**‘Bottlenecks to Survival’ – Survival modelling update**

**May 2023**

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# Methods

### Background

Cormack-Jolly-Seber (CJS) models (Cormack, 1964; Jolly, 1965; Seber, 1965) are often applied to study the directed migrations of species (such as Pacific salmon) through use of telemetry data (Buchanan and Skalski, 2007; Brown *et al*., 2013). However, issues can arise when telemetry data presents low recapture or detection rates, low survival rates, or low sample sizes, which can result in imprecise model parameters and survival estimates (Pollock et al. 1990; O’Brien, Robert & Tiandry 2005; Morris et al. 2006). Multi-state mark-recapture models can be applied to such datasets with low detection and survival probabilities, allowing data to be ‘borrowed’ from other sites while also allowing for different survival, movement, and detection probabilities at each ‘state’ (Calvert et al., 2009). Multi-state mark-recapture models can be fitted with either Frequentist or Bayesian approaches. Bayesian approaches can provide greater analytical power and precision for sparse telemetry data as prior knowledge about parameter distribution can be incorporated, and parameters are considered random variables as opposed to fixed and unknown (Harwood & Stokes, 2003; Gelman et al., 2004; Calvert et al., 2009; Kéry and Schaub, 2011). Further, Calvert et al. (2009) found hierarchical Bayesian multi-state mark-recapture models produced more precise and accurate parameter estimates when compared with non-hierarchical models for sparse datasets.

We developed a hierarchical Bayesian CJS model capable of estimating survival and detection probabilities over multiple states for our ‘bottlenecks to survival’ dataset. All data preparation and modelling were performed using R statistical software (R Core Team, 2022).

### Data preparation

For most river systems in this project, fish tagging efforts occur on three occasions across different life stages of Pacific salmon target species: (1) fry tagging occurring in the hatchery environment, (2) smolt tagging occurring in the estuarine environment, and (3) sub-adult tagging occurring during microtrolling. At each of these events, fish are captured, tagged, and released, and there is also opportunity for recapture of previously tagged individuals. In addition, PIT receivers have been installed in the riverine environment, allowing detection of tagged individuals downstream of the hatchery environment, and upon spawning migration return. Our dataset therefore comprises of five ‘states’, with tagged individuals released at three separate stages. This data was formatted as binary data, where ‘1’ represented either a tag release or detection at a following site and ‘0’ represented no detection at a site (meaning either the individual passed undetected, permanently emigrated, or died). Capture histories of each individual could therefore be represented by a five-digit, binary code representing presence or absence (1 or 0, respectively) of a fish across our five stages. For example, a fish tagged in the hatchery environment, detected as it passed the downstream PIT receiver, not recaptured during estuarine netting or microtrolling efforts, but detected at the final PIT receiver upon spawning migration return would be represented by a capture history of ‘11001’.

### Model framework

We developed a Bayesian CJS model capable of estimating detection probability at each site (*ρ*), survival probability between each site (*θ* ), and probability of survival from tagging release to each detection occasion (*ψ* ). This model estimates detection and survival probabilities separately for each site.

If a fish *f* successfully reaches site *s* it is denoted by *xf,s* = *1*; if fish *f* does not successfully reach site *s* it is denoted by *xf,s* = *0*. Survival to each site by a fish is therefore given as binary data. If fish *f* successfully reaches site *s*, the successful detection of that fish at that site is denoted by *yf,s* = *1*; if the fish is not successfully detected it is denoted by *yf,s* = *0*. We make the assumption that there are no false positive detections.

Following this, the detection probability *ρ* of fish *f* at site *s* is given by:

where probability density values were calculated for the Beta Distribution bounded between [0,1]. For a fish to be successfully detected at site *s* (), the fish must also have survived to that site ().

Survival probability *θ* of fish *f* between two sites is given by:

Initial detection probability *ρ* and survival probability *θ* for the first tagging site of each fish was set as 1, as the fish was known alive and ‘detected’ during tagging. Our model was also constrained in that detection probability at site 5 (final adult return PIT receiver) was set at 0.9, thus assuming 90 % detection efficiency at this site. This value is therefore user defined and needs to be specified prior to running the model.

We further constructed a hierarchical model to estimate the presence of a fish at a given site *yf,* s in terms of detection probability *ρ f, s*; here, presence of a fish at a site is assumed to be a random process with Bernoulli distribution (Forbes et al., 2011) and probability a function of the detection probability at that site () and probability that the fish reaches that site ():

Survival of a fish to a given site *xf, s* is also assumed to be a random process with Bernoulli distribution and probability a function of site survival probability *θ*. This function also contains an observation component ( because the fish must’ve been alive in ‘*s*-1’ to have non-zero survival probability at ‘*s’*:

Finally, probability of survival from tagging release to each detection occasion (*ψ f, s*), or ‘cumulative survival’, is given as a function of probability of cumulative survival of a fish to the previous location (*ψ f, s-1*) and probability of detection of a fish at the given location *θ f, s*. Cumulative survival, *ψ*, for a fish at its initial tagging site was set at 1. Cumulative survival, *ψ*, of all following sites is given by:

### Model fitting and evaluation

Our Bayesian CJS model was fitted using a Markov Chain Monte Carlo (MCMC) approach through R package “rjags” (Plummer, 2022) which provides an interface from R statistical software to the JAGS library (Plummer, 2003) for data analysis. The model was estimated using four MCMC chains, each with 2,500 iterations, 2,500 burn-in with thinning by selecting the 5th iteration. We constrained our model by specifically inputting the known detection efficiency of the final PIT receiver installed to detect tagged adults returning to the river during spawning migrations. PIT receiver detection efficiencies are calculated separately and this value can therefore be specified as a prior in our model. Three parameters were calculated in this model: (i) detection probability at each site, (ii) survival probability between each site, and (iii) probability of surviving from release to a detection occasion (i.e., cumulative survival).

We tested our model for successful convergence using Gelman and Rubin’s convergence diagnostic (Gelman and Rubin, 1992). This was performed using the *gelman.diag()* function of R package “coda” (Plumer et al., 2022). We considered the model to have successfully converged if no parameters had Gelman-Rubin statistics greater than 1.05. Diagnostic plots were also produced to visualize convergence and model parameters using R package “postpack” (Staton, 2022) which allowed us to examine plots of autocorrelation, trace, and posterior density for each parameter. Through this package we also calculated 95 % confidence intervals and coefficient of variation (CV) values for all model parameters estimated at each site. Finally, effective sample size (ESS) was calculated to assess the information content of the MCMC chain in our model (Kass et al., 1998; Martino et al., 2017). ESS was calculated using the *effectiveSize()* function of R package “coda”.

### Simulated Data

Currently, the model has been produced, developed, and tested on a simulated dataset. Developing models using simulated datasets can be preferred as it allows us to test model parameters based on the known survival and detection probabilities used to create the simulated dataset, thus allowing us to refine and validate our model. See Tables 1 and 2 for an overview of the survival and detection probabilities defined in our simulated dataset. These parameter values were chosen based on known survival, detection, and recapture probabilities from a similar bottlenecks study conducted on Cowichan River Chinook salmon (*Oncorhynchus tshawytscha*) by K. Pellett et al. Such simulations also allow us to test sample sizes (tag numbers) deployed at various locations in this project under a variety of survival and detection efficiency scenarios to assess the expected precision and confidence of model parameters subsequently produced in the survival model.

|  |  |  |
| --- | --- | --- |
| Description | Model parameter | Defined value |
| Survival from hatchery to downstream PIT receiver | phi [t2] | 85 % |
| Downstream PIT receiver detection efficiency | p [t2] | 6 % |
| Survival from downstream PIT receiver to estuary | phi [t3] | 85 % |
| Estuary recapture rate of tagged hatchery fish | p [t3] | 0.3 % |
| Survival between estuary tagging and September | phi [t4] | 25 % |
| Recapture of tagged fish in microtroll | p [t4] | 0 % |
| Survival between microtroll and adult return | phi [t5] | 10 % |
| Adult return PIT receiver detection efficiency | p [t5] | *User defined* |
| Hatchery facility to adult return cumulative survival | survship [t5] | 0.5 % |

*Table 1.* Simulated data parameters defined for hatchery fish.

|  |  |  |
| --- | --- | --- |
| Description | Model parameter | Defined value |
| Survival between estuary tagging and September | phi [t4] | 25 % |
| Recapture of tagged fish in microtroll | p [t4] | 0 % |
| Survival between microtroll and adult return | phi [t5] | 10 % |
| Adult return PIT receiver detection efficiency | p [t5] | *User defined* |
| Hatchery facility to adult return cumulative survival | survship [t5] | 1 % |

*Table 2.* Simulated data parameters defined for wild fish.

# Results

The following pages outline the results of our Bayesian CJS survival model (from here on ‘survival model’) testing and simulations. The results are divided into three sections: (1) testing of model output parameters based on known, user-defined survival and detection probability values of the simulated dataset; (2) simulations run using hatchery- and wild simulated datasets to investigate the impact of altering tag numbers (of hatchery- and wild origin fish), detection probability (of final adult return PIT receiver), and survival estimates, and (3) a first look into real data (provided by K. Pellett) run in the model.

## 1. Testing model output

We ran both simulated hatchery- and wild-origin fish data in our survival model to compare the model output to the defined values stage survival (‘phi’), detection probability (‘p’), and cumulative survival (‘survship’) that were used to develop the simulated dataset. This allows us to test and validate our survival model for its ability to accurately estimate such parameters on similar, real datasets. For the purpose of this exercise, we ran our survival model using hatchery- and wild-origin fish separately. The survival model was constrained with a final detection efficiency set at 95%.

Our simulated dataset comprised of five tagging or detection stages (here defined as t1 – t5): t1 represents a hatchery facility (tagging only), t2 represents a PIT receiver located downstream of the hatchery facility (detection only), t3 represents the estuary environment (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only). See Tables 1 and 2 for an overview of the stage survival and detection probabilities defined in our simulated dataset for hatchery- and wild-origin fish, respectively.

### 1a) Survival model output for hatchery-origin fish

Our simulated dataset for hatchery-origin fish comprised of N = 5,000 fish tagged at a hatchery facility (t1), N = 492 tagged in estuary (t3), and N = 47 tagged in microtroll (t4). See Table 3 for a breakdown of hatchery-origin fish capture histories.

Our survival model was able to accurately estimate the following parameters with a coefficient of variation (CV) of less than or equal to 20%: detection probability of the hatchery downstream PIT receiver (p[2]), survival from hatchery facility to the downstream PIT receiver (phi[2]), cumulative survival to the downstream PIT receiver (survship[2]), and cumulative survival to adult return (survship[5]; Table 4). The model estimates for these parameters with low CV values were all closely matched with the defined values for these parameters used to create the simulated dataset (Table 1), thus we can assume this model is capable of estimating accurate survival and detection probability values if the corresponding CV is less than or equal to 20%; see Table 4.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 3.* Capture histories of tagged hatchery-origin (A) and wild-origin (B) fish, developed in our simulated dataset. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | Defined value |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| p | **2** | **p[2]** | **0.0606** | **0.0077** | **0.0587** | **0.0505** | **0.0802** | **0.1273** | **0.06** |
| p | 3 | p[3] | 0.0061 | 0.0027 | 0.0056 | 0.0025 | 0.0130 | 0.4467 | 0.003 |
| p | 4 | p[4] | 0.0032 | 0.0040 | 0.0019 | 0.0001 | 0.0138 | 1.2515 | 0 |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | 0.95 |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| phi | **2** | **phi[2]** | **0.8515** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | **0.85** |
| phi | 3 | phi[3] | 0.5590 | 0.1870 | 0.6578 | 0.2813 | 0.9565 | 0.3837 | 0.85 |
| phi | 4 | phi[4] | 0.1201 | 0.0641 | 0.1069 | 0.0336 | 0.2885 | 0.5340 | 0.25 |
| phi | 5 | phi[5] | 0.0923 | 0.0417 | 0.0870 | 0.0286 | 0.1874 | 0.4520 | 0.1 |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| survship | **2** | **survship[2]** | **0.8515** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | **0.85** |
| survship | 3 | survship[3] | 0.5937 | 0.1834 | 0.5633 | 0.2706 | 0.9139 | 0.3088 | NA |
| survship | 4 | survship[4] | 0.0684 | 0.0427 | 0.0567 | 0.0231 | 0.1969 | 0.6243 | NA |
| survship | **5** | **survship[5]** | **0.0050** | **0.0010** | **0.0049** | **0.0032** | **0.0071** | **0.1974** | **0.005** |

*Table 4.* Survival model output for hatchery-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons.



