All H Analyzer (AHA) User Guide

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Introduction

The "All H Analyzer" (AHA) was developed by Washington State fishery co-managers to facilitate the discussion of strategy options to the restore and manage salmon populations in the Pacific NW. AHA allows managers to explore the implications of different ways of balancing habitat restoration, hatchery practices, harvest and the operation of hydroelectric dams. Each of these major policy areas has been the topic of intense regional and local debate. Considerable research has been devoted to understanding how these actions affect the environment and the condition of fish populations. Analytical models have been constructed to analyze each area in detail. However, the balance between habitat, hatcheries, harvest and hydroelectric effects (the "4-H's") in restoration planning is seldom addressed in an integrated way. The need for this level of discussion has become apparent as the region has moved toward the development of comprehensive plans for fish recovery and restoration. AHA was developed to encourage and document such a discussion among fishery and environmental managers and stakeholders.

This documentation describes the assumptions and operation of AHA version 3.23 released on April 1, 2005. AHA has been developed by the managers in response to an acute need. It is frequently changed and improved as a result of experience and new ideas. Documentation also must be continually changed and refined as well. One purpose of AHA is to facilitate an open and collaborative approach to the development of fish restoration plans. We encourage and seek new ideas for both the Analyzer and for this documentation.

Purpose of AHA

The All H Analyzer (AHA) is a Microsoft Excel-based tool to evaluate salmon management options in the context of the four "H's"—**H**abitat, [passage through the] **H**ydroelectric system, **H**arvest and **H**atcheries. Its purpose is to allow managers to explore the implications of alternative ways to balance these four major areas of management control over abundance and persistence of salmon populations. AHA does not make decisions nor does it judge the "correctness" of management policies. It simply illustrates the implications of alternative ways of balancing the four "H's" so that informed decisions can be made.

AHA should not be viewed as a new model, but rather as a platform for combining existing models. AHA makes relatively few new assumptions but instead brings together the results of other models such as EDT for habitat, SIMPASS for Columbia River hydroelectric passage and others. It does not replace these other models but instead relies on them to provide inputs to AHA. We have tried to keep the Analyzer simple so that it is fast and easy to use but, most especially, so that it focuses on the important elements of regional decision making regarding the four H's. The present version is a generational model with no age structure. A version with age structure has been drafted and is being tested, but it is a bit more cumbersome both in terms of computational speed and in the number of input values that must be provided—in many cases the simpler generational model may be adequate and preferable.

Background

AHA was initially created in 2004 by the Hatchery Scientific Review Group (HSRG), Washington State Department of Fish and Wildlife (WDFW) and Northwest Indian Fisheries Commission (NWIFC) for use in a series of regional, technical workshops held during the summer of 2004. The purpose of the workshops was to explore options for managing hatcheries, harvest and habitat in light of regional hatchery reform efforts and current understandings of fish husbandry and conservation genetics. Because the focus of the original model was on Puget Sound and coastal Washington fisheries management, it did not explicitly incorporate the effect of passage through a hydroelectric system except by inclusion with other survival factors. The model incorporates some critical concepts and assumptions about the interactions between hatchery and natural stocks. These assumptions are based on recently published work (Ford, 2002 and Lynch and O'Hely, 2001) and further development of these ideas by (Campton, Busack, and Currens, personal communication).

More recently, AHA has been applied to Columbia River fisheries management to explore its utility as an aid to the efforts by the Northwest Power and Conservation Council and NOAA Fisheries to develop restoration plans for Columbia Basin salmon populations. The Analyzer was reviewed by the Council's Independent Scientific Review Group who made several helpful suggestions that are reflected in the most recent version of AHA. Specifically, the model now explicitly incorporates adult and juvenile survival through the mainstem dams so that it is now, truly, an "All-H Analyzer". The model is moving toward a position of playing a coordinating role between other, more detailed models. For example, habitat productivity and capacity are input to AHA as single numbers. However, their derivation may come from a detailed EDT analysis of reach scale habitat characteristics. Similarly, the single inputs for adult and juvenile survival through the hydroelectric system could be the result of detailed analysis of operational effects using SIMPASS, CRiSP or other available tools. Rather than incorporate all the detail of each model into AHA, we have elected to maintain the simplicity of AHA as a rapid aid to regional decision making, while making it possible to explore very detailed scenarios through the use of other models.

Getting Started

AHA is constructed in Microsoft Excel. If you are familiar with Excel then operation of AHA should be quite simple. This manual provides instructions on how to use the AHA model and presumes that the user is generally familiar with spreadsheets and the use of Microsoft Excel.

