Adjusting for Bias in Apparent Survival Estimates Based on Passive Integrated Transponder Experiments

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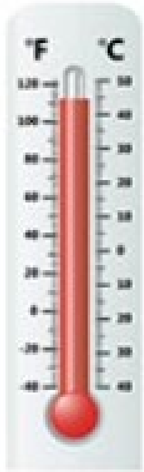
Oliver Murray, Roberto Licandeo, Eric Parkinson, Tom Porteus
& Murdoch McAllister
University of British Columbia
Institute for The Oceans and Fisheries

Integrated Passage Assessment (IPA) Team

Integrated Passage Assessment

PIT Tag Based Survival Estimates in the IPA

- Upper Willamette Offers PIT tag data for all 4 Sub-basins and the two species of interest to IPA
  - Many experiments performed: multiple years, hatchery vs wild, range of fish sizes, release dates, and release locations, 2+ detection sites…
- PIT tag studies can provide survival rate estimates that *integrate* over many factors
  - Dam passage survival, river reach passage survival, water conditions, route selection, temperature etc…



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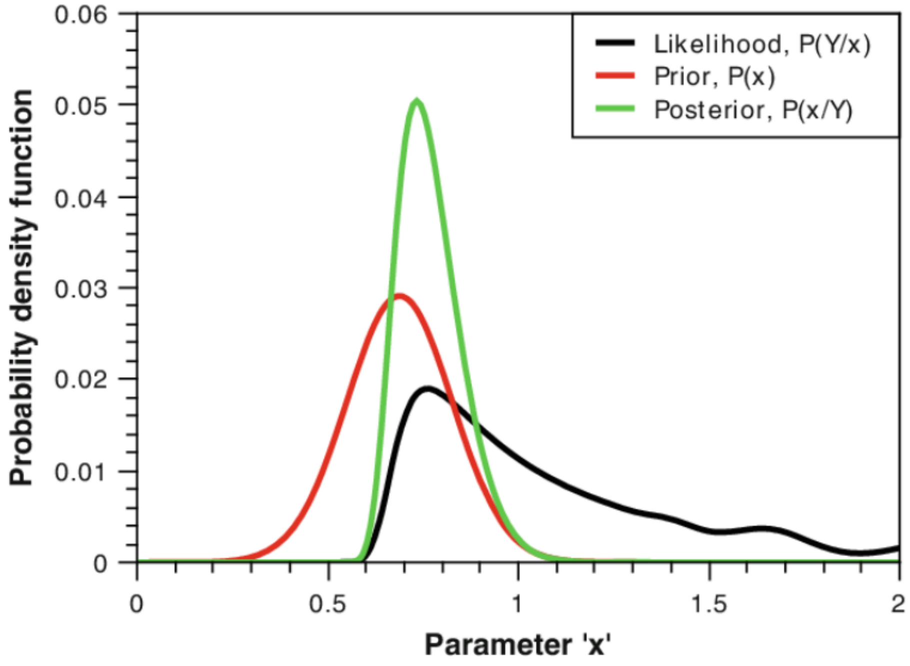
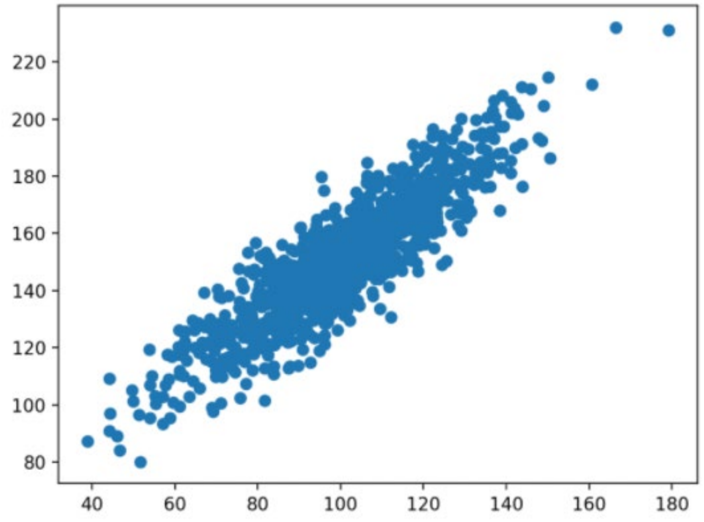
PIT Tag Based Survival Estimates in the IPA

