Program Basin TribPIT

Cohort Analysis of Juvenile Salmonid Movement and Survival in Tributaries

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Chapter 1: Overview

1.1 Objective

Traditional release-recapture models have been used on the Columbia River system to estimate survival with the assumption that from release to a detection point, or from one detection point to the next, an individual fish either (1) migrates downstream or (2) dies. Studies of Chinook salmon and steelhead, however, show that many juvenile salmon and steelhead stay upstream ("residualize") in the tributaries for one or more years before migrating downstream. A traditional release-recapture analysis, which assumes all released fish migrate downstream in the release year, would treat the fish that residualize as mortalities. Program Basin TribPIT provides cohort-based survival estimates that account for the possibility of an individual fish overwintering for multiple years during the downstream migration process.

In addition, the sample sizes for studies in the tributaries often make it difficult to obtain precise estimates of the survival-related parameters. Basin TribPIT allows the user to take advantage of the fact that multiple releases may occur within the same basin and may merge downstream with some shared parameters across multiple releases. Program Basin TribPIT supersedes Program TribPIT by having all the capabilities of TribPIT plus the additional capability of analyzing multiple release groups simultaneously. This boosts the effective sample size of the release–recapture study and allows for better estimates of the parameters of interest.

1.2 Changes from Program TribPIT

Program Basin TribPIT has added more flexibility to the study scenarios that can be analyzed. Namely,

- There can be multiple upstream tributary releases with unique survival/movement probabilities to the first detection site, with the possibility of shared parameters downstream for additional precision.

- It allows auxiliary downstream releases from locations that are not necessarily detection sites.
- A study can have different final detection sites for different years and releases.
- The user can define custom biologically meaningful migration periods rather than simply using the calendar year.

Chapter 2: Basin TribPIT Model

2.1 BasinTribPIT Parameters

The parameters of a BasinTribPIT model are described below. Note that each of the parameters has an initial index of "r" representing the release. For the sake of clarity, the release index is omitted in the following descriptions.

β_{rijk} = the probability of survival and movement from the initial release to the first downstream site i, released in year j, and detected at site i in year k.

ϕ_{rijk} = the probability of survival and movement from site $i-1$ in year j to site i in year k, given that the individual was alive at site $i-1$ in year j.

P_{rik} = the probability of detection at site i in year k, given that an individual was alive at site i in year k.

λ_{rijk} = the probability of survival and movement and detection from the penultimate site $i-1$ in year j to the final site i in year k, given that the individual was alive at the penultimate site in year j. Survival and movement cannot be estimated separately from detection in the last reach.

When the user selects "Fit the Models" after loading the data and configuring the study, Basin TribPIT estimates the parameters for a series of hierarchical models based on the nature of the study data. The models to be estimated are determined automatically by Basin TribPIT. Basin TribPIT then calculates the Akaike Information Criterion (AIC) for each model and reports the optimal, or "best," model for the study data.

The models are created by equating the parameters across releases. Parameters may be equated as follows:

1. Across releases that are released in the same year, or
2. Across releases that are released from the same site, or
3. Across all releases regardless of release site or year.

In addition, the parameters that are equated may include:

1. Only the detection parameters (P_{rik}), or
2. The detection parameters (P_{rik}) and the survival and movement parameters (ϕ_{rijk} and λ_{rijk}).

Basin TribPIT equates only "equivalent" parameters across releases. Equivalent parameters are:

1. Of the same type. ϕ parameters can only be equated to ϕ parameters of another release; the same goes for λ and p parameters. β parameters are never equated with other β parameters. In some cases, as explained in Section 2.4, β parameters may be equated to ϕ parameters, if they meet condition 2 below.
2. In addition to being of the same type, all the indices except the release index must be the same. For example, ϕ_{1223} is equivalent to ϕ_{2223} but not ϕ_{2233}.

There are seven possible scenarios based on the study data, explained in more detail in the following section. TribPIT determines the appropriate scenario as follows.

1. If there is only one release, it uses **Scenario 1**.
2. If there are multiple releases from the same site in multiple years, it uses **Scenario 2**.
3. If there are multiple releases in the same year from multiple sites, it uses **Scenario 3**.
4. If there are multiple releases from the different sites and in different years:
    a. If there are no replicate releases from the same site, and there are no replicate releases in the same year, it uses **Scenario 4**.
    b. If there are replicate releases from at least one site, but no replicates in any one year, it uses **Scenario 5**.
    c. If there are replicate releases in at least one year, but no replicates from any one site, it uses **Scenario 6**.
    d. If there are replicate releases for at least one site and at least one year, it uses **Scenario 7**.

Models with the same ID but in different scenarios are equivalent (e.g., M.ys.2 in Scenarios 5 and 7).

2.2 Basin TribPIT Models

Sections 2.2.1 to 2.2.7 describe what models are available in all possible scenarios. The "Model ID" is a unique identifier assigned for ease of reference.

2.2.1 Scenario 1: Single Release Only

The study data consist of a single release.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.n.1	Unique	Unique

2.2.2 Scenario 2: Multiple Releases from the Same Site But in Different Years

The study data consist of multiple releases from the same site but across multiple years.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.y.1	Unique	Unique
M.y.2	Equated across release years	Unique
M.y.3	Equated across release years	Equated across release years

2.2.3 Scenario 3: Multiple Releases in the Same Year But from Different Sites

The study data consist of multiple releases, all in the same year but each from a different release location.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.s.1	Unique	Unique
M.s.2	Equated across release sites	Unique
M.s.3	Equated across release sites	Equated across release sites

2.2.4 Scenario 4: Multiple Releases from Different Sites and Years

The study data consist of multiple releases from different sites and different years, but no more than one release from each site and no more than one release in the same year.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.ys.1	Unique	Unique
M.ys.2	Equated across all releases	Unique
M.ys.3	Equated across all releases	Equated across all releases

2.2.5 Scenario 5: Multiple Releases from Different Sites and Years, Multiple Releases from at Least One Site; All Release Years Unique

The study data consist of multiple releases from different sites and in different years. There is no more than one release in a given year at a site, but there are multiple releases from one or more sites.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.ys.1	Unique	Unique
M.ys.2	Equated across release years, release sites unique	Unique
M.ys.3	Equated across release years, release sites unique	Equated across release years, release sites unique
M.ys.6	Equated across all releases	Unique
M.ys.7	Equated across all releases	Equated across all release years, release sites unique
M.ys.9	Equated across all releases	Equated across all releases

2.2.6 Scenario 6: Multiple Releases from Different Sites and Years, Multiple Releases from at Least One Year; All Release Sites Unique

The study data consist of multiple releases from different sites and in different years. There is no more than one release from a given site, but there are multiple releases from one or more years.

Model ID	Equivalent Capture Parameters	Equivalent Survival and Movement Parameters
M.ys.1	Unique	Unique
M.ys.4	Equated across release sites, release years unique	Unique
M.ys.5	Equated across release sites, release years unique	Equated across release sites, release years unique
M.ys.6	Equated across all releases	Unique
M.ys.8	Equated across all releases	Equated across all release sites, release years unique
M.ys.9	Equated across all releases	Equated across all releases

2.2.7 Scenario 7: Multiple Releases from Different Sites and Years, Multiple Releases from at Least One Site, Multiple Releases in at Least One Year

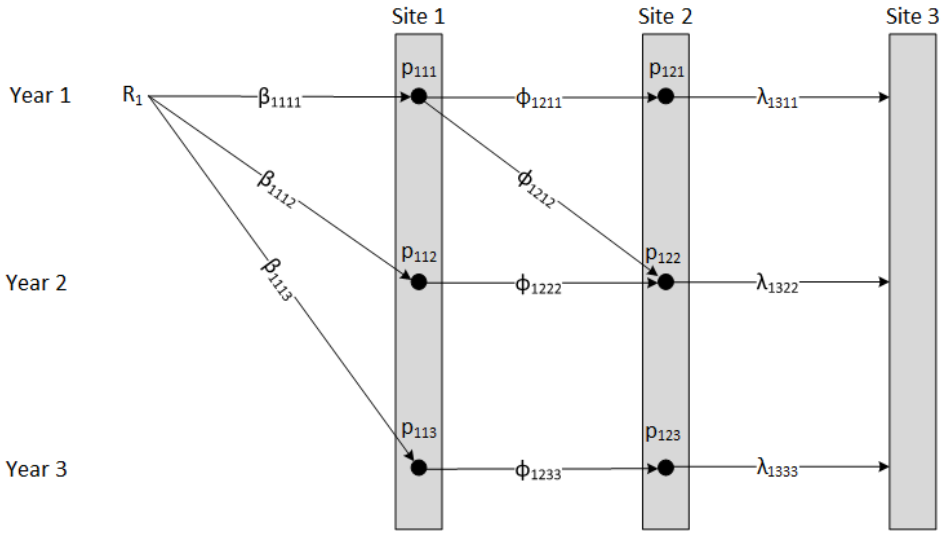
The study data consist of multiple releases from different sites and in different years. There are multiple releases from one or more sites, and there are multiple releases in one or more years.

Model ID	Capture Parameters	Equivalent Survival and Movement Parameters
M.ys.1	Unique	Unique
M.ys.2	Equated across release years, release sites unique	Unique
M.ys.3	Equated across release years, release sites unique	Equated across release years, release sites unique
M.ys.4	Equated across release sites, release years unique	Unique
M.ys.5	Equated across release sites, release years unique	Equated across sites, release years unique
M.ys.6	Equated across all releases	Unique
M.ys.7	Equated across all releases	Equated across release years, release sites unique
M.ys.8	Equated across all releases	Equated across release sites, release years unique
M.ys.9	Equated across all releases	Equated all releases

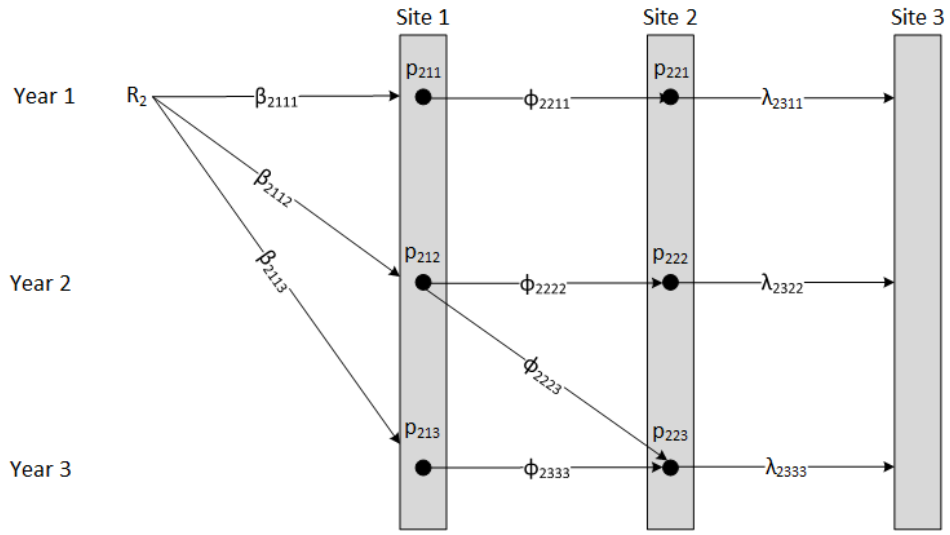
2.3 An Illustrated Example

Figures 1a, 1b, and 1c illustrate three hypothetical releases with three downstream detection sites. The first two releases, R_1 and R_2, are released in year 1 from two different sites upstream of site 1 and thus considered primary releases. R_3 is released in year 2 upstream of site 2 and is considered an auxiliary release. This is an example of two releases in the same year, with all release sites unique (Scenario Six). Figures 1a through 1c illustrate the case of the full model with no parameters equated across releases.

