Effects of sea lion predation on Willamette River winter steelhead viability

Matt Falcy
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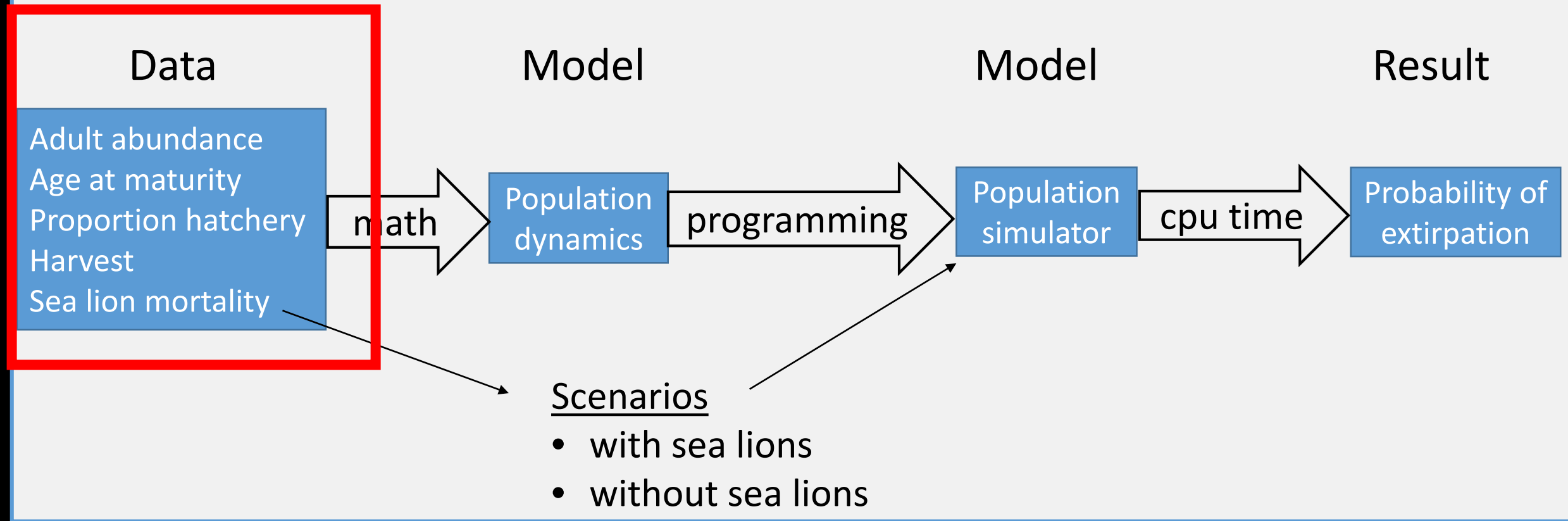
Willamette Falls

Goal: Quantify threat of extirpation posed by sea lions

Method: Population Viability Analysis (PVA)



