistence by naturally reproducing spring-chinook populations with land use and landscape patterns to test a null hypothesis that persistence is independent of current habitat condition. Persistence will be the presence of some minimum number of spawners during recent years utilizing a temporal analysis evaluating habitat condition trends upon stock recruitment for pre- versus post-impoundment of the lower Snake River to see whether hydrosystem development confounded or was additive to habitat impacts. Historic distribution (20 or more years ago) will be based on survey records for populations which have been extirpated. Land use and landscape patterns will be derived from EA data. Evaluate when disturbances occurred, then look for changing patterns in disturbance between upriver and downriver index stocks during the time the hydrosystem has been operating. Evaluate for differences in land use between index stock areas upriver and down river and determine if there is alternative sources of mortality occurring which is being ascribed to hydrosystem or ocean. A lack of time series data on tributary habitat condition precludes attempts to correlate changes with fish productivity and habitat condition. However, similar inferences might be drawn from current patterns - in a sense, substituting space for time. The analysis can be structured around data series for 2 or 3 distinct time periods of comparison for impacts/degrees of disturbance. They will consult Model Watershed Process documentation for historic land use practices or patterns. If empirical evidence finds that spring chinook populations remain only in relatively high quality habitat for instance, one inference might be that habitat degradation has contributed to historic declines in net chinook abundance.

10.2.7 Case Study Review

A review was initiated to identify habitat modification case studies that estimate quantitative change in Ricker alpha and beta, time scale, ln(R/S), and/or mainstem habitat conversions (Appendix 5). Summaries of Rhodes et al (1994) case studies was one relevant initiating source for quantitative and qualitative evidence of habitat change effects on anadromous stocks.

10.2.8 Modified GLIM Analysis

Paulsen (1996) has been reviewed and may be incorporated as an integration in hypothesis refinement and testing. Paulsen (1996) supports the indirect, broader scaled analysis of Petrosky and Schaller (1996, Chapter 9), but continues with a proposal in Chapter 4 to acquire impact/cause-and-effect data from USFS Districts and perform a revised, and possibly more robust and descriptive GLIM analysis. An initial conferencing with Overton's database at USFS-INT would direct such an exercise. The GLIM analysis may be limiting because Paulsen's (1996) multiple age class model may likely not provide the increased degrees of freedom anticipated due to the lack of independence among ages of recruits. Over parameterization is a continuing concern for these type of models whenever the number of variables are increased.

10.3 Results and Discussion

10.3.1 Retrospective Hypothesis Formulation and Testing

There are numerous published studies describing the effects of land-use activities on habitat conditions, and linking habitat conditions to survival and productivity of anadromous fishes (Meehan 1991; Murphy 1995). Sully et al. (1990) show that egg-to-parr survival for chinook salmon in degraded streams with high sand content was less than one-eighth that exhibited in low-sand areas. Scwiebert (1977) documented habitat modification effects occurring in the Columbia River Basin that remain evident and problematic 20 years later. These effects are reinforced in a review synthesis by Rhodes et al. (1994).

RQ1: FSR/PS habitat degradation in the Snake River Basin (SRB) has contributed to spring/summer chinook stock declines.

Case studies can provide supporting evidence for this hypotheses. The only available inferences including historical time periods are historic sediment delivery estimates documented in Rhodes et al. (1994). Rhodes et al (1994) summarizes a lot of information that supports this hypotheses in specific cases. Evidence needed to support this hypothesis would also be applicable to RQ2b.

Refer also to supporting statements for RQ3ai below.

Evidence for RQ1:

1. "Data from Idaho consistently indicate that tributary streams with higher levels of fine sediment have lower salmon densities, lower salmon survival, and have undergone steeper population declines than in nearby tributaries within the same watersheds with lower sediment levels (Bjornn, 1971a as cited in Seyedbagheri et al., 1987; Platts et al., 1989; Scully and Petrosky, 1991; Rich et al., 1992; Boise National Forest, 1993; Rich and Petrosky, 1994; Petrosky and Schaller, in press)." in Rhodes et al., 1994 p. 7.

2. Achord and Sandford (1996 draft, Appendix 4) compared detection rates to an assigned stream condition/habitat from the tagging release sites and found that detection rates of fish in Category 1 [pristine habitat quality] were significantly higher (P=0.05) than fish from habitat of lower quality [Categories 2, 3, 4]. No significant differences (P > 0.05) were found between fish in Category 2,

3, or 4 streams. Fish from pristine streams apparently survived at a significantly higher rate than fish in slightly to heavily degraded streams.

3. It is also clear that the loss of pools and LWD [large woody debris] is a problem in the Snake River Basin (existing studies indicate 50-80% pool loss over the past 50 years in managed watersheds with high levels of sediment delivery and insignificant in wilderness watersheds (Sedell and Everest, 1990; McIntosh, 1992; B. McIntosh, USFS PNW Research Station Res. Asst., pers. comm., 1993; Boise National Forest, 1993; McIntosh et al., 1994)). Pool loss is greatest in grazed watersheds (B. McIntosh, USFS PNW Research Station Res. Asst., pers. comm., 1992; J. Sedell, USFS PNW Research Station Aquatic Ecologist, pers. comm., 1992). (in Rhodes et al., 1994. p 31).

4. Theurer et al (1985) estimated that no spring chinook production would occur on sections of the Tucannon River where mean daily water temperature for July exceeds 68F and the average maximum daily July water temperature exceeds 75F. Consequently they estimated that about 24 miles of the Tucannon mainstem had been lost as usable habitat due to increases in summer water temperatures; *they estimated that the elevation of water temperature had reduced production capacity from 2200 to about 900 adult spring chinook salmon.* (in Rhodes et al., 1994, p 39).

5. “Salmon habitat has been rendered unusable by acid mine drainage in Panther Creek, a tributary of the Salmon River; the spawning runs in the drainage were decimated by the pollution (Nelson et al., 1991). Cyanide heap leaching also poses a considerable threat to chinook (Nelson et al., 1991).” (in Rhodes et al., 1994, p 46).

6. Lolo Creek was once a significant producer of spring/summer chinook salmon in the Clearwater River Subbasin (Fulton, 1968; Chapman, 1981; and Espinosa, 1987). Chapman (1981) estimated that Lolo Creek was capable of producing 84,000 spring chinook smolts in its pristine condition. In 1990, it was estimated by Rich et al. (1992) that Lolo Creek was seeded at 11% of its potential carrying capacity. (from Rhodes et al, 1994, p B-4). Escapements do not necessarily reflect habitat condition alone. Massive hatchery supplementation has been conducted in the Lolo system, and could be a confounding factor along with hydrosystem development and operation as contributing bottlenecks to wild stock decline. Despite heavy stocking, escapement of adult chinook and densities of pre-smolt salmon remain at critically low levels in Lolo Creek (Espinosa and Lee, 1991). In the past few years, adult escapement has probably ranged from 50 to 75 fish (Murphy, pers. comm.) (from Rhodes et al, 1994, p B-4).

7. Studies on population response comparisons from healthy versus disturbed habitats, such as Huntington’s studies in the Clearwater National Forest.

RQ2a: Watersheds in SRB and outside SRB which show similar levels of FSR/PS habitat quality show similar trends in salmon production.

California: Burns (1972) found that stream sedimentation from logging along northern California streams caused loss of pool area, resulting in reduction of coho and large trout. (in Rhodes et al., 1994. p 27).

This question could be addressed using the index stocks and qualitative habitat rankings developed by the state agencies, the run reconstructions, the trend information from Paulsen and Schaller et al (1996), and the productivity information from the Deriso et al. (1996) MLE analysis (Table 10-1). Using the Lower and Mid Columbia River stocks once the influence of the early ocean residence and ocean distribution assumptions are discussed and, if possible satisfied or verified (i.e. Paulsen and Fisher’s 23 May 1996 report titled: “Ocean harvest distribution of hatchery spring chinook -- preliminary results.”). Compare case studies outside the Columbia River basin that have estimated smolt reach survival to the estuary, to control for any early ocean or offshore ocean effects. It appears that Columbia Basin stream-type chinook share common estuary and near shore early ocean environments, and may distribute off-shore of ocean fisheries. If this assumption is satisfied, then changes that may have occurred in the estuary and early ocean would not explain the differential decline in productivity between upriver and downriver index stocks (Schaller et al. 1996).

Table 10-1: Example Table to be completed to support analysis.

Reg	Wshd	Stock	[1] MLE alpha	[2] Stock trend (ln R/S vs time)			Ricker alpha	Ricker beta	Freshwater survival	[3] State Habitat Quality Ranking
				overall	pre-1970	post-1970				
SRB	Mainstem	Imnaha								

[1] From Deriso et al, 1996 - Draft Retrospective Report
[2] From Beamesderfer et al. 1996 and Schaller et al, 1996 Chapter 2 (Paulsen 1996), 3, 4 (Paulsen 1996) of draft retro report
[3] Habitat quality rankings developed by state agencies.

RQ2b: On a regional basis, FSR/PS habitat degradation has had a greater aggregate effect on spring/summer chinook in the SRB when compared to Columbia River and coastal Oregon and Washington stocks.

RQ3a: On a regional basis, habitat degradation has reduced FSR/PS survival of the aggregate Snake River spr/sm chinook since completion of the FCRPS in 1975 and this partially explains the overall decline of these populations.

Arguments in Favor:

Many references in Rhodes et al. 1994.

RQ3ai: Habitat degradation has reduced freshwater spawning and rearing survival (FSR) and prespawning (PS) in specific watersheds in the SRB for index stocks ***prior to*** *major Federal Columbia River Power System (FCRPS) construction beginning in 1958-1967 and this partially explains the decline of these populations.*

Arguments in Favor of RQ3ai:

See: Lichatowich and Mobrand **(**1995). Discussion of historical habitat impact on spring/summer and fall chinook is included.

Salmonid density is positively correlated to pool volume and frequency; pool loss reduces the production capability of salmonid habitat (Everest et al., 1985; Sedell and Everest, 1990;

MacDonald et al., 1991; Nickelson et al., 1992a; Fausch and Northcote, 1992). (in Rhodes et al., 1994. p 22).

"Negative trends in habitat condition (quality pools) are evident in several managed watersheds, whereas unmanaged watersheds have shown greater stability, over half-century time scales (McIntosh et al. 1994 as cited in Petrosky and Schaller, 1996 chp 9 draft). Streams with high levels of pool loss include the Lemhi, Stanley, Clearwater tributaries, Grande Ronde tributaries, and Middle Fork Salmon River tributaries (Sedell and Everest, 1990; McIntosh, 1992; B. McIntosh, USFW PNW Research Station Res. Asst., pers. comm., 1993; Boise National Forest, 1993). (in Rhodes et al., 1994. p 28).

Pool quality: Platt (1974) found a significant positive relationship between pool quality and the standing crop of salmonids. (in Rhodes et al., 1994. p 22) - pool quality, distribution of species and age class related to macrohabitat type, variant of macrohabitat type, and quality, the productive capacity of a stream is dependent upon the diversity of habitat qualities by type. (in Rhodes et al., 1994. p 22).

Salmon River tributaries in Idaho: Overton et al (1993) found a statistically significant difference in pool frequency and LWD frequency between a watershed that had been logged, roaded, and grazed and a relatively undisturbed watershed; the undisturbed watershed had about twice the LWD frequency and more than twice the frequency of pools than in the logged watershed. (in Rhodes et al., 1994. p 26).

Case study of the "heavily degraded" South Fork Salmon River (see previous notes from Rhodes et al. 1994).

RQ3aii: Habitat degradation has reduced freshwater spawning and rearing survival (FSR) and prespawning (PS) in specific watersheds in the Snake River Basin (SRB) for index stocks ***since completion*** *of the Federal Columbia River Power System (FCRPS) in 1975 and this partially explains the decline of these populations.*

Arguments in favor of RQ3aii:

Many references reviewed in Rhodes et al. 1994.

Arguments in disfavor of RQ3aii:

Petrosky and Schaller 1996, draft (Chapter 9) analysis shows no empirical support for a decrease in spawner to smolt survival in Snake River Basin after completion of FCRPS.

Weakness of argument in disfavor:

1. "As long as the amount and distribution of high-quality habitat available remains proportional to the number of spawners and in locations used by the fishes, the apparent productivity of the population will remain fairly constant. Thus it may be impossible to detect a historical decline in habitat conditions over a period when numbers of spawning adults are declining as well, if one looks only at the number of smolts produced per adult." (Lee and Rieman, 1996, Draft, page3).

2. "The relative stability in FSR survival since the early 1960's implied from this analyses, with aggregate populations, may not extend to individual populations within the Snake River Basin... dynamics of individual spawning populations at the FSR life-stage can be expected to respond to

habitat conditions at the local and basin scales." (Petrosky and Schaller, 1996 Chapter 9 Draft) (p 9-8).

3. With respect to potential depensatory mechanisms initiating at low escapements, "As pointed out in BRWG (1994), classic production functions of the form used here [Ricker] inevitably overestimate production at low escapements" (Petrosky and Schaller, 1996 Chapter 9 Draft p. 9-8).

   re 3: The analysis of Lee and Rieman (1996) would refute the ecological and conservation implications of this statement based upon the functional assumptions accepted in the use of the Ricker (1975) production function. Lee and Rieman (1996) does not necessarily refute depensation, but suggests possible compensation could become stronger at low escapements than might be predicted from stock recruitment observations at higher escapements.

4. Chapter 9 conclusion that regression evaluation does not rule out small decreases in FSR survival in recent years.

RQ4ai: Within the SRB, trends in stock indicators are correlated with trends in environmental stressors (human-induced alteration in habitat) in the FSR life stage (i.e. water temperature, road densities, sediment deliveries).

RQ4aii: Within the SRB, trends in stock indicators are correlated with trends in environmental variables in the FSR life stage (i.e. annual background water temperature, snowpack, subbasin precipitation, drought year flow, natural (background) sediment deliveries).

Supporting Evidence: Paulsen Chapter 4 GLIM analysis.

RQ4b: Within and outside the SRB, rate of change parameter estimations are better correlates as stock indicators compared to time or spatially averaged parameters (e.g., degree days, flow/runoff ramping rates, sediment delivery)?

Arguments in Favor: Rhodes et al. 1994, parr PIT-tag studies.

RQ4c: Time series trends for environmental stressors are suitable surrogates for time series trends in habitat quality and quantity for the SRB index stocks.

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*RQ5a: Mortality in FSR is *density dependent and **habitat specific with relation to lifestage (spawning/early rearing [S/ER], downstream rearing [DR], and overwintering [OW])*

Evidence in Favor of RQ5a:

*Increase in productivity [as measured by ln(smolt/spawner)] with decreasing spawner numbers is consistent with density dependence as expressed in production functions (Ricker (1975) as cited in Petrosky and Schaller, 1996 Chapter 9 Draft at page 9-8).

**Data from ODFW spring chinook life history studies in the Grande Ronde (Keefe et al. 1994) partially supports the "habitat specific" part of RQ5a. During 1993, juvenile chinook that moved out of the upper Grande Ronde rearing areas and over wintered in lower valley habitat exhibited a higher mean detection rate at mainstem Snake River dams than juveniles that remained in the upper

Grande Ronde habitat for the winter. The authors caution that these data are preliminary for conclusion about winter habitat for spring chinook in the Grande Ronde basin.

From Achord et al. (1996): “10,880 PIT tags were detected at Lower Granite Dam... Of these, 2,542 originated from wild releases, 5.6% of the total number of wild fish released and 0.4-15.2% for individual streams over the years... The overall percentage of released wild fish detected at the dam was lowest in 1989. In part, this was because fish from a few streams (Crooked and Red Rivers; which are non-ESU supplemented hatchery derived stocks released into acclimation ponds) in which large numbers of fish were tagged were detected in very low numbers... We suspect that unusually low overwintering survival, caused by s succession of extreme environmental conditions, contributed to low detections of fish in 1989. Back-to-back droughts resulted in low river discharge in the study streams during summer, fall, and winter 1988. Normally, large numbers of parr migrate downstream out of the upper tributaries in fall... The magnitudes of these migrations differ annually and can result in fish moving far downstream into the larger tributaries, where quality overwintering habitat is more abundant. Factors such as stream discharge, temperature, turbidity, and habitat availability affect the migrations... Low stream discharge may have impeded the fall migrations. Thus, more fish than normal may have remained upstream in the tributaries where quality overwintering habitat was limited.”

RQ5ai: Mortality in FSR life stage is dependent upon the timing and duration of FSR residence.

RQ5aii: Overwintering conditions (temperature, riparian cover, sediment loading) are more critical to smolts produced to the mainstem passage corridor than spawning or downriver rearing.

Evidence in Favor:

-several references in Rhodes et al (1994).
- Achord et al. (1996).

RQ5b: Within SRB, trends in stock recruitment indicators [Ricker’s alpha and beta, ln R/S] are dependent upon or correlated with seeding from the UP life stage and/or PS escapement.

Arguments in Favor:

Petrosky and Schaller 1992, Lee and Rieman 1996.

Arguments in Disfavor:

Rhodes et al. 1994.

RQ5ci: FSR habitat quality and quantity is dependent upon adult seeding and /or trophic production according to an annually adjusting carrying capacity.

in contrast, an alternative hypothesis would be,

RQ5cii: S/ER, DR, and/or OW carrying capacities are constant but resources are under utilized because of under seeding of spawners.

Arguments in Disfavor:

Lee and Rieman (1996) SLCM analysis.

RQ6a: Degraded habitat conditions have the greatest impact on geographically restricted or genetically isolated salmon populations that exhibit lower annual production.

Arguments in Favor: Results of USFS-INT EA/PATH analyses (Section 10.32.2), Rhodes et al. 1994.

RQ6b: Degraded habitat conditions are cumulative/additive to the demographic effects of small populations, such as the probability of finding a mate and/or genetic depression (BRWG 1994).

Arguments in Favor: BRWG (1994), although those analyses not specific to habitat condition.

Arguments in Disfavor: Lee and Rieman Draft (1996) - Appendix 1; Section 10.3.3.

Opportunity to test RQ6aii by development of alternative stock recruit production function to Ricker (1975) as suggested in Petrosky and Schaller (1996; Chapter 9).

RQ6c: Habitat structure and function that is increasing in quality will respond with an increasing trend in FSR production regardless of the condition classification it was assigned at the beginning of the evaluation period. Is there a response in FSR production relative to different habitat conditions as habitat quality improves over time, and would such a response be measurable in time to elucidate protective management measures?

