Use of the Cormack-Jolly-Seber (CJS) Model for Wind River Steelhead Life Cycle Modeling

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OUTLINE

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GOALS & NOTES

- Use tag data from Wind River steelhead parr, smolt, and adult PIT tagging to estimate life stage survival and capture probabilities using Cormack-Jolly-Seber (CJS) model

- In CJS model survival (ϕ)= apparent survival, which is survival in the study area. In this case, if we PIT tagged resident *0. mykiss* parr that do not emigrate as smolts survival estimates are biased low.

Hierarchical Models

- All annual adult PIT tag detection efficiencies at BON come from a common distribution of detection efficiencies and their ordering does not affect the model (exchangeable)
- Individual estimates from hierarchical models borrow strength from other annual detection efficiencies because they are similar; reduces model overfitting; hierarchical models are a compromise between individual and fully pooled estimates.
- Hierarchical parameter estimates have improved precision because they shrink toward the mean; shinkage depends on the variance of the random parameters.
- Borrowing strength is often viewed as being beneficial when data is sparse, as in many tagging studies.

Wind River Steelhead

- Located at RM 153 ~ 11 mile upstream BON
- Wild steelhead sanctuary since 2000
- Escapement (range 200-1500);mean (600+)
- Summer steelhead - 95% to 99% of escapement
- Freshwater Age - age 2 ~75% & age 3 ~ 25%
- Marine Age- age 1<5%, age 2~85%, age 3<10%
- Annual (2.2s) and Skip Repeat Spawners (2.2s1)
- PIT Tagging
  - smolts since 2003 annual tag range (1100-2500),
  - parr since 2007 tag annual range (300-600), &
  - adults since 2008 annual tag range (30-300)

CJS Model

- This CJS model is life cycle model using tagging, detection, and recapture sites to partition life stage survival.
- Assume all parr tagged in spring emigrate as smolts following year.
- Most fish are PIT tagged at the smolt stage & CJS model tracks smolt outmigration cohorts
- Adults tagged at Shipherd Falls ladder added to appropriate smolt outmigration year based on scale ages.

East Sand Island
(ESANIS)
RM 5.5

Jones Beach
RM 47
NOAA Trawl
(TWX)