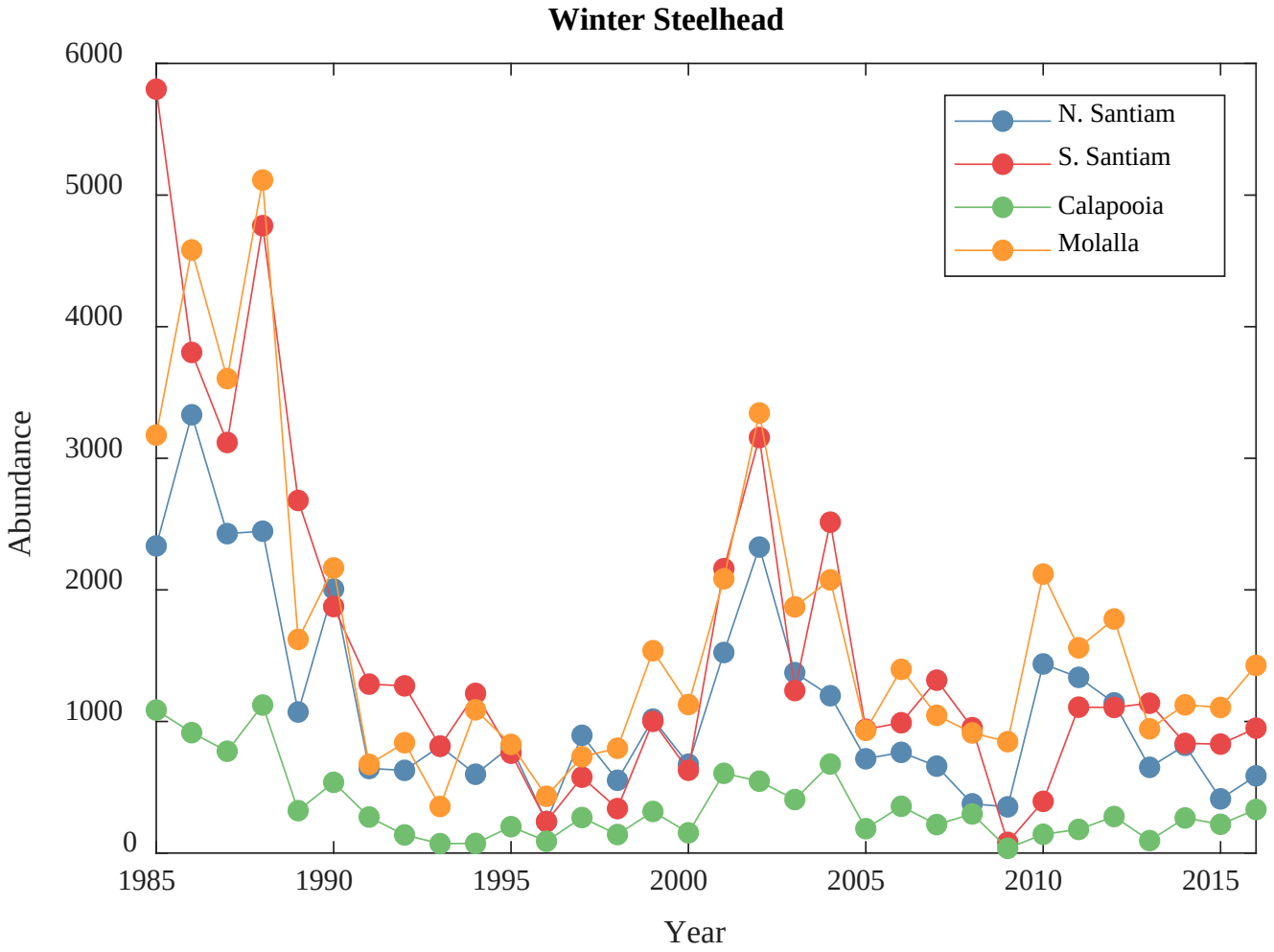
Steelhead Spawner Abundance

Base enumeration

- counted at Willamette Falls (WF)
- 62% at WF spawn in focal populations (U of I)

Apportion to populations

- amount of spawning habitat
- redd-density surveys
- multiple imputation for missing observations