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10.3.2 FSR Habitat Condition Description

State Agency Classification of Habitat Quality for PATH Index Stock FSR Areas

Idaho, Oregon, and Washington provided subjective habitat quality rankings for the reconstructed index stocks (Table 10-2). Appendix 3 contains further specific information compiled by Langness, et al. The qualitative rankings were based on the amount of land use disturbance. In ranking habitat, geomorphological and physiographic characteristics of the subbasin which may define a stock's inherent productivity were not considered. Habitat quality rankings are subjective without defined criteria for consistency in ranking, but there was a coordinated attempt to make them consistent across State agencies and subbasin geomorphological variance regimes. The ranks of 1, 2, or 3 correspond to High, Medium, and Low habitat quality, specifically: 1 corresponds with little or no land use impact with minor degradation; 2 corresponds with land use impacts with moderate degradation; and, 3 corresponds with land use impacts with heavy degradation. The FSR life stage was divided into three components: spawning/ (early) rearing (S/R); downstream rearing (DR); and overwintering (OW).

Note that the only stock with a significant time series effect is Poverty Flat. If a time series analysis is planned, then for S/R the values would go 2,3,2, and then for DR the values would go 2,3,2.

Table 10-2: Habitat quality rankings for reconstructed index stocks.

	S/R	DR	OW

Middle Fork Salmon			
Sulphur	1	1	1
Marsh	2	1	1
Bear Valley/Elk	3	2	1
South Fork Salmon			
Poverty Flat	3	3	2
Johnson	2	2	2
Mid-Columbia			
Wenatchee	1	2	2
Entiat	2	2	3
Methow	2	2	2
Minam	1	1	1
Imnaha	1	1	1
Warm Springs	2	2	2
John Day	2	2	2
Wind	1	1	2
Klickitat	1	2	2

The Index streams appear to fall within the moderate impact with medium habitat quality or low impact with high habitat quality areas of the Eastside Assessment analysis map.
The areas were relatively stable over time (except Poverty Flats).

USFS Habitat Classification

The Eastside Assessment (EA) targeted USFS and BLM management needs. Aquatic systems were a small but significant piece of the total landscape assessment. Aquatic habitat was characterized throughout the basin as well as possible using available data that was a mixture of coarse and fine measurements. There is some detailed information on some streams such as the Klickitat and Wind Rivers. The focus was primarily on fish, with some focus on riparian and other types of aquatic habitat.

USFS-INT possess data on 1700 km of stream habitat distributed across the basin. They tried to get coarse resolution on aquatic habitat quality and tried to link or correlate to land use effects at the subbasin level for fish using subwatershed delineation. Using judgment calls, local biologists at the USFS and BLM District level determined if and what species of resident and anadromous fish are present or absent. If present, is the population strong (>50% of historical abundance) or depressed (<50% of historical abundance). Anadromous species were mostly depressed or absent. They evaluated for seven salmonids including anadromous species of steelhead and ocean and stream type chinook and non-anadromous trout. Also a survey of all fish species was characterized to create distribution maps. This led to: high/moderate/low intensity watershed land use, land management opportunities, and concerted actions. Public release of EIS and Scientific Assessment reports is currently scheduled for September 1996.

Habitat quality classifications are derived from the presence/absence analyses integrating species strength ratings with other information (e.g. land use types, patterns, intensities using variables such as road densities). The EA classified by: 1) low impact, high habitat quality; 2) moderate impact, medium habitat quality; and 3) high impact, low habitat quality (mostly agricultural areas). There exists a large array of observed and subjective information with varying resolution of data dependent on past monitoring intensities within localized geographical areas, plus basic knowledge of the geo-physiographics of the subbasins to derive a subjective classification scheme with the three categories. Classifications are not tightly assumed to be fixed for any defined period of time, but are a starting point for discussion.

USFS lands contain more roads than those which appear printed on the evaluation maps produced. There are system vs non-system roads. Data is inconsistent across the basin. They usually have more resolute road type and mileage data where sediment models have been run. Road density is placed into six categories ranging from None (0-0.02 miles/mile^2) to Extremely high (4.7+ miles/mile^2). There is no differentiation of road type or condition in the evaluation, however, roads can be differentiated by land type (e.g., high risk areas classified by slope, aspect, soils, etc.). USFS constructed roads generally make up the bulk of the system roads.

PATH / Eastside Assessment Comparison

Horan performed descriptive summary queries upon the EA database comparing the overlap of the State Agency's index stock subwatershed delineations with the EA designated subwatersheds where chinook stock and chinook habitat were present. The index stocks for which run reconstructions have been developed for PATH cover about 38.8% of the 74,622 km2 area characterized as chinook habitat in the EA (Tables 10-3 and 10-4 show the breakdown by Area and Percent). Lee found that the State agency habitat quality classifications based upon amount of management activity were generally consistent correlating well with the broadscale landscape variable and chinook presence/absence based classifications of the EA process. Horan standardized for life stage designated habitat overlap and/or repetition in the analysis. For example, nearly 100% of the SER and DR designated habitat watersheds by the State agencies were also designated as used for OW habitat.

The quality classification distribution (Table 10-3 and Figure 10-1) indicates that a medium or moderate habitat rating dominates the DR and OW lifestage habitats, whereas the SER lifestage exhibits a dominating split between high and medium habitat ratings. This relationship is likely due to the amount of SER habitat area that is currently managed under some degree of land use protection (Table 10-5). The slightly higher half of the split demonstrating medium habitat quality is likely explainable by the amount of high road density that remains in SER habitat (71%, Table 10-6) as remnants of land use activities that occurred prior to Federally protected status and/or outside of, but juxtapositioned to the higher quality habitat located within the 19% of total USFS Eastside lands managed as wilderness. High road density, which is one primary measurable variable contributing as a sourcing variable not only to higher sediment deposition, but also to increased access for anthropogenic intervention via mining, logging, and recreation, dominates all three life stage habitat types (SER, DR, and OW), especially within the John Day River subbasin. The Salmon River subbasin exhibits low to moderate road density, although the subbasin is characteristically contained within the highly erodable Idaho batholic geome where certain stream courses have been highly degraded with sedimentation.

One interesting relationship is that the South Fork Clearwater River is dominated by high road density resulting from rather intensive dredge mining during the 1950s through the 1960s, but exhibits fairly good riparian areas within higher slope and aspect stream courses. The Clearwater River system does not contain a protected ESU stock because of past extirpation, which lead to management involving supplementation with hatchery derived stocks where early life stages are acclimated in side channel flow-through systems. Achord et al. (1996) eliminated two of these supplementation stocks from the South Fork Clearwater River metapopulation, Crooked and Red Rivers, from their parr PIT-tag studies following lack of detection of these tagged stocks at Lower Granite Dam in 1989. Low presmolt survival was inferred.

USFS-INT EA queries lend some support to acceptance of Hypothesis RQ6ai suggesting that PATH index stocks may better represent more robust stocks that occupy the more productive streams relict from the higher sediment deposition time series of 1950-1960s. Weaker stocks that were more vulnerable to geographic and/or genetic isolating mechanisms may have been lost to the aggregate basin-wide population.

Maps showing a geographic comparison of USFSA-INTEA areas and PATH index areas are contained in Appendix 6.

Table 10-3: Total Area (km^2) and Percent (%).

Eastside Area: 74,622 km^2
Key: 1 = high; 2 = medium; 3 = low; SR = spawning/rearing; DR = downstream rearing; OW = overwintering

Table 10-4: Percent of Eastside Area.

Eastside Area: 74,622 km^2
Key: 1 = high; 2 = medium; 3 = low; SR = spawning/rearing; DR = downstream rearing; OW = overwintering

Figure 10-1: PATH Area and Percent of Eastside Area by Quality Rating and Habitat Type.

Table 10-5: PATH Index Stock Distribution: Land Ownership and Management.

Table 10-6: PATH Index Stock Distribution: Road density

10.3.3 Stock Recruit Relationships

Lee and Rieman (1996) Analysis:

In the absence of empirical studies, stock-recruitment models that incorporate habitat quality variables suggest that declines in habitat productivity can have a disproportionate effect on population persistence and total population size. Thurow and Burns (1992) provided an example where 20 percent loss in habitat productivity resulted in greater than 50 percent reduction in adult numbers, and 50 percent reduction in habitat productivity was sufficient to result in extinction. In the following example, Lee and Rieman (1996) used the stochastic life cycle model (SLCM) of Lee and Hyman (1992) to compare effects of simultaneously altering freshwater FSR quantity and quality with mainstem smolt passage survival (Appendix 1).

Lee and Rieman (1996) illustrate the relative effects of simultaneously varying incubation success (spawning habitat quality), parr carrying capacity (rearing habitat quantity), and downstream passage survival (mainstem smolt passage survival) on a hypothetical population of chinook salmon. Incubation success was defined as the proportion of eggs produced that were successfully deposited in redds and survived to emergence. They used incubation success as an indicator of habitat conditions in terms of both spawning and incubation conditions (Bjornn and Reiser 1991). Parr capacity was defined as the maximum number of parr or juvenile chinook that an area can physically support. It reflects both habitat quality and quantity, but Lee and Rieman (1996) use the variable heuristically to measure habitat quantity only, while assuming habitat quality remains constant or is inputted in terms of incubation success. Downstream passage survival was defined as the proportion of the smolts that leave natal streams or rearing areas and survive migration to the Columbia River estuary. Passage survival may reflect many variable influences, but Lee and Rieman use it to index the effects of changes to smolt and prespawner survival in the hydroelectric system.

Lee and Rieman (1996) examined eleven levels of incubation success (15% to 65%, in 5% increments) in combination with three levels each of parr capacity (50, 100, and 150 thousand) and downstream passage survival (35%, 45%, and 55%). All other parameters, such as fecundity, ocean survival, and maturity rates, were held constant at reasonable values for an upriver Columbia Basin stream-type chinook population. Lee and Rieman simulated 500 games for each parameter combination (49,500 games total). Each game started with an initial population of 250 female spawners and ran for 100 simulated brood years or until the population declined to zero (simulated extinction). Results were summarized by plotting the proportion of games where the simulation population did not reach zero within the 100 year period (probability of persistence) and the average number of female spawners (mean run size) for each parameter combination.

Results show that the probability of persistence responds to changes in incubation success and passage survival in a manner that is consistent across different levels of parr carrying capacity. As passage survival decreases, the level of incubation success required to ensure population persistence increases. Increasing parr capacity has no apparent effect on the relationship. Furthermore, the drop from certain persistence to certain extinction is fairly abrupt. Decreasing the incubation success from 50% to 25% was sufficient to cause certain extinction of an apparently robust population, regardless of the passage survival or parr carrying capacity (Scully et al. 1990 observed an eightfold difference in their study). This result suggests that increasing the amount of available habitat (parr capacity) without any increase in quality (incubation success) would have no discernible effect on the probability of population persistence through time. Alternatively, increasing habitat of lower quality is less advantageous in terms of population persistence than a decrease or stabilized amount of habitat of higher quality.

All three measures can affect population numbers through time. Habitat quantity can have a measurable effect on mean run size, but only beyond a certain threshold combination of passage survival and incubation success. In this example, the response curves for the different parr capacities begin to diverge beyond the point where the product of passage survival and incubation success exceeds 16% (e.g., 35% passage survival and 45% incubation success, or vice versa). The asymptotic nature of carrying capacity limiting population numbers is observed only in the combinations of highest passage survival that would act to increase spawner seeding and concomitant high incubation success, where ocean effects are assumed constant.

This forwards the following question for future analyses: What would be the response be on parr density if passage survival is 60% as estimated by some recent CRISP 1.5 runs, or <20% as estimated in BRWG (1994) evaluations for probability of persistence? This modeling exercise could be expanded to incorporate BRWG (1994), Deriso et al. (1996) estimates of *mu*, and other more recent estimates of survivals required for probability of persistence and average number of female spawners (above zero) estimated for extinction with or without depensation.

Petrosky and Schaller (1996) Analysis

Petrosky and Schaller (1996, Chapter 9) examined and tested for the hypothesis, *"Has there been a net decrease in survival during the freshwater spawning and rearing* (FSR) *stage for Snake River spring/summer chinook since completion of the Federal Columbia River Power System* (FCRPS) *that could explain the decline in adult recruitment and productivity?"*. A decrease in FSR survival could explain the decline in adult recruitment and productivity of Snake River spring/summer chinook. Wild spring/summer chinook spawner and smolt numbers were indexed at the uppermost dam for 1962-1973, 1962-1982, and 1990-1993 brood years. Ability to test the hypothesis is data constrained, hence Petrosky and Schaller (1996, Chapter 9) developed an indirect method to index survival in the FSR life stage. A long time series dating to before completion of the FCRPS would be desirable to rigorously evaluate hypotheses about decreased FSR survival.

Petrosky and Schaller's (1996) conclusion in Chapter 9 is basically that survival in spawning and rearing habitat in the Snake River basin has not changed significantly enough to detect an influential change in natal productivity or recruitment (spawner-to-smolt), therefore there is little evidence that habitat quality has not played a major role in the reduction in stock productivity documented since the completion of the FCRPS. Two points exists regarding this issue: 1) Even if survival in Snake River natal habitat has not changed since 1963, the regression technique used is not robust or sensitive enough to not indicate that FSR has not been or is not presently a contributing factor to salmon decline. Persistence of low survival rates attributable to FSR habitat effects when combined with the additional mortality at the dams can explain run declines, even if it is assumed that survival in natal habitat has not changed. Even if FSR has not changed since the completion of the FCRPS, prior degradation may have had a substantially contributing role in salmon decline that became more observable when the FCRPS was completed and shifted the total lifecycle mortality to levels that precluded replacement of spawners. 2) The approach employed may not be sensitive to even large changes in environmental degradation. Research has indicated that such models may be somewhat insensitive to detecting environmental degradation (Reisenbichler 1989). It is stated that a net decrease in habitat quality has not been demonstrated for the Snake River basin (Petrosky and Schaller 1996, page 9-2 in Draft Retrospective Analysis, PATH 1996), which is dismissive of a large body of published and unpublished evidence. The vast bulk of available information and data indicates that degradation has remained severe in most of the Snake River basin and that habitat quality has declined in many areas (Rhodes et al. 1994, McIntosh 1995, Espinosa et al., *in press*).

The two spawner indices used in Chapter 9 by Petrosky and Schaller (1996) bracket a range of potential spawners at the uppermost dam. Use of the SP1 index implicitly assumes hatchery spawners are completely ineffective, while use of SP2 assumes hatchery spawners are equally effective as wild spawners. If SP1 were true, no significant decreases in FSR survival were detected by Petrosky and Schaller (1996). If SP2 were true, FSR survival decreased significantly in a single case. If hatchery spawners were somewhat less effective than wild spawners, only weak decreases might be expected.

Table 10-7: Averaged summary results for spawners and smolts estimated by Petrosky and Schaller (1996, Chapter 9).

	1962-73		1962-82		1990-93 w/ 56% FPE		1990-93 w/ 40% FPE	
	SP1	SP2 (hatchery adjusted)	SP1	SP2	SP1	SP2	SP1	SP2
Spawners (SP) (thousand)	39.6	39.9	30.2	30.5	8.5	11	8.5	11
Smolts (SM) (million)	2.33	2.33	2.04	2.04	0.83	0.83	1.16	1.16
SM/SP	61	61	80	78	104	81	145	114

Their regression models typically showed a significant density dependence between ln(smolts/spawner) and spawner when a wide range of spawning escapements were examined. For brood years 1962-73 analyzed alone, numbers of smolts per potential wild spawner (SP1) showed a weak pattern of density dependence. For brood years 1962-82 analyzed alone, numbers of smolts per SP1 showed significant density dependence, where predicted smolts per SP2 were similar to the 1962-73 data set. These responses should be expected with the degree of overlap in the 1962-73 partition of both data sets. Petrosky and Schaller should segment out 1974-82 to analyze against 1962-73 and 1990-93.

Based upon one-tailed means tests, only the number of spawners was found to be significantly lower after brood year 1974. While spawner numbers declined significantly since completion of the lower Snake River hydropower system, productivity as measured by smolts/spawner and ln(smolts/spawner) increased. Based upon two-tailed means tests between pre- versus post-FCRPS completion brood year periods 1962-74 versus 1975-1993, spawner numbers declined significantly, while most smolt per spawner indices increased significantly, possibly indicating some relief from density-dependent factors. This result is not only consistent with density dependent production functions like Ricker (1975), but would be expected based upon Rhodes et al. (1994) review which is highly indicative that the greatest decline in habitat quality from historically perceived “pristine”, as measured by estimated sediment loading and transport input, occurred prior to major lower Snake River dam construction. It would be likely that a new less variable equilibrium with respect to sediment sourcing and resultant responses like pool depth and number, embeddedness, and gravel infiltration would have been formed prior to the early years of measurement for stock recruitment data.

A means test of the residuals indicated that the index of FSR survival showed no significant decline since completion of the hydropower system for four combinations of spawner and juvenile indices (Table 10-7). The pattern of residuals from 1962-82 versus 1990-93 brood years indicate greater variability in the later period, and F-tests of the variances were significant ($P < 0.05$) for all four combinations of spawner index and FGE assumptions. Three of the largest negative residuals from the means tests occurred in the second period (post-1975), and were associated with major drought years during the year of smolt migration (1977, 1992, and 1994). The other major drought year in the second time series (1973) did not have negative residuals. The influence of different spawner indices on the residual pattern predictably became more pronounced with time, because of increases in hatchery adult releases into Snake River tributaries. Analysis of covariance (ANCOVA) of the same data sets indicated a significant decline in FSR survival for one of the four combinations. Adverse environmental conditions such as below average runoff may have reduced FSR survival in some brood years. The Snake and Columbia River basins experienced prolonged drought from 1987 through 1994. When drought years were removed from the data set, the index of FSR survival showed no significant decline. Petrosky and Schaller’s (1996) evaluation does not eliminate the possibility of small decreases in FSR resulting from localized life stage specific habitat effects in recent years (e.g., overwintering).

The trends and patterns in FSR survival observed for aggregate populations may not extend to individual populations within the Snake River basin. Although poorly quantified, dynamics of individual spawning populations at the FSR life stage can be expected to respond to habitat conditions at the local and basin scales. A broad mix of land use influences, from relatively pristine to intensive management for irrigated agriculture, livestock grazing, logging and mining, existed throughout the time series. Negative trends in habitat condition (e.g. quality pools) are evident in several managed watersheds, whereas wilderness or unroaded watersheds have shown greater stability, over half-century time scales. Reductions in sediment deposition have also been documented in the heavily degraded South Fork Salmon River since the mid-1960s, and major fish screening programs were completed by the late 1960s in the Upper Salmon and Grande Ronde rivers. While FSR survival of individual populations would be expected to track with these localized trends, the aggregate data provide no empirical support for a major shift in spawner-to-smolt survival that would explain the higher rate of decline in productivity of Snake River spring/summer chinook since completion of the FCRPS (Schaller et al. 1996 (see Chapter 3)).

Future Analyses

1. For Prospective Investigation: The proportion of hatchery fish allowed to stray, spawning, and mixing with wild smolts has increased during recent years, and will continue to increase with the Tribal strategy for increased supplementation through acclimation facility construction. Hypothesis: *If reproductive success is lower for hatchery stray or supplement spawning in streams than for wild spawners (Chilcote et al. 1986), then aggregate FSR survival would exhibit an apparent decline.* Petrosky and Schaller (1996) indicate that if hatchery spawners are less effective than wild spawners, only weak decreases might be expected.