*Figure 1.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 1b) Survival model output for wild-origin fish

Our simulated dataset for wild-origin fish comprised of N = 492 fish tagged in the estuary environment (t3) and N = 548 fish tagged during the microtroll (t4). See Table 5 for a breakdown of hatchery-origin fish capture histories. Simulated data for wild-origin fish differs from that of hatchery-origin fish as there is no tagging at a hatchery facility (stage t1) or subsequent detections at the downstream PIT receiver (stage t2). For wild-origin fish, tagging occurs in either the estuary environment or during microtrolling efforts. These fish may therefore be detected as either a recapture in the microtroll or as a PIT receiver detection upon adult return. Based on known data from previous studies (K. Pellett data), we estimated survival to adult return to be twice that of hatchery-origin fish. Detection probabilities were assumed to be the same as that of hatchery-origin fish.

Our survival model was able to accurately estimate survival of microtroll-tagged wild-origin fish to adult return (phi[5]) with a CV of less than 15%; Table 6.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 480 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 68 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 486 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 6 |

*Table 5.* Capture histories of tagged hatchery-origin (A) and wild-origin (B) fish, developed in our simulated dataset. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | *Defined value* |
| p | 3 | p[3] | 1 | 0 | 1 | 1 | 1 | NA | *1* |
| p | 4 | p[4] | 0.02059 | 0.0251 | 0.0120 | 0.0004 | 0.0873 | 1.2172 | *0* |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | NA | *0.95* |
| phi | 3 | phi[3] | 1 | 0 | 1 | 1 | 1 | NA | *1* |
| phi | 4 | phi[4] | 0.1142 | 0.0481 | 0.1086 | 0.0395 | 0.2304 | 0.4213 | *0.25* |
| phi | **5** | **phi[5]** | **0.1139** | **0.0145** | **0.1134** | **0.0859** | **0.1432** | **0.1276** | ***0.10*** |
| survship | 3 | survship[3] | 1 | 0 | 1 | 1 | 1 | NA | *1* |
| survship | 4 | survship[4] | 0.1142 | 0.0481 | 0.1086 | 0.0395 | 0.2304 | 0.4213 | *NA* |
| survship | 5 | survship[5] | 0.0128 | 0.0051 | 0.01204 | 0.0047 | 0.0248 | 0.4000 | *0.01* |

*Table 6.* Survival model output for wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons.



*Figure 2.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 1c) Survival output model for hatchery- and wild-origin fish combined

Finally, we compared hatchery- and wild-origin fish survival by running both groups of fish in the same model. To allow for more effective comparisons, only hatchery- and wild-origin fish tagged during the estuary or microtrolling efforts were included in the model. For hatchery-origin fish, N = 492 were tagged in the estuary (t3) and N = 47 were tagged in microtroll (t4; see Table 3). For wild-origin fish, N = 492 were tagged in the estuary environment (t3) and N = 548 were tagged during the microtroll (t4; see Table 5).

Table 7 shows the survival model output, allowing comparison of parameters values between hatchery- and wild-origin fish. Figure 3 visualizes these results.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | origin |
| p | 3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| p | 3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| phi | 3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| phi | 3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| survship | 3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| survship | 3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| p | 4 | p[2] | 0.0309 | 0.0423 | 0.0160 | 0.0006 | 0.1476 | 1.3703 | hatchery |
| p | 4 | p[2] | 0.0187 | 0.0205 | 0.0118 | 0.0003 | 0.0737 | 1.1001 | wild |
| phi | 4 | phi[2] | 0.0991 | 0.0766 | 0.0780 | 0.0154 | 0.3118 | 0.7735 | hatchery |
| phi | 4 | phi[2] | 0.1181 | 0.0462 | 0.1117 | 0.0477 | 0.2278 | 0.3916 | wild |
| survship | 4 | survship[2] | 0.0991 | 0.0766 | 0.0780 | 0.0154 | 0.3118 | 0.7735 | hatchery |
| survship | 4 | survship[2] | 0.1181 | 0.0462 | 0.1117 | 0.0477 | 0.2278 | 0.3916 | wild |
| p | 5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery |
| p | 5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild |
| phi | 5 | phi[3] | 0.0831 | 0.0404 | 0.0766 | 0.0246 | 0.1773 | 0.4866 | hatchery |
| phi | **5** | **phi[3]** | **0.1143** | **0.0150** | **0.1136** | **0.0861** | **0.1461** | **0.1316** | **wild** |
| survship | 5 | survship[3] | 0.0065 | 0.0035 | 0.0059 | 0.0015 | 0.0145 | 0.5349 | hatchery |
| survship | 5 | survship[3] | 0.0133 | 0.0049 | 0.0128 | 0.0055 | 0.0242 | 0.3688 | wild |

*Table 7.* Survival model output comparing hatchery- and wild-origin fish survival in our simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened.



*Figure 3.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

### 1d) Conclusions

* If coefficient of variation is less than 20%, the parameter values appear to be accurate.
* Stages with low detection efficiency (for example the estuary beach seine and microtroll which have very low recaptures) are not capable of producing accurate survival estimates.

## 2. Simulations and tagging scenarios

After developing and validating our survival model, we proceeded to run further simulations to investigate how varying tag numbers, detection probabilities, and survival estimates might affect model results and accuracy. We investigated the following scenarios by running simulations through the survival model:

1. Model not constrained with a final detection efficiency
2. Altering final detection probability
   1. Final detection probability, p[5], of 95 %
   2. Final detection probability, p[5], of 75 %
   3. Final detection probability, p[5], of 50 %
3. Altering number of wild fish tagged
   1. N = 300 tagged in estuary environment
   2. N = 500 tagged in estuary environment
   3. N = 750 tagged in estuary environment
   4. N = 1,000 tagged in estuary environment
   5. N = 1,500 tagged in estuary environment
   6. N = 2,000 tagged in estuary environment
   7. N = 2,500 tagged in estuary environment
4. Tag numbers based on actual tag numbers from Nanaimo and Puntledge in 2021 and 2022
   1. Nanaimo (East VI Fall) 2021
   2. Nanaimo and Puntledge Summer 2021
   3. East Coast VI Coho 2021
   4. Qualicum Puntledge Fall 2021
   5. Nanaimo (East VI Fall) 2022
   6. Nanaimo and Puntledge Summer 2022
   7. Qualicum Puntledge Fall 2022
5. Altering number of hatchery fish tagged
   1. N = 5,000
   2. N = 7,500
   3. N = 10,000
6. Altering fry-to-adult survival estimates
   1. 0.5% fry-to-adult survival
   2. 1.5% fry-to-adult survival
   3. 3% fry-to-adult survival
   4. 5% fry-to-adult survival

### 2a) Model not constrained with a final detection efficiency

This exercise involved our simulated dataset of 5,539 hatchery-origin fish. The capture histories produced in the simulated dataset are outlined in Table 8 and parameter values (stage survival and detection efficiencies) are listed in Table 1. The final adult return PIT receiver detection efficiency, p[5], was not constrained during this exercise and was instead estimated by the model.

The survival model output is shown in Table 9 and visualized in Figure 4. When the model is not constrained, we get highly uncertain survival and detection probability estimates for the final adult return stage.An unconstrained model also reduces the accuracy of final survival estimates.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 8.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **2** | **p[2]** | **0.0616** | **0.0109** | **0.0812** | **0.0616** | **0.1064** | **0.1339** | ***0.06*** |
| p | 3 | p[3] | 0.0075 | 0.0025 | 0.0071 | 0.0038 | 0.0137 | 0.3320 | *0.003* |
| p | 4 | p[4] | 0.0030 | 0.0034 | 0.0018 | 0.0001 | 0.0127 | 1.1375 | *0* |
| p | 5 | p[5] | 0.3653 | 0.2608 | 0.2938 | 0.0553 | 0.9306 | 0.7138 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **2** | **phi[2]** | **0.8733** | **0.0811** | **0.6681** | **0.5174** | **0.8523** | **0.1204** | ***0.85*** |
| phi | 3 | phi[3] | 0.6591 | 0.1510 | 0.6728 | 0.3598 | 0.9419 | 0.3291 | *0.85* |
| phi | 4 | phi[4] | 0.1489 | 0.0650 | 0.1328 | 0.0587 | 0.2984 | 0.4370 | *0.25* |
| phi | 5 | phi[5] | 0.3700 | 0.2644 | 0.2848 | 0.0699 | 0.9396 | 0.7146 | *0.1* |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.6733 | 0.0811 | 0.6681 | 0.5174 | 0.8523 | 0.1204 | *0.85* |
| survship | 3 | survship[3] | 0.4370 | 0.0867 | 0.4402 | 0.2665 | 0.6057 | 0.1984 | *NA* |
| survship | 4 | survship[4] | 0.0636 | 0.0274 | 0.0589 | 0.0248 | 0.1307 | 0.4311 | *NA* |
| survship | 5 | survship[5] | 0.0235 | 0.0213 | 0.0152 | 0.0041 | 0.0805 | 0.9034 | *0.005* |

*Table 9.* Survival model output for our hatchery-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was not constrained and thus estimated through the model.



*Figure 4.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 2b) Altering final detection probability

For the following scenarios investigated here in section 2b, we used simulated data comprised of hatchery-origin fish only (total N = 5,539). The capture histories are defined for each simulation and parameter values (stage survival and detection efficiencies) are listed in Table 1. We ran simulations using this simulated dataset to investigate model output when the final detection efficiency (adult return PIT receiver) is constrained to 95%, 75%, and 50%.

#### i) Final detection probability of 95%

The capture histories produced in the simulated dataset are outlined in Table 10 and parameter values (stage survival and detection efficiencies) are listed in Table 1. The final adult return PIT receiver detection efficiency, p[5], was constrained to 95%.

The survival model output is shown in Table 11 and visualized in Figure 5. When the model is constrained to a high final detection efficiency, we get accurate (CV < 20%) parameters estimates for detection efficiency of p2 (downstream PIT receiver), survival to stage 2 (phi2), and cumulative survival to the downstream PIT receiver and to adult return (see Table 11).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 10.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **2** | **p[2]** | **0.0606** | **0.0077** | **0.0587** | **0.0505** | **0.0802** | **0.1273** | ***0.06*** |
| p | 3 | p[3] | 0.0061 | 0.0027 | 0.0056 | 0.0025 | 0.0130 | 0.4467 | *0.003* |
| p | 4 | p[4] | 0.0032 | 0.0040 | 0.0019 | 0.0001 | 0.0138 | 1.2515 | *0* |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **2** | **phi[2]** | **0.8715** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | ***0.85*** |
| phi | 3 | phi[3] | 0.6590 | 0.1870 | 0.6578 | 0.2813 | 0.9565 | 0.3837 | *0.85* |
| phi | 4 | phi[4] | 0.1201 | 0.0641 | 0.1069 | 0.0336 | 0.2885 | 0.5340 | *0.25* |
| phi | 5 | phi[5] | 0.0923 | 0.0417 | 0.0870 | 0.0286 | 0.1874 | 0.4520 | *0.1* |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **2** | **survship[2]** | **0.8715** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | ***0.85*** |
| survship | 3 | survship[3] | 0.5937 | 0.1834 | 0.5633 | 0.2706 | 0.9139 | 0.3088 | *NA* |
| survship | 4 | survship[4] | 0.0684 | 0.0427 | 0.0567 | 0.0231 | 0.1969 | 0.6243 | *NA* |
| survship | **5** | **survship[5]** | **0.0050** | **0.0010** | **0.0049** | **0.0032** | **0.0071** | **0.1974** | ***0.005*** |

*Table 11.* Survival model output for our hatchery-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.



*Figure 5.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### ii) Final detection probability of 75%

The capture histories produced in the simulated dataset are outlined in Table 12 and parameter values (stage survival and detection efficiencies) are listed in Table 1. The final adult return PIT receiver detection efficiency, p[5], was constrained to 75%.

