APPENDIX B: SALMON POPCYCLE MODEL STRUCTURE

INSTRUCTION FOR USE, AND ASSUMPTIONS

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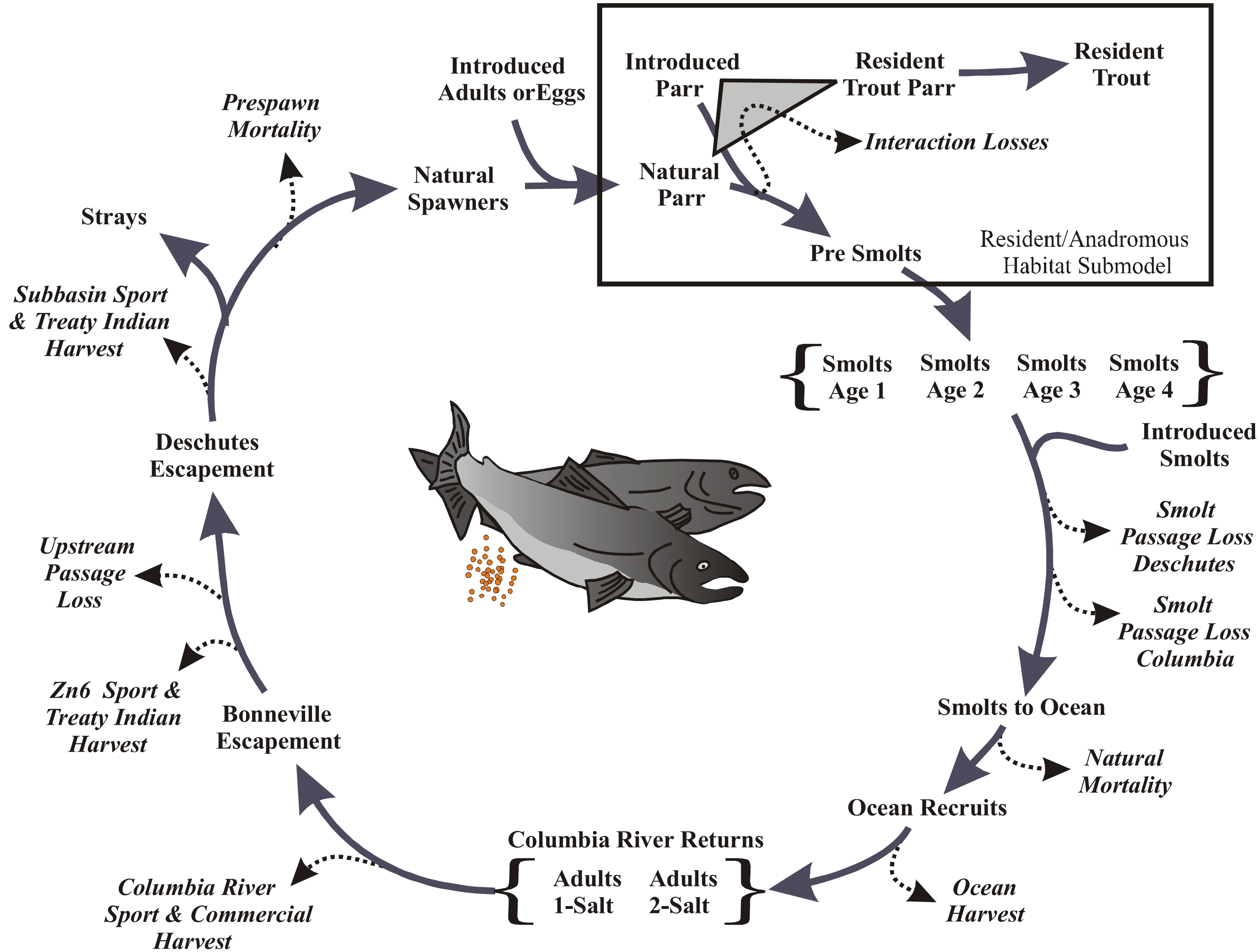
We applied a model to the Lewis basin which was originally developed as a life cycle model to systematically explore the potential for successful reintroduction of steelhead into the upper Deschutes Basin above Pelton and Round Butte dams (Beamesderfer, 2000). The model projects future upper Lewis adult spawner return numbers by reservoir based on reintroduction actions including stocking, fish passage, harvest, reproduction and survival rates, and capacity estimates derived from habitat assessments and EDT analysis by Mobrand Biometrics, Inc., 2002.

Model Structure

The Salmon PopCycle model is a series of mathematical equations which calculate future salmon or steelhead numbers based on numbers of eggs, juveniles, or adults outplanted or passed above Merwin, Yale, or Swift dams, survival rates, and reproduction rates. The model breaks the salmon life cycle into different stages so that the effects of specific activities and limiting factors can be evaluated (Appendix Figure B- 1). For instance, smolt passage mortality in the Lewis is an input which can be varied to examine its effects on future salmon numbers. Similarly, ocean survival rate is an input which can be used to examine how salmon numbers would be affected by changes in ocean rearing conditions which have contributed to poor returns of many salmon stocks in recent years. The model also can simulate a hypothetical resident trout population and its interaction with steelhead.

The population model is also a computer program which packages the mathematical equations with user-friendly “front” and “back” ends which make it easy to change inputs and look at graphs, tables, and averages of model outputs. Use of the model to answer key questions and evaluate the sensitivity of conclusions to assumptions is greatly facilitated by the addition of the interface which allows users other than the model developer to conduct simulations and inspect results. Other informed biologists can readily use the model to evaluate their own “what if” scenarios. For instance, key inputs for competition, habitat capacity, passage survival, etc. may be varied at the option of the user. The subsequent robustness and credibility of model conclusions is enhanced because its use can be readily demonstrated and tested by other users. Further, the interface can greatly simplify analysis of the central biological issues and focus on key choices rather than the arcane nuts and bolts in the underlying model.

Finally, the model is also a set of numbers and options which describe the expected fish population in the upper Lewis basin. Some input values such as future smolt and adult passage or collection rates at the dams remain unknown. Input values for these variables can be systematically varied to examine model sensitivity to their effects.



Appendix Figure B- 1. Diagram of steelhead and trout life cycle components represented in Deschutes model.

The model can be run in either deterministic or stochastic modes. Deterministic is a fancy way of saying that any given set of inputs leads to only one outcome. Thus, two plus two always equals four. This mode is particularly useful for looking at how changes in one input (passage survival for instance) affect future steelhead or salmon numbers. The stochastic mode incorporates the effects of chance and uncertainty to assign probabilities to future outcomes. In the stochastic mode, two plus two equals four on average but sometimes it also equals three or five. The stochastic model works by running many rather than just one set of simulations, randomly selecting input values which vary about a specified mean and variance. The frequency of different ending points is tallied to calculate probabilities of different results. The average ending point for simulation iterations is generally the same as the average condition predicted by the deterministic model. Stochasticity is important in evaluating things like extinction risks where populations might bottom out and go extinct because of normal variability in survival rates. Stochasticity is also important in examining the effects of periodic cycles in ocean survival conditions. For instance, reintroduction which might appear promising under favorable ocean cycles, might fail during unfavorable cycles and the stochastic model could identify the corresponding chances. The stochastic portions of the salmon PopCycle reintroduction model were adapted from a population viability model developed for ODFW assessments of fishing risks for Willamette spring Chinook (Beamesderfer 2000).

The intended use of the model is primarily by informed biologists as a gaming tool for exploring the results of alternative reintroduction scenarios and combinations of assumptions. To facilitate this use, the model includes the minimum complexity required to estimate impacts of the key factors of interest. For instance, the model treats the spring Chinook, coho, or steelhead populations in each of the three reservoirs as one homogenous unit rather than a series of sub-populations inhabiting a series of tributaries and reaches. Therefore, there are nine Lewis sub-populations that can potentially be analyzed in the PopCycle model. A common misconception is that more detailed models will provide more accurate and realistic results when in practice the opposite is often the case. Models which attempt to explicitly detail spatial scales and processes of a complicated biological system often provide unrealistic projections because of the difficulty in accurately estimating values and interactions for all detailed inputs. Over-parameterized models can also be difficult to use to explore the effects of different management actions and assumptions because simple changes in assumptions might require changes to many inputs.

The difference equations which comprise the model are solved at annual intervals. Number and life stage of salmon or steelhead planted upstream from the Lewis Projects are input by year and these fish are tracked by year and cohort from spawning and freshwater rearing through smolt migration, ocean rearing, fisheries, and freshwater migration of adults back to the spawning grounds. Options for outplants include eggs, smolts, and adults. Number of eggs produced was estimated as the product of spawner number, sex ratio, and fecundity. Wild parr numbers were estimated from eggs based on habitat conditions derived from EDT analysis. All density-dependent mortality for steelhead and salmon was thus assumed to occur during the freshwater egg to parr rearing stage. The model also can provide options for steelhead and trout interactions in the parr stage.

The model calculates surviving smolts beginning migration, passing through reservoirs, collected and trucked or passing the projects, passing through the lower Lewis and lower Columbia to reach the ocean, recruiting to maturity in the ocean, escaping ocean fisheries, escaping lower Columbia freshwater fisheries, returning to the Lewis basin, escaping lower Lewis fisheries, passing or trap and truck at the projects, and surviving to spawn in the upper basin. Adult recruits produced by each year-specific spawning cohort included adults returning at several ages.