2. Aggregate population data should be used with caution to infer the strength of depensatory mechanisms for Snake River spring/summer chinook salmon. Stronger populations tend to dominate recruitment patterns within the aggregate (Ricker 1975); those populations most likely experiencing depensation could be underrepresented in the aggregate. Classic stock recruit production functions such as Ricker possess high probability to intuitively overestimate production at low escapements due to their operational functionality acting to increase productivity to a maximum value at one spawner, where no density-dependence mechanisms would be assumed and applied. One spawner would constitute effective extinction for that brood year and be too low to be influenced by demographic or genetic factors. Aggregate escapements for brood years 1994 and 1995 were substantially lower (1100 - 1700) than those used in the Petrosky and Schaller (1996) analysis (5000 - 52,700). Future estimates of smolts/spawner from these brood years may provide additional insight into the relative strength of depensatory mechanisms in Snake River spring/summer chinook. To test for a depensation hypothesis, future analysis could utilize alternate productivity functions provided by Brian Dennis; developed by Petrosky, Schaller, and or Paulsen; or utilize a logistic derivation used previously within SLCM.

10.3.4 Wild Parr PIT-tag Analysis

Achord and Standford (1996, Appendix 4 (draft)) reported that overall detection rate percentages of PIT-tags detected at lower Snake and Columbia River dams for all parr release streams and sample years were highly variable and ranged from 2.3 to 31.9% (Table C10 A4-1 in Appendix 4). A significantly (P = 0.01) smaller percentage were detected from populations marked in streams the farthest distance upstream of

Lower Granite Dam. They assumed that parr reared in the general stream area where they were captured, tagged and released. If true, the habitat in those streams likely affected their subsequent condition and survival to smolts.

Detection rates from pristine streams were significantly higher ($P = 0.035$) than for near pristine, moderately degraded, and degraded streams. No significant detection differences ($P > 0.05$) were found between fish in the near pristine, moderately degraded, or degraded streams. These observations would support Lee and Rieman's (1996) analysis indicating habitat quality would be the more important and limiting habitat variable over quantity of habitat.

However, although fish were detected at significantly lower rates the farther they had to migrate to Lower Granite Dam, there were no representative fish in the samples from pristine populations that also had the greatest distances to migrate. Thus, it was not possible to determine the extent that distance and/or habitat had on subsequent detection rates.

Furthermore, it was not possible to determine if differences in detections between years were related directly to habitat partly due to the dependence of the behavioral response to overwinter conditions related to interannual precipitation and snow pack. Significantly ($P = 0.02$) more fish were detected from the lower average flow outmigration of 1993 than from the higher average flow outmigration of 1995, but there were no significant ($P > 0.05$) differences in detections between the more similar 1993 and 1994 or the 1994 and 1995 outmigrations. The timing of spring outmigration runoff peaks and rates of increase in water temperature may have been greater influencing variables between these years over the averaging influence to calculate total river discharge.

10.3.5 SER/ DR/ OW Habitat Decision Tree

See diagram of Habitat Decision Tree (Figure 10-2).

Figure 10-2: Habitat Decision Tree.

10.3.6 Test of Persistence Being Independent of Current Time Series Habitat Condition

To Be Completed

10.3.7 Case Study Review

Refer to Appendix 5 for review of case studies.

10.3.8 Modified GLIM Analysis

To Be Completed.

10.4 Conclusions

The evaluations presented in this Chapter support the conclusion that existing high-quality habitats be maintained in order to deter extinction of Snake River anadromous fishes and other at-risk stocks, and to maintain population resiliency until other causes of mortality are reduced. To ensure positive progress toward recovery, the amount of high-quality habitats currently available are critical and must remain proportional to the number of returning adults, so that there is no net loss in productivity as adult escapement increases as a result of improved mainstem passage survival, ocean distribution conditions, and/or increased habitat quantity with concomitant quality. The differences between those that persist and those that are extirpated will also include incorporating variability to account for impacts due to stochastic catastrophic events related to the survival and productivity of the stocks as they are largely influenced by freshwater habitat quality connected across the early life stages. Without substantial improvement in migrant survival, protecting existing high quality FSR habitats with appropriate connectivity and enhancing the quality of FSR habitats, more specifically rearing and overwintering components, may make the critical difference in persistence for many of the remaining populations. In the long term, assuming mainstem conditions are resolved, it will be necessary to conserve and restore broader habitat networks to support the full expression of life histories and species (Lichatowich and Mobrand 1995; National Research Council 1995). To fully realize the benefits of improved migration and ocean survival, there must be a commensurate increase in the distribution of high-quality spawning and rearing habitats.

Any comparative analysis utilizing landscape variables must consider that the erodability of the Idaho batholith habitats can be much greater than that of the Cascades range, coastal continental U.S. and B.C., mid-Columbia, and lower Columbia River comparison stocks, such as the Deschutes stocks (Warm Springs).

The precise measure of magnitude of the contribution of decline to anadromous salmon that can be attributed to degradation of FSR habitats remains ill-defined to unknown, and likely unpredictable with much certainty. The available data remains of low resolution and constraining. It will remain difficult to answer management questions requiring high resolution of confidence because complex covarying changes in the FSR habitat and FCRPS have occurred and pre-treatment data to perform before-and-after comparisons do not exist. For example, stock-recruit data back to 1957-1969 for up to 45% of the chinook habitat is available for run reconstructions, but analysts lack landscape variable time series data in which to correlate, although Rhodes et al. (1994) include historical sediment delivery or transport measurements in their synthesized review). In addition, the complexity of interactions across life stages confounds even the best of studies. For example, the debate over the efficacy of barge transporting smolts downriver focuses not so much on the survival through the mainstem transportation process per se, but rather on the latent effect that barge and/or truck transportation has on post-release survival and adult return rates. Similar questions could be raised regarding early rearing of salmon. For example, do juvenile fishes from degraded habitats exhibit the same migration and early marine survival as those from better habitats? Hartman and Scrivener (1990) suggest that the juveniles studied from British Columbia habitats of varying quality do not survive in similar patterns. Possible supporting evidence of a subbasin response mechanism would be the observations forwarded in Rhodes et al. (1994) that chinook juveniles will redistribute from temporarily poor seasonal or annual habitat with high temperature to more optimal low temperature habitat, where population number sampling may not capture such a response.

FSR habitat changes are also difficult to precisely measure because of confounding processes associated with the compensatory nature of fish-habitat relationships. Compensatory factors support the hypothesis that high-quality habitat is a critical limiting factor to persistence and recovery of severely depressed populations. When spawner escapement declines, Ricker-type (1975) stock recruit production functions assume that surviving adults are released from heavy competitive forces to choose areas offering the best physical conditions. Similarly, juveniles from newly hatched fry through parr can spend their time in the better habitats with reduced competition for resources. The net result is that the number of smolts produced per adult can actually increase as the number of spawners decline. As long as the amount and distribution of available high-quality habitat remains proportional to the number of spawners and in locations that can be located by the spawners, the apparent productivity of the population will remain fairly stable. Thus, it may be impossible to detect a historical decline in habitat conditions over a period when numbers of spawning adults are declining as well, if one looks only at the number of smolts produced per adult. This is the likely situation in the Snake River subbasins above Lower Granite reservoir for both spring/summer chinook and appears to be the response of the wild subyearling population below Brownlee Dam. During and after construction of the federal dams in the lower Snake river (post-1970), numbers of returning adult chinook salmon declined dramatically compared to run sizes in the 1950s and 1960s (Petrosky and Schaller 1992). The declining numbers of adult salmon do not permit an adequate test of the hypothesis that habitat conditions changed during the same time period. An adequate test would require a sensitivity analysis utilizing alternate stock recruitment production functions that would allow depensatory and compensatory responses while simulating a return to estimated historical numbers of spawning adults that predate the dams.

The conclusions of Lee and Rieman (1996, Appendix 1) are appropriate for summarizing the Retrospective Analysis effort for initiating into the pre-Prospective Analysis.

1. *What are the relative contributions of habitat on the current state of populations within the interior Columbia Basin?*

This question cannot be answered precisely. The relative contribution also varies across the entire basin. It can be expected that the contribution of freshwater habitat changes to be least in the less-disturbed areas of central Idaho and in the northern Cascades, but greater in the lower Snake and mid-Columbia drainages. Similarly, the contribution of hydropower declines downriver where there are fewer dams between the freshwater spawning and rearing areas and the ocean. In some subbasins such as the Umatilla, irrigation withdrawals may be the major contributor to declines in naturally reproducing populations.

2. *If all other factors were held constant, would a further degradation of habitat increase the risks of extirpation or extinction?*

Yes. Regardless of the contribution of other factors, spawning and juvenile rearing habitat remains an important component in the viability equation. As demonstrated above, freshwater habitat can be most important in ensuring viability of stocks that are depressed through a combination of other factors.

3. If all other factors were held constant, would an improvement in freshwater habitat conditions increase fish abundance and reduce the risks of extirpation or extinction?

Yes, though the magnitude of the effect would vary greatly from subbasin to subbasin. In areas where present habitat is degraded and hydropower effects are smaller, such as the Deschutes River, habitat improvements could result in immediate increases in numbers of fish. In areas where habitat is degraded and hydropower effects are large, such as in the Grande Ronde River and some tributaries of the Salmon River, increases in population numbers due to habitat restoration would be more modest and gradual. In other areas where there is abundant high-quality habitat but few adult spawners, such as the Middle Fork Salmon River, immediate increases in fish abundance would not be expected. One aspect of habitat improvement that could have long-term repercussions, if not immediate benefits, is that increased availability of high-quality habitats reduces the chances that a random, catastrophic event such as a large fire followed by flooding would wipe out all of the best available habitat. A wider distribution of high-quality habitats also improves the likelihood of increased genetic diversity--an additional benefit over the longer term.

4. *If nothing is done to restore habitat, and mitigation of major factors such as the dams is successful, would there be sufficient habitat available to accommodate increasing fish numbers?*

The answer varies across the basin. Population numbers in much of the interior Columbia Basin are far below what current habitat conditions could likely support under a scenario of increased downriver survival. Some remote areas potentially could support hundred-fold increases or better in the number of adult numbers. But this is not the case everywhere. There are more disturbed areas where increased adult numbers would lead to compensatory declines in freshwater survival rates, thus reducing the per capita productivity of the population and limiting the effectiveness of downstream improvement efforts. To fully realize the benefits of downstream improvements, commensurate increases in the availability and distribution of high-quality habitat will be necessary.

10.5 Prospective Analysis

10.5.1 Prospective Hypotheses

PQ1: Improvement in FSR habitat related stock/recruitment productivity can compensate for survival losses in the SRB hydrosystem.

Arguments in Favor:

Lee and Rieman (1996) where habitat is degraded.

Arguments in Disfavor:

Lee and Rieman (1996) where "in other areas where there is abundant high quality habitat but few adult spawners, such as the Middle Fork Salmon River, immediate increases in fish abundance would not be expected."

NOTE: A persistence analysis should be completed simultaneously for stocks in good and poor habitat to determine responses for a suite of stocks in the Snake River basin (Petrosky, Schaller, and Langness comments to Draft Chapter 10, PATH Retrospective Analysis, 1996).

PQ2a: Size, density, condition, and time of emigration from FSR positively influences mainstem migratory corridor survival rates.

Evidence in Favor of PQ2a:

> ODFW Grande Ronde Life History PIT tagging studies and Smolt Migration studies.

PQ2b: Distance traveled from rearing area to the first reservoir (Lower Granite) influences mainstem migratory corridor survival rates.

Evidence in favor of PQ2b:

> Achord and Sandford (1996, draft) compared detection rates with the distance traveled to Lower Granite dam from the tagging/release sites and found that a significantly (P=0.01) smaller percentage of fish were detected from populations of fish marked in streams the furthest distance upstream of Lower Granite dam. These populations having the longest migration distance, the upper Salmon River, also have the most irrigation diversions, which are incorporated into the State's quality ratings.

PQ3a: Maintenance of existing habitat conditions will contribute to the extirpation of geographically-restricted spawning populations.

PQ3b: Access to historically closed FSR habitat (i.e., Hells Canyon) will increase the rate of recovery of spring/summer chinook salmon.

PQ4a: Widespread, consistent, and unimpeded habitat recovery is required to reduce demographic risks to regional salmon populations and the genetic risks to isolated populations.

PQ4bi: Incremental improvement in land management activities [relative to the past] will be adequate to improve habitat conditions and increase FSR survival.

PQ4bii:Incremental improvement in land management activities [relative to the past] will not be adequate to improve habitat conditions and increase FSR survival thus the temporal rate of improvement should be more progressive.

PQ4c: Improvements in natal habitat and resultant FSR survival will likely occur without suspending the causes of degradation.

PQ5: Protection of a system of refugia/priority watersheds on a regional scale will be adequate to restore salmon populations.

PQ6: It is possible to identify the watersheds where protection and restoration efforts will be most effective in preventing salmon extirpation and in rebuilding runs.

PQ7: Salmonid habitat quality degradation increases the probability of predation upon smolts by selecting for favorable predator habitat variables.

Little is known about the effect of pool and cover loss on predation efficiency and some have argued that it is a density-independent effect (D. Chapman, Consulting Fish. Bio. pers. comm., 1992). (in Rhodes et al., 1994. p 24/25)

Shifts in competitive advantage for food and space requirements among warmwater tolerant and intolerant species or increased predation by warmwater species on coldwater species under general increases in water temperatures adversely affect coldwater species by reducing growth rate, survival, and spatial distribution. (in Rhodes et al., 1994, p 37)

Can test hypothesis further by surveying documentation for smallmouth bass and other predator increases in downriver rearing or overwintering habitat.

PQ8: No single independent [habitat] or dependent [stock indicator] FSR variable is the dominant determinant of the optimum health and survival of salmonids delivered to the mainstem migratory corridor.

Little is known about the synergistic effects on juvenile and adult salmon caused by the loss of cover and pools, combined with increased temperature extremes, reduced water flows, and increased fine sediment, all of which typically exist where pool loss has been significant. (in Rhodes et al., 1994. p 25).

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APPENDICES

10-35

Appendix 1
Lee and Reiman. 1996. Federal Land management, Freshwater Habitat, and Anadromous Fishes in the Interior Columbia River Basin

DRAFT June 4, 1999

Federal Land Management, Freshwater Habitat, and Anadromous Fishes in the Interior Columbia River Basin

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Historical changes in the interior Columbia River Basin have influenced aquatic conditions and contributed to declines in fish populations and ecological integrity in ways that are readily apparent in the distributions and status of naturally reproducing anadromous salmonids (NPPC 1986, Nehlsen and others 1991, Lee and others 1996). The familiar list of contributing issues includes hydroelectric development, flood control, irrigated agriculture, hatcheries, ocean and in-river harvest, and degradation of freshwater spawning and juvenile rearing habitats. Issues that affect salmon in the Columbia basin often are grouped under four principal factors: Habitat, Hatcheries, Hydropower, and Harvest. While not all issues and problems facing anadromous fish fall nicely within these factors, this is a convenient taxonomy that we adopt for the current discussion. For clarity though, we separate habitat into two components: freshwater habitat where spawning and early rearing of juveniles occur, and estuarine and marine habitat that governs growth and survival beyond the Columbia River mouth.

While the relative contribution of each of these factors to historical declines and to currently depressed levels of production has been much discussed (e.g., NPPC 1986, Raymond 1988, Chapman and others 1991, Lichatowich and Mobrand 1995, Lee and others 1996, Lichatowich and others 1996), no one has been able to unequivocally assign proportionate responsibility to any single factor. This failure to allocate responsibility is not for lack of trying; rather it is an unavoidable consequence of the inherent interdependencies among factors and the complex life history displayed by these fish. As we discuss below, this problem is especially difficult to quantify in the case of freshwater habitat.

Even though we cannot quantify the contribution of each factor precisely, it is useful to discuss each factor qualitatively and to demonstrate their relative contribution with the use of models. To begin the qualitative discussion, some type of mental model or analogy of the relationship of the four factors is needed. One such model is the idea of limiting factors. Under this model, a single factor can limit the overall productivity of the system; until the limiting factor is mitigated, improvements in other areas will have no effect on overall system performance. In this regard, the limiting factor model is analogous to a circular bucket brigade in which the amount of water that can be cycled through the brigade at a single time is no larger than the smallest bucket (Figure C10 A1-1).

Figure C10 A1-1:. A conceptual view of salmon life history as a bucket brigade of limiting factors. The numbers of salmon that can circulate through the system is limited by the size of the smallest bucket.

Those who have critically evaluated the limiting factor model as a model for Pacific salmon have generally rejected it. The model is inadequate because it overly emphasizes capacity and ignores the multiplicative effect that increases in productivity in any phase of the life cycle can have on overall stock performance (Mobrand and others 1996). It also tends to derail efforts to simultaneously address all components of the life cycle, by focusing on a single issue.

