UNDERSTANDING OUT-OF-SUBBASIN EFFECTS FOR OREGON SUBBASIN PLANNING
With particular reference to Ecosystem Diagnosis and Treatment assessments

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I. Introduction

Subbasin planning, by definition, is focused on the major tributaries to the mainstem Columbia and Snake rivers. However, many focal species migrate, spending varying amounts of time and traveling sometimes extensively outside of the subbasins. Salmon populations typically spend most of their lives outside the subbasin. Unhindered, sturgeon will spend short periods in the ocean. Lamprey typically spend most of their life as juveniles in freshwater, but gain most of their growth in the ocean. Planning for such focal species requires accounting for conditions during the time these populations exist away from their natal subbasin. Out-of-subbasin effects (OOSE) encompasses all mortality factors from the time a population leaves a subbasin to the time it returns to the subbasin. These effects can vary greatly from year to year, especially for wide ranging species such as salmon. Out-of-subbasin factors can be natural in origin (e.g. ocean productivity), human-caused (e.g. fisheries) or a combination (e.g. mainstem survival is dependent on both mainstem flows and dam operations). Because of the richness and depth of information available for salmon outside their natal subbasins and because of the scarcity of information available for other anadromous focal species, the remainder of this report describes out-of-subbasin effects for salmon only.

This report is organized into four main sections. The first two describe, in qualitative terms, the OOSE structure of the EDT model and environmental cycles which cause salmon survival to vary widely. The third section describes quantitatively OOSE survival estimates under base period conditions and an expected survival range to represent environmental variation. The fourth section offers guidance for evaluating subbasin plans in light of OOSE survival and variation. The following discussion draws from existing data and previous analyses. It is a summary of existing knowledge and hypotheses. The following discussion is confined to OOSE pertaining to salmon populations, because of data limitations for other migratory species. Particular attention is given to out-of-subbasin effects as represented in the Ecosystem Diagnosis and Treatment (EDT) model because this is the most commonly used tool for developing assessments for salmon during this round of subbasin planning. Although much of the following discussion centers around the EDT model, the final recommendations can be used with any assessment tool.

II. EDT Baseline Conditions

N.B. This section is abstracted from Marcot et al. 2002. Readers are referred to that report for additional details. The use of personal pronouns in this section refers to the original authors.

It is important to note that the EDT analyses do not include any new data or information about survival outside the subbasins.

EDT is a habitat model and is structured differently from population models typically used to define and estimate survival parameters in the mainstem Columbia, therefore there is no direct correspondence between EDT parameters and those used by other models. For example, EDT incorporates growth, development, migration patterns and travel speeds for individuals (i.e. individual life history trajectories), rather than for populations or groups of fish.

In general the default values for out-of-subbasin survival are those used in the "Multi-Species Framework" analysis (Marcot et al 2002). Where more recent information is available for harvest impacts on individual populations, that information has been incorporated.

The simplest way to summarize the assumptions built into the EDT model for the out-of-subbasin portion of the salmon life history is to compute the average survival for a population from juveniles entering the mainstem Columbia (or Snake) River to adults reentering the subbasin. This Juvenile to Adult Return rate (JAR) is computed as the total number of adult returns divided by the total number of juvenile outmigrants. These outmigrants include juveniles of all ages and life stages entering the mainstem and may not be directly comparable to the smolt to adult return rates estimated from empirical data. The composition of out migrants (age, size, and life stage mix) is affected by habitat conditions in both the mainstem and the subbasin and varies between subbasins and between current and historic conditions.

The following briefly summarizes the out-of-subbasin assumptions in the EDT tool. Readers are referred to the methods section in the Multi-Species Framework Report (Marcot et al. 2002) for a fuller description of most of the assumptions.

Mainstem Passage Effects

This is the most complex part of the EDT tool, outside of the natal subbasins. Juvenile survival through the mainstem Columbia and Snake rivers depends upon habitat quality and quantity, river flow, juvenile travel time, juvenile migration timing, dam survival, transportation survival, survival of naturally migrating fish, and competitive interactions with hatchery fish.