Adult winter steelhead return to freshwater in the winter and spawn in spring. Offspring of those adults migrate seaward in the spring at least one year following spawning at freshwater ages 1+ to 4+. Adults mature and return to freshwater after 1 to 3 years in the ocean. Thus each brood year of parent spawners can contribute recruits which included 2-year olds three years later, 3-year olds four years later, and so on.

Adult coho return to freshwater in the fall and spawn in the same year. Offspring of these salmon species migrate seaward in the spring 1+ years following spawning. Adults mature and return to freshwater after two summers in the ocean, resulting in age-3 fish providing the entire adult spawning population.

Adult spring Chinook return to freshwater in the spring and spawn in early fall of the same year. Offspring typically migrate at least 1 year following spawning with some migration beginning in the fall but most migrate seaward in the spring after 1+ years in freshwater. Adults mature and return to spawn after 2 to 4 years in the ocean, thus each brood year contributes future adult spawners 4, 5, and 6 years after the parent spawns.

Model Development

We adapted this model from examples we applied to spring Chinook in the Willamette basin and steelhead in the Clearwater, Snake River, and Deschutes basins. Similar life cycle models have been widely applied throughout the Northwest to weigh salmon management and recovery alternatives. Many biologists working on the upper Deschutes system may be familiar with the PasRAS model which was developed for evaluations of Chinook and sockeye reintroduction efforts. The Salmon PopCycle model is similar to PasRAS in that both are life cycle models built with user-friendly computer software which makes it easy to run simulations and inspect results. Both models can be used to provide stochastic or deterministic results. Another similar life cycle model is the Lewis River Fish Passage Analysis Model (LRFPA) developed by Malone (2002) to evaluate reintroduction of coho into the upper Lewis basin. One difference between models is that the PopCycle model was tailored to include steelhead, spring Chinook, and coho life histories, while the LRFPA was developed specifically to model coho. A very important similarity is that both models do not explicitly require reach by reach inputs of habitat quality and capacity. Instead, reach-specific capacity estimates are used independent of the life cycle models to calculate an aggregate reservoir capacity by species which is then entered as a single input value which can be varied to explore the effects on model predictions.

Model building steps included:

1. Developing the conceptual model which identifies the key life stages and factors affecting steelhead, spring Chinook, and coho populations. We identified separate conceptual sub-models for the Lewis including: a) Swift spring Chinook, b) Yale spring Chinook, c) Merwin spring Chinook, d) Swift coho, e) Yale coho, f) Merwin coho, g) Swift steelhead, h) Yale steelhead, i) Merwin steelhead.
2. Determining the mathematical relationships among the model components included in the conceptual models.
3. Constructing a computer program to run the model.
4. Estimating parameter values for the mathematical functions to be used. Initial values for population parameters including reproduction and survival rates were selected from EDT analysis were derived from Mobrand Biometrics, Inc. (2002).
5. A series of sensitivity analyses were also performed where key parameters were varied to ensure the model was working as expected.
6. Using the model to simulate future scenarios.

Model Interface

To facilitate use by other biologists involved in this investigation, the model was developed as an application program with a graphical interface for varying inputs and inspecting results. The model interface includes a summary screen that displays when the model starts. The summary screen shows key inputs and results and provides a short cut/wizard way to run simulations. This wizard provides for a more user-friendly means for other informed biologists to easily explore the effects of alternative assumptions for passage mortality, habitat capacity, juvenile rearing density dependence, mainstem Columbia River smolt passage mortality, and other assumptions. The model also has detailed input and result display pages where more detailed and explicit changes in model inputs can be made. All inputs are identified on the input detail page. A subset of those inputs are displayed on the summary page. Values can be changed on either page.

Installation

The “stand-alone” executable program written in Visual Basic 6.0 also facilitates portability and eliminates problems of software incompatibility. The model is installed by running a setup program which unzips and installs the appropriate files. The setup adds the model to a computer’s Program Directory from which it can be started:

1. Load CD or copy model files (setup.exe, reintro.cab, reintro.dep) to your hard drive.
2. Run setup.exe using the run facility in the Windows start menu or using Windows explorer.
3. Answer questions in the setup utility.
4. OK to warning message to close other applications.
5. Click on install box to install in default directory (or change to another directory if desired).
6. OK to create a new project group (or install in existing group if desired).
7. Successful installation message should appear if everything works as it should.

Running the Model

The model program is started from the Windows program screen. Click on “Project 1” and “Deschutes Steelhead Model.” Default input values are automatically loaded and run when the model is started. New sets of input values can be saved to a file which can be reloaded for future simulations. This saves having to remember or re-enter a complicated series of changes when you wish to rerun or modify them. Input files are saved using the pull-down menu <File><Save> option. The sub-population models for the upper Lewis were loaded in this fashion.

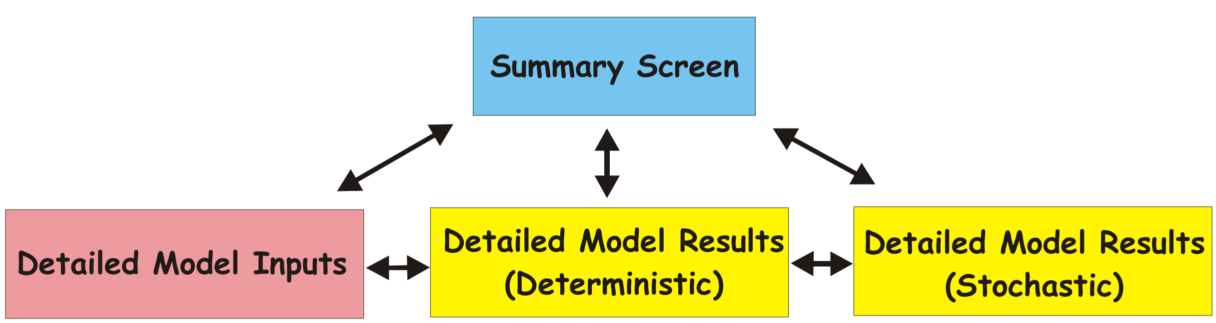
The typical modeling sequence involves changing default inputs, solving for new results based on new inputs, and inspecting new model results. Unlike a spreadsheet, the model will not automatically calculate results based on new inputs until the model is resolved. The model is resolved either by using the pull-down menu <Go> option under <Solve> or by clicking on <Solve> shortcut button in the lower left hand corner of the screen. Summaries of model results and the inputs which produced those results can by printed by selecting the <File><Print> option in the pull down menu. The model also automatically saves detailed results of each simulation in files named “lastrun1.txt” “lastrun2.txt”, and “lastrun3.txt.” Information in these files can be used for more detailed inspection of model results, additional analyses, or other graphs.

To exit the model, use the pull-down menu <File><Exit> option or click on the <Quit> shortcut button in the lower left hand corner of the screen.

The model is organized into four computer screens (Appendix Figure B- 2):

1. Summary Screen – This screen is displayed at start. The summary screen displays key inputs and results. Simple simulations can be run entirely from the summary screen.
2. Detailed Model Inputs Screen – This screen displays all model inputs and set-up options of which only a subset are displayed on the summary screen.
3. Detailed Model Results (Deterministic) Screen – This screen displays summary statistics, graphs, and tables of simulation results. A subset of these results are also displayed on the summary screen. Deterministic results are the average results projected by the model.
4. Detailed Model Results (Stochastic) Screen – This screen displays summary statistics, graphs, and tables of simulation results. A subset of these results are also displayed on the summary screen. Stochastic results include the frequencies of different model results based on random variation in input values.

The user can toggle between different display screens either by using pull-down menu options under “View” or by clicking on shortcut buttons in the lower left hand corner of the screen.



Appendix Figure B- 2. Screen interface structure.

Summary Screen

The summary screen (Appendix Figure B- 3) pops up when the model starts. This screen shows key inputs and results and provides a wizard way to run simulations. This wizard is a short cut for exploring the effects of things which are of particular interest. The summary page includes only a subset of the inputs and options required to configure and run the model.

Inputs on the summary screen are organized into two general categories including things we might manage and things generally beyond our control. Manageable inputs include things like numbers of eggs to be outplanted, years of egg outplants, juvenile passage survival, etc. Things beyond our control include the intensity of competition between trout and salmon, density dependence in the freshwater rearing stage, and inherent stock productivity.

The summary screen also displays simulation results in summary value, graphical, and tabular forms. Summary values include average, maximum, and starting and ending steelhead and trout numbers. Summary values also include the ratio of steelhead or salmon spawners produced to the spawner number which produced them. (This is an index of stock productivity.) Several different plots of results can be displayed by clicking on option buttons. Tables of results corresponding to selected options and graphs are also displayed.

Appendix Figure B- 3. Model summary screen. Labels refer to detailed descriptions in Appendix Table B- 1.

Appendix Table B- 1. Examples of inputs for Swift spring Chinook reintroduction model.