When you open the AHA spreadsheet you should get a security message concerning macros. Choose “enable macros” upon opening the file. Some users may have their security within Excel set to a level that prevents use of all macros. If so, at the top Excel menu bar, go to Tools➔Macros➔Security and set the level to Medium.

Glossary Of Terms And Variables

The following is a list of key terms and variables used in the AHA model and this user’s manual:

- HOS = the number of hatchery-origin fish spawning naturally.
- NOS = the number of natural origin fish spawning naturally.
- NOB = the number of natural-origin fish used as hatchery broodstock.
- HOB = the number of hatchery origin fish used as hatchery broodstock.
- HORs = hatchery-origin recruits. The number of HORs equals the sum of HOS + HOB + hatchery-origin fish intercepted in fisheries.
- NORs = natural origin recruits. The number of NORs equals the sum of NOB, + NOS + natural-origin fish intercepted in fisheries.
- pHOS = proportion of natural spawners composed of HORs. Equals HOS/(NOS + HOS).
- pNOB = proportion of hatchery broodstock composed of NORs. Equals NOB/(HOB + NOB)
- PNI = proportion of natural influence on a composite hatchery-/natural-origin population. Can also be thought of as the percentage of time the genes of a composite population spend in the natural environment. Equals 1 - pNOB/(pNOB + pHOS).
- SAR = smolt to adult return.

Model Layout

The AHA workbook is divided into worksheets, indicated by the tabs along the bottom of the application window. There are two levels of input, a normal operating level and an advanced or detailed level. Most users will be operating at the normal level and that is what is addressed in this users guide. Input and output for the normal level of use are on the “Populations” page. Most calculations occur on the pages behind the Populations page. Additional parameters in the model can be controlled on these other pages but changing these parameters is normally not necessary and should be approached cautiously.

The Population page is where most users will interact with AHA. It is intended to be a self-contained “one-page” summary of the inputs and outputs for five management options. The other pages provide additional information regarding how the model calculates results, and a place for knowledgeable users to further customize data to more accurately reflect particular conditions.

While most users will only use the Populations page, below we describe each page in the AHA workbook. To access a specific page, click on its associated tab. If the tab is not showing, use the horizontal scroll button to scroll left or right until you see the tab.

Brief explanations of each page are provided below.

- *Population* – The primary location for users to input data and view results.

- *NaturalComponent* – Contains the NOR survival data used by the model to compute the abundance of natural-origin fish and the make-up of the composite hatchery/natural population in future generations. Knowledgeable users can manipulate some of the data in this section.

- *HatcheryComponent* – Contains the hatchery program and HOR survival data used by the model to compute the abundance of hatchery-origin fish and the make-up of the composite hatchery/natural population in future generations. Knowledgeable users can manipulate some of the data in this section.

- *Fitness* – Contains the data and equations used to calculate fitness loss for the composite population. Knowledgeable users can manipulate some of the data in this section; though it is recommended that only those cells in yellow be altered.

- *Definitions of Variables* – Provides definitions and variables for several of the key terms used in this model.

- *Scenario O, A, B, C, and D* – Displays the data and equations used to compute the results of the model over 80 generations for each alternative scenario.

- *SARs* – Displays the randomly generated Smolt to Adult Survival Rates (SAR) used in the model.

Population Page

Figure 1 is a snapshot of the entire main interface on the Population tab. This picture has been zoomed out show the entire page. Normally, you zoom in and look at a smaller portion of the page and use the scroll bars to move around the page. All commonly used inputs are controlled through the upper Input panel and all commonly seen output is in the lower four output panels. There are some calculated values in the upper panel; however, all input cells are yellow. Non-input cells are protected to prevent inadvertent modification of formulas.