Habitat Quality and Quantity

Biological rules do not exist for deriving mainstem habitat ratings; therefore, we constructed the quality ratings for mainstem habitat, for the Historic Potential and Current Potential, based on existing literature and the professional expertise of fisheries biologists familiar with both Columbia and Snake river systems. The biologists used the

existing data and their knowledge to rate the following biological performance attributes for each river reach of interest:

- Habitat Quality
- Temperature
- Predation
- Competition with Hatchery Fish
- Competition with Other Species
- Habitat Diversity

The quantity of both riverine and reservoir habitat presented under both conditions were estimated from USGS Topo maps, average monthly river flow, and reservoir size and length data presented in the CRiSP 1.5 manual (Anderson et al., 1996).

River Flow

We obtained estimates of average monthly river flow for both the Columbia and Snake rivers under the Current Potential and Historic Potential from streamflow model runs developed by Council staff.

Juvenile Travel Time

We assumed that the time required for subyearling and yearling chinook to migrate through the mainstem corridor is affected by river flow (water velocity) and habitat types present (i.e., riverine or reservoir). Thus, juvenile migration speed is assumed to differ under the Current Potential (primarily reservoir) and Historic Potential (riverine).

We developed subyearling and yearling chinook travel speeds for both conditions using CRiSP Model 4. A description of the model, inherent assumptions, formulas and inputs can be found in Zabel and Anderson (1997). In addition, for the Historic Potential, we estimated water velocity by dividing average monthly river flow by the average cross section of each stream reach. We used travel speed and timing data in this analysis to determine the survival conditions encountered by each juvenile as it migrates through the mainstem Snake and Columbia rivers.

Juvenile Migration Timing

We approximated subyearling and yearling juvenile migration timings from data developed by the Fish Passage Center (FPC 1999). Yearling chinook were assumed to migrate during the period April – June and subyearling chinook during the period June – August.

Dam Survival (Juveniles)

Dam survival rates for juvenile salmonids are discussed below for the Current Potential only; dams do not exist for the Historic Potential, thus survival estimates are not needed for that condition.

The survival rate of juvenile salmonids migrating past Columbia and Snake river hydroelectric projects is dependent on riverine conditions, juvenile behavior, and physical facilities present at each project. We calculated both yearling and subyearling survival rates through spillways, turbines, and juvenile bypass systems for each project using data presented in the NMFS white paper titled "Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams" (NMFS 2000). It should be noted that the survival values do not include the mortality component associated with juvenile passage through reservoirs (see below).

<u>In-river Survival (Juveniles)</u>

The survival rates used for modeling the Current Potential for subyearling and yearling juveniles migrating in-river through the hydroelectric complex were based on the range of values presented in recently published scientific literature.

Data presented by NMFS (2000) show that from 1993-1999 yearling survival from Lower Granite Reservoir to the tailrace of Bonneville Dam ranged from about 31% to 51%. This equates to a project survival rate of approximately 86-92%. For modeling the Current Potential, we assumed that yearling survival past eight hydroelectric projects averages 36% (88% per project).

For subyearling chinook we assumed that in-river survival from the head of Lower Granite Reservoir to the tailrace of Bonneville Dam was 29%. This equates to a project survival rate of ~85%. The survival value only applies to active migrants. For inactive migrants, or life history trajectories that spend more time in the reservoirs (rearing stage), mortality increases in proportion to the time spent in the reservoirs. Thus, overall survival varies dependent on the trajectory examined. This approach is consistent with the data presented in a recent NMFS document titled *"Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams."* NMFS scientists reported that subyearling survival varied dramatically (13-51%) in tests conducted in the Snake River from 1995-1999. However, these survival estimates included mortality from parr to the active migrant stage.

The juvenile survival rates presented above formed the basis for model calibration with regard to overall survival through the mainstem Columbia and Snake Rivers. Because the dam survival values were fixed, the overall survival targets for both life histories required that juvenile survival rates through the reservoirs be adjusted as needed, which we achieved by modifying the habitat quality attributes for each reservoir during the key juvenile migration periods (see Juvenile Migration Timing). It should be noted that juvenile survival through the reservoirs is affected by the amount of time the juvenile spends in the reservoir and the benchmark survival value for the specific life stage (subyearling, yearling, etc.).

We set the survival benchmarks for yearling and subyearling chinook at 97.5% and 35%, respectively. These benchmark survival values were based on the assumption that yearlings require 14 days, and subyearling 56 days, to migrate from natal streams to the estuary under ideal environmental conditions. This equates to a daily survival rate of 99.8% ($97.5^{1/14)}$ for yearlings and 98.1% ($0.35^{1/56}$) for subyearlings.

