APPENDIX 2

Parameters of model.

As a framework upon which to ground a biological opinion on steelhead viability in the CRLMA and Lapwai Creek, a stochastic relative abundance model was created to characterize the population in terms of source/sink meta-population dynamics. The dynamics of subpopulations and their relative input to the growth of the population as a whole has been recognized as an important consideration both in the legal fight over the BOR/LOID water withdrawal plan and on overall steelhead population in the CRLMA and the Clearwater basin as a whole.

Due to the paucity of data for individual streams, and the complexity of a model for each stream in the Clearwater, the basic assumption of the model is that sub-basins can be assumed to interact with each other as if they are a single stream.

To this end we utilized a simple model based on that set forth by Cooper and Mangel (1999) to model the relative abundance and population dynamics of salmon in a declining system. The basic equation is listed below:

$$N(i,t+1) = r(i,t)\left\{N(i,t)(1-f) + \sum_{j \neq i} s(j,i,t)\right\}.$$

$N(i,t)$ = the deme abundance in stream i in year t;
$r(i,t)$ = the per-capita reproduction in stream i in year t;
$s(j,i,t)$ = the number of fish that stray from their natal stream j to stream i in year t; and
f = the fraction of fish that stray from their natal stream (assumed equal for all demes).

Growth rate (r)is assumed to be determined by relative habitat ability with a baseline reproductive rate (z_0) and competing growth curves determined by z_1 and z_2 and limited by maximum and minimum constants for the decrease or increase in habitat (g and b).

$$r(i,t) = z_0 + g\left\{1 - e^{-z_1(i,t)}\right\} - b\left\{1 - e^{-z_2(i,t)}\right\}$$

To impart a more realistic stochastic affect on population abundance a random multiplier for (r) was added. This multiplier is a random number picked from a normal distribution with $\mu=1$ and $\sigma=0.066$ and is meant to simulate the natural year to year variability of reproduction due to environmental conditions.

The model was set up with the same parameters as was the simulation done by Cooper and Mangel with the exception of initial abundance and z_1 and $z_{2.}$

Based on the Table 1 of smolt potential/realized potential/stream miles a rough relative abundance for each stream was set (Table 2). This abundance equaled the smolt potential times the percent realization for each sub-basin converted to a ratio by dividing each by the total. This gives a relative score which should approximate the current values in the river. Absolute abundance is unnecessary in the model as it is simply comparative.

Relative abundance was then calculated as (100*r*[relative abundance score])

Absolute habitat values were scarce in our research. Rather than randomly assign habitat values to equal an expected “r” we instead estimated the productivity of the stream and ranked the streams in much the same way as for abundance. The realized smolt calculation from above was divided by the available stream miles to give an approximation of the productivity of the stream. These scores were each divided by the total to give a ratio of productivity. Z2 (bad habitat) was then held constant for all streams and the productivity score was entered for z1. Z_2 was varied to vary the # of sources and sinks while maintaining relative realtionships between streams.

This in effect changed the model to an “r” value based on habitat to one based on productivity. We believe that this is nonetheless a decent prediction of actual comparative growth rate in the stream and is more quantitative than the habitat assessments and thus more amenable to modeling. These scores fit nicely with the habitat assessments of each basin from our research with the Lochsa and Selway being considered the prime habitat and the Lower Clearwater and South Fork coming in a distant second place followed by the Middlefork and Lolo Creek which are considered to be comprised of much less breeding habitat.

In all cases habitat decreased at 5%/year beginning after the 5th year of the model. Individual streams were varied from that baseline rate in order to test the populations response to changes in habitat. Each model condition was replicated 5 times to create an average response to the treatment.

Table 1: From Clearwater Sub-basin Summary. Draft submitted to the Northwest Power Planning Council (November 2001) Estimated spawning/rearing area, total carrying capacity (smolt) and average percent of carrying capacity (parr) realized between 1985 and 1997 for steelhead trout within each Clearwater subbasin AU

Assessment Unit	Usable Area[1] (stream miles)	Estimated Capacity (# smolts)	Avg. percent realized[2] (85-97) (Idaho Dept. Fish and Game 1999a)
Lower Clearwater (A-run)	525.5	184,764	38
Lower North Fork	2	4,709	Unknown
Upper North Fork	Not Accessible	--	--
Lolo/Middle Fork	263.7	135,419	23
Lochsa	437.3	482,182	37
Lower Selway	241.8	238,978	46
Upper Selway	563.7	487,849	12
South Fork	389.2	201,358	25
Subbasin Total	2423.2	1,735,259	27

[1]Excludes reaches used only for migration purposes
[2]Derived from parr monitoring Database and presented for comparative purposes. No direct link has been established between parr and smolt production.