a. Primary release R_1 in a hypothetical study



b. Primary release R_2 for a hypothetical study



c. Auxiliary release R_3 for a hypothetical study

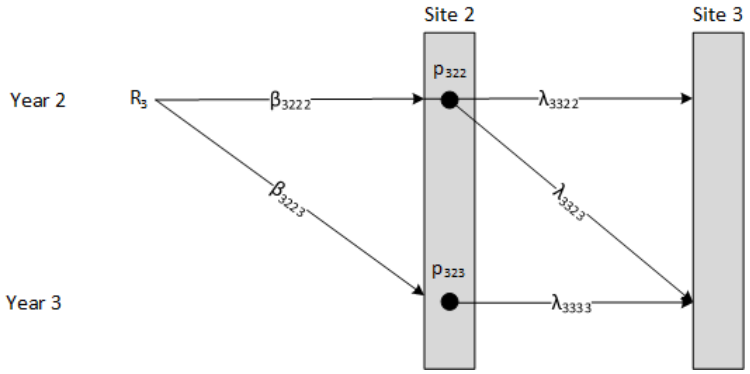


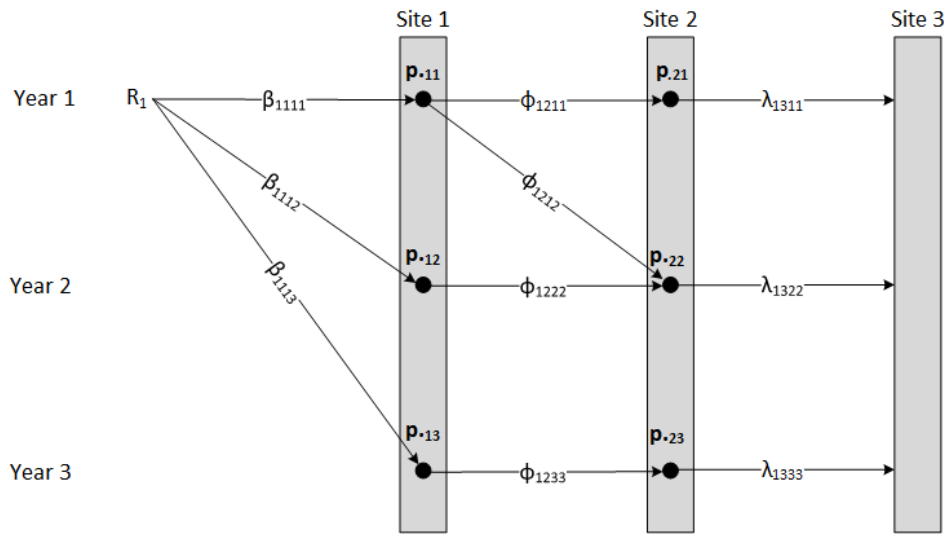
Figure 1. A graphical representation of Model M.ys.1 with no shared parameters for a hypothetical study.

The next model created by Basin TribPIT for scenario six is M.ys.4, illustrated in Figures 2a and 2b. Since R_1 and R_2 are released in the same year, their site-specific capture parameters are equated across releases, reducing the total number of parameters to be estimated by six.

For Figure 2a and 2b and following, a period (".") replaces the release index of parameters that are equated. Thus, in Figure 2a and 3b, $p_{.11}$ is the capture probability at site 1 in year 1 for both releases R_1 and R_2.

Release R_3 is not shown in Figure 2; it was released in a different year from R_1 and R_2 and, thus, it shares no parameters in common with release R_1 and R_2.

a. Primary release R_1 with capture parameters equated across release sites



b. Release R_2 with capture parameters equated across release sites

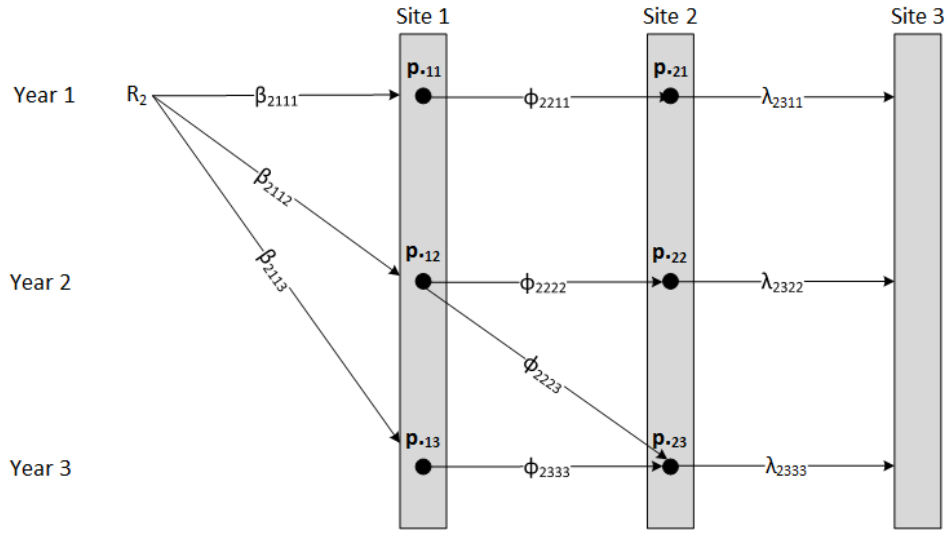
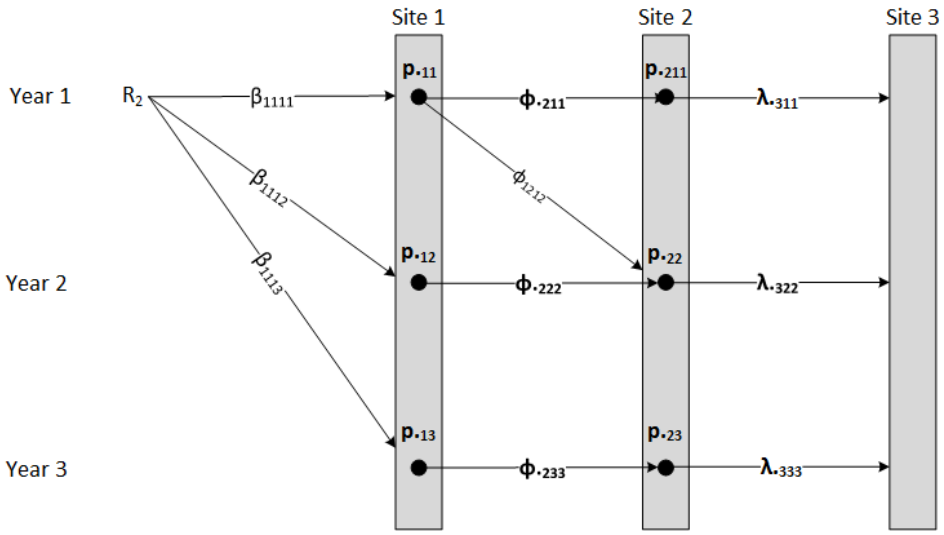


Figure 2. A graphical representation of Model M.ys.4 with the capture parameters (in bold) equated across release sites.

For model M.ys.5, illustrated in Figure 3a and b, the site-specific capture parameters and survival and movement parameters are equated across release sites R_1 and R_2 beginning at site 1. Above site 1 parameters are different because release locations R_1 and R_2 were different. Again, since R_3 was released in a different year, it shares no parameters in common with R_1 and R_2, and is not shown.

a. Primary release R_1 with all parameters equated across release sites



b. Primary release R2 with all parameters equated across release sites

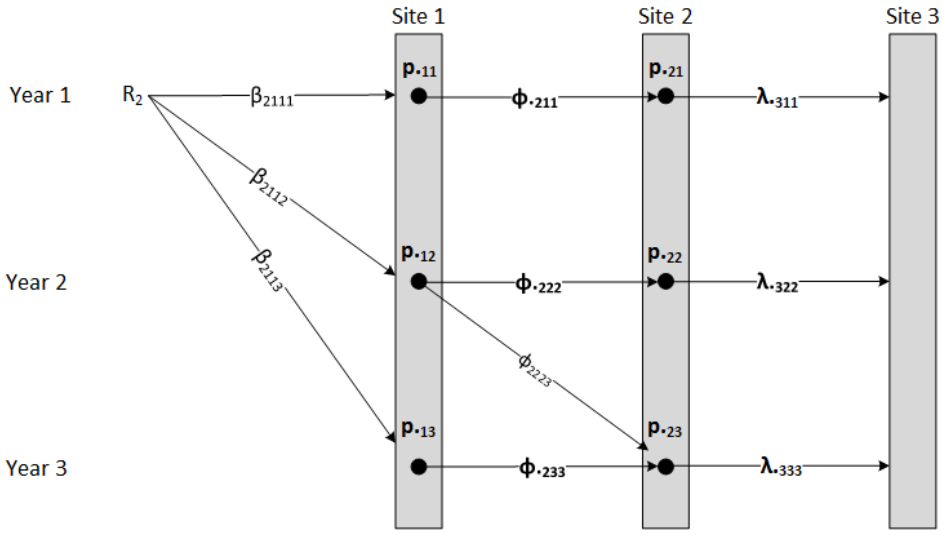
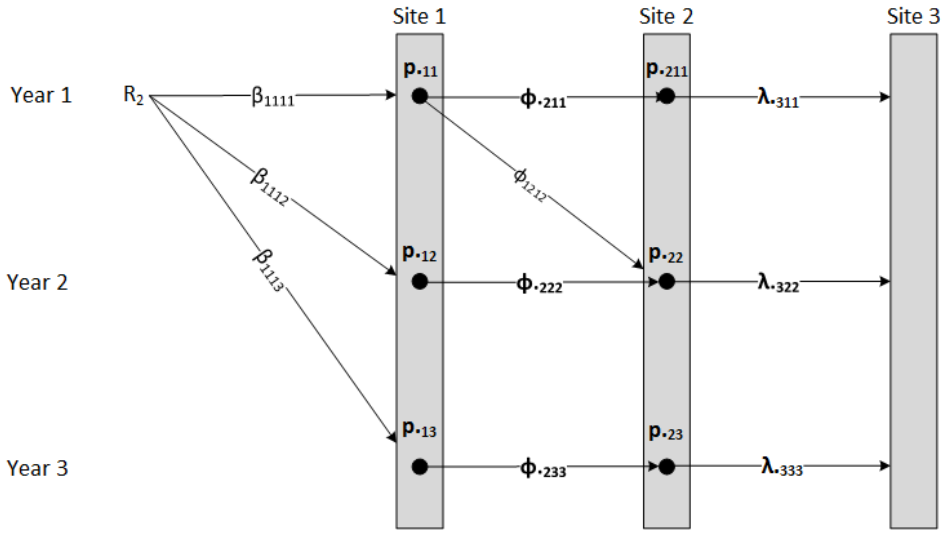


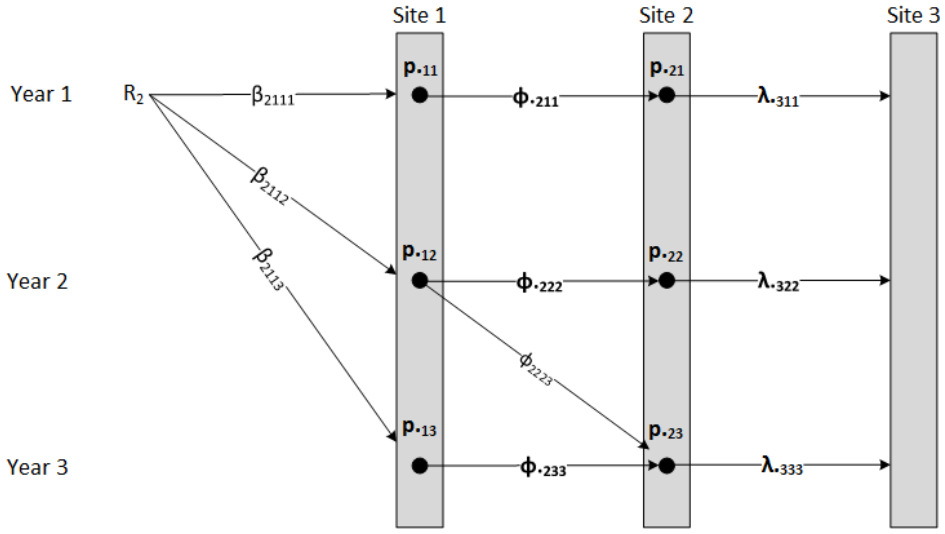
Figure 3. A graphical representation of Model M.ys.5 with all parameters equated across release sites. The equated parameters are in bold.