The survival model output is shown in Table 13. When the model is constrained to a medium final detection efficiency (of 75%), we get accurate (CV < 20%) parameters estimates for detection efficiency of p2 (downstream PIT receiver), survival to stage 2 (phi2), and cumulative survival to the downstream PIT receiver and to adult return (see Table 13). This is therefore suggesting that detection probabilities of 75% or greater can produce reliable parameter values in our survival model when fry-to-adult survival is as low as 0.5%.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 12.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **2** | **p[2]** | **0.0675** | **0.0109** | **0.0650** | **0.0530** | **0.0942** | **0.1619** | ***0.06*** |
| p | 3 | p[3] | 0.0088 | 0.0037 | 0.0083 | 0.0034 | 0.0176 | 0.4157 | *0.003* |
| p | 4 | p[4] | 0.0028 | 0.0034 | 0.0016 | 0.0001 | 0.0121 | 1.2250 | *0* |
| p | 5 | p[5] | 0.75 | 0 | 0.75 | 0.75 | 0.75 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **2** | **phi[2]** | **0.8799** | **0.1119** | **0.8360** | **0.5798** | **0.9821** | **0.1364** | ***0.85*** |
| phi | 3 | phi[3] | 0.4975 | 0.1809 | 0.4592 | 0.2452 | 0.8682 | 0.4637 | *0.85* |
| phi | 4 | phi[4] | 0.1845 | 0.1042 | 0.1601 | 0.0535 | 0.4588 | 0.5647 | *0.25* |
| phi | 5 | phi[5] | 0.1058 | 0.0470 | 0.0999 | 0.0375 | 0.2200 | 0.4446 | *0.1* |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **2** | **survship[2]** | **0.8799** | **0.1119** | **0.8360** | **0.5798** | **0.9821** | **0.1364** | ***0.85*** |
| survship | 3 | survship[3] | 0.4016 | 0.1446 | 0.3684 | 0.2149 | 0.7144 | 0.3600 | *NA* |
| survship | 4 | survship[4] | 0.0678 | 0.0342 | 0.0588 | 0.0242 | 0.1564 | 0.5046 | *NA* |
| survship | **5** | **survship[5]** | **0.0059** | **0.0011** | **0.0058** | **0.0039** | **0.0083** | **0.1951** | ***0.005*** |

*Table 13.* Survival model output for our hatchery-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.75.

#### iii) Final detection probability of 50%

The capture histories produced in the simulated dataset are outlined in Table 14 and parameter values (stage survival and detection efficiencies) are listed in Table 1. The final adult return PIT receiver detection efficiency, p[5], was constrained to 50%.

The survival model output is shown in Table 15. When the model is constrained to a low final detection efficiency (of 50%), the survival model does not return any accurate (CV < 20%) parameters estimates (see Table 15). The final cumulative survival parameter (survship[5]) is estimated by the survival model as 0.0091, which is nearly twice that of the true value defined in the simulated dataset of 0.005. Thus, if the final detection efficiency of the final adult return PIT receiver is set at 50%, the survival estimates produced by our survival estimate may not be accurate. This is therefore suggesting that detection probabilities of 50% or lower are not sufficient to produce reliable parameter values in our survival model when fry-to-adult survival is as low as 0.5%.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 14.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | Defined value |
| p | 1 | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | t2 | p[2] | 0.0888 | 0.0184 | 0.0875 | 0.0591 | 0.1243 | 0.2176 | *0.06* |
| p | 3 | t3 | p[3] | 0.0080 | 0.0032 | 0.0073 | 0.0037 | 0.0157 | 0.3942 | *0.003* |
| p | 4 | t4 | p[4] | 0.0026 | 0.0032 | 0.0015 | 0.0000 | 0.0114 | 1.1991 | *0* |
| p | 5 | t5 | p[5] | 0.5 | 0 | 0.5 | 0.5 | 0.5 | 0 | *0.95* |
| phi | 1 | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | t2 | phi[2] | 0.6352 | 0.1299 | 0.6184 | 0.4483 | 0.9013 | 0.3045 | *0.85* |
| phi | 3 | t3 | phi[3] | 0.6965 | 0.2015 | 0.7217 | 0.3388 | 0.9882 | 0.2893 | *0.85* |
| phi | 4 | t4 | phi[4] | 0.2014 | 0.1514 | 0.1465 | 0.0536 | 0.6556 | 0.7517 | *0.25* |
| phi | 5 | t5 | phi[5] | 0.1550 | 0.0782 | 0.1420 | 0.0453 | 0.3321 | 0.5047 | *0.1* |
| survship | 1 | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | t2 | survship[2] | 0.6352 | 0.1299 | 0.6184 | 0.4483 | 0.9013 | 0.2045 | *0.85* |
| survship | 3 | t3 | survship[3] | 0.4296 | 0.1158 | 0.4446 | 0.2400 | 0.6387 | 0.2696 | *NA* |
| survship | 4 | t4 | survship[4] | 0.0778 | 0.0468 | 0.0632 | 0.0255 | 0.1974 | 0.6018 | *NA* |
| survship | 5 | t5 | survship[5] | 0.0091 | 0.0018 | 0.0090 | 0.0060 | 0.0129 | 0.2939 | *0.005* |

*Table 15.* Survival model output for our hatchery-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.50.

**

*Figure 6.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.50. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

*iv) Conclusions (detection probability)*

* Final PIT receiver detection probabilities of greater than 75 % are still capable of producing accurate stage survival and cumulative survival estimates given sufficient tag numbers
* When the model is constrained to a final detection efficiency of 50%, the survival model does not return any confident parameters estimates and the survival estimates produced by the survival model may not be accurate.
* Note that the simulations run in this section were for N = 5,539 hatchery-origin fish with fry-to-adult survival of 0.5%. It would be expected that if we were to increase tag numbers or fry-to-adult survival in the model, lower final detection efficiency would be sufficient.

### 2c) Altering the number of wild-tagged fish

For the following simulations in Section 2c, we used a simulated, wild-origin dataset. Stage survival and stage detection efficiency values used to create the simulated dataset are listed in Table 2. For all below simulations, final adult return detection efficiency was set at 95%. In the following simulations, we varied the number of wild-origin fish tagged in the estuary environment; specific tag numbers and capture history summaries are listed for each simulation below.

#### i) N = 318 tagged in estuary environment

* N = 318 wild-origin fish tagged in the estuary, N = 265 wild-origin fish tagged in the microtroll, see Table 16 for the capture history summary.
* Final detection efficiency set at 95%.
* Only stage survival between microtroll and adult return (phi[3]) was accurately estimated by the survival model with CV < 20% (see Table 17).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 239 |
| 0 | 1 | 1 | 011 | 26 |
| 1 | 0 | 0 | 100 | 314 |
| 1 | 0 | 1 | 101 | 4 |

*Table 16.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0310 | 0.0359 | 0.0194 | 0.0007 | 0.1308 | 1.1598 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1278 | 0.0682 | 0.1148 | 0.0349 | 0.2928 | 0.5340 | *0.25* |
| phi | **3** | **phi[3]** | **0.1067** | **0.0197** | **0.1057** | **0.0729** | **0.1507** | **0.1849** | ***0.10*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1278 | 0.0682 | 0.1148 | 0.0349 | 0.2928 | 0.5340 | *NA* |
| survship | 3 | survship[3] | 0.0131 | 0.0064 | 0.0121 | 0.0038 | 0.0290 | 0.4907 | *0.01* |

*Table 17.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

**

*Figure 7.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### ii) N = 505 tagged in estuary environment

* N = 505 wild-origin fish tagged in the estuary, N = 273 wild-origin fish tagged in the microtroll, see Table 18 for the capture history summary.
* Final detection efficiency set at 95%.
* Only stage survival between microtroll and adult return (phi[3]) was accurately estimated by the survival model with CV < 20% (see Table 19).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 249 |
| 0 | 1 | 1 | 011 | 24 |
| 1 | 0 | 0 | 100 | 499 |
| 1 | 0 | 1 | 101 | 6 |

*Table 18.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0153 | 0.0165 | 0.0099 | 0.0004 | 0.0609 | 1.0754 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1389 | 0.0552 | 0.1301 | 0.0544 | 0.2630 | 0.3975 | *0.25* |
| phi | **3** | **phi[3]** | **0.0952** | **0.0174** | **0.0946** | **0.0643** | **0.1321** | **0.1826** | ***0.1*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1389 | 0.0552 | 0.1301 | 0.0544 | 0.2631 | 0.3975 | *NA* |
| survship | 3 | survship[3] | 0.0129 | 0.0048 | 0.0122 | 0.0053 | 0.0237 | 0.3702 | *0.01* |

*Table 19.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

**

*Figure 8.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iii) N = 1,005 tagged in estuary environment

* N = 1,005 wild-origin fish tagged in the estuary, N = 312 wild-origin fish tagged in the microtroll, see Table 20 for the capture history summary.
* Final detection efficiency set at 95%.
* Only stage survival between microtroll and adult return (phi[3]) was accurately estimated by the survival model with CV < 20% (see Table 21).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 286 |
| 0 | 1 | 1 | 011 | 26 |
| 1 | 0 | 0 | 100 | 992 |
| 1 | 0 | 1 | 101 | 13 |

*Table 20.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0070 | 0.0073 | 0.0047 | 0.0001 | 0.02627 | 1.0483 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1556 | 0.0496 | 0.1495 | 0.0789 | 0.2691 | 0.3188 | *0.25* |
| phi | **3** | **phi[3]** | **0.0911** | **0.0163** | **0.0903** | **0.0605** | **0.1255** | **0.1793** | ***0.1*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1556 | 0.0496 | 0.1495 | 0.0789 | 0.2691 | 0.3188 | *NA* |
| survship | 3 | survship[3] | 0.0137 | 0.0037 | 0.0134 | 0.0075 | 0.0218 | 0.2660 | *0.01* |

*Table 21.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

**

*Figure 9.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iv) N = 1,505 tagged in estuary environment

* N = 1,505 wild-origin fish tagged in the estuary, N = 342 wild-origin fish tagged in the microtroll, see Table 22 for the capture history summary.
* Final detection efficiency set at 95%.
* Only stage survival between microtroll and adult return (phi[3]) was accurately estimated by the survival model with CV < 20% (see Table 23).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 316 |
| 0 | 1 | 1 | 011 | 26 |
| 1 | 0 | 0 | 100 | 1486 |
| 1 | 0 | 1 | 101 | 19 |

*Table 22.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0043 | 0.0046 | 0.0028 | 0.0001 | 0.0169 | 1.0671 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1700 | 0.0506 | 0.1634 | 0.0898 | 0.2962 | 0.2974 | *0.25* |
| phi | **3** | **phi[3]** | **0.0923** | **0.0150** | **0.0818** | **0.0551** | **0.1135** | **0.1824** | ***0.1*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1700 | 0.0506 | 0.1634 | 0.0898 | 0.2962 | 0.2974 | *NA* |
| survship | 3 | survship[3] | 0.0135 | 0.0030 | 0.0133 | 0.0081 | 0.0202 | 0.2138 | *0.01* |

*Table 23.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

**

*Figure 10.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### v) N = 2,005 tagged in estuary environment

* N = 2,005 wild-origin fish tagged in the estuary, N = 291 wild-origin fish tagged in the microtroll, see Table 24 for the capture history summary.
* Final detection efficiency set at 95%.
* Stage survival between microtroll and adult return (phi[3]) and cumulative survival to adult return (survship[3]) were accurately estimated by the survival model with CV < 20% (see Table 25).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 267 |
| 0 | 1 | 1 | 011 | 24 |
| 1 | 0 | 0 | 100 | 1980 |
| 1 | 0 | 1 | 101 | 25 |

*Table 24.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0038 | 0.0043 | 0.0025 | 0.0001 | 0.0153 | 1.1211 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1454 | 0.0408 | 0.1403 | 0.0810 | 0.2421 | 0.2807 | *0.25* |
| phi | **3** | **phi[3]** | **0.0914** | **0.0167** | **0.0905** | **0.0622** | **0.1266** | **0.1826** | ***0.1*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1454 | 0.0408 | 0.1403 | 0.0810 | 0.2421 | 0.2807 | *NA* |
| survship | **3** | **survship[3]** | **0.0128** | **0.0026** | **0.0127** | **0.0083** | **0.0184** | **0.1998** | ***0.01*** |

*Table 25.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

**

*Figure 11.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### vi) N = 2,505 tagged in estuary environment

* N = 2,505 wild-origin fish tagged in the estuary, N = 261 wild-origin fish tagged in the microtroll, see Table 26 for the capture history summary.
* Final detection efficiency set at 95%.
* Stage survival between microtroll and adult return (phi[3]) and cumulative survival to adult return (survship[3]) were accurately estimated by the survival model with CV < 20% (see Table 27).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 10 | 236 |
| 0 | 1 | 1 | 11 | 25 |
| 1 | 0 | 0 | 100 | 2474 |
| 1 | 0 | 1 | 101 | 31 |

*Table 26.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | 2 | p[2] | 0.0032 | 0.0034 | 0.0021 | 0.0001 | 0.0126 | 1.0720 | *0* |
| p | 3 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | 2 | phi[2] | 0.1304 | 0.0341 | 0.1269 | 0.0727 | 0.2026 | 0.2617 | *0.25* |
| phi | **3** | **phi[3]** | **0.1036** | **0.0192** | **0.1023** | **0.0712** | **0.1445** | **0.1857** | ***0.1*** |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | 2 | survship[2] | 0.1304 | 0.0341 | 0.1269 | 0.0727 | 0.2026 | 0.2617 | *NA* |
| survship | **3** | **survship[3]** | **0.0130** | **0.0024** | **0.0130** | **0.0089** | **0.0182** | **0.1820** | ***0.01*** |

*Table 27.* Survival model output for our wild-origin, simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95.