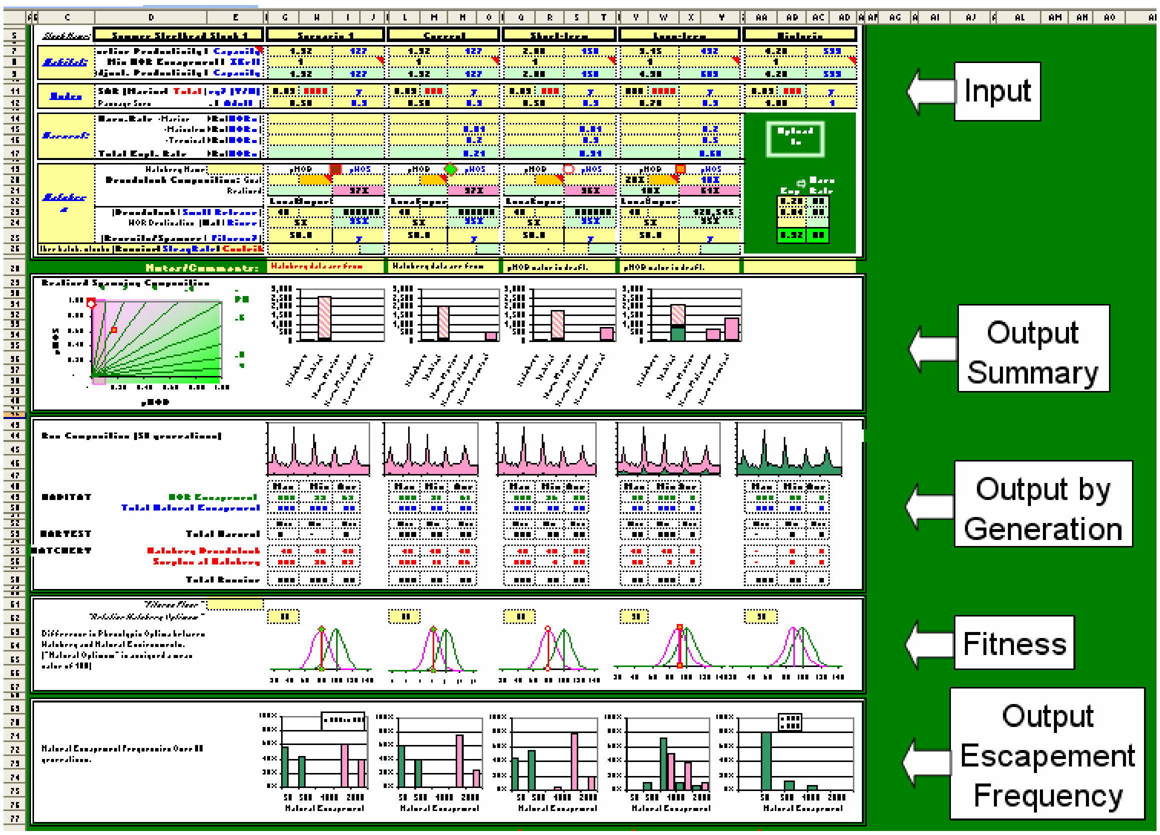

Figure 1. Layout of the Population page in the AHA workbook. This is the main input and output area in AHA and is the sheet that most users will interact with in using AHA.

Scenarios

AHA can analyze five scenarios simultaneously so that results can be easily compared. The Population tab is divided vertically into five sections to the right of the labels column; each scenario section has two columns in the spreadsheet (the columns under Scenario 1 in Figure 2).

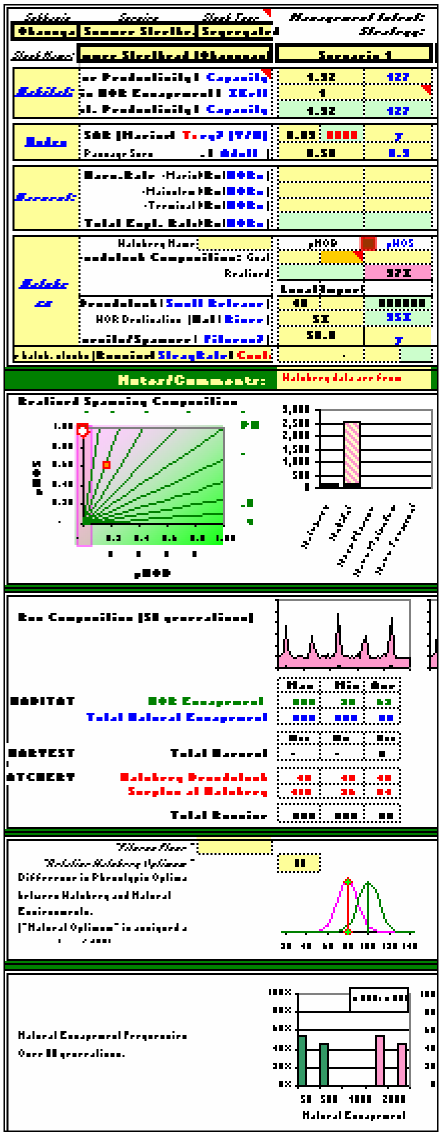

Figure 2. An individual scenario in the Population sheet. The cells under Scenario 1 contain both the input (upper panel) and output (lower panels) for an individual scenario. AHA arrays five scenarios across the Population page.