For models M.ys.6, M.ys.8, and M.ys.9, the capture parameters are equated across all three releases. Figure 4 illustrates model M.ys.9 with all parameters equated across all releases, regardless of release year or release site.

a. Release R_1 with all parameters equated across all releases



b. Release R_2 with all parameters equated across all releases



c. Release R_3 with all parameters equated across all releases

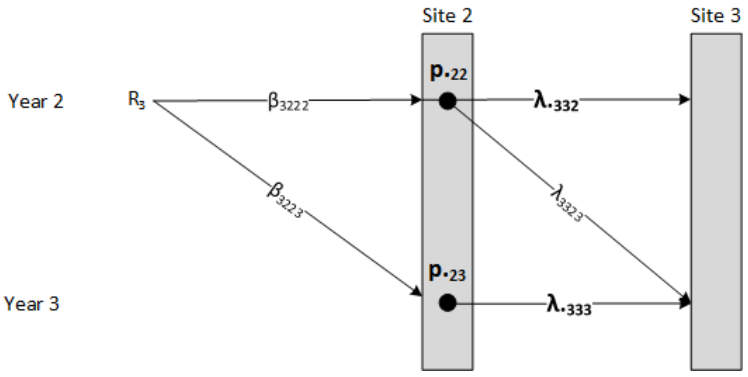


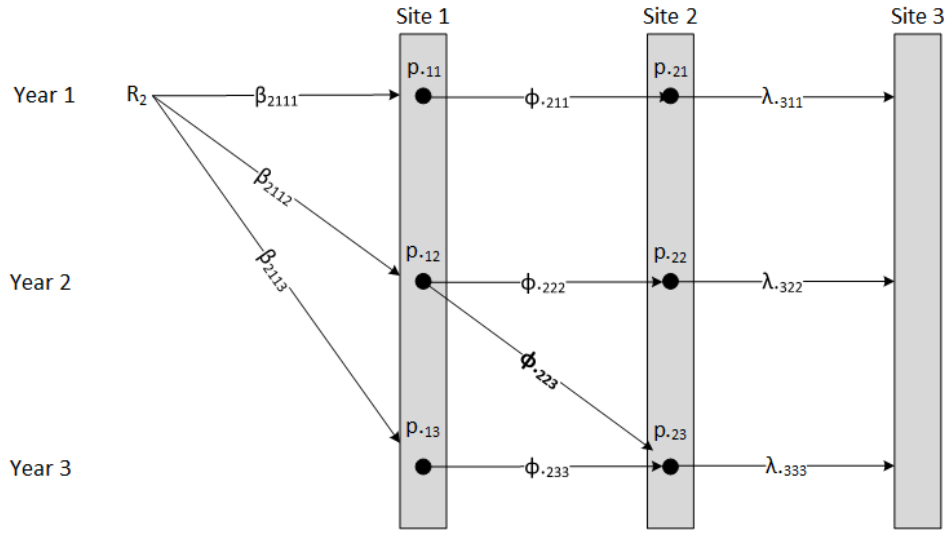
Figure 4. A graphical representation of Model M.ys.9 with all parameters shared by releases R_1, R_2, and R_3 and equated across all releases. The equated parameters are in bold.

2.4 Equating Initial Survival and Movement Parameters

In Figure 4, notice that none of the beta (β) parameters in the first reaches are equated. That is, β_{1111} and β_{2111} are not equated, β_{1112} and β_{2112} are not equated, and β_{1113} and β_{2113} are not equated, because they are from different release locations.

For release R_3, β_{3222} is equivalent to $\phi_{\cdot 222}$, and β_{3223} is equivalent to $\phi_{\cdot 223}$. There are two possibilities: (1) the R_3 release site is not a detection site, and the parameters should never be equated, or (2) the R_2 release site is actually site 1, and thus the user may want to equate the parameters as shown in Figure 5. In the case where a downstream release site of an auxiliary release is a detection site, Basin TribPIT gives the user the option of equating the initial survival and movement parameters (β) with the analogous survival and movement parameters from the upstream releases (ϕ) (explained in Section 3.2.2).

a. Release R_2 with β parameters from R_2 equated with upstream ϕ parameters



b. Release R_3 with β parameters equated to upstream ϕ parameters

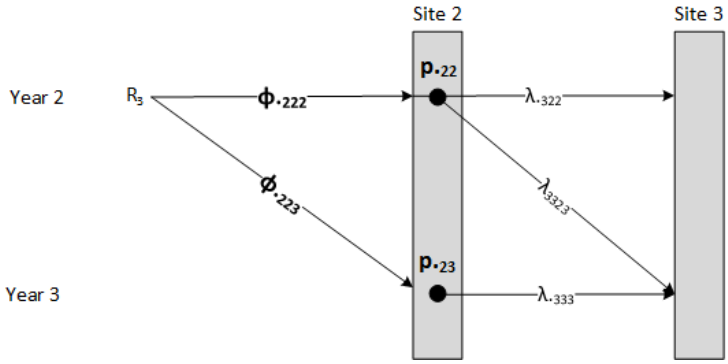
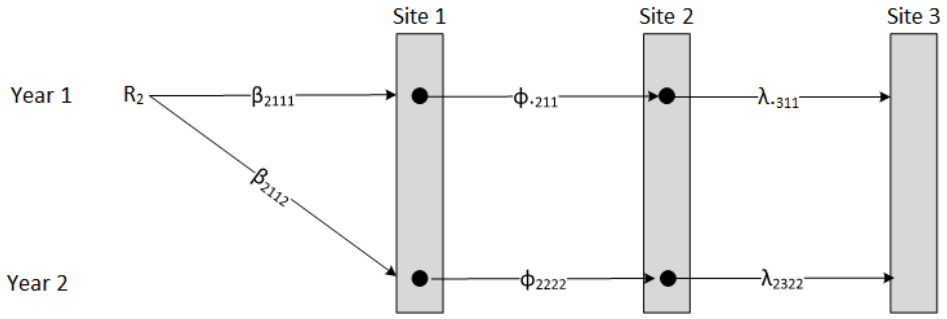


Figure 5. A graphic representation of Model M.ys.4D with all parameters equated across all releases, including β parameters from R_3. The equated parameters are in bold.

2.5 Releases with Different End Sites

Basin TribPIT provides additional flexibility over TribPIT, version 1, by allowing different end sites within a release and across releases. Figure 6 illustrates a scenario where there are no detections at the final site in year 2 for R_1. Basin TribPIT deals with this by assigning the λ parameter to represent survival and detection to site 2 in year 2. A consequence of this is that it reduces the number of parameters that can be equated; in this example, λ_{1222} cannot be equated to ϕ_{2222}.

a. Fully parameterized model



b. Reparameterization in the case where there were no detections at site 3 in year 2

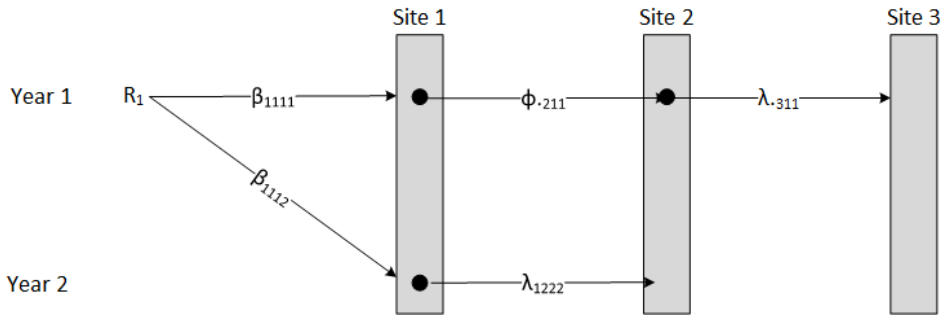


Figure 6. A release with different end sites in different years

Chapter 3: Using Basin TribPIT

Figure 7 shows the Basin TribPIT program at startup. The Navigation Panel on the left side lists all available user actions in the order in which they should be used. The Configuration Panel on the right side is used during the model configuration stage.

The user actions on the Navigation Panel are grouped under four main headings:

1. **Data**, for loading the data for a cohort into Basin TribPIT;
2. **Configuration**, for configuring the releases, sites, and periods;
3. **Estimation**, for estimating the survival-related parameters, and
4. **Results**, for viewing reports/graphs.

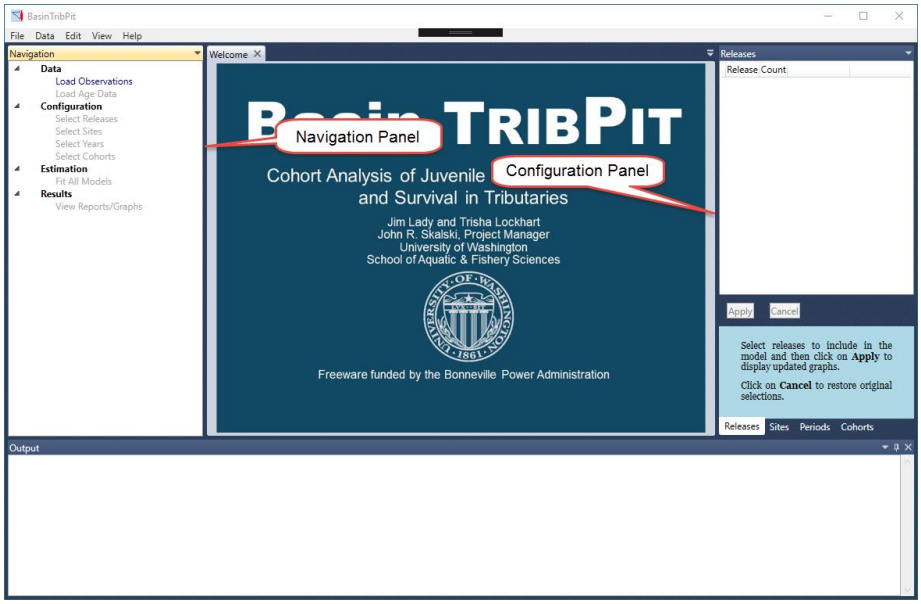


Figure 7. Basin TribPIT at startup

3.1 Data

There are two types of data that may be loaded into Basin TribPIT: (1) Observations, and (2) Age Data. Both files types are in comma separated value (CSV) format.

3.1.1 Detection Data

The detection data are required and must be loaded before any other action can be taken; "Load Observations" is the only user action available at startup. The observation files contain the actual PIT-tag detections, and they are obtained using the Columbia Basin Research (CBR) website at www.cbr.washington.edu/dart/query/pit_basin_branching.

Basin TribPIT allows the user to load more than one observation file at a time using the standard Windows file selection commands cntrl-click and shift-click.

3.1.2 Age Data

The age data may be loaded after the observation data have been loaded. Unlike the detection data, loading the age data is optional; if none is loaded, Basin TribPIT assumes that all of the observations are of a common cohort.

There are two possible formats for the age data, described in Appendix A.

3.2 Configuration

Configuration constitutes the major portion of the work in Basin TribPIT. In the configuration portion, the user defines the sites, periods and releases to be included in the analysis. Often times, due to the sparseness of the data, some sites and years must be excluded from the analysis in order to allow the parameters to be estimated. Additionally, the user may wish to redefine the periods to be more biologically meaningful rather than use the default calendar years.

When observations are loaded into Basin TribPIT, a new tabbed window is created for each release in the main part of the user interface. Each release is represented in a diagram, with a row for each time period (e.g., nominally a year) and a column for each detection site.

