Individual-based fish modeling in the Snoqualmie River

Snohomish Basin Salmonid Recovery Technical Committee

April 7 2010

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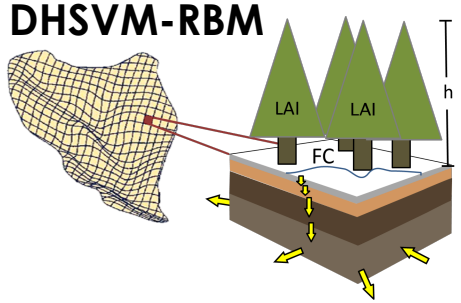
Individual Based Fish Model

Climate change scenarios

Riparian vegetation scenarios

DHSVM-RBM



WDFW

Inputs

spatiotemporally -explicit **water temp. & flow**

+

spawning locations

Model

- spawning & incubation
- movement
- biological interactions
- bioenergetics
- mortality

Outputs*

phenology

&

growth/size

&

survival

*calibrated with empirical data

Data for parameterizing the model:

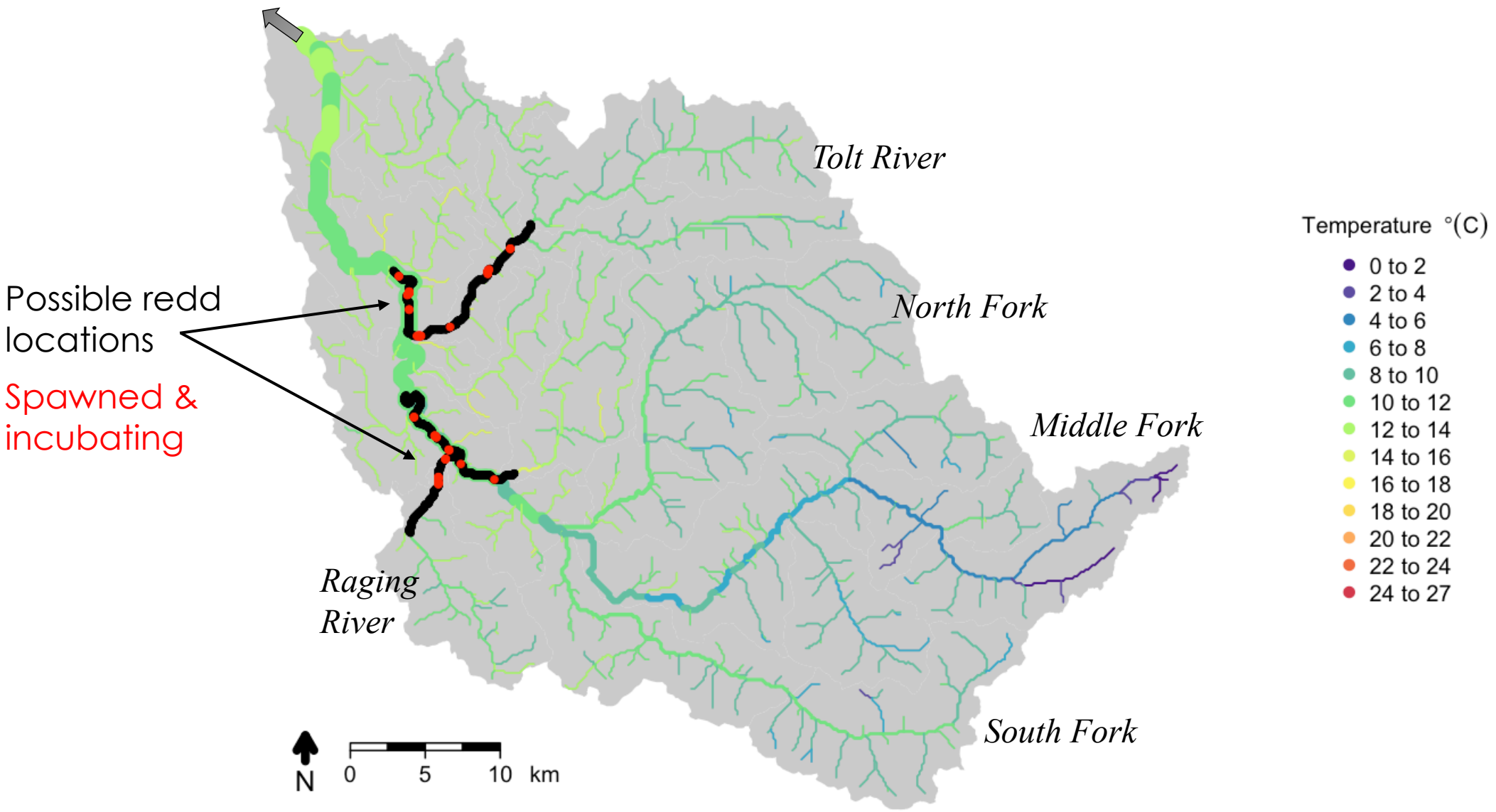
Metric	Min	Mean	Max	Year(s)	Watershed	Source
Species distributions				--	Snoqualmie	StreamNet
Redd locations				2005-2016	Snoqualmie	WDFW data
Spawning begins	4-Sep	11-Sep	23-Sep	2005-2016	Snoqualmie	WDFW data
No. spawn days	10	58	87	2005-2016	Snoqualmie	WDFW data
No. redds	280	851	1435	2002-2012	Snoqualmie	Kubo et al. 2013
Eggs per redd		4558		--	Columbia	McMichael et al. 2005