The column groups continue vertically through both the input and output panels. Each column group includes the input and output for a single alternative. ANY five scenarios can be described. A common sequence is to start with a scenario describing conditions before ESA listing and then add the current situation, perhaps one for a subbasin plan, and then a fourth alternative that addresses delisting of the stock. The fifth scenario is the historical or "normative" scenario describing the intrinsic habitat potential without any harvest or hatchery influences. The intent is to set a logical sequence of scenarios side-by-side and be able to compare both input and output.

Inputs

The input panel on the Population page is divided horizontally into four sections corresponding to each of the four H's. Figure 3 shows a portion of the input panel for a single alternative. Yellow cells are inputs while calculated cells are green. Notes pertaining to a cell are identified by the red triangle in the upper right corner. Figure 3 also shows the header information for an AHA session. This indicates the subbasin, species and stock type (segregated, integrated or natural) and the name of the stock.

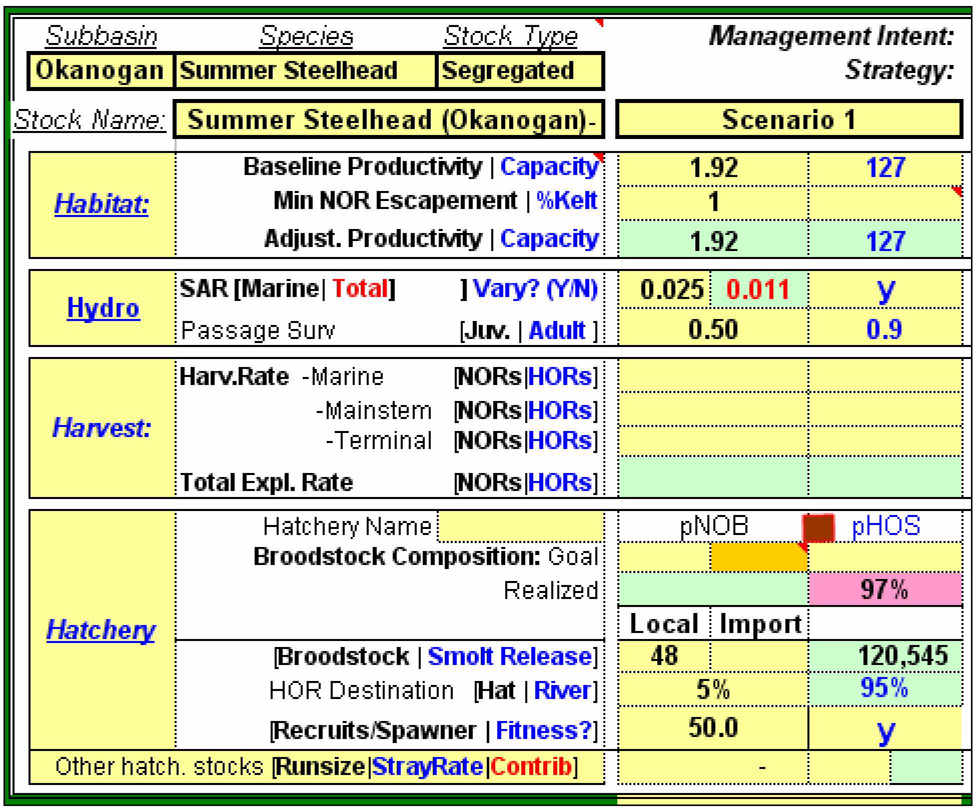

Figure 3. Detail of the input panel on the Populations page for a single scenario. Inputs correspond to each of the four H's.

<u>Habitat</u>. This section describes the natural environment. In many cases, the inputs to this section come from an EDT analysis of habitat condition.

Baseline Productivity and Capacity. Productivity and capacity are parameters of a Beverton-Holt production function. Productivity is the density independent survival rate of the species in the environment measured as return/spawner over the entire life history. This is the maximum possible survival without competition or density effects. Capacity is the maximum number of individuals that could be supported by the habitat. This is the asymptote of the production function.

Min NOR Escapement/ % Kelt. The Min NOR Escapement is used if there is an escapement goal established for the population. In most cases there is not and this parameter is set to a value of 1 (it should not be left blank). For steelhead, the proportion of repeat spawners (kelts) can be specified. For other species, this should be left blank.

Adust. Productivity/Capacity. These are calculated from the baseline production factors and the information under the Hydro section below. The baseline production factors described above are calculated from EDT over the entire life history of the species using a set of assumptions for conditions outside the subbasin for natural survival and Hydro conditions.