Rather than view the salmon life cycle as a bucket brigade, a more accurate analogy would be an unusual system comprised of a pump and a circular system of large-diameter, but leaky piping (Figure C10 A1-2). The pump (freshwater habitat) requires a small, but steady stream of incoming water (adults) to prime the pump. Adults provide both eggs to produce the next generation, and nutrients to encourage their growth. The habitat pump produces a larger stream of outgoing water (smolts). As the water courses through the pipes, much of it is lost (mortality) due to inefficiencies or leaks in the system (e.g., hydropower losses) and some is purposefully removed for other uses (harvest). Rarely does the diameter of the pipes limit the flow rate. In this analogy, flow rate can be increased by increasing the efficiency (reducing the leakage) at any point in the cycle. For example, either reducing the losses from the hydrosystem or increasing the number of smolts produced per adult in the freshwater habitat stage will increase population numbers cycling through the system. Hatcheries reflect an engineered solution to increasing productivity per adult by shielding young fish from natural sources of mortality. Problems arise when the hatchery-reared fish are of substandard quality or of ill-adapted genetic composition relative to the naturally produced fish. Since so many factors influence survival, including the size and condition of fish, improvements in one portion of the life cycle may lead to unexpected efficiency gains in later life stages

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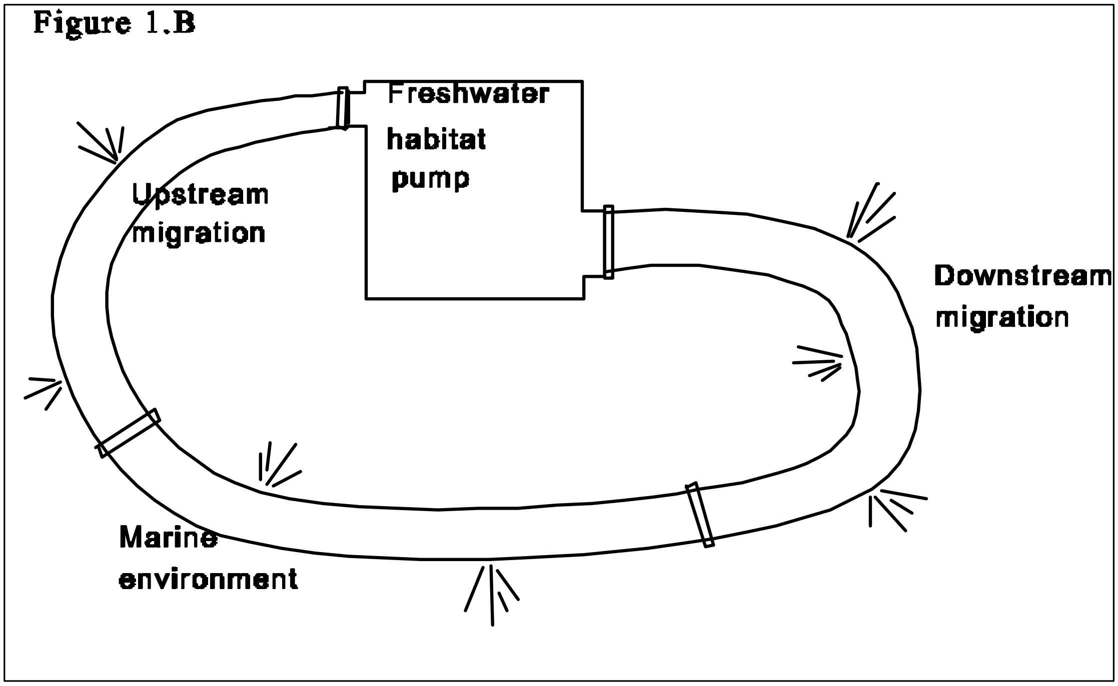

Figure C10 A1-2: A conceptual view of the salmon life cycle as a pump and circular system of leaky pipes. Freshwater habitat (the pump) requires an inflow of adults from which it produces a flow of smolts into the river, on to the ocean, and return. Leakage in the system is analogous to mortality.

One sees practically all combinations of pumps and pipes in the interior Columbia Basin, so it is very hard (and misleading) to generalize. Each major population must be evaluated on its own merits by looking at the relative strength of the population, the number of dams that must be negotiated, local watershed conditions, and historical indicators of potential population performance. In some Salmon River drainages, for example, there are very strong pumps with very leaky pipes. These stocks could benefit most from improvements in migration survival to stop the leaks. Conversely, habitat degradation could reduce pumping efficiency, leading to system failure. Lower in the Columbia system (e.g., the Deschutes River subbasin), the pipes are not so leaky but the pump is not as strong as it once was. Only in systems such as the John Day River subbasin and some portions of the mid-Columbia River (for ocean-type chinook) does one find the fortuitous combination of productive habitat and seemingly surmountable passage conditions.

With this conceptual model of the relationship among the four factors, we now look more closely at the specific influence of freshwater habitat.

Forest Service and BLM Contribution

Freshwater habitat is the one factor most prominently influenced by the Forest Service and Bureau of Land Management (BLM), which administer much of the remaining habitat used for spawning and juvenile rearing by anadromous fishes. How much responsibility the Forest Service and BLM have for contributing to the decline of anadromous fishes, and how far the agencies should go to correct perceived problems is an open debate that reaches beyond the arena of science. On one end of the spectrum are those who admit to no relationship among activities on federal lands, habitat degradation, and declines in anadromous fishes. To admit culpability is to implicitly acknowledge some responsibility for restoring population abundance. Since active restoration might constrain the activities of those with extractive interests in the National Forests and BLM-administered lands, there may be an economic motivation for some to disavow a connection between land management and anadromous fish declines. On the other end of the spectrum are those with a different agenda, who maintain that the Forest Service and BLM are responsible for deplorable habitat conditions that have single-handedly driven anadromous salmonids to the brink of extinction.

Both extremes of opinion are straightforward to debunk. Relative to the no-habitat-effect hypothesis, there are numerous published studies describing the effects of land-use activities on habitat conditions, and linking habitat conditions to survival and productivity of anadromous fishes. Nehlsen and others (1991) identify habitat loss as a major problem for 195 of 214 (91%) anadromous salmonid populations in California and the Pacific Northwest. Meehan (1991) and Murphy (1995) provide excellent comprehensive overviews of the linkages between land management, habitat, and fish. The differences in fish survival between pristine and degraded habitats can be dramatic. Scully and others (1990) show that egg-to-parr survival for chinook salmon in degraded streams with high sand content is less than one eighth that exhibited in low-sand areas.

An equally large literature documents anthropogenic effects in other life stages, which argues against freshwater habitat degradation as the sole reason for decline. A collection of papers in Schwiebert (1977), for example, documents a litany of problems in the Columbia River Basin that still apply 20 years after publication. Hydroelectric development is generally regarded as a principal factor in the decline of anadromous populations, irrespective of changes in freshwater habitat (NPPC 1986, Raymond 1988). Explicit recognition of the role of hydroelectric development contributed to passage of the Northwest Power Planning and Conservation Act of 1980, and to development of the Northwest Power Planning Council's Fish and Wildlife Program, a regional effort to simultaneously address the four principal factors affecting anadromous fish (among other issues).

The information provided by the broad-scale assessment of aquatic habitats and species within the interior Columbia Basin by Lee and others (1996) lends further support to a scientifically credible view that is emphasized repeatedly in the literature: habitat change is pervasive and at times dramatic, but impacts are not evenly distributed across the landscape. High-quality areas remain that are capable of supporting anadromous fishes at near-historical levels. Furthermore, restoration of depressed populations cannot rely on habitat improvement alone, but requires a concerted effort to address causes of mortality in all life stages. These include freshwater spawning, rearing, juvenile migration, ocean survival, and adult migration.

The question is not whether Federal land management has an effect on anadromous salmonids; it does, though not to the extent that some suggest. Rather, the central issue is how important is spawning and rearing habitat, and will efforts to improve and/or protect this habitat aid in the recovery of depressed populations--given the litany of other factors affecting these fishes.

Heuristic Examples

One way to examine the importance of freshwater habitat in the absence of empirical studies, is through the use of models which mimic the population dynamics of salmonids. Using this approach, previous authors have noted that declines in habitat productivity can have a disproportionate effect on population persistence and total population size. Thurow and Burns (1992), for example, demonstrate how a 20 percent loss in habitat productivity results in more than a 50 percent reduction in adult numbers, while a 50 percent reduction in habitat productivity causes extinction. Lawson (1993) uses a conceptual model of declining freshwater habitat quality and cyclic ocean conditions to show that freshwater habitat is most critical during periods of depressed ocean survival, and shows how improving ocean conditions can mask declines in habitat quality. In the following example, we used the stochastic life-cycle model of Lee and Hyman (1992) to compare the effects of simultaneously altering freshwater habitat quantity and quality, and downstream passage survival.

The Stochastic Life-cycle Model (SLCM) was developed by Lee and Hyman (1992) in order to simulate the life cycle of anadromous salmonids. It is designed to mimic the basic mechanisms regulating populations of

Pacific salmon, while capturing some of the intra-annual and inter-annual variation inherent in these populations. The SLCM was designed for population viability assessments and has been used in recent years by the National Marine Fisheries Service and the Bonneville Power Administration.

Using the SLCM, we illustrate the relative effects of simultaneously varying incubation success, parr carrying capacity, and downstream passage survival on a hypothetical population of chinook salmon. Incubation success refers to the proportion of eggs produced that are successfully deposited in the redd and survive to emergence from the gravel. It can be viewed as an indicator of habitat conditions in terms of both spawning and incubation conditions (Bjornn and Reiser 1991). Parr capacity refers to the maximum number of parr or juvenile fish that an area can support. It reflects both habitat quality and quantity, but we use it here heuristically to measure habitat quantity only, assuming quality remains constant. Downstream passage survival refers to the proportion of the smolts that leave natal streams or rearing areas and survive migration to the estuary. Again, passage survival may reflect many things, but we use it here to index the effects of changes in the hydroelectric system.

We examined eleven levels of incubation success (15% to 65% in 5% increments) in combination with three levels each of parr capacity (50, 100, and 150 thousand) and downstream passage survival (35%, 45%, and 55%). All other parameters, such as fecundity, ocean survival, maturity rates, etc., were held constant at reasonable values for an upriver Columbia Basin stream-type chinook population. Since SLCM is a stochastic model that produces a unique result for each realization or trial, we simulated 500 trials for each parameter combination (49,500 trials total). Each trial started with an initial population of 250 female spawners and ran for 100 simulated brood years, or until the population declined to zero (simulated extinction). Results were summarized by plotting the proportion of the trials where the simulated population did not reach zero within the 100 year period (probability of persistence, Figure C10 A1-3) and the average number of female spawners (mean run size, Figure C10 A1-4) for each parameter combination.

The plots in Figures C10 A1-3 and C10 A1-4 are instructive. Comparing Figures C10 A1-3A, 3B, and 3C, one sees that the probability of persistence responds to changes in incubation success and passage survival in a manner that is consistent across different levels of parr carrying capacity. As passage survival decreases, the level of incubation success required to ensure population persistence increases. Increasing parr capacity has no apparent effect on the relationship. Furthermore, the drop from certain persistence to certain extinction is fairly abrupt. Halving the incubation success (say from 50% to 25%) is sufficient to cause certain extinction of an apparently robust population, regardless of the passage survival or parr carrying capacity (remember the eight-fold difference observed by Scully and others [1990]). In practical terms, this suggest that increasing the amount of available habitat (parr capacity), without any increase in quality (incubation success), would have no discernible effect on the chances of the population persisting through time. Alternatively, more habitat of lower quality is less advantageous in terms of population persistence than less habitat of higher quality.

As evident in Figure C10 A1-4, all three factors can affect population numbers through time. Habitat quantity can have a measurable effect on mean run size, but only beyond a certain threshold combination of passage survival and incubation success. In this example, the response curves for the different parr capacities begin to diverge beyond the point where the product of passage survival and incubation success exceeds 16% (e.g., 35% passage survival and 45% incubation success, or vice versa). The asymptotic nature of carrying capacity limiting population numbers is observed only in the highest combinations of passage survival and incubation success (Figure C10 A1-3C).

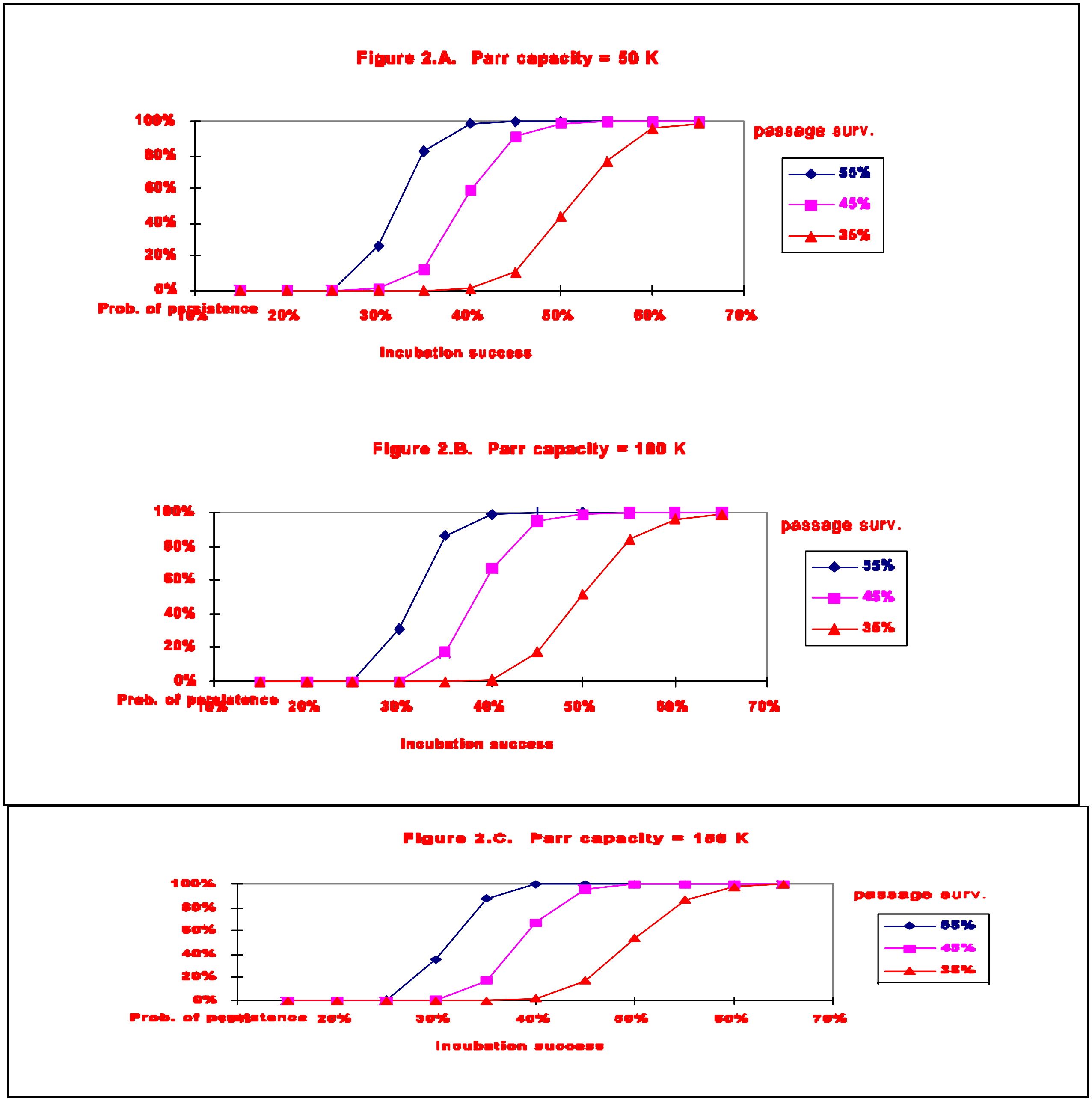

Figure C10-A1-3: Probability of persistence versus incubation survival for three levels of downstream passage survival (55%, 45%, 35%) and 3 levels of parr capacity (50, 100, and 150 thousand).

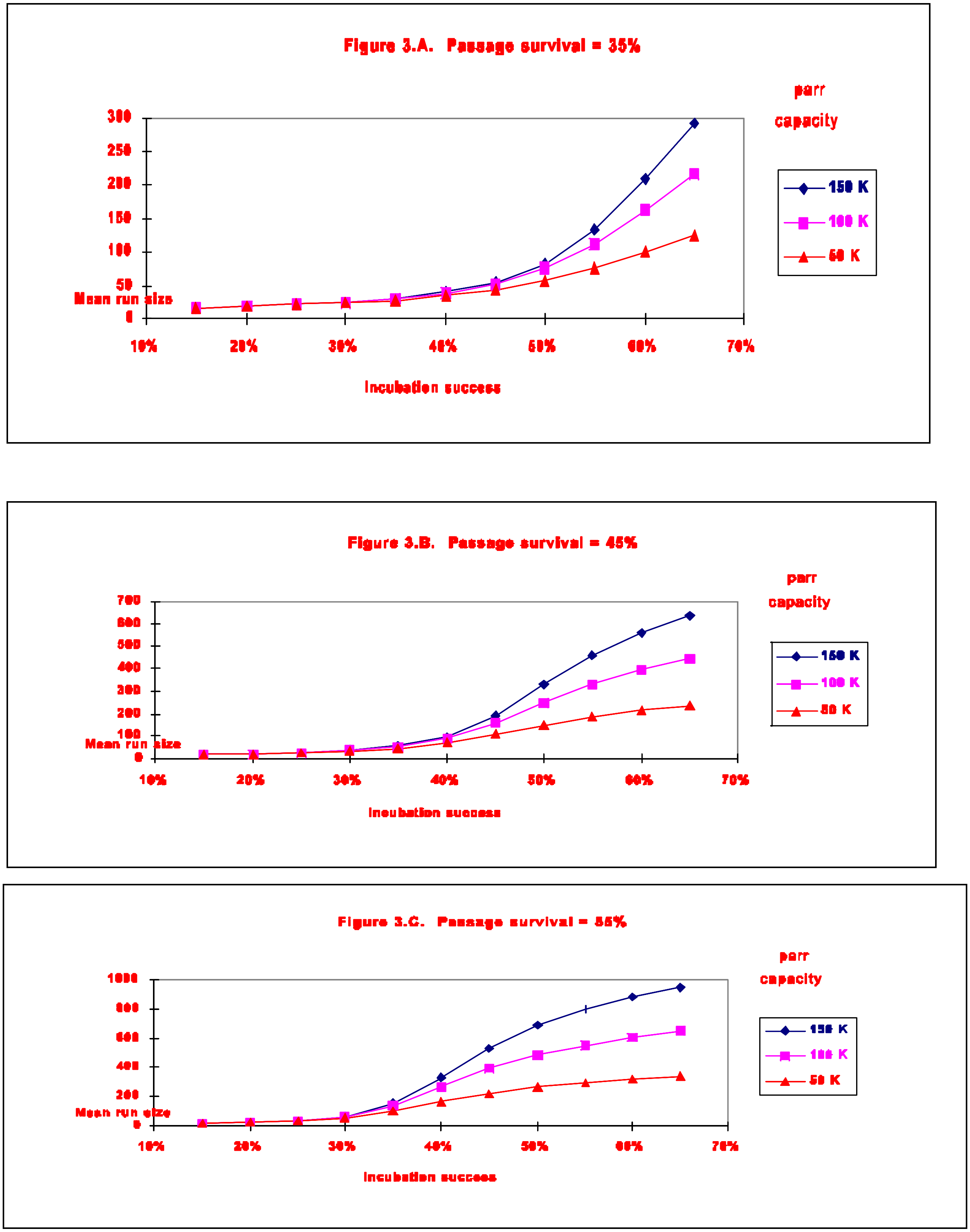

Figure C10 A1-4. Mean run size versus incubation success for 3 levels of parr carrying capacity and 3 levels of downstream passage survival. Note that run size is scaled differently in each plot.

Problems with Measuring Effects

While modeling exercises can suggest the importance of freshwater habitat, they do not measure the effects of habitat alteration directly. Estimates based on empirical data are the best means of quantifying specific effects. Unfortunately, the extent of the loss to anadromous fishes in the interior Columbia River Basin that is due to degradation of spawning and rearing habitats cannot be empirically measured with reasonable certainty. Similarly, although positive responses to habitat restoration are expected, no precise estimate of the expected benefit is possible. The data are neither in hand to answer these questions, nor are they expected.