Table 2: Calculations based on table

1.

Sub-Basin	~Actual #Smolts (Capacity*%Realized)	Relative Abundance Score (~actual/total~actual)	Smolts/mile (~actual/Useable Area)	Productivity Score (~actual smolts/usablearea)/total
Lower Clearwater	70,203	0.21	133	0.1
Lolo	31,146	0.09	118	0.09
Middlefork	31,146	0.09	408	0.09
Lochsa	178,407	0.05	454	0.3
Lower Selway	109,929	0.32	103	0.34
Upper Selway	58,541	0.17	129	0.08
South Fork	50,339	0.15	129	0.1

Model output.

In constructing the model several relationships became clear. The Lower Selway and Lochsa were by far the most productive streams and thus were considered the prime sources within the overall population over a very wide range of poor habitat conditions ($z_{2)}$. Thus, under most situations 2 of seven streams are sources (28%), much lower than the assumption of 60:40% assumed by Cooper to be the ratio of a heavily impacted population.

As bad habitat (z_2) decreased the Lower Clearwater and South Fork eventually reach the point of becoming a population source. The two streams become sources at the same time meaning that the percentage of source streams jumps to 4 of 7 (60%).

This switch has implications for salmon populations. If habitat conditions are good enough that The Lower Clearwater and South Fork are sources the population could be much more stable than has been thought, an unlikely scenario based on population trends. It also presents the possibility that focus on habitat restoration in these two sub-basins could provide a high return on investment in terms of population stability as they are ‘next in line’ to become source populations if habitat improves.

Two model treatments were tested to examine the most interesting aspects of population dynamics given a declining system as a whole. The first was the condition in which a source population is allowed to degrade at a higher rate than the whole population.

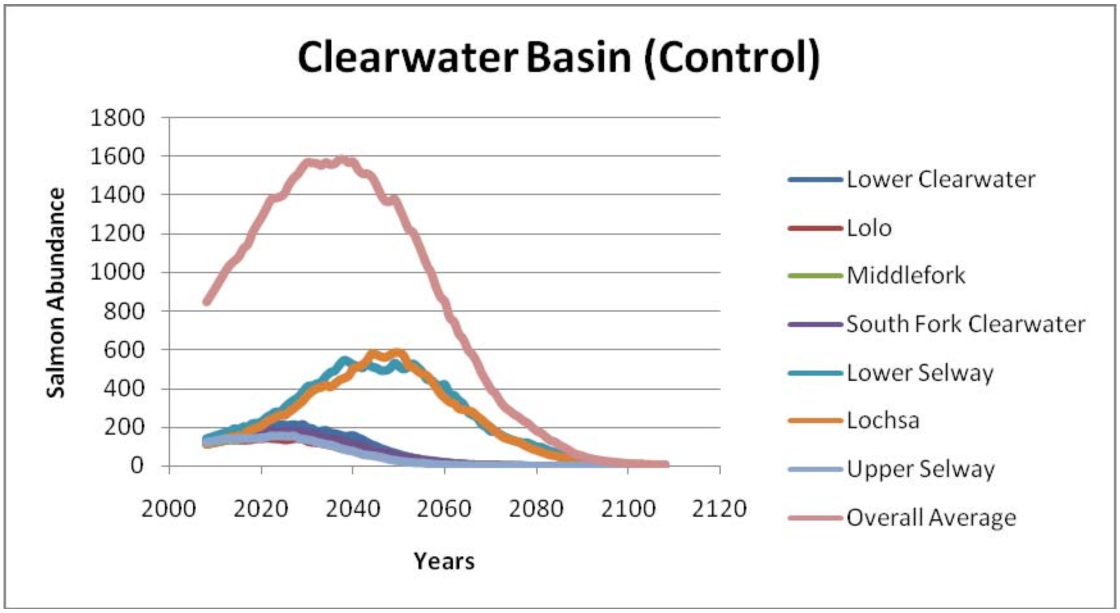
In the case of Lapwai creek this models the outcome that the BOR/LOID project is left at current levels over the long term. In terms of an overall declining system static, or increased, water withdrawal from a system results in increasing habitat destruction relative to the other sub-basins over time.