- Parameters can be estimated using
  - PIT tag release and detection records
  - Prior information from comparable system data, and expert opinion
  - Resulting posterior distributions for parameters include credible values and the correlations between parameters





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PIT Tag Based Survival Estimates in the IPA

- The posterior distributions for parameters are incorporated into life cycle models using a Monte Carlo simulation framework
  - Survival rate estimates used however are “apparent survival rates”
  - Smolt-Adult survival rate estimates include both natural mortality and fishing mortality rates – the former and latter need to be separated out for IPA modelling

Issues With Apparent Estimates

- Challenge – survival rate estimates from PIT tag data may be biased
- Three main sources of bias to be addressed here
  - Tag Loss
  - Tag Induced Mortality
  - Differences between Tagged Population and Population of Interest

- Many experiments completed under different conditions
  - e.g., fish sizes, tag sizes/models, and geographies yet very little consensus on adjustments
- Modeling approaches which rely on PIT tags for estimates of survival components do not adjust for potential biases in estimates
- Accounting for bias in PIT tags requires
  - Careful design of tag experiment
  - Application of bias corrections (adjustments) to the apparent survival estimates

Applying Adjustments To Estimated Survivals

- Arnason and Mills (1981) – survival probability estimates confounded with probability of tag loss

- The estimate of the survival rate ($\hat{S}$) corrected for imperfect tag retention ($\hat{\tau}$, 1-probability of tag loss) in the apparent survival rate ($\hat{\phi}$)

$$\hat{S} = \frac{\hat{\phi}}{\hat{\tau}}$$

- This adjustment has been applied in Bradshaw 2003, in the context of estimating survival and captured probabilities of New Zealand fur seals (*Arctocephalus forsteri*)

- This form of the adjustment has also been applied Melnychuk 2014 to account for residualization in Steelhead (*Oncorhynchus mykiss*)

Applying Adjustments To Estimated Survivals

- Following Melnychuk (2014) and extending the Arnason and Mills (1981) adjustment to three sources of bias

$$\hat{S} = \frac{\widehat{\phi}}{\hat{\tau}_l \hat{\tau}_M \hat{\tau}_H}$$

- Where
  - $\hat{\tau}_l$ is the tag retention rate accounting for tag loss
  - $\hat{\tau}_M$ is equal to 1 – tag induced mortality
  - $\hat{\tau}_H$ is the ratio of the survival rate of the study group to the conservation group
  - $\widehat{\phi}$ is the apparent survival rate
  - $\hat{S}$ is the adjusted survival rate
- We assume independence across the three sources of adjustments and ignore correlation between sources of bias

Tag Loss

- PIT tag loss depends on the life-history of the salmon/steelhead on their migration
  - 0^+ to 6 months → from the release site (e.g., above dam) to their last in river detection site (Sullivan Juvenile Bypass Facility)
  - 6 months – 4/5 years → passage at Sullivan (as smolts) to return at Willamette Falls Fishway
- Foldvik (2018): Atlantic salmon - 91% retention over 533 day period
  - majority of loss in 1st 1-6 months and 1 – 1.5 years
- Knudsen (2009): Chinook salmon – 98% retention 1-2 months, 80.5-82.8% retention 6months-4 years
- Comparative Survival Study for Chinook salmon (Fish Passage Center 2018)
  - 92.3-96.6% PIT tag retention juvenile release to adult return depending on quality of tagger

Tag Loss

- Many variables to consider

Species

size of tag relative to fish

laboratory test vs in-situ double tag experiment

recovery time after tagging

skill of tagger

method of tag implantation

methods and quality of analysis

population specific stressors

similarity of study conditions to our case study, etc…

Difficult to find a comparable study

Tag Loss

- Several other studies (about 10 in total) reviewed
- Results typically in range summarized in three studies on previous slides
  - Common observations of loss 2-10%
  - Less frequent observation of loss more along the lines of Knudsen i.e. > 15%
- Difficult to find a comparable study

