Overshoot Bayesian Methods

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Contents

1 Goal

Estimate the number of overshoots that reach Priest. If PIT tag rates for wild steelhead were known, we could expand detection (assuming 100%) at PRD of known overshoots (juveniles PIT tagged from MCR and SR DPS and detected at PRD) to estimate overshoot abundance at PRD. Since population specific PIT tag rates are unknown we need another method to estimate overshoot abundance.

2 Available Data

- Number of fish tagged as juveniles from downstream areas that are detected at Priest in year i (T_i).
- Number of fish tagged as juveniles from downstream areas that are detected at Priest and detected succesfully falling back and entering downstream area j which is part of the patch-occupancy model in year i ($s_{i,j}$).
- Estimates, from patch-occupancy model, of total fallbacks (fish that crossed Priest, then fell back and entered a downstream tributary) in year i (F_i). These are based on a different set of tags from adults tagged at Priest, who are detected downstream. It accounts for imperfect detection at the downstream arrays.
- Estimates, from patch-occupancy model, of detection probability of all downstream sites.

The detection probability estimates are shown in Table 1. Estimates of fallback abundance from the POM are shown in Table 2.

Table 1: Summaries of detection probabilities of sites downstream of PRD.

Site	Avg Tags	Mean	SD of Mean	Avg SE	Avg CV
ICH	286	0.987	0.008	0.008	0.008
PRO	53	0.903	0.048	0.041	0.046
PRV	6	0.570	0.390	0.090	0.193
TMF	3	0.750	0.463	0.000	0.000
JD1	2	0.460	0.309	0.130	0.298

Table 2: Estimates by subbasin and PTAGIS code of overshoot fallback steelhead downstream of Priest Rapids Dam. (PRO = Prosser Dam; ICH = Ice Harbor Dam; PRV = Pierce RV Park instream array; TMF = Three Mile Falls Dam; JD1 = Lower John Day at McDonald Ferry).

Year	PRO_W	PRO_H	ICH_W	ICH_H	PRV_W	PRV_H	TMF_W	TMF_H	JD1_W	JD1_H
2011	840	56	690	1397	55	0	33	23	0	22
2012	364	29	363	1698	21	0	0	0	0	0
2013	181	28	324	1832	20	14	13	0	0	0
2014	334	32	639	1433	19	51	19	13	38	19
2015	579	60	1169	2504	75	27	53	22	43	11
2016	324	20	426	882	57	20	24	0	29	0
2017	89	26	117	685	20	26	12	0	20	0
2018	116	13	65	254	12	9	0	0	21	0
Mean	353	33	474	1336	35	18	19	7	19	6