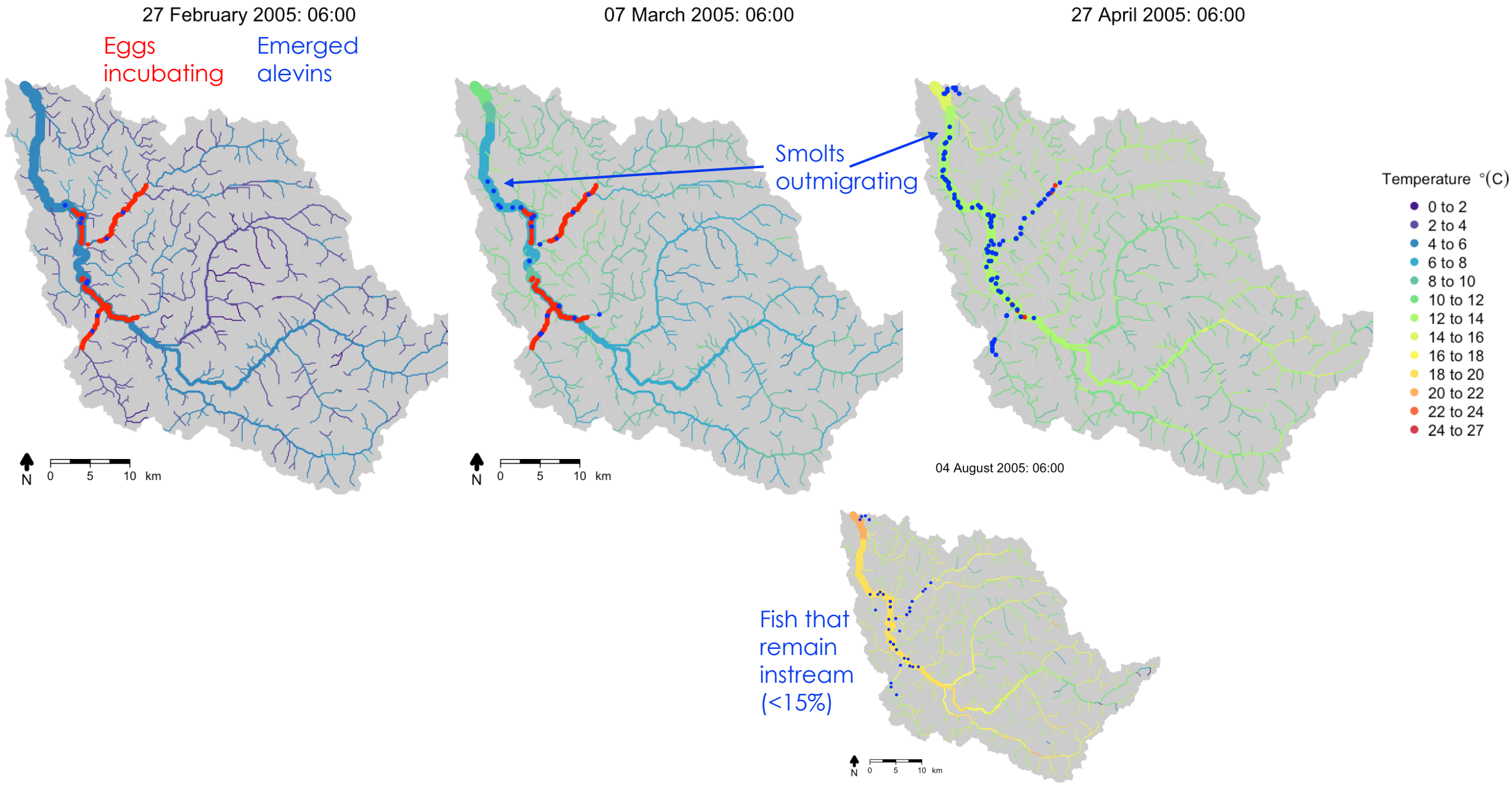
Calibrating emergent outcomes to match:

Spawning ends	21-Oct	8-Nov	5-Dec	2005-2016	Snoqualmie	WDFW data
Emergence begins	mid Dec	Jan	late Jan	--	Snohomish	leDoux et al. 2017
Emergence ends	mid Feb	late Feb	early Mar	--	Snohomish	leDoux et al. 2017
Egg-fry survival	0.090	0.578	0.910	2009-2012	Yakima	Pess 2016
Fry-smolt survival	0.029	0.080	0.218	2002-2016	Snoq.,Yakima	[egg-smolt surv. / mean egg-fry surv.]
Egg-smolt survival	0.017	0.046	0.126	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data
Outmigration begins	early Feb	Mar	early May	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data
Outmigration ends	late May	June	late June	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data
Subyearling migrant weight[1]	1.8g	3.2g	28.1g	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data
Yearling migrant weight, 2nd year[1]	4.0g	9.6g	71.2g	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data
Proportion yearly migrants	0.03	0.14	0.46	2002-2016	Snoqualmie	Kubo et al. 2013; Tulalip data

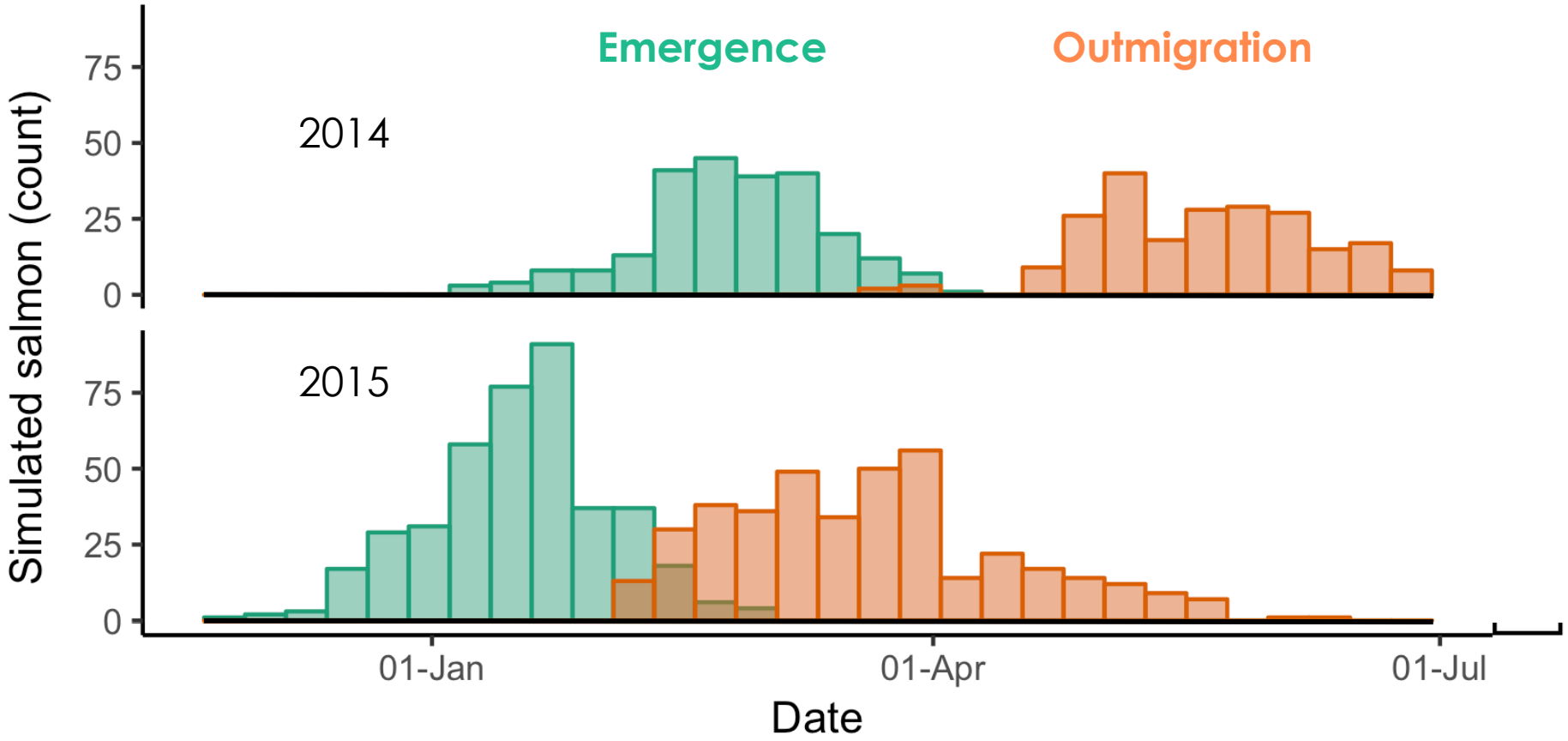
[1] Estimated using fork lengths from Tulalip smolt trap data and the equation $W = 1.07 \times 1.02^{FL}$ from Denny et al. (2014).

15 September 2004: 18:00




27 February 2005: 06:00
Eggs incubating
Emerged alevins
07 March 2005: 06:00
Smolts outmigrating
27 April 2005: 06:00
04 August 2005: 06:00
Fish that remain instream (<15%)
N
0 5 10 km
Temperature °(C)
0 to 2
2 to 4
4 to 6
6 to 8
8 to 10
10 to 12
12 to 14
14 to 16
16 to 18
18 to 20
20 to 22
22 to 24
24 to 27