In part, one cannot measure effects of habitat changes because myriad changes in the system have occurred simultaneously and the pre-treatment data to do a before-and-after comparison do not exist. For example, many of the factors that contribute to habitat degradation (e.g., timber harvest, mining, irrigation diversions) have been in play for a century or more. In contrast, reliable estimates of fish production are available for only the past few decades. This disconnect makes it impossible to test for changes in production that are due to historical changes in freshwater habitat. In their analysis of changes in freshwater spawning and rearing survival (FSR) since completion of the Federal Columbia River Power System (FCRPS), Petrosky and Schaller (in review) note, "A long time series, dating to before completion of the FCRPS, would be desirable to rigorously evaluate hypotheses about decreased FSR survival." Clearly, the post-1960 data used by Petrosky and Schaller do not meet this standard.

The complexity of interactions across life stages further confounds even the best of studies. For example, the raging debate over the efficacy of transporting smolts downstream focuses not so much on the survival through the transportation process per se, but rather on the latent effect that transportation has on post-release survival and adult returns. Similar questions could be raised regarding early rearing. For example, do juvenile fishes from degraded habitats exhibit the same migration and early marine survival as those from better habitats? Research in British Columbia suggests not (Hartman and Scrivener 1990).

Another reason why the effects of spawning and rearing habitat changes are difficult to precisely measure concerns the compensatory nature of fish-habitat relations. This compensation is also a reason why high-quality habitat is so vital to maintaining and rebuilding populations. When the number of spawning adults declines as it has in recent years, the adults can choose areas offering the best conditions. Similarly, juveniles from newly hatched fry through parr can spend their time in the better habitats with reduced competition for resources. The net result is that the number of smolts produced per adult can actually increase as the number of spawners decline. As long as the amount and distribution of high-quality habitat available remains proportional to the number of spawners and in locations used by the fishes, the apparent productivity of the population will remain fairly constant. Thus, it may be impossible to detect a historical decline in habitat conditions over a period when numbers of spawning adults are declining as well, if one looks only at the number of smolts produced per adult. This is the situation in the Snake River subbasins above Lower Granite Dam. During and after construction of the federal dams in the lower Snake River (post 1970), numbers of returning adult chinook salmon declined dramatically compared to run sizes in the 1950s and 1960s (Petrosky and Schaller 1992). The declining numbers of adult salmon do not permit an adequate test of the hypothesis that habitat conditions changed during the same time period. Such a test would require a return to historical levels of spawning adults that predate the dams.

Discussion

The information presented above reinforces the argument that existing high-quality habits must be maintained in order to prevent extinction of Snake River anadromous fishes and other at-risk stocks, and to maintain population resiliency until other causes of mortality are reduced. To ensure recovery, the amount of high-quality habitats available must remain proportional to the number of returning adults and in appropriate areas, so that there is no net loss in productivity as adult numbers increase. Because of current population losses associated with dams and other factors, only the most productive populations may retain the resilience to persist in the face of natural and human caused disturbance. Simply put, with current conditions in migrant survival, many stocks are at serious risk. The differences between those that persist and those that are extirpated will include chance events and the survival and productivity of the stocks as they are largely influenced by freshwater habitats. Without substantial improvement in migrant survival, securing (where available) and restoring (where needed) high-quality freshwater habitats may make the critical difference in persistence for many populations. In the longer term, assuming mainstem conditions are resolved, it will be necessary to conserve and restore broader habitat networks to support the full expression of life histories and species (Lichatowich and Mobrand 1995; National Research Council 1995). To fully realize the benefits of improved migration and ocean survival, there must be a commensurate increase in the distribution of high-quality spawning and early rearing habitats. Federal land management is crucial to this task.

The modeling examples also demonstrate the difficulty of trying to extrapolate conclusions about the relative influence of habitat (or any other principal factor) in one area of the basin to a separate area with a different management history and natural features. Each of the 99 points which compose Figures C10 A1-3 and C10 A1-4 can be viewed as a different combinations of habitat quantity and quality and passage conditions. To say that a marginal improvement in habitat quality would have the same relative effect everywhere is obviously untrue. The nonlinear shape of the response functions in compose Figures C10 A1-3 and C10 A1-4 suggest that in some places the effect might be dramatic, while in others there would be little visible impact. Thus, there can be no single answer for the entire interior Columbia Basin. As stated above, each population must be examined on its own merits. Such site-specific responses suggest that viability judgments on local populations are best performed using higher resolution data than are generally available.

Conclusions

We state our conclusions as answers to four basic questions that have been asked by Forest Service and BLM leadership.

1. *What are the relative contributions of habitat, hydropower, hatcheries, and harvest on the current state of populations within the interior Columbia Basin?*

This question cannot be answered precisely. Simultaneous changes in a variety of factors, combined with the lack of historical data, prevents estimation of the proportionate influence of each factor. The relative contribution of each factor also varies across the entire basin. We expect the contribution of freshwater habitat changes to be least in the less-disturbed areas of central Idaho and in the northern Cascades, but greater in the lower Snake and mid-Columbia drainages. Similarly, the contribution of hydropower declines downriver where there are fewer dams between the freshwater spawning and rearing areas and the ocean. Hatcheries are an important element throughout the basin, but their effects on native stocks is quite variable. Harvest, which has been much curtailed in recent years, has less of an effect today than it did historically. In some subbasins such as the Umatilla, irrigation withdrawals may be the major contributor to declines in naturally reproducing populations.

2. *If all other factors were held constant, would a further degradation of habitat increase the risks of extirpation or extinction?*

Yes. Regardless of the contribution of other factors, spawning and juvenile rearing habitat remains an important component in the viability equation. As demonstrated above, freshwater habitat can be most important in ensuring viability of stocks that are depressed through a combination of other factors.

3. *If all other factors were held constant, would an improvement in freshwater habitat conditions increase fish abundance and reduce the risks of extirpation or extinction?*

Yes, though the magnitude of the effect would vary greatly from subbasin to subbasin. In areas where present habitat is degraded and hydropower effects are smaller, such as the Deschutes River, habitat improvements could result in immediate increases in numbers of fish. In areas where habitat is degraded and hydropower effects are large, such as in the Grande Ronde River and some tributaries of the Salmon River, increases in population numbers due to habitat restoration would be more modest and gradual. In other areas where there is abundant high-quality habitat but few adult spawners, such as the Middle Fork Salmon River, immediate increases in fish abundance would not be expected. One aspect of habitat improvement that could have long-term repercussions, if not immediate benefits, is that increased availability of high-quality habitats reduces the chances that a random, catastrophic event such as a large fire followed by flooding would wipe out all of the best available habitat. A wider distribution of high-quality habitats also improves the likelihood of increased genetic diversity--an additional benefit over the longer term.

4. *If nothing is done to restore habitat, and mitigation of major factors such as the dams is successful, would there be sufficient habitat available to accommodate increasing fish numbers?*

The answer varies across the basin. Population numbers in much of the interior Columbia Basin are far below what current habitat conditions could likely support under a scenario of increased downriver survival. Some remote areas potentially could support hundred-fold increases or better in the number of adult numbers. But this is not the case everywhere. There are more disturbed areas where increased adult numbers would lead to compensatory declines in freshwater survival rates, thus reducing the per capita productivity of the population and limiting the effectiveness of downstream improvement efforts. To fully realize the benefits of downstream improvements, commensurate increases in the availability and distribution of high-quality habitat will be necessary.

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Appendix 2
Eastside Assessment Selection Criteria Guiding Questions

Evaluation of Alternatives

Broad Scale Issues and Questions Related to Viability and Diversity

Does the alternative:

1. Sustain biodiversity through emphasis on conserving the distribution of species, genetic diversity, narrowly distributed endemic species, Threatened, Endangered, or sensitive species, fringe populations, and anadromous populations of high genetic integrity?

2. Maintain a well-connected mosaic of complex habitat at multiple scales and maintain, protect, and / or restore aquatic habitat integrity?

More specifically for each species, does the alternative:

3. Conserve core areas of (relatively) high population density within the species' range?

4. Identify at-risk areas and use those areas to priorize restoration and management prescriptions?

5. Emphasize the uncertainty of restoration treatments and provide a framework for adaptive management as better information is available to judge treatment results?

6. Decrease fragmentation of aquatic habitats and maintain / restore corridors as critical components of connectivity among populations?

7. Attempt to minimize the effects of introduced species?

8. Maintain, protect, and / or restore proper functioning conditions of riparian habitats within the range of this species?

9. Adequately protect aquatic habitats within the range of this species from increased sedimentation associated with land-use activities?

10. Maintain, protect, and / or restore water quality within the range of this species?

11. Maintain, protect, and / or restore water quantity within the range of this species?

12. Address other specific threats to this species?

13. Address the importance of non-federal lands to conservation and restoration strategies?

Guiding principles:

Emphasize conservation of best remaining areas first, then proceeds with restoration.

Recognize that aquatic classes are not prescriptions; lower classes and lower emphasis areas may retain key populations for conservation and restoration.

Appendix 3:
Idaho, Oregon, and Washington Habitat Condition Ratings

The following is our subjective habitat quality rankings for the reconstructed stocks. The qualitative rankings were based on the amount of land use disturbance. In ranking habitat, we did not consider the geomorphological and physiographic characteristics of the subbasin which may define a stock's inherent productivity. The ranks of 1, 2, or 3 correspond to High, Medium, and Low habitat quality, specifically: 1 corresponds with little or no land use impact with minor degradation; 2 corresponds with land use impacts with moderate degradation; and 3 corresponds with land use impacts with heavy degradation. The FWS life stage was divided into three components: spawning / (early) rearing; downstream rearing; and overwintering.

	Spawning / Rearing	Downstream Rearing	Overwintering
Middle Fork Salmon			
Sulphur	1	1	1
Marsh	2	1	1
BV / Elk	3	2	1
South Fork Salmon			
Poverty Flat	3	3	2
Johnson	2	2	2
Mid-Columbia			
Wenatchee	1	2	2
Entiat	2	2	3
Methow	2	2	2
Minam	1	1	1
Imnaha	1	1	1
Warm Springs	2	2	2
John Day	2	2	2
Wind	1	1	2
Klickitat	1	2	2

Note that the only stock with a significant time series effect is Poverty Flat. If a time series analysis is planned, then for S / R the values would go 2,3,2, and then for DR the values would go 2,3,2. This could be a point of discussion at our next meeting, Monday, May 13, at 1:30 pm in the "Martin" conference room at ODFW.

10-65

Appendix 4:
Wild Parr PIT-Tag Analysis

An Analysis of Detection Rates at Snake and Columbia River Dams of Wild Spring/Summer Chinook Salmon Smolts PIT-tagged As Parr the Previous Year

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We examined PIT-tag detection rates at Snake and Columbia River dams of wild spring/summer chinook salmon smolts from the Snake River Basin that were PIT-tagged the previous year as parr. We compared detection rates with the distance traveled to Lower Granite Dam from the tagging/releases sites of the parr, between years, and to an assigned stream condition/habitat from the tagging/releases sites. We rated the stream condition/habitats for individual areas based on personal observation. The following four categories were used:

1) Pristine--Stream in a natural, wild state. There was minimum to no influence from human development and domestic animals. The in-stream habitat and riparian areas were excellent.

2) Near Pristine--Stream in a close to natural, wild state. There was some evidence of influence by human development and domestic animals. The in-stream habitat and riparian areas were good.

3) Moderately Degraded--Stream influenced by human development and domestic animals. There was some in-stream habitat and riparian degradation. Irrigation diversions and pollution were sometimes present.

4) Degraded--Stream severely influenced by human development and/or domestic animals. The in-stream habitat and riparian areas were damaged by domestic livestock, logging, mining, or irrigation diversions. Stream were also sometimes polluted.

Fish for these analyses were tagged as parr by the National Marine Fisheries Service (NMFS), the Idaho Department of Fish and Game (IDFG), and the Oregon Department of Fish and Wildlife (ODFW) in the year prior to their smolt migration. The total number of smolt detections at dams were derived from first-time PIT-tag detections at Snake and Columbia River dams. Detections were adjusted for spill. We assumed a one-to-one ratio of fish per volume of flow through the spill compared to the powerhouse and adjusted tag detections upward as spill increased.

The number of streams in which parr were marked was much lower between 1988 and 1990. A consistent effort to mark fish in all areas began in 1992, which produced the outmigrations in 1993 to 1995. Because overwinter conditions affect parr survival and subsequent smolt migrations, we limited our analyses to detection percentages for the more complete data set between 1993 and 1995.

Results

Overall detection rates at Snake and Columbia River dams for all streams and years were highly variable and ranged from 2.3 to 31.9% (Table C10 A4-1). A significantly ($P = 0.01$) smaller percentage of fish were detected from populations of fish marked in streams the farthest distance upstream of Lower Granite Dam. Secondly, significantly ($P = 0.02$) more fish were detected from the 1993 outmigration than from the 1995 outmigration, but there were no significant ($P > 0.05$) differences in detections between the 1993 and 1994 or the 1994 and 1995 outmigrations. Finally, detection rates of fish from Category 1 streams were significantly higher ($P = 0.035$) than for fish from Category 2, 3 or 4 streams. No significant detection differences ($P > 0.05$) were found between fish in Category 2, 3 or 4 streams.

Discussion

We assumed that the detection rates at dams were an indication of the relative survival of fish from different streams to the dams. However, this assumption presumes that the probability of detection at the dam for all groups of fish is unchanged throughout the migration season. Probability of detection was not constant for all groups of fish, but we assumed that differences were related to differences in spill rates at the dam. If some other factors affected detection rates at the dam, they were not considered.

We assumed that parr reared in the general stream areas where they were captured, tagged, and released. If so, the habitat in those streams likely affected their subsequent condition and survival to smolts. Fish from pristine streams apparently survived at a significantly higher rate than fish in slightly to heavily degraded streams. Although fish were detected at significantly lower rates the farther they had to migrate to Lower Granite Dam, there were no representative fish from pristine populations that also had the greatest distances to migrate. Thus, it was not possible to determine the extent that distance and/or habitat had on subsequent detection rates.

It was also not possible to determine if differences in detections between years was related directly to habitat. The value of habitat, besides the physical observations that we made, likely depends on overwinter conditions. Different years may have had different precipitation and snow pack which may have affected habitat utilization. Depending on conditions, fish may in some years migrate downstream to larger rivers from the small stream habitats where they were captured and marked, whereas under other conditions, choose to overwinter in the habitat where they were marked and released.

Table C10 A4-1: Combined first-time smolt detection rates at Snake and Columbia River Dams of juvenile spring/summer chinook salmon marked as parr the previous year at a number of different Snake River Basin streams. The agency that marked the fish are in parentheses ( )

Migration year	Detection percentage at dams	Rated quality of the stream habitat	Average stream distance above Lower Granite Dam (Km)
UPPER SALMON RIVER (NMFS)			
Valley Creek			
1989	5.3	4	
1990	5.8	4	
1991	6.5	4	
1992	6.3	4	
1993	8.1	4	
1994	11.2	4	
1995	6.3	4	
Average	7.1	4	750
East Fork of the Salmon River			
1989	13.2	3	
1990	----		
1991	7.1	3	
1992	9.6	3	
1993	7.8	3	
1994	10.8	3	
1995	10.5	3	
Average	9.8	3	696
UPPER SALMON RIVER (IDFG)			
Salmon River (upper)			
1989	4.7	4	
1990	5.3	4	
1991	3.2	4	
1992	3.5	4	
1993	3.5	4	
1994	9.9	4	
1995	3.7	4	
Average	4.8	4	760

		Huckleberry Creek	
1990	7.0	3	
1991	---		
1992	6.6	3	
1993	---		
1994	---		
1995	13.8	3	
Average	9.1	3	756
		Fourth of July Creek	
1992	12.5	4	
1993	7.6	4	
Average	10.0	4	762
		Alturas Lake Creek	
1989	8.7	4	
1990	---		
1991	5.9	4	
1992	3.2	4	
1993	14.1	4	
1994	----		
1995	4.5	4	
Average	7.3	4	766
		Smiley Creek	
1990	3.1	3	
1991	---		
1992	---		
1993	---		
1994	7.1	3	
1995	6.3	3	
Average	5.5	3	776
		Frenchman Creek	
1990	6.2	3	
1991	2.5	3	
1992	2.8	3	
1993	18.3	3	
1994	2.3	3	
1995	6.8	3	
Average	6.5	3	779

MIDDLE FORK OF THE SALMON RIVER (NMFS)

Bear Valley Creek

1990	8.7	4	
1991	19.3	4	
1992	9.8	4	
1993	14.0	3	
1994	20.0	3	
1995	8.2	3	
Average	13.3	3.5	630

Elk Creek

1991	19.4	4	
1992	13.9	4	
1993	12.7	3	
1994	14.2	3	
1995	8.9	3	
Average	13.8	3.4	636

Sulphur Creek

1990	10.0	1	
1991	----		
1992	16.7	1	
1993	9.1	1	
1994	----		
1995	17.6	1	
Average	13.3	1	605

Marsh Creek

1990	10.4	2	
1991	10.8	2	
1992	9.9	2	
1993	15.2	2	
1994	16.0	2	
1995	12.8	2	
Average	12.5	2	622

Loon Creek

1993	24.5	1	
1994	22.7	1	
1995	19.1	1	
Average	22.1	1	556

	Camas Creek		
1993	18.5	3	
1994	20.5	3	
1995	9.5	3	
Average	16.2	3	528
	Big Creek (upper)		
1990	11.1	2	
1991	13.1	2	
1992	8.8	2	
1993	12.4	2	
1994	8.8	2	
1995	14.0	2	
Average	11.4	2	532
	Big Creek (lower)		
1993	31.9	1	
1994	28.5	1	
1995	28.9	1	
Average	29.8	1	490
	SOUTH FORK OF THE SALMON RIVER		
	South Fork Salmon River		
1989	6.2	3	
1990	---		
1991	14.4	3	
1992	12.1	3	
1993	16.7	3	
1994	11.5	3	
1995	9.3	3	
Average	11.7	3	463
	Secesh River		
1989	14.6	2	
1990	10.2	2	
1991	9.5	2	
1992	5.4	3	
1993	16.8	3	
1994	10.7	3	
1995	12.2	3	

Average	11.3	2.6	431

MAIN SALMON RIVER

West Fork Chamberlain Creek

1992	6.6	1	
1993	19.3	1	
1994	9.7	1	
1995	9.1	1	
Average	11.2	1	438

OREGON STREAMS (ODFW)

Wenaha/S. F. Wenaha

1993	23.9	1	
1994	14.6	1	
1995	13.8	1	
Average	17.4	1	206

Minam

1993	19.0	1	
1994	24.0	1	
1995	14.4	1	
Average	19.1	1	284

Lostine River

1992	16.5	2	
1993	25.8	2	
1994	18.8	2	
1995	20.9	2	
Average	20.5	2	288

Catherine Creek

1992	13.2	3	
1993	19.7	3	
1994	18.6	3	
1995	15.8	3	
Average	16.8	3	374

	Grand Ronde River (upper)		
1989	13.0	3	
1990	----		
1991	----		
1992	----		
1993	27.4	4	
1994	10.0	4	
1995	16.3	4	
Average	16.7	3.7	416
	Imnaha River (upper)		
1993	15.0	2	
1994	12.1	2	
1995	8.4	2	
Average	11.8	2	238
	Imnaha River (lower)		
1989	11.1	2	
1990	12.1	2	
1991	9.8	2	
1992	20.7	2	
Average	13.4	2	172

Appendix 5:
Case Studies

Potential Case Study Material from Rhodes *et al.*, 1994.