So that conditions outside the subbasin can be manipulated in AHA, the spreadsheet recalculates baseline productivity and capacity to reflect a change in conditions outside the subbasin relative to what was used for the baseline calculation in EDT. For example, an increase in passage survival reflecting a specific change in the operations of the dams results in an increase in the overall productivity and capacity of the population[1]. This becomes clearer by spending a few minutes spent changing conditions in the Hydro section and seeing how it changes the Adjusted Productivity and Capacity in the Habitat section.

Hydro. This section could also be labeled "Out of Subbasin Effects" referred to as OOSE in some sections. This is where a specific survival rate through the hydroelectric system is supplied. This can be an estiumate from a fish passage model such as SIMPAS or CRiSP. Inputs to this section also include the Smolt to Adult survival rate or SAR reflecting survival conditions downstream of the hydroelectric system.

SAR[Marine/Total]/ The SAR [Marine] is the survival of juvenile fish leaving the hydroelectric system to their return as adult entering the hydroelectric system, absent harvest. In other words, SAR is the Bonneville to Bonneville Dam survival rate excluding harvest which is provided in the next section. The SAR [Total] is a calculated field that is the survival from the mouth of the subbasin back to the subbasin including theSAR [Marine] and the effect of the hydroelectric system.

Vary? (Y/N). This factor allow us to account for a measure of environmental variability. We attach random variability to the SAR [Marine] input based on published patterns of variation in ocean survival conditions. The procedure that calculates this variation is included under the SARs page but inputs would not normally be modified.

Passage Surv. The survival rate of juvenile and adult fish through the hydroelectric system is calculated independently of EDT using a fish

[1] Note that capacity is related to productivity such that an increase in productivity (survival) increases capacity as well.

passage model such as SIMPASS. Any assumed post-Bonneville survival factors (i.e. the D factor) can be built into the juvenile passage survival rate.

Harvest. Harvest inputs are obtained from analysis of coded wire tags or from harvest analysis models. Separate harvest inputs can be provided for natural origin fish (NORs) and hatchery origing fish (HORs).

Harv.Rate. Harvest rate is the fishing mortality imposed at a specific location. Location is treated very generally and addresses only the harvest in marine areas, the mainstem (e.g. Columbia River) and terminal area within the subbasin. Separate rates can be provided for natural (NORs) and hatchery (HORs) origin fish.

Total Expl. Rate. Exploitation rate is the total mortality imposed on fish by harvest in terms of adult equivalents at spawning. This is a calculated field in AHA that is based on the harvest rates provided.

Note: On the right side of the input section there is a simple calculator to go from exploitation rate to harvest rate. However, keep in mind that the input to AHA is harvest rate.

Hatchery. Because of the lack of independent hatchery models similar to those available for the other H's, AHA devotes more attention to the details of hatchery operations. Indeed, many applications of AHA involve questions of how hatcheries could be managed to achieve management goals in the context of the other H's. The first set of hatchery inputs relate to two categories of fish: pNOB is the proportion of Natural Origin Broodstock used by the hatchery program. pHOS is the proportion of Hatchery Origin Spawners that spawn naturally.

Broodstock composition. The goals for pNOB and pHOS refer to the intended proportion of natural origin fish that are taken into the hatchery in each generation (pNOB) and the proportion of hatchery origin returns that are allowed to spawn naturally (pHOS). To the right of the pNOB input is an orange cell. If "R" is provided here the model will take broodstock randomly from the combined return of natural (NORs) and hatchery (HORs) origin fish.

Realized Regardless of the intent or goal of the program, the actual values for pNOB and pHOS will depend on the size of the hatchery program and the return of natural origin fish to the system. These calculated cells provided the actual pNOB and pHOS. These values will always be equal to or less than the goals for pNOB and pHOS.

Broodstock. This is the number of adult fish that are spawned in the hatchery (males plus females). Spawners imported from outside the system can also be indicated; the total broodstock is the sum of local and imported fish.

Smolt Released. The total number of smolts released is a calculated field based on eggs/female, percent female, egg to fry and fry to smolt survival rates in the hatchery. The factors that go into computing the smolt release are found on the Hatchery Component page.

HOR Destination. This refers to the distribution of hatchery origin fish (HORs) returning to the subbasin. A proportion of returning hatchery fish enter the hatchery but some percentage enters the natural spawning component either through straying or by deliberate practice. The input here refers to the proportion that enters the hatchery; the proportion entering the natural population is calculated as 1-the proportion entering the hatchery.

Recruits/Spawner. This factor for hatchery fish is analogous to the productivity value entered above for the natural population. It is the survival rate from spawner to smolt in the hatchery and out of subbasin survival factors. It is usually computed from coded wire tag data or other hatchery information.