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*Figure 12.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 2d) Simulations based on actual numbers of fish tagged in Nanaimo and Puntledge, 2021/2022

Table 28 shows the number of hatchery-origin and wild-origin fish (identified through either GSI or PBT, respectively) tagged in Nanaimo and Puntledge over two years. These fish were tagged in 2021 and 2022, so we do not yet have return data from these fish which would allow us to run the data in our survival model, however we were interested in testing whether such tag numbers would be sufficient to produce reliable survival model output.

In this section (2d) we replicated hatchery- and wild-origin tag numbers for each system (i.e., each row in Table 28) in our simulated dataset to evaluate the potential survival model output. Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

**

*Table 28.* Overview of wild-origin and hatchery-origin fish tagged in the river environment, identified through either GSI or PBT, respectively. This table shows the number of wild- and hatchery-origin fish across various systems and over two years. This table is copied from the midterm progress report titled ‘Determination of Bottlenecks Limiting Wild and Enhanced Juvenile Salmon and Steelhead Production in BC using PIT tags and Spatially Comprehensive Arrays’.

#### i) East VI Fall (Nanaimo) 2021

* Wild-origin fish tagged in estuary, N = 391.
* Hatchery-origin fish tagged in estuary, N = 269.
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| p | t4 | p[2] | 0.0473 | 0.0671 | 0.0241 | 0.0007 | 0.2349 | 1.4209 | hatchery | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| phi | t4 | phi[2] | 0.1449 | 0.1353 | 0.1020 | 0.0163 | 0.5680 | 0.9338 | hatchery | *0.25* |
| phi | t5 | phi[3] | 0.0762 | 0.0377 | 0.0707 | 0.0215 | 0.1684 | 0.4943 | hatchery | *0.1* |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| survship | t4 | survship[2] | 0.1449 | 0.1353 | 0.1020 | 0.0163 | 0.5680 | 0.9338 | hatchery | *NA* |
| survship | t5 | survship[3] | 0.0085 | 0.0058 | 0.0071 | 0.0012 | 0.0240 | 0.6880 | hatchery | *0.005* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| p | t4 | p[2] | 0.0159 | 0.0170 | 0.0101 | 0.0003 | 0.0631 | 1.0674 | wild | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| phi | t4 | phi[2] | 0.1788 | 0.0693 | 0.1696 | 0.0746 | 0.3480 | 0.3877 | wild | *0.25* |
| phi | **t5** | **phi[3]** | **0.1077** | **0.0135** | **0.1073** | **0.0822** | **0.1343** | **0.1253** | **wild** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| survship | t4 | survship[2] | 0.1788 | 0.0693 | 0.1696 | 0.0746 | 0.3480 | 0.3877 | wild | *NA* |
| survship | t5 | survship[3] | 0.0190 | 0.0069 | 0.0181 | 0.0082 | 0.0348 | 0.3637 | wild | *0.01* |

*Table 29.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2021 East VI Fall (Nanaimo) Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 13.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery origin fish:



*Figure 14.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:



*Figure 15.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### ii) Nanaimo and Puntledge summer 2021

* Wild-origin fish tagged in estuary, N = 270
* Hatchery-origin fish tagged in estuary, N = 112
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| p | t4 | p[2] | 0.0931 | 0.1267 | 0.0443 | 0.0019 | 0.467055 | 1.3598 | hatchery | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| phi | t4 | phi[2] | 0.1672 | 0.1541 | 0.1199 | 0.0107 | 0.5857 | 0.9217 | hatchery | *0.25* |
| phi | t5 | phi[3] | 0.0778 | 0.0373 | 0.0717 | 0.0222 | 0.1636 | 0.4792 | hatchery | *0.1* |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| survship | t4 | survship[2] | 0.1672 | 0.1541 | 0.1199 | 0.0107 | 0.5857 | 0.9217 | hatchery | *NA* |
| survship | t5 | survship[3] | 0.0109 | 0.0092 | 0.0082 | 0.0009 | 0.0356 | 0.8463 | hatchery | *0.005* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| p | t4 | p[2] | 0.0228 | 0.0256 | 0.0146 | 0.0005 | 0.0919 | 1.1246 | wild | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| phi | t4 | phi[2] | 0.1824 | 0.0848 | 0.1697 | 0.0553 | 0.3726 | 0.4651 | wild | *0.25* |
| phi | **t5** | **phi[3]** | **0.1116** | **0.0140** | **0.1115** | **0.0846** | **0.1400** | **0.1259** | **wild** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| survship | t4 | survship[2] | 0.1824 | 0.0848 | 0.1697 | 0.0553 | 0.3726 | 0.4651 | wild | *NA* |
| survship | t5 | survship[3] | 0.0200 | 0.0088 | 0.0189 | 0.0062 | 0.0398 | 0.4417 | wild | *0.01* |

*Table 30.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2021 Nanaimo and Puntledge summer Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 16.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:



*Figure 17.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:



*Figure 18.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iii) East coast VI coho

* Wild-origin fish tagged in estuary, N = 3
* Hatchery-origin fish tagged in estuary, N = 0
* Final adult return PIT receiver detection efficiency set at 95%.

Insufficient numbers to run in the model.

#### iv) Qualicum Puntledge Fall, 2021

* Wild-origin fish tagged in estuary, N = 206
* Hatchery-origin fish tagged in estuary, N = 356
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | Defined value |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| p | t4 | p[2] | 0.0342 | 0.0500 | 0.0167 | 0.0005 | 0.1665 | 1.4607 | hatchery | 0 |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | 0.95 |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| phi | t4 | phi[2] | 0.1633 | 0.1799 | 0.0986 | 0.0162 | 0.7705 | 1.1014 | hatchery | 0.25 |
| phi | t5 | phi[3] | 0.0598 | 0.0345 | 0.0536 | 0.0125 | 0.1463 | 0.5771 | hatchery | 0.1 |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| survship | t4 | survship[2] | 0.1633 | 0.1799 | 0.0986 | 0.0162 | 0.7705 | 1.1014 | hatchery | NA |
| survship | t5 | survship[3] | 0.0065 | 0.0043 | 0.0055 | 0.0010 | 0.0172 | 0.6659 | hatchery | 0.005 |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| p | t4 | p[2] | 0.0307 | 0.0354 | 0.0188 | 0.0007 | 0.1391 | 1.1552 | wild | 0 |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | 0.95 |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| phi | t4 | phi[2] | 0.1911 | 0.0899 | 0.1773 | 0.0566 | 0.4006 | 0.4703 | wild | 0.25 |
| phi | **t5** | **phi[3]** | **0.1103** | **0.0148** | **0.1095** | **0.0832** | **0.1400** | **0.1341** | **wild** | **0.1** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| survship | t4 | survship[2] | 0.1911 | 0.0899 | 0.1773 | 0.0566 | 0.4006 | 0.4703 | wild | NA |
| survship | t5 | survship[3] | 0.0208 | 0.0095 | 0.0194 | 0.0064 | 0.0427 | 0.4572 | wild | 0.01 |

*Table 31.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2021 Qualicum Puntledge fall Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 19.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:



*Figure 20.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:



*Figure 21.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### v) East Cost VI Coho

* Wild-origin fish tagged in estuary, N = 134
* Hatchery-origin fish tagged in estuary, N = 45
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | Defined value |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| p | t4 | p[2] | 0.2868 | 0.2706 | 0.1924 | 0.0038 | 0.9312 | 0.9436 | hatchery | 0 |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | 0.95 |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| phi | t4 | phi[2] | 0.1217 | 0.1574 | 0.0568 | 0.0019 | 0.5721 | 1.2938 | hatchery | 0.25 |
| phi | t5 | phi[3] | 0.0571 | 0.0325 | 0.0522 | 0.0118 | 0.1332 | 0.5701 | hatchery | 0.1 |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | 1 |
| survship | t4 | survship[2] | 0.1217 | 0.1574 | 0.0568 | 0.0019 | 0.5721 | 1.2938 | hatchery | NA |
| survship | t5 | survship[3] | 0.0060 | 0.0083 | 0.0029 | 0.0001 | 0.0299 | 1.3678 | hatchery | 0.005 |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| p | t4 | p[2] | 0.0415 | 0.0474 | 0.0262 | 0.0010 | 0.1636 | 1.1424 | wild | 0 |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | 0.95 |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| phi | t4 | phi[2] | 0.2244 | 0.1247 | 0.1983 | 0.0506 | 0.5413 | 0.5557 | wild | 0.25 |
| phi | **t5** | **phi[3]** | **0.1098** | **0.0134** | **0.1092** | **0.0842** | **0.1384** | **0.1218** | **wild** | **0.1** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | 1 |
| survship | t4 | survship[2] | 0.2244 | 0.1247 | 0.1983 | 0.0506 | 0.5413 | 0.5557 | wild | NA |
| survship | t5 | survship[3] | 0.0243 | 0.0132 | 0.0215 | 0.0057 | 0.0565 | 0.5450 | wild | 0.01 |

*Table 32.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2021 East Coast VI Coho. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 22.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:



*Figure 23.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

**

*Figure 24.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### vi) East Coast VI Fall (Nanaimo) 2022

* Wild-origin fish tagged in estuary, N = 444
* Hatchery-origin fish tagged in estuary, N = 1151
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| p | t4 | p[2] | 0.0133 | 0.0179 | 0.0077 | 0.0003 | 0.0584 | 1.3504 | hatchery | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| phi | t4 | phi[2] | 0.0923 | 0.0512 | 0.0798 | 0.0265 | 0.2142 | 0.5548 | hatchery | *0.25* |
| phi | t5 | phi[3] | 0.0826 | 0.0363 | 0.0773 | 0.0294 | 0.1652 | 0.4396 | hatchery | *0.1* |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| survship | t4 | survship[2] | 0.0923 | 0.0512 | 0.0798 | 0.0265 | 0.2142 | 0.5548 | hatchery | *NA* |
| survship | t5 | survship[3] | 0.0063 | 0.0023 | 0.0061 | 0.0027 | 0.0118 | 0.3645 | hatchery | *0.005* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| p | t4 | p[2] | 0.0143 | 0.0159 | 0.0092 | 0.0003 | 0.0576 | 1.1084 | wild | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| phi | t4 | phi[2] | 0.1748 | 0.0660 | 0.1651 | 0.0749 | 0.3352 | 0.3777 | wild | *0.25* |
| phi | **t5** | **phi[3]** | **0.1112** | **0.0130** | **0.1110** | **0.0863** | **0.1376** | **0.1171** | **wild** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| survship | t4 | survship[2] | 0.1748 | 0.0660 | 0.1651 | 0.0749 | 0.3353 | 0.3777 | wild | *NA* |
| survship | t5 | survship[3] | 0.0191 | 0.0066 | 0.0182 | 0.0086 | 0.0348 | 0.3465 | wild | *0.01* |

*Table 33.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2022 East Coast VI fall Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

**

*Figure 25.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:

**

*Figure 26.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

**

*Figure 27.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### vii) Nanaimo and Puntledge summer 2022

* Wild-origin fish tagged in estuary, N = 191
* Hatchery-origin fish tagged in estuary, N = 41
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| p | t4 | p[2] | 0.2792 | 0.2746 | 0.1756 | 0.0041 | 0.9366 | 0.9837 | hatchery | *0* |
| p | t5 | p[3] | 0.3131 | 0.2545 | 0.2266 | 0.0378 | 0.9438 | 0.8126 | hatchery | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| phi | t4 | phi[2] | 0.1439 | 0.1857 | 0.0661 | 0.0018 | 0.7139 | 1.2902 | hatchery | *0.25* |
| phi | t5 | phi[3] | 0.3568 | 0.2688 | 0.2698 | 0.0427 | 0.9440 | 0.7533 | hatchery | *0.1* |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| survship | t4 | survship[2] | 0.1439 | 0.1857 | 0.0661 | 0.0018 | 0.7139 | 1.2902 | hatchery | *NA* |
| survship | t5 | survship[3] | 0.0507 | 0.0877 | 0.0169 | 0.0003 | 0.3399 | 1.7323 | hatchery | *0.005* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| p | t4 | p[2] | 0.0285 | 0.0328 | 0.0176 | 0.0006 | 0.1218 | 1.1519 | wild | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| phi | t4 | phi[2] | 0.2172 | 0.1041 | 0.2010 | 0.0605 | 0.4482 | 0.4794 | wild | *0.25* |
| phi | **t5** | **phi[3]** | **0.1065** | **0.0136** | **0.1058** | **0.0812** | **0.1336** | **0.1275** | **wild** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| survship | t4 | survship[2] | 0.2172 | 0.1041 | 0.2010 | 0.0605 | 0.4482 | 0.4794 | wild | *NA* |
| survship | t5 | survship[3] | 0.0228 | 0.0107 | 0.0212 | 0.0065 | 0.0462 | 0.4702 | wild | *0.01* |

*Table 34.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2022 Nanaimo and Puntledge summer Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

**

*Figure 28.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:

**

*Figure 29.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

**

*Figure 30.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### viii) Nanaimo and Puntledge summer 2022

* Wild-origin fish tagged in estuary, N = 22
* Hatchery-origin fish tagged in estuary, N = 10
* Final adult return PIT receiver detection efficiency set at 95%.