I present here a summary of information relevant for case studies on changes to salmon productivity due to changes in spawning and rearing habitat for several regions, information which addresses the time line for recovery of damaged spawning and rearing habitat and quantitative information on salmonid spawning and rearing habitat condition and the presence of salmonids. All this information is drawn from Rhodes *et al* (1994). Citations are listed in full at the end of the sections. Case study material is grouped into material which is specific to the Snake River Basin and material which is associated with other regions and species. For the Snake River Basin there is information for the Salmon River and its tributaries, several case studies for Clearwater River tributaries, some information for the Grande Ronde River and Tucannon River. Material in the other regions and species category includes information for coastal Oregon, western Washington, the Okanagan River, California, British Columbia and Alaska. The information presented is primarily for chinook although there are also references for sockeye and steelhead which may be of use later. Following the case study material I present information on recovery times for spawning and rearing habitat post-disturbance and following habitat rehabilitation activities. This section is followed by a collection of material suggesting quantitative connections between the quality of salmonid spawning and rearing habitat and salmonid productivity.

Snake River Basin case study material:

Salmon River and tributaries:

Changes in productivity and time line to recovery:

“Data from Idaho consistently indicate that tributary streams with higher levels of fine sediment have lower salmon densities, lower salmon survival, and have undergone steeper population declines than in nearby tributaries within the same watersheds with lower sediment levels (Bjornn, 1971a as cited in Seyedbagheri et al., 1987; Platts et al., 1989; Scully and Petrosky, 1991; Rich et al., 1992; Boise National Forest, 1993; Rich and Petrosky, 1994; Petrosky and Schaller, in press).” in Rhodes et al., 1994 p. 7.

“Salmon densities are consistently several time higher in streams with lower levels of fine sediment than in adjacent streams with high levels of fine sediment . . .” (Rich et al.,1992; Rich and Petrosky, 1994 - note: rapid emigration from area of high fine sediment is a possible source of bias) in Rhodes et al., 1994 p.7

“The case history of the **South Fork Salmon River** clearly indicates that salmon survival can be significantly increased in a fairly short time period, but only if the <u>causes</u> of degradation are arrested and reversed.” (wrt fine sediment conditions) Rhodes et al., 1994 pp. 15-16.

“The **south fork Salmon River** data (Platts et al., 1989; Idaho Dept. of Health and Welfare, 1991; Megahan et al., 1992) and other available models and information (Scully and Petrosky, 1991) indicate that the reductions in fine sediment in the South Fork Salmon River may have increased STE [survival to emergence] by an order of magnitude over 15 years, although salmon STE in the South Fork Salmon River appears to continue to be depressed at low levels (R. Thurow, USFS Intermountain Research Station Fish. Bio., pers. comm., 1994).” in Rhodes et al., 1994 p. 16.

“Substrate conditions in the **South Fork Salmon River** still have not fully recovered from the mass failures which occurred in 1965 (Platts et al., 1989). (in Rhodes et al., 1994, p 63).

“It has been well documented that salmon populations in the **South Fork Salmon River** still have been significantly reduced by catastrophic sedimentation primarily caused by debris flows (Platts et al., 1989). (in Rhodes et al., 1994, p 63).

"Habitat conditions in grazed and ungrazed tributaries to the **Middle Fork of the Salmon River** provide an example of the effects of grazing on salmon survival. Currently, salmon STE is estimated to be about 0.5% in Johnson Creek (NMFS, 1993), and about 3% in Bear Valley Creek (Boise National Forest, 1993; Scully and Petrosky, 1991), while STE averages about 29% in ungrazed tributaries draining wilderness areas (Scully and Petrosky, 1991) although the survival estimates may be somewhat biased by rapid emigration of juvenile salmon from Bear Valley Creek into less degraded streams." (in Rhodes et al., 1994, p 94).

"In **Johnson and Bear Valley Creeks**, accelerated erosion from unstable banks and channels appears to be one of the primary contributors to the high fine sediment levels that have resulted in extremely low levels of salmon survival (Boise National Forest, 1993; NMFS, 1993)." (in Rhodes et al., 1994, p 94).

Notes on habitat changes and impacts:

Salmon River tributaries in Idaho: Overton et al (1993) found a statistically significant difference in pool frequency and LWD frequency between a watershed that had been logged, roaded, and grazed and a relatively undisturbed watershed; the undisturbed watershed had about twice the LWD frequency and more than twice the frequency of pools in the logged watershed. (in Rhodes et al., 1994. p 26).

Streams with high levels of pool loss include the Lemhi, Stanley, Clearwater tributaries, Grande Ronde tributaries, and **Middle Fork Salmon River** tributaries (Sedell and Everest, 1990; McIntosh, 1992; B. McIntosh, USFW PNW Research Station Res. Asst., pers. comm., 1993; Boise National Forest, 1993). (in Rhodes et al., 1994. p 28).

Bear Valley Creek, Idaho: Boise National Forest (1990), found that fine sediment levels were inversely related to bank stability. The inverse relationship between bank stability and fine sediment levels appear to generally hold among watersheds in the Idaho batholith based on limited data ($R2=0.46$, $p<0.10$ see Figure 6 and Table 3) (in Rhodes et al., 1994. p 33).

"Salmon habitat has been rendered unusable by acid mine drainage in **Panther Creek**, a tributary of the Salmon River; the spawning runs in the drainage were decimated by the pollution (Nelson et al., 1991). Cyanide heap leaching also poses a considerable threat to chinook (Nelson et al., 1991)." (in Rhodes et al., 1994, p 46).

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Petrosky, C.E. and H.S. Schaller, *in press*. A comparison of productivities for Snake River and Lower Columbia River spring and summer chinook stocks. Proceedings of salmon management in the 21st Century: Recovering stocks in decline. 1992 Northwest Pacific Chinook and Coho Workshop, Am. Fish. Soc., Idaho Chapter, Boise, Id.

Platts W.S., Torquemada, R.J., McHenry, M.L. and Graham, C.K., 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Trans. Am. Fish. Soc., 118:274-283.

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Rich, B.A. and Petrosky, C.E., 1994. Idaho habitat and natural production monitoring: Part I. General monitoring subproject annual report 1992. BPA Project No. 83-7, Bonneville Power Admin., Div. of Fish and Wildlife, Portland, Or.

Rich, B.A., Scully, R.J., and Petrosky, C.E., 1992. Idaho habitat and natural production monitoring: Part I. General monitoring subproject annual report 1990. BPA Project No. 83-7, Bonneville Power Admin., Div of Fish and Wildlife, Portland.

Scully, R.J. and Petrosky, C.E., 1991. Idaho habitat and natural production monitoring Part I. General monitoring subproject annual report 1989. BPA Project No. 83-7, Bonneville Power Admin., Div of Fish and Wildlife, Portland, Or.

Sedell, J.R. and Everest, F.H., 1990. Historical changes in pool habitat for the Columbia River Basin salmon under study for TES listing--Draft. Unpublished briefing paper, USDA-FS, PNW Research Station, Corvallis Or.

Clearwater River tributaries:

The following information is taken from Espinosa (1994) (Appendix B of Rhodes et al, 1994, citation below). Statements not referenced are from Espinosa (1994). Espinosa (1994) presents a case study analysis of why existing plans have failed to protect salmon habitat in the Clearwater National Forest, Idaho. I drew information from the case studies for Lolo Creek, Eldorado Creek, Pete King Creek and Squaw Creek. From these case studies I summarize: 1) geophysical/hydrological background; 2) salmon production information; 3) development activities; 4) monitoring and rehabilitation activities; 5) impacts of development activities on salmon habitat; and 6) any conclusions or statements on status relevant to our needs. I have left the citations made by Espinosa (1994) within the text and provided full listings at the end of this section. The page number from Rhodes *et al.* (1994) from which information was taken is also included. Many of the passages in this report have been taken verbatim from Espinosa (1994) and this is not always indicated by quotes. If you find data or information discrepancies, please check with me or the original report.

Espinosa, F.A. 1994. Case History: The failure of existing plans to protect salmon habitat on the Clearwater National Forest in Idaho. Appendix B in Rhodes *et al*. 1994, A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. CRITFC Technical Report 94-4.

<u>Lolo Creek:</u>

Geophysical/hydrological background:

Lolo Creek is a 42 mile long, 7th order stream which enters the mainstem of the Clearwater River at river mile 54. It drains a watershed of approximately 72,673 acres within the boundaries of the Clearwater National Forest. Only 18 miles of its mainstem are within the National Forest boundary, the remaining 24 miles traverse mixed ownership land (private, Nez Pierce Tribe, Bureau of Land Management). The watershed ranges in elevation from 5238 ft at its headwaters (near Hemlock Butte) to 1299 ft at it's confluence with the Clearwater River. There is a wide amplitude of flow ranging from an average of 500 cfs during spring runoff to an average of 25 cfs during late summer (Espinosa and Lee, 1991) (from Rhodes et al, 1994, p B-4).

Salmon production:

Lola Creek drains 78.4 miles of existing and potential anadromous fish habitat and was once a significant producer of spring/summer chinook salmon in the Clearwater River Subbasin (Fulton, 1968; Chapman, 1981; and Espinosa, 1987). Chapman (1981) estimated that Lolo Creek was capable of producing 84,000 spring chinook smolts in its pristine condition. In 1990, it was estimated by Rich et al. (1992) that Lolo Creek was seeded at 11% of its potential carrying capacity. (from Rhodes et al, 1994, p B-4).

Massive hatchery supplementation has been conducted in the Lolo system. Despite heavy stocking, escapement of adult chinook and densities of pre-smolt salmon remain at critically low levels in Lolo Creek (Espinosa and Lee, 1991). In the past few years, adult escapement has probably ranged from 50 to 75 fish (Murphy., pers. comm.) (from Rhodes et al, 1994, p B-4).

Development Activities:

Lolo drainage has a 30+ year history of timber management in the National Forest. Timber management has had the most deleterious form of impact compared to placer (gold) mining and grazing on fish habitat. Road construction and riparian harvesting have generated the most severe impacts on the aquatic habitats of the Lolo system. Excessive sedimentation, channel impingement, and elimination of large woody debris were the major impacts documented by Espinosa (1975) during a baseline habitat study. (Espinosa in Rhodes et al, 1994, p B-5).

Monitoring/Rehabilitation Activities:

Monitoring: Fish habitat monitoring was initiate in 1973 and 1974 in the Clearwater National Forest (Espinosa, 1975). Before the 1970's, little data was available although Murphy and Metsker (1962) observed and documented sediment problems in the Lolo watershed. Streambed coring of salmon spawning habitat in was conducted in Lolo Creek from 1974 to 1983. From 1983 to present [1993?], other sediment and fish habitat variables have been monitored (Espinosa and Lee, 1991). After 1983 (when the substrate monitoring program was dropped because of timing and budgetary constraints), fish habitat in Lolo Creek was monitored periodically with a "comprehensive transect methodology" that measured channel structural elements plus selected sediment variables like cobble embeddedness and % surface fines (see Espinosa et al.

1987; Espinosa and Lee, 1991; Huntington, 1988 and 1993). (from Espinosa in Rhodes et al, 1994, p B-5/6).

Rehabilitation: In 1983, the fish and riparian habitats of Lolo Creek were subjected to extensive rehabilitation efforts funded by the Columbia Basin Fish and Wildlife Program. Rehabilitation primarily involved riparian restoration, in-stream efforts to increase habitat diversity, cattle exclusion. The program included evaluation of fish habitat and population responses. Increase in habitat diversity (pool quantity and quality) and spawning habitat were documented in Lolo Creek, but cobble embeddedness remained essentially unchanged (54% in 1974, 51% in 1988). Statistically significant increases of steelhead and chinook parr in summer rearing habitat were observed for enhanced habitats over control habitats (Espinosa and Lee, 1991; Scully et al., 1990) (from Espinosa in Rhodes et al, 1994, p B-6).

In 1987, the Forest Plan of the Clearwater National Forest was approved for implementation. (Espinosa in Rhodes et al, 1994, p B-5).

Impacts of Development Activity on Salmonid Habitat:

Extensive timber development started in the Lolo watershed in 1957 and was accompanied by a sharp increase in sedimentation produced by logging and associated road construction. Road construction in Lolo's riparian zone significantly altered the streams channel and induced instability (Espinosa, 1975). Streamside roads were significant and chronic sources of sediment to Lolo Creek and its tributaries (Espinosa, 1975). (Espinosa in Rhodes et al, 1994, p B-5).

Sediment Yield: Prior to 1957, sediment yield was below the Forest's estimated "impact threshold" of 35% above natural. In 1957, sediment yield was estimated at 60% over natural (WATBAL database, Clearwater National Forest). In the period from 1957 to 1973, sediment yield ranged from a minimum of 60% over natural in 1957 to a maximum of 149% over natural with mean and median levels of 120% and 122% respectively. Sediment yields gradually declined from 1969 to 1972 but peaked higher than previously during the period from 1973 to 1976. Levels as high as 200% over natural were observed in 1975-76. (Espinosa in Rhodes et al, 1994, p B-5).

From 1977 to 1993 sediment production declined with mean and median levels of 102% and 64% respectively. From 1984 to 1993, sediment yields approached 20 to 30% over natural, a target considered essential for Lolo Creek before recovery in substrate conditions can commence (Clearwater Forest Plan, 1987). (Espinosa in Rhodes et al, 1994, p B-5).

Sediment Levels in habitat: Substrate coring data collected from Lolo Creek from 1974 to 1983 show sediment levels in chinook spawning substrate which far exceed conditions considered optimum (<20%) for chinook production (Bjornn and Reiser, 1991; Stowell et al., 1983). Sediment yields remained consistently high before during and after the monitoring period, with levels of sediment in the spawning habitat ranging from 34% in 1975 to 43% in 1976 with a mean and median of 39% (95% confidence intervals of +/- 2%). (Espinosa in Rhodes et al, 1994, p B-6).

Cobble embeddedness: The quantity and quality of winter habitat in Lolo Creek are two factors which likely limit the production of anadromous salmonids in the system (Espinosa et al., 1987; Huntington, 1988) an observation supported by the following evidence. The Clearwater National Forest reported in their Phase I Report (1992) that cobble embeddedness for Lolo Creek was at 49%, a level that equates to roughly 60% habitat capability (the standard assigned to Lolo Creek was 80% habitat capability in terms of smolt production potential as affected by substrate sediment conditions). Huntington (pers. comm.) observed cobble embeddedness to be approximately 45% during his 1993 survey. Monitoring of winter habitat quality from 1990 to 1993 revealed a decline of 54% in quality from baseline (Espinosa, unpublished data). (from Espinosa in Rhodes et al, 1994, p B-6).

Other habitat impacts: pool quantity and quality remain well below optimum standards (Espinosa and Lee, 1991; Phase I Report, Clearwater National Forest). According to the Clearwater National Forest, the overall habitat quality of Lolo Creek was assessed at 63%, some 17% below their Forest Plan standard (Phase I Report, 1992). (from Espinosa in Rhodes et al, 1994, p B-6).

Conclusion/Status:

"Based on data for substrate conditions and sediment yield, and habitat capability analyses, it is concluded that essentially little or no recovery in habitat sediment conditions in Lolo Creek has taken place over a period of 19 years despite a substantial decline in sediment yield and extensive rehabilitation during this time." (from Espinosa in Rhodes et al, 1994, p B-7).

Eldorado Creek:

Geophysical/hydrological background:

Eldorado Creek is a 26.5 mile long fifth order stream and the principal tributary of Lolo Creek. It drains approximately 12 miles and 38.2 acres of anadromous fish habitat. Its watershed is approximately 29630 acres and ranges in elevation from 5399 ft near its headwaters to 2850 feet near it confluence with Lolo Creek. The entire watershed is in National Forest ownership. (from Espinosa in Rhodes et al, 1994, p B-7).

Salmon production:

Eldorado Creek is capable of providing 0.42 acres of spawning habitat suitable for chinook salmon.

Since the early 1980's, thousands of pre-smolt and smolt chinook salmon have been stocked in Eldorado (Espinosa and Lee, 1991). (from Espinosa in Rhodes et al, 1994, p B-7).

During the summer of 1993, the first adult salmon was observed in the stream, presumably from these plants (Larson, pers. comm.). (from Espinosa in Rhodes et al, 1994, p B-7).

Development Activities:

primarily logging

Monitoring/Rehabilitation Activities:

Monitoring: The habitat monitoring program in Eldorado has been restricted to periodic surveys and evaluation of habitat improvement projects. (from Espinosa in Rhodes et al, 1994, p B-7).

Fish habitat has been surveyed periodically as part of the Clearwater National Forest's ongoing fisheries program. (from Espinosa in Rhodes et al, 1994, p B-8).

Rehabilitation: In 1984, passage barriers near the mouth of Eldorado Creek were removed to ease upstream migration of chinook salmon (Espinosa and Lee, 1991). In 1985, the rearing habitat of Eldorado was rehabilitated with instream structures over an 8 mile reach. In the 1990's, the Clearwater National Forest constructed several sediment traps in small tributaries and initiated a sediment removal program. The

Nez Perce Tribe has selected Eldorado as one of its production tributaries for its hatchery and supplementation programs. (from Espinosa in Rhodes et al, 1994, p B-7).

Impacts of Development Activities on Salmon Habitat:

Sediment Yield: Extensive timber harvesting began in 1957 and was accompanied by a sharp increase in sediment yield produced by the associated logging road construction activity. Logging roads constructed in the riparian zones were significant and chronic sources of sediment to Eldorado Creek. In the period from 1957 to 1993, sediment production accelerated dramatically and sustained high levels. During this period, the sediment yield did not drop below 45% above natural (Clearwater N.F.'s assumed "impact threshold"). By 1958, sediment yield was estimated at 80% over natural. Sediment levels in Eldorado Creek were higher than those for Lolo Creek, exceeding the "geomorphic threshold" (which is 272% over natural levels for Eldorado Creek) for four years during this period. Sediment yield ranged from 80% over natural in 1957 to 341% over natural in 1961 with a mean and median yield of 219% and 209% respectively. (from Espinosa in Rhodes et al, 1994, p B-7/8).

From 1974 to 1989 the sediment levels fluctuated between recovery and exceeding the "geomorphic threshold". Since 1990, sediment yield has gradually decreased, but still remains above the "estimated threshold" that must be achieved before recovery can commence (i.e. 20-30%). (from Espinosa in Rhodes et al, 1994, p B-8).

From 1973 to 1993 sediment yield ranged from 60% to 306% with a mean and median of 143% and 140% over natural respectively. (from Espinosa in Rhodes et al, 1994, p B-8).