Sea Lion Predation

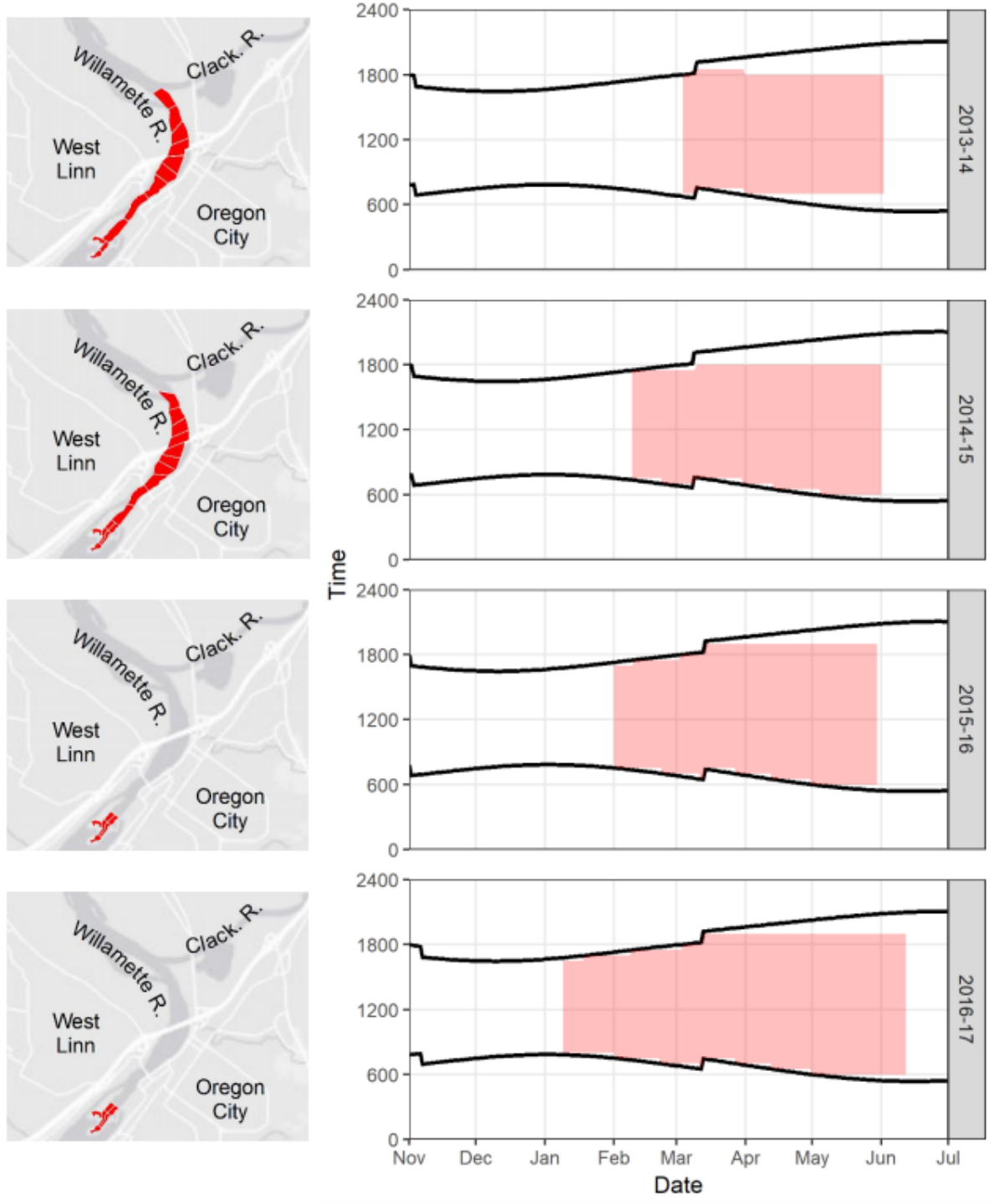
Observe (surface) feeding events

Stratified three-stage cluster sampling design

- days of week
- site-shift (block of hours at given site)
- 30-min observation bouts (3 of 4)