Tag Induced Mortality

- Fish Passage Center (CSS 2018): 4 years, 75k fish/year, double tag experiment → no impact
- Knudsen (2009): 5 years, 40k fish/year, double tag experiment → 4-33%, average 10%
- Camacho (2018): IDFG run reconstruction 1996-2014 SARs were 46% greater than PIT tag-based estimates
- Schaller (2007): NOAA run reconstruction 1994-2004 SARs were 19% greater than PIT tag-based estimates

Tag Induced Mortality

- Key points of contention raised by Fish Passage Center on Chinook studies
  - Efficiency of Hand Detectors in Knudsen (2009) not factored into mortality estimates
  - Run reconstruction estimate comparisons could contain bias
- However, counter arguments can be made on these claims
  - There are other factors to consider, e.g., evidence in many other studies (about 10 in total reviewed).
  - Systematic literature review indicates the issue is not settled

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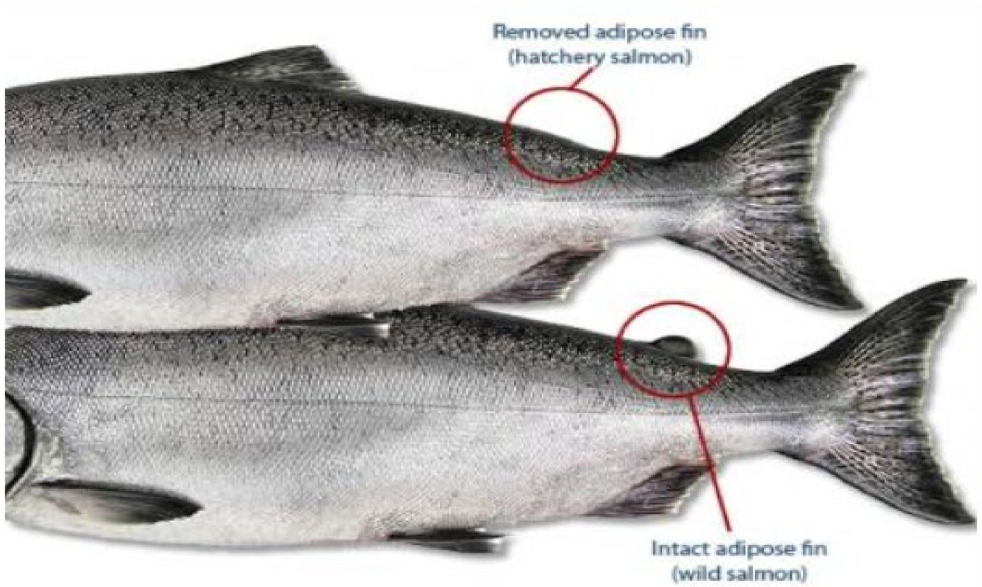
Adjusting for Unrepresentative Population

- Major distinction between tagged population and population of interest
  - Breeding lineage – hatchery vs wild
  - Rearing lineage – hatchery stressors vs wild stressors and selectivity (predation, stress, foraging, etc…)
  - Physical characteristics – Fork length, phenotype, age/development status at release
- The state of the literature – many studies have been performed; two approaches to consider

There are a large number of reports indicating a difference on the order of 2-3x,

There are reports indicating there is no difference



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Adjusting for Unrepresentative Population

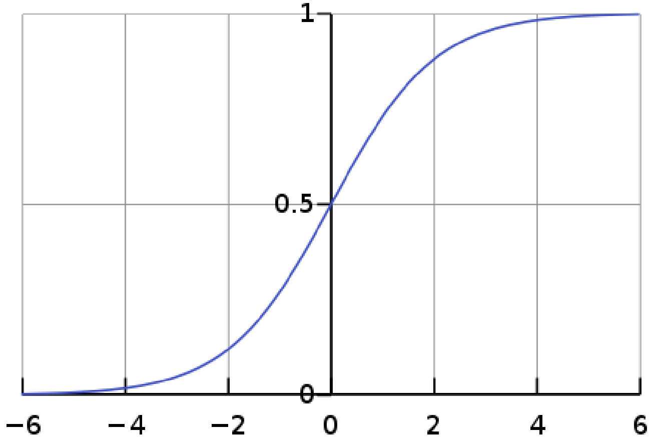
- Melnychuk (2014), Moore (2012): estimate relationship between apparent CJS survival probabilities and explanatory variables using a logit function.