Figure 8 shows a portion of one such window from one release. Key areas of the diagram are circled and numbered as follows:

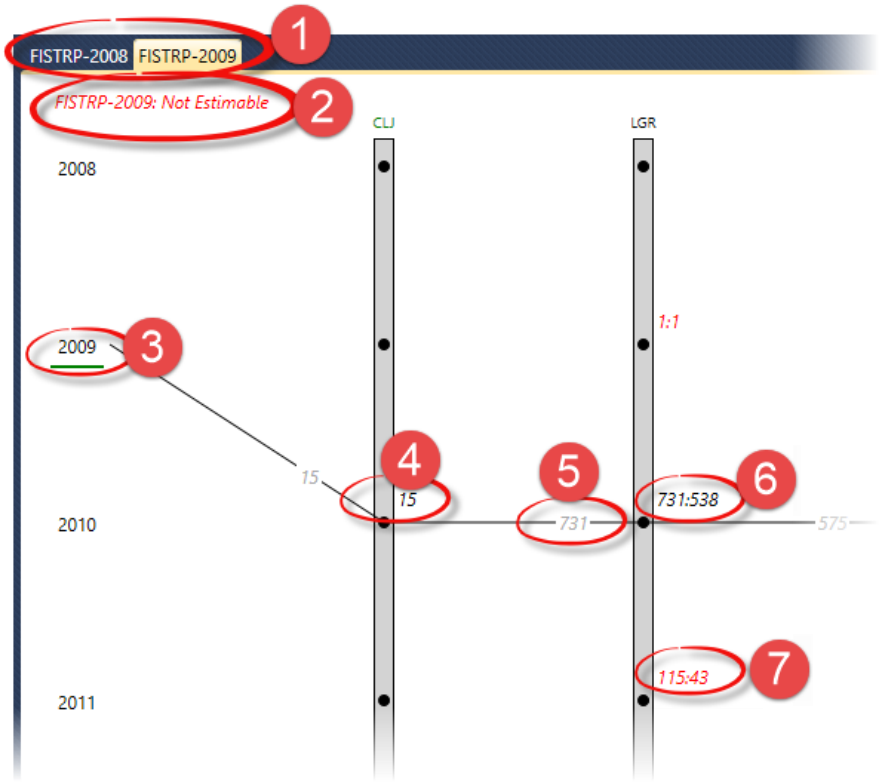


Figure 8. A portion of a configuration window for one release with key areas numbered

1. Each release is shown on a separate page with the name of the release in the tab for the page. Currently, the release FISTRP-2009 has been selected and is shown.
2. The text indicates that the parameters of the model are not estimable. Thus, the "Fit All Models" action is unavailable.
3. The years are shown on the left, one row per year. The release year is underlined in green.
4. 15 fish were detected at site CLJ in 2010 with no removals.
5. 731 fish are known to have passed from CLJ to LGR in 2010.
6. 731 fish were detected at LGR in 2010; 538 of these were "removed" from further analysis downstream.
7. 115 fish were detected at LGR in 2011; 43 of these were removed. These numbers are in red, because there is no observed path to LGR in 2011—hence, making the parameters unestimable in this last reach of the last year.

Ultimately, all parameters for every release must be estimable before the "Fit All Models" command on the Navigation Panel is available, allowing the user to estimate parameters for each model.

In order to estimate the model parameters, the user may need to remove some years and detections sites from the analysis. In the example in Figure 8, for example, the user may need to remove the CLJ site from the analysis.

Via the Configuration Panel or the Configuration Menu items, the user can selectively include or exclude items from the following:

- Releases
- Sites
- Years

Figure 9 shows the configuration items on the Navigation Panel, corresponding to the tabs on the Configuration Panel. In Figure 10, the "Releases" tab is active by default, showing the two releases that have been loaded: "FISTRP-2008" and "FISTRP-2009," both selected, so the user can choose to exclude a given release by clicking on its check box and unselecting it. In Figure 11, the user has excluded "FISTRP-2008" from the analysis. The user must now press the "Apply" button to apply the change.

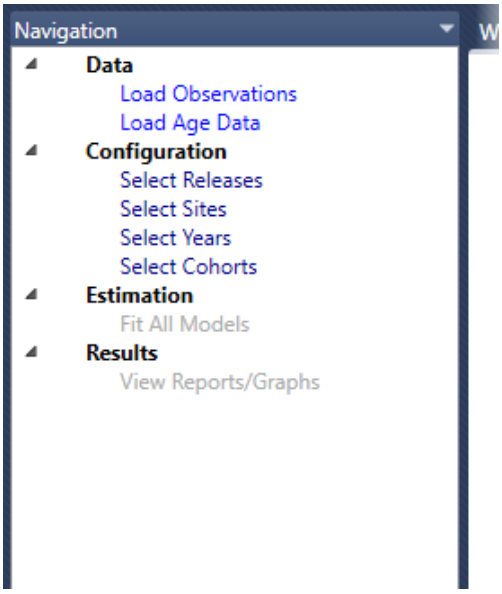


Figure 9. The Configuration Menu on the Navigation Panel

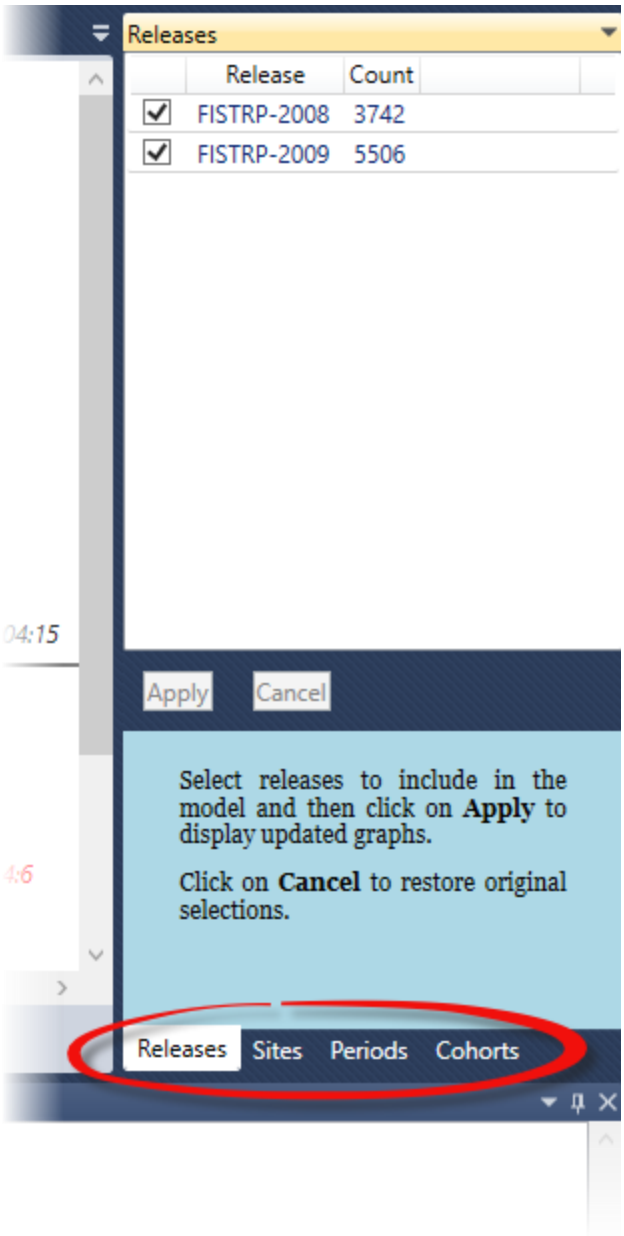


Figure 10. The Configuration Panel with two releases selected

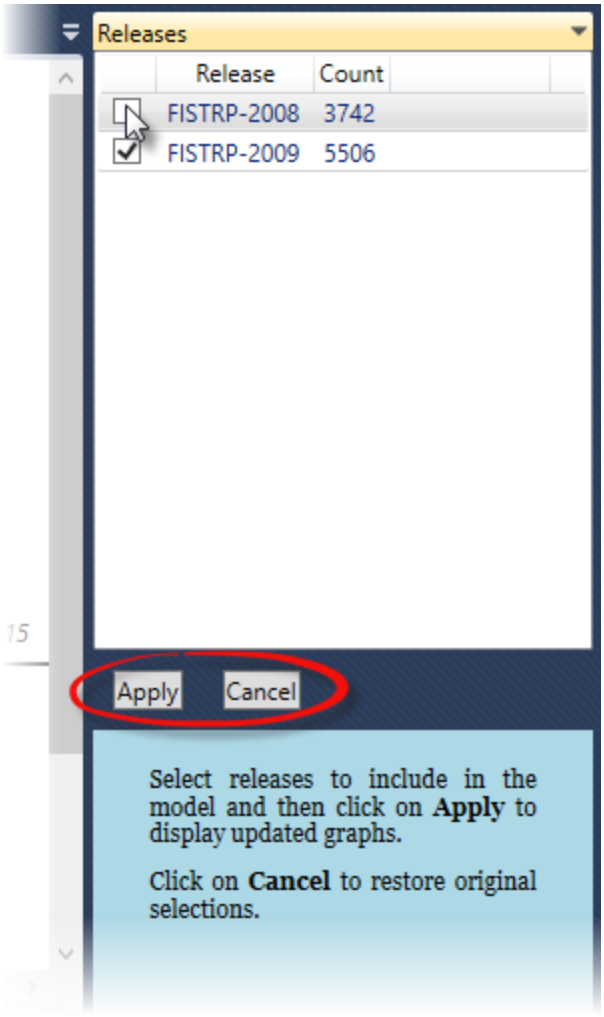


Figure 11. The Configuration Panel with one release excluded from the analysis by unchecking it

In the same way, the user can select which sites, periods, and cohorts to include in the analysis by selecting the appropriate tab on the Configuration Panel and making the appropriate changes.

3.2.1 Configure Sites and Years via the Context Menu

An alternative way to remove sites and years from the analysis is via the context menu. In Figure 12, the user has right-clicked on the CLJ site to bring up the context menu. The user can then select "Remove Site CLJ." Note that due to how context menus are created, the user may have to right-click twice.

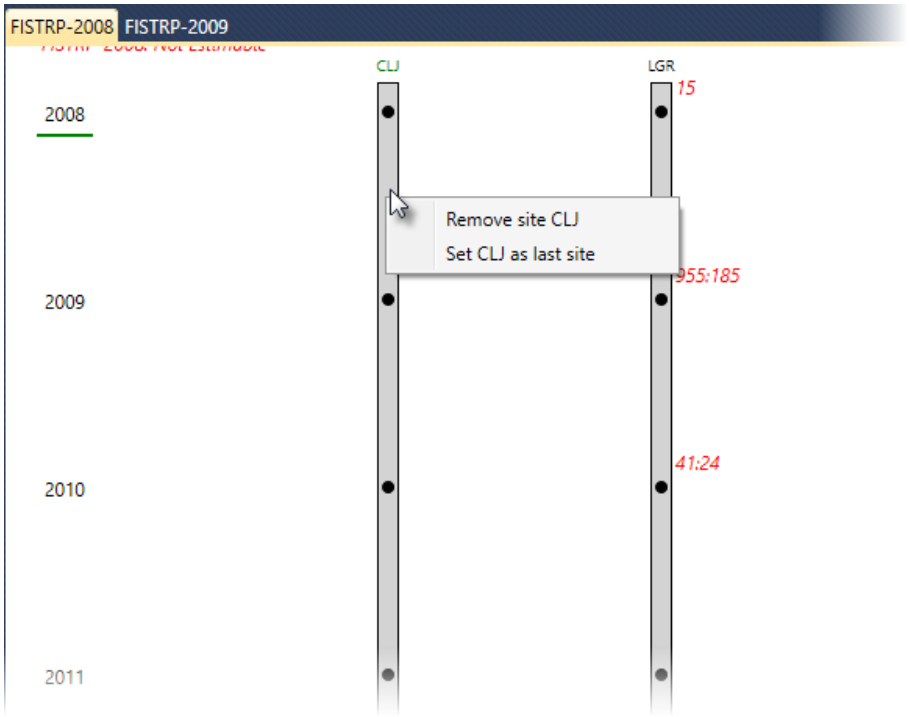


Figure 12. Removing a site via the Context Menu

In Figure 13, the user has right-clicked (twice) on the year "2012." The user can then select "Remove year 2012" in order to remove detections in 2012 from the analysis.

