

Escaped Salmon Risk Assessment Tool

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Introduction

A risk analysis requires specifying the potential states of nature, their probabilities, potential management actions (note that this includes taking no action), and their effects on the states of nature. In this case, the states of nature we are interested in are the kind of interactions that might occur between wild and escaped Atlantic Salmon. The Salmon Risk model provides a tool for exploring the long-range consequences of these interactions and applying a variety of management scenarios in a hypothetical salmon stream, based on the U.S. Fish and Wildlife Service Atlantic Salmon Status Review.

The model simulates a small population of wild salmon based in a particular stream/estuary system, into which an aquaculture facility is losing fish to escapes. Assuming that an (adjustable) number of smolts and adults escape each year, the user chooses an interaction scenario, and the model calculates the changes in the populations of wild and escaped fish, projecting forward in time from 2000 to year 2100. A variety of management actions can be applied to the interaction scenario, including reducing escapes, recapturing fish, or taking no action. Results are recalculated for the choice of management plans, and displayed alongside the no-management results. Model results may be displayed graphically and/or as text output.

The model was parameterized as much as possible from the Atlantic Salmon Status Review (<http://library.fws.gov/salmon/>). Survival rates, rates of return, and age at smolting are among the values taken from the report. Table 1 illustrates some of the model assumptions.

Table 1. Model assumptions

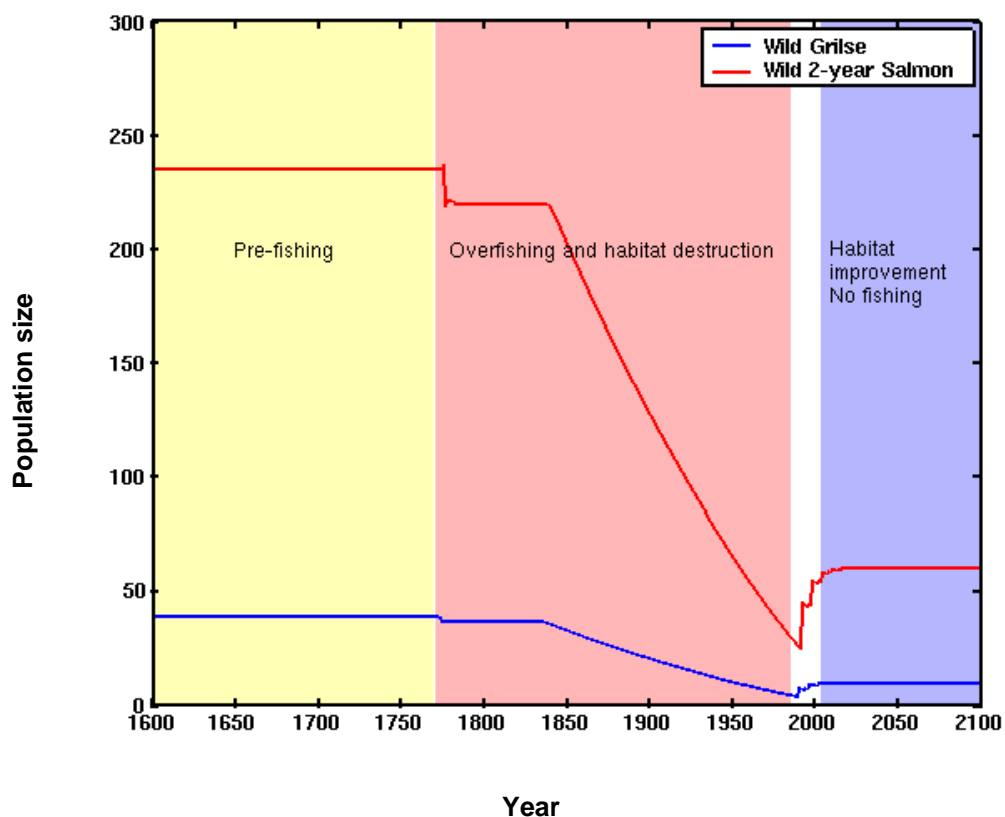
Characteristic	Description	Nominal Value
Habitat improvement	Freshwater only	1% per year
Fishing	occurs from 1771 - 1985	determines the base population of wild fish
Smolting	occurs after one or two years in freshwater	80% of parr smolt after one year
Adult returns	occur after one (grilse) or two years in the ocean	5% of smolts return after one sea-year.
Survival	Rates depend on life stage	range from 8% - 60%
Escapes	Reproduction of escaped smolts is governed by the physiological model. Escapes begin on Julian day 90 (March 31) and continue throughout the year	20 smolts/year 100 adults/year Catastrophic escapes consist of 5,000 adults and 1,000 smolts.
Freshwater Competition	egg and/or parr	choice of intensities
Competition at sea	We assume (for now) that ocean resources are non-limiting	none
Disease	Seawater (estuarine) : migrating smolts	10%