- Highest credibility model (AIC) from Melnychuk included covariates

  - Fork length (FL), release date (RD), hatchery vs wild (HW), reach specific parameters (d), initial mortality parameters (M)

$$\widehat{\phi}(d, FL, RD, HW, M)$$

- Examining studies in McKenzie sub-basin across years and different covariates could provide insight about the "Unrepresentative Population" in the Willamette

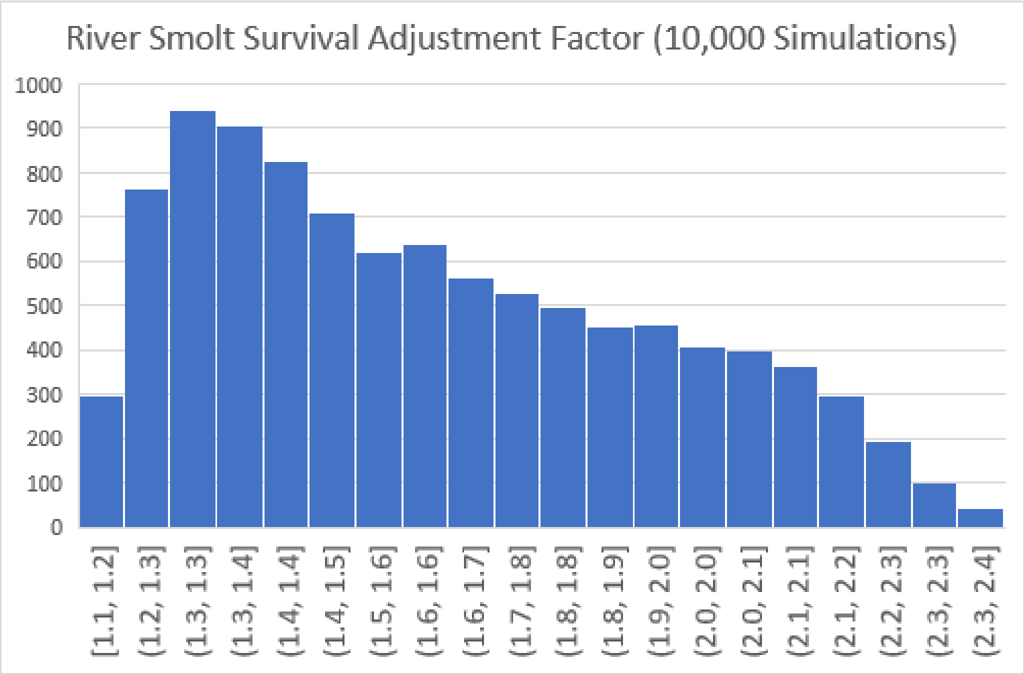


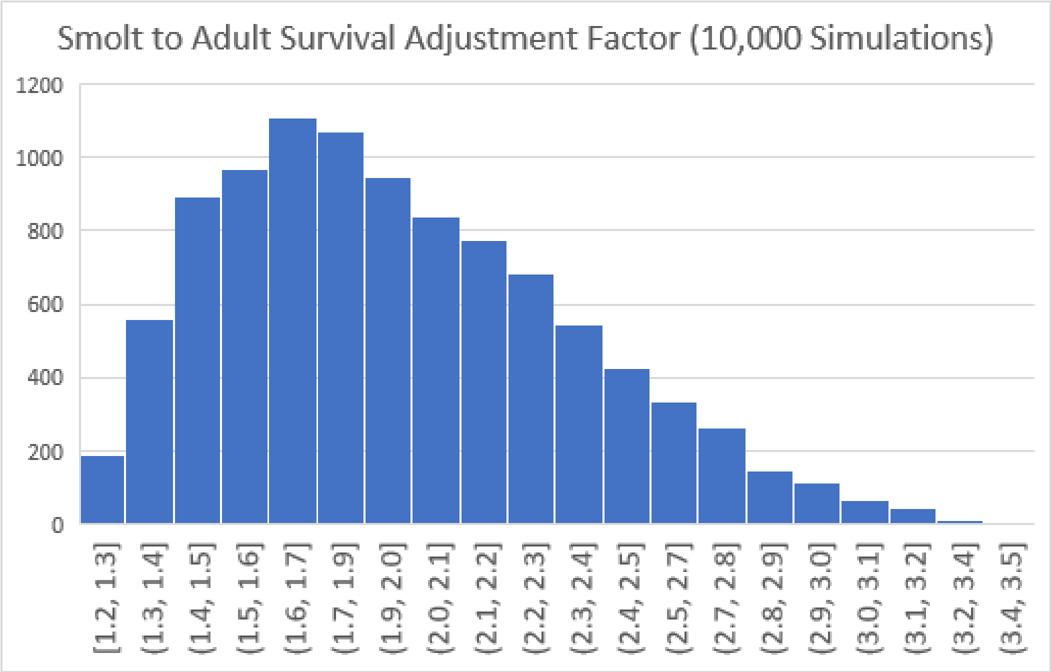
Applying Adjustments From All Three Factors

- Provisional upper and lower bounds on uniform distributions for tag adjustment factors

	T_{Lmin}	T_{Lmax}	T_{Mmin}	T_{Mmax}	T_{Hmin}	T_{Hmax}
River Smolt Survival	0.97	0.99	0.85	0.95	0.5	0.95
Smolt to Adult Survival	0.85	0.98	0.67	0.96	0.5	0.95

- Simulated River Smolt Survival and Smolt to Adult Survival adjustment terms





UBC Integrated Passage Assessment

Applying Adjustments From All Three Factors

- Adjustments can have a considerable impact on downstream passage survival: average increases to lower bounds, median, and upper bounds under provisional assumptions are around 2 X

Apparent and Adjusted Survival Estimates									
				Dexter Paired Release			Lookout Point Head of Reservoir		
Phase	Year	Condition	Estimate Type	Lower (95%)	Median	Upper (95%)	Lower (95%)	Median	Upper (95%)