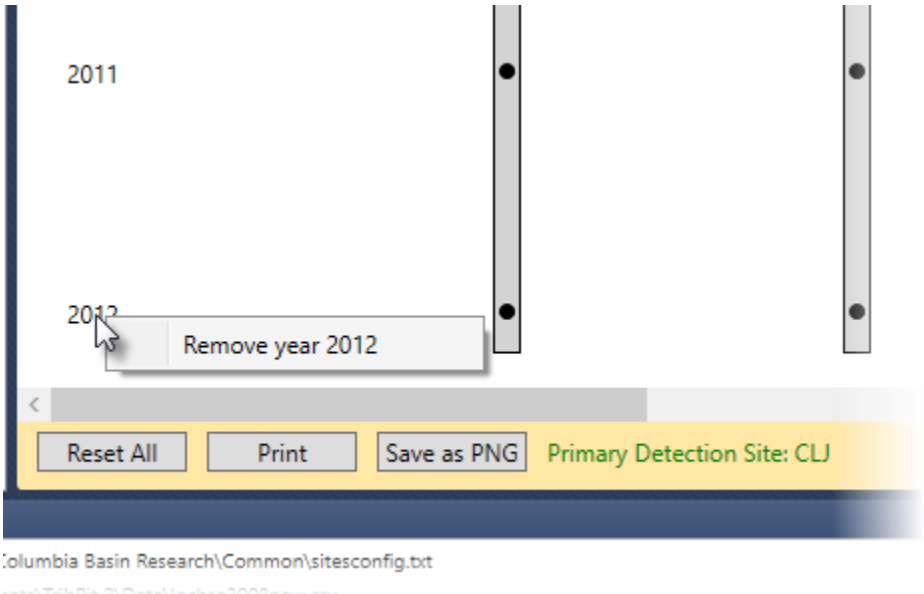


Figure 13. Removing a year via the Context Menu

In Figure 14, the user right-clicked on site "IHR" and selects "Set IHR as the last site." This causes on downstream detections to be pooled and considered as detections at IHR. This reduces the number of parameters to be estimated and is an effective way of increasing the precision when the user is interested only is the survival further upstream.

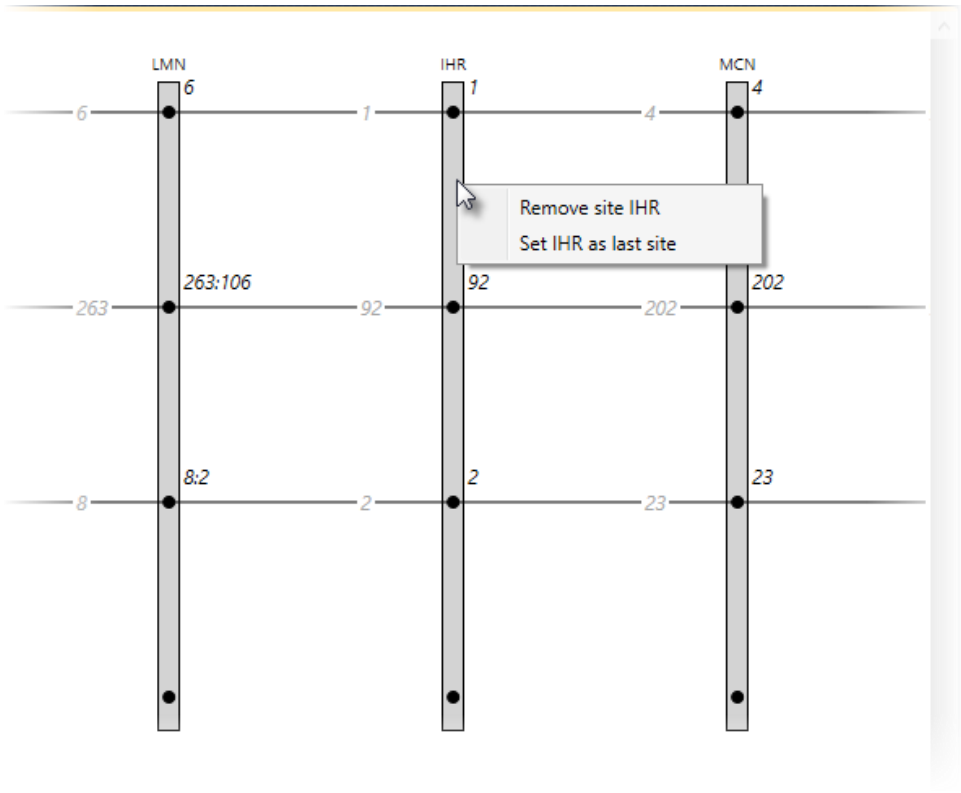


Figure 14. Setting the last site via the Context Menu

The same effect can be achieved by deselecting all sites downstream of IHR in the Configuration Panel as show in Figure 15.

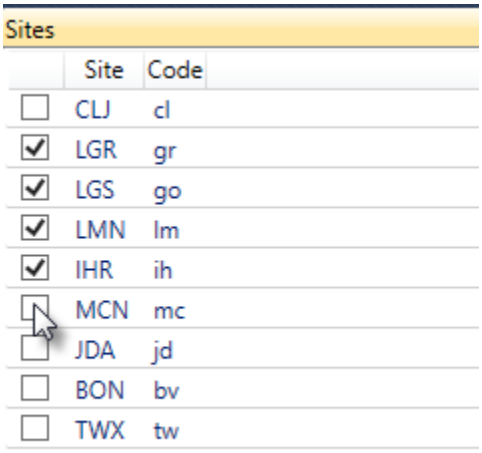


Figure 15. Setting the last site via the Configuration Panel

3.2.2 Configuration of Initial Release Parameter at Detection Site

Basin TribPIT allows downstream releases from sites that are not detection sites—thus, the parameter β_{rijk} represents survival from release to the nearest downstream detection site. At times, however, there may be a release from a downstream site that is also a detection site, and the user may wish to equate the initial release parameter with the equivalent survival and movement parameter from an upstream release when appropriate, as explained in Section 2.4.

Figure 16 shows an example of a release named "LGR-2011" that is released at a detection site (LGR). If the user checks the "Equate" checkbox, Basin TribPIT will equate β parameters from LGR-2011 with the analogous ϕ parameters for release LOCHSA-2011.

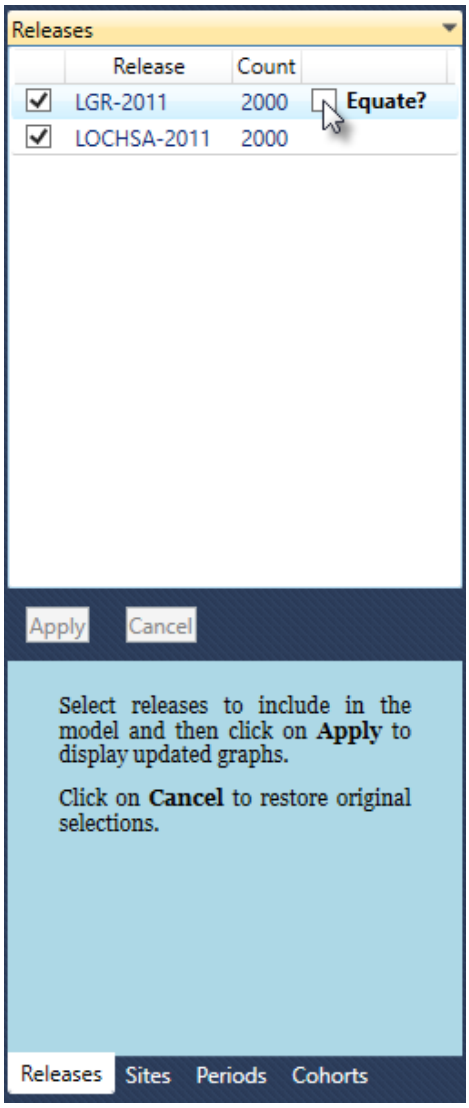


Figure 16: Equate initial release parameters with equivalent upstream release parameters via the Configuration Panel.

3.2.3 Setting the Primary Detection Site

A consequence of the flexibility of Basin TribPIT in allowing multiple upstream releases, and allowing releases from sites that are not detection sites, is that there can be more than one possible interpretation of a given dataset.

Basin TribPIT defines the primary detection site as the first detection site downstream of the primary release(s). By default, Basin TribPIT sets the primary detection site as the most upstream detection site that is downstream of all included releases.

Figure 17 is a graphical representation of three releases, two released in 2011, and a third in 2012: 4JULYC-2011, LOCHSA-2011, ALMOTC-2012.

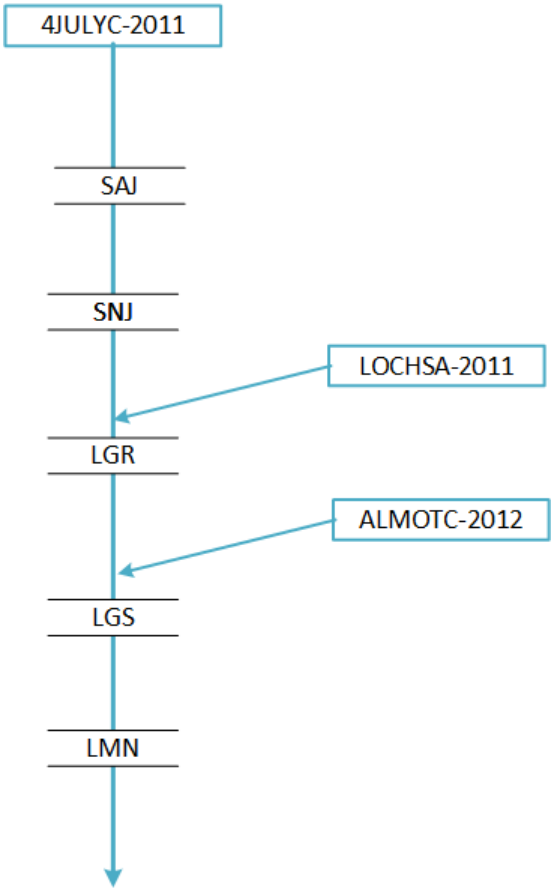


Figure 17. Primary detection site example: A graphical representation of three releases

Since LGS is the most upstream detection site shared by all three releases, it is set as the primary detection site by default.

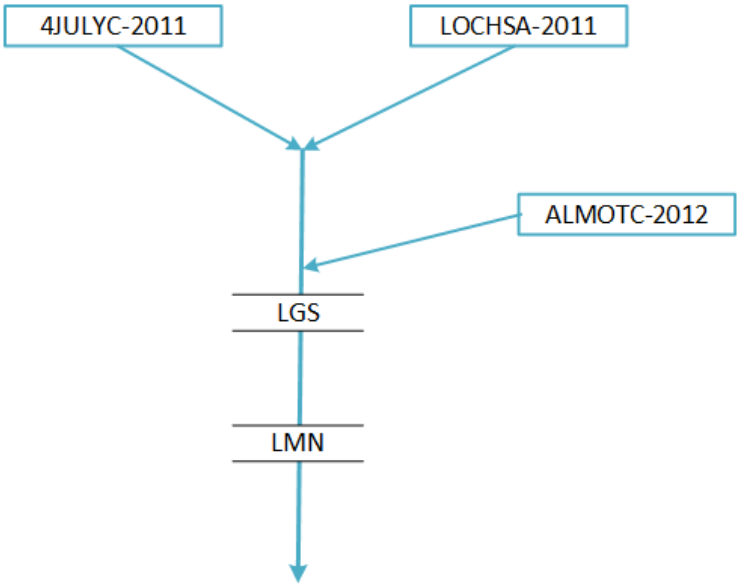


Figure 18. Primary detection site example: The default configuration with LGS as the primary detection site

The default configuration for the release scenario in Figure 17 is shown in Figure 18. Note that all detection sites above LGR—SAJ, SNJ and LGR—are ignored. Both 4JULYC-2011 and LOCHSA-2011 are considered primary releases, since they are both upstream of LGS. Although ALMOTC-2012 is also upstream of LGS, it is considered an auxiliary release because it was released in a later year.

