Using demographic rates to estimate freshwater productivity of anadromous *Oncorhynchus mykiss* (steelhead) in the Skagit River, Washington.

Michael LeMoine

Upper Skagit Indian Tribe

Skagit Steelhead Recovery

- Single stage adult to adult
- Prioritizing recovery actions
- Identify gaps in knowledge
  - Constraining stages
  - Habitat impacts on productivity
  - Reach scale***

RJ Schulyer on the Skagit River

Tributary Production

- Assess constraining stage
  - Survival across stages
  - Vital rate models
- Conditional life strategy

Step 1 Estimating Survival

- Cormack–Jolly–Seber (CJS) model
  - Apparent survival and probability of detection
- Barker model (Connor et al. 2015)
  - Survival , fidelity, and probability of detection
  - Program MARK (MLE)
  - LDLDLD

Animal Biodiversity and Conservation 27.1 (2004) 177

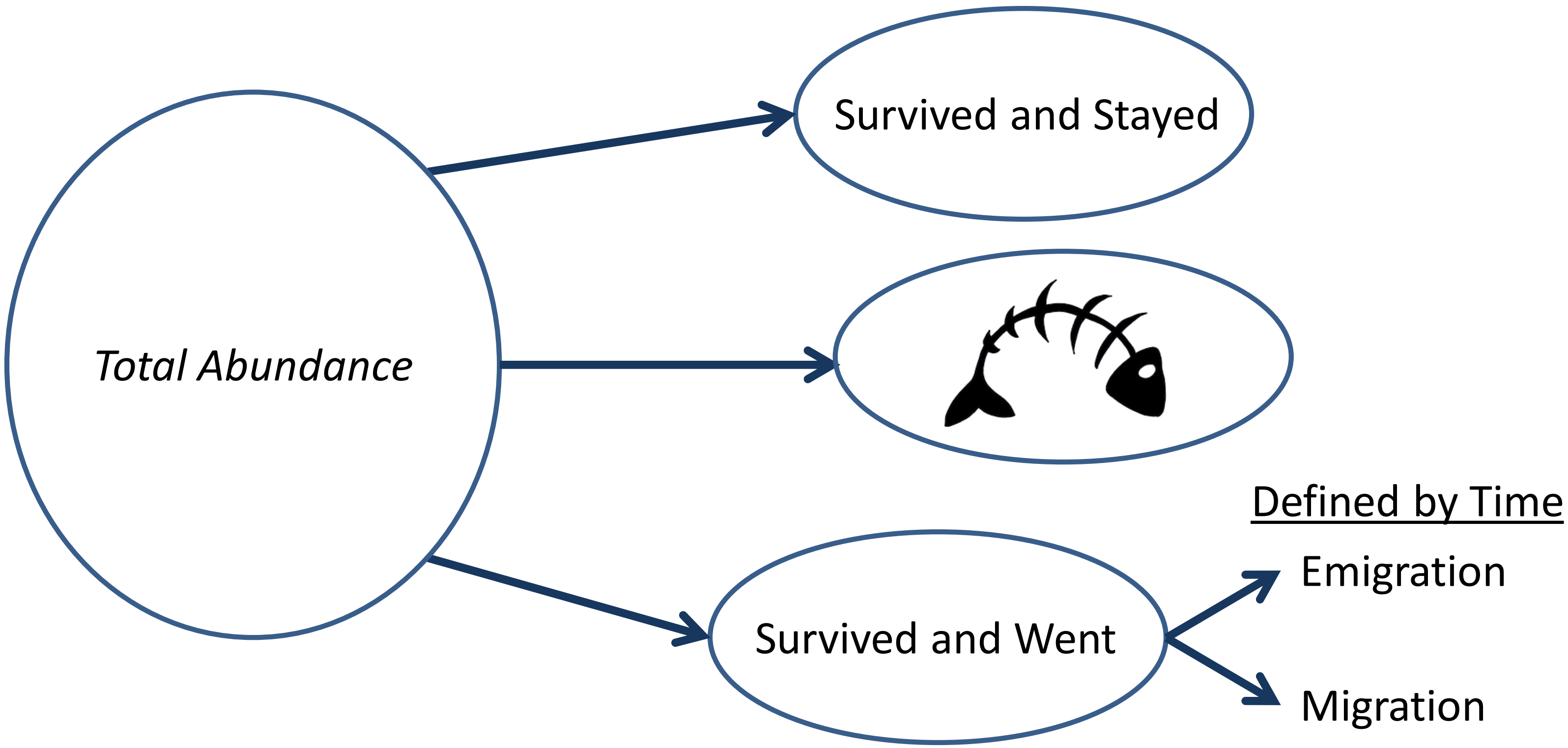
Towards the mother–of–all–models: customised construction of the mark–recapture likelihood function