Fitness. This is simply a toggle regarding the use of a fitness factor to scale the performance of hatchery origin fish relative to that of natural origin fish. The input for fitness is found in the Fitness panel below the input panel on the Populations page. Fitness of hatchery fish relative to natural fish is addressed using the Ford fitness equations that are found on the Fitness page.

Other Hatchery Stocks. The influx of hatchery fish from other subbasins and stocks is not explicitly included in the AHA calculations. However, their influence is recognized and noted in this section. The contribution of hatchery fish from other programs is checked relative to guidelines established by the HSRG.

Output

The results of the AHA computations are summarized in figures on the lower three panels of the Population sheet. Generation by generation results for each scenario can be found in the Scenario pages.

Realized Spawning Composition. This chart (Figure 4) simply plots the realized contribution of hatchery fish to the natural population (pHOS) against the proportion of natural origin broodstock taken into the hatchery (pNOB). These numbers are calculated in the input section and were discussed above. Note that each scenario has a distinctive marker. The marker is shown in the hatchery input section between the pNOB and pHOS labels. The results of each scenario are plotted on the chart so that the relative movement of the spawning population can be examined.

This chart also shows the Proportion of Natural Influence (PNI) of the scenario. PNI is a function of the proportion of natural spawners that are of hatchery origin (pHOS); as pHOS decreases, PNI increases.

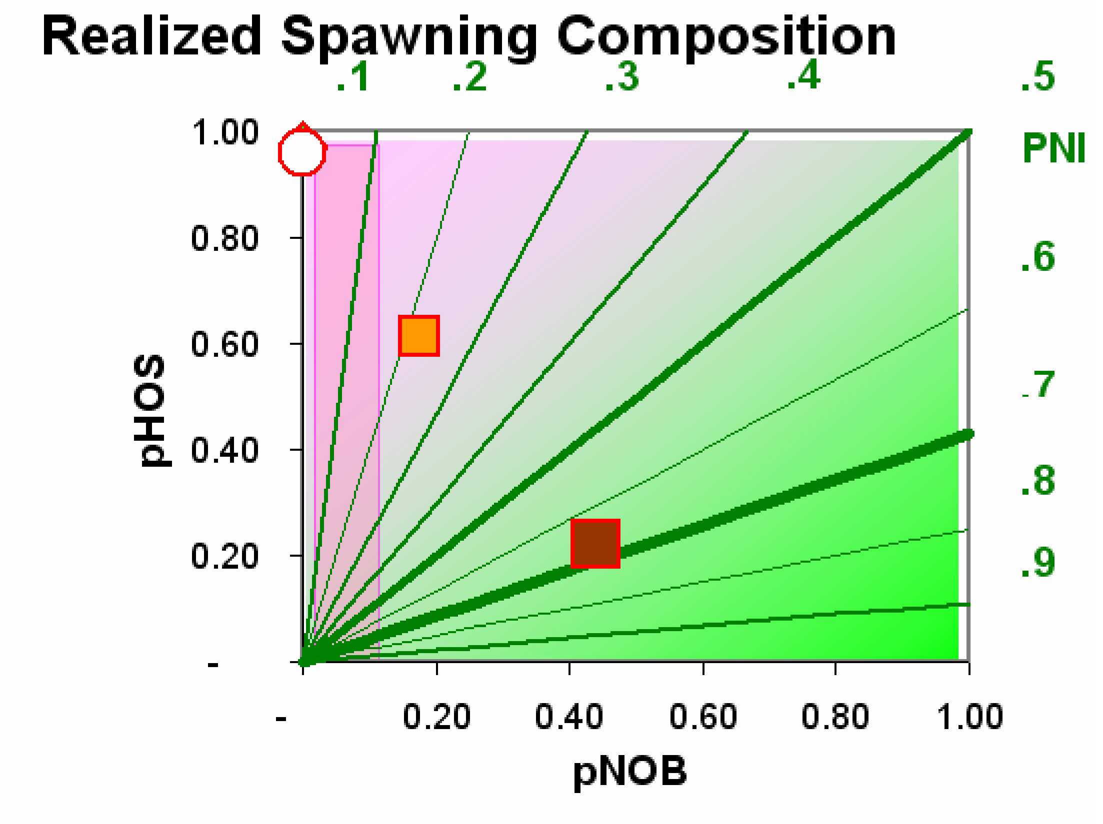

Figure 4. AHA output chart comparing the proportion of hatchery origin fish in the naturally spawning component (pHOS) and the proportion of natural origin fish in the hatchery broodstock (pNOB). PNI is the proportion of natural influence in the program.