Insufficient numbers to run in the model.

#### ix) Qualicum Puntledge fall 2022

* Wild-origin fish tagged in estuary, N = 304
* Hatchery-origin fish tagged in estuary, N = 1413
* Additionally, we simulated N = 261 as tagged during microtrolling efforts to mimic real data.
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery- and wild-origin datasets are listed in Tables 1 and 2, respectively.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| p | t4 | p[2] | 0.0078 | 0.0092 | 0.0048 | 0.0001 | 0.0322 | 1.1802 | hatchery | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| phi | t4 | phi[2] | 0.1114 | 0.0605 | 0.0973 | 0.0338 | 0.2528 | 0.5437 | hatchery | *0.25* |
| phi | t5 | phi[3] | 0.0753 | 0.0339 | 0.0693 | 0.0257 | 0.1536 | 0.4507 | hatchery | *0.1* |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery | *1* |
| survship | t4 | survship[2] | 0.1114 | 0.0605 | 0.0973 | 0.0338 | 0.2528 | 0.5437 | hatchery | *NA* |
| survship | t5 | survship[3] | 0.0069 | 0.0021 | 0.0068 | 0.0033 | 0.0116 | 0.3080 | hatchery | *0.005* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| p | t4 | p[2] | 0.0193 | 0.0219 | 0.0122 | 0.0005 | 0.0800 | 1.1334 | wild | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| phi | t4 | phi[2] | 0.2002 | 0.0889 | 0.1850 | 0.0751 | 0.4316 | 0.4442 | wild | *0.25* |
| phi | **t5** | **phi[3]** | **0.1070** | **0.0139** | **0.1063** | **0.0820** | **0.1359** | **0.1301** | **wild** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild | *1* |
| survship | t4 | survship[2] | 0.2002 | 0.0889 | 0.1850 | 0.0751 | 0.4316 | 0.4442 | wild | *NA* |
| survship | t5 | survship[3] | 0.0210 | 0.0087 | 0.0196 | 0.0081 | 0.0417 | 0.4138 | wild | *0.01* |

*Table 35.* Survival model output for estuary-tagged hatchery-origin and wild-origin fish, created as a simulated dataset. Tag numbers of fish in the estuary environment reflected actual numbers of fish tagged for 2022 Qualicum-Puntledge fall Chinook. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 31.* Visual representation comparing hatchery-origin and wild-origin survival for fish tagged in either the estuary or microtrolling efforts.

Hatchery-origin fish:

**

*Figure 32.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

**

*Figure 33.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 2e) Altering the number of hatchery-origin fish tagged at the hatchery facility

For the following simulations in Section 2e, we used a simulated, hatchery-origin dataset. Stage survival and stage detection efficiency values used to create the simulated dataset are listed in Table 1. For all below simulations, final adult return detection efficiency was set at 95%. For the purpose of this exercise, we investigated how increasing the number of hatchery-origin fish tagged in a hatchery facility might improve the output of our survival model. Specifically, we set hatchery facility tag numbers as either 5,000, 7,500, or 10,000. Specific tag numbers and capture history summaries are listed for each simulation below.

#### i) N = 5,000

* Hatchery-origin fish tagged in hatchery facility, N = 5,000
* Hatchery-origin fish tagged in estuary, N = 492
* Hatchery-origin fish tagged in microtroll, N = 47
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery-origin datasets are listed in Table 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | Frequency |
| 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 36.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish. **The total number of fish tagged in the hatchery facility is 5,000.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | SD | 50% | 2.50% | 97.50% | CV | Defined value |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| p | **2** | **p[2]** | **0.0606** | **0.0077** | **0.0587** | **0.0505** | **0.0802** | **0.1273** | **0.06** |
| p | 3 | p[3] | 0.0061 | 0.0027 | 0.0056 | 0.0025 | 0.0130 | 0.4467 | 0.003 |
| p | 4 | p[4] | 0.0032 | 0.0040 | 0.0019 | 0.0001 | 0.0138 | 1.2515 | 0 |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | 0.95 |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| phi | **2** | **phi[2]** | **0.8615** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | **0.85** |
| phi | 3 | phi[3] | 0.6590 | 0.1870 | 0.6578 | 0.2813 | 0.9565 | 0.2837 | 0.85 |
| phi | 4 | phi[4] | 0.1201 | 0.0641 | 0.1069 | 0.0336 | 0.2885 | 0.5340 | 0.25 |
| phi | 5 | phi[5] | 0.0923 | 0.0417 | 0.0870 | 0.0286 | 0.1874 | 0.4520 | 0.1 |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| survship | **2** | **survship[2]** | **0.8615** | **0.0879** | **0.9296** | **0.6892** | **0.9967** | **0.0975** | **0.85** |
| survship | 3 | survship[3] | 0.5937 | 0.1834 | 0.5633 | 0.2706 | 0.9139 | 0.3088 | NA |
| survship | 4 | survship[4] | 0.0684 | 0.0427 | 0.0567 | 0.0231 | 0.1969 | 0.6243 | NA |
| survship | **5** | **survship[5]** | **0.0050** | **0.0010** | **0.0049** | **0.0032** | **0.0071** | **0.1974** | **0.005** |

*Table 37.* Survival model output for tagged hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 34.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### ii) N = 7,500

* Hatchery-origin fish tagged in hatchery facility, N = 7,500
* Hatchery-origin fish tagged in estuary, N = 489
* Hatchery-origin fish tagged in microtroll, N = 48
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery-origin datasets are listed in Table 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 46 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 2 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 486 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 7039 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 35 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 21 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 402 |
| 1 | 1 | 0 | 0 | 1 | 11001 | 2 |
| 1 | 1 | 1 | 0 | 0 | 11100 | 1 |

*Table 38.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish. **The total number of fish tagged in the hatchery facility is 7,500.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **2** | **p[2]** | **0.0662** | **0.0108** | **0.0634** | **0.0524** | **0.0897** | **0.1624** | ***0.06*** |
| p | 3 | p[3] | 0.0074 | 0.0032 | 0.0068 | 0.0032 | 0.0150 | 0.4323 | *0.003* |
| p | 4 | p[4] | 0.0020 | 0.0026 | 0.0012 | 0.0000 | 0.0087 | 1.3098 | *0* |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **2** | **phi[2]** | **0.8360** | **0.1195** | **0.8539** | **0.6112** | **0.9916** | **0.1929** | ***0.85*** |
| phi | 3 | phi[3] | 0.5614 | 0.1667 | 0.5647 | 0.2752 | 0.8330 | 0.2969 | *0.9* |
| phi | 4 | phi[4] | 0.1739 | 0.1017 | 0.1515 | 0.0528 | 0.4396 | 0.5847 | *0.25* |
| phi | 5 | phi[5] | 0.0774 | 0.0316 | 0.0726 | 0.0309 | 0.1498 | 0.4078 | *0.1* |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **2** | **survship[2]** | **0.8360** | **0.1195** | **0.8539** | **0.6112** | **0.9916** | **0.1929** | ***0.85*** |
| survship | 3 | survship[3] | 0.4724 | 0.1676 | 0.4326 | 0.2170 | 0.7680 | 0.3547 | *NA* |
| survship | 4 | survship[4] | 0.0717 | 0.0312 | 0.0652 | 0.0323 | 0.1559 | 0.4343 | *NA* |
| survship | **5** | **survship[5]** | **0.0048** | **0.0007** | **0.0047** | **0.0034** | **0.0063** | **0.1565** | ***0.005*** |

*Table 39.* Survival model output for estuary-tagged hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

**

*Figure 35.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iii) N = 10,000

* Hatchery-origin fish tagged in hatchery facility, N = 10,000
* Hatchery-origin fish tagged in estuary, N = 485
* Hatchery-origin fish tagged in microtroll, N = 49
* Final adult return PIT receiver detection efficiency set at 95%.
* Stage survival, stage detection efficiency, and cumulative survival values used to create the simulated hatchery-origin datasets are listed in Table 1.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 47 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 2 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 482 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 9382 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 49 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 29 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 538 |
| 1 | 1 | 0 | 0 | 1 | 11001 | 1 |
| 1 | 1 | 1 | 0 | 0 | 11100 | 1 |

*Table 40.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish. **The total number of fish tagged in the hatchery facility is 10,000.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **2** | **p[2]** | **0.0685** | **0.0130** | **0.0647** | **0.0530** | **0.1011** | **0.1904** | ***0.06*** |
| p | 3 | p[3] | 0.0079 | 0.0038 | 0.0067 | 0.0033 | 0.0169 | 0.4826 | *0.003* |
| p | 4 | p[4] | 0.0010 | 0.0012 | 0.0006 | 0.0000 | 0.0043 | 1.2326 | *0* |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **2** | **phi[2]** | **0.8350** | **0.1340** | **0.8423** | **0.5280** | **0.9973** | **0.1945** | ***0.85*** |
| phi | 3 | phi[3] | 0.5692 | 0.1885 | 0.6246 | 0.2361 | 0.8472 | 0.3311 | *0.85* |
| phi | 4 | phi[4] | 0.2728 | 0.1532 | 0.2342 | 0.0719 | 0.6689 | 0.5616 | *0.25* |
| phi | 5 | phi[5] | 0.0562 | 0.0301 | 0.0487 | 0.0184 | 0.1298 | 0.5352 | *0.1* |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **2** | **survship[2]** | **0.8350** | **0.1340** | **0.8423** | **0.5280** | **0.9973** | **0.1945** | ***0.85*** |
| survship | 3 | survship[3] | 0.4659 | 0.1865 | 0.4678 | 0.1938 | 0.8376 | 0.4003 | *NA* |
| survship | 4 | survship[4] | 0.1149 | 0.0612 | 0.1018 | 0.0350 | 0.2869 | 0.5326 | *NA* |
| survship | **5** | **survship[5]** | **0.0050** | **0.0007** | **0.0050** | **0.0037** | **0.0065** | **0.1482** | ***0.005*** |

*Table 41.* Survival model output for estuary-tagged hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

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*Figure 36.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

### 2f) Altering fry-survival-to-adult-return estimates

* Based on previous research, fry-to-adult survival of Puntledge Chinook has been estimated to be approximately 0.5%, fry-to-adult survival of Cowichan Chinook has been estimated to be approximately 1.5%, and fry-to-adult survival of Coho has been estimated to be approximately 3-5%.
* In this section (2f), we investigate scenarios of fry-to-adult survival of (i) 0.5%, (ii) 1.5%, (iii) 3%, and (iv) 5%. Tables 42 and 43 show the parameter values used to create the simulated datasets for this exercise.
* These scenarios involve both hatchery-origin (N = 5,539) and wild-origin (N = 1,040) fish from a simulated dataset.Tables 44 and 45 show the breakdown of tag numbers and capture history for hatchery- and wild-origin fish, respectively.