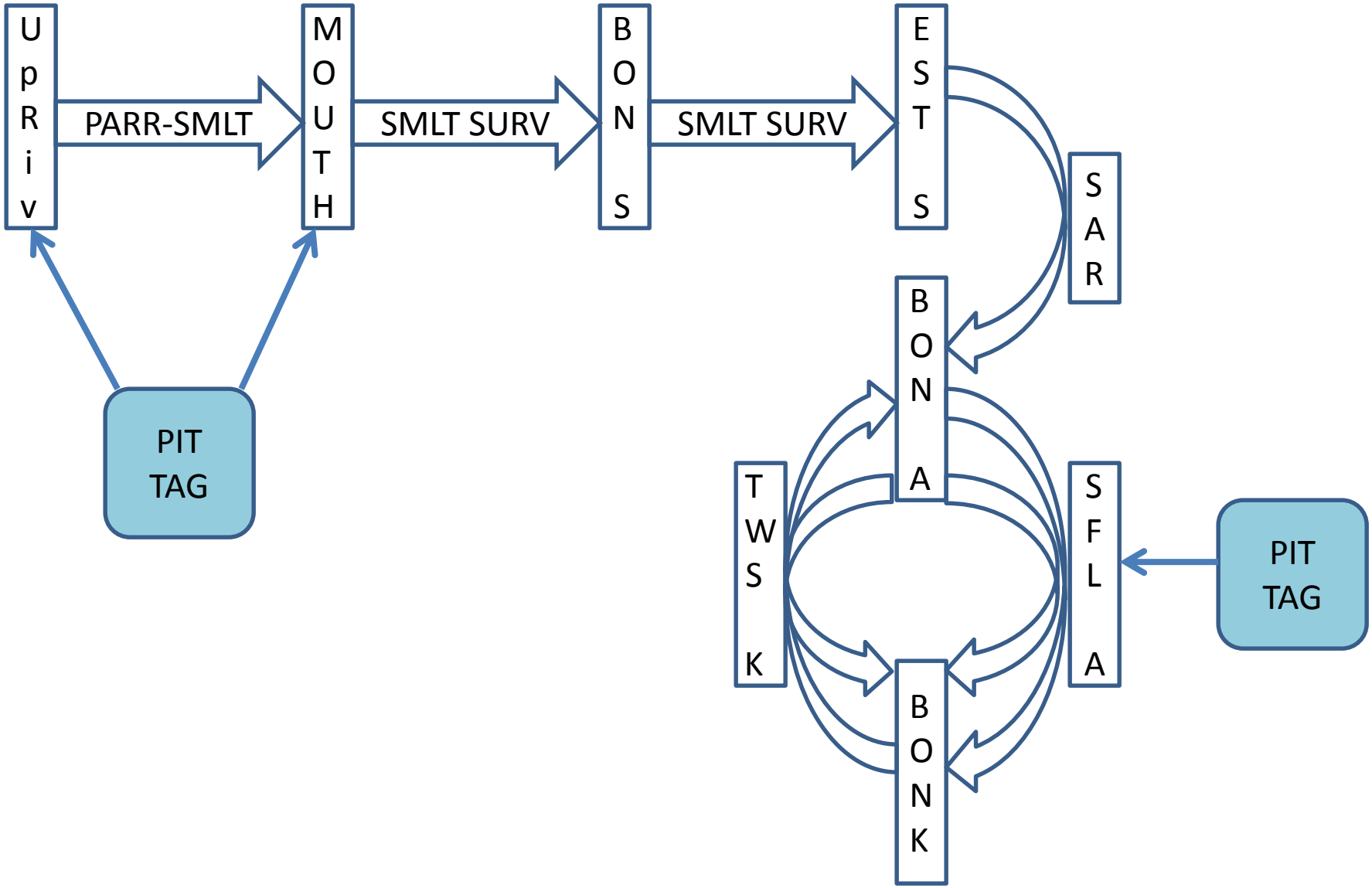
Columbia
River

Wind River
RM 154.5

Shipherd
Falls
Adult
Trap

Bonneville Dam
(BON)
RM 143.4

WIND RIVER STEELHEAD LIFE CYCLE MODEL



2008 CJS Wind River m-array

- Create individual capture histories (0,1) at each site based on PTAGIS query
- Sum individual capture histories to create m-array for analysis

2008	LW_ST	BONsm	TWX/ES	BONma	SFTma	BONk1	TWXk1	BONr1	SFTr1	BONk2	TWXk2	BONr2	Not Seen
UR_ST	1	0	4	3	0	0	0	0	0	0	0	0	299
LW_ST	0	187	145	64	0	0	0	0	0	0	0	0	761
BONsm	0	0	34	15	0	0	0	0	0	0	0	0	138
TWX/ES	0	0	0	3	0	0	0	0	0	0	0	0	24
BONma	0	0	0	0	10	5	1	2	0	0	0	0	67
SFTma	0	0	0	0	0	45	1	17	0	0	0	0	211
BONk1	0	0	0	0	0	0	0	9	0	0	0	0	41
TWXk1	0	0	0	0	0	0	0	0	0	0	0	0	2
BONr1	0	0	0	0	0	0	0	0	4	5	0	3	16
SFTr1	0	0	0	0	0	0	0	0	0	1	0	0	5
BONk2	0	0	0	0	0	0	0	0	0	0	0	0	6
TWXk2	0	0	0	0	0	0	0	0	0	0	0	0	0

Models (Years 2003-11)

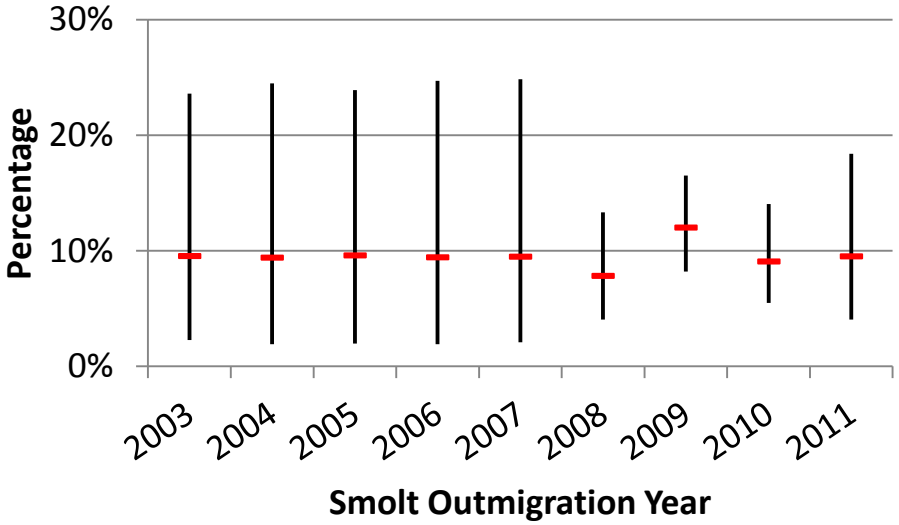
- Model 1 - survival and capture probabilities are pooled (constant) for each cohort
- Model 2 – survival and capture probabilities are independent for each cohort
- Model 3 – survival and capture probabilities are for each cohort are hierarchical across years.
- Model 4 - survival and capture probabilities are for each cohort are hierarchical across years but same capture probabilities for all adults at BON, SF, and kelts at BON and TWX