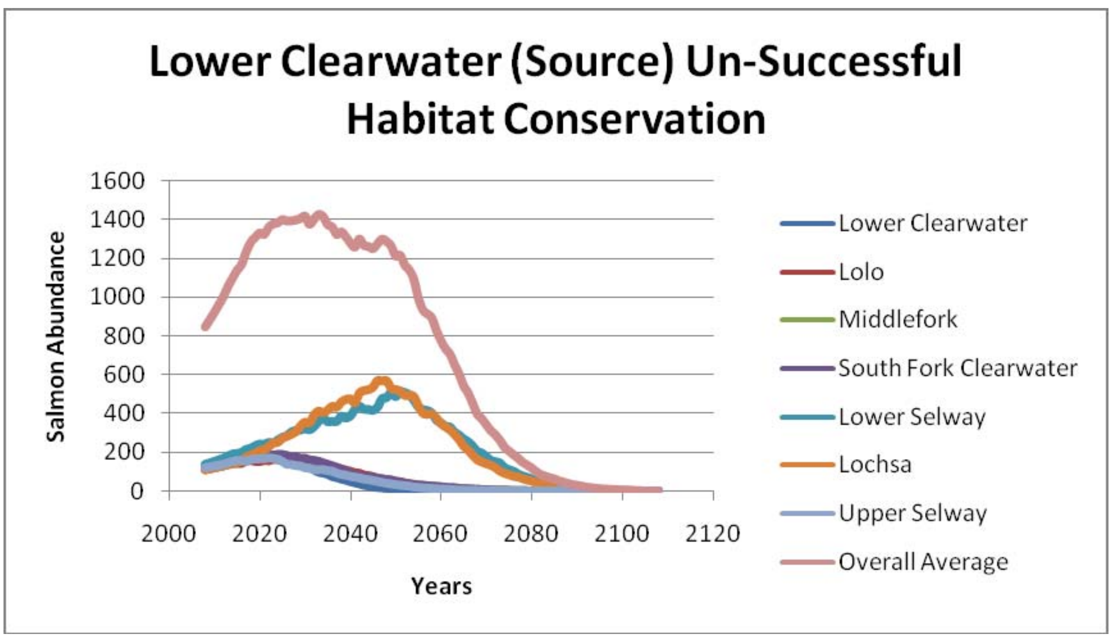
In this condition we assumed that overall habitat conditions in the CRLMA were favorable enough to allow the Lower Clearwater to become a population source (and assuming that Lawai creek contributes the majority of population growth within the sub-basin).

We set the z_1 of the Lower Clearwater to be slightly higher than the South Fork in this instance (So that the South fork was still a sink in the model) to better gauge only the affect of the Lower Clearwater. The Lower Clearwater was allowed to degrade at 8%/year compared to the rest of the populations which degraded at 5%/year.

In this case the reduction in habitat eventually rendered the Lower Clearwater a sink population. In five trials the increased degradation model resulted in an 11% average decrease in maximum salmon abundance in the ecosystem and resulted in a slightly faster rate of extinction. The difference was not statistically significant however the sample size (n=5) provided little power. The results are summarized below in Figure 1.