The chart has a color pattern to indicate the degree of hatchery and natural integration. Increasing levels of natural origin fish in the hatchery broodstock (pNOB) trend toward the green areas of the chart while increasing levels of hatchery origin fish on the spawning ground tend toward the pink. The HSRG concluded that the goal of integrated programs shouldbe to allow selection in the natural environment to dominate over selection in the hatchery. Hence, integrated programs should appear in the green areas of the chart. Said another way, the HSRG guideline is that integrated programs should have a PNI above 0.5.

<u>Adult Return Composition.</u> This chart (Figure 5) provides for each scenario the number and composition of fish produced by the program for marine, mainstem and terminal harvest, and the hatchery and natural spawners.. Composition of the fish in each category is indicated by the color coding explained in the caption to Figure 5.

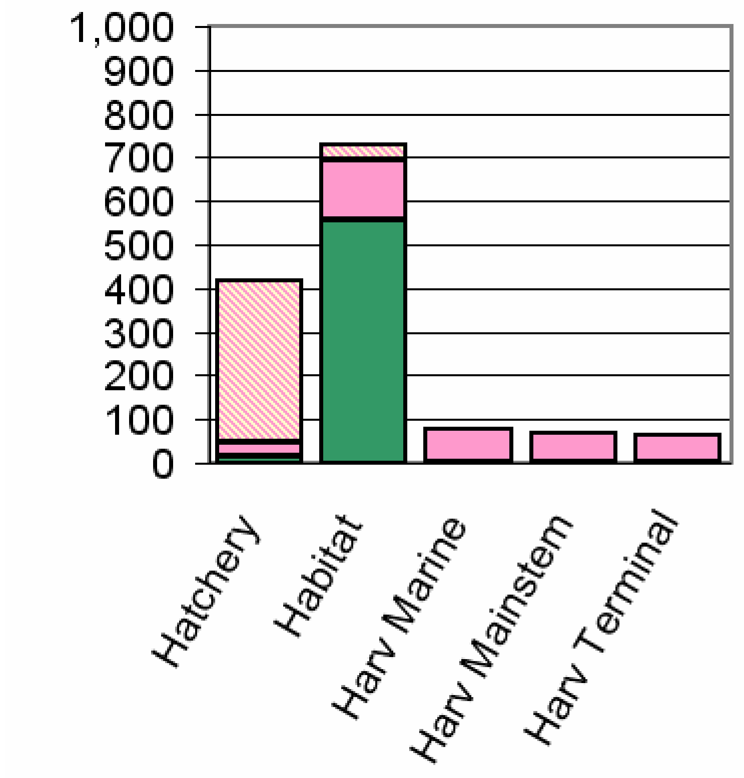

Figure 5. Summary of AHA results comparing the number of adult fish in the spawning population and in harvest. The contribution of hatchery origin fish (HOS) in each area is shown in pink, and the of natural origin fish (pNOB) are shown in green. "Candy-stripe" indicates hatchery fish returning in excess to spawning needs while "khaki" indicates return of hatchery origin fish that have been selected at least one generation in the natural environment.

APPENDIX

Computations in the AHA spreadsheet

The AHA spreadsheet was developed as an aid to discussions about trade-offs and interactions resulting from different assumptions about habitat, harvest, hydro and hatcheries. It was intended to be a simple platform where different assumptions for the four Hs could be integrated. In the following we describe the computations included in the spreadsheet as it is currently configured for application in the Columbia Basin. It should not be viewed as a new model, but rather as a platform for combining existing models.

We have tried to keep the spreadsheet simple so that it is fast and easy to use. The present version is a generational model with no age structure. A version with age structure has been drafted and is being tested, it is a bit more cumbersome both in terms of computational speed and in the number of input values that must be provided—in many cases the simpler generational model may be adequate and preferable. In the current version we have chosen to include stochastic variation only in the marine survival life history segment, future version will include options to stochastically vary additional survival parameters.

In general, the Beverton-Holt survival function is assumed for each life stage for hatchery and natural fish:

$$N_{i+1} = \frac{N_i \cdot p_{i+1}}{1 + \dfrac{N_i \cdot p_{i+1}}{c_{i+1}}},$$

where N_i is the number of fish alive at the end of life stage i, and p_i and c_i are input parameters.

The AHA spreadsheet keeps track of two population components: hatchery origin returns (HORs -- fish originating from a hatchery) and natural origin returns (NORs – fish originating from natural spawning). In other words a fish becomes a NOR after one generation in the wild.