Model Selection & Goodness of Fit (GOF) Test

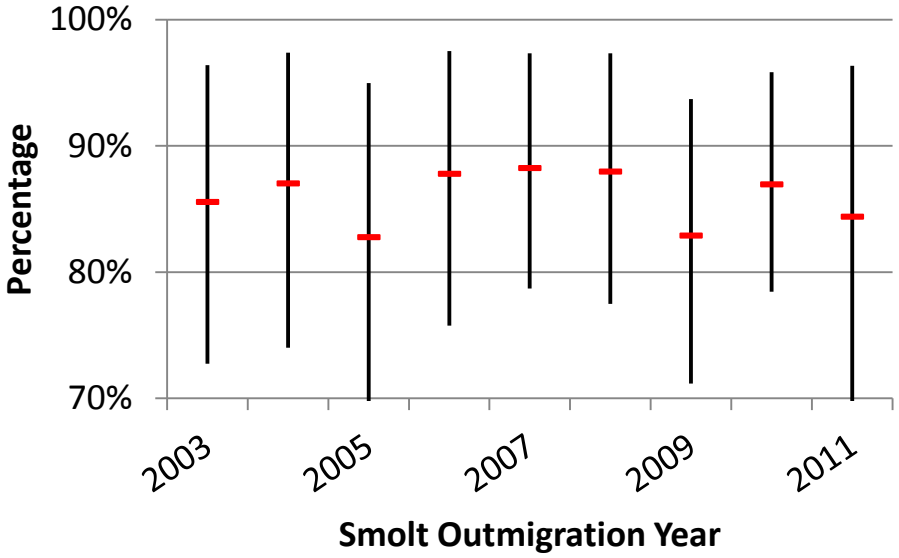
- Deviance Information Criteria (DIC), a Bayesian analog for AIC, was used for model selection (lower values are better fit).
- Bayesian *p*-values compare observed and expected data from the model, which is similar to a $\chi 2$ test; difference is perfect fit for Bayesian p-values =0.5, and values near 0 or 1 indicate lack of fit

Model No.	Model	DIC	Bayesian *P*-value Range	ΔDIC	Comments
4	Model 3 plus Hier. Adult *p* at BON, SF, &TWX	820.83	0.10 to 0.60	0.00	"Best" Model
3	Hierarchical for p and ϕ	824.05	0.13 to 0.93	3.22	Some Support
2	Independent	827.24	0.16 to 0.67	6.41	Some Support
1	Pooled	1895.06	0 .00 to 0.00	1074.23	No Support