R. J. Barker & G. C. White

Tributary Model

Fall 2016
<u>Mark/Recapture</u>
Back Electrofishing

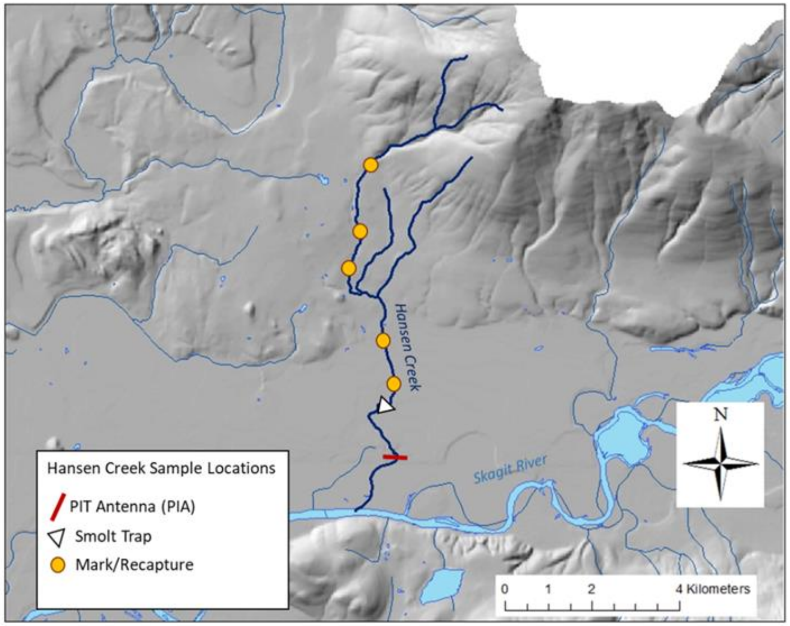
2016-2017
<u>Resight/Recovery</u>
Passover PIT Antenna Array
Mobile PIT Antenna