Interactions

The ecological scenarios available fall into two categories. Scenarios in which no interactions occur between the wild and farmed fish can be explored with or without aquaculture escapes occurring. Interaction scenarios, such as Egg or Parr Competition or Genetic Introgression, can occur in any combination, or all together.

No Aquaculture: The output of the model is the trajectory of wild stock in the absence of aquaculture. In this case, no management actions are considered, and the output of the model is a plot of the populations of adult salmon and grilse from the year 1600 to the year 2100. The plot shows the draw-down of the population from fishing and habitat loss, followed by recovery projected to occur between 2000 and 2100 (Figure 1).

Figure 1. Model results for wild salmon in the absence of aquaculture.



No Interactions: The output of the model is the trajectory of wild stock and aquaculture stock given that escapes are occurring, but no specific interactions apply. However, escaped fish survive and reproduce, and their existence dilutes the fraction of the population that are wild salmon.

Egg Competition: The output of the model is the trajectory of wild stock and aquaculture stock given that egg competition is occurring in the redds, leading to fewer hatchings of wild fish. This parameter can be set to any of {none, low, medium and high} values.

Parr Competition: The output of the model is the trajectory of wild stock and aquaculture stock given that parr compete for resources in the streams, affecting parr survival. This parameter can be set to any of {none, low, medium and high} values.

Enhanced Predation: The output of the model is the trajectory of wild stock and aquaculture stock given that there is predator attraction to the mouths of rivers due to aquaculture and thus enhanced predation on both wild and escaped smolts.

Genetic Introgression: The output of the model is the trajectory of wild stock and aquaculture stock given that there is genetic introgression caused by mating between wild and aquaculture fish. The offspring of crosses between wild and aquaculture fish are tracked as aquaculture fish. Only the offspring of two wild parents are considered wild fish.

Disease: The output of the model is the trajectory of wild stock and aquaculture stock given that out-migrating smolts are attracted to aquaculture facilities because of abundant food concentrations in the water, and they contract a disease from proximity to the penned fish, which kills them. Currently, 10% of smolts are affected by disease.

Catastrophic Escapes: This option is only available if an interaction scenario has been chosen. Aquaculture escapes occur as usual (100 adults and 20 smolts) in most years. In year 2030, instead of the regular numbers, 5,000 adults and 1,000 smolts escape. This large escape is repeated in 2060 and 2061, and then again in each year between 2080 and 2085.

Management Scenarios

Adult recapture: The model predicts the trajectory of wild stock and aquaculture stock under the ecological scenario defined by selected interactions. The rate of recapture may be chosen to be between 10% and 100%. Recapture causes an additional mortality on wild stocks proportional to the rate of recapture, up to 5% for 100% recapture. Note that because recapture is of returning adults, but both smolts and adults escape, that even with 100% recapture there will still be aquaculture fish at the end of the simulation, representing those smolts that have escaped and not yet returned to be captured.

Escape numbers reduced: The model predicts the trajectory of wild stock and aquaculture stock under the ecological scenario defined by selected interactions. The amount of escape reduction, may be selected to be between 10% and 100%.