|  |  |  |
| --- | --- | --- |
| Description | Model parameter | Defined value |
| Survival from hatchery to downstream PIT receiver | phi [t2] | 85 % |
| Downstream PIT receiver detection efficiency | p [t2] | 6 % |
| Survival from downstream PIT receiver to estuary | phi [t3] | 85 % |
| Estuary recapture rate of tagged hatchery fish | p [t3] | 0.3 % |
| Survival between estuary tagging and September | phi [t4] | 25 % |
| Recapture of tagged fish in microtroll | p [t4] | 0 % |
| Survival between microtroll and adult return | phi [t5] | 10 % |
| Adult return PIT receiver detection efficiency | p [t5] | *95 %* |
| Hatchery facility to adult return cumulative survival | survship [t5] | 0.5 – 5% |

*Table 42.* Simulated data parameters defined for hatchery fish.

|  |  |  |
| --- | --- | --- |
| Description | Model parameter | Defined value |
| Survival between estuary tagging and September | phi [t4] | 25 % |
| Recapture of tagged fish in microtroll | p [t4] | 0 % |
| Survival between microtroll and adult return | phi [t5] | 10 % |
| Adult return PIT receiver detection efficiency | p [t5] | *95 %* |
| Hatchery facility to adult return cumulative survival | survship [t5] | 0.5 - 5% |

*Table 43.* Simulated data parameters defined for wild fish.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **t1** | **t2** | **t3** | **t4** | **t5** | **cap\_hist** | **Frequency** |
| **1** | 0 | 0 | 0 | 1 | 0 | 00010 | 44 |
| **2** | 0 | 0 | 0 | 1 | 1 | 00011 | 3 |
| **3** | 0 | 0 | 1 | 0 | 0 | 00100 | 489 |
| **4** | 0 | 0 | 1 | 0 | 1 | 00101 | 3 |
| **5** | 1 | 0 | 0 | 0 | 0 | 10000 | 4690 |
| **6** | 1 | 0 | 0 | 0 | 1 | 10001 | 25 |
| **7** | 1 | 0 | 1 | 0 | 0 | 10100 | 15 |
| **8** | 1 | 1 | 0 | 0 | 0 | 11000 | 270 |

*Table 44.* Capture histories of tagged hatchery-origin fish, developed in our simulated dataset. These are the sample sizes in each capture history used in the model for this section of results. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **t1** | **t2** | **t3** | **t4** | **t5** | **cap\_hist** | **Frequency** |
| **1** | 0 | 0 | 0 | 1 | 0 | 00010 | 480 |
| **2** | 0 | 0 | 0 | 1 | 1 | 00011 | 68 |
| **3** | 0 | 0 | 1 | 0 | 0 | 00100 | 486 |
| **4** | 0 | 0 | 1 | 0 | 1 | 00101 | 6 |

*Table 45.* Capture histories of tagged wild-origin fish, developed in our simulated dataset. ‘t1’ represents a hatchery facility (tagging only), ‘t2’ represents a PIT receiver located downstream of the hatchery facility (detection only), ‘t3’ represents the estuary environment (both tagging and detection possibilities), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

#### i) Fry-to-adult-survival of 0.5%

Hatchery fish:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | Defined value |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| p | **t2** | **p[2]** | **0.0698** | **0.0134** | **0.0666** | **0.0523** | **0.1062** | **0.1916** | **0.06** |
| p | t3 | p[3] | 0.0059 | 0.0025 | 0.0053 | 0.0027 | 0.0124 | 0.4234 | 0.003 |
| p | t4 | p[4] | 0.0028 | 0.0035 | 0.0015 | 0.0000 | 0.0124 | 1.2681 | 0 |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | 0.95 |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| phi | **t2** | **phi[2]** | **0.8698** | **0.1245** | **0.8185** | **0.5138** | **0.9884** | **0.1556** | **0.85** |
| phi | t3 | phi[3] | 0.8469 | 0.1671 | 0.7540 | 0.4024 | 0.9853 | 0.2237 | 0.85 |
| phi | t4 | phi[4] | 0.1939 | 0.2106 | 0.1129 | 0.0422 | 0.8503 | 1.0863 | 0.25 |
| phi | t5 | phi[5] | 0.0746 | 0.0409 | 0.0704 | 0.0151 | 0.1651 | 0.5487 | 0.1 |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | 1 |
| survship | **t2** | **survship[2]** | **0.8698** | **0.1245** | **0.8185** | **0.5138** | **0.9884** | **0.1556** | **0.85** |
| survship | t3 | survship[3] | 0.6008 | 0.1723 | 0.6205 | 0.2897 | 0.8999 | 0.2868 | NA |
| survship | t4 | survship[4] | 0.0986 | 0.0777 | 0.0698 | 0.0266 | 0.3107 | 0.7880 | NA |
| survship | **t5** | **survship[5]** | **0.0049** | **0.0010** | **0.0048** | **0.0031** | **0.0069** | **0.1971** | **0.005** |

*Table 46.* Survival model output for hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 37.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild fish:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | t4 | p[2] | 0.0644 | 0.0808 | 0.0365 | 0.0012 | 0.3020 | 1.2543 | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | t4 | phi[2] | 0.0433 | 0.0295 | 0.0368 | 0.0069 | 0.1186 | 0.6815 | *0.25* |
| phi | **t5** | **phi[3]** | **0.1069** | **0.0136** | **0.1062** | **0.0824** | **0.1344** | **0.1270** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | t4 | survship[2] | 0.0433 | 0.0295 | 0.0368 | 0.0069 | 0.1186 | 0.6815 | *NA* |
| survship | t5 | survship[3] | 0.0046 | 0.0030 | 0.0039 | 0.0007 | 0.0123 | 0.6656 | *0.005* |

*Table 47.* Survival model output for wild-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

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*Figure 38.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### ii) Fry-to-adult survival of 1.5%

Hatchery fish:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **t2** | **p[2]** | **0.0688** | **0.0079** | **0.0682** | **0.0555** | **0.0852** | **0.1142** | ***0.06*** |
| p | t3 | p[3] | 0.0051 | 0.0014 | 0.0050 | 0.0028 | 0.0085 | 0.2785 | *0.003* |
| p | t4 | p[4] | 0.0010 | 0.0011 | 0.0006 | 0.0000 | 0.0040 | 1.1217 | *0* |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **t2** | **phi[2]** | **0.8245** | **0.0769** | **0.7938** | **0.6548** | **0.9381** | **0.0968** | ***0.85*** |
| phi | **t3** | **phi[3]** | **0.8377** | **0.1058** | **0.8046** | **0.6125** | **0.9834** | **0.1326** | ***0.85*** |
| phi | t4 | phi[4] | 0.3264 | 0.1617 | 0.2833 | 0.1139 | 0.7667 | 0.4956 | *0.25* |
| phi | t5 | phi[5] | 0.0894 | 0.0395 | 0.0827 | 0.0303 | 0.1888 | 0.4418 | *0.1* |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **t2** | **survship[2]** | **0.8245** | **0.0769** | **0.7938** | **0.6548** | **0.9381** | **0.0968** | ***0.85*** |
| survship | **t3** | **survship[3]** | **0.6300** | **0.0791** | **0.6157** | **0.5116** | **0.8038** | **0.1256** | ***NA*** |
| survship | t4 | survship[4] | 0.2026 | 0.1025 | 0.1811 | 0.0746 | 0.4925 | 0.5060 | *NA* |
| survship | **t5** | **survship[5]** | **0.0149** | **0.0016** | **0.0148** | **0.0118** | **0.0183** | **0.1095** | ***0.015*** |

*Table 48.* Survival model output for hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 39.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild fish:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | t4 | p[2] | 0.0170 | 0.0196 | 0.0111 | 0.0004 | 0.0683 | 1.1520 | *0* |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | t4 | phi[2] | 0.1361 | 0.0514 | 0.1307 | 0.0546 | 0.2535 | 0.3779 | *0.25* |
| phi | **t5** | **phi[3]** | **0.1138** | **0.0142** | **0.1131** | **0.0881** | **0.1451** | **0.1244** | ***0.1*** |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | t4 | survship[2] | 0.1361 | 0.0514 | 0.1307 | 0.0546 | 0.2535 | 0.3779 | *NA* |
| survship | t5 | survship[3] | 0.0153 | 0.0055 | 0.0147 | 0.0066 | 0.0276 | 0.3598 | *0.015* |

*Table 49.* Survival model output for wild-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 40.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iii) Fry-to-adult survival of 3%

Hatchery-origin fish:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **p[2]** | **0.0595** | **0.0050** | **0.0592** | **0.0509** | **0.0699** | **0.0842** | ***0.06*** |
| p | p[3] | 0.0045 | 0.0013 | 0.0043 | 0.0024 | 0.0076 | 0.2924 | *0.003* |
| p | p[4] | 0.0006 | 0.0007 | 0.0004 | 0.0000 | 0.0025 | 1.1480 | *0* |
| p | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **phi[2]** | **0.8746** | **0.0568** | **0.9147** | **0.7966** | **0.9983** | **0.0621** | ***0.85*** |
| phi | **phi[3]** | **0.8140** | **0.1033** | **0.8096** | **0.6062** | **0.9717** | **0.1885** | ***0.85*** |
| phi | phi[4] | 0.4399 | 0.1810 | 0.4053 | 0.1879 | 0.9105 | 0.4115 | *0.25* |
| phi | phi[5] | 0.1092 | 0.0391 | 0.1040 | 0.0539 | 0.1940 | 0.3585 | *0.1* |
| survship | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **survship[2]** | **0.8746** | **0.0568** | **0.9147** | **0.7966** | **0.9983** | **0.0621** | ***0.85*** |
| survship | **survship[3]** | **0.7356** | **0.1067** | **0.7321** | **0.5402** | **0.9367** | **0.1450** | ***NA*** |
| survship | survship[4] | 0.3145 | 0.1131 | 0.2902 | 0.1558 | 0.5556 | 0.3596 | *NA* |
| survship | **survship[5]** | **0.0303** | **0.0024** | **0.0302** | **0.0258** | **0.0350** | **0.0783** | ***0.03*** |

*Table 50.* Survival model output for hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 41.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | p[2] | 0.0078 | 0.0083 | 0.0052 | 0.0002 | 0.0324 | 1.0539 | *0* |
| p | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | phi[2] | 0.2704 | 0.0761 | 0.2645 | 0.1404 | 0.4294 | 0.2814 | *0.25* |
| phi | **phi[3]** | **0.1167** | **0.0145** | **0.1157** | **0.0905** | **0.1462** | **0.1242** | ***0.1*** |
| survship | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | survship[2] | 0.2704 | 0.0761 | 0.2645 | 0.1404 | 0.4294 | 0.2814 | *NA* |
| survship | survship[3] | 0.0311 | 0.0079 | 0.0307 | 0.0172 | 0.0473 | 0.2527 | *0.03* |

*Table 51.* Survival model output for wild-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 42.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

#### iv) Fry-to-adult survival of 5%

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | **t2** | **p[2]** | **0.0580** | **0.0044** | **0.0577** | **0.0504** | **0.0674** | **0.0762** | ***0.06*** |
| p | t3 | p[3] | 0.0038 | 0.0010 | 0.0037 | 0.0021 | 0.0061 | 0.2654 | *0.003* |
| p | t4 | p[4] | 0.0004 | 0.0004 | 0.0002 | 0.0000 | 0.0014 | 1.0096 | *0* |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | **t2** | **phi[2]** | **0.9158** | **0.0422** | **0.9417** | **0.8376** | **0.9967** | **0.0451** | ***0.9*** |
| phi | **t3** | **phi[3]** | **0.8826** | **0.0818** | **0.9330** | **0.7332** | **0.9973** | **0.0906** | ***0.9*** |
| phi | t4 | phi[4] | 0.6368 | 0.1559 | 0.6375 | 0.3275 | 0.9222 | 0.3447 | *0.25* |
| phi | t5 | phi[5] | 0.1027 | 0.0274 | 0.0968 | 0.0660 | 0.1717 | 0.2665 | *0.1* |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | **t2** | **survship[2]** | **0.9158** | **0.0422** | **0.9417** | **0.8376** | **0.9967** | **0.0451** | ***0.9*** |
| survship | **t3** | **survship[3]** | **0.8441** | **0.0810** | **0.8375** | **0.7073** | **0.9798** | **0.0960** | ***NA*** |
| survship | t4 | survship[4] | 0.5336 | 0.1270 | 0.5355 | 0.2986 | 0.7773 | 0.2380 | *NA* |
| survship | **t5** | **survship[5]** | **0.0516** | **0.0031** | **0.0515** | **0.0457** | **0.0574** | **0.0598** | ***0.05*** |