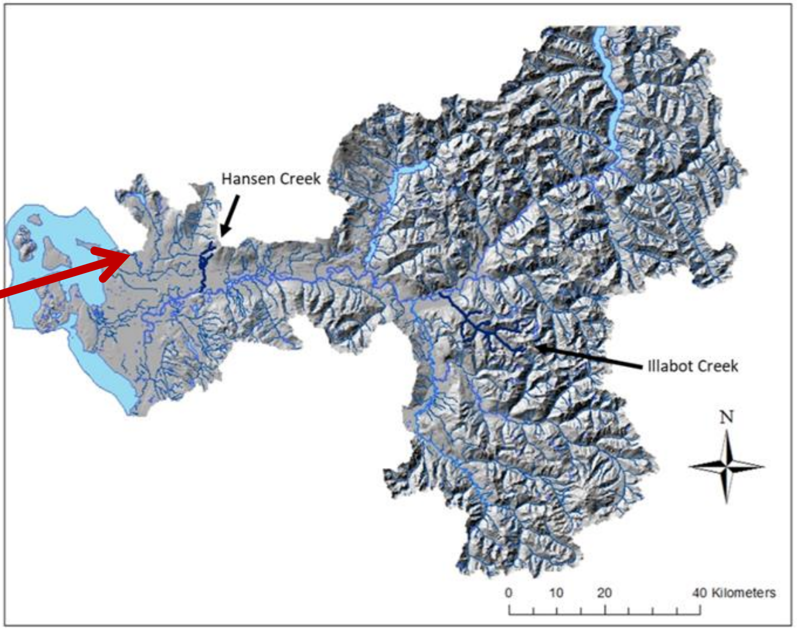


Naive model (S,F,R) with time varying p

Winter Steelhead

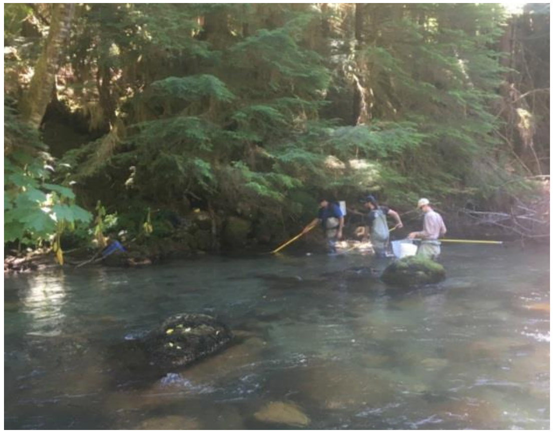
- Hansen Creek
  - rain system (warmer and low gradient)
  - smolts generally 2 year olds (~150 mm FL)
- Illabot Creek
  - snow/rain system (cooler, high gradient)
  - smolts generally 3 year olds (~170 mm FL)





Tributary Mark-Recaptures

	2016 Marks	2016 Recaps	2017 Marks	2017 Recaps	2016 Recap in 2017
Hansen 1	77	14	69	5	3
Hansen 2	214	71	212	78	12
Hansen 3	85	33	163	53	22
Hansen 4	90	32	144	66	28
Hansen 5	76	58	89	46	23
Hansen Total	542	218	677	248	88
Illabot 1	71	5	37	4	0
Illabot 2	178	26	97	10	9
Illabot 3	217	32	115	27	17
Illabot 5	87	16	117	20	18
Illabot Total	553	159	366	88	44