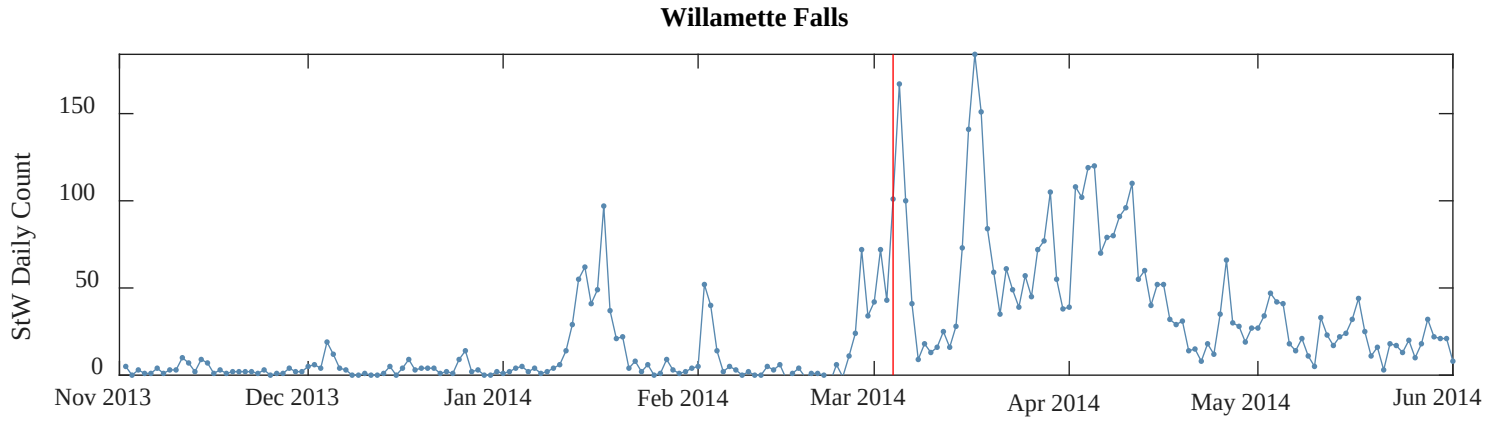
Predation events assigned to species

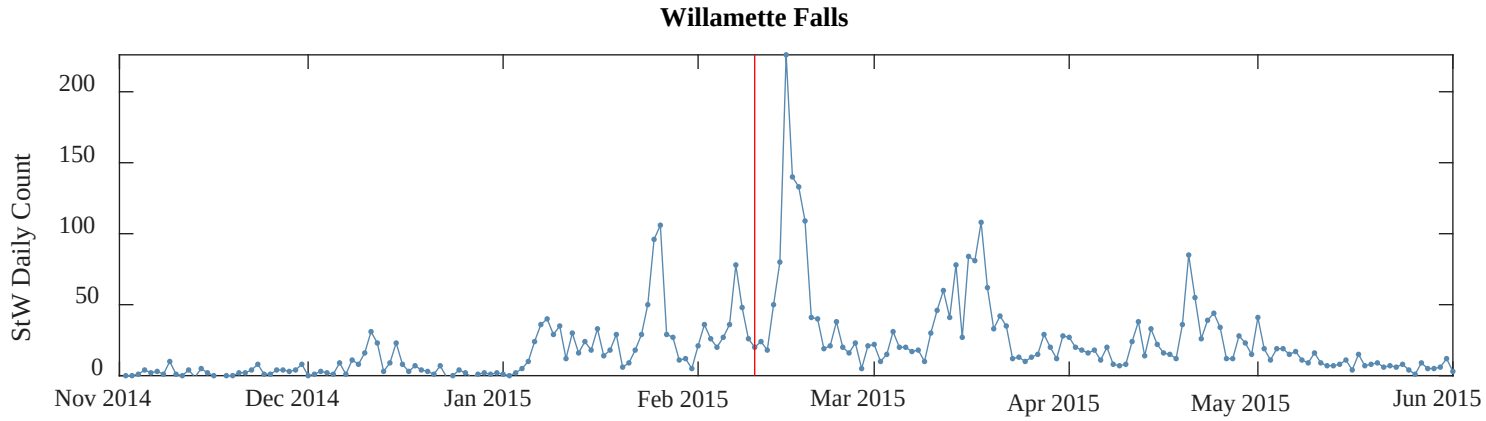
- observed
- species composition at window (1, 7, 14 d)
- Monte Carlo