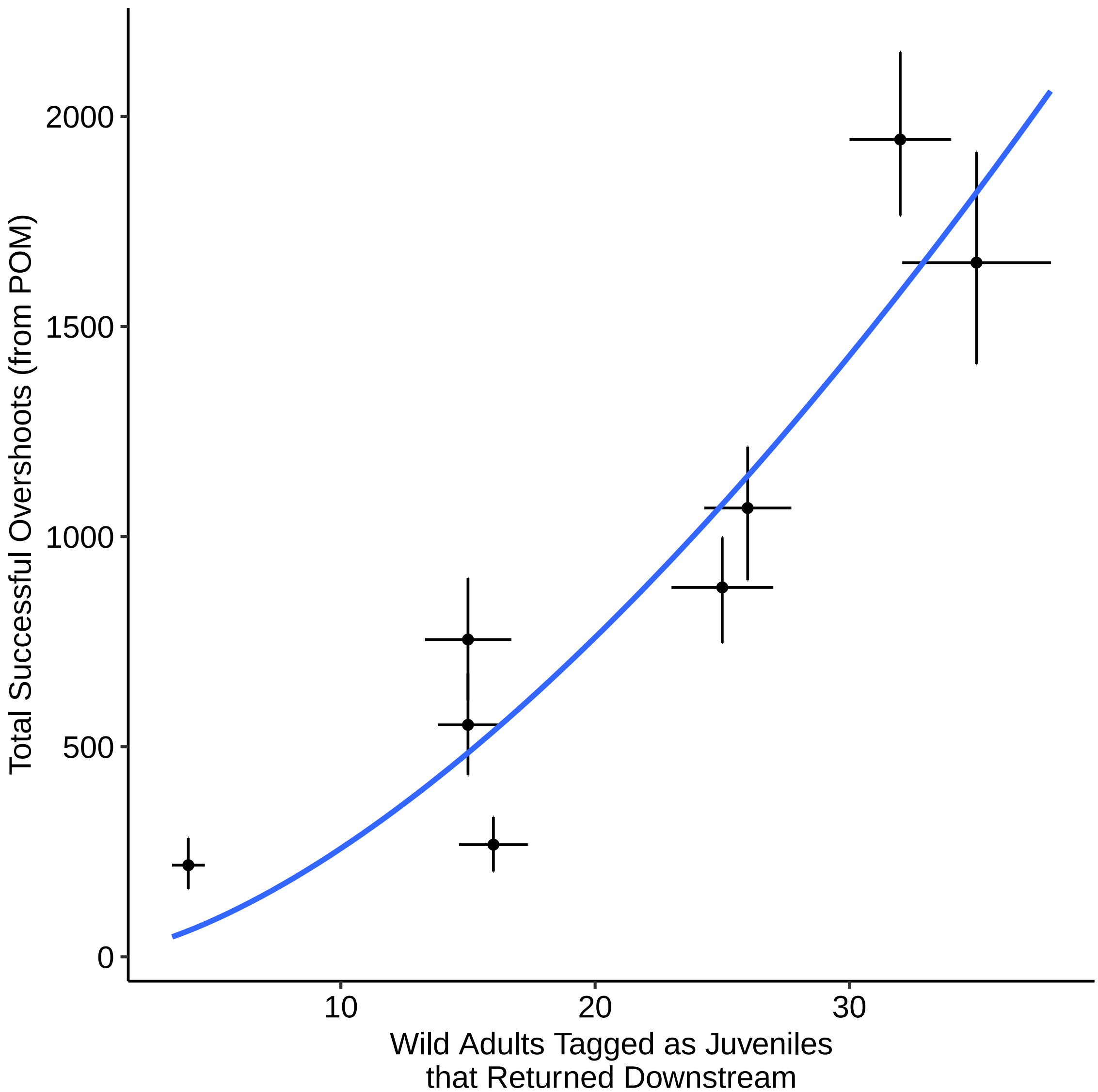
3 Methods

First, we need to account for imperfect detection at the downstream sites so we can expand the number of known overshoot tags detected there. We do that by using the estimates of detection probablity from the patch-occupancy model for year i at each site j, and then summing up the estimated tags at each detection site to get an estimate of total overshoot return tags, $\hat{t_i}$.

$$t_i = \sum_j^J \frac{s_{i,j}}{\hat{p_{i,j}}}$$

Next, we develop a relationship between the number of overshoot return tags, t_i and the total overshoot return abundance, F_i. We assumed a log-log relationship (see Figure @**??**fig:tag_escp_fig)).

$$F_i \sim e^{\beta_0} * t_i^{\beta_1} \log(F_i) \sim \beta_0 + \beta_1 * \log(t_i)$$



We then use that relationship, $(\hat{\beta})$, and the total number of known overshoot tags observed at Priest, T_i, to predict the total overshoot abundance at Priest, O_i. The overshoot return survival, ϕ_i, is the calculated from that and the estimate of total downstream abundance.

$$\phi_i = \frac{N_i}{O_i}$$

Written out mathematically, the whole things looks like this:

$$
\mu_i = \sum_{j}^{J} \frac{s_{i,j}}{\hat{p_{i,j}}}
$$

$$
t_i \sim N(\mu_i, \sigma_i^2)
$$

$$
F_i \sim e^{\beta_0} * t_i^{\beta_1}
$$

$$
\log(F_i) = \beta_0 + \beta_1 * \log(t_i) + e_i
$$

$$
e_i \sim N(0, \tau^2)
$$

$$
\log(\omega_i) = \beta_0 + \beta_1 * \log(T_i)
$$

$$
O_i \sim N(\omega_i, \tau^2)
$$

$$
N_i \sim N(F_i, \gamma^2)
$$

$$
\phi_i = \frac{N_i}{O_i} \approx \left(\frac{t_i}{T_i}\right)^{\beta_1}
$$

We fit this entire model in a Bayesian framework, using JAGS software. The JAGS model looks like this:

```
jags_model = function() {
  "  # PRIORS
  for(i in 1:2) {
    beta[i] ~ dt(0, 0.01, 1)
  }
  sigma ~ dt(0, 0.01, 1)T(0,)
  tau <- pow(sigma, -2)

  # MODEL
  for(i in 1:length(tags_est)) {
    n_tags_org[i] ~ dnorm(tags_est[i], tags_prec[i])
    n_tags[i] <- round(n_tags_org[i])

    # couldn't figure out how to incorporate this uncertainty,
    # because n_escp_log would end up on the left side twice
    # n_escp_log[i] ~ dlnorm(escp_est[i], escp_prec[i])

    mu[i] <- beta[1] + beta[2] * log(n_tags[i])

    # assuming downstream escapement estimates are known
    escp_est_log[i] ~ dnorm(mu[i], tau)
  }
```

Table 3: Estimated abundance of overshoot steelhead at Priest Rapids Dam and the overshoot return rate or proportion of fish observed downstream of Priest Rapids Dam prior to spawning.