Figure 19 shows the Sites tab of the Configuration Panel after loading theses releases. Note that all sites upstream of LGS are de-selected.

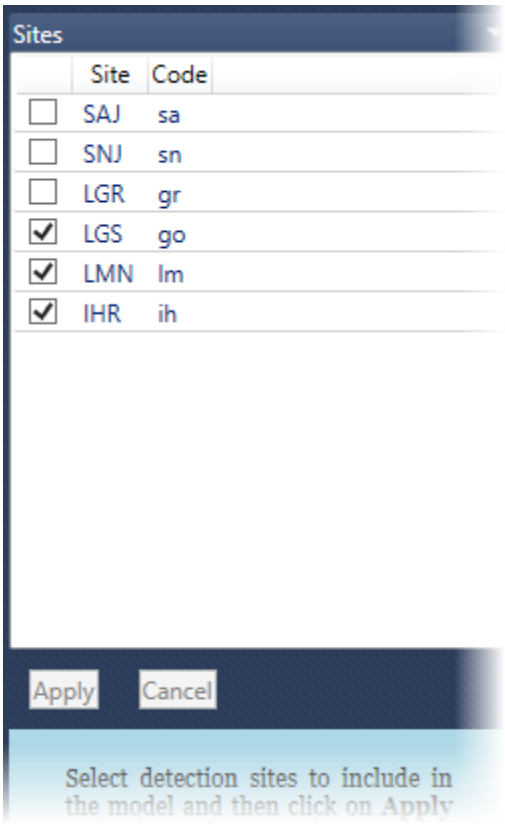


Figure 19. Primary detection site example: The default sites configuration with LGS as the primary detection site. Only sites with a check (✓) are selected for inclusion in the model.

In Figure 20, the user has selected sites SNJ and LGR to be included. After pressing the Apply button, the configuration is now as shown in Figure 21. Note that LOCHSA-2011 is now considered an auxiliary release since it is downstream of the primary detection site SNJ.

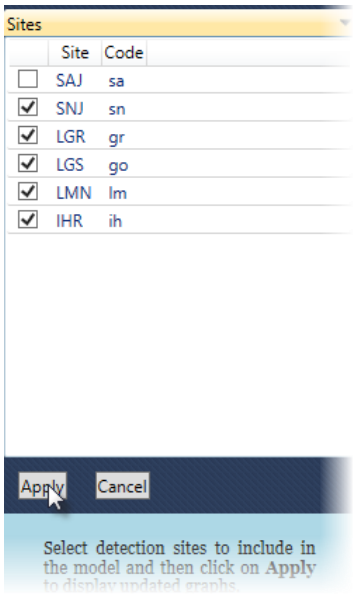


Figure 20. Primary detection site example: The site configuration for including sites SNJ and LGR

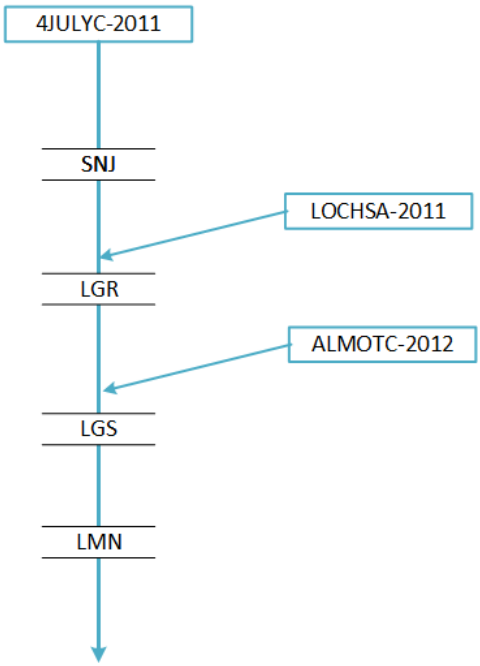


Figure 21. Primary detection site example: A diagram of the configuration after making SNJ the primary detection site

On the configuration page for each release, the primary detection site is listed (shown circled in Figure 22).

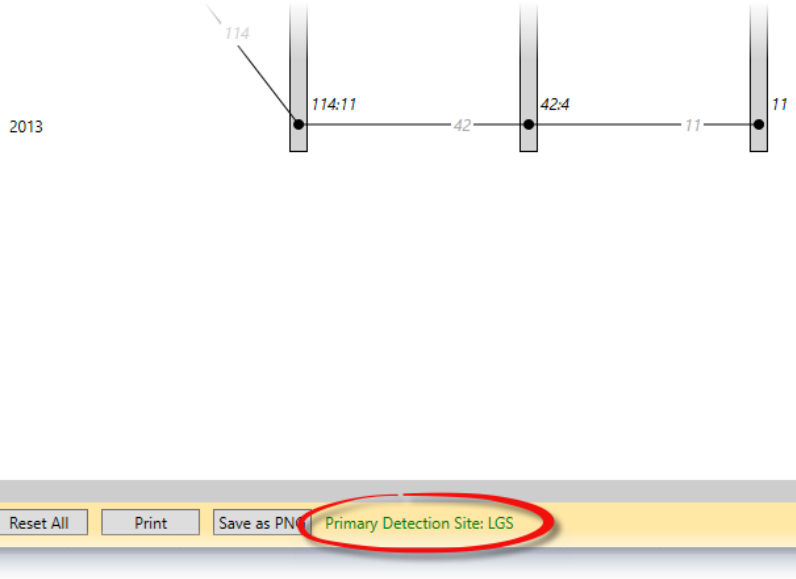


Figure 22. Primary detection site example: The primary detection site indicator during configuration

3.2.4 Configure Custom Periods

By default, Basin TribPIT uses the calendar years for the periods. The user has the option of changing the periods to more biologically meaningful periods.

On the Configuration Panel with the Periods tab active, click on the "Custom Periods" button as shown in Figure 23.

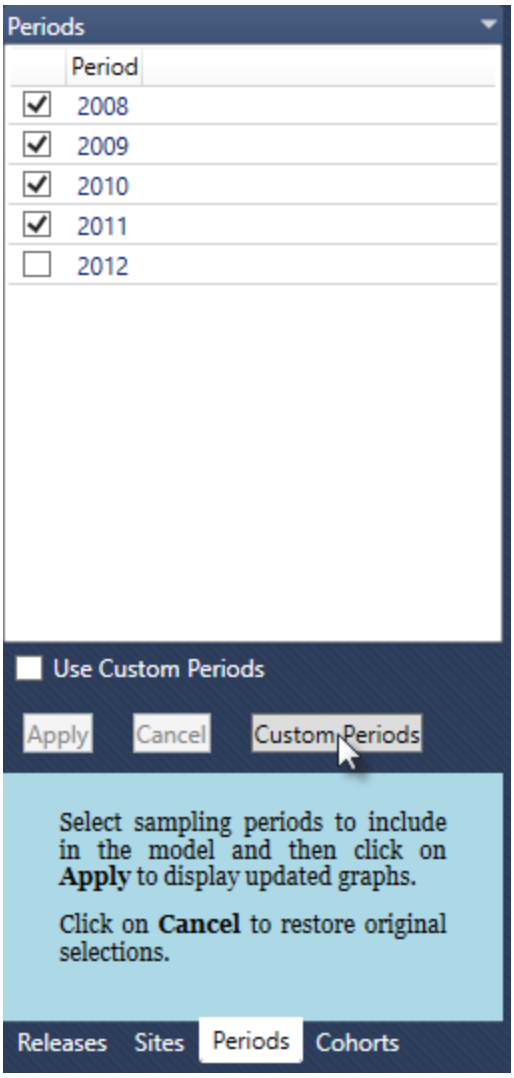


Figure 23. Selecting the Custom Periods button on the Configuration Panel

This brings up the custom periods dialog as shown in Figure 24.

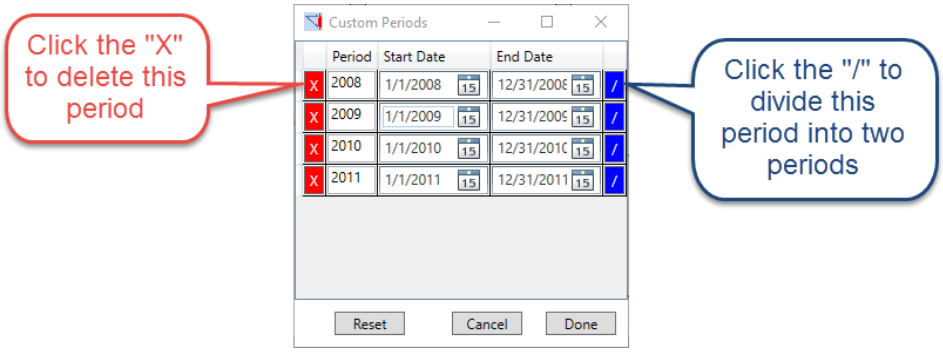


Figure 24. The dialog for defining Custom Periods

There are five columns in the custom periods dialog:

1. A red "X" to delete a period,
2. The name of the period (the calendar year by default, but the user can edit this to be any text),
3. The start date of the period,
4. The end date of the period,
5. A blue "/" used to divide the current period into two periods.

The user clicks the "Done" button to exit the dialog and apply the custom periods. The Periods tab then reflects the changes to the periods. In the example in Figure 25, the user has divided 2008 into two periods, 2008a and 2008b. The user can clear the "Use Custom Periods" checkbox on the top to revert to the default periods, and re-check it again to use the previously defined custom periods.

Figure 25. The Configuration Panel with Custom Periods defined

3.2.5 Saving the Configuration Data

Basin TribPIT allows the user to save the current configuration so that it can be reloaded into the program later. To save the configuration, go to the "File" menu and select either "Save" or "Save as." The program will show a default file name and location that the user may change.

To restore a previously saved configuration, got to the "File" menu, select "Open," and select the configuration file to be loaded. Basin TribPIT does not save any parameter estimates—only the current configuration.

3.3 Settings

The Settings menu provides some actions for the user to configure the behavior of Basin TribPIT. The settings can accessed by going to the "Edit" menu and selecting "Settings." The Settings dialog is shown in Figure 26. There are three tabs for the settings: (1) General, (2) Sites Configuration, and (3) Advanced.

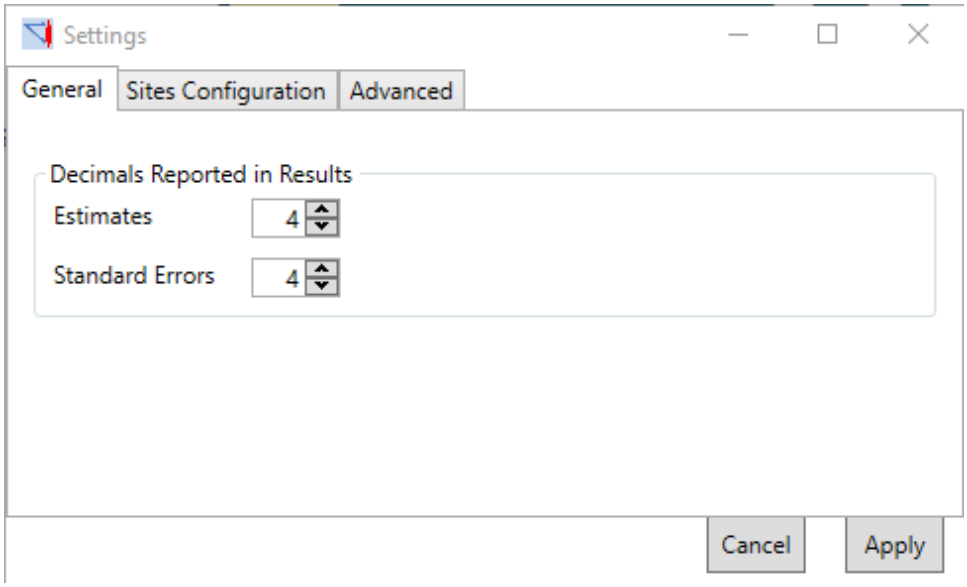


Figure 26. The settings dialog

The only options available on the General tab are the number of decimal places for the estimates and their associated standard errors in the results reports.