Label		Input description	Value
		Hatchery Releases	
	1	Adult outplants in upper basin (per year)	500
		Number of years of adult outplants are made	2
		Fitness scalar for planted adult survival (proportion relative to wild rate)	0.7
A	2	Egg outplants in upper basin (per year)	0
B		Number of years of egg outplants are made	0
		Fitness scalar for planted egg survival (proportion relative to wild rate)	0.7
	3	Smolt outplants / year	100,000
		Number of years of smolt outplants are made	5
		Fitness scalar for planted smolt survival (proportion relative to wild rate)	0.7
		Freshwater competition	
	4	Juvenile trout number prior to steelhead reintroduction	0
	5	Adult trout number prior to steelhead reintroduction	0
I	6	Competition (% reduction in steelhead carrying capacity as a result of competition with trout)	0
		Habitat quality	
H	7	Percentage of current (this scalar can be used to consider habitat improvements)	100
	8	Years to reach increased percentage	--
		Model set up	
	9	Years to run	50
	10	Iterations (1 for deterministic simulations, many for stochastic simulations)	1
	11	Stochastic parameter – small population number below which frequency is be tracked	300
	12	Stochastic parameter – average ending population size above which frequency is to be tracked	1,800
	13	Stochastic parameter - large population number above which frequency is to be tracked	1,800
		Depensation	
	14	Option buttons used to reduce stock productivity at low run sizes consistent with small population demographic or genetic risks. Input value is population size below which depensation occurs. Use the plot parr vs. spawners option to observed effects (R in the summary, 7 in deterministic results screens)	None
		At none, egg to presmolt survival follows the stock-recruitment curve which increases to the maximum specified rate in #18	--
		At low, egg to presmolt survival is capped at the rate specified for the stock-recruitment curve at the population size where depensation begins	--
		At high, egg to presmolt survival gradually drops to zero below the rate specified for the stock-recruitment curve at the population size where depensation begins	--
		Reproduction	
	15	Sex ratio of adult return (female proportion)	50
	16	Fecundity (average eggs per female)	4,200
J	17	Egg to presmolt survival options	
		Beverton-Holt is density dependent stock recruitment curve using parameter inputs specified in input #18 and #19	Yes
		Density independent uses an average rate which is input in #18. Note that the program automatically toggles between Beverton-Holt and average input values for #18 as the option is switched	No
K	18	Beverton-Holt equation - maximum egg to presmolt survival rate (avg.)	0.0680
L	19	Beverton-Holt equation parameter – juvenile rearing capacity	68,172

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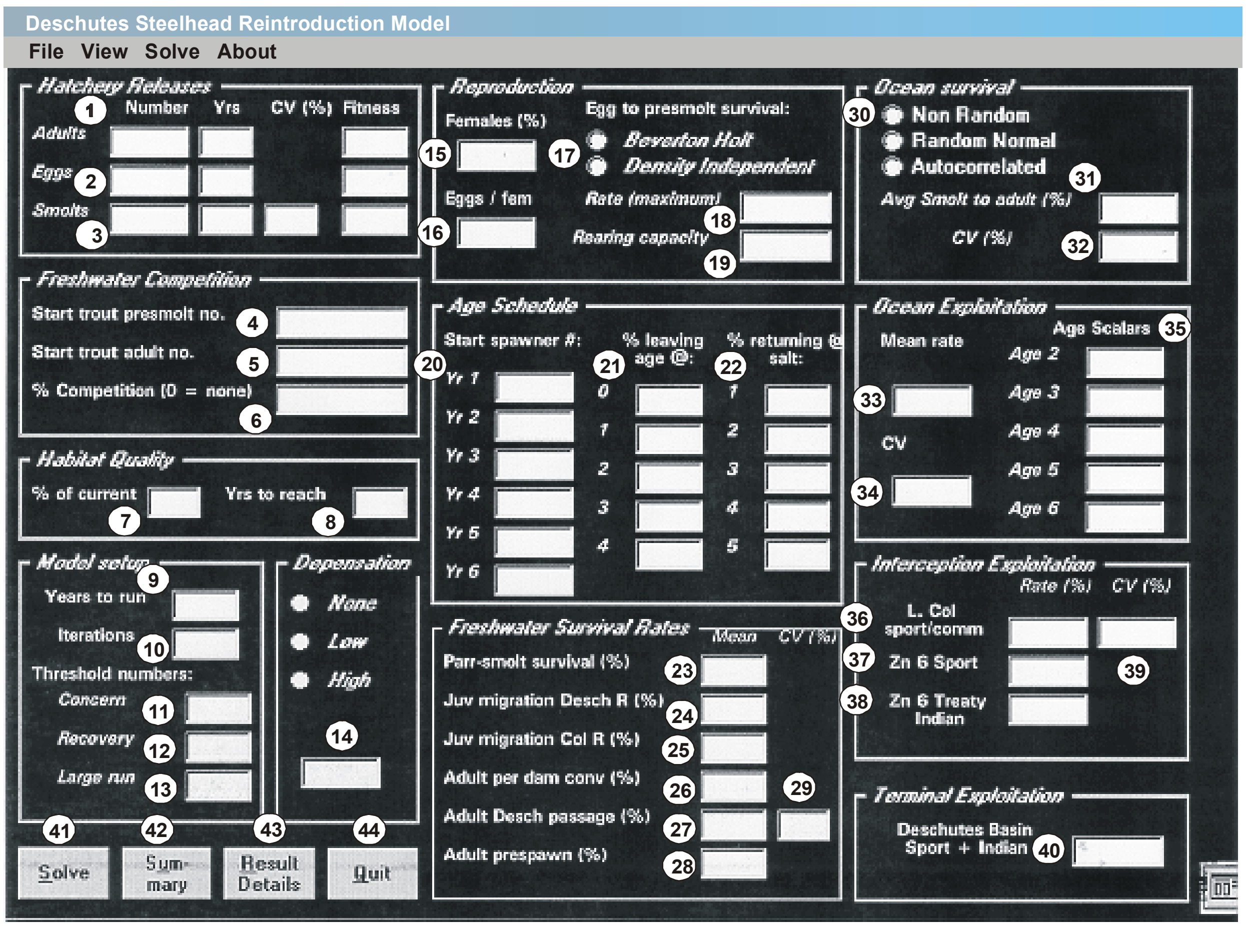
Appendix Table 1. (continued)

Label		Input	Value
		Age schedule	
	20	Spawner numbers for up to 6 prior years. This is used only where modeling an existing population which contributes to current returns	0,…,0
	21	Smolt migration proportion at ages 1,…,4	10,90,0,0
	22	Maturation proportion after 1, 2, or 3 years in ocean. Note that for steelhead these are independent of smolt migration age because we lack data to determine otherwise	0,10,60,30
		Freshwater survival rates	
	23	Parr-smolt survival rate – density independent proportion of presmolts that survive to begin migration	100
C	24	Deschutes smolt passage efficiency (% that are collected and survive passage at projects)	Variable
D	25	Columbia River smolt migration survival	Variable
	26	Mainstem upstream conversion survival rate of adults per dam	Variable
G	27	Deschutes adult passage efficiency (% that are collected and survive passage at projects)	Variable
	28	Prespawn survival (% of adults passed into the upper basin that survive to spawn)	95
	29	Coefficient of variation in adult passage efficiency expressed as a percentage of the average rate. This variability could be used in stochastic simulations but is otherwise 0	0
		Ocean survival	
M	30	Ocean survival rate options between smolts which reach the ocean and adults available to ocean fisheries or spawning migrations	
		Non random would be a fixed deterministic rate at the #31 input value	Yes
		Random normal varies about the mean rate based on a coefficient of variation input for #32	No
		Autocorrelated varies about a mean rate based on an autocorrelated pattern similar to that which typically occurs where poor years tend to be clumped	
	31	Average smolt to adult survival rate upon reaching the ocean	.029
	32	Coefficient of variation in average smolt to adult survival rate upon reaching the ocean	0, 29
		Ocean exploitation	
	33	Ocean harvest rate – average percentage of adult ocean recruits impacted by ocean fisheries	.11
	34	Coefficient of variation in ocean harvest rate	0
	35	Age scalars used to calculate age-specific ocean harvest impact rates (Actual age-specific rate is product of average rate and age scalar)	1,…,1
		Interception exploitation	
	36	Harvest rate/impact in combined lower Columbia River fisheries	.03
	37	Harvest rate/impact in Zone 6 sport fishery	0
E	38	Harvest rate/impact Zone 6 Treaty Indian	0
	39	Coefficient of variation in lower Columbia River fishing impact rate	0
		Terminal exploitation	
F	40	Harvest rate/impact rate in combined Deschutes basin sport and Indian fisheries	.02