Example results from a prior study on Chinook salmon in the Snoqualmie River

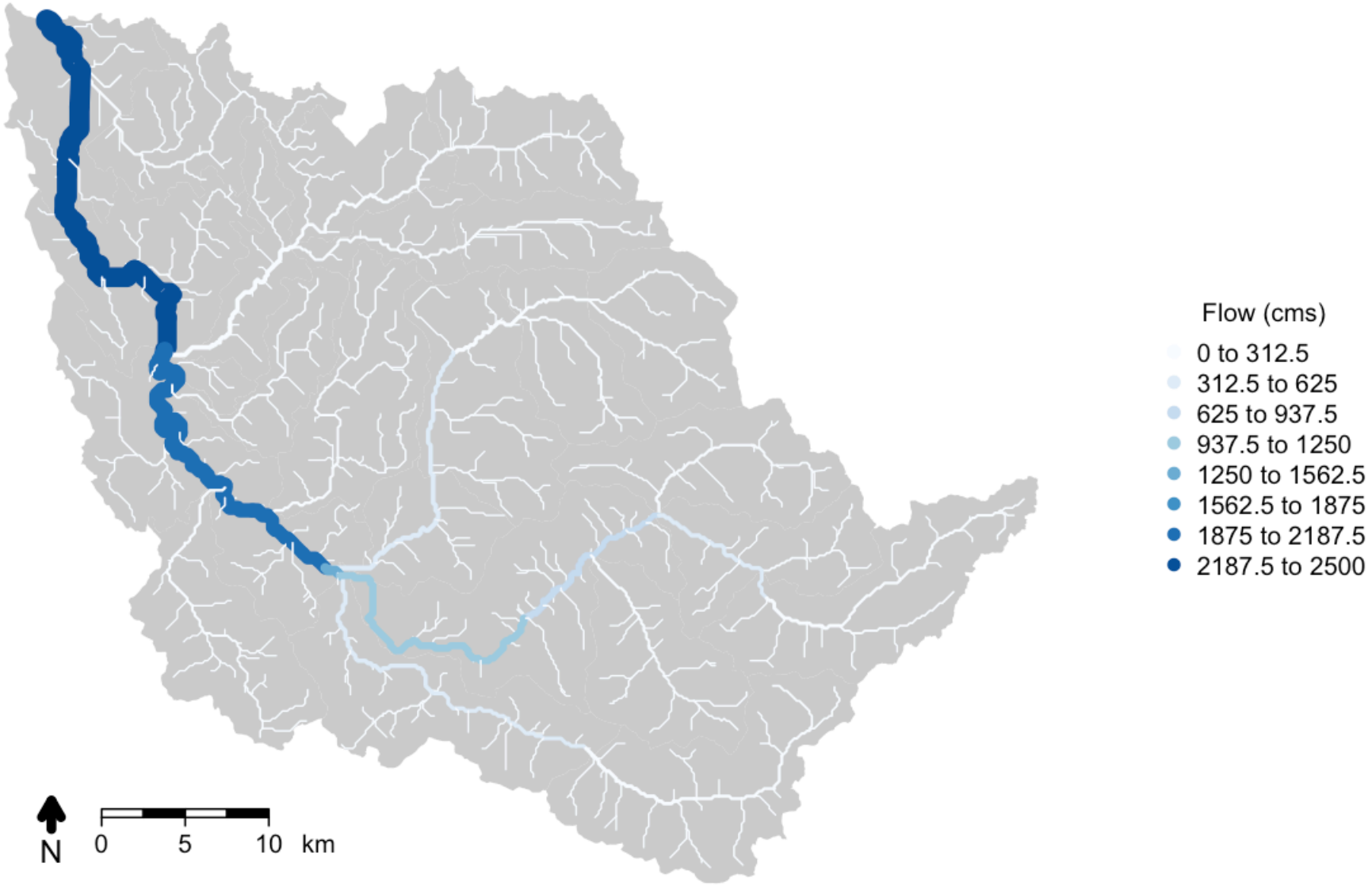


The model also produces fish size distributions, survival, and proportion yearlings

Hawkins et al. in review

07 November 2006: 06:00

(Day of one of the biggest floods on record)



Possible Effects of Flow on Salmon

INCUBATION:
- Redds can be scoured during floods, decreasing egg to fry survival directly.
- Redds can be dewatered during extreme low flow conditions during egg incubation, decreasing survival.

MOVEMENT:
- Increasing flow accelerates downstream movement (smolts may 'ride the wave' out to sea).
- Increasing flow impedes upstream movements by juveniles (rare anyhow?).

GROWTH:
- Flood events increase access to food-rich floodplain habitats, thereby increasing growth.
- With increasing velocity, drift amount increases but capture rate decreases.
- Respiration cost increases (via increased swimming activity) with velocity unless cover is available.