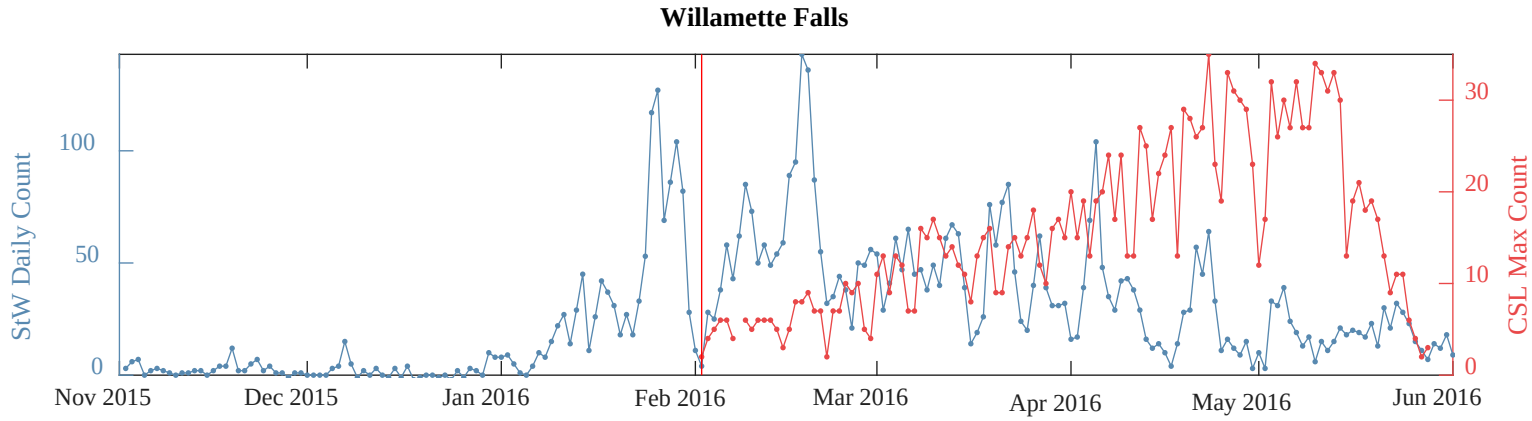


Sea Lion Predation

Expand estimated predation for steelhead run passing before predation monitoring.







Age data

Dr. Scheuerell's integrated population model…

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1985	NaN	NaN	NaN	NaN	NaN	NaN
1986	9	0	4	22	17	1
1987	4	0	0	2	7	0
1988	21	4	0	52	38	5
1989	4	0	0	4	8	2
1990	10	0	0	7	6	1
1991	0	0	4	0	3	1
1992	4	0	0	21	11	0
1993	0	0	0	0	1	0
1994	0	0	0	1	0	0
1995	NaN	NaN	NaN	NaN	NaN	NaN
1996	NaN	NaN	NaN	NaN	NaN	NaN
1997	NaN	NaN	NaN	NaN	NaN	NaN
1998	NaN	NaN	NaN	NaN	NaN	NaN
1999	NaN	NaN	NaN	NaN	NaN	NaN
2000	NaN	NaN	NaN	NaN	NaN	NaN
2001	0	0	25	69	8	0
2002	NaN	NaN	NaN	NaN	NaN	NaN
2003	0	0	0	22	8	0
2004	0	0	9	35	3	0
2005	0	0	1	5	1	0
2006	NaN	NaN	NaN	NaN	NaN	NaN
2007	NaN	NaN	NaN	NaN	NaN	NaN
2008	NaN	NaN	NaN	NaN	NaN	NaN
2009	NaN	NaN	NaN	NaN	NaN	NaN
2010	NaN	NaN	NaN	NaN	NaN	NaN
2011	NaN	NaN	NaN	NaN	NaN	NaN
2012	0	0	2	50	33	11
2013	0	0	2	69	36	10
2014	0	0	2	69	36	4
2015	NaN	NaN	NaN	NaN	NaN	NaN
2016	NaN	NaN	NaN	NaN	NaN	NaN

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