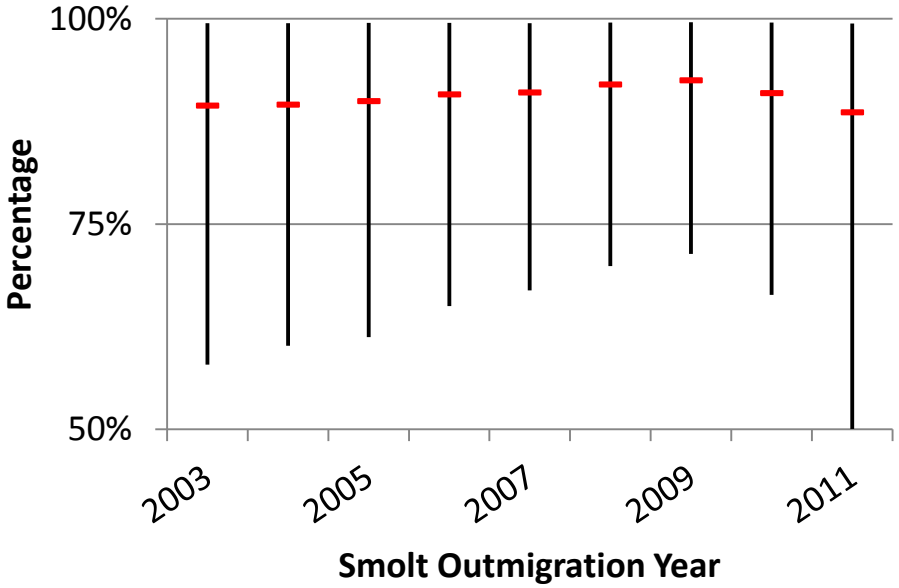
Wind River Parr-Smolt Survival



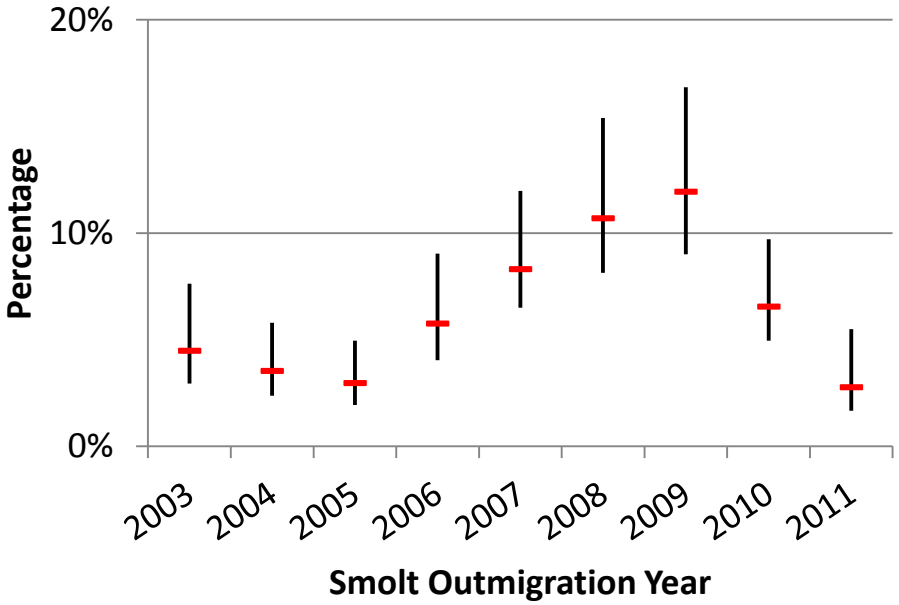
Wind R. Smolt Survival, Mouth-BON

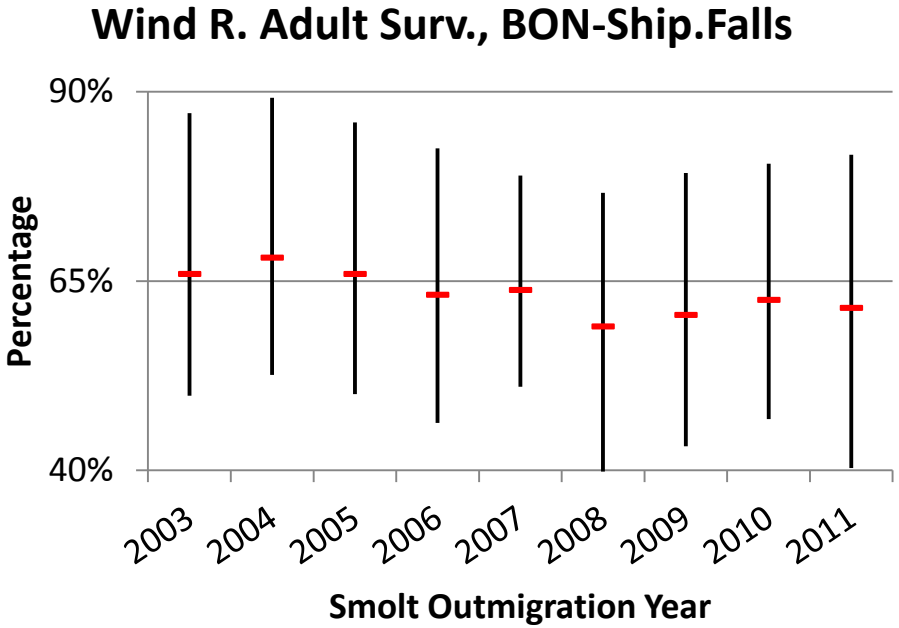


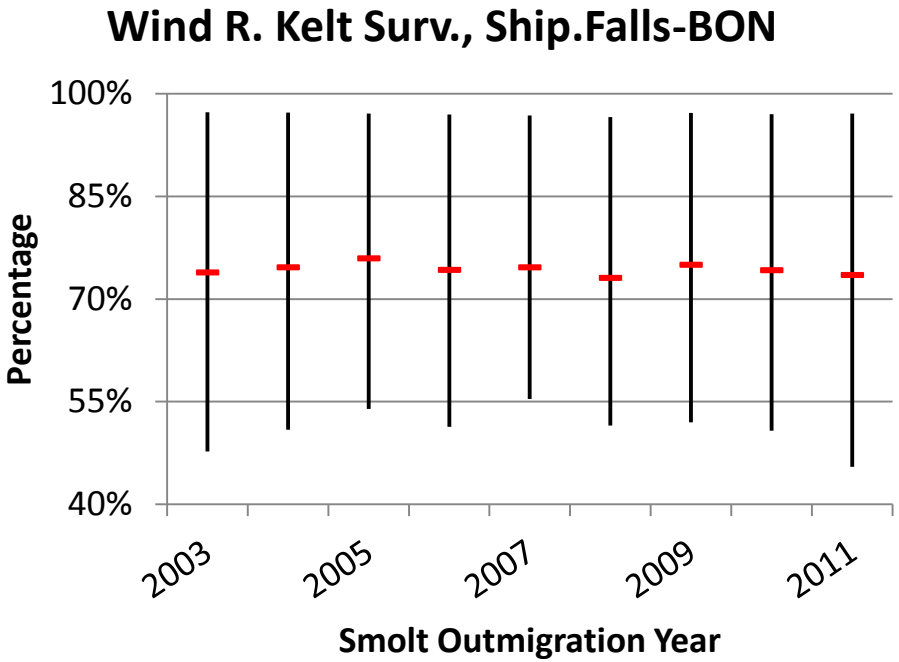
Wind R. Smolt Survival, BON-Estuary

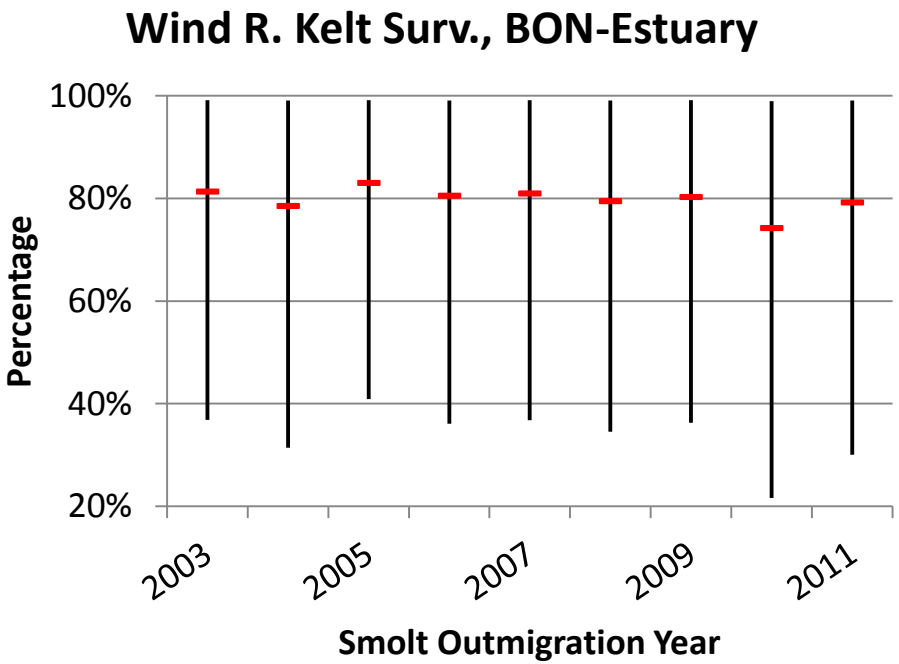


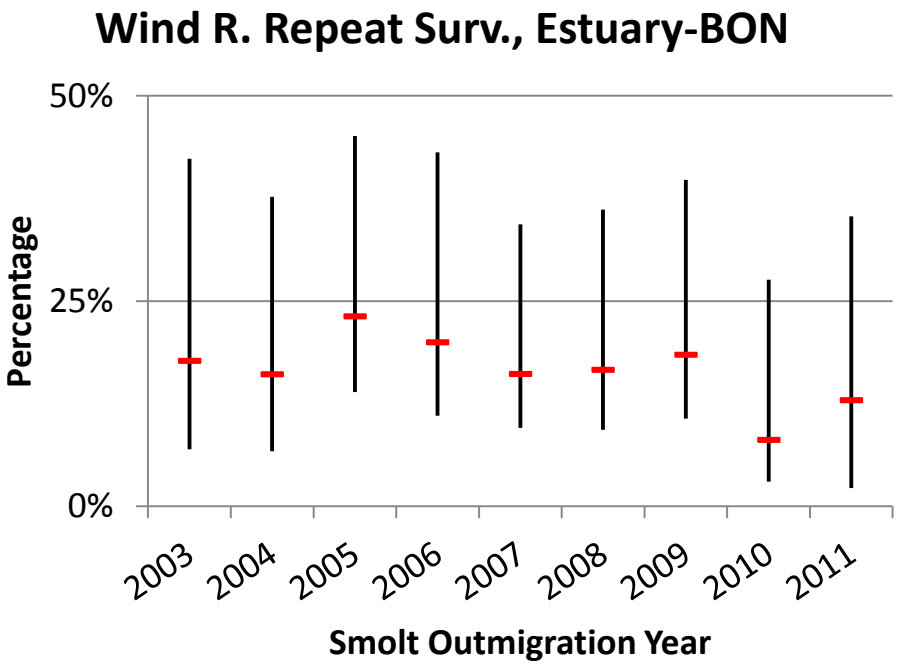