For each reservoir, we calculated the daily survival rate for juvenile chinook using the following formulas:

$$\text{Daily Yearling Survival Rate} = (B*RSR)^{1/14}$$
$$\text{Daily Subyearling Survival} = (B*RSR)^{1/56}$$

Where-

B= benchmark survival rate
RSR = Reservoir survival rate by month

For example, the daily survival rate for a yearling chinook migrating through Lower Granite Reservoir in May would be 99.1 percent $(0.975*0.91)^{1/14}$.

We calculated the survival values based on mainstem habitat quality, juvenile travel time through each reach, and the benchmark survival values used for each life stage.

Fish Transportation (Juveniles)

Survival associated with juvenile fish transportation is presented below for Current Potential only; juvenile transport does not occur under the Historic Potential.

We assumed 98% of the transported juveniles survive to the point of release (NMFS 2000 White Paper Transportation). We also assumed survival rates of transported Snake River yearling and subyearling chinook once released from the barges are 50% and 35% that of juveniles migrating in-river, respectively. We selected these values based on a review of recent literature estimating the differential post-Bonneville Dam survival for in-river and transported juvenile salmonids. The 50% value we used for yearling chinook was based on data presented in Bouwes et al. (1999). The subyearling value (35%) was based on data presented in PATH (1999). We increased the transport survival rate for subyearlings transported from McNary Dam to 60% to maintain a transport survival benefit for subyearling chinook migrating from the mid-Columbia River.

Competitive Interactions with Hatchery Fish

In the EDT analysis, hatchery fish can affect wild/natural populations through ecological or genetic interactions. Ecological interactions involve competition for food and space, predation (directly or indirectly by affecting behavior of predators), and ecological function. Genetic interactions result from hatchery fish interbreeding with wild fish in the natural environment.

We estimated competition effects due to hatchery fish based on estimated densities of hatchery juveniles by stream reach over time and on maximum densities drawn from the literature. We computed the density of hatchery fish from time and rate of release of hatchery fish at each facility and estimated rates of downstream movement of those fish. Using the Beverton-Holt survival function and benchmark maximum density parameters, we estimated the survival impacts on wild fish for every stream reach and time period. We did not include direct and indirect effects of predation in this analysis. We did include ecological effects due to nutrient enhancement from carcasses (positive increase in survival) and due to pathogens associated with hatchery programs as direct, site specific inputs.

Hatchery fish access natural spawning grounds inadvertently through straying or as a result of supplementation with the intent to augment natural spawning.

Adult (upstream) Dam Survival

Adult chinook survival past each mainstem dam was assumed to average 93% under the Current Potential (PATH 2000). Thus, total adult survival through mainstem river reaches is highly dependent on the number of dams each adult must pass. For example, adult chinook returning to the Salmon River would have to pass eight mainstem dams, and thus their overall survival rate would be 56% (0.93^8 = 56%)[1]. In contrast, the survival rate for adults returning to the John Day River would be approximately 80% because they must migrate past only three mainstem dams.

Under the Historic Potential, adult chinook survival through the mainstem Columbia and Snake Rivers was assumed to average 92%.

Genetic Effects of Hatchery Spawners

EDT assumes that, if hatchery fish are present in any specific population, they will spawn with naturally produced fish in the wild

Hatchery fish access natural spawning grounds inadvertently through straying or as a result of supplementation with the intent to augment natural spawning. We relied on RASP (1992) for estimates of the survival (fitness) effect on natural populations of hatchery introgression as a function of the hatchery-natural composition of the spawning population (Table 1). In order to calculate the ratio of hatchery to wild and compute the demographic contribution of hatchery spawners to the subsequent generation, we somewhat arbitrarily assumed that the total escapement (hatchery plus natural) to the spawning grounds would not exceed the natural spawner capacity.

[1] Corrected from 0.98^8=60% in Marcot et al. (2002).

Table 1. Relative survival parameters for hatchery produced fish and for natural populations influenced by hatchery fish (Moderate worldview).

Culture Method	Multiplier on natural production based on presence of hatchery fish			
	Percent hatchery fish spawning with naturally produced fish			
	> 50%	20-50%	10-20%	<10%
Conventional hatchery	75%	83%	93%	100%
Supplementation hatchery	82%	88%	95%	100%

Estuary Effects

Because biological rules were not developed for these areas, we used data from the literature and professional expertise to determine juvenile survival in each component of the marine environment. These survival rates were applied to each of the 74 salmon stocks analyzed.

