Overshoot Bayesian Methods

Kevin See

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.

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

Site	Avg Tags	Mean	SD of Mean	Avg SE	Avg CV
ICH	279	0.985	0.010	0.009	0.009
PRO	48	0.810	0.062	0.085	0.106
PRV	5	0.544	0.371	0.103	0.222
TMF	3	0.625	0.518	0.000	0.000
JD1	2	0.346	0.342	0.108	0.460

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	929	53	675	1428	45	0	33	23	0	23
2012	401	36	351	1683	22	0	0	0	0	0
2013	214	33	316	1814	21	14	0	0	0	0
2014	348	38	626	1370	19	51	18	13	140	87
2015	537	57	1088	2451	69	21	48	21	115	35
2016	311	16	411	880	58	20	20	0	58	0
2017	90	29	123	681	21	21	8	0	30	18
2018	122	14	61	259	9	0	0	0	28	0
Mean	369	34	456	1321	33	16	16	7	46	20

- 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.

Re-create Table 2

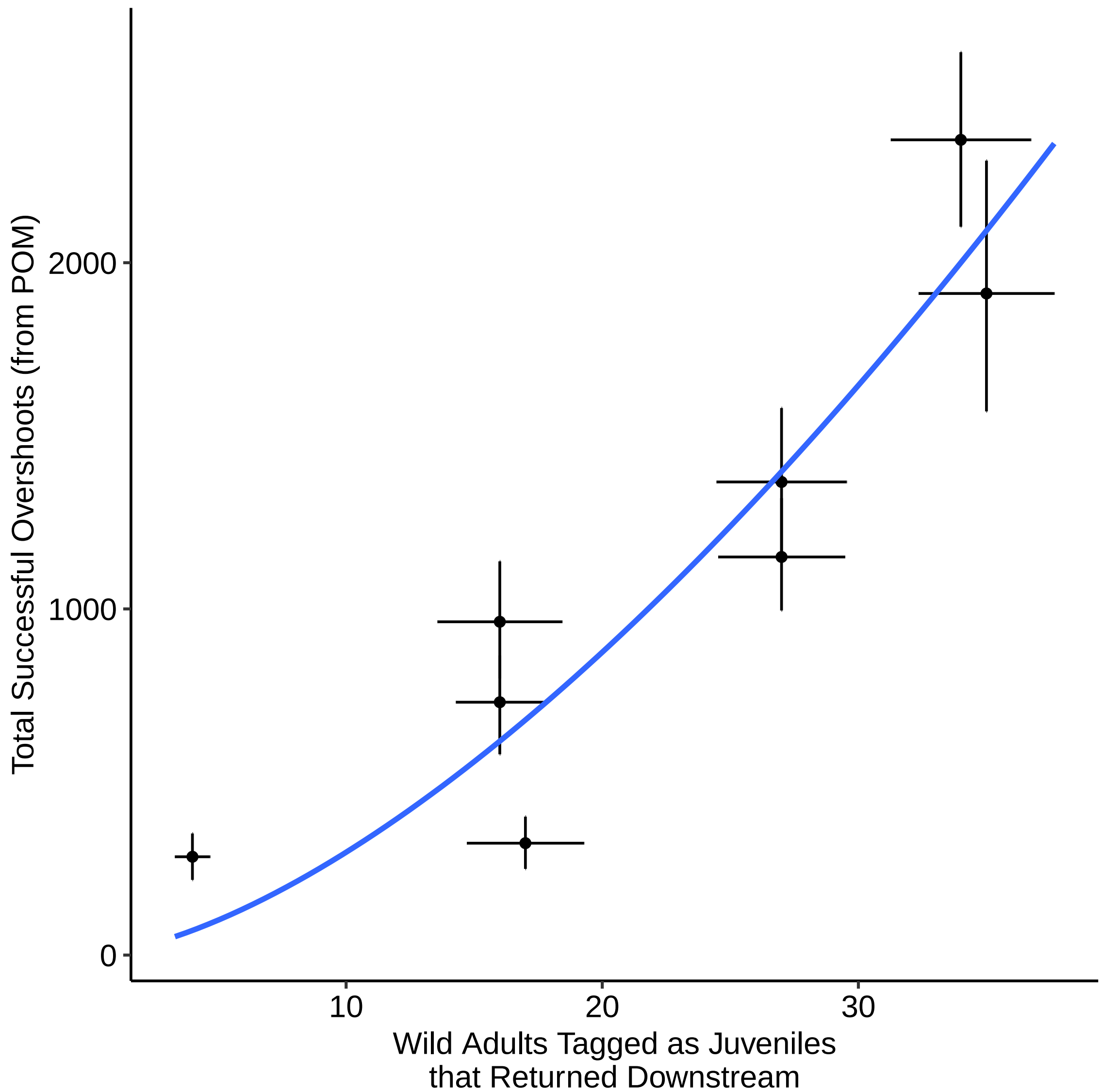
3 Methods

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.