*Table 52.* Survival model output for hatchery-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 43.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

Wild-origin fish:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | param | mean | sd | 50% | 2.50% | 97.50% | cv | *Defined value* |
| p | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| p | p[2] | 0.004643 | 0.004867 | 0.003213 | 0.000131 | 0.017279 | 1.048388 | *0* |
| p | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | *0.95* |
| phi | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| phi | phi[2] | 0.466411 | 0.10234 | 0.460893 | 0.288409 | 0.683475 | 0.219421 | *0.25* |
| phi | **phi[3]** | **0.116384** | **0.014478** | **0.115579** | **0.09065** | **0.147417** | **0.1244** | ***0.1*** |
| survship | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | *1* |
| survship | survship[2] | 0.466411 | 0.10234 | 0.460893 | 0.288409 | 0.683475 | 0.219421 | *NA* |
| survship | **survship[3]** | **0.053541** | **0.010227** | **0.052963** | **0.035021** | **0.074762** | **0.191014** | ***0.05*** |

*Table 53.* Survival model output for wild-origin fish, created as a simulated dataset. Parameter estimates with CV of less than or equal to 20% are boldened. The final column (italicized) shows the defined value for each parameter that was used to create the simulated dataset, to allow for easier comparisons. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’, ‘t3’ represents the estuary environment (tagging only), ‘t4’ represents microtrolling efforts (both tagging and detection possibilities), and finally ‘t5’ represent the final, in-river PIT receiver detection adult returns (detection only). ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



*Figure 44.* Plots visualizing the model output for the three parameters estimated through our survival model. Plot (A) shows the detection probability calculated at each site. The model is constrained whereby the detection efficiency at the hatchery is set at 1 (as all fish were tagged and thus detected at this site), and the detection efficiency at the adult return PIT receiver is set at 0.95. Plot (B) shows the estimated survival at each site from the immediately preceding site. Plot (C) shows the cumulative survival over time between all sites.

*v) Conclusions (altering fry-to-adult survival)*

* Increasing fry-to-adult survival from 0.5% to 5% seems to have the most noticeably dramatic effect on improving the model compared to all other simulations in this document (i.e., altering detection efficiency, increasing tag numbers).
* Higher fry-to-adult survival produces a model output with a greater number of accurate parameter estimates with higher confidence.

## 3. ‘Real’ data provided by K. Pellett

This section overviews the survival model output with ‘real’ data from tagged Cowichan River Chinook salmon provided by K. Pellett. Pellett et al PIT tagged Chinook salmon across six years (2014-2019). For the purposes of this exercise, each tagging cohort year was run separately in the model. We did not run the tagged 2019 cohort year in the model due to concerns of incomplete adult returns, therefore the following pages detail the survival model output for years 2014 to 2018.

The ‘Pellett dataset’ comprised of five tagging or detection stages (here defined as t1 – t5): t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

For each year (2014-2018), the model output is shown for hatchery-origin fish, and wild-origin fish separately, as well as a combined origin plot that allows for comparison of survival between hatchery- and wild-origin fish. The total number of fish tagged varies each year, and detailed tag numbers and capture histories are shown in the below sections for each year.

### a) Pellett data 2014

Hatchery fish 2014:

* Total number of tagged fish across all stages = 2,181

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 8 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 259 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 27 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 1870 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 8 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 9 |

*Table 54.* Capture histories of tagged hatchery-origin fish from actual tagging and detection/recapture data for fish tagged in 2014. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| p | t2 | p[2] | 0.0010 | 0.0013 | 0.0006 | 0.0000 | 0.0046 | 1.2139 | hatchery |
| p | t3 | p[3] | 0.0175 | 0.0109 | 0.0145 | 0.0054 | 0.0462 | 0.6189 | hatchery |
| p | t4 | p[4] | 0.0131 | 0.0184 | 0.0059 | 0.0001 | 0.0697 | 1.4023 | hatchery |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| phi | t2 | phi[2] | 0.6304 | 0.2587 | 0.7075 | 0.2087 | 0.9761 | 0.4104 | hatchery |
| phi | t3 | phi[3] | 0.6147 | 0.2062 | 0.5904 | 0.2816 | 0.9622 | 0.3354 | hatchery |
| phi | t4 | phi[4] | 0.1895 | 0.1976 | 0.1084 | 0.0183 | 0.7396 | 1.0428 | hatchery |
| phi | t5 | phi[5] | 0.1082 | 0.0933 | 0.0812 | 0.0098 | 0.3482 | 0.8623 | hatchery |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| survship | t2 | survship[2] | 0.6304 | 0.2587 | 0.7075 | 0.2087 | 0.9761 | 0.4104 | hatchery |
| survship | t3 | survship[3] | 0.3616 | 0.1553 | 0.3548 | 0.1234 | 0.7215 | 0.4296 | hatchery |
| survship | t4 | survship[4] | 0.0664 | 0.0752 | 0.0334 | 0.0060 | 0.2870 | 1.1324 | hatchery |
| survship | t5 | survship[5] | 0.0029 | 0.0011 | 0.0027 | 0.0012 | 0.0055 | 0.3809 | hatchery |

*Table 55.* Survival model output for hatchery-origin fish in 2014 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Wild fish 2014:

* Total number of tagged fish across all stages = 4,825

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 78 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 2 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 2135 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 16 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 464 |
| 0 | 1 | 0 | 0 | 1 | 01001 | 1 |
| 0 | 1 | 1 | 0 | 0 | 01100 | 1 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 2120 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 7 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 1 |

*Table 56.* Capture histories of tagged wild-origin fish from actual tagging and detection/recapture data for fish tagged in 2014. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| p | t2 | p[2] | 0.0011 | 0.0013 | 0.0006 | 0.0000 | 0.0047 | 1.1934 | wild |
| p | t3 | p[3] | 0.0036 | 0.0024 | 0.0031 | 0.0007 | 0.0100 | 0.6736 | wild |
| p | t4 | p[4] | 0.0017 | 0.0023 | 0.0008 | 0.0000 | 0.0085 | 1.3774 | wild |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| phi | t2 | phi[2] | 0.5513 | 0.2371 | 0.4893 | 0.2064 | 0.9886 | 0.4301 | wild |
| phi | t3 | phi[3] | 0.6015 | 0.2235 | 0.5766 | 0.2459 | 0.9845 | 0.3716 | wild |
| phi | t4 | phi[4] | 0.3189 | 0.2113 | 0.2470 | 0.0748 | 0.8082 | 0.6626 | wild |
| phi | t5 | phi[5] | 0.0366 | 0.0227 | 0.0317 | 0.0092 | 0.0930 | 0.6184 | wild |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| survship | t2 | survship[2] | 0.5513 | 0.2371 | 0.4893 | 0.2064 | 0.9886 | 0.4301 | wild |
| survship | t3 | survship[3] | 0.2939 | 0.0913 | 0.2875 | 0.1471 | 0.4651 | 0.3106 | wild |
| survship | t4 | survship[4] | 0.0978 | 0.0818 | 0.0669 | 0.0181 | 0.3414 | 0.8360 | wild |
| survship | t5 | survship[5] | 0.0023 | 0.0008 | 0.0022 | 0.0011 | 0.0040 | 0.3387 | wild |

*Table 57.* Survival model output for wild-origin fish in 2014 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Hatchery vs wild-origin fish comparison plot (2014):



### b) Pellett data 2015

### 

Hatchery fish 2015:

* Total number of tagged fish across all stages = 7,206

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 145 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 2 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 1671 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 9 |
| 0 | 0 | 1 | 1 | 0 | 00110 | 1 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 335 |
| 0 | 1 | 0 | 0 | 1 | 01001 | 2 |
| 0 | 1 | 1 | 0 | 0 | 01100 | 4 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 4963 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 23 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 36 |
| 1 | 0 | 1 | 0 | 1 | 10101 | 1 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 13 |

*Table 58.* Capture histories of tagged hatchery-origin fish from actual tagging and detection/recapture data for fish tagged in 2015. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site\_num | param | mean | sd | 50% | 2.50% | 97.50% | cv |
| p | 1 | p[1] | 1 | 0 | 1 | 1 | 1 | NA |
| p | 2 | p[2] | 0.0042 | 0.0015 | 0.0039 | 0.0020 | 0.0078 | 0.357452 |
| p | 3 | p[3] | 0.0165 | 0.0040 | 0.0159 | 0.0105 | 0.0263 | 0.241799 |
| p | 4 | p[4] | 0.0008 | 0.0007 | 0.0006 | 0.0001 | 0.0026 | 0.846745 |
| p | 5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | NA |
| phi | 1 | phi[1] | 1 | 0 | 1 | 1 | 1 | NA |
| phi | **2** | **phi[2]** | **0.6882** | **0.1510** | **0.7044** | **0.4362** | **0.9904** | **0.1429** |
| phi | **3** | **phi[3]** | **0.7141** | **0.1666** | **0.7036** | **0.4438** | **0.9860** | **0.1624** |
| phi | 4 | phi[4] | 0.6276 | 0.1810 | 0.6676 | 0.2762 | 0.9600 | 0.2883 |
| phi | 5 | phi[5] | 0.0148 | 0.0058 | 0.0134 | 0.0073 | 0.0294 | 0.3893 |
| survship | 1 | survship[1] | 1 | 0 | 1 | 1 | 1 | NA |
| survship | **2** | **survship[2]** | **0.6882** | **0.1510** | **0.7044** | **0.4362** | **0.9904** | **0.1429** |
| survship | **3** | **survship[3]** | **0.4728** | **0.0782** | **0.4767** | **0.3106** | **0.6152** | **0.1654** |
| survship | 4 | survship[4] | 0.2972 | 0.1053 | 0.2884 | 0.1362 | 0.5195 | 0.3543 |
| survship | **5** | **survship[5]** | **0.0039** | **0.0007** | **0.0039** | **0.0026** | **0.0054** | **0.1824** |

*Table 59.* Survival model output for hatchery-origin fish in 2015 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Wild fish 2015:

* Total number of tagged fish across all stages = 7,257

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 232 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 10 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 3252 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 58 |
| 0 | 0 | 1 | 1 | 0 | 00110 | 2 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 1701 |
| 0 | 1 | 0 | 0 | 1 | 01001 | 22 |
| 0 | 1 | 0 | 1 | 0 | 01010 | 1 |
| 0 | 1 | 1 | 0 | 0 | 01100 | 25 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 1919 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 15 |
| 1 | 0 | 0 | 1 | 0 | 10010 | 2 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 14 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 4 |

*Table 60.* Capture histories of tagged wild-origin fish from actual tagging and detection/recapture data for fish tagged in 2015. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 |
| p | t2 | p[2] | 0.0044 | 0.0022 | 0.0040 | 0.0013 | 0.0096 | 0.4950 |
| p | t3 | p[3] | 0.0186 | 0.0045 | 0.0181 | 0.0114 | 0.0283 | 0.2395 |
| p | t4 | p[4] | 0.0027 | 0.0014 | 0.0024 | 0.0008 | 0.0059 | 0.5172 |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 |
| phi | **t2** | **phi[2]** | **0.5999** | **0.1172** | **0.5928** | **0.3975** | **0.8264** | **0.1953** |
| phi | **t3** | **phi[3]** | **0.7601** | **0.1214** | **0.7564** | **0.5357** | **0.9856** | **0.1597** |
| phi | t4 | phi[4] | 0.4473 | 0.1401 | 0.4197 | 0.2645 | 0.8016 | 0.3132 |
| phi | t5 | phi[5] | 0.0423 | 0.0124 | 0.0414 | 0.0205 | 0.0668 | 0.2921 |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 |
| survship | **t2** | **survship[2]** | **0.5999** | **0.1172** | **0.5928** | **0.3975** | **0.8264** | **0.1953** |
| survship | t3 | survship[3] | 0.4545 | 0.1094 | 0.4457 | 0.2834 | 0.6846 | 0.2407 |
| survship | t4 | survship[4] | 0.2078 | 0.0989 | 0.1725 | 0.0993 | 0.4581 | 0.4759 |
| survship | **t5** | **survship[5]** | **0.0078** | **0.0017** | **0.0077** | **0.0049** | **0.0114** | **0.1964** |

*Table 61.* Survival model output for wild-origin fish in 2015 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.