For the estuary, biologists determined impacts to salmonids by developing ratings for a subset of the biological performance attributes. The ratings were based on USGS river flow data, river temperature information, the results of bird predation studies conducted near the mouth of the Columbia River (Roby et al. 1998) and marine mammal predation studies (reviewed in Park 1993).

Natural Ocean Survival

The nearshore area was used to describe the early ocean life of juvenile salmonids (period from ocean entry to December 31).

Chinook ocean survival rates used for modeling purposes beginning with the first full year in the ocean were the same as those used by the Pacific Salmon Commission Chinook Technical Committee (CTC 1988). The derivation of these rates is undocumented but are used the CTC for chinook cohort analysis, thus are consistent with their ocean modeling exercises. The rates are summarized by age (shown are ages for ocean type life history) in Table 2.

Table 2. Ocean survival rate by age class (chinook).

Age	Ocean Survival
2	0.6
3	0.7
4	0.8
5	0.9

Harvest

We obtained the data used in this analysis to determine the rate and location of adult harvest from the following sources:

- Fisheries Regulatory Assessment Model (**FRAM**)
- Chinook Technical Committee, Pacific Salmon Commission (**??**)
- Status Report, Columbia River Fish Runs and Fisheries, 1938-2000. (WDFW and ODFW 2002)
- 1996 All Species Review, Columbia River Fish Management Plan. US V. Oregon, **Technical Advisory Committee, 1997**.
- Biological Assessment, **Technical Advisory Committee. 1998**

For this analysis, we defined the harvest rate base period to be 1992-1996, and we developed harvest rates for both ocean and mainstem Columbia River fisheries (Zones 1-6). We based the harvest rates used in this analysis on published rates for ten Columbia River Harvest indicator stocks (see Marcot et al. 2004 for specific details). These indicator stocks were used in setting harvest rates for each of the 74 fish populations examined in the Multi-Species Framework analysis. The analysis does not include estimates of sport or commercial harvest in the tributaries. Thus, the adult run sizes reported for each subbasin are based on the number of fish entering each tributary.

III. Modifying Conditions

Pacific Decadal Oscillation

Ocean conditions strongly affect overall salmon survival. Salmon spend most of their life in the ocean and early ocean survival is widely considered to be a time of particularly high mortality. In recent years, a growing body of evidence from field, tagging, and correlation studies shows that Pacific salmon experience large year-to-year fluctuations in survival rates of juvenile fish making the transition from freshwater to marine environment (Hare et al. 1999). Climate-related changes have the most affect on salmon

survival very early in the salmon's marine life history (Pearcy 1992, Francis and Hare 1994).

The Pacific Decadal Oscillation is a pan-Pacific, recurring pattern of ocean-atmospheric variability that alternates between climate regimes every 20-30 years (Hare et al. 1999). The PDO affects water temperatures off the coast of Oregon and Washington and has cold (negative) and warm (positive) phases (Hare et al. 1999). A positive PDO phase brings warmer water to the eastern North Pacific, reducing upwelling of nutrient-rich cooler water off the coast of North America and decreasing juvenile salmon survival (Hare et al. 1999). The negative phase of the PDO has the opposite effect, tending to increase salmon survival.

Climatic changes are manifested in both returns and harvests. Mantua et al. (1997) found evidence of an inverse relationship between harvests in Alaska and off the coast of Oregon and Washington. The negative phase of the PDO resulted in larger harvests of Columbia River stocks and lower harvests of Alaskan stocks. In the positive phase, warmer water resulted in lower harvests (and runs) in the Columbia River, but higher harvests in Alaska. Phase reversals occurred around 1925, 1947, 1977, and possibly 1999. The periods from 1925-1947 and from 1977-1999 were periods of low returns to the Columbia River, while periods from 1947-1977 and the current period are periods of high returns.

El Nino/Southern Oscillation

The El Nino-Southern Oscillation (ENSO), commonly referred to as El Nino and La Nina), like the PDO, affects water temperatures off the coast of Oregon and Washington and has both a cold (negative) and warm (positive) phase. ENSO events are much shorter than PDO events in that events typically occur every 2-7 years and last 12-18 months. Positive ENSO events occur more frequently during positive PDO phases and less frequently during negative PDO phases (Hare et al. 1999). ENSO events intensify or moderate the effects of PDO changes on salmon survival.