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

Written out mathematically, the whole things looks like this:

$$\mu_i = \sum_j^J \frac{s_{i,j}}{\hat{p_{i,j}}}$$
$$t_i \sim N(\mu_i, \sigma_i^2)$$

$$F_i \sim e^{\beta_0} * t_i^{\beta_1}$$
$$\log(F_i) = \beta_0 + \beta_1 * \log(t_i) + e_i$$
$$e_i \sim N(0, \tau^2)$$

$$\log(O_i) \sim N(\hat{\beta}_0 + \hat{\beta}_1 * \log(T_i), \hat{\tau^2})$$

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

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

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: Steelhead abundance (adjusted for ladder re-ascension) at Priest Rapids Dam and the estimated number of overshoot fallback steelhead using the patch occupancy model, 2010-2017.

			Estimated Overshoot Fallback Abundance							
	Adjusted Priest Rapids Dam Count		Wild				Hatchery			
Run Year	Wild	Hatchery	%	Estimate	95% CI		%	Estimate	95% CI	
					Lower	Upper			Lower	Upper
2010	7,257	17,938	26.3 %	1,911	1,570	2,295	9.8 %	1,755	1,475	2,022
2011	4,672	15,115	20.6 %	963	799	1,137	12.8 %	1,931	1,696	2,141
2012	3,065	13,008	23.8 %	730	580	866	16.8 %	2,180	1,957	2,399
2013	4,864	9,027	28.1 %	1,367	1,161	1,580	19.5 %	1,757	1,522	1,988
2014	6,232	12,088	37.8 %	2,355	2,104	2,608	23.8 %	2,879	2,644	3,105
2015	4,675	8,949	24.6 %	1,150	995	1,320	13.2 %	1,179	1,053	1,338
2016	1,404	4,709	23 %	323	249	400	21.8 %	1,027	896	1,151
2017	1,817	3,573	15.6 %	284	217	351	15.1 %	540	456	635
Mean	4,248	10,551	25 %	1,135	959	1,320	16.6 %	1,656	1,462	1,847
SD	2,040	4,950	6.4 %	729	649	820	4.8 %	730	676	778

```
  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

5 Tables

Recreate Table 1 of manuscript:

Recreate Table 2 of manuscript:

Recreate Table 3 of manuscript:

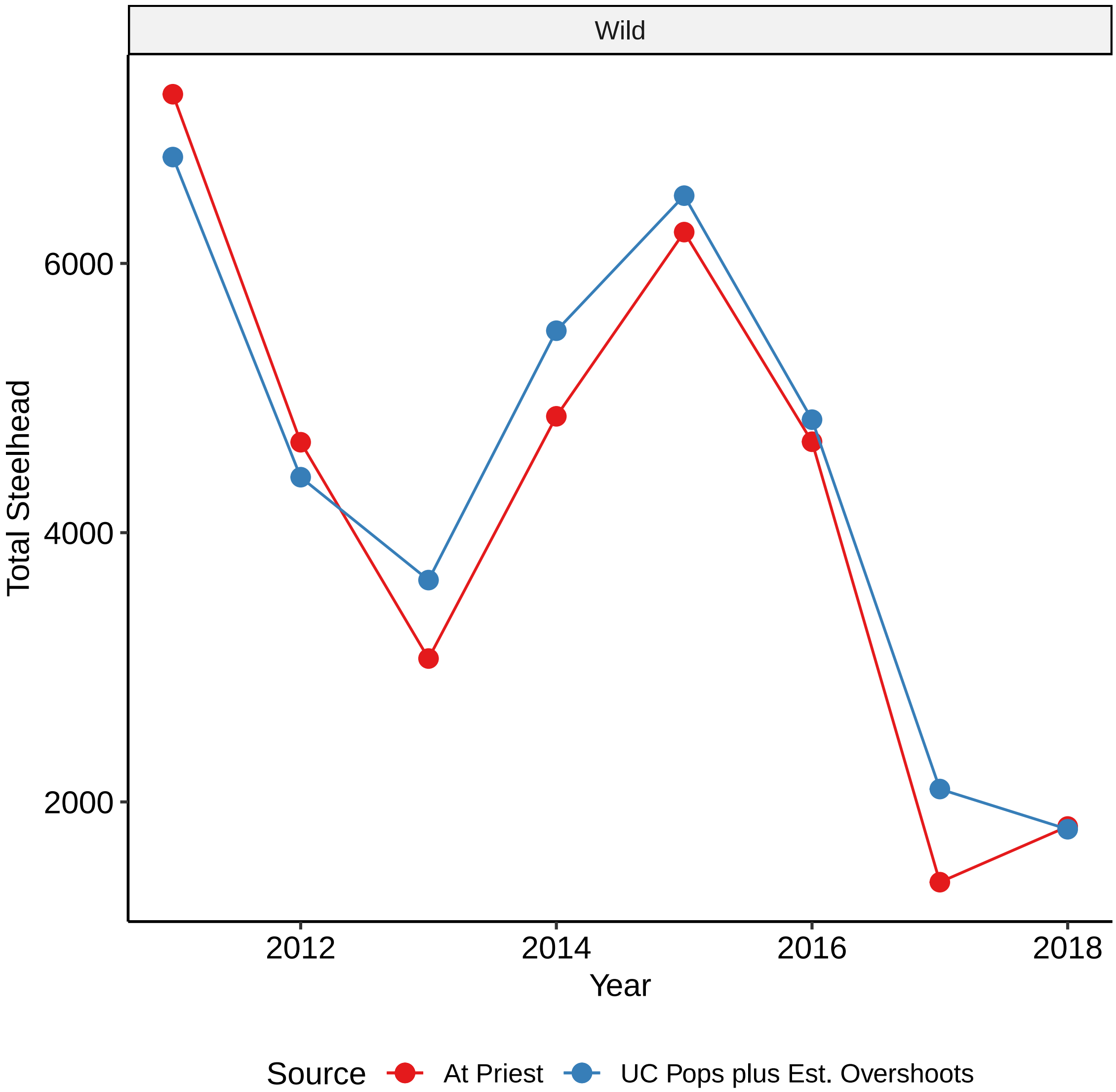