Detailed Model Inputs Screen

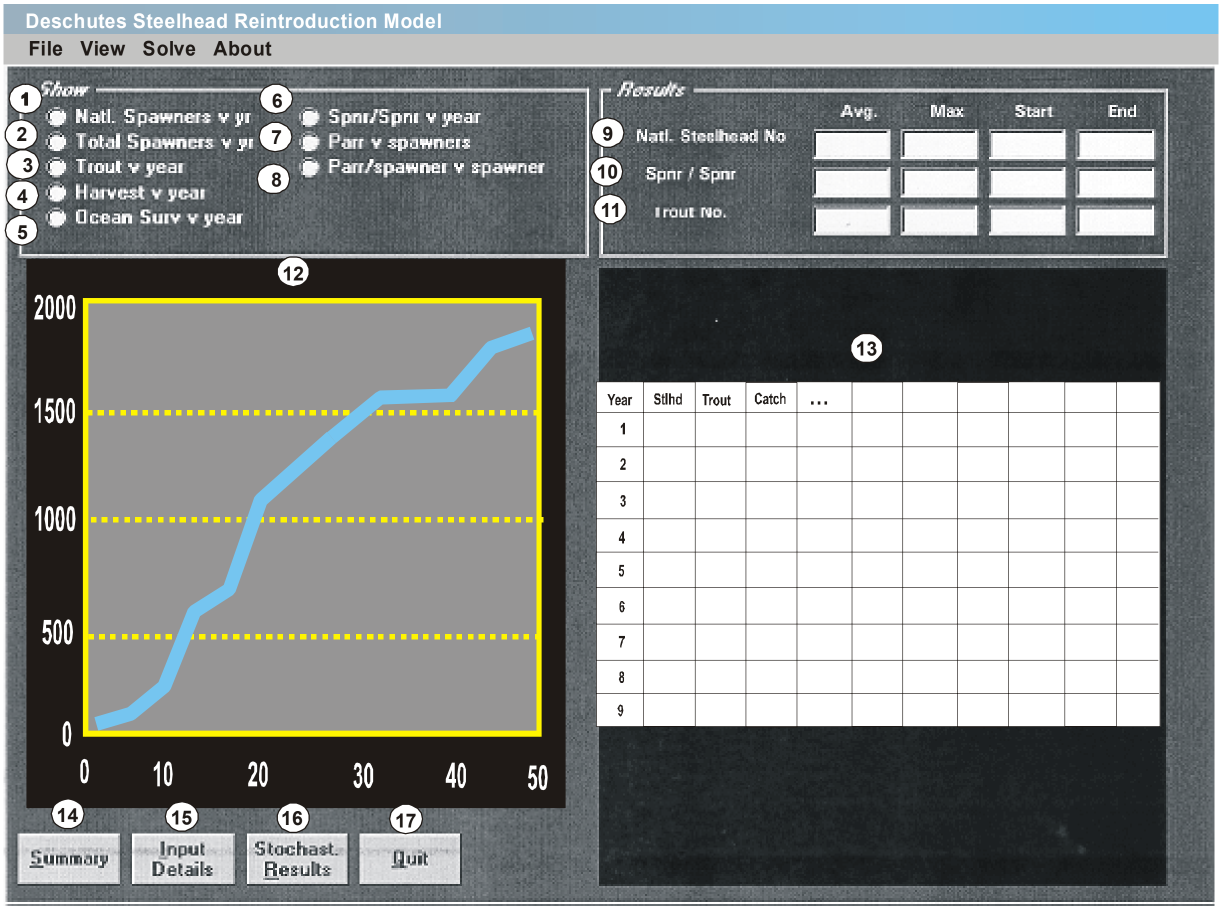
All model inputs and options are displayed on the input detail page. Values can be changed on either the summary or detailed input pages. Input categories include model setup, hatchery release numbers, freshwater competition, habitat quality, reproduction, depensation, age schedules, freshwater survival rates, ocean survival rates, ocean exploitation rates, interception exploitation rates, and terminal exploitation rates.



Appendix Figure B- 4. Detailed model inputs screen. Labels refer to detailed descriptions in Appendix Table B- 1.

Detailed Model Results (Deterministic) Screen

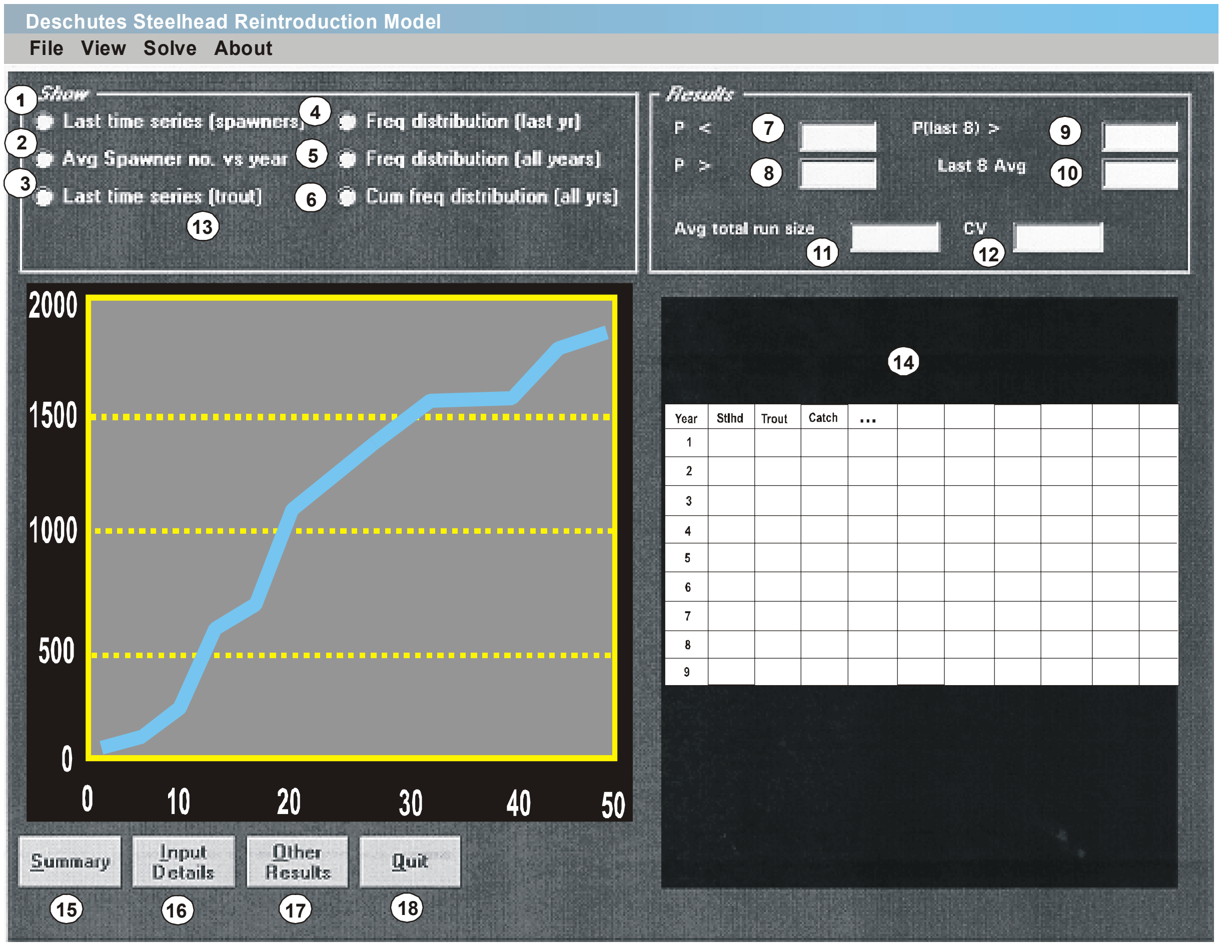
The deterministic model results screen displays many of the same results displayed on the summary screen and some additional options.



Appendix Figure B- 5. Detailed model result (deterministic) screen. Labels refer to detailed descriptions in Appendix Table B- 1.

Detailed Model Results (Stochastic) Screen

The stochastic model results screen displays provides more detailed descriptions of results of simulations where multiple iterations were run using random variability for selected model inputs. This page thus shows probabilities of different extremes rather than the average results displayed on the summary and deterministic result pages.



Appendix Figure B- 6. Detailed model result (stochastic) screen. Labels refer to detailed descriptions in Appendix Table B- 1.

Model Inputs

Introduction Numbers

Reintroduction options including releases of adults, eggs, or smolts are at the discretion of the user. Numbers, duration, and fitness are input. The fitness scalar option was provided for each life stage so that outplant performance could be discounted if outplanting resulted in poorer-than-natural performance. For instance, the fitness scalar for eggs would be 1.0 if eggs are assumed to survive at a rate equal to those of naturally spawned eggs. If survival was only 50% of naturally spawned eggs, the fitness scalar would be 0.5.

We recommend a fitness scalar of approximately 0.7 for hatchery smolt outplants relative to naturally-spawned smolt performance based on the following rationale. Columbia River mouth return rates averaged 5.6% for 1975-1996 brood year hatchery smolt releases in the Deschutes River. At an assumed 10% passage mortality in each of two mainstem Columbia River dams, the corresponding average smolt survival rate would be 6.9%. This hatchery smolt survival rate is approximately 70% of the assumed 10% natural survival rate we applied to naturally produced steelhead smolts.

Appropriate fitness scalars for adult outplants are unclear. Significant differences in reproductive success of hatchery steelhead and wild steelhead have been observed for some stocks. For instance, spawning success of winter and summer steelhead adults from some Washington hatcheries has been observed to be between 0% and 32% that of wild fish, primarily because hatchery stocks have been selectively bred for an early spawn timing (Dan Rawding, WDFW, personal communication). Relative spawning success has averaged about 10% for Chambers Creek winter steelhead (a Puget Sound stock) and 12-15% for Skamania summer steelhead in the Kalama River (Dan Rawding, WDFW, personal communication). Whether hatchery selection pressures will result in similar differences for Lewis River wild and hatchery stock steelhead is unclear. However, differences in the survival rates of wild and hatchery smolts spawned and reared in Round Butte Hatchery (Reisenbichler and McIntyre 1977) suggest some divergence has occurred.

An appropriate fitness scalar for egg outplants is similarly unclear because we lack information on relative survival rates of naturally spawned and hatch-box eggs. However, some reduction in hatch-box survival rates relative to naturally spawned eggs seems likely because of widely reported difficulties with maintenance of flows and natural temperatures in hatch-boxes. In the absence of more definitive information on the relative fitness of outplants of hatchery fish and of eggs reared in hatch-boxes, we applied the same 0.7 that we derived for hatchery smolt outplants.

The fitness scaler for outplants does not effect the long term results of the model as long term population stability is dependent on survival and productivity of fish spawned and reared in the natural environment. The short term returns, however, are affected by the fitness scaler when a significant proportion of the returning adults are produced from parents originating from the hatchery environment.

