ECONOMIC EVALUATION OF BARRIERS TO MINIMIZE ESCAPEMENT OF RESERVOIR SPORTFISHES

Device Requirements

The web page is functional on mobile devices, tablets, and computers; however, to ensure the best user experience, analyzing data on a computer is recommended. No prior experience with or installation of R is required unless users want to use the source code to investigate scenarios that fall outside the scope of the application.

Overview

The application is set to default values which represent the costs to construct a barrier on Brushy Creek Lake in Iowa in 2020. On the sidebar, you can select and drag values to evaluate how changes in spillway size, or various construction costs metrics will change the cost distribution over time.

For fish escapement cost metrics, these values are based on Muskellunge (species 1) and Walleye (species 2) stocking and survival metrics in Brushy Creek Lake, IA. As the sidebar elements are moved, the app will automatically update plots and tables. The first plot below shows the cost distribution for two species and the barrier.

To visualize results for species individually, the ‘Plot and Summary Statistics - Species 1’ and ‘Plot and Summary Statistics - Species 2’ tabs can be used. The ‘Barrier Cost Table’ and ‘Escapement Cost Table’ tabs store and display results from individual simulations. For more details on how the model works and the inputs, please navigate to the ‘Model Inputs & Mechanics’ tab.

Step-by-Step Guide to Using the Application

Sidebar Inputs

The sidebar on the application is where you will start by inputting your data. As you adjust values, the plots and results will automatically update. If you refresh your browser, the application will revert back to the default input values.

Simulation Parameters

In this section, you can drag the inputs to the desired number of years you are interested in simulating (default = 10 years), and the total number of simulations (default = 10,000).
Note: Increasing the number of simulations will affect the speed of the application.

Spillway Characteristics and Estimated Construction Costs

This section s where the barrier cost data will be input. The first selection is whether you have itemized estimates for construction costs.

If you select *'No'*, the application will update and provide you with a box to enter a total construction cost estimate. This feature is useful if your barrier of interest does not include the same cost categories as a parallel-bar barrier (e.g., an electric barrier may not have concrete costs), This feature may also be useful in the planning or design phase of a project where multiple potential designs are being considered.

If you select '*Yes'* for itemized estimates, you will be prompted to enter values for the following categories:

Spillway Length (meters) – the length of the spillway, or length of the area that a barrier will be installed around (e.g., for a box-type outlet structure, this would be the perimeter).

Mobilization – a common line item on contractor bids, this includes expenses incurred by contractors to transport materials and equipment to a jobsite, and all other costs associated with preparing the jobsite for construction.

Grading – the cost of site preparation and leveling if necessary.

Spillway Concrete Volume (m^3) – represents the volume of concrete needed (area * depth).

Material Cost (Per Linear Meter)- the total cost of materials needed per linear meter (e.g., for a parallel-bar barrier this includes the posts, rails, clamps, and hardware). This number will be multiplied by spillway length.

Concrete Cost (Per Cubic Meter) – the cost of concrete per cubic meter to be multiplied by the spillway concrete volume needed.

Engineering (Cost per Hour) – this estimate would be based on an engineers bid or invoice for design, and could also include steps such permitting depending on the structure of the agency.

Engineering time required (hours)– Cost per hour, above, is multiplied by this number to calculate a total cost for design and engineering.

Note: You can enter '0' for some categories that are not applicable; however, opting to use the non-itemized estimate will enable easier interpretation in these scenarios. The following inputs are scaled, therefore, if you enter a value for one you must enter a value for both to be considered into the model:

- Spillway length and material most
- Concrete volume needed and concrete cost
- Engineering cost per hour and engineering time required

If you have additional lump-sum costs that are not covered in the itemized categories (e.g., cost of a permit), you may incorporate those by adding them to the lump-sum items above (mobilization or grading).

On-going Barrier Maintenance and Upkeep Costs
This section will include your annual maintenance costs and repair costs.

Maintenance costs - entered as a minimum and maximum value, and are drawn each year from a uniform distribution based on the provided range. The maintenance cost value should include all cost associated with upkeep of the barrier, including labor, materials needed, or other recurring costs (e.g., power costs to operate an electric barrier).

Repair costs - also input as a minimum and maximum and drawn from a uniform distribution. However, unlike maintenance costs, repair costs do not necessarily occur on a periodic annual basis. Therefore, the next input is '*Repair Probability'*. This number (from 0 to 1) represents the probability that a barrier will need to be repaired in a given year. A binomial multiplier (0 or 1) is drawn reach year based on this probability and multiplied to the repair cost value

Barrier Efficiency is the final input in this section, and represents the estimated proportion of escapement that is reduced, or expected to be reduced, by your barrier (from 0 to 1). For example, an efficiency of 1 would mean that all escapement is stopped by the barrier, whereas an efficiency of 0.80 would add 20% of the escapement value each year to the barrier costs.

Note: Exact estimates for the cost of barrier maintenance, repairs, and the efficiency of the barrier may not be known in initial planning phases; however, the application could be run with a number of different potential costs scenarios for these estimates to provide an idea of all possible outcomes. Additionally, this section may be useful for barrier planning and design where a trade-off may exist between maintenance and efficiency. For example, a wider bar spacing may reduced maintenance costs and repair probability by allowing more debris to pass through, but may concurrently reduce efficiency. The application could be run with several cost and efficiency scenarios to visualize trade-offs in the final barrier cost.

Escapement Parameters
In this section you will input your escapement parameters for each species. For a given species, the inputs are:

Species (text label) – this is completely optional and simply labels your plots with the name you type in here to help keep track of your results.