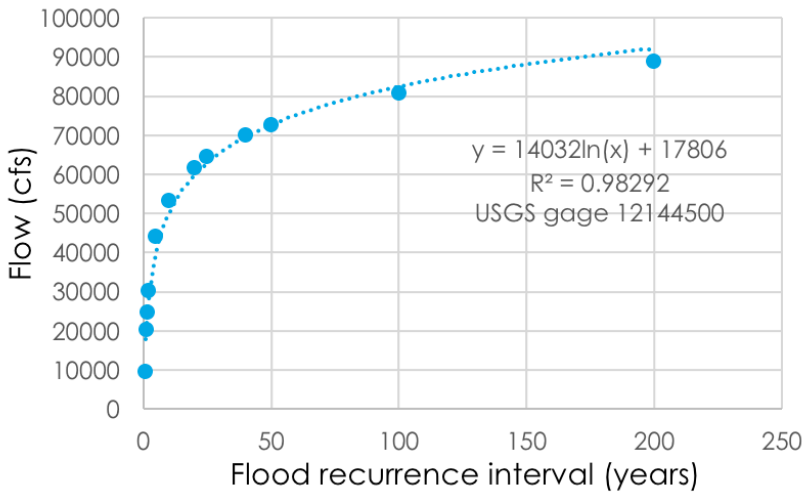
SURVIVAL:
- Direct effects on eggs (see above) and indirect effects manifested through growth and size.
- Big floods increase turbidity and therefore decrease predation.

Egg to migrant survival ~ peak flow

Step 1: Translate DHSVM-predicted flow into flood recurrence interval

High Flow Event	Sum of the Forks	Snoqualmie River near Snoqualmie	Snoqualmie River near Carnation
December 8-9, 2015	41,120 c.f.s.	49,500 c.f.s.	56,200 c.f.s.
November 17-18, 2015	42,700 c.f.s.	48,000 c.f.s.	46,600 c.f.s.
January 5-6, 2015	44,210 c.f.s.	50,100 c.f.s.	53,900 c.f.s.
January 7-8, 2009	54,110 c.f.s.	60,700 c.f.s.	82,900 c.f.s.