Year	ovrst_tags	ovrst_PRD	prd_ci_low	prd_ci_upp	phi	phi_ci_low	phi_ci_upp
2010	53	3,112	1,640	7,578	0.622	0.218	0.977
2011	18	1,289	714	3,367	0.686	0.222	0.985
2012	31	1,614	595	4,727	0.451	0.116	0.919
2013	40	2,262	1,075	6,130	0.578	0.174	0.967
2014	44	3,129	1,917	7,131	0.701	0.275	0.986
2015	35	1,952	908	5,505	0.557	0.156	0.962
2016	21	1,051	334	2,960	0.344	0.089	0.819
2017	6	428	199	1,168	0.646	0.179	0.984

```
  for(i in 1:length(ovrst_tags)) {
    # deal with uncertainty in downstream escapement estimates
    est_dwnstrm_org[i] ~ dnorm(dwnstrm_escp[i], 1 / (dwnstrm_se[i]^2))
    est_dwnstrm[i] <- round(est_dwnstrm_org[i])

    # predict the number of overshoot fish at Priest
    pred_mu_log[i] <- beta[1] + beta[2] * log(ovrst_tags[i])
    pred_ovrshts_log[i] ~ dnorm(pred_mu_log[i], tau)T(log(est_dwnstrm[i]),log(1e4))
    pred_ovrshts[i] <- round(exp(pred_ovrshts_log[i]))

    # estimate survival of overshoots
    phi[i] <- est_dwnstrm[i] / pred_ovrshts[i]
  }"
}
```

4 Results

Recreate Table 3 of manuscript:

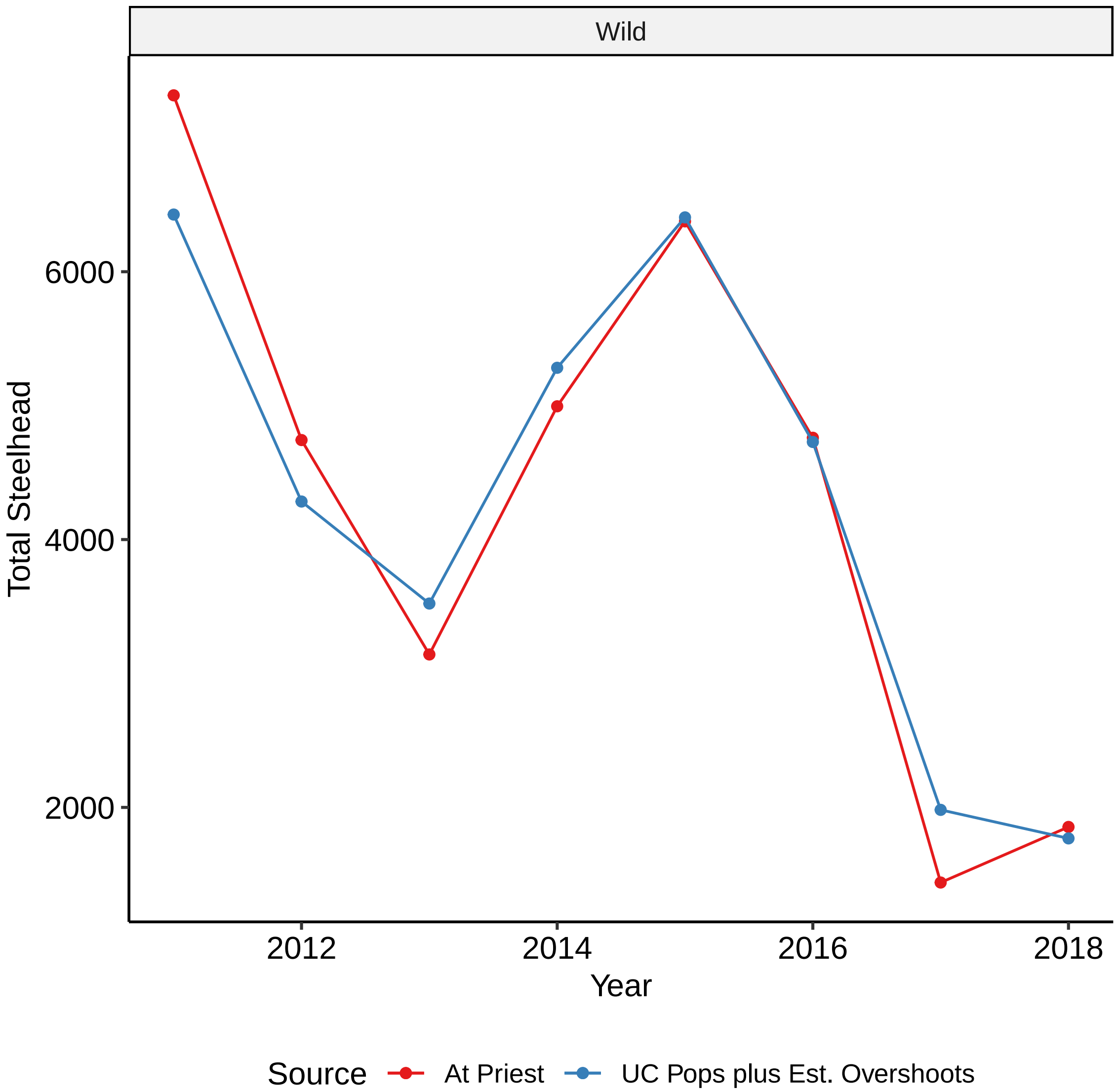


Figure 1: Comparison of total adusted counts at Priest and the sum of predicted overshoots and escapement to four upper Columbia steelhead populations.