Natural Production

Estimates of natural production start with eggs produced by female spawners. The spawner numbers are based on escapement past Lewis River dams minus pre-spawning mortality. Some adult steelhead and salmon die of natural causes during the period of freshwater holding before spawning. Olsen et al. (1991) reported a 9.2% average pre-spawning mortality rate for 1973-1989 brood years of hatchery summer steelhead held at Round Butte Hatchery after collection at the Pelton Ladder Trap. The NPPC (1989) used a value of 10% pre-spawning mortality in their System Planning Model for summer steelhead. Similar values have been estimated for spring Chinook salmon based on egg retention in carcass samples (Beamesderfer et al. 1997). We assumed a lower pre-spawning mortality in the Lewis model because of a generally reduced holding time for winter steelhead, coho, and spring Chinook as compared to summer steelhead in the mainstem Columbia and Deschutes. We modeled a fixed 5 percent pre-spawning mortality for all species in the Lewis model.

Total eggs are the product of spawners, the percentage of spawners that are females, and female fecundity. Female sex ratio and fecundity were estimated. Average values were used for all simulation years. The average fecundity used for steelhead was 5,000 eggs per female, for spring Chinook 4,000 per female, and for coho 2,600 per female. The female sex ratio used was 50 percent for all species.

Habitat Condition

The model provides for adjustments to habitat condition relative to a starting baseline so that model sensitivity to habitat restoration or degradation can be examined. Model inputs include a scalar which describes the new habitat condition as a percentage relative to the baseline (i.e. 150% = a 50% improvement in habitat condition). Model inputs also include the time period in years over which the change occurs. For each simulation year during the period of change, the model increments habitat condition by the percentage change divided by the number of years in the time period. For instance, a 150% condition achieved within 25 years would result in a (150-100) / 25 or 2% increase per year.

In the framework of this life cycle model, habitat condition affects fish through quality and capacity effects. The model relates habitat quality and capacity to density-dependent survival of eggs through some point in the freshwater juvenile stage. We generically denote this stage as parr. Increases in the quality of a given area of habitat, through habitat improvement activities for instance, might be expected to increase productivity of the population which the model expresses as an increase in egg-to-parr survival rates for a given density of eggs or spawners. Increases in quantity of habitat, as where removal of a passage barrier opens up new production areas, increase the carrying capacity which the model expresses as the maximum number of parr which could theoretically be supported by the available habitat. The habitat condition scalar input for the model affects the habitat capacity parameter of the density-dependent egg-to-parr survival rate equation but does not affect the habitat quality parameter.

Stock Productivity

The success or failure of salmon and steelhead reintroduction into the upper Lewis basin hinges in part on the productivity of the reintroduced population. Productivity can be defined as the capacity of a population to increase or replace itself. Productive populations produce many juvenile and adult recruits per spawner. Unproductive populations produce few recruits per spawner. Populations cannot be sustained over the long term if adult recruits per spawner are less than one. A highly productive population can expand readily into new areas, increase rapidly from low numbers, and withstand significant human impacts or variation in natural survival conditions. An unproductive population expands or increases slowly and is vulnerable to other mortality factors including fishing, dam passage, and variable ocean conditions. Various indices of population productivity have been described including the intrinsic rate of increase used by the NMFS cumulative risk initiative for listed stocks and stock-recruitment relationship parameters favored by many fishery biologists.

The model applies stock productivity based on density-dependent egg-to-parr survival rates, which are derived from results of Mobrand's 2002 EDT analysis. We used a multistage function described by Moussalli and Hilborn (1986) which allowed us to emulate a Beverton-Holt stock-recruitment relationship. Moussalli and Hilborn (1986) demonstrated that a single Beverton-Holt curve could be used to describe a series of life stages with density dependent survival, or conversely, that density-dependent functions could be disaggregated into separate functions for each stage. Similar functions have been widely validated as underlying constraints to salmonid population dynamics and provide for realistic models of population behavior over a broad range of population sizes (NPPC 1986; Byrne et al. 1992). The function includes productivity (p) and capacity (c) parameters:

$$\text{Parr} = (\text{Eggs} * p) / \{1 + [(\text{Eggs} * p) / c]\}$$

Capacity (c) is the asymptotic maximum number of parr which can be produced by the habitat and productivity (p) is the maximum egg-to-parr survival rate which would be expected to occur at low densities. This approach results in egg-to-parr survival rates which decrease as habitat capacity is approached. All density-dependent freshwater rearing effects are thus represented in the egg-to-parr stage. Density dependent survival for steelhead and salmon is typically modeled between spawning and juvenile rearing. Egg-to-parr survival rates for the upper Lewis sub-populations include: 0.068 for Swift spring Chinook, 0.054 for Yale spring Chinook, 0.077 for Swift coho, 0.057 for Yale coho, 0.051 for Merwin coho, 0.036 for Swift steelhead, 0.043 for Yale steelhead, and 0.046 for Merwin steelhead.

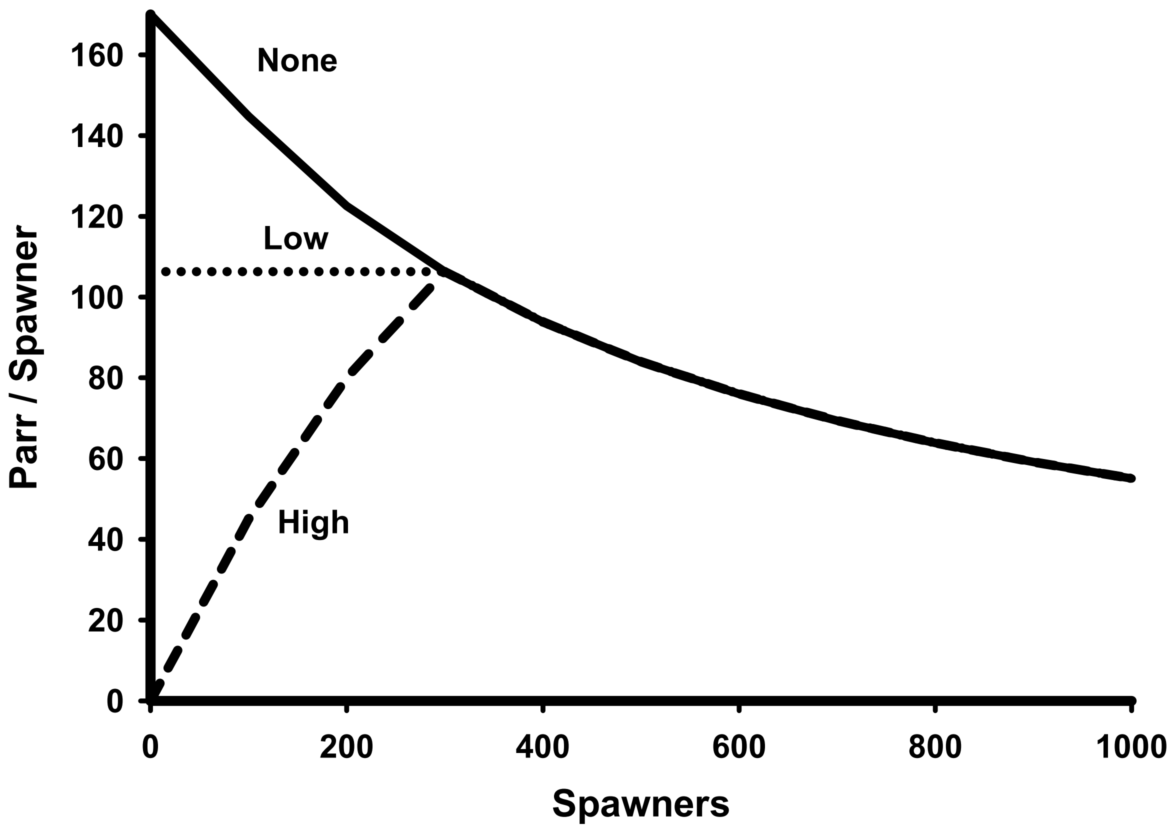
Freshwater Carrying Capacity

The model defines freshwater carrying capacity at the smolt stage based on the maximum number of parr which the habitat will support given current habitat conditions as determined by habitat assessments and EDT analysis by Mobrand Biometrics, Inc. 2002. This asymptote parameter is input as the rearing capacity in the Beverton-Holt egg-to-parr survival equation. The baseline parr and smolt capacity estimate corresponds to an adult spawner capacity developed in the EDT analysis. There are nine separate smolt carrying capacities estimates used to model sub-populations of the upper Lewis watershed including; 68,172 spring Chinook in Swift, 26,945 spring Chinook in Yale, 0 spring Chinook in Merwin, 226,879 coho in Swift, 80,842 coho in Yale, 49,068 coho in Merwin, 29,920 steelhead in Swift, 2,588 steelhead in Yale, and 2,965 steelhead in Merwin.

Depensation

Options are included in the model to allow depensation at low spawner escapements. Depensation is the reduced production or survival which may occur at low spawner numbers. The traditional stock-recruitment function calculates ever-increasing recruitment rates at low spawner numbers such that theoretical populations based on these relationships are unrealistically difficult to extirpate and assessments over estimate stock productivity. In practice, the traditional stock-recruitment begins to fall apart at low population sizes as a result of the loss of genetic diversity which helps maintain the stock over a wide range of habitat and environmental conditions, inbreeding depression which increases chances for expression of deleterious recessive traits, demographic problems such as difficulties in finding a mate, and predator or competitor traps. Low population processes are often referred to as “allele effects” (Hilborn and Walters 1992, McElhany et al. 2000).