Resight-Recoveries

PIT Antenna Arrays

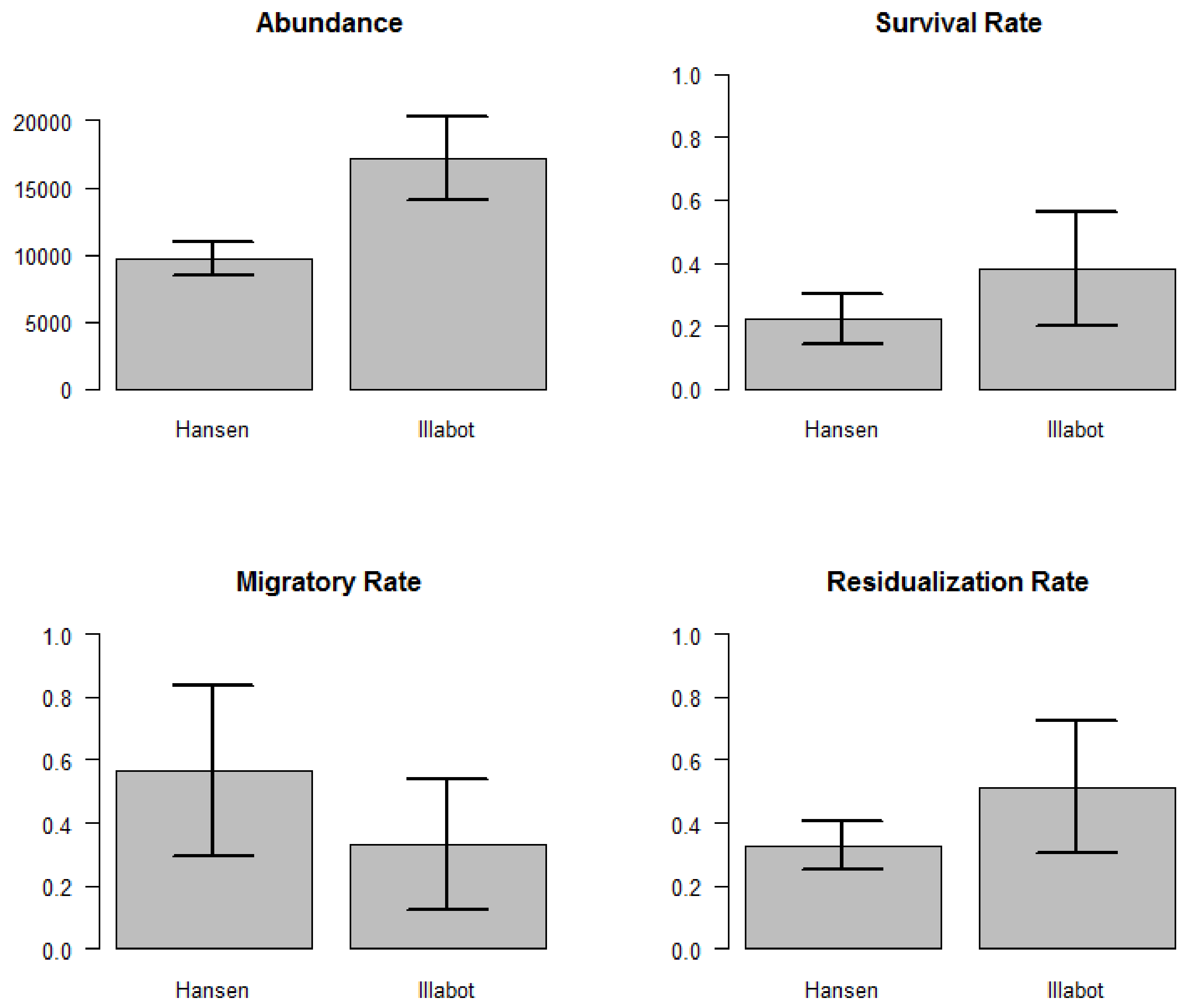
Hansen PIA p=0.88

Illabot PIA p=0.82

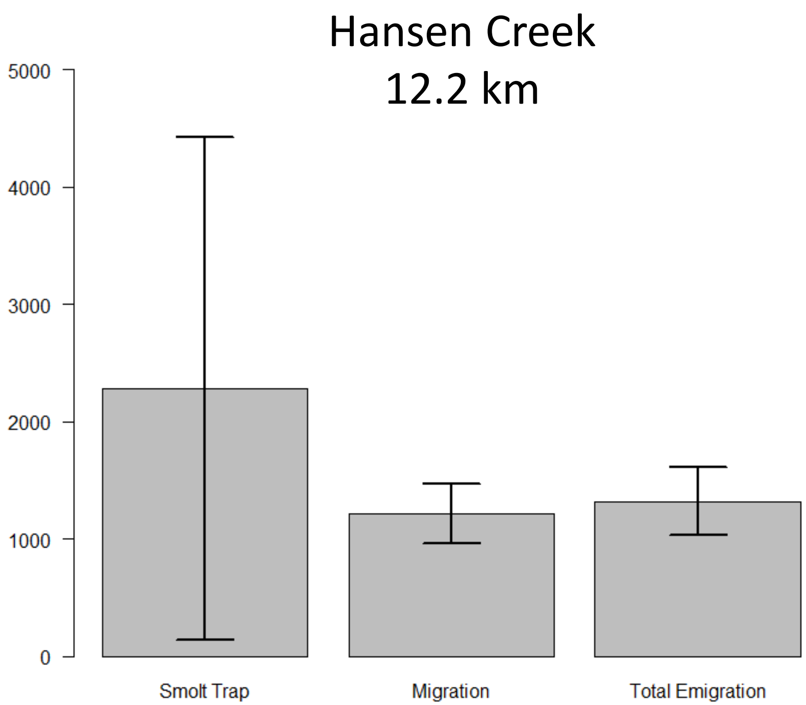
Mobile PIT