Number of Age-Classes- the application can handle from 1 to 4 age-classes of escapement for a given species at one time. For example, in our case study reservoir,

escapement generally does not occur until fish are adults (3+), therefore, we quantified escapement from fish from age-3 to age-6. Conversely, in some systems, escapement may only occur for juvenile fish, therefore, it could potentially make sense to only quantify escapement value for age-1 fish. We limited the maximum to four age-classes to reduce complexity in the application and ensure relatively fast computing time; however, additional year-classes could be included if necessary by altering the source code available in GitHub.

Number Stocked – the number of fish stocked into a system annually.

Price per fish – the total cost to stock one fish. The calculation of this cost may vary by agency, but would generally include the cost of raising the fish, and the cost of transport and stocking. The most accurate results would be based on data from the hatcheries that produce the fish for a given system; however, if that data is not available, the 'AFS Guide to the Monetary Value of Fish Kill Investigations' (Southwick and Loftus 2017) contains region specific cost estimates for a range of species and sizes of fish.

Post Stocking Survival - entered as a minimum and maximum value, and drawn each year from a uniform distribution based on the provided range. Post stocking survival represents the estimated survival for the first-year post-stocking.

Adult Survival – Annual adult survival value, entered as a minimum and maximum value, and drawn each year from a uniform distribution based on the provided range.

First age at escapement – Represents years in the system from stocking to the first age at which fish escape.

Note: the minimum age that can be entered is 1. If fish are escaping within the first year post-stocking, the replacement cost value would be equivalent to the cost of stocking because a survival rate has not yet been applied. The exception to this would be a case in which you assume some rate of mortality that occurs immediately post-stocking, or at some point prior to escapement but still within a year. The application could be manipulated to handle that scenario, but would require the user to investigate the source code and model diagrams to ensure proper interpretation of results.

Second, third, etc. age at escapement – These selections will appear as you change the number of ages you want to evaluate. This represents years in the system from stocking to the first age at which fish escape. Years do not have to be evenly spaced. For example, you could enter ages 1 and 2, and then ages 5 and 6; however, it would assume that no escapement occurs in ages 3 and 4.

Escapement Rate - Annual escapement rates (0-1), entered as a minimum and maximum value, and drawn each year from a uniform distribution based on the provided range.

The same set of inputs are then repeated for Species 2.

Note: If you are only interested in results for one species, ensure that you are recording and interpreting results from the correct, single species tab. If you enter inputs for one species only, and record or interpret results from the homepage, the default costs for the other species will be added in.

Main Panel: Results - Plot and Summary Statistics

The main panel of the application is where results are displayed. The following descriptions are applicable for the home page 'Plot and Summary Statistics' and for the species-specific pages (tabs labeled 'Plot and Summary Statistics – Species X').

Cost Distribution Plot

The primary plot displayed is a probability density plot which displays the results for the present value of escapement and the present value of the barrier cost over however many years and simulations were specified by the user. The x-axis displays the present value over n-years, and the y-axis shows the density, which is essentially analogous to frequency in a histogram.

Summary Table

The summary table, located under the plot, shows the mean present-value cost for the barrier and for the escapement over n-years and the n-simulations, as well as the minimum present value and maximum present value.

Below the summary table, the probability of a positive net benefit is displayed. A positive net benefit occurs when the value of escaped fish exceeds the cost of the barrier. The time period when this probability equals 1 could be interpreted as the time period at which you could be confident that the barrier would be the cost effective option. However, given that these analyses are not focused on quantifying benefits in terms of 'profit', but rather value saved, there may be lower probability thresholds that an agency or user is willing to accept. For example, there may be scenarios where even if the barrier has a 50% probability of being cost effective, an agency may opt for the installation rather than continue to lose fish to escapement. Therefore, the interpretation of the results will be system and user specific.

Raw Data Download Buttons

Users can download the raw results from a simulation by clicking these buttons, which will open a prompt to select where the data should be downloaded to. Downloading these raw data files is a way to save results from multiple scenarios for

later comparison, and enables users to expand on the summary statistics and/or figures that they can develop for their data.

For an explanation of the headers in the downloaded CSV's, please see the 'Barrier Application Metadata' excel file (Supplementary Materials), or download the file in the 'Help' tab in the application.

Main Panel: Results - Plot and Summary Statistics (Species 1 / 2)

The species 1 and species 2 tabs contain the same results described above; however, the plot and summary table are calculated for only one species. In addition to the results described above, the species specific tabs have the following two tables:

Replacement Cost by Age

The replacement cost table shows the mean, minimum, and maximum annual replacement cost values for each age-class of a given species.

Number Escaped by Age

The number escaped table shows the mean, minimum, and maximum annual number escaped for each age-class of a given species.

Main Panel: Barrier Cost Table and Escapement Cost Table

The 'Barrier Cost Table' and 'Escapement Cost Table' tabs display the results from each simulation and are identical to the files downloaded by clicking the download buttons. For an explanation of the headers, please see the 'Barrier Application Metadata' excel file (Supplementary Materials), or download the file in the 'Help' tab in the application.

Main Panel: Barrier Pictures

Pictures from before, during and after barrier construction on Brushy Creek Lake (2020).

Main Panel: Model Inputs & Mechanics

This tab contains the diagrams demonstrating how the application calculates escapement cost and barrier cost.

Main Panel: Instructions and Contact

This tab contains the instruction document and metadata for download, as well as contact information for any further questions about the application.