November 6-7, 2006	53,500 c.f.s.	55,000 c.f.s.	71,800 c.f.s.
February, 1996	43,740 c.f.s.	51,700 c.f.s.	61,600 c.f.s.
November, 1995	47,960 c.f.s.	50,200 c.f.s.	62,400 c.f.s.
November, 1990	48,250 c.f.s.	74,300 c.f.s.	65,200 c.f.s.

https://green2.kingcounty.gov/rivergagedata/gage-data.aspx?r=snoqualmie



https://your.kingcounty.gov/dnrp/library/2016/kcr2777/kcr2777-txt.pdf

Egg to migrant survival ~ peak flow

Step 2: Calculate probability of survival based on Beamer and Pess 1999

Challenge: translate population/annual scale → individual/sub-daily scale

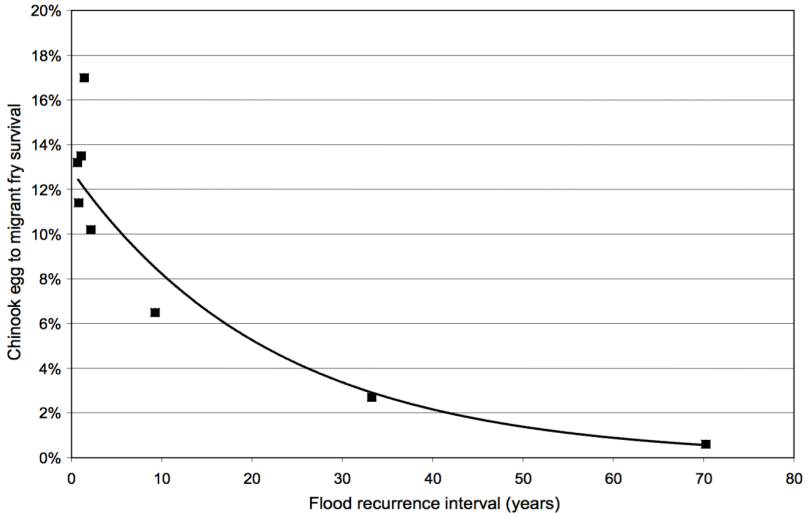
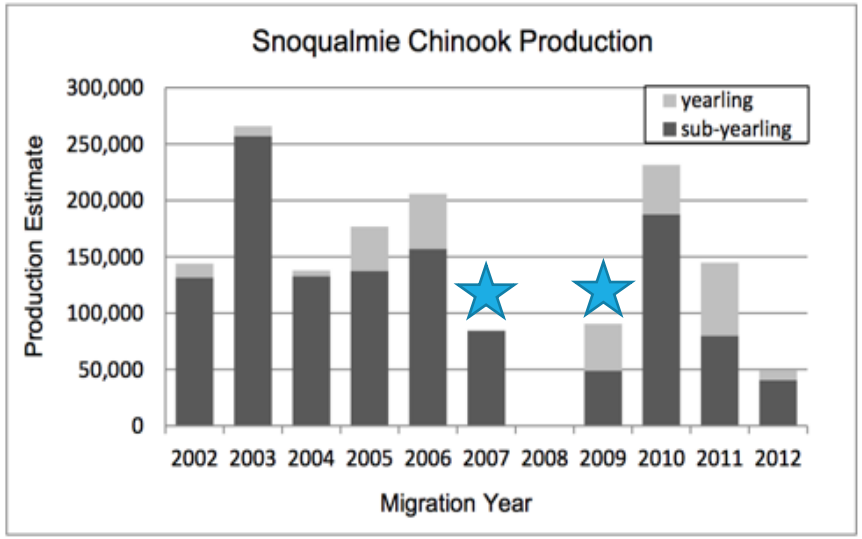