Depensation options include “low” depensation where parr-per-egg survival rates are fixed at spawner numbers less than a designated threshold and “high” depensation where parr-per-egg numbers incrementally decline to zero at spawner numbers less than the designated threshold (Appendix Figure B- 7). Various threshold levels have been identified (McElhany et al. 2000, Beamesderfer 2001). For sensitivity analyses in this assessment, we used a threshold of 300 spawner consistent with the Oregon Department of Fish and Wildlife Native Fish Conservation Policy. This threshold should be considered a benchmark for comparative purposes rather than a hard-and-fast limit. The exercise is primarily to determine what level of depensation might be important if in fact it does occur. Simulation with depensation can be used to provide more conservative assessments of reintroduction prospects. Depensation options are primarily used in stochastic simulations of low population risks. We use the 300 spawner threshold to represent a value in which to judge relative risks when comparing sustainability of natural salmon and steelhead populations in the three reservoirs.



Appendix Figure B- 7. Effects of depensation options on parr versus egg relationships.

Parr to Smolt Survival and Smolt Ages

The model estimates smolt numbers as the product of parr and a density-independent parr-to-smolt survival rates. This quantity allows us to partition juvenile mortality into a density-dependent component which we represented in the egg-to-parr stage and a density-independent component which we represented in the parr-to-smolt stage. We fit the Salmon PopCycle to the EDT results which estimated carrying capacity in smolt numbers instead of parr. We made the transition by inputting the EDT smolt carrying capacity in the parr capacity input of the model, but used a 100 percent parr-smolt survival rate to equate the input to a smolt capacity value consistent with EDT. The model could also be used with a parr capacity value if preferred by simply expanding the EDT smolt capacity by a parr-to-smolt survival rate. For example, the Swift spring Chinook smolt capacity is estimated by Mobrand Biometrics, Inc. to be 68,172 and would correspond to a parr capacity of 136,344 if a 50 percent parr-to-smolt survival rate was assumed. Wild steelhead studies in Idaho estimated that parr-to-smolt survival averages 50% (Cramer et al 1997). We simplified our approach by entering the smolt capacity as parr capacity input and then applied an artificial 100 %percent parr-to-smolt survival. The outcome of both approaches results in the same smolt capacity of 68,172 for Swift spring Chinook.

Resident Trout Interactions

The model currently includes hypothetical relationships for trout populations and steelhead-trout interactions which can be used to explore sensitivity to competition. The strength of the competitive interaction, trout parr numbers, and trout adult numbers are explicit model inputs. The strength of the competitive interaction identifies a reduction in steelhead parr carrying capacity which results from the input parr number. For instance, an input of 20% will reduce the habitat capacity parameter in the egg-to-parr survival rate curve by 20%. The model calculates a trout-steelhead competition coefficient based on the competitive interaction input which it applies to future steelhead and trout numbers:

coefficient = [(parr capacity) * (competitive interaction)] / (number of trout parr)

The future capacity of the habitat for steelhead parr is reduced proportional to the product of future trout parr numbers and this competition coefficient. Future trout numbers are reduced proportional to the product of steelhead parr numbers and this competition coefficient. Future trout adult numbers are estimated based on trout parr numbers and the ratio of input parr and adult numbers. We did not activate the resident trout interaction relationship for modeling steelhead reintroduction in the upper Lewis.

Smolt Passage Survival

Smolts produced in the upper Lewis basin are subject to downstream passage mortality at Swift 1 and 2, Yale, and Merwin projects. Because the passage survival rates needed for successful steelhead and salmon restoration are a key outcome of the model, passage rates were treated in a sensitivity analysis as well as a fixed model input. We modeled net passage survival at the projects as the combined effect of all specific behaviors and mechanisms related to passage rather than as an explicit representation of each component of passage (attraction, collection, diversion, mortality, etc.). Our primary objective was to weigh the effects of changes in smolt survival on the potential for successful reintroduction rather than formulate conclusions of how passage survival might vary in response to changes in dam and reservoir operation and configuration. The sensitivity analysis approach enables the reviewers to understand the smolt passage survival criteria necessary for successful reintroduction and then utilize that information to inform decisions concerning passage alternatives. Smolt passage survival inputs can be selected based on empirical data to represent various passage configurations. For example, we selected a smolt passage survival from the head of the reservoir to the lower Lewis below the dam of 75% when conducting sensitivity analysis for harvest and adult passage under Alternative B (reintroduction above Swift reservoir only with fish collected and trucked downstream). The 75% smolt passage survival rate is a product of an assumed 90% survival through Swift reservoir, 85% collection efficiency at Swift Dam, and 98% trucking survival. The NMFS (2000b) reported a range of FGE of 0.43-0.96 for yearling Chinook and 10,000 Years Institute (2001) uses 0.70 as a mid-point in the passage analysis.

Downstream passage survival rates of smolts through the lower Lewis and lower Columbia rivers are primarily affected by predation and perhaps for fish trucked, a “differential” mortality (D Factor) in addition to the immediate mortality accounted for in the trucking mortality rate. The D factor is controversial with limited information available on the extent of difference in survival between smolts that migrate through projects voluntarily and those trucked or barged around the projects. Passive Integrated Transponder (PIT) tag studies of Snake River fish show some difference in survival for some broods of salmon that cannot be accounted for in immediate mortality. Some scientists believe the crowded conditions in the barges with multiple species cause stress and disease and some believe there may be a timing disruption with artificial transport that moves fish to the lower river before they are biological prepared to transition to salt water. Although many scientists believe there may be a differential survival factor, primarily because the below Bonneville Dam smolt-to-adult survival rate has been measured higher for fish not barged, but the extent of the difference is certainly not agreed to even by those who believe it is a realistic phenomenon. NMFS (2000) has estimated 'D' value for juvenile passing the federal hydro system at 0.63-0.73 for Chinook and 0.52-0.58 for steelhead. We believe it is reasonable to assume that fish trucked in relatively low numbers 40 miles from Swift reservoir to below Merwin Dam would not be subjected to the same level of additional stress as fish barged in crowded conditions nearly 300 miles from Lower Granite Dam to below Bonneville Dam. An example of how to apply a D value variable to the sensitivity analysis would be with an assumed 75% passage survival. If .95 D value were assumed then the survival of smolts to the ocean would be reduced to 71% (75x.95), or if the D value were assumed to be more significant at .80 the survival to the ocean would be reduced to .60 (75x.80). We modeled smolt survival from the lower Lewis through the lower Columbia and to the ocean ranging from 50-80% in the sensitivity analysis. We believe an appropriate D assumption can be covered within this range. The modeler can match variable fish collection efficiency and D values within the 50 to 80% survival range to assess effect on future adult spawning numbers. However, if collection efficiency is assumed to be less then 60% the D value cannot be less then .85 to be covered within this range.

Ocean Survival

The model estimates the number of steelhead and salmon recruiting to adulthood in the ocean as the product of the number of smolts surviving to reach the ocean and a smolt-to-adult survival rate.

For wild origin smolts, we modeled smolt-to-adult ocean survival rates in the absence of human-caused mortality. These rates were based on averages calculated by Mobrand Biometrics, Inc. (2002) as part of the EDT analysis. The rates were 2.9% for spring Chinook, 3.99% for coho, and 8% for steelhead.

Recent experience has demonstrated that ocean survival rates can be highly variable. The log-normal coefficient of variation for Deschutes River hatchery steelhead was slightly greater (29%) than the average (19%) for eight other Northwest steelhead populations (Appendix Table B- 2). Survival rates are also autocorrelated among years because of overlapping generations and periodic ocean regime shifts which result in extended sequences of poor or good survival years (Beamish and Boullion 1993). We used the observed variability in the lower Deschutes River hatchery steelhead survival to represent the expected variation in wild steelhead. The model provides options for random normal variation in ocean survival and for autocorrelated variation in ocean survival. We applied the hatchery survival coefficient of variation to the assumed average 8% natural smolt survival rate in random normal simulations. In autocorrelated simulations, we used a sequence of scalars derived by dividing annual hatchery survival rates by the average for all years. Scalars were used in order starting with one selected at random. After the last scalar in the sequence, the model jumps to the beginning of the time series and continues until every scalar is used. The cycle then started again with a new random selection. This ensures that all years of data are weighted equally. We used the variable stochastic model option to measure the percentage of years in which a population would fall below the high risk level in the sensitivity analysis.

Adult Age Composition

Adult steelhead in the ocean are apportioned between return years based on observed frequencies of one- and two-salt fish for lower Deschutes River steelhead (Olsen et al. 1991). Thus 53% return after 1 year in the ocean and 47% return after 2 years in the ocean. No three-salt fish steelhead were reported by Olsen et al. for wild Deschutes River steelhead. The model did not provide for repeat spawners because of a low reported incidence in the Columbia River steelhead populations. Ages of adult maturation are applied independent of ages of smoltification.

Adult coho were apportioned based on observed rates of 10% of the population maturing as 2-year-old jacks and 90% as 3-year-old mature adults. Spring Chinook returns were apportioned at 10 percent 3-year-old jacks, 60% 4-year-old adults, and 30% 5-year-old adults. Spring Chinook can also mature as 2-year-old mini-jacks with a few months ocean time and as 6-year-old adults with 4 years ocean time, but those proportions are low enough that we determined there to be little value in including those ages in the model.

Appendix Table B- 2 . Reported smolt-to-adult survival rates for Northwest steelhead populations.