**

Hatchery vs wild-origin fish comparison plot (2015):



### c) Pellett data 2016

Hatchery fish 2016:

* Total number of tagged fish across all stages = 7,018

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 242 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 4 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 1462 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 12 |
| 0 | 0 | 1 | 1 | 0 | 00110 | 1 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 202 |
| 0 | 1 | 0 | 0 | 1 | 01001 | 2 |
| 0 | 1 | 0 | 1 | 0 | 01010 | 1 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 5049 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 14 |
| 1 | 0 | 0 | 1 | 0 | 10010 | 3 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 26 |

*Table 62.* Capture histories of tagged hatchery-origin fish from actual tagging and detection/recapture data for fish tagged in 2016. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| p | t2 | p[2] | 0.0003 | 0.0004 | 0.0002 | 0.0001 | 0.0014 | 1.0812 | hatchery |
| p | t3 | p[3] | 0.0152 | 0.0048 | 0.0142 | 0.0087 | 0.0271 | 0.3175 | hatchery |
| p | t4 | p[4] | 0.0047 | 0.0027 | 0.0041 | 0.0014 | 0.0116 | 0.5833 | hatchery |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| phi | t2 | phi[2] | 0.5889 | 0.1711 | 0.5575 | 0.3110 | 0.8841 | 0.2906 | hatchery |
| phi | t3 | phi[3] | 0.6348 | 0.2210 | 0.6246 | 0.2980 | 0.9770 | 0.3481 | hatchery |
| phi | t4 | phi[4] | 0.4441 | 0.1490 | 0.4376 | 0.1740 | 0.7294 | 0.3355 | hatchery |
| phi | t5 | phi[5] | 0.0209 | 0.0073 | 0.0199 | 0.1030 | 0.0393 | 0.3474 | hatchery |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| survship | t2 | survship[2] | 0.5889 | 0.1711 | 0.5575 | 0.3110 | 0.8841 | 0.2906 | hatchery |
| survship | t3 | survship[3] | 0.3425 | 0.0716 | 0.3510 | 0.1960 | 0.4563 | 0.2090 | hatchery |
| survship | t4 | survship[4] | 0.1499 | 0.0572 | 0.1383 | 0.0594 | 0.2867 | 0.3822 | hatchery |
| survship | **t5** | **survship[5]** | **0.0028** | **0.0006** | **0.0028** | **0.0018** | **0.0041** | **0.1940** | **hatchery** |

*Table 63.* Survival model output for hatchery-origin fish in 2016 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Wild fish 2016:

* Total number of tagged fish across all stages = 15,144

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| t1 | t2 | t3 | t4 | t5 | cap\_hist | freq |
| 0 | 0 | 0 | 1 | 0 | 00010 | 1069 |
| 0 | 0 | 0 | 1 | 1 | 00011 | 38 |
| 0 | 0 | 1 | 0 | 0 | 00100 | 6271 |
| 0 | 0 | 1 | 0 | 1 | 00101 | 121 |
| 0 | 0 | 1 | 1 | 0 | 00110 | 14 |
| 0 | 0 | 1 | 1 | 1 | 00111 | 2 |
| 0 | 1 | 0 | 0 | 0 | 01000 | 1878 |
| 0 | 1 | 0 | 0 | 1 | 01001 | 38 |
| 0 | 1 | 0 | 1 | 0 | 01010 | 3 |
| 0 | 1 | 1 | 0 | 0 | 01100 | 2 |
| 1 | 0 | 0 | 0 | 0 | 10000 | 5598 |
| 1 | 0 | 0 | 0 | 1 | 10001 | 58 |
| 1 | 0 | 0 | 1 | 0 | 10010 | 1 |
| 1 | 0 | 1 | 0 | 0 | 10100 | 37 |
| 1 | 1 | 0 | 0 | 0 | 11000 | 14 |

*Table 64.* Capture histories of tagged wild-origin fish from actual tagging and detection/recapture data for fish tagged in 2016. Data provided by K. Pellett. Stages: t1 represents in-river tagging efforts (tagging only), t2 represents estuary tagging efforts (both detection and tagging possibilities), t3 represents purse seine tagging efforts (both tagging and detection possibilities), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| p | t2 | p[2] | 0.0037 | 0.0011 | 0.0036 | 0.0020 | 0.0062 | 0.3001 | wild |
| p | t3 | p[3] | 0.0089 | 0.0018 | 0.0087 | 0.0058 | 0.0131 | 0.2068 | wild |
| p | t4 | p[4] | 0.0034 | 0.0009 | 0.0033 | 0.0019 | 0.0055 | 0.2628 | wild |
| p | t5 | p[5] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| phi | **t2** | **phi[2]** | **0.7139** | **0.0970** | **0.7000** | **0.5674** | **0.9487** | **0.1358** | **wild** |
| phi | **t3** | **phi[3]** | **0.7674** | **0.1153** | **0.7872** | **0.5326** | **0.9601** | **0.1503** | **wild** |
| phi | **t4** | **phi[4]** | **0.5636** | **0.0935** | **0.5564** | **0.3907** | **0.7724** | **0.1659** | **wild** |
| phi | **t5** | **phi[5]** | **0.0361** | **0.0050** | **0.0357** | **0.0274** | **0.0467** | **0.1388** | **wild** |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| survship | **t2** | **survship[2]** | **0.7139** | **0.0970** | **0.7000** | **0.5674** | **0.9487** | **0.1358** | **wild** |
| survship | **t3** | **survship[3]** | **0.5420** | **0.0779** | **0.5294** | **0.4113** | **0.6983** | **0.1437** | **wild** |
| survship | **t4** | **survship[4]** | **0.3024** | **0.0495** | **0.3030** | **0.2179** | **0.4009** | **0.1638** | **wild** |
| survship | **t5** | **survship[5]** | **0.0107** | **0.0012** | **0.0107** | **0.0086** | **0.0132** | **0.1106** | **wild** |

*Table 65.* Survival model output for wild-origin fish in 2016 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Hatchery vs wild-origin fish comparison plot (2016):



### d) Pellett data 2017

Hatchery fish 2017:

* Total number of tagged fish across all stages = 1,203

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 199 |
| 0 | 1 | 1 | 011 | 2 |
| 1 | 0 | 0 | 100 | 999 |
| 1 | 0 | 1 | 101 | 3 |

*Table 66.* Capture histories of tagged hatchery-origin fish from actual tagging and detection/recapture data for fish tagged in 2017. Data provided by K. Pellett. Stages: t3 represents purse seine tagging efforts (tagging only), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| p | t4 | p[2] | 0.0067 | 0.0115 | 0.0030 | 0.0001 | 0.0390 | 1.7067 | hatchery |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| phi | t4 | phi[2] | 0.2860 | 0.1949 | 0.2451 | 0.0423 | 0.7763 | 0.6815 | hatchery |
| phi | t5 | phi[3] | 0.0141 | 0.0082 | 0.0124 | 0.0038 | 0.0353 | 0.5792 | hatchery |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| survship | t4 | survship[2] | 0.2860 | 0.1949 | 0.2451 | 0.0423 | 0.7763 | 0.6815 | hatchery |
| survship | t5 | survship[3] | 0.0031 | 0.0017 | 0.0028 | 0.0008 | 0.0069 | 0.5350 | hatchery |

*Table 67.* Survival model output for hatchery-origin fish in 2017 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Wild fish 2017:

* Total number of tagged fish across all stages = 4,407

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t3 | t4 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 444 |
| 0 | 1 | 1 | 011 | 7 |
| 1 | 0 | 0 | 100 | 3931 |
| 1 | 0 | 1 | 101 | 24 |
| 1 | 1 | 0 | 110 | 1 |

*Table 68.* Capture histories of tagged wild-origin fish from actual tagging and detection/recapture data for fish tagged in 2017. Data provided by K. Pellett. Stages: t3 represents purse seine tagging efforts (tagging only), t4 represents microtrolling efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t3 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| p | t4 | p[2] | 0.0016 | 0.0013 | 0.0012 | 0.0001 | 0.0050 | 0.8103 | wild |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild |
| phi | t3 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| phi | t4 | phi[2] | 0.3565 | 0.1284 | 0.3270 | 0.1715 | 0.6182 | 0.3601 | wild |
| phi | t5 | phi[3] | 0.0183 | 0.0058 | 0.0177 | 0.0092 | 0.0314 | 0.3149 | wild |
| survship | t3 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| survship | t4 | survship[2] | 0.3565 | 0.1284 | 0.3270 | 0.1715 | 0.6182 | 0.3601 | wild |
| survship | **t5** | **survship[3]** | **0.0059** | **0.0012** | **0.0058** | **0.0038** | **0.0086** | **0.2036** | **wild** |

*Table 69.* Survival model output for wild-origin fish in 2017 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t3 represents purse seine efforts, t4 represents microtrolling efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Hatchery vs wild-origin fish comparison plot (2017):



### e) Pellett data 2018

Hatchery fish 2018:

* Total number of tagged fish across all stages = 4,718

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t1 | t2 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 40 |
| 1 | 0 | 0 | 100 | 4666 |
| 1 | 0 | 1 | 101 | 12 |

*Table 70.* Capture histories of tagged hatchery-origin fish from actual tagging and detection/recapture data for fish tagged in 2018. Data provided by K. Pellett. Stages: t1 represents river tagging efforts (tagging only), t2 represents beach seining efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| p | t2 | p[2] | 0.0020 | 0.0032 | 0.0009 | 0.0000 | 0.0117 | 1.5748 | hatchery |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | hatchery |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| phi | t2 | phi[2] | 0.1927 | 0.1257 | 0.1634 | 0.0293 | 0.4458 | 0.6522 | hatchery |
| phi | t5 | phi[3] | 0.0226 | 0.0197 | 0.0154 | 0.0047 | 0.0756 | 0.8734 | hatchery |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | hatchery |
| survship | t2 | survship[2] | 0.1927 | 0.1257 | 0.1634 | 0.0293 | 0.4458 | 0.6522 | hatchery |
| survship | t5 | survship[3] | 0.0026 | 0.0007 | 0.0025 | 0.0014 | 0.0042 | 0.2880 | hatchery |

*Table 71.* Survival model output for hatchery-origin fish in 2018 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Wild fish 2018:

* Total number of tagged fish across all stages = 3,525

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| t1 | t2 | t5 | cap\_hist | freq |
| 0 | 1 | 0 | 010 | 2939 |
| 0 | 1 | 1 | 011 | 20 |
| 1 | 0 | 0 | 100 | 561 |
| 1 | 0 | 1 | 101 | 5 |

*Table 72.* Capture histories of tagged wild-origin fish from actual tagging and detection/recapture data for fish tagged in 2018. Data provided by K. Pellett. Stages: t1 represents river tagging efforts (tagging only), t2 represents beach seining efforts (both tagging and detection possibilities), and finally t5 represent the final, in-river PIT receiver detection adult returns (detection only).

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| param\_grp | site | param | mean | sd | 50% | 2.50% | 97.50% | cv | origin |
| p | t1 | p[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| p | t2 | p[2] | 0.0025 | 0.0030 | 0.0016 | 0.0000 | 0.0107 | 1.1804 | wild |
| p | t5 | p[3] | 0.95 | 0 | 0.95 | 0.95 | 0.95 | 0 | wild |
| phi | t1 | phi[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| phi | t2 | phi[2] | 0.7620 | 0.1970 | 0.8173 | 0.2917 | 0.9940 | 0.2585 | wild |
| phi | t5 | phi[3] | 0.0077 | 0.0015 | 0.0075 | 0.0051 | 0.0109 | 0.1920 | wild |
| survship | t1 | survship[1] | 1 | 0 | 1 | 1 | 1 | 0 | wild |
| survship | t2 | survship[2] | 0.7620 | 0.1970 | 0.8173 | 0.2917 | 0.9940 | 0.2585 | wild |
| survship | t5 | survship[3] | 0.0058 | 0.0018 | 0.0058 | 0.0022 | 0.0094 | 0.3095 | wild |

*Table 73.* Survival model output for wild-origin fish in 2018 (data provided by K. Pellett). Parameter estimates with CV of less than or equal to 20% are boldened. The final adult return PIT receiver detection efficiency, p[5], was constrained to 0.95. In the column ‘site’: t1 represents in-river tagging efforts, t2 represents estuary beach seining efforts, and finally t5 represent the final, in-river PIT receiver detection adult returns. ‘cap\_hist’ represents the five-digit binary code that details where each fish was tagged and any subsequent detections in later stages for each fish.



Hatchery vs wild-origin fish comparison plot (2018):



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