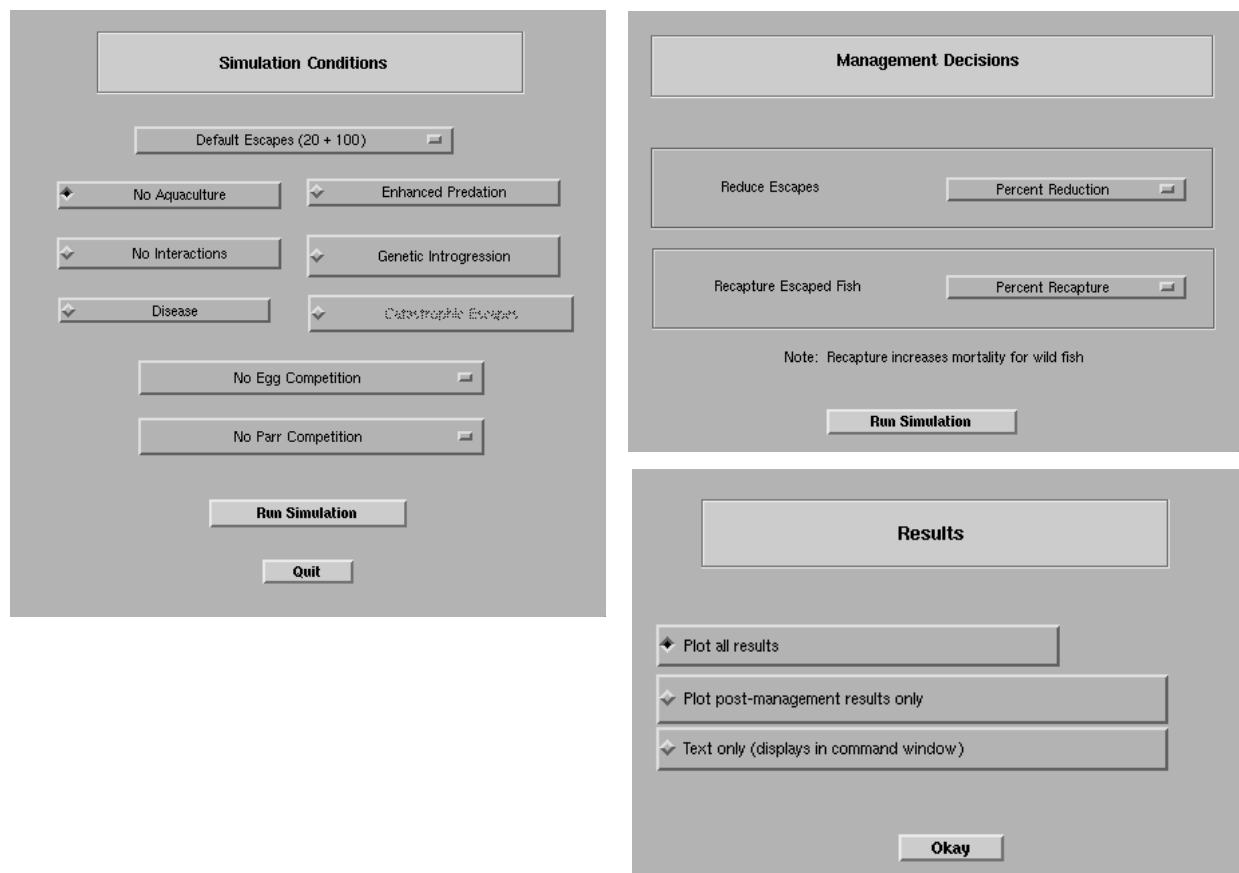
Running the Model

Requirements: Matlab 6.5 (R13). Versions are available for Mac OSX and PC.

Run Matlab, and choose “Open” from the File menu. Browse to find the folder in which you installed the risk tool, and choose Salmon_risk.m. You will be prompted to add the directory to the search path; choose the second option (Add directory to the top of the search path).

Once the file is open, pull down the Debug menu, and choose “Run”. The Salmon Risk tool is driven by a series of pop-up menus that control the simulation, management and output options (Figure 2).

Figure 2. Popup menus controlling simulation options.



Selecting simulation conditions

The model is driven by a series of three menus. The first menu allows selection of interaction options describing the ecological scenario for simulation. Escapes can be set to the default rate of 20 Smolts and 100 Adults per year, or can be limited to Smolt escapes (20 per year) or Adult escapes (100 per year) only.

The “No Aquaculture” and “No Interactions” scenarios exclude other choices. The other choices describe possible interactions that could occur simultaneously, so any combination of those may be selected, by clicking on the button(s) with the mouse.

Once a scenario is chosen, clicking on the “Run Simulation” button pops up the next menu.