Figure 2. Egg to migrant fry survival as a function of peak flow during egg incubation (at Mt. Vernon) in the Skagit River basin (1989 to 1996) ($y=0.1285e-0.0446x, R^2=0.97$).

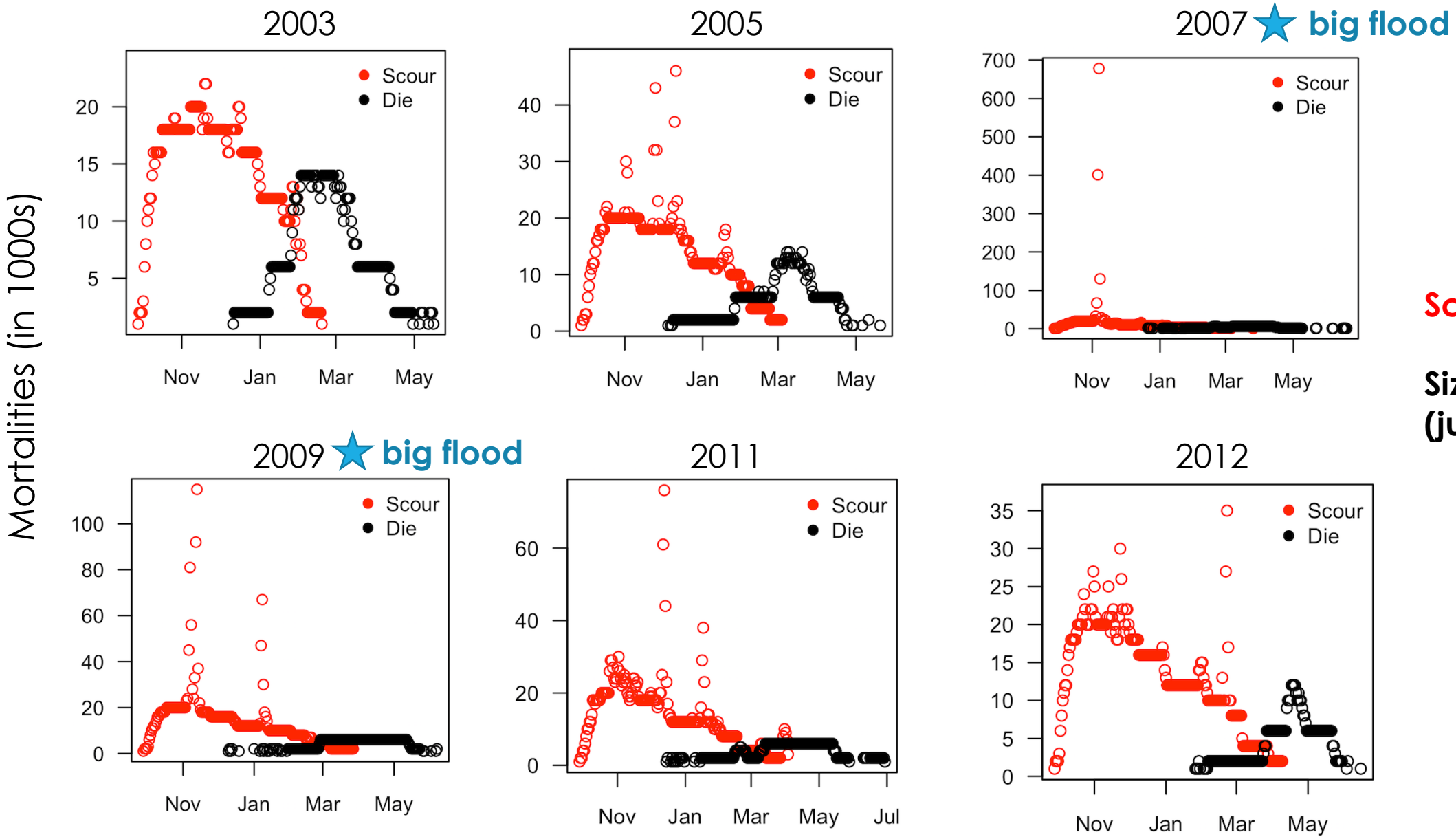
Beamer and Pess 1999



big floods

Figure 32: Ssnoqualmie sub-yearling and yearling Chinook production estimates for migration years 2001-2012. Yearling Chinook production was not included in 2007 due to identification issues.