Sediment level:

Cobble Embeddedness: In the Forest Plan's database, Eldorado's level of cobble embeddedness is listed at an average of 37% (data collected in the mid-1970's). In the mid 1980's cobble embeddedness ranged from 50% to 60% in salmon habitat. Clearwater National Forest (1993) reported cobble embeddedness at an average of 73% over surveyed reaches. Some critical reaches are in better shape with a range of 45% to 60% cobble embeddedness (Huntington, 1992).

Other habitat impacts: Other habitat problems identified for Eldorado Creek by Vogelsang et al., (1985) are: low pool frequency, poor pool quality, low levels of large woody debris, poor winter habitat, lack of substrate diversity, low levels of in-stream cover, and high water temperatures during critical rearing periods. Most of these habitat conditions were associated with excessive harvesting of riparian timber and poor road construction. (from Espinosa in Rhodes et al, 1994, p B-8).

Conclusions/Status:

Eldorado Creek has been listed (tentatively) as a water quality limited waterbody by the State of Idaho and the Environmental Protection Agency.

<u>Pete King Creek:</u>

Geophysical/hydrological background:

Pete King Creek is a fourth order tributary of the Lower Lochsa River near its confluence with the Selway River. Pete King Creek drains a watershed of approximately 17,526 acres and has a channel length of 12.5 miles. The watershed ranges from 1475 to 5218 feet in elevation. It is almost entirely within National Forest ownership except for a small patented mining operation near its mouth.

Salmon Production:

The Lochsa River was once a significant producer of steelhead and spring chinook (Espinosa and Lee, 1991). Huntington (1992) estimated that Peter King Creek could provide 17.8 acres of rearing habitat for anadromous fish and but only 0.0077 acres of spawning habitat (most of which was classified as poor) for chinook salmon. The steep gradient of the stream would likely restrict chinook spawning to the lower 4.5 miles of the stream. Some summer rearing of juvenile chinook does occur in the lower reaches of Peter King Creek, but because of excessive summer rearing temperatures (>68F), it is at best marginal salmon habitat.

Development Activities:

The Pete King Creek Watershed has a long history of logging, mining, and grazing. Logging and its associated road construction have been the major activities since the mid-1950's with headwaters and riparian areas subject to the greatest impacts. The watershed was also subject to large and intense fire in the early 1900s.

Monitoring/Rehabilitation Activities:

Monitoring: Fish habitat and populations have been monitored in Pete King since the late 1970s. The Pete King Creek monitoring program was conducted at a frequency and intensity great enough to provide feedback to management on impacts to fish habitat so irrefutable that the sustained impacts of an aggressive timber program could no longer be overlooked. (from Espinosa in Rhodes et al, 1994, p B-10).

Rehabilitation: Starting in the 1970s, watershed and habitats have undergone extensive rehabilitation. In the mid-1980s, there was extensive in-stream restoration of spawning and rearing habitats as part of the Columbia Basin Fish and Wildlife Program (Espinosa and Lee, 1991). Several in-stream sediment traps were constructed in Pete King Creek and its tributaries during this period. Pete King was recently selected as a research stream for chinook salmon supplementation (Bowles and Leitzinger, 1991). (from Espinosa in Rhodes et al, 1994, p B-9).

Impacts of Development Activities on Salmon Habitat:

Sediment yield: Logging and associated roading began in the mid-1950's and accelerated in the late 1950's to the mid-1960's. Sediment yield was estimated at 65% above natural in 1955 and peaked at 347% over natural in 1963. From 1961-1974 sediment yields were sustained at levels exceeding the “geomorphic threshold” of 174% above natural. From 1955 to 1972, sediment yields averaged 197% with a median of 220% over natural. From 1973 to 1993, the mean and median sediment yields were 77% and 54% over natural respectively.

While there has been a significant [statistically?]decline in timber harvesting and roading since 1970, these activities continue so sediment levels remain elevated. In the 1990s sediment yields approached levels of <35% over natural, a level considered necessary for recovery to be initiated. (from Espinosa in Rhodes et al, 1994, p B-9).

Substrate sediment levels: Coring of substrate in the mid-1980s indicates a range of 30% to 47% fines with a mean and median of 37% and 36% respectively over the period from 1985 to 1993. These levels are above those considered optimum for salmonid survival. In-stream fines remained high despite a decline in sediment yield from 1973-1993. In stream fines declined in 1992 and 1993 (B. Stotts, pers. comm.) which may be attributed to sediment trapping and removal which commenced in 1986. (from Espinosa in Rhodes et al, 1994, p B-10).

Cobble embeddedness: The most critical habitat concerns for chinook salmon in the Pete King watershed are likely sediment in winter habitat and temperature (Espinosa and Lee, 1991; Huntington, 1992). In the Forest Plan database, Pete King Creek is listed with an average cobble embeddedness of 47%. In the early to mid-1980s, observed cobble embeddedness ranged from 50% to 60% (Talbert and Espinosa, 1986). Huntington (1992) recorded an overall average cobble embeddedness of 53% (that included the West Fork). The mainstem of Pete King below the confluence of its forks displayed a mean cobble embeddedness of 45% to 87% among its reaches. (from Espinosa in Rhodes et al, 1994, p B-11).

Conclusion/Status:

Despite a decline in sediment yield and extensive rehabilitation, habitat data indicate that recovery of degraded substrate conditions in fish habitat has not taken place in Pete King Creek. (from Espinosa in Rhodes et al, 1994, p B-10).

Although there is some evidence that summer and winter rearing habitats in the mainstem are showing some signs of recovery (Huntington, 1992 and Clearwater National Forest Monitoring Report, 1992), regression analysis indicates that there has been no statistically significant recovery trend from 1985 to 1992 despite sediment trapping. (from Espinosa in Rhodes et al, 1994, p B-10).

<u>Squaw Creek</u>:

Geophysical/hydrological background:

Squaw Creek is a fourth order tributary of the Upper Lochsa River. It drains a watershed of some 17,267 acres and has a mainstem channel length of 4 miles. It is estimated to provide 18.7 acres of rearing habitat and 0.173 acres of spawning habitat for anadromous fish (Espinosa and Lee, 1991). (from Espinosa in Rhodes et al, 1994, p B-11).

Salmon Production:

Squaw Creek was once a significant producer of steelhead trout and spring salmon (Espinosa and Lee, 1991).

Development Activities:

logging

Monitoring/Rehabilitation Activities:

Monitoring:

Rehabilitation: In the mid-1980s, extensive in-stream and riparian rehabilitation was conducted in the mainstem and East Fork. Excessive harvesting and riparian road construction have altered and simplified a great deal of the rearing habitat in Squaw Creek and its tributaries, in many areas the damage is permanent. In-stream restoration associated with the Columbia Basin Fish and Wildlife Program has attempted to alleviate some of these problems by introducing large woody debris and rock. Espinosa and Lee (1991) have documented the habitat and population responses to this effort. (from Espinosa in Rhodes et al, 1994, p B-11).

Squaw Creek has been selected as a research test stream for chinook salmon supplementation and is currently being evaluated by the Nez Perce Tribe (Bowles and Leitzinger, 1991).

Impacts of Development Activities on Salmon Habitat:

Sediment yield: Extensive timber harvesting and with its associated roading was initiated in the mid-1950s. In 1956, sediment yield was estimated to exceed the assumed "impact threshold" of 45% over natural and attained a level of 62% over natural. From 1956 to 1963, it ranged from 60% to 100% over natural. In 1964, it increased to 125% over natural and reached levels of 293% and 372% over natural in 1969 and 1970 respectively. During the pre-1970 period, sediment yields exceeded the "geomorphic threshold" (270% over natural for Squaw Creek) for three years and showed a mean and median level of 148% and 123% over natural respectively. (from Espinosa in Rhodes et al, 1994, p B-11).

Starting in 1972, sediment levels declined slightly until 1979 when another increasing trend was initiated. From 1982 to 1985, sediment yields again decreased slightly. From 1986 to 1988, an increasing trend was again observed. Since then, sediment yields have declined slightly approaching "assumed recovery thresholds" (<30% over natural) in the 1990s at which point continued improvement in substrate fine sediment can be expected to commence. (from Espinosa in Rhodes et al, 1994, p B-11).

From 1973 to 1993, the mean and median sediment yields for Squaw Creek were 86% and 87% over natural, respectively. Sediment did not exceed the "geomorphic threshold during this period. (from Espinosa in Rhodes et al, 1994, p B-11).

Substrate sediment level:

Cobble embeddedness: Surveys in 1970s showed a mean cobble embeddedness of 50%. Kramer et al (1985) reported a range of CE of 30% to 40% prior to in-stream rehabilitation. Clearwater National Forest listed cobble embeddedness at 45% for mainstem Squaw above Doe Creek (Phase 1 Report, 1992). (from Espinosa in Rhodes et al, 1994, p B-11).

Selected Clearwater Case Study References:

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Espinosa, F.A., Jr., and K.M. Lee. 1991. Natural propagation and habitat improvement. Idaho: Lolo Creek and Upper Lochsa. Clearwater National Forest, USDA Forest Service. Project #84-6. Final Report to BPA. 101p.

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Vogelsang, R., W. Murphy, and F.A. Espinosa, Jr. 1985. Eldorado Creek -- A plan for enhancement of key anadromous fish habitat in the Clearwater River Basin, project #84-6 USDA Forest Service. Annual Report to BPA. 31p.

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Grande Ronde River:

McIntosh (1992) found that the annual peakflows currently occur about 2 weeks earlier in the Grande Ronde than historically. (in Rhodes et al., 1994, p 48).

Some heavily logged drainages may have increased summer low flows; summer low flow has increased in some parts of the Grande Ronde over the past 50 years (McIntosh, 1992).

The increases in low flows do not appear to have improved salmonid survival because the water quality is so poor and stream habitats have been heavily degraded (B. McIntosh, USFS PNW Research Station Res. Asst. pers. comm., 1993) due to upstream logging, grazing, and road construction (Anderson et al., 1993; McIntosh et al., 1994). (in Rhodes et al., 1994, p 48).

Anderson, J.W., Beschta, R.L., Boehne, P.L., Bryson, D., Gill, R., McIntosh, B.A., Purser, M.D., Rhodes, J.J., Sedell, J.W., and Zakel, J., 1993. A comprehensive approach to restoring habitat conditions needed to protect threatened salmon species in a severely degraded river-- The Upper Grande Ronde River Anadromous Fish Habitat Protection, Restoration and Monitoring Plan. Riparian Management: Common Threads and Shared Interests, pp. 175-179, USFS Gen, Tech. Rept. RM-226, Fort Collins, Co.

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McIntosh, B.A. 1992. Historical changes in anadromous fish habitat in the upper Grande Ronde River, Oregon, 1941-1990. Unpub. M.S. thesis, Ore. State Univ., Corvallis, Or.

McIntosh, B.A., Sedell, J.R., Smith, J.E., Wissamar, R.C., Clarke, S.E., Reeves, G.H.M, and Brown, L.A., 1994. Management history of Eastside Ecosystems: Changes in fish habitat over 50 years, 1935 to 1992. Eastside Forest Ecosystem Health Assessment, Vol III, USFS Gen. Tech. Rept. PNW-GTR-321, Portland, Or.

Tucannon River Spring Chinook:

Case Study - Impact of water temperature on production of spring chinook, Tucannon River: Bugert et al. (1987). Tucannon River, southeast Washington. Data can be used to infer summertime temperature limitations on spring chinook rearing distribution. July-August, 1990, surveyed spring chinook parr densities in lower 25 mile section of river. Found no parr. 1990/1991 - only 2 redds in this section. No redds observed here in 1986. 1991 August water temperature in this reach, daily maxima of 81F observed. Mean daily for Aug was 72F. Mean-maximum for Aug was 77F. Theurer et al (1985) estimated that no spring chinook production would occur on sections of the Tucannon River where mean daily water temperature for July exceeds 68F and the average maximum daily July water temperature exceeds 75F. Consequently they estimated that about 24 miles of the Tucannon mainstem had been lost as usable habitat due to increases in summer water temperatures (see Figure 25); *they estimated that the elevation of water temperature had reduced production capacity from 2200 to about 900 adult spring chinook salmon (See Figure 26).* (in Rhodes et al., 1994, p 39).

Bugert et al. (1987) ? 1992 is the only reference listed

Bugert, R., K. Peterson, G. Mendel, L. Ross, D. Milks, J. Dedloff, M. Alexandersdottir. 1992. Lower Snake River Compensation Plan. Tucannon River Spring Chinook Salmon Hatchery Evaluation Program. 1991 Annual Report. AFF 1/LSR-92-08, Wash. Dept. of Fish., Olympia, Wash.

Theurer, F.D., I. Lines and T. Nelson. 1985. Interaction between riparian vegetation, water temperature and salmonid habitat in the Tucannon River. Water Res. Bull., 21:53-64.

Other Regions and species:

Okanagan River Sockeye:

Hatch et al. (1993) reported that as water temperatures reached 73F in the **Okanagan River**, sockeye passage upstream to Lake Osoyoos terminated. During the migratory period, sockeye did not migrate from the Columbia River staging area upstream on the Okanagan River until temperatures dipped below 73F. (in Rhodes et al., 1994, p 36).

Hatch, D., A. Wand, A. Porter, and Schwartzberg, M. 1993. The feasibility of estimating sockeye salmon escapement at Zosel dam using underwater video technology. 1992 Annual Progress Report. Prepared for Public Utility District No. 1 of Douglas County, Columbia River Inter-Tribal Fish Commission, Portland, Or.

John Day River Spring Chinook:

Case Study - Impact of water temperature on spring chinook, John Day River: Lindsey et al (1986). Presents clear evidence regarding the effects of maximum water temperatures on spring chinook distribution. They found that distribution of spring chinook fingerlings after emergence in the John Day River, Oregon extends downstream from the three primary spawning areas. From the spawning areas in the North Fork, fingerlings extend their distribution downstream below the North Fork mouth. As water temperatures increase in early summer, juveniles migrate back upstream. On the North Fork, the lower limit of juvenile rearing retreated above river mile 70 in response to increased temperatures (Lindsey et al., 1986 (see Figure 24)). A similar pattern of juvenile movement downstream after emergence, followed by a return movement upstream during July-August in response to increasing temperatures was observed in the Middle Fork. Temperature data from thermographs in the North Fork and Middle Forks of the John Day River allow regressions to be developed expressing the downstream boundary of distribution in relation to the water temperature at the thermograph. North Fork - mean-max water temp 73F at a point for 2 week period, no juveniles below that point; Middle Fork - mean-max water temp. at a point 67F for two weeks at point, no juveniles below that point. *This study clearly shows that available rearing area decreases as water temperature increases.* (in Rhodes et al., 1994, p 38-39).

Lindsey, R.B., W.J. Knox, M.W. Flesher, B.J. Smith, E.A. Olsen and L.S. Lutz. 1986. Study of wild spring chinook salmon in the John Day River system. 1985 Final Report. BPA Project No. 79-4, Bonneville Power Admin., Div. of Fish and Wildlife, Portland, Or.

Steelhead Trout:

Li et al. (1992) reported a decline in steelhead biomass from 0.37 lb/100 ft^2 at a maximum summer water temperature of 60.8F in tributaries of the **John Day River** to 0 lb/100ft2 at a maximum temperature of 82.4F. The sharp reduction in steelhead biomass with increasing temperature is an indication of either progressive mortality or emigration from zones exceeding temperature preferenda. (in Rhodes et al., 1994, p 41).

Reeves et al. (1987) found steelhead to be dominant in steelhead/shiner interactions in laboratory streams when water temperatures ranges from 54-59F but that shiners were dominant when water temperatures were 66-72F. This study indicates that in addition to the lethal effects of temperature that become prominent above 72F, negative competitive interactions reduce the ability of salmonids to maintain feeding stations and grow in streams with temperatures above this threshold. (in Rhodes et al., 1994, p 41).

Li, H.W., T.N. Pearsons, C.K. Tait, C.K., J.L. Li. 1992. Approaches to evaluate habitat improvement programs in streams of the John Day Basin. Completion report, Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Ore. State Univ., Corvallis, Or., unpublished.

Reeves, G.H., F.H. Everest and J.D. Hall. 1987. Interaction between redside shiner (*Richarsonius balteatus*) and the steelhead trout (*Salmo gairdneri*) in western Oregon: the influence of water temperature. Can J. Fish and Aquat. Sci., 44: 1603-1613.

Willamette River Salmonids:

Dimick and Merry field (1945) reported that no salmonids occurred in the **Willamette River system** where water temperatures exceeded 73F; the majority of **salmonids** were associated with water temperatures ranging from 55-66F and were always in lower abundance within the temperature range of 67-72F.

Dimick, R.E. and F. Merryfield. 1945. The fishes of the Willamette River system in relation to pollution. Oregon State College Engineering Experiment Station Bulletin Series 20:7-55, Oregon State College, Corvallis, Or.

Umatilla River, Oregon:

In the **Umatilla River in Oregon**, where water availability is a major problem, flows during the spawning and rearing period appear to exert a profound influence on the number of returning **steelhead** (Confederated Tribes of the Umatilla Indian Reservation, 1994 (see Figure 30)). (in Rhodes et al., 1994, p 47).

Confederated Tribes of the Umatilla Indian Reservation. 1994. Umatilla Basin Natural Production Monitoring and Evaluation Annual Progress Report 1992-1993. BPA Project No. 90-005-01, Bonneville Power Admin. Div. of Fish and Wildlife, Portland, Or.

Southwestern Oregon:

"Reeves et al. (1993) found that salmonid diversity was decreased with increased timber harvest in **southwestern Oregon**, although the abundance of specific age classes and species of salmonids had limited statistical relationship to the amount of logging related activities within the basins studied." (in Rhodes et al., 1994, p 85).

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of juvenile anadromous salmonid assemblages in coastal Oregon Basins with different levels of timber harvest. Trans. Amer. Fish. Soc., 122:309-317.

British Columbia:

Carnation Creek, B.C.: Hartmann et al. (1987), intensive clearcutting, careful clearcutting, leave strip of variable width. best was leave strip although pool depth still decrease from upstream sediment.(in Rhodes et al., 1994. p 26).

Coastal B.C. watersheds: Hogan (1987), logging of watersheds in coastal B.C. reduced size and abundance of recruitable riparian trees and consequent changes in channel morphology - also noted that unlogged channels had a very complex morphology with frequent vertical steps and sediment storage areas and a greater variance in channel width. (in Rhodes et al., 1994. p 27).

For adult sockeye on **Fraser River** spawning grounds, mortality of females ranges from 5-86% from gill bacterial infections at temperatures of 72F (International Pacific Salmon Fisheries Commission, 1962 as cited by Parker and Krenkel, 1969). (in Rhodes et al., 1994, p 36).