3.3.1 Sites Configuration

Basin TribPIT relies on the sites configuration file to determine which sites are valid, where the sites are located, and the validity of detections at sites. The default sites configuration file is generated by Columbia Basin Research, and is downloaded by Basin TribPIT.

There may be times when the user needs to modify the sites configuration file for a particular study. The user may then take the default sites configuration file, and modify it for his or her particular needs. This alternate sites configuration file can then be used instead of the default. When this is done, Basin TribPIT will issue a warning that all previously loaded observations must be reloaded. If the user then continues, all previously loaded data will be removed from the program. The user will then need to reload the data with the new sites configuration file.

3.3.2 Advanced

The one option on the "Advanced" tab is a checkbox to allow Basin TribPIT to include detection events that were occurred before the release date and time. By default, such detections are ignored.

Chapter 4: Results from Basin TribPIT

After the user clicks "Fit All Models" and Basin Tribpit will estimate the parameters for all models, and the Results Window will appear as shown in Figure 27. As with the main Basin TribPIT window, the Navigation Panel appears on the left. There are three main sections in the Navigation Panel:

1. **Summary Results**, showing results across multiple models;
2. **Graphical Results**, showing the parameter estimates graphically; and
3. **Model-Specific Reports**, showing the parameter estimates for the optimal model, or any of the sub-optimal models if desired.

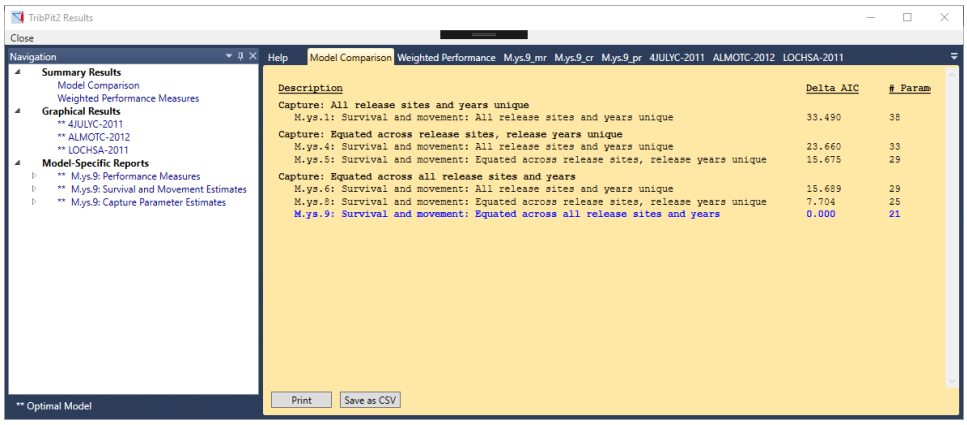


Figure 27. The Results Window

In all the reports, the point estimates are followed by their standard errors in parentheses. There are two buttons at the bottom of each report: (1) "Print" to print the report, and (2) "Save as CSV" to save the report in comma-separated-value (CSV) format.

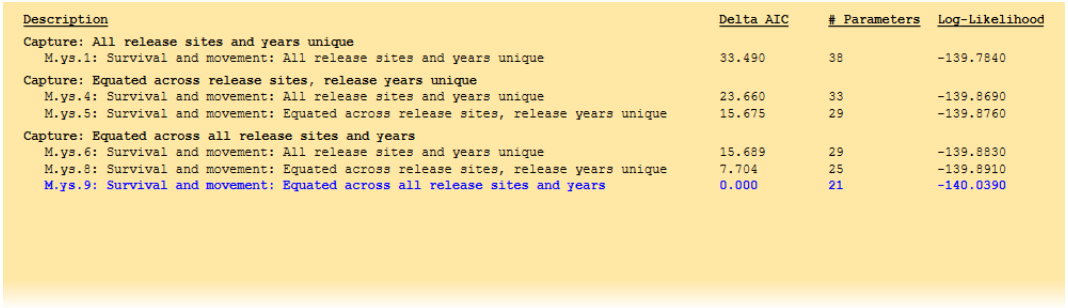
4.1 Summary Results

Under the Summary Results heading of the results, there are two reports that the user may select: the Model Comparison Report, and, if available, the Weighted Performance Measures Report.

4.1.1 Model Comparison Report

Figure 28 shows the Model Comparison Report for data that matches Scenario 6 in Section 2.2.6. There are three columns to the report. The report has one entry for each model for which parameter estimates were calculated. The report has four columns:

1. A description of the model, including the Model ID and a full description;
2. The Delta AIC. The optimal model—the model with the lowest AIC—is assigned a Delta AIC of zero and is highlighted in bold and blue. For all other models, the Delta AIC is calculated as the AIC of the model minus the AIC of the optimal model;
3. The number of parameters in the model.
4. The log-likelihood value.



Description	Delta AIC	# Parameters	Log-Likelihood
Capture: All release sites and years unique			
M.ys.1: Survival and movement: All release sites and years unique	33.490	38	-139.7840
Capture: Equated across release sites, release years unique			
M.ys.4: Survival and movement: All release sites and years unique	23.660	33	-139.8690
M.ys.5: Survival and movement: Equated across release sites, release years unique	15.675	29	-139.8760
Capture: Equated across all release sites and years			
M.ys.6: Survival and movement: All release sites and years unique	15.689	29	-139.8830
M.ys.8: Survival and movement: Equated across release sites, release years unique	7.704	25	-139.8910
M.ys.9: Survival and movement: Equated across all release sites and years	**0.000**	**21**	**-140.0390**

Figure 28. The Model Comparison Report

The models are arranged in a hierarchical manner. Each heading describes a parameterization of the capture parameters. All models under a heading use the same parameterization of the capture probabilities and different parametrization of survival and movement probabilities.

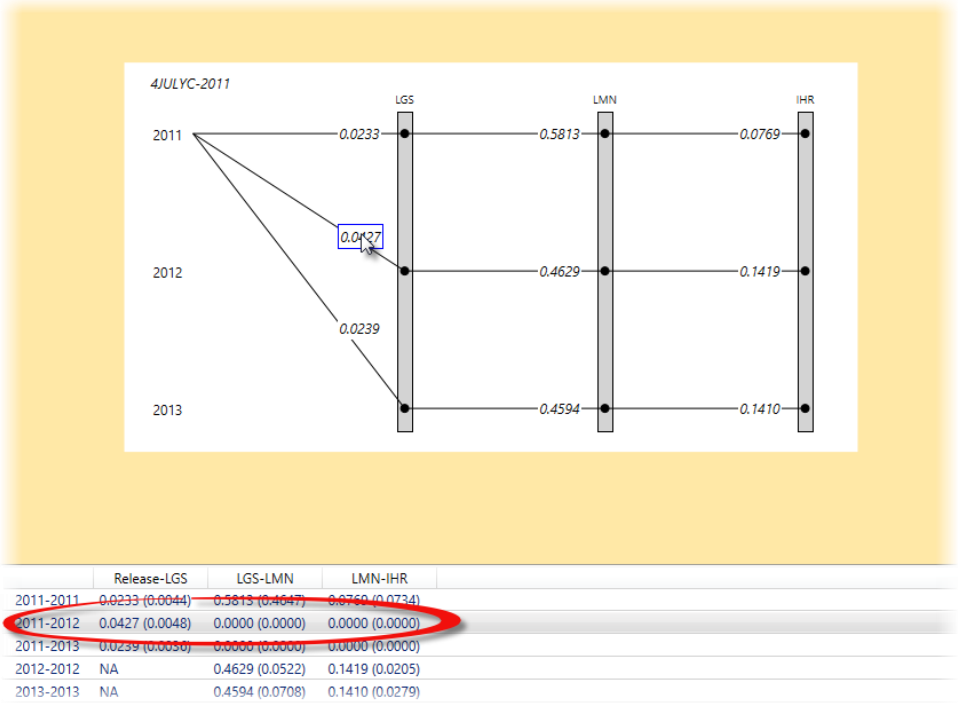
4.1.2 Weighted Performance Measures Report

The Weighted Performance Measures Report mirrors the model-specific Performance Measures Report described in Section 4.3.1. It is only available if there is at least one suboptimal model with a Delta AIC of less than 10.

The estimates of the weighted performance report are model-weighted estimates (described in Appendix B) from the optimal model and all suboptimal models with a Delta AIC less than 10.

4.2 Graphical Results

The graphical results display the survival and movement parameter estimates on graphs for each release that correspond to the graphs used during model configuration (Section 3.2). The user clicks on the release name to show the results graphically for that release. Figure 29 shows an example for a hypothetical release named 4JULYC-2011. If the user puts the mouse over a result, the corresponding estimates at the bottom will be highlighted in gray. In Figure 29, the mouse is over the estimate for 2011–2012, release to LGS. The highlighted row at the bottom shows the estimate of 0.0427 has a standard error of 0.0048.



	Release-LGS	LGS-LMN	LMN-IHR
2011-2011	0.0233 (0.0044)	0.5813 (0.4647)	0.0769 (0.0734)
2011-2012	0.0427 (0.0048)	0.0000 (0.0000)	0.0000 (0.0000)
2011-2013	0.0239 (0.0056)	0.0000 (0.0000)	0.0000 (0.0000)
2012-2012	NA	0.4629 (0.0522)	0.1419 (0.0205)
2013-2013	NA	0.4594 (0.0708)	0.1410 (0.0279)

Figure 29. The graphical results diagram

4.3 Model-Specific Reports

There are three model-specific reports under the header "Reports" in the Navigation Panel:

1. Performance Measures
2. Survival and Movement Parameters
3. Capture Parameter Estimates

As shown in Figure 30, each report name in prefaced by the Model ID of the optimal model (M.ys.9 in Figure 30). When the user clicks on one of these reports, the report for the optimal model is displayed.

Figure 30. The Model-Specific Reports on the Navigation Panel of the Results Window

In order to view a report for a suboptimal model, click on the small arrow to the left of the desired report type. In Figure 31, the user has clicked on the arrow for the Performance Measures, allowing them to view the Performance Measures report for any of the models.

Figure 31. The Model-Specific Reports for all suboptimal models on the Navigation Panel of the Results Window

4.3.1 Model-Specific Reports Heading

Each of the three model-specific reports have a header in common. An example is shown in Figure 32. The header lists:

1. The name of the primary releases,
2. The name of the auxiliary releases,
3. The Model ID,
4. A description of the model,
5. The number of parameters,
6. The log-likelihood,
7. The Akaike Information Criterion (AIC).