Wind R. SAR, Estuary-BON



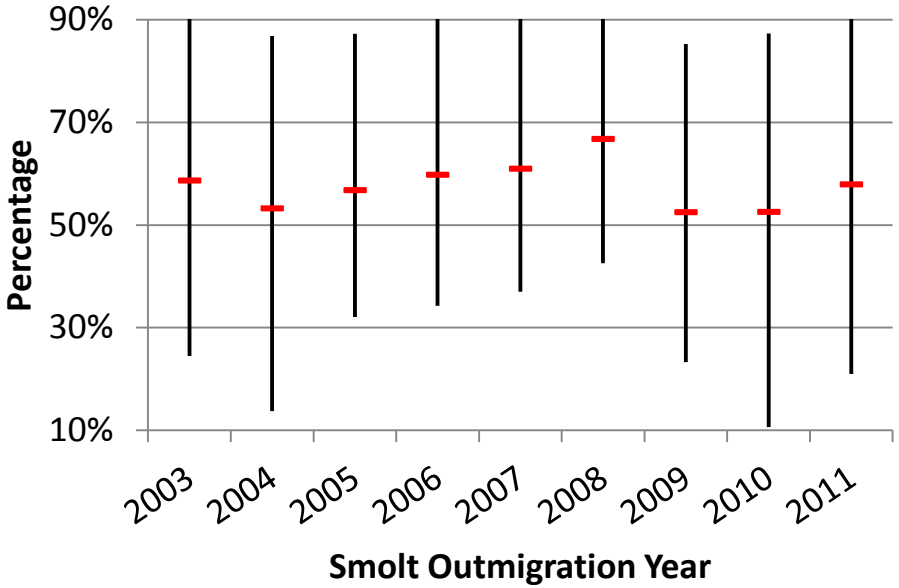

Wind R. Adult Surv., BON-Ship.Falls
90%
65%
40%
Percentage
2003
2004
2005
2006
2007
2008
2009
2010
2011
Smolt Outmigration Year


Wind R. Kelt Surv., Ship.Falls-BON
100%
85%
70%
55%
40%
Percentage
2003
2005
2007
2009
2011
Smolt Outmigration Year