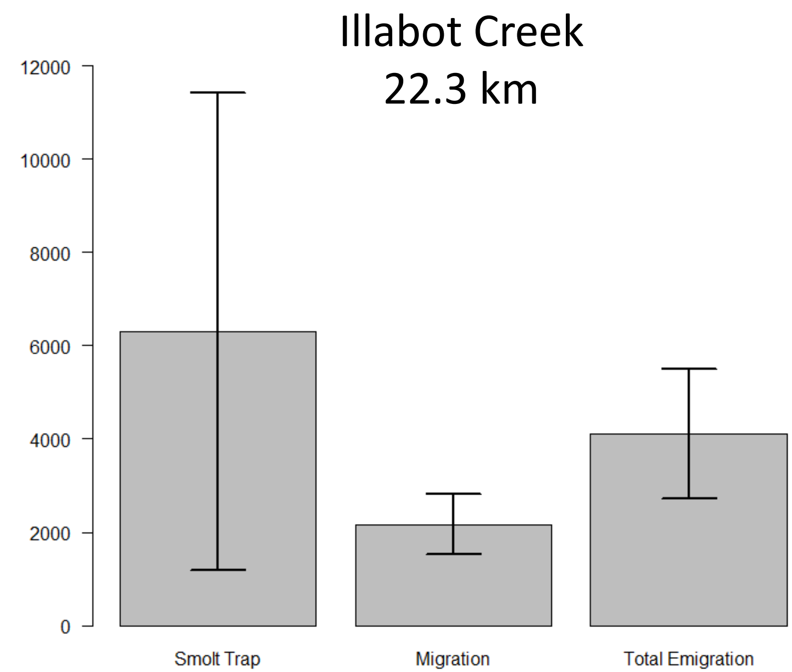
Hansen		**Oct. 16**	**Dec. 16**	**Jan. 17**	**Jul. 17**
Live|Dead		122|22	75|14	4|3	93|8
	p	0.54 (0.22)	0.42 (0.12)	0.01(0.01)	0.33 (0.18)