Smolt Year	Deschutes Summer Hatchery	Eagle Crk. Winter Hatchery	Kalama Winter Hatchery	Kalama Summer Hatchery	Up. Col. Summer Hatchery	Umpqua Summer Hatchery	Snow Crk. Winter Wild	Queets Winter Wild	Keogh Winter Wild
1965	--	--	--	--	2.0%	3.6%	--	--	--
1966	--	--	--	--	2.1%	3.9%	--	--	--
1967	--	--	--	--	1.6%	6.4%	--	--	--
1968	--	--	--	--	1.0%	8.0%	--	--	--
1969	--	--	--	--	1.4%	5.8%	--	--	--
1970	--	--	--	--	1.9%	4.8%	--	--	--
1971	--	--	--	--	1.4%	4.3%	--	--	--
1972	--	--	--	--	1.4%	2.1%	--	--	--
1973	--	--	--	--	0.1%	1.7%	--	--	--
1974	--	--	--	3.1%	0.8%	2.2%	--	--	--
1975	--	--	0.5%	6.0%	1.9%	3.5%	--	--	--
1976	8.1%	--	2.4%	5.4%	2.0%	3.7%	--	--	
1977	2.4%	--	0.5%	4.0%	0.2%	4.8%	--	--	15.2%
1978	10.0%	--	1.3%	18.1%	1.5%	2.7%	6.5%	--	7.4%
1979	8.6%	--	1.5%	16.0%	1.2%	3.7%	10.7%	--	15.2%
1980	7.7%	--	0.8%	9.6%	1.4%	1.2%	5.6%	--	8.4%
1981	1.4%	--	0.6%	2.9%	0.7%	1.4%	2.2%	--	25.4%
1982	14.5%	--	1.7%	4.9%	5.3%	3.1%	6.1%	--	26.1%
1983	6.9%	2.4%	1.5%	8.0%	2.9%	5.3%	10.5%	--	15.5%
1984	11.7%	2.3%	3.0%	12.4%	4.5%	5.6%	4.8%	17.3%	18.3%
1985	11.9%	1.2%	1.2%	8.0%	1.9%	7.7%	3.5%	11.4%	25.3%
1986	6.2%	0.8%	1.6%	6.2%	1.3%	6.3%	7.1%	13.5%	10.0%
1987	4.2%	0.6%	2.0%	7.8%	0.7%	4.7%	1.3%	9.8%	13.3%
1988	3.5%	1.2%	1.3%	6.1%	0.7%	3.4%	1.7%	17.7%	6.7%
1989	1.6%	0.9%	1.8%	4.9%	0.7%	3.7%	1.6%	13.0%	15.4%
1990	4.6%	1.7%	2.4%	13.7%	1.3%	1.3%	3.0%	11.7%	6.3%
1991	1.8%	1.0%	1.2%	6.2%	0.8%	1.4%	2.1%	16.1%	3.6%
1992	0.3%	0.7%	0.4%	3.6%	0.3%	1.2%	1.6%	8.6%	3.0%
1993	3.3%	0.7%	0.5%	1.6%	0.7%	2.0%	2.8%	7.7%	3.3%
1994	3.5%	0.2%	2.0%	4.5%	0.5%	4.9%	6.6%	7.9%	2.6%
1995	4.8%	--	--	1.9%	1.1%	2.9%	--	12.1%	4.0%
1996	4.5%	--	--	0.7%	--	--	--	--	--
1997	2.4%	--	--	--	--	--	--	--	--
1998	1.8%	--	--	--	--	--	--	--	--
Averages									
All years	*5.5%*	*1.1%*	*1.4%*	*6.8%*	*1.5%*	*3.8%*	*4.6%*	*12.2%*	*11.8%*
pre 1985	*7.9%*	*2.3%*	*1.4%*	*8.2%*	*1.8%*	*3.9%*	*6.6%*	*17.3%*	*16.4%*
1985-pres	*3.9%*	*0.9%*	*1.4%*	*5.4%*	*0.9%*	*3.6%*	*3.1%*	*11.8%*	*8.5%*
CV[1]	*29%*	*14%*	*13%*	*26%*	*18%*	*16%*	*21%*	*13%*	*32%*

[1] *Coefficient of variation (standard deviation / mean) based on Ln(SAR).*

Adult Passage Mortality

Upper Lewis River adult salmon and steelhead would be subject to mortality associated with upstream passage through dams. We use a range of 60 to 90% adult -passage survival in the sensitivity analysis. The first factor considered for any passage alternative is the percentage of the adult salmon and steelhead which escape past fisheries and actually present themselves to a trap at or a fish passage ladder. A percentage of the returning adults will likely stray and spawn below the dam or choose to not enter the trap or ladder. We refer to this as a conversion rate, which represents the percentage of fish escaping fisheries that are actually accounted for in a trap or ladder. A 95% conversion rate was used by 10,000 Years Institute (2001).

The 10,000 Years Institute report assumes a 98% ladder and reservoir survival for Merwin and Yale dams and a 95% survival for Swift Dam. Malone used the combined trap conversion and ladder / reservoir survival rates for a survival of 93 percent for Merwin and Yale and 90% for Swift in the LRFPA model. Passage mortality rates for adults at mainstem Columbia River dams has been modeled at 5% per dam. More precise estimates cannot be derived because of uncertainties in dam counts, tributary turnoffs, and fishing impacts. Pratt and Chapman (1989) concluded that 5% per dam was a reasonable estimate for steelhead based a review of the available data on interterm loss of adults. The *U. S. v. Oregon* Technical Advisory Committee is also using a 5% standard in run reconstruction calculations of fishery impacts. We believe that 95% adult ladder passage survival for the Lewis system is optimistic because of the high-head dams requiring ladders of exceptional length compared to the ladders of Columbia River dams. A 95% conversion rate was used by 10,000 Years Institute (2001)

We estimated that 95% of the fish trucked would survive the handling and trucking to be placed in the upstream reservoirs. It was assumed that 95% of the fish surviving to the reservoir would actually spawn in the tributaries after pre-spawning mortality.

Because the adult passage survival rates needed for successful steelhead restoration are a key outcome of the model, we treated this parameter through sensitivity analysis as well as a fixed model input. The range of adult passage analyzed was 60 to 90%, with 80% used as a fixed base rate to analyze other elements. Examples of adult passage rate assumptions are: Under alternative B, if 95% of the fish were trapped at Merwin and 95% survived the transport to Swift reservoir, the result would be a 90% passage rate. Under Alternative C, if 95% of the fish found and entered each trap and 95% survived the trucking at each trap, the result would be a 74% passage rate to Swift reservoir. Under Alternative D, if 95% of the fish survived each ladder and reservoir, the passage rate would be 81% to Swift reservoir. We believe that 60 to 90% range will cover a broad set of assumptions for passage alternatives in the sensitivity analysis.

Fishing

Harvest related fishery impacts of wild salmon and steelhead produced in the Columbia basin are a result of ocean and freshwater fisheries intended to direct their effort towards healthy stocks that can sustain variable levels of harvest. These healthy stocks are predominately hatchery fish in the Columbia, but also include healthy wild fish produced in Oregon, Washington, California, Canada and, Alaska.

Harvest impacts to wild lower Columbia salmon can be represented in two general fishery categories: 1) fisheries intended to target healthy stocks but allowed to retain all captured legal salmon and 2) catch and release mortalities in fisheries that can only retain hatchery fish marked with a clipped adipose fin and must release wild fish. All mainstem Columbia River and tributary sport and commercial spring Chinook fisheries below Bonneville Dam are selective and can only retain adipose fin-clipped hatchery fish. Net-pen reared hatchery spring Chinook are also harvested commercially in certain sloughs and bays where wild fish do not pass on the way to their stream of origin. Mainstem Columbia coho fisheries include sport fisheries that can only retain hatchery fish and commercial fisheries that target hatchery fish based on time and area limitations, but retain all fish captured. Most ocean fisheries which occur in areas where Columbia River coho are present are selective to adipose fin-clipped hatchery fish. Most ocean Chinook fisheries are not selective to hatchery fish but are limited by annual abundance of hatchery fish and key wild stocks. The harvest levels in the ocean are controlled by Pacific Salmon Treaty (PST) agreements between the United States and Canada, and the Magnuson/Stevens Fisheries Conservation Act, and Endangered Species Act (ESA) administered by NOAA Fisheries.

Wild Steelhead harvest impacts in the lower Columbia and tributaries below Bonneville Dam are associated with fisheries selective to adipose fin-clipped hatchery steelhead or incidental to fisheries targeting salmon. Steelhead are not commonly intercepted in ocean salmon fisheries because their migration behavior takes them farther offshore then salmon.

The annual Ocean salmon fishery regulation process includes negotiations between the U.S. and Canada to ensure fishing levels in Canada, Alaska, and the Southern United States are consistent with the PST agreements. The Pacific Fishery Management Council (PFMC), a council established under the Magnuson/Steven Act recommends U.S. Pacific Ocean (south of the Canadian border to the Mexican border) fishing seasons to the Secretary of Commerce, considers annual salmon abundance, PST, ESA, and catch allocation agreements. Columbia River Chinook and coho are further managed in a public process named “North of Cape Falcon” to provide a link between ocean fisheries management and Columbia River and coastal conservation and fishery objectives. Fisheries in the mainstem Columbia River are regulated by the Columbia River Compact, a joint Washington and Oregon public forum to establish concurrent fishery regulations in shared waters of the mainstem Columbia River. The Columbia River seasons are set based on Washington, Oregon, and Idaho salmon status, spawning goals, ESA limitations, and *U.S. v. Oregon* court agreements regarding Indian and non-Indian allocation. Lower Columbia tributary sport seasons are set by the respective state Fish and wildlife Commissions based on spawning escapement goals and ESA limitations.