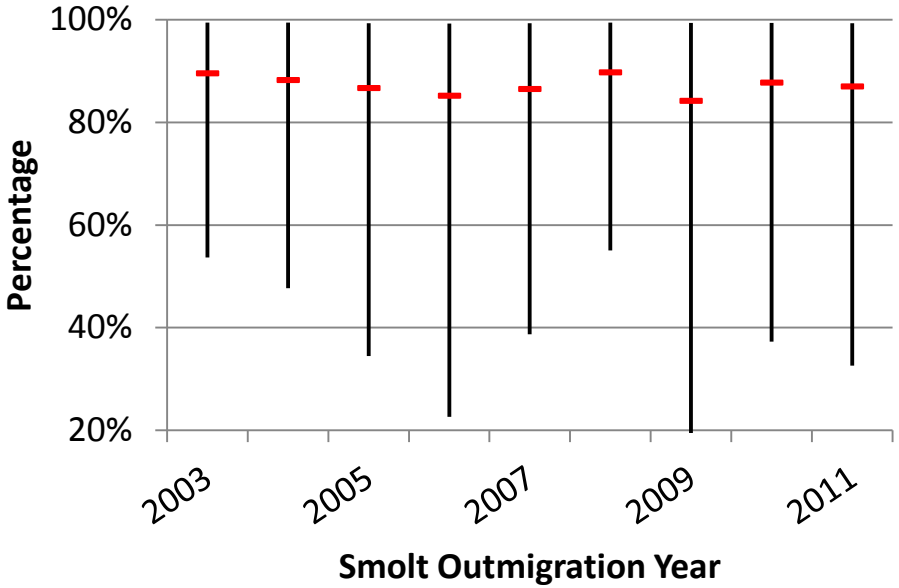

Wind R. Kelt Surv., BON-Estuary
100%
80%
60%
40%
20%
Percentage
2003
2005
2007
2009
2011
Smolt Outmigration Year


Wind R. Repeat Surv., Estuary-BON
50%
25%
0%
Percentage
2003
2004
2005
2006
2007
2008
2009
2010
2011
Smolt Outmigration Year