Hartmann, G. J.C. Scriver, L.B. Holtby, and L. Powell. 1987. Some effects of streamside treatments on physical conditions and fish population processes in Carnation Creek, a coastal ran forest stream in British Columbia. Streamside Management: Forestry and Fishery Interactions, pp. 330-372, Univ, of Wash. Inst. of Forest Resources Contribution No. 57, Seattle, WA.

Hogan, D.L. 1987. The influence of large organic debris on channel recovery in the Queen Charlotte Islands, British Columbia, Canada. Erosion and sedimentation in the Pacific Rim, Proceedings of the Corvallis Symposium, August, 1987, pp. 343-353, International Assoc. Hydrol. Sci. Pub. no. 165, Wallingford, U.K.

International Pacific Salmon Fisheries Commission, 1962 as cited by Parker and Krenkel, 1969.

Parker, F.L. and P.A. Krenkel. 1969. Thermal pollution. Status of the Art Report. Rept. No. 3 Dept. of Env. and Water Resour. Eng., Vanderbuilt University, Nashville, Tenn.

California:

California: Burns (1972) found that stream sedimentation from logging along northern California streams caused loss of pool area, resulting in reduction of coho and large trout. (in Rhodes et al., 1994. p 27).

Burns, J.W. 1972. Some effects of logging and associated road construction on northern California streams. Trans. Am. Fish. Soc. 101:1-17.

Timeline for Habitat Recovery:

This section presents selected information from Rhodes *et al*. (1994) which discusses stream habitat recovery times and the current status of streams which have been rehabilitated and monitored for recovery over time. The purpose of this information is to get an estimate of the timeline for aquatic habitat recovery. There may be some duplication of information with previously presented case study material.

"Madej (1987) has calculated that it will take decades to centuries for excessive sediment to be flushed from some reaches of Redwood Creek, California. She further postulated that it may take centuries for complete mainstem recovery (i.e., removal of flood-deposited sediments; Madej, 1987)." (Espinosa in Rhodes et al, 1994, p B-6).

Summer rearing habitat may recover more quickly than winter rearing habitat: After extensive habitat rehabilitation in Lolo Creek an increase in habitat diversity (pool quantity and quality) and spawning habitat were documented, but cobble embeddedness remained essentially unchanged (54% in 1974, 51% in 1988). Statistically significant increases of steelhead and chinook parr in summer rearing habitat were observed for enhanced habitats over control habitats (Espinosa and Lee, 1991; Scully et al., 1990). However, based on data for substrate conditions and sediment yield, and habitat capability analyses, it was concluded that essentially little or no recovery in habitat sediment conditions in Lolo Creek had taken place over a period of ***19 years*** despite a substantial decline in sediment yield and extensive rehabilitation during this time." (from Espinosa in Rhodes et al, 1994, p B-6/7).

The loss of LWD sources is significant because the recruitment of coniferous LWD does not begin to occur until about 50 years or more after removal (Bisson et al., 1987); **more than 200 years is required for full recovery of LWD sizes and amounts in the western Cascades** after logging (Gregory and Ashkenas, 1990). Due to slower rates of regrowth, the **full ecological recovery time for LWD recruitment** in the Snake River Basin may be even longer. (in Rhodes et al., 1994. p 26).

Habitat requirements:

This section is currently a collection of interesting information relating habitat quality to salmonid production:

Spatial organization of macrohabitat types in relation to **summer /winter rearing habitat**. . . example of **coastal coho** . . move into tributary sloughs etc. in winter where risk of downstream displacement is low . . move back to mainstem in spring. Survival in off-channel areas can be at least twice as great as in mainstem habitats during the winter period (Bustard and Narver, 1975b).

Loss of **complex primary pools** plus elimination of **off-channel rearing areas** can create a significant limiting factor in **coho production in coastal streams** (Nickelson et al., 1992b). (in Rhodes et al., 1994. p 22).

Pool quality: Platt (1974) [Platts, 1984?] found a significant positive relationship between **pool quality and the standing crop of salmonids**. (in Rhodes et al., 1994. p 22) - pool quality, distribution of species and age class related to macrohabitat type, variant of macrohabitat type, and quality, the productive capacity of a stream is dependent upon the diversity of habitat qualities by type. (in Rhodes et al., 1994. p 22).

Many studies indicate a strong positive relationship between **salmonid production and LWD** (Everest et al., 1985; Bisson et al., 1987; MacDonald et al., 1991; Nickelson et al., 1992a; Fausch and Northcote, 1992). In **Southwestern British Columbia**, Tschaplinski and Hartmann (1983) reported that the midwinter numbers of juvenile coho salmon in each study reach were linearly correlated with LWD volume (R^2=0.89); coho juveniles were eliminated from clearcut stream sections without stable LWD when late fall/early winter freshets occurred. Murphy et al (1984) found a similar relationship in **Alaskan streams**. Dollof (1987) found that winter production of coho was lowest in areas with low pool volumes and where LWD was ineffective in creating habitat structure. Hiefetz et al. (1986) cite several **Alaskan studies** emphasizing the importance of maintaining high quality overwintering habitat created by LWD for salmonids that spend one or more years in freshwater. (in Rhodes et al., 1994. p 23).

Changes in pool frequency and quality and LWD levels can lead to shifts in species age composition. Bisson and Sedell (1984) found that when an old growth stream is clearcut there is a shift to higher percentages of 0+ steelhead and 0+ cutthroat trout and lower percentages of 0+ coho and 1+ and 2+ cutthroat - in **western**

Washington. attributed to loss of pool volume and LWD cover. Reeves et al. (1993) found salmonid diversity decreased with decreasing LWD and pool frequency in streams in **coastal Oregon**.

References for both Timeline for recovery and Habitat requirements:

Bisson, P.A., M.D. Bryant, C.A. Dollof, G.B. Grette, R.A. House, M.L. Murphy, K.V. Koski, J.R. Sedell. 1987. Large woody debris in the Pacific Northwest: Past, present and future. Streamside management: forestry and fishery interactions, pp. 143-190, Univ. of Wash. Inst. of Forest Resources Contribution No. 57, Seattle, Wash.

Bisson, P.A. and J.R. Sedell. 1984. Salmonid populations in streams in clear-cut vs old-growth forests of western Washington. Fish and Wildlife Relationships in Old-Growth Forests. Proceedings of a Symposium Held April 12-15, 1982 in Juneau, Alaska, pp. 121-129, Am. Inst. of Fish. Res. Biologists, Morehead City, NC.

Bustard, D.R. and Narver, D.W. 1975b. Aspects of the winter ecology of juvenile coho salmon (*Onchorhyncus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Bd. Can., 32:667-680.

Dollof, C.A. 1987. Seasonal population characteristics and habitat use by juvenile coho salmon in a small southeast Alaska stream. Trans. Am. Fish. Soc., 116: 829-838.

Espinosa, F.A. 1994. Case History: The failure of existing plans to protect salmon habitat on the Clearwater National Forest in Idaho. Appendix B in Rhodes *et al*. 1994, A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. CRITFC Technical Report 94-4.

Everest, F.H., N.B. Armatrout, S.M. Keller, W.D. Parante, J.R. Sedell, T.E. Nickelson, J.N. Johnson, G.N. Haugen. 1985. Salmonids. Management of wildlife and fish habitats in Western Oregon and Washington, pp 200-230, USFS PNW Region, Portland, Or.

Fausch, K.D. and T.G. Northcote. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. Can. J. Fish. Aquat. Sci. 49:682-693.

Gregory, S. and L. Ashkenas. 1990. Riparian Management Guide Willamette National Forest, Willamette National Forest, USFS Pacific Northwest Region, Portland, Or.

Hiefetz, J. M.L. Murphy and K.V. Koski. 1986. Effects of logging on winter habitat of juvenile salmonids in Alaskan streams. N. Am. J. Fish. Manage. 6:52-58.

MacDonald, L.H., A.W. Smart, R.C. Wissamar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry on Streams in the Pacific Northwest and Alaska. EPA 910/9-91-001, USEPA, Water Division, Region 10, Seattle, Wash.

Madej, M.A. 1987. Residence times of channel stored sediment in Redwood Creek, Northwestern California. In: Erosion and Sedimentation in the Pacific Rim; proceedings of the Corvallis Symposium, August, 1987; IAHS Publ. #165. 429-438.

Murphy, M.L., K.V. Koski, J. Heifetz, S.W. Johnson, D. Kirchofer, J.F. Thedinga. 1984. Role of large organic debris as winter habitat for juvenile salmonids in Alaska Streams. Proc. West. Assoc. Fish. Wildl. Agencies. 64:251-262.

Nickelson, T.E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992a. Seasonal changes in habitat use by juvenile coho salmon (*Onchorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish Aquat. Sci. 49: 783-789.

Nickelson, T.E., M.F. Solazzi, S.L. Johnson, and J.D. Rodgers. 1992b. Effectiveness of selected stream improvement techniques to create suitable summer and winter rearing habitat for juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49: 790-794.

Platts, 1974. - no Platts 1974 in refs, only Platts, 1984.

Platts, W.F. 1984. Determining and evaluating riparian-stream enhancement needs and fish response. Proceedings: Pacific Northwest Stream Habitat Management Workshop, pp. 181-190. Amer. Fish. Soc., Calif. Coop. Fish. Research Unit, Humboldt State Univ., Arcata, Calif.

Reeves, G.H., F.H. Everest, and J.R. Sedell. 1993. Diversity of juvenile anadromous salmonid assemblages in coastal Oregon Basins with different levels of timber harvest. Trans. Amer. Fish. Soc., 122:309-317.

Tschaplinski, P.J. and G.F. Hartmann. 1983. Winter distribution of juvenile coho salmon (Onchorhyncus kisutch) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Can. J. Fish. and Aquat. Sci., 40: 452-461.

More information for a John Day River case study from:

Torgersen, C.E., D.M. Price, H.W. Li, and B.A. McIntosh. 1995. Thermal refugia and chinook salmon habitat in Oregon: applications of airborne thermal videography.

The use of thermal refugia by adult spring chinook salmon in the Middle Fork and the North Fork of the John Day River was examined by comparing fish distributions with remotely sensed image data and relating individual fish locations to thermal refugia and reach scale isotherms.

Background:

The John Day River basin is located in central Oregon and drains approximately 20,300 km^2. The study sites in the North Fork and Middle Fork flow through predominantly coniferous forest with interspersed meadow lands at elevations up to 1800m. Summer temperatures are relatively high (38^{o} C maximum) with low humidity. The predominant land uses in the altered stream, the Middle Fork, are grazing and logging which has resulted in degradation and removal of riparian vegetation, sloughing of undercut stream banks, and upland soil compaction.

“Elevated stream temperatures resulting from land use practices, such as logging, road building, grazing, and mining throughout the basin are significant factors limiting the current distribution of spawning chinook to the uppermost headwater reaches of the Mainstem, Middle Fork, and North Fork of the John Day River (Wissmar et al., 1994).”

The river reaches utilized by spawning salmon today represent less than a third of the probable historical distribution in the John Day River system.

“The average density of adult spring chinook in the Middle Fork is 18 fish/km. The North Fork study site is located in designated wilderness in the Umatilla National Forest. Nearly all chinook holding and spawning occurs in the North Fork wilderness reach, which supports more than twice as many chinook per kilometer as the Middle Fork [holding adults?].”

“Spring chinook salmon return from the 2-3 year ocean phase of an anadromous life cycle to their natal streams in late spring. The adult salmon migrate upstream and then hold in cooler headwater reaches during the hot months of summer, the salmon spawn in the fall when stream temperatures become more tolerable. Adult salmon cease to feed upon entering fresh water and , therefore, function on a limited energy reserve until spawning. Because salmon are poikilothermic, i.e., their body temperature is the same as the water temperature, their metabolic rate increases directly with temperature. Thus high water temperatures (>20^{o} C) prior to spawning compromise energy necessary to insure reproductive success. Salmon that are able to reside in coolwater refugia before spawning are energetically fit to spawn and produce viable offspring."

Results:

Spring chinook salmon in the upper Middle Fork were consistently located in coolwater patches which were 1-3^{o} C cooler than surrounding habitat within a 10m radius.

Coolwater areas occurred most frequently in pool habitats where cold groundwater flow may be entering the channel laterally through the pool substratum. The actual presence and magnitude of such groundwater flow remains to be investigated.

Many of the coolwater refugia in the grazed reaches of the Middle Fork could not be linked to obvious surface vegetation or channel morphology characteristics and, hence, were not identifiable without the use of FLIR imagery.

"In contrast to the Middle Fork, the wilderness reaches of the North Fork were 5-7^{o} C cooler and spatially uniform in temperature. The wilderness reaches had steeper canyon walls, denser riparian vegetation, and were higher gradient then the Middle Fork reaches, so shading may be a significant factor leading to homogeneously cool water temperatures."

"Habitat use by chinook salmon in the two basins differed noticeably. Chinook salmon were rarely observed utilizing riffle habitats in the Middle Fork, presumably because they were 1-3^{o} C warmer than pools. Ninety-five percent of the chinook salmon observed in the Middle Fork were holding in pools and 5 percent were found in riffles. In contrast, only 83 percent of the salmon in the North Fork were found in pools, with the remaining 17 percent in riffles. *We believe that higher water temperatures in riffle habitats in the Middle Fork makes them unsuitable for holding salmon thereby effectively reducing the overall habitat available for salmon*. Other elements of instream cover such as depth, undercut banks, overhanging shore vegetation, large substrate, and large woody debris may be either primary or secondary determinants of habitat selection by salmon, depending on the degree of thermal stress (McIntosh et al. 1993, 1994)."

Papers cited in Torgersen *et al*. 1995 that look useful:

McIntosh, B.A., H.W. Li, D.M. Price and C.E. Torgersen. 1993, 1994. Distribution, habitat utilization, movement patterns, and the use of thermal refugia by spring chinook in the Grande Ronde, Imnaha, and John Day basins. Progress Reports to the Bonneville Power Administration. Project No. 88-108. FY-1994.

Wissmar, R.C., J.E. Smith, B.A. McIntosh, H.W. Li, G.H. Reeves and J.R. Sedell. 1994. Ecological health of river basins in forested regions of eastern Washington and Oregon, Gen. Tech. Rep. PNW-GTR-326. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p.

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Information from:

McIntosh, B.A., C.E. Torgersen, D.M. Price, and H.W. Li. 1995. Distribution, habitat utilization, movement patterns, and the use of thermal refugia by spring chinook in the Grande Ronde, Imnaha, and John Day basins. Annual Report to the Bonneville Power Administration, Project No. 93-7000 FY-1995.

Summary of Previous findings:

1) Habitat selection by spring chinook salmon differs among the drainages of the North Fork, Middle Fork, and Upper Mainstem drainages of the John Day River, Imnaha, and Upper Grande Ronde basins. This reflects differences in habitat structure, habitat availability, and temperature among these watersheds.

2) high stream temperature limits the distribution of adult spring chinook salmon in the John Day basin.

3) Spring chinook adults in the Middle Fork are exposed to temperatures above the upper incipient lethal temperature for several hours daily during July and August.

4) The spatial character of holding and spawning distributions of spring chinook differed among the study basins. In the North Fork, fish spawned over the same reaches used for holding. In contrast, fish in the Middle Fork and Mainstem spawned in limited upstream reaches often far from holding locations. We believe this reflects habitat limitations due to warm stream temperature and a lack of instream cover.

5) Spring chinook in the cooler streams, e.g. North Fork, Granite Creek, Clear Creek, Imnaha, and Wenaha, spawn earlier (mid August through early September) than salmon in warmer streams such as the Middle Fork and Mainstem (mid September through early October).

Summary of new findings:

1) all radio-tagged fish were found in or frequented coldwater refugia in the Middle Fork John Day basin. Coldwater refugia were associated with groundwater sources and cool tributary junctions detected using forward-looking infrared (FLIR) videography. Many of these refugia were pools.

2) The thermal patterns of the North Fork vs. the Middle Fork John Day rivers were distinctly different. The North Fork was homogeneously cool and its riparian zone was shaded and also cool. The Middle Fork was thermally warm with isolated patches of cool water. *The spring chinook salmon carrying capacity with respect to temperature, of the North Fork per linear unit of stream is about twice that of the Middle Fork.*

3) The habitats used by the spring chinook salmon in the Middle Fork John Day River were almost exclusively pools. Pools were still important habitats in North Fork, but 15% of the habitats occupied were in riffles. We suspect that the cool water and better structure allows chinook salmon a greater diversity of adequate holding habitat in the North Fork.

4) see the information from the manuscript described above.

Documents we should review for Habitat chapter:

References from:

Lee, D.C., B.E. Rieman. 1996. June 24, 1996 Draft - Federal Land Management and Anadromous Fishes. USDA Forest Service, Intermountain Research Station, Boise, ID.

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Potential Case study material from Table 3.5 of Bauer and Burton (1993). **Bear Valley Creek**; An example in monitoring design.

Bear Valley Creek is located in the headwaters of the Middle Fork Salmon River in the Boise National Forest, Id. A portion of the Creek is located in wilderness area. It is a high elevation valley is mostly forested with meadows along the streams. These meadows provide forage for cattle.

Low gradient streams in Bear Valley have the potential to provide ideal spawning and rearing conditions for spring chinook salmon. The decline of salmon in the drainage has been attributed to downstream impacts on migration and to poor habitat conditions related to grazing, mining, and logging impacts. For example, a dredge mining operation historically contributed massive sediment loads to the stream. This area has been stabilized to reduce sediment inputs. Logging roads networks are minimal and future timber harvests has been designed to result in a net decrease in sediment through road stabilization and road closures. Grazing in the meadows adjacent to the stream channels is thought to be the current major impact.

Fish densities and habitat conditions were measured in Bear Valley Creek and nearby unimpacted streams. Spawning and rearing habitat had been significantly reduced by large amounts of fine sand. Bedload sediment was filling pools and altering stream substrates. This impaired egg incubation and rearing of fry and juveniles. Survival of young salmon in Bear Valley Creek was only one tenth of survival in the reference areas and substrate fine sediment was two to four times greater than in the reference streams.

Inside and outside the wilderness area, stream reaches associated with cattle grazing were correlated to habitat degradation. Direct streambank modification was determined to be the primary detrimental effect of grazing. Desired future condition was established by examining unimpacted reference streams and defined in terms of riparian vegetative composition, substrate fine sediment, and bank stability and cover. Grazing management has been modified to include riparian pastures, corridor fencing, herding to modify livestock distribution, and changes in season of use. Parameters monitored: bank stability and cover (primary), as well as, (additional) forage utilization adjacent to stream banks, Green Line vegetative composition (Green Line = the first perennial vegetation that is available above the stable low water line of a stream or water body), and woody species regeneration. Idaho Fish and Game monitors redd numbers, juvenile survival, and surface fine sediment. Additional parameters provide information for ongoing evaluation of cause, effect and improvement in the beneficial uses.

Appendix 6:
Maps of USFS-INT Eastside Assessment and PATH Index Area Watersheds