Illabot		**Oct. 16**	**Nov. 16**	**Jan. 17**	**Jul. 17**
Live|Dead		12|3	12|7	9|4	11|0
	p	0.06 (0.02)	0.02 (0.01)	0.08 (0.02)	0.13 (0.03)


Abundance
20000
15000
10000
5000
0
Hansen
Illabot
Survival Rate
1.0
0.8
0.6
0.4
0.2
0.0
Hansen
Illabot
Migratory Rate
1.0
0.8
0.6
0.4
0.2
0.0
Hansen
Illabot
Residualization Rate
1.0
0.8
0.6
0.4
0.2
0.0
Hansen
Illabot

Production

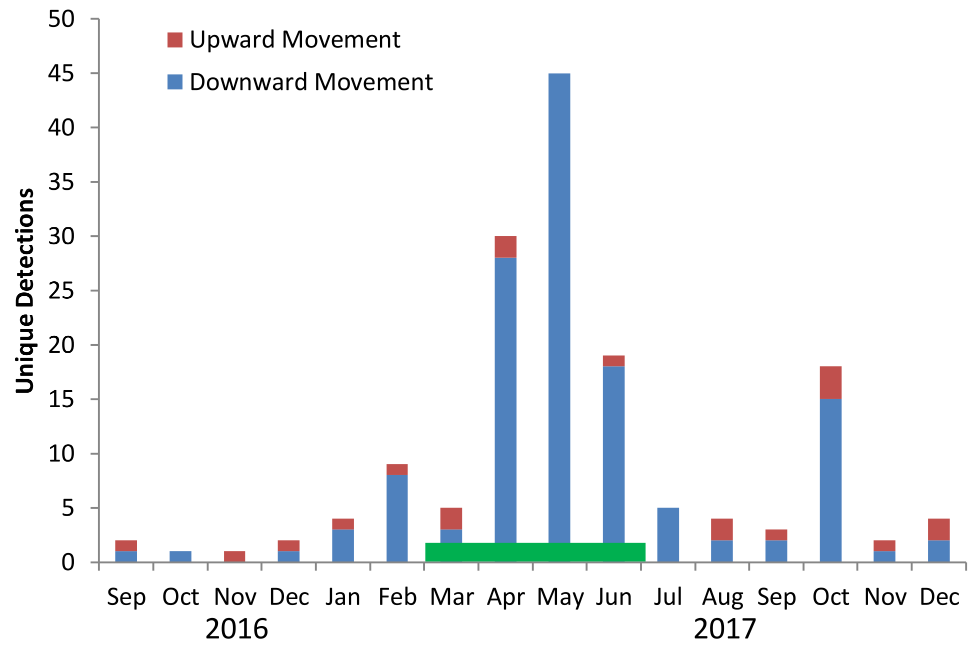




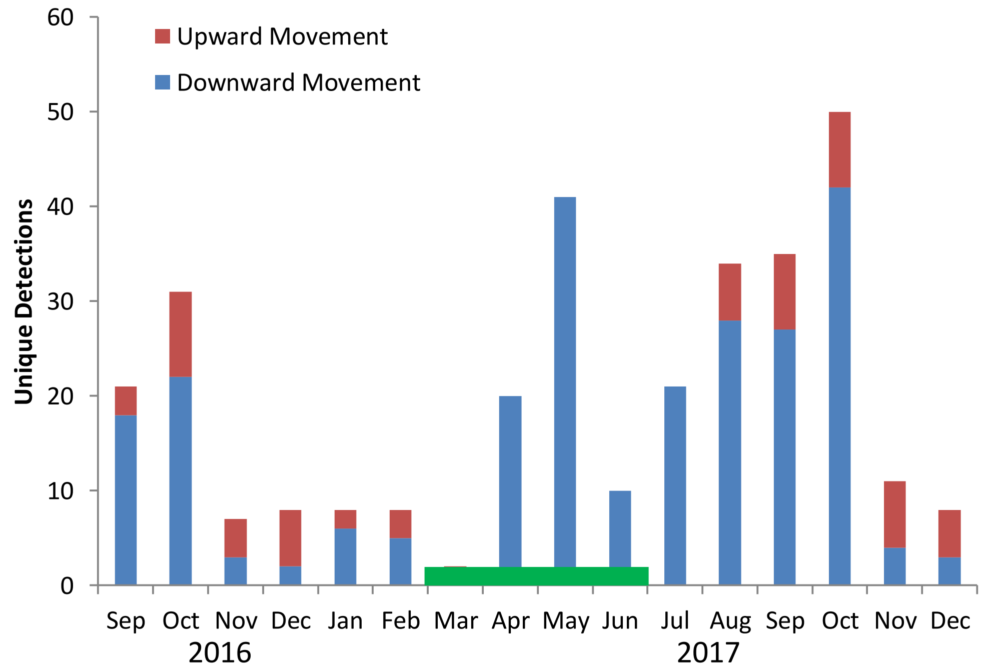
Tributary Abundance * Survival * Total Emigration Rate

Tributary Abundance * Survival * Migration Rate

Hansen Creek



Illabot Creek



Migratory Period

Step 2 Vital Rate Model

- Mohapatra et al. (2015) develop vital rate models for partial migration
  - Before birth pulse
  - Female only to adult

$$\boldsymbol{X}(t+1) = A_1(\boldsymbol{X}(t))\boldsymbol{X}(t), \tag{11}$$

where $A_1(\boldsymbol{X}) = \begin{pmatrix} 0 & f_2^s & \cdots & f_n^s & f_2^r & \cdots & f_{m-1}^r & f_m^r \\ \phi t_1^s(x_1) & 0 & \cdots & 0 & 0 & \cdots & 0 & 0 \\ \vdots & \ddots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ 0 & \cdots & t_{n-1}^s(x_{n-1}) & t_n^s(x_n) & 0 & \cdots & 0 & 0 \\ (1-\phi)t_1^r(x_1) & 0 & \cdots & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & \cdots & 0 & t_2^r(x_{n+1}) & \cdots & 0 & 0 \\ \vdots & \vdots & \cdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & 0 & \cdots & t_{m-1}^r(x_{n+m-2}) & t_m^r(x_{n+m-1}) \end{pmatrix}, \quad \boldsymbol{X} = \begin{pmatrix} \text{eggs}(x_1) \\ \text{first migrant stage}(x_2) \\ \vdots \\ \text{last migrant stage}(x_n) \\ \text{first resident stage}(x_{n+1}) \\ \vdots \\ \text{last resident stage}(x_{n+m-1}) \end{pmatrix}$$