A positive ENSO (El Nino) event also results in higher North Pacific Ocean temperatures, while a negative ENSO (La Nina) results in lower temperatures. Positive ENSO events occur more frequently during positive PDO phases and less frequently during negative PDO phases (Hare et al. 1999).

PDO and ENSO also affect freshwater habitat of salmon. Positive PDO and ENSO events generally result in less precipitation in the Columbia Basin. Lower stream flows result in higher water temperatures and a longer outmigration. It is likely that less water will be spilled over mainstem Columbia and Snake river dams to assist smolt outmigration (Hare et al. 1999).

Climate Change

Climate change on a longer term than the PDO could have a large impact on the survival of Columbia Basin salmon. Finney et al. (2000) used lake sediment elemental composition to find evidence of very long term cycles of abundance of sockeye salmon the Bristol Bay and Kodiak Island regions of Alaska over the past 300 years. No doubt there have been similar variations in the abundance of Columbia Basin salmon.

Computer models generally agree that the climate in the Pacific Northwest will become, over the next half century, gradually warmer and wetter, with an increase of precipitation in winter and warmer, drier summers (USDA Forest Service 2004). These trends mostly agree with observed changes over the past century. Wetter winters would likely mean more flooding of certain rivers, and landslides on steep coastal bluffs (Mote et al. 1999) with higher levels of wood and grass fuels and increased wildland fire risk compared to previous disturbance regimes (USDA Forest Service 2004). The region's warm, dry summers may see slight increases in rainfall, according to the models, but the gains in rainfall will be more than offset by losses due to increased evaporation. Loss of moderate-elevation snowpack in response to warmer winter temperatures would have enormous and mostly negative impacts on the region's water resources, forests, and salmon (Mote et al. 1999). Among these impacts are a diminished ability to store water in reservoirs for summer use, and spawning and rearing difficulties for salmon.

Climate models lack the spatial resolution and detailed representation of critical physical processes that would be necessary to simulate important factors like coastal upwelling and variation in currents. Different models give different answers on how climate change will affect patterns and frequencies of climate variations such as ENSO and PDO.

For the factors that climate models can simulate with some confidence, however, the prospects for many Pacific Northwest salmon stocks could worsen. The general picture of increased winter flooding and decreased summer and fall streamflows, along with elevated stream and estuary temperatures, would be especially problematic for in-stream and estuarine salmon habitat. For salmon runs that are already under stress from degraded freshwater and estuarine habitat, these changes may cause more severe problems than for more robust salmon runs that utilize healthy streams and estuaries.

While it is straightforward to describe the probable effects of these environmental patters individually, their interaction (PDO, ENSO, climate change) is more problematic. The main question appears to be the duration of the present favorable (for salmon) PDO period and the timing and intensity of the subsequent unfavorable period. Prudence suggests planning for a shorter favorable period and a subsequent longer, if not more intense, unfavorable period.

IV. Synthesis

To simplify application of OOSEs to subbasin assessments, we have aggregated the major sources of impact into a single smolt-to-adult-return rate (SAR) for survival from the time a population leaves the subbasin to the time it returns. If and when planners want to address the balancing of impacts across the four Hs (hydropower, habitat, harvest, hatcheries), SAR numbers will have to be disaggregated into the various components.

Aggregate Effects

The juvenile-to-adult ratios (JARs) used in the EDT Multi-Species Framework assessments are provided by Mobrand Biometrics (Chip McConnaha, personal communication) in Table 3. These rates are the total survival rate of juvenile fish from the mouth of the subbasin to their return to the subbasin as adults. They were calculated from intermediate EDT results.

Table 3. Juvenile-to-Adult survival rates (%) for chinook salmon used in EDT (Mobrand 2003)

	Yearling Outmigrants	Subyearling Outmigrants
Lower Granite Pool	0.9	0.4
Little Goose Pool	1.0	0.4
Lower Monumental Pool	1.1	0.5
Ice Harbor Pool	1.3	0.6
Lower Snake River	1.4	0.8
McNary Pool	1.4	0.7
John Day Pool	1.5	0.8
The Dalles Pool	2	0.9
Bonneville Pool	2.2	1.0
Lower Columbia River	3.1	1.4
Wells Pool	0.7	0.3
Rock Island Pool	0.9	0.4
Wanapum Pool	1.1	0.4
Priest Rapids Pool	1.2	0.6
Hanford Reach	1.4	0.8