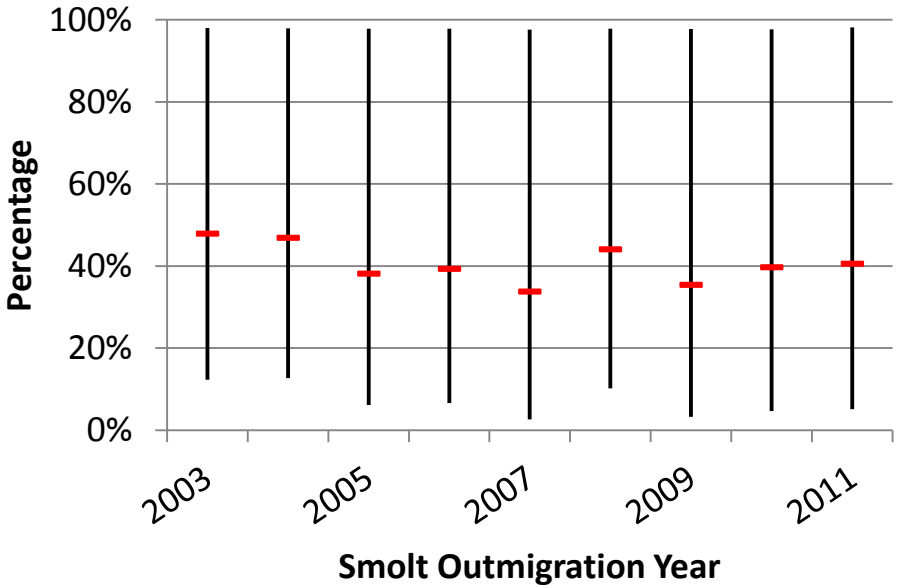
Wind R. Repeat Surv., BON-Ship.Falls



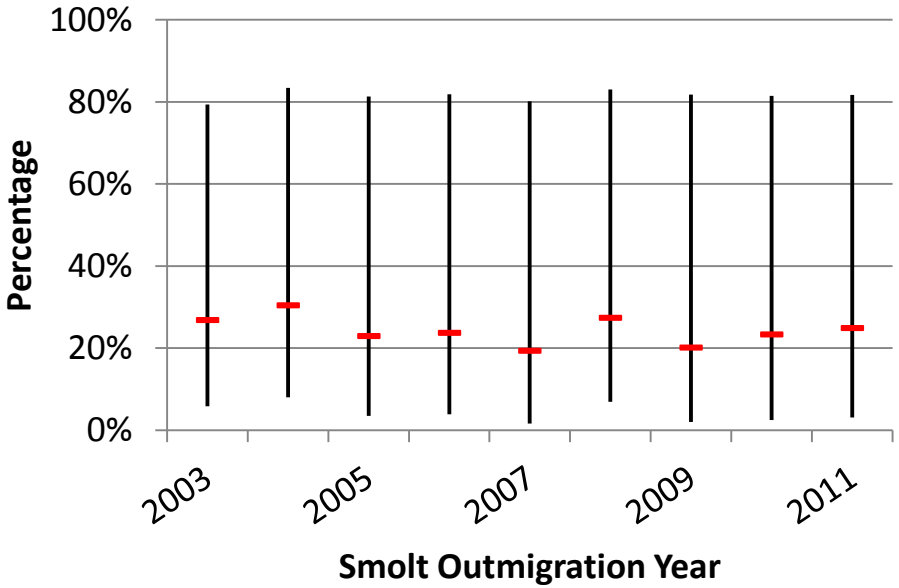
Wind R. Kelt2 Surv., Ship.Falls-BON



Wind R. Kelt2 Surv., BON-Estuary



Wind R. Repeat2 Surv., Estuary-BON



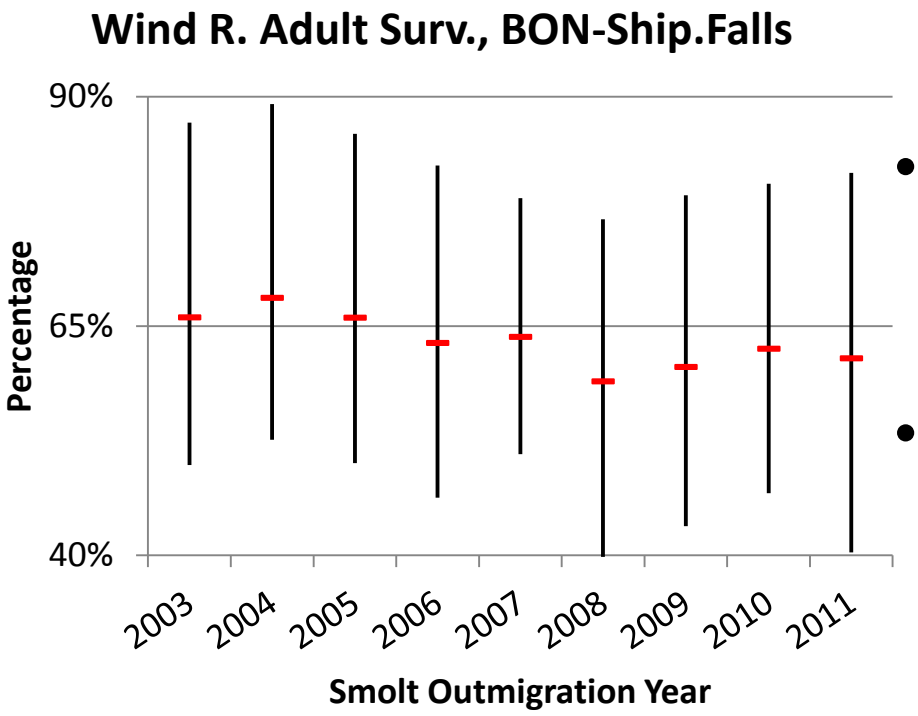
CJS Assumptions

- Every marked fish present at sampling period *i* has the same prob. of capture (*p*). Every marked animal present at sampling period *i* has the same prob. of survival (ϕ) to the next period.
  - Based on omnibus Bayesian GOF test (*P*-values [0.10-0.60]) assumption is met. Similar GOF tests in the program MARK.
- Marks are not lost/overlooked and correctly reported.
  - Short-term tag loss in Wind parr and smolt from double tagging experiments <1%; tagged in dorsal sinus (not expelled during spawning).
  - Knudsen et al. (2009) identified tag loss and mortality (2% juveniles & 18% adults) with PIT tags for hatchery spring Chinook salmon; so our survival estimates are likely biased low until adult stage at BON if Knudsen results are applicable.

CJS Assumptions

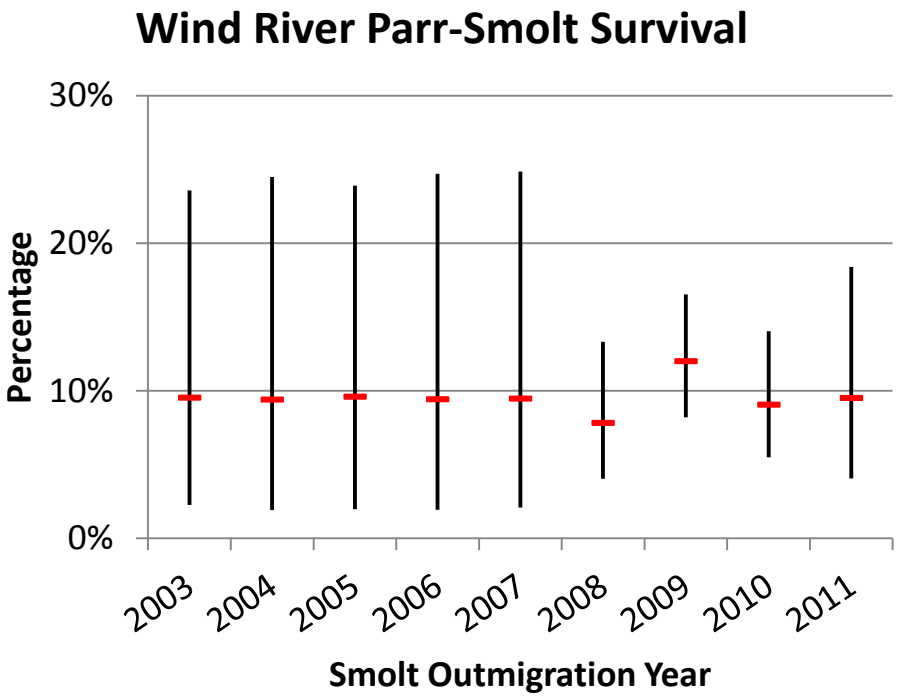
- Sampling is instantaneous and all fish are released immediately after capture.
  - Juvenile and kelt sampling is ~2 months but adult sampling at BON and SF is 12 months.
  - Simulations by Hargrove and Borlund (1994) suggests parameters not too sensitive to this assumption.
- The fate of each fish with respect to capture and survival probability is independent of the fate of other fish.
  - If this assumption not met this leads to overdispersion; estimates will be unbiased but variance will be underestimated.