RSS	2011	Good Spring Spill	Unadjusted	27%	59%	97%	10%	22%	68%
			Adjusted	43%	92%	100%	15%	34%	100%
SAS	2011	Poor Marine	Unadjusted	0.02%	0.08%	0.29%	0.04%	0.20%	0.81%
			Adjusted	0.03%	0.15%	0.54%	0.07%	0.38%	1.52%
RSS	2012	Some Spring Spill	Unadjusted	16%	27%	40%	4%	8%	18%
			Adjusted	25%	42%	63%	7%	13%	28%
SAS	2012	Good Marine	Unadjusted	0.05%	0.10%	0.21%	0.3%	0.7%	1.5%
			Adjusted	0.09%	0.19%	0.39%	0.6%	1.4%	2.9%
RSS	2013	Some Spring Spill	Unadjusted	11%	23%	54%	5%	13%	33%
			Adjusted	17%	36%	84%	8%	20%	53%
SAS	2013	Poor Marine	Unadjusted	0.01%	0.06%	0.18%	0.08%	0.25%	0.76%
			Adjusted	0.03%	0.10%	0.33%	0.15%	0.46%	1.42%
RSS	2014	Some Spring Spill	Unadjusted	4%	9%	27%	0.3%	0.7%	3.6%
			Adjusted	6%	13%	43%	0.5%	1.1%	5.7%
SAS	2014	Good Marine	Unadjusted	0.005%	0.06%	0.27%	0.06%	0.7%	3.6%
			Adjusted	0.009%	0.10%	0.51%	0.12%	1.2%	6.6%

Summary

- Range of different sources of adjustments to tag based survival estimates
- Tag loss and tag mortality adjustments sourced from literature
- Adjustments between test populations and conservation populations can potentially be estimated from data
- Adjustments of Survival estimates could be up to a factor of two

Acknowledgements

- The Columbia Basin PIT Tag Information System (PTAGIS)
- Numerous field experimenters in the Upper Willamette: Romer, Schroeder, Liedtke, …