The EDT estimates of survival were compared to smolt-to-adult survival estimates for spring chinook (yearling) populations above Lower Granite Dam (C. Petrosky, Idaho Department of Fish and Game January 9, 2004 e-mail), Table 4. These data update the earlier run reconstruction data reported by Marmorek et al. (1998). Since 1992 (the period used for the Multi-Species Framework project), the SAR geometric mean has been 0.8% and with an SAR range of 0.19% to 3.0%. The JAR from EDT of 0.9% is very

close to the post 1992 geometric mean. Therefore, we feel the EDT JARs can be used as a reasonable point estimate for yearling chinook SARs for those life history types entering each of the mainstem Columbia/Snake river reservoirs. To avoid excessive jargon we will use the acronym SAR to refer to survival from the time a fish leaves its natal subbasin to the time it returns as an adult, whether the number comes from EDT or empirical observations.

Table 4. Estimated smolt to adult survival from Lower Granite Dam to Lower Granite Dam for spring chinook and steelhead smolt outmigration years 1964-2000 based on run reconstruction.

Smolt Outmigration Year	Chinook SAR	Steelhead SAR
1964	2.35%	4.21%
1965	2.32%	3.68%
1966	2.31%	3.93%
1967	4.49%	4.01%
1968	2.58%	3.39%
1969	3.83%	3.66%
1970	1.92%	2.55%
1971	1.53%	2.27%
1972	1.02%	1.52%
1973	0.49%	0.63%
1974	1.39%	1.29%
1975	3.11%	1.84%
1976	0.92%	1.70%
1977	0.35%	0.90%
1978	0.98%	3.07%
1979	1.09%	3.18%
1980	0.55%	2.54%
1981	1.39%	1.11%
1982	1.70%	3.37%
1983	1.83%	2.63%
1984	2.56%	3.66%
1985		3.07%
1986		3.05%
1987		3.63%
1988		2.01%
1989		1.02%
1990		2.33%
1991		1.55%
1992	0.19%	1.04%
1993	0.38%	1.07%
1994	1.02%	1.18%
1995	0.31%	1.40%
1996	0.36%	1.61%
1997	1.72%	1.39%

1998	1.15%	1.89%
1999	2.91%	3.16%
2000	3.00%	4.68%

Given the exceptionally low 1992 SAR of 0.19%, we used the geometric mean for the four poorest post-1992 SARs (1992, 1993, 1995, and 1996) of 0.3% to represent for a SAR lower bound. And we used the highest SAR (3.0% in 2000) to represent good outmigration/ocean conditions for yearling chinook entering the Snake River above Lower Granite Dam. Choosing these estimates means that, under good conditions, SARs are 3.0/0.9=3.3 or 330% better than the point estimate. Under poor conditions, SARs are 0.3/0.9=0.33 or 33% of the point estimate. We applied this range of 33% to 330% to each point estimate from EDT to obtain the range of estimates for yearling Chinook outmigrants entering each reservoir listed in Table 5.

Table 5. Smolt-to-Adult (SAR) survival estimates (%) with ranges for Chinook yearling outmigrants.

Point of Entry	EDT Point estimate	Lower range	Upper range
Lower Granite Pool	0.9	0.30	2.97
Little Goose Pool	1.0	0.33	3.30
Lower Monumental Pool	1.1	0.36	3.63
Ice Harbor Pool	1.3	0.43	4.29
Lower Snake River	1.4	0.46	4.62
McNary Pool	1.4	0.46	4.62
John Day Pool	1.5	0.50	4.95
The Dalles Pool	2	0.66	6.60
Bonneville Pool	2.2	0.73	7.26
Lower Columbia River	3.1	1.02	10.23
Wells Pool	0.7	*	*
Rock Island Pool	0.9	*	*
Wanapum Pool	1.1	*	*
Priest Rapids Pool	1.2	*	*
Hanford Reach	1.4	*	*

* Specific SAR estimates for these populations were not available

No similar run reconstruction data is available for subyearling outmigrants. However, the Pacific Salmon Commission does calculate survival indices for fall chinook originating from the Hanford Reach. There is a significant linear relationship between the fall chinook survival indices and the spring chinook SARs since 1992 ($p<0.001$, $r2=0.749$, Figure 1). Furthermore, the rate of change between the SAR and the indices is similar as the slope of the regression line is 0.96. Therefore, it seems reasonable to use the same range (33% to 330%) around the subyearling chinook SARs as the yearling chinook SARs. The results are shown in Table 6.