Spring Chinook

Fishery impacts to Lewis River spring Chinook occur in ocean commercial, sport, and tribal fisheries, lower Columbia River sport and commercial fisheries, and tributary sport fisheries. There are currently no treaty Indian spring Chinook fisheries in the lower Columbia mainstem or tributaries. The base model input for spring Chinook harvest was derived from an evaluation of coded-wire-tag recoveries of 1989-94 brood Lewis River Hatchery produced spring Chinook for ocean fisheries (WDFW 2002)and expected future wild spring Chinook catch and release impacts in mainstem Columbia and Lewis River selective fisheries. The total annual harvest impacts were projected to average 20% of the mature Lewis River wild adult spring Chinook population. Future harvest is projected to be 15% ocean, 3% mainstem Columbia and 2% lower Lewis River fisheries

The ocean spring Chinook harvest impact is highest in Alaska and Canadian fisheries with Washington coastal harvest limited by timing of fisheries compared to migration and controlled Chinook fishing effort. Ocean harvest rates on lower Columbia spring Chinook were significantly higher in the 1980s compared to the 1990s. The reduced ocean harvest in recent years coincides with low production for Columbia River and Canadian Chinook stocks. The model input value anticipates future ocean harvest to average close to the levels of recent years (20%) due to the PST abundance based management agreements and in anticipation of further development of selective fisheries for hatchery Chinook. It is noted, however, that lower Columbia spring Chinook are not included directly as a stock to be considered in abundance based management agreements with Canada. Harvest impacts in ocean fisheries could be higher then modeled in years when Chinook abundance is high for key Canadian or U.S. stocks. Ocean harvest could potentially be reduced if selective Chinook fisheries were implemented through the PSC and PFMC processes. Although coho selective fisheries have been widely used in recent years' ocean management, Chinook selective fisheries have been limited due to a number of increased technical complexities in implementing selective ocean Chinook fisheries.

Mainstem Columbia River harvest impacts were derived from sport and commercial impact rates projected for Willamette wild spring Chinook (ODFW, 2001) and Snake River wild spring Chinook ESA impact limits set by *a U.S. v. Oregon* agreement. The Willamette wild Chinook impacts are projected to average 4.3% (Beamesderfer 2000) while the Snake River wild limits for lower Columbia fisheries are limited to 1.7% (ODFW and WDFW, 2001). The Willamette spring Chinook migration through the lower Columbia is earlier then Lewis spring Chinook and the Snake River spring Chinook are later-timed then Lewis Chinook. Since the Lewis fish are timed in between the two runs, we assumed fisheries structured to meet the objectives of those stocks would result in a Lewis River spring Chinook harvest rate somewhere between the harvest rates of the two other stocks. Therefore, 3% was used as a mid-point value between the rates expected for Willamette and Snake river stocks in mainstem Columbia fisheries.

Lewis River sport harvest impacts were derived from a projected average handling rate of 20% in the Lewis sport fishery and an estimated 10% catch and release handling mortality. The 10% mortality for Chinook captured and released in the sport fishery is consistent with the rate applied by the *U.S. v. Oregon* Technical Advisory Committee for estimating mainstem Columbia fisheries mortality of released ESA listed stocks. The Lewis sport fishery handling rate was estimated from an average 37% Lewis sport harvest rate for hatchery spring Chinook derived from 1989-94 brood tag recoveries. We reduced the handling rate to 20% for wild fish because the fishing effort is focused downstream of the Lewis River Hatchery and we expect that wild fish returning to the upper watershed would not delay below the hatchery to the degree that hatchery fish would, resulting in a reduced exposure to fishing effort.

The lowest harvest rate modeled for spring Chinook was 16% under the optimistic model scenario. This low harvest rate would assume that freshwater fisheries would continue to be selective and remain at 5%, but ocean fisheries would reduce from 15% to 11% as a result of expanded use of selective fisheries in the ocean. The high harvest rate modeled for spring Chinook was 40%. The high harvest rate would assume increased impacts in both ocean and freshwater fisheries. This higher harvest rate would not likely occur unless a portion of the production was adipose fin-marked for directed take along with hatchery fish in selective fisheries, or there were terminal fisheries allowed in the upper Lewis watershed.

Coho

Fisheries impacts to Lewis River coho occur in ocean sport and commercial fisheries, mainstem Columbia sport and commercial fisheries, and Lewis River sport fisheries. The base model input for future Lewis wild coho harvest impacts was derived from current management regulatory limitations for wild Oregon lower Columbia coho listed under the Oregon state ESA, and for federal ESA listed wild Oregon Coastal Natural (OCN) coho. Both of these listed coho stocks have similar ocean migratory behavior as Lewis coho and therefore unmarked Lewis coho would be subjected to similar ocean harvest. Early stock Lewis coho have similar Columbia River migratory timing as Oregon state listed early coho and would likely be subjected to similar mainstem Columbia harvest impacts. Lewis River sport fishing impacts would be projected based on a 10% catch and release handling mortality.

Columbia River and OCN coho are managed based on a production and harvest rate matrix in which harvest impact limits are dependent on both marine survival and parent escapement values. The harvest limit ranges from a low of less then 8% to a high of 45% depending on the annual production indicators. Since wild coho have been managed with a productivity-based harvest criteria (beginning with OCN coho in 1998) harvest impacts has been limited to less then 15% and has been as low as 6%. Because harvest above 15% would be conditioned upon exceptional productivity, we assumed a 15% average harvest for future Lewis wild coho.

Columbia River coho ocean harvest occurs almost entirely off the Washington and Oregon coasts, with very small impacts occurring in Canadian or Alaskan fisheries.

Early stock coho are generally more southern distributed then late stock but both stocks have a predominant presence off the southern Washington and Oregon coasts. The Oregon and Washington marine coho fisheries are predominately selective to hatchery fish.

Columbia River mainstem sport harvest occurs primarily in the Buoy 10 fishery in the Columbia estuary. The Buoy 10 fishery can harvest 5 to 25% of the marked hatchery coho return, but unmarked Lewis fish would only be subjected to a 10% catch and release mortality. The Columbia River commercial fishery does not release unmarked coho, but is restricted by area and gear type to minimize impacts to early stock coho and late-timed Clackamas coho. Combined Columbia River commercial and sport impacts to these stocks will be restricted to less then 5% in most years based on the harvest criteria.

If Lewis late stock coho were used for introduction to the upper Lewis, a higher Columbia River harvest rate would be modeled. The Columbia River commercial fishery is regulated to protect late stock Clackamas coho by completing the fishery by the end of October. However, the current Lewis or Cowlitz late stock is timed earlier then Clackamas late coho and would be subjected to higher October commercial fishing pressure. The total harvest rate for Lewis late stock introduced coho would likely be higher then 15%.

The Lewis River sport fishery impact is expected to be 1% or less based on an average 10% hatchery stock harvest rate and a 10% catch and release mortality.

A 15% harvest for combined ocean and freshwater fisheries was used for both optimistic and expected model scenarios. A higher harvest rate modeled at 40% could occur if the introduced fish were adipose fin-marked for harvest, late stock Lewis hatchery stock were used for introduction, or a terminal fishery were established in the upper Lewis watershed.

Steelhead

Winter Steelhead fishery impact occurs in Columbia River sport fisheries, Columbia River commercial fisheries and Lewis River sport fisheries. Coded-wire-tag analyses indicate that steelhead are not taken in significant numbers in any ocean fishery, apparently because of an offshore, high-seas distribution pattern. Non-Indian commercial fisheries for steelhead in the Columbia River have been prohibited beginning in 1975. Catch and release impacts occur in March commercial live capture tangle net fisheries targeting on hatchery spring Chinook salmon. State biologists are monitoring steelhead mortality associated with this new fishery and adapting fishing gear and other strategies to minimize the effect on wild steelhead.

Columbia River sport fisheries above and below Bonneville Dam keep only fin-marked hatchery fish since 1984 for summer steelhead and 1992 for winter steelhead. Winter steelhead are taken in lower Columbia River mainstem sport fisheries primarily in March during spring Chinook fisheries. Impacts to wild winter steelhead are restricted to catch and release mortality which is estimated by the *U. S. v. Oregon* Technical

Advisory Committee to be about 10% based on a review of the available literature data. The annual impact on wild winter steelhead in the mainstem Columbia River combined sport and commercial fisheries is restricted to no more then 2% based on ESA limitations established by NOAA Fisheries.

Sport fisheries for steelhead occur in the Lewis River from the mouth to the fishing deadline below Merwin Dam. It was assumed that the Lewis River sport fishery impact on wild winter steelhead would be no more then 1% based on a 10% handling rate and a 10% catch and release mortality rates subjected to ocean salmon fishery impacts and the time of exposure to fishery impacts in the Columbia River is very short.

The total fishery impact for wild winter steelhead was modeled at 2% mainstem Columbia and 1% for the Lewis sport fishery for a total fishery impact of 3%. The harvest rate was fixed for winter steelhead in the models because there are less uncertainties in harvest management criteria for winter steelhead, primarily because steelhead are not subjected to ocean salmon fishery impacts and their run timing into the Columbia results in limited exposure to Columbia River fishing effort.

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