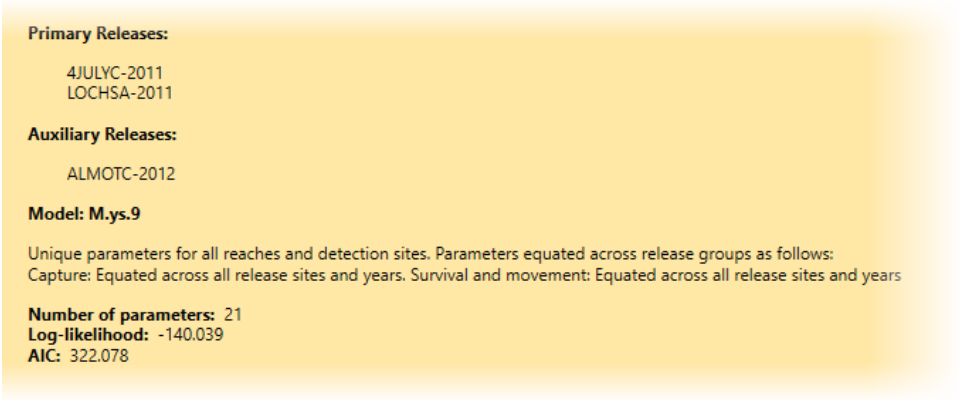


Figure 32. The header for all Model-Specific Reports

4.3.1 Performance Measures Report

Figure 33 shows an example of a Performance Measures Report (minus the header). The elements of the report are:

- **Overall Cohort Survival:** The survival probability from release to the site furthest downstream for which survival is estimable (the penultimate site) for each of the primary releases.
- **Cohort Survival by Site Location:** The survival probability from release to each downstream site, first for the primary releases and then the auxiliary releases.
- **Age Composition of Migrants by Site:** The proportion of each age-class at each detection site for each primary release.
- **Down-River Survivals Below Residualization:** The survival from the last site for which there is residualization (overwintering) to each subsequent downstream site for each primary and auxiliary release. This is only available if there are at least two downstream detection sites below the last residualization site.

Overall Cohort Survival

Release	Overall Cohort Survival Estimate
4JULYC-2011	0.0443 (0.0114)
LOCHSA-2011	0.0801 (0.0079)

Cohort Survival by Site Location

Primary Releases

Release	LGS	LMN
4JULYC-2011	0.0899 (0.0073)	0.0443 (0.0114)
LOCHSA-2011	0.2505 (0.0142)	0.0801 (0.0079)

Auxiliary Releases

Release	LGS	LMN
ALMOTC-2012	0.5301 (0.0197)	0.2448 (0.0213)

Age Composition of Migrants by Site

Release: 4JULYC-2011

Age	LGS	LMN
Sub-Yearlings (2011)	0.2593 (0.0400)	0.3060 (0.1707)
Yearlings (2012)	0.4750 (0.0412)	0.4463 (0.1168)
2-Year-Olds (2013)	0.2656 (0.0354)	0.2477 (0.0729)

Release: LOCHSA-2011

Age	LGS	LMN
Sub-Yearlings (2011)	0.3074 (0.0319)	-----
Yearlings (2012)	0.4160 (0.0282)	0.6025 (0.0496)
2-Year-Olds (2013)	0.2765 (0.0245)	0.3975 (0.0496)

Down-River Survivals Below Residualization

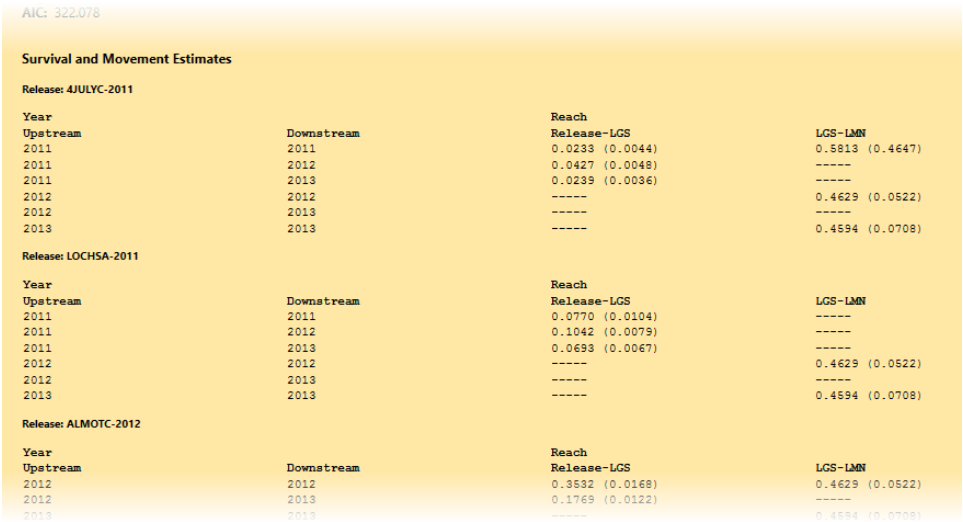
Release	Year at LGS	Survival Estimate at IHR
4JULYC-2011	2011	0.5813 (0.4647)
	2012	0.4629 (0.0522)
	2013	0.4594 (0.0708)
LOCHSA-2011	2012	0.4629 (0.0522)
	2013	0.4594 (0.0708)
ALMOTC-2012	2012	0.4629 (0.0522)
	2013	0.4594 (0.0708)

Figure 33. The Performance Measures Report

The details of the calculations for the Parameter Estimates Report can be found in Appendix C.

4.3.2 Survival and Movement Parameter Estimates Report

Figure 34 shows a portion of a Survival and Movement Parameter Estimates Report. For each release, the estimate and standard error are listed for all estimable survival and movement parameters.



AIC: 322.078

Survival and Movement Estimates

Release: 4JULYC-2011

Year Upstream	Downstream	Reach Release-LGS	LGS-LMN
2011	2011	0.0233 (0.0044)	0.5813 (0.4647)
2011	2012	0.0427 (0.0048)	-----
2011	2013	0.0239 (0.0036)	-----
2012	2012	-----	0.4629 (0.0522)
2012	2013	-----	-----
2013	2013	-----	0.4594 (0.0708)

Release: LOCHSA-2011

Year Upstream	Downstream	Reach Release-LGS	LGS-LMN
2011	2011	0.0770 (0.0104)	-----
2011	2012	0.1042 (0.0079)	-----
2011	2013	0.0693 (0.0067)	-----
2012	2012	-----	0.4629 (0.0522)
2012	2013	-----	-----
2013	2013	-----	0.4594 (0.0708)

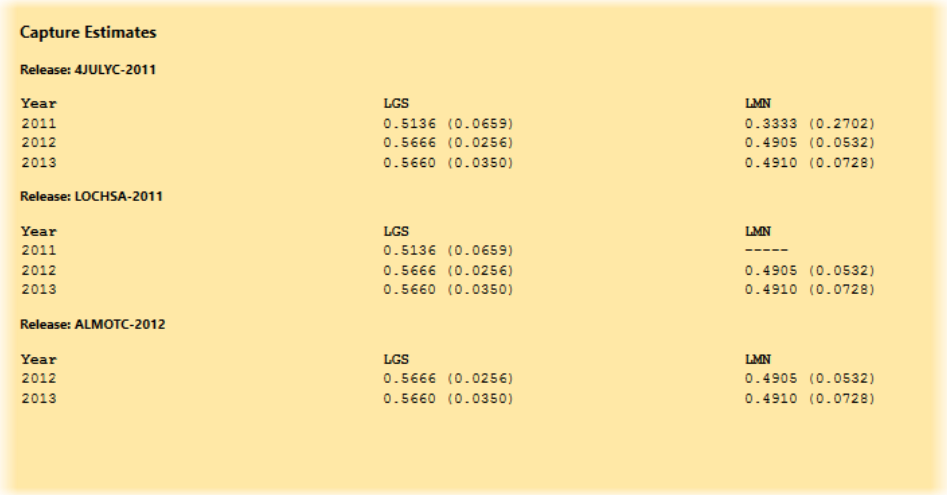
Release: ALMOTC-2012

Year Upstream	Downstream	Reach Release-LGS	LGS-LMN
2012	2012	0.3532 (0.0168)	0.4629 (0.0522)
2012	2013	0.1769 (0.0122)	-----
2013	2013	-----	0.4594 (0.0708)

Figure 34. A portion of the Survival and Movement Parameter Estimates Report

4.3.3 Capture Parameter Estimates Report

Figure 35 shows a portion of a Capture Parameter Estimates Report. For each release, the estimates and standard errors are listed for all estimable capture parameters.



Capture Estimates

Release: 4JULYC-2011

Year	LGS	LMN
2011	0.5136 (0.0659)	0.3333 (0.2702)
2012	0.5666 (0.0256)	0.4905 (0.0532)
2013	0.5660 (0.0350)	0.4910 (0.0728)

Release: LOCHSA-2011

Year	LGS	LMN
2011	0.5136 (0.0659)	-----
2012	0.5666 (0.0256)	0.4905 (0.0532)
2013	0.5660 (0.0350)	0.4910 (0.0728)

Release: ALMOTC-2012

Year	LGS	LMN
2012	0.5666 (0.0256)	0.4905 (0.0532)
2013	0.5660 (0.0350)	0.4910 (0.0728)

Figure 35. The Capture Parameter Estimates Report

Appendix A: Age Data

The age data file is a comma separated value (CSV) file. All lines beginning with a hash mark ("#") are ignored. Otherwise, there is one line for each fish. There are two possible formats for each fish record:

1. Two fields: (1) tag ID, followed by (2) the brood year.
2. Three fields: (1) tag ID, (2) release year, (3) age at release. The brood year is then calculated by subtracting the age from the release year.

An "NA" for the age in the first format, or if the age at release is unknown, that tag will be excluded from analysis.

If any line has an invalid format, or if the tag ID is not found in the observations data, an error message will be recorded, and Basin TribPIT will continue loading the age data with the next line.

Appendix B: Model Weighted Estimates

Let $\hat{\theta}_i$ be an estimate of θ for the ith fitted model.

$\widehat{\mathrm{Var}}(\hat{\theta}_i)$ = the variance estimate for $\hat{\theta}_i$ for the ith model.

W_i = the AIC weight for the ith model.

The model-averaged estimator is

$$\hat{\bar{\theta}} = \sum_{i=1}^{R} W_i \hat{\theta}_i \quad \text{over R models}$$

with associated variance estimator

$$\widehat{\mathrm{Var}}\left(\hat{\bar{\theta}}\right) = \left[\sum_{i=1}^{R} W_i \sqrt{\widehat{\mathrm{Var}}(\hat{\theta}_i) + \left(\hat{\theta}_i - \hat{\bar{\theta}}\right)^2}\right]^2.$$

The weights are calculated as

$$W_i = \frac{e^{-\frac{1}{2}\Delta_i}}{\sum_{i=1}^{R} e^{-\frac{1}{2}\Delta_i}}$$

and where $\Delta_i = \mathrm{AIC}_i - \mathrm{AIC}_{\min}$ and where AIC_i = AIC value for the fitted model.

Note: Best model has $\Delta_i = 0$; alternative models are used in the calculations only if $\Delta_i < 10$.

Reference: Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference. Springer-Verlag, New York.

Appendix C: Performance Measure Calculations

The following describes the calculation of point estimates. The corresponding variances are calculated using the delta method.

For a given release r,

S_{rkj} = survival to site k in year j,

j_0 = release year,

k_0 = release site,

$$S_{rkj} = \beta_{rkj_0j} \quad \text{for } k > k_0 + 1.$$

$$S_{rkj} = \sum_{m=j_0}^{j} \phi_{rkmj} S_{r,k-1,m} \quad \text{for } k > k_0 + 1$$

S_{rk} = probability of survival to site k

$$S_{rk} = \sum_{j=j_0}^{J} S_{rkj}$$

where J = last observed detection year.

Age Composition of Migrant by Site

A_{rkj} = proportion of age j at site k for release r

$$A_{rkj} = \frac{S_{rkj}}{S_{rk}}$$

Downriver Survivals below Residualization

Let w = the first site downstream of all residualization,

ϕ_{rmjj} = the probability of survival and movement to site m – 1 in year j to site m in year j, given the individual is alive at site m – 1 in year j.

And let SR_{rjw} = the downriver survival for release r in year j for the first site downstream of site w.

$$SR_{rjw} = \prod_{m=w}^{K-1} \phi_{rmjj}.$$