Hatchery Production

For hatchery spawning, incubation, and rearing we compute the number of hatchery smolts produced (H_{smolt}) as follows:

$$H_{smolt} = \left[HOB \cdot (eggs/spawner)_H + NOB \cdot (eggs/spawner)_N \cdot (NOBfactor)\right] \cdot (fry/egg)_H \cdot (smolt/fry)_H$$

where *HOB* and *NOB* are the numbers of hatchery and natural origin broodstock used in the hatchery. *NOBfactor* is the relative reproductive success from return to hatchery release of smolts of natural origin fish in the hatchery environment. The remaining variables are inputs from hatchery records.

Survival of hatchery fish from smolt to returning adult is computed as:

$$H_{adult} = \frac{H_{smolt} \cdot p_{sm-ad} \cdot p_H}{1 + \dfrac{(H_{smolt} + N_{smolt} \cdot f_N) \cdot p_{sm-ad} \cdot p_H}{C_{sm-ad}}},$$

where f_N is a relative competition factor, p_H is a survival factor for hatchery fish in the wild, and,

$$p_{sm-ad} = s_D \cdot SAR \cdot s_U \, ,$$

where s_D is juvenile Downstream passage survival, s_U is adult Upstream survival, and SAR is survival from smolt entering the estuary to adult return (all ages). SAR has a lognormal distribution with default means and variances for high, medium, and low ocean survival phases. SAR variability can be toggled on or off be the user.

Harvest is computed as adult equivalents based on user supplied adult equivalent harvest rates. Marine, mainstem, and terminal harvests are removed in sequence.

Hatchery adults that escape fisheries are directed to either the hatchery or the natural spawning grounds as determined by user provided destination fractions.

Natural Production

Reproductive success and survival of natural origin fish is computed in three stages, spawner to fry, fry to smolt , and smolt to spawner. Computations are as follows:

$$N_{fry} = \frac{p_{sp-fry} \cdot F_{sp-fry} \cdot \left(NOS + HOS \cdot p_{N1}{}^{HOS/(HOS+NOS)}\right)}{1 + \dfrac{p_{sp-fry} \cdot F_{sp-fry} \cdot \left(NOS + HOS \cdot p_{N1}{}^{HOS/(HOS+NOS)}\right)}{C_{sp-fry}}} \, ,$$

where, $p_{sp\text{-}fry}$ is the Beverton-Holt productivity parameter for the spawner to fry stage, $F_{sp\text{-}fry}$ is a [genetic] fitness factor (see below), and *NOS* and *HOS* are the numbers of natural and hatchery origin spawners on the spawning grounds. The parameter p_{N1} is a user provided [phenotypic] productivity factor for hatchery spawners in the wild, and $C_{sp\text{-}fry}$ is the Beverton-Holt capacity parameter.

Similarly,

$$N_{smolt} = \frac{p_{fry-sm} \cdot F_{fry-sm} \cdot N_{fry} \cdot p_{N2}{}^{HOS/(HOS+NOS)}}{1 + \dfrac{p_{fry-sm} \cdot F_{fry-sm} \cdot N_{fry} \cdot p_{N2}{}^{HOS/(HOS+NOS)}}{C_{fry-sm}}} \, ,$$

and

$$N_{adult} = \frac{p_{sm-ad} \cdot F_{sm-sp} \cdot N_{smolt} \cdot p_{N3}{}^{HOS/(HOS+NOS)}}{1 + \dfrac{p_{sm-ad} \cdot F_{sm-sp} \cdot N_{smolt} \cdot p_{N3}{}^{HOS/(HOS+NOS)} + p_{sm-ad} \cdot p_H \cdot H_{smolt} \cdot f_N}{C_{sm-ad}}} \, .$$

Harvest is computed as adult equivalents based on user supplied adult equivalent harvest rates for natural origin fish. Marine, mainstem, and terminal harvests are removed in sequence.

The number of natural origin adults (NOB) required for hatchery broodstock are removed after harvest.

The user can specify a minimum number of NORs in the natural escapement. This "escapement goal" will restrict both fisheries and broodstock collection.

Fitness Computations

If the fitness toggle in the AHA spreadsheet is set to "Y", a fitness loss factor (F_i *above*) is computed for the naturally spawning population component. The fitness function includes several user supplied input parameters, which in combination with the calculated hatchery vs natural origin composition in the hatchery broodstock and in the natural spawning population, determine the fitness factor. The fitness computations are derived from concepts developed by Ford (2002), Lynch and O'Hely (2001), and by Campton, Busack, and Currens (personal communication). A paper detailing this approach is being prepared for publication.

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Lynch, M., and M. O'Hely. 2001. Supplementation and the genetic finess of natural populations. Conservation Genetics 2: 363-378.

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