Figure 1: Model of un-successful habitat restoration in the Lower Clearwater

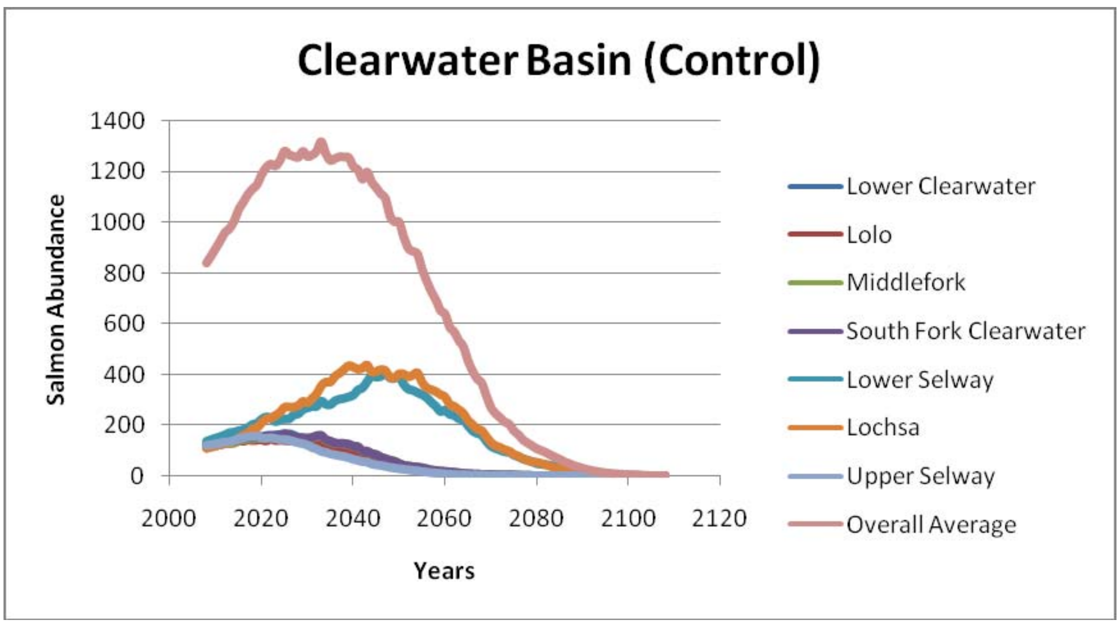


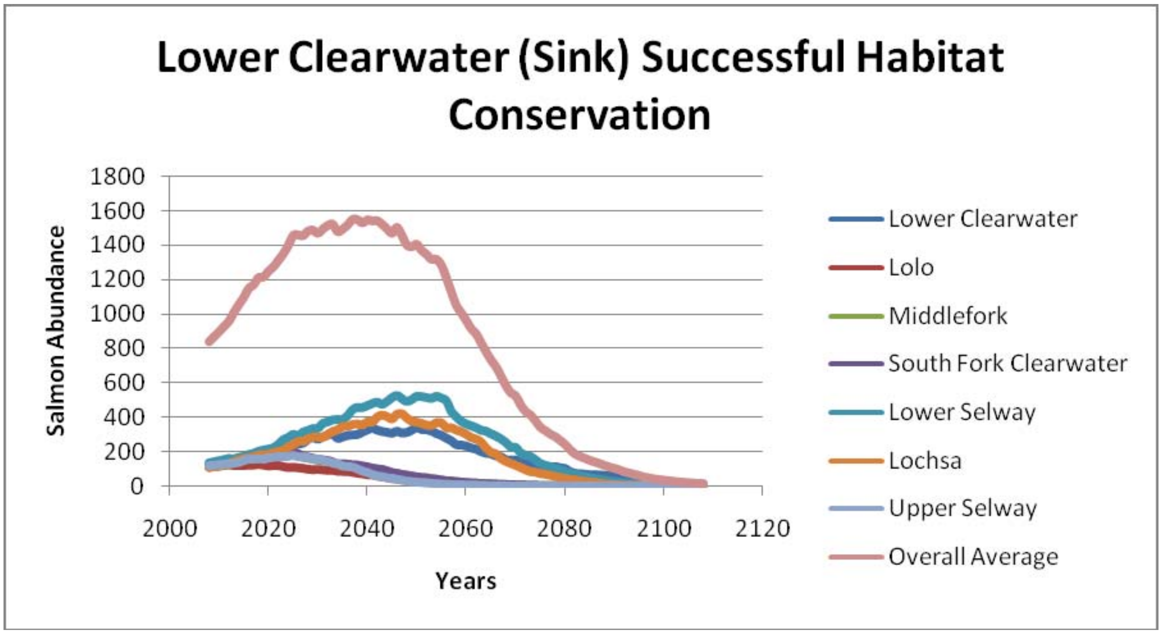


The second model treatment tested an assumption that all sub-basins in the system were sinks. It is possible for all populations to be sink habitats in a declining system due to habitat degradation. Populations can still persist for long periods (Cooper and Mangel), however they are doomed to decrease to extinction.

One interesting case for Lapwai creek would be if habitat restoration were successful despite Lapwai being a sink population. Overall habitat degradation in that case would be lower than that for the basin as a whole. When a model was run assuming that the Lower Clearwater degraded at a lower rate (2% vs. 5%) it was shown that despite starting as a sink the sub-basin became a relative source around year 2020. This subsequent increase in population due to improved habitat created a 15% increase in maximum abundance and helped to stabilize the population. The results could be expected to climb as relative habitat quality increases beyond this point as well. The results are detailed below in figure 2.

Figure 2: Lower Clearwater successful habitat restoration





Overall this data is encouraging and forms the basis of our opinion that the meta-population structure of steelhead in the Clearwater basin provides a good return on investment for effort expended to improve habitat in the Lapwai basin.

From our data it appears that Lapwai has the potential to be a strong source population for the overall Clearwater basin as well as within the CRLMA. Unfortunately data is too incomplete to show definitively that it is or is not. Still, Lapwai provides a large percentage of the steelhead adults in the CRLMA and thus could help to lift the Lower Clearwater region to the level of a source.

Based on the models in the worst case scenario, if Lapwai is allowed to stay the same or degrade, we can assume that it will have a deleterious effect on the entire region, albeit small. The Lower Clearwater sub-basin, however, could have a large stabilizing impact on the population if it were improve to become a source. There are currently most likely only 2 source populations (Lower Selway and Lochsa) which would tend to make the entire population less stable. Adding another, even at a lower rate would increase extinction time, and allow time for overall habitat improvement, and would also add significantly to the abundance.

In this instance it would be biologically advisable to improve the Lapwai habitat in the hopes of stabilizing the entire meta-population through the addition of the CRLMA as another source habitat . This will likely increase current population, a major goal for many stakeholders, while improving the outlook of the population in the future.