Very Simple Vital Rate Model

- Adapted model
  - Survival then migration
  - Both sexes
  - 1 time step smolt

Hansen Creek

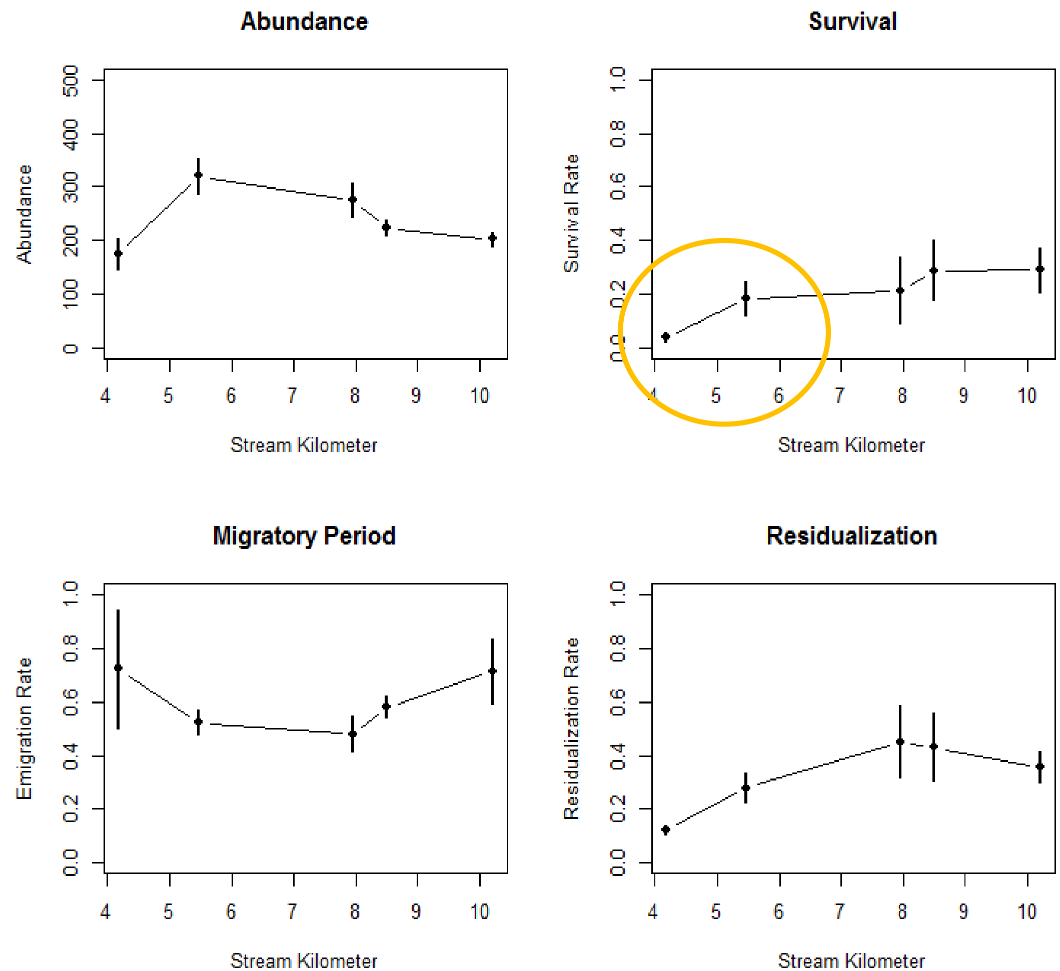
$$
\begin{array}{l}
 \\
age_{yoy} \\
age_1 \\
age_2 \\
age_3
\end{array}
\begin{array}{c}
N_t \\
\begin{bmatrix} 4502 \\ 3211 \\ 1223 \\ 845 \end{bmatrix}
\end{array}
\qquad
\begin{array}{cccc}
S_1*E_1 & S_2*E_2 & S_3*E_3 & S_4*E_4
\end{array}
$$

$$
\begin{bmatrix}
0 & 0 & 0 & 0 \\
0.15 * 0.14 & 0 & 0 & 0 \\
0 & 0.34 * 0.82 & 0 & 0 \\
0 & 0 & 0.33 * 0.31 & 0.40 * 0.15
\end{bmatrix}
$$

Over parameterized model

Hansen Creek (Survival Issue)

- 3% survival near mouth
- High temperatures and low flows
- Younger age classes
- 6% survival --> 18% more emigrants