Figure 1: Comparison of total adusted counts at Priest and the sum of predicted overshoots and escapement to four upper Columbia steelhead populations.

Table 4: Estimates of overshoot fallback steelhead downstream of Priest Rapids Dam, by sub-basin and PTAGIS location code. (PRO = Prosser Dam; ICH = Ice Harbor Dam; PRV = Pierce RV Park instream array; TMF = Three Mile Falls Dam; JD1 = Lower John Day instream array at McDonald Ferry). Parentheses indicate PIT tag detection probability (mean, mean of SE). W = wild and H = hatchery.

	Yakima PRO (0.81, 0.08)		Snake ICH (0.98, 0.01)		Walla Walla PRV (0.54, 0.1)		Umatilla TMF (0.62, 0)		John Day JD1 (0.35, 0.11)	
Run Year	W	H	W	H	W	H	W	H	W	H
2010	929	53	675	1,429	45	0	33	23	0	23
2011	401	36	351	1,683	22	0	0	0	0	0
2012	214	33	316	1,815	21	14	0	0	0	0
2013	348	38	626	1,371	19	51	18	13	140	87
2014	537	57	1,088	2,451	69	21	48	21	115	35
2015	311	16	411	880	58	20	20	0	58	0
2016	91	29	123	681	21	21	8	0	30	18
2017	122	14	61	259	9	0	0	0	28	0
Mean	369	34	456	1,321	33	16	16	7	46	20
%	15.9	1.5	19.7	57	1.4	0.7	0.7	0.3	2	0.9

Table 5: Estimated abundance of overshoot steelhead at Priest Rapids Dam and the percentage of overshoot fallback or percentage of fish observed downstream of Priest Rapids Dam prior to spawning.

		Estimated Wild Steelhead Overshoot Abundance			Overshoot Fallback Percentage (# fallbacks / # overshoots)		
			95% CI			95% CI	
Run Year	Known Overshoot Fish	Estimate	Lower	Upper	Estimate	Lower	Upper
2010	53	3,578	1,864	8,212	0.620	0.229	0.978
2011	18	1,603	906	4,097	0.697	0.234	0.987
2012	31	1,925	770	5,377	0.488	0.132	0.935
2013	40	2,708	1,366	6,770	0.603	0.198	0.975
2014	44	3,642	2,313	7,814	0.716	0.299	0.988
2015	35	2,323	1,165	6,147	0.595	0.186	0.970
2016	21	1,229	402	3,487	0.356	0.092	0.818
2017	6	542	263	1,510	0.649	0.186	0.983
Mean	31	2,194	1,131	5,427	0.591	0.194	0.954
SD	15	1,094	703	2,288	0.118	0.063	0.058