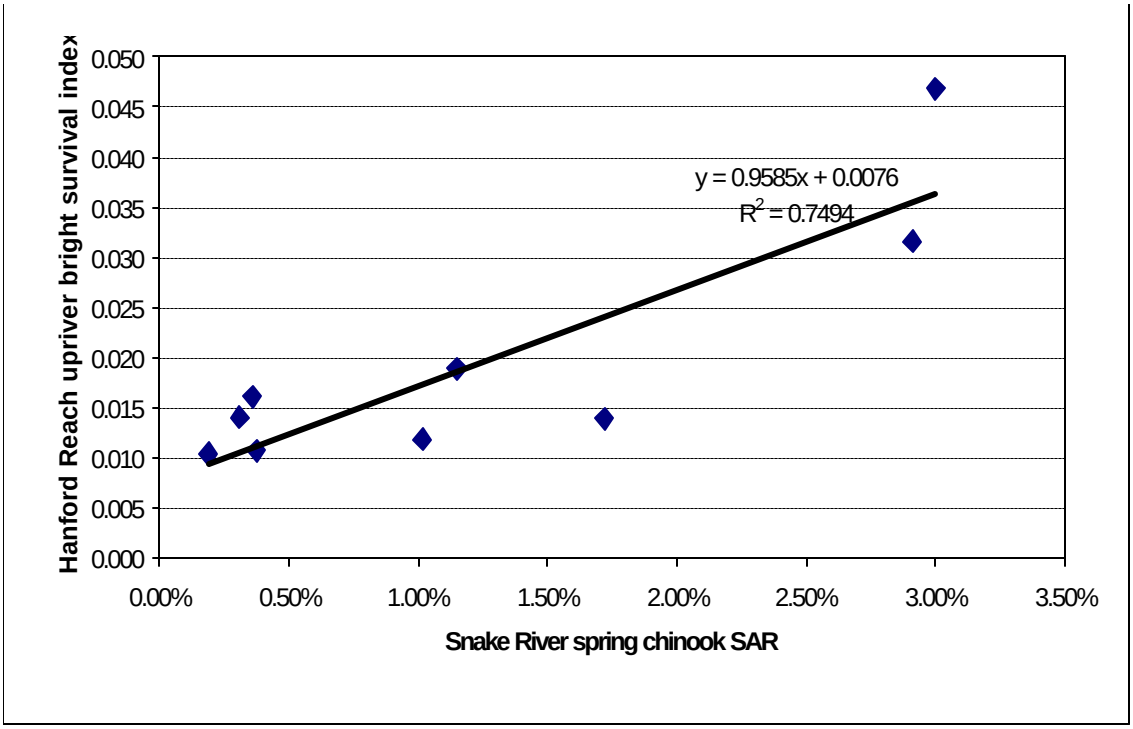

Figure 1. Comparison of Snake River spring chinook SARs and Hanford Reach upriver bright survival indices for smolt outmigration years 1992-2000

Table 6. Smolt-to-Adult (SAR) survival point estimates (%) with ranges for Chinook subyearling outmigrants.

Point of Entry	EDT Point Estimate	Lower Range	Upper Range
Lower Granite Pool	0.4	0.13	1.32
Little Goose Pool	0.4	0.13	1.32
Lower Monumental Pool	0.5	0.16	1.65
Ice Harbor Pool	0.6	0.20	1.98
Lower Snake River	0.8	0.26	2.64
McNary Pool	0.7	0.23	2.31
John Day Pool	0.8	0.26	2.64
The Dalles Pool	0.9	0.30	2.97
Bonneville Pool	1.0	0.33	3.30
Lower Columbia River	1.4	0.46	4.62
Wells Pool	0.3	*	*
Rock Island Pool	0.4	*	*

Wanapum Pool	0.4	*	*
Priest Rapids Pool	0.6	*	*
Hanford Reach	0.8	*	*

* Specific SAR estimates for these populations were not available

Species Other Than Chinook

Steelhead

EDT assessments for Steelhead populations were not included in the Multi-Species Framework project. Therefore, we used SAR survival estimates for steelhead populations above Lower Granite Dam (C. Petrosky, Idaho Department of Fish and Game January 9, 2004 e-mail), Table 4. The geometric mean SAR since 1992 for steelhead has been 1.69%. The minimum SAR since 1992 was 1.04% in the 1992 smolt year, while the maximum SAR was 4.68% in the 2000 smolt year. We assumed the same per-dam mortality rate as that for spring chinook to develop the SAR estimates in Table 7.