https://nr.tulaliptribes.com/Content/documents/Tulalip-Skykomish-Snoqualmie-Outmigrant-Study-2013.pdf



Scour (eggs)

Size-selective (juveniles)

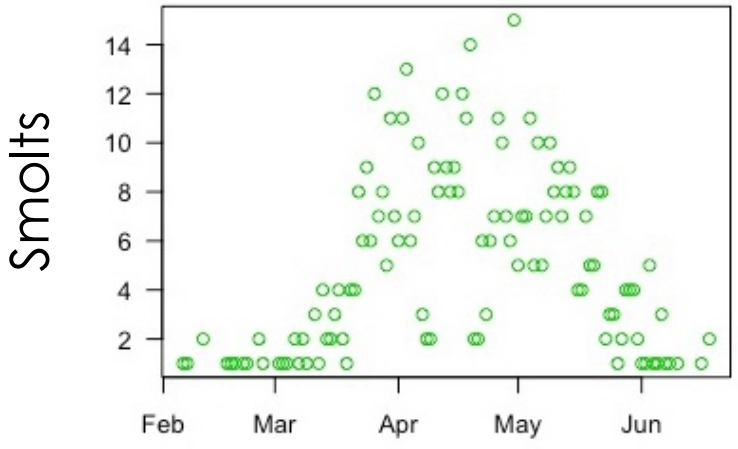
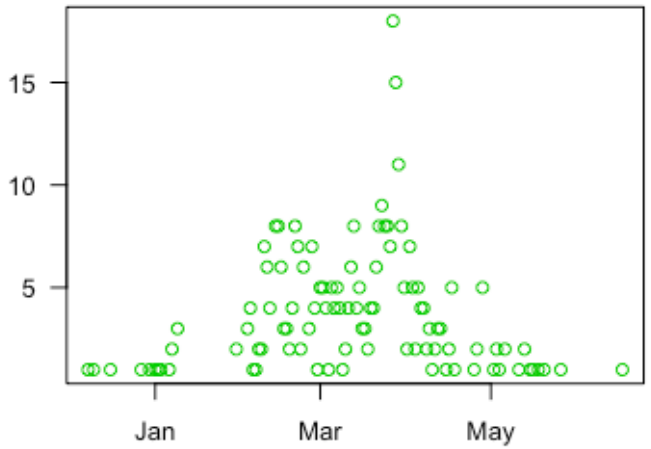
Flow partly determines downstream fish movement

probability of movement downstream$_{l,t}$ ~
f(fish mass$_t$ & date) * flow$_{l,t}$ / bankfull flow$_l$

l = current fish location
t = current time step

stronger downstream drive as fish grows, but only occurs within a date window

no flow:



with flow: