Estimating Stage-Specific Survival and Abundance for Anadromous Salmonids using the Multistate Emigration Model

Mariska Obedzinski
CA Sea Grant / University of CA Cooperative Extension

Gregg Horton
Sonoma County Water Agency

INTRODUCTION

The California Coastal Monitoring Program (CMP) lists estimates of smolt and returning adult abundance at Life Cycle Monitoring Stations as the basis for estimating freshwater and ocean survival for anadromous salmonid populations in coastal California river systems (i.e. $N(time^2)/N(time^1)$) (Adams et al. 2011). Unfortunately, the difficulties inherent in operating trapping facilities during high water conditions prevalent during winter-time coho and steelhead migration periods make this a difficult task (Figure 1).

Figure 1. Adult trap on Mill Creek during base flow and storm flow conditions.

Seasonal and unpredicted data gaps are caused by trap failures due to high flow events and the fact that traps are typically operated only during "peak" migration seasons for smolts and adults (Figure 2) .

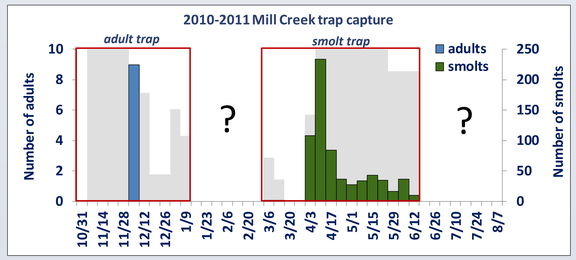

Figure 2. Individuals captured each week during adult and smolt trapping seasons. Shaded background indicates when the traps were operational.

An additional problem is that life-cycle monitoring programs are often conducted in smaller, headwater streams located far away from the ocean thus leading to estimates of survival that may be confounded among habitat types. For example, in Mill Creek, located 55 km from the Pacific Ocean, estimates of marine survival are confounded with riverine and estuarine survival (Figure 3).

Figure 3. Map of Mill Creek located in the Russian River watershed, California.

Mill Creek Watershed

- *58 km² watershed, 29 km salmonid habitat*
- *Life cycle monitoring stream for coho and steelhead*
- *Coho conservation hatchery program*
- *55 km from Pacific Ocean*
- *Riverine and estuarine survival confounded with marine survival*

OBJECTIVES

1. Document year-round fish movement patterns through key habitats in the Russian River using PIT tag detection systems.
2. Estimate life-stage specific survival of coho populations by applying the multistate emigration model to Mill Creek data.

FIELD METHODS

- FDX PIT tag detection systems placed at key habitat transitions along migration corridor (Figure 4).
- Flat plate antennas operated year-round in conjunction with seasonal smolt trap on Mill Creek.
- PIT-tagged juvenile coho released into Mill Creek in the fall.

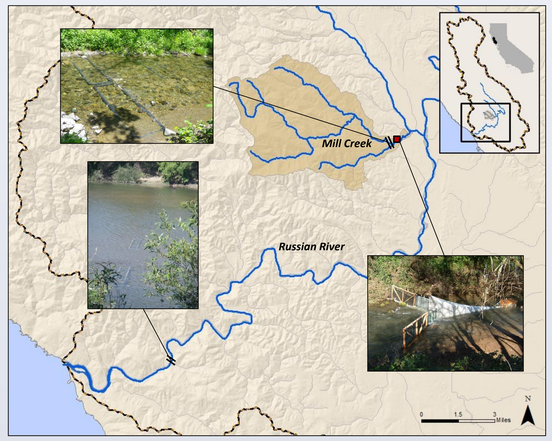

Figure 4. Map of PIT tag detection sites along coho salmon migration corridor in the Russian River watershed.

MULTISTATE EMIGRATION MODEL

- Separate mortality from pre-smolt emigration using an individual-based model incorporating continuous emigration detection data (e.g. PIT detections) and data from discrete sampling events (Horton et al. 2011) (Figure 5).
- Applied model through the smolt stage for five cohorts and through the adult stage for one cohort (Program MARK, White and Burnham 1999).
- Used a simulation approach to gain an understanding of the relationship between the number of individuals tagged and precision over a range of survivals.

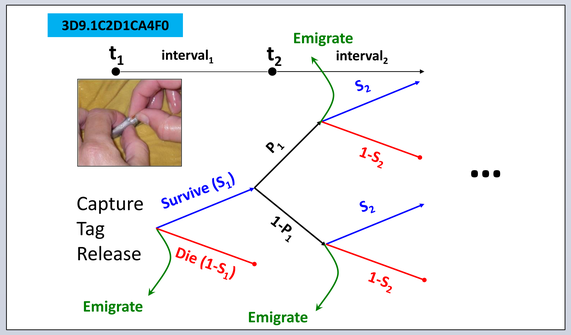

Figure 5. Application of multistate emigration model to a population of PIT-tagged individuals.

RESULTS

Year-round juvenile movement patterns:

- Juvenile coho were detected emigrating from Mill Creek during fall and winter prior to installation of a smolt trap each year (Figure 6).
- Proportion of juveniles moving during fall and wintered varied by year (Figure 6).

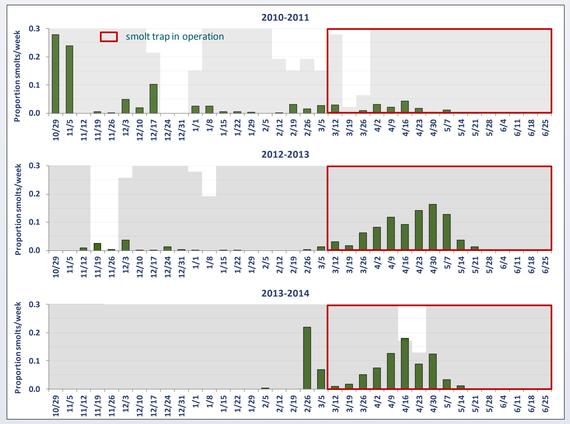

Figure 6. Proportion of unique coho detections each week between late October and mid-June. Shaded background represents when PIT antennas were in operation.

Estimates of true survival and pre-smolt emigration:

- Individuals leaving Mill Creek prior to 3/1 were considered pre-smolt emigrants.
- The multistate emigration model was used to estimate fall to smolt survival and pre-smolt emigration for five cohorts of coho salmon in Mill Creek (Figure 7).

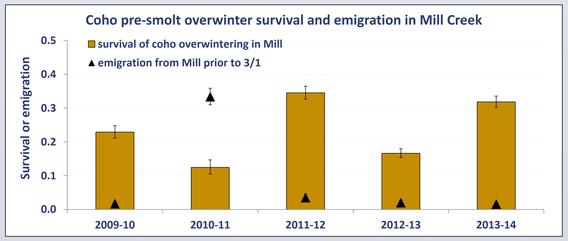

Figure 7. Mill Creek coho salmon overwinter survival and pre-smolt emigration.

- Fork length at tagging in the fall was used as an individual covariate in the multistate emigration model to test for a relationship between size and pre-smolt emigration.
- Fish that were larger in the fall had a higher probability of emigrating prior to 3/1 (Figure 8).

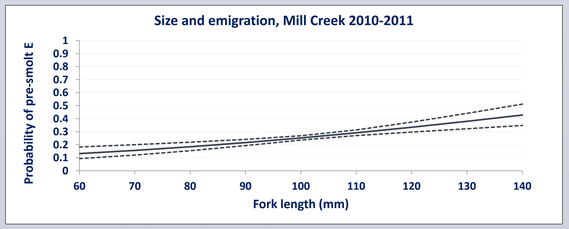

Figure 8. Relationship between fall size and pre-smolt emigration.

RESULTS (*continued*)

Application of full life cycle model:

- The multistate emigration model was used to estimate juvenile overwinter survival, pre-smolt emigration, and estuarine + marine survival for the 2010 Mill Creek cohort (Figure 9).

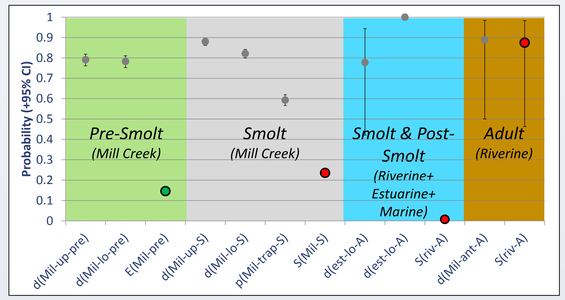

Figure 9. Estimated probabilities from the multistate emigration model, Mill Creek, 2010.

Simulations: How many fish do I need to PIT tag?

- We simulated data sets with a range of underlying probabilities (true survival, emigration, antenna detection, trap recapture) based on observed data from five years of coho salmon monitoring of fish tagged in Mill Creek.
- Simulated data sets were then input to Program MARK using the multistate emigration structure to obtain estimates of pre-smolt emigration and survival to the smolt and adult stages.
- Estimates of true survival were evaluated by plotting the coefficient of variation (CV) as a function of number of PIT-tagged smolts and stage-specific survival (Figure 10).

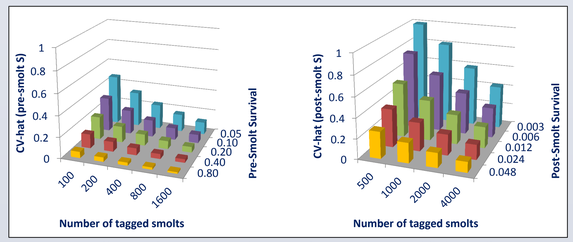

Figure 10. Coefficient of variation as a function of pre-smolt survival (left panel), post-smolt survival (right panel) and number of PIT-tagged smolts.

REFERENCES

Adams P. B., L. B. Boydstun, S. P. Gallagher, M. Lacy, T. McDonald, K. Shaffer. 2011. California coastal salmonid population monitoring: strategy, design, and methods. Fish Bulletin 180. California Department of Fish and Game. 82 pp.

Horton, G.E., B.H. Letcher, and W.L. Kendall. 2011. A multistate capture-recapture modeling strategy to separate true survival from permanent emigration for a passive integrated transponder tagged population of stream fish. Transactions of the American Fisheries Society 140, 320-333.

White, G. C. and Burnham, K. P. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46: 120-139.

ACKNOWLEDGEMENTS

Significant core funding and support was provided by multiple partners:

This project would not be possible without the dedicated field and hatchery crews and the gracious support of hundreds of private landowners.