Management Implications



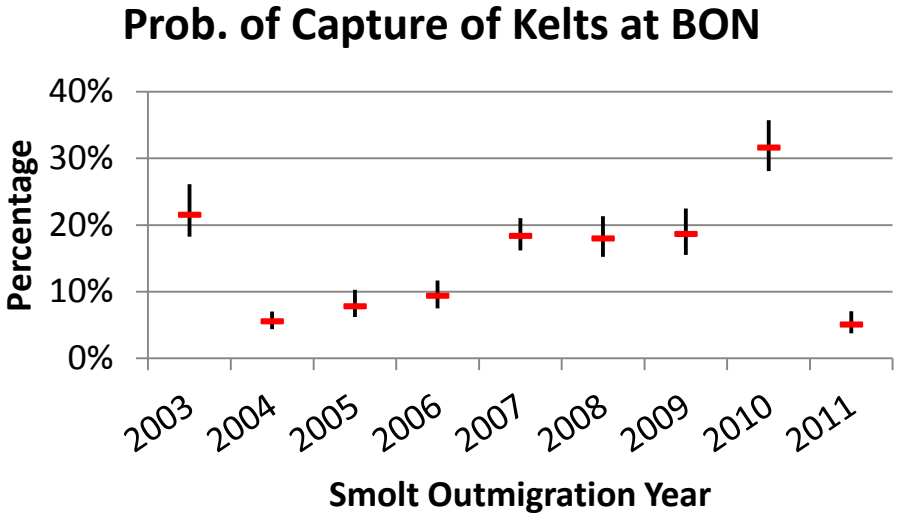
- Approximately 35% of the Wind River steelhead do not survive the 13 miles from BON to SF.
- Wind River PIT tag Z6 fall harvest rate~ 7% in 2010 & 2011
- Harvest rates are unknown in other Z6 fisheries and recreational wild release fisheries.
- Over 25% of the adult wild steelhead passing BON are unaccounted for

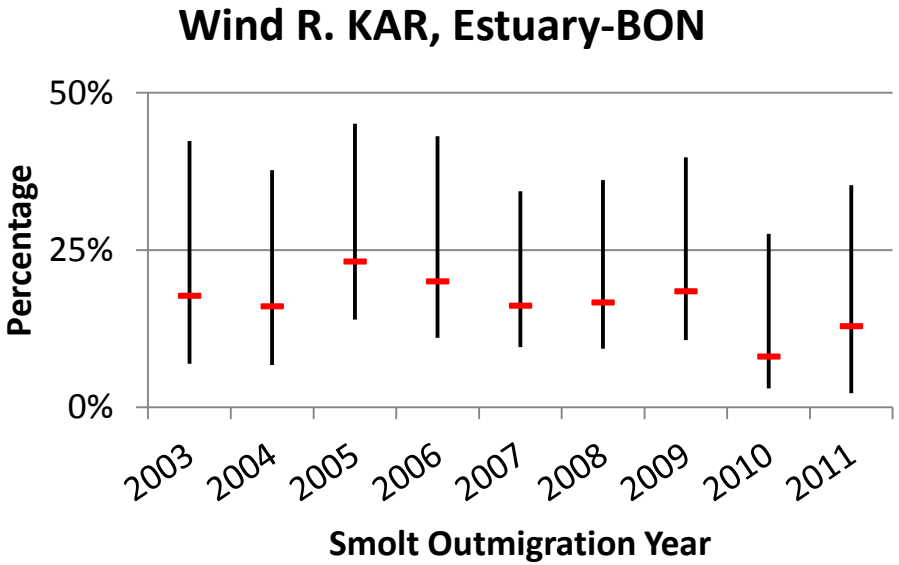
Management Implications



- Apparent survival for parr to smolt is ~ 10% for primary rearing area between upper and lower traps.
- No parr tagging from 2003 to 2007, so the estimate is the hierarchical estimate.
- Density dependence & parr residualization may contribute to the low survival for this life stage.

Management Implications





- Approximately 17% (range 5% to 30%) of the kelts are detected at BON; most are detected in the corner collector or ice and trash sluiceway.
- Approximately 20% of the kelts (range 5% to 25%) survive from entry into the estuary as kelts to returning adults (repeats) at BON.

Summary

- CJS model is typically applied to in the Columbia River to estimate juvenile reach survival but can be used to estimate survival/mortality by life stage for anadromous fish.
- This approach allows an estimate of survival by life stages/migration periods to identify limiting stages.
- Poor precision on double repeat spawner survival and capture estimates due to few tags and low detection probabilities for kelts.
- When few tags are releases or when detection rates are low, hierarchical models can improved the precision of estimates given the assumption of exhangability.
- Model selection and GOF tests support the use of hierarchical models for Wind River CJS life cycle model.

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