Illabot Creek

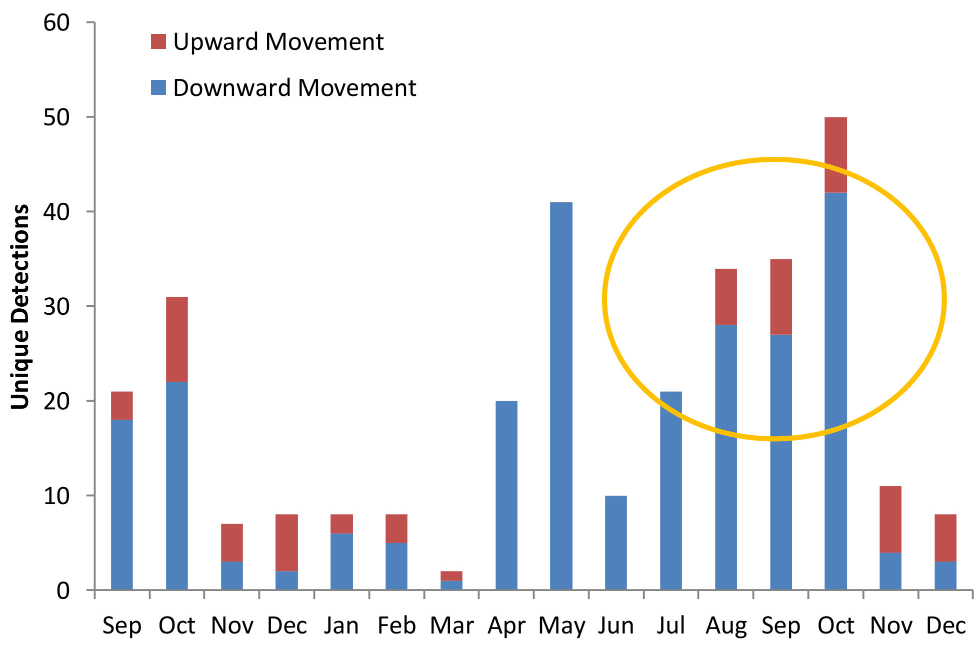
- Freshwater only
- Post Birth
- Both Sexes
- Start at age 1

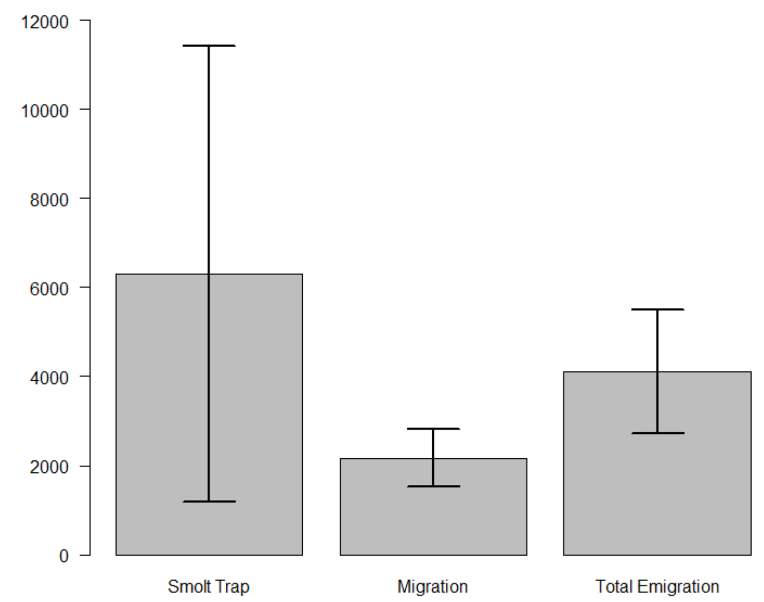
$$
\begin{array}{cc}
 & N_t \\
\begin{array}{c} age_1 \\ age_2 \\ age_3 \\ age_4 \\ age_5 \end{array} &
\begin{bmatrix} 7231 \\ 7023 \\ 2236 \\ 1012 \\ 308 \end{bmatrix}
\end{array}
\quad
\begin{array}{c}
\begin{array}{ccccc} S_1{*}E_1 & \quad S_2{*}E_2 & \quad S_3{*}E_3 & \quad S_4{*}E_4 & \quad S_5{*}E_5 \end{array} \\
\begin{bmatrix}
0 & 0 & 0 & 0 & 0 \\
0.28 * 0.02 & 0 & 0 & 0 & 0 \\
0 & 0.42 * 0.33 & 0 & 0 & 0 \\
0 & 0 & 0.51 * 0.88 & 0 & 0 \\
0 & 0 & 0 & 0.61 * 0.55 & 0.66 * 0.14
\end{bmatrix}
\end{array}
$$

Over parameterized model

Illabot Creek (River rearing type)

- Estimate abundance by age of river-type emigrants
- Apply age specific survival and emigration rates
  - Potential of 937 migrants from river rearing





Conclusions

- Viable method
  - Estimates of productivity
  - Survival, emigration, site fidelity
- Survival and emigration differed
- “What if” scenarios
- Less effort than expected

Next Steps

- Mobile PIT surveys
- 3rd Tributary
- In river acoustic
- Vital rate model
  - Pull in published Literature
  - True smolt production?

Diobsud Creek PIA install

Thanks!