Table 7. Smolt-to-Adult (SAR) survival point estimates (%) with ranges for steelhead outmigrants.

Point of Entry	Point Estimate	Lower Range	Upper Range
Lower Granite Pool	1.69	1.04	4.68
Little Goose Pool	1.88	1.16	5.20
Lower Monumental Pool	2.07	1.27	5.72
Ice Harbor Pool	2.44	1.50	6.76
Lower Snake River	2.63	1.62	7.28
McNary Pool	2.63	1.62	7.28
John Day Pool	2.82	1.73	7.80
The Dalles Pool*	6.76	2.31	10.40
Bonneville Pool*	4.13	2.54	11.44
Lower Columbia River*	5.82	3.58	16.12

* Values are extrapolated from observations at Lower Granite Dam. Local data should be used instead, if available.

Sockeye

Sockeye salmon SARs were estimated for the three existing stocks (Fryer memo). Redfish Lake (Salmon River) sockeye SARs were from data supplied by Idaho Department of Fish and Game while Okanogan and Wenatchee SARs were computed using smolt estimates from smolt traps as well as the age composition of returning adults. Salmon River estimates represent the 1989-1994 brood years, Wenatchee estimates represent the 1995-1997 brood years, while the Okanogan estimates represent the 1994-1997 outmigration years. Two different techniques were used to estimate SARs for

basins where sockeye reintroduction may be considered. Given the proximity of the mouths of the Grande Ronde and Salmon rivers, the Grande Ronde SAR was assumed to be the same as the Salmon River SAR. Yakima and Deschutes SARs were estimated from Wenatchee SARs after factoring out 15% per project mortality.

Table 8. Smolt-to-Adult (SAR) survival point estimates (%) with ranges for sockeye salmon outmigrants.

Stock	Point Estimate	Minimum	Maximum
Wenatchee	1.3%	0.39%	4.29%
Okanogan	0.9%	0.27%	2.97%
Salmon	0.18%	0.05%	0.59%
Grande Ronde*	0.18%	0.05%	0.59%
Yakima*	2.2%	0.66%	7.26%
Deschutes*	3.0%	0.90%	9.90%

* Specific SAR estimates for these populations were not available

V. Application to Subbasin Plans

Subbasin planners can use this information to evaluate the robustness of and likelihood of achieving their objectives. The key parameter for evaluating the persistence and rate of rebuilding of a population is its productivity or average annual survival rate. This is one of the parameter estimates reported in the EDT output. The estimated population abundance is another assessment measure that can often be used to evaluate whether objectives will be met under various restoration scenarios. Subbasin planners can evaluate restoration options by using EDT output and the information on out-of-subbasin survival to respond to the following questions.

1. Describe the balance between within-subbasin and out-of-subbasin survival for each salmon focal species or population. This will provide a general perspective about the magnitude of the total problem and the proportion that can be addressed in the subbasin plan. If within-subbasin survival estimates are not available, a reasonable approximation can sometimes be obtained from a nearby subbasin or population.

2. Are subbasin objectives met under the preferred restoration scenario and average environmental conditions (point estimate SAR in the preceding tables)?

3. If not, are they met under:
    a. The most aggressive subbasin restoration scenario?
    b. The most optimistic out-of-subbasin environmental conditions (upper range SAR in the preceding tables)?

c. How much of a gap exists under “a” and “b,” above, if objectives are not met?

4. If subbasin objectives are likely to be met under one of the above scenarios, are they also met under expected poor environmental conditions (lower range SAR in the preceding tables)?

   If the answer to question 4 is “yes,” that is an indication that the plan is robust and sustainable. This is most likely to occur for populations using undisturbed habitats or located lower in the Columbia Basin.

   If the answer to question four is “no,” planners should discuss how they can use periods of above average survival to build a population to a status where they are likely to withstand periods of poor environmental conditions when survival is below average. In these situations, objectives may be met some, but not all, of the time.

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