Selecting Management Options

The second menu in Figure 2 offers choices for management. Clicking on a button in this menu brings up a pulldown-list of settings (from 10% to 100%) for reducing escapes, or for recapturing escaped fish. Making no selection in either box results in no management action taken.

Once the management decisions are satisfactory, the “Run Simulation” button brings up the third menu.

Selecting Output Options

The third menu is for selection of output options. The three options are:

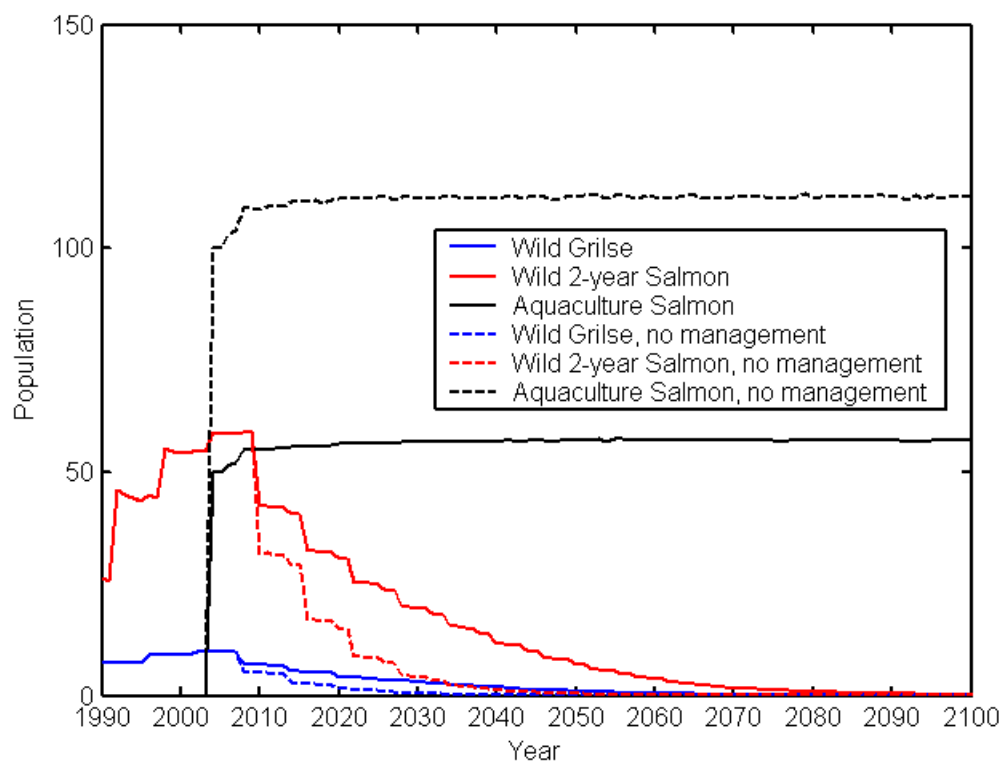
- Text Only
A text description of the scenario and outcome are displayed in the Matlab command window
- Plot post-management results
A text description of the scenario and outcome are displayed in a results window, and trajectories are plotted for the populations under managed conditions
- Plot All results
A text description of the scenario and outcome are displayed, and trajectories are plotted for the pre- and post-management results

The results options are only offered when the first simulation is run.

Once the “Okay” button is pressed, calculations begin and results are displayed. Figure 3 shows the graphic trajectory and numerical results for a multi-effect, managed scenario.

The paired text and graphics windows are titled to reflect the simulation number, to avoid confusion after multiple simulations have been run. Note that the population results for these simulations are relative to actual populations, not absolute values.

Figure 6. Example results from a managed scenario.



Simulation conditions:

Genetic introgression

Management actions:

Escape reduction 50 %

Fish stocks in year 2100 (no management):

Wild	Farmed
14.4408	118.685

Fish stocks in year 2100 (with management):

Wild	Farmed
49.2571	57.2415

Exiting the program

All results windows remain when the program exits, and must be closed individually.

After the calculations are complete and results are displayed, the original menu reappears. New scenarios may be explored repeatedly, although the system will eventually run out of memory if the results and trajectories windows aren't closed. The final option on the conditions menu is "Quit" and once all scenarios of interest have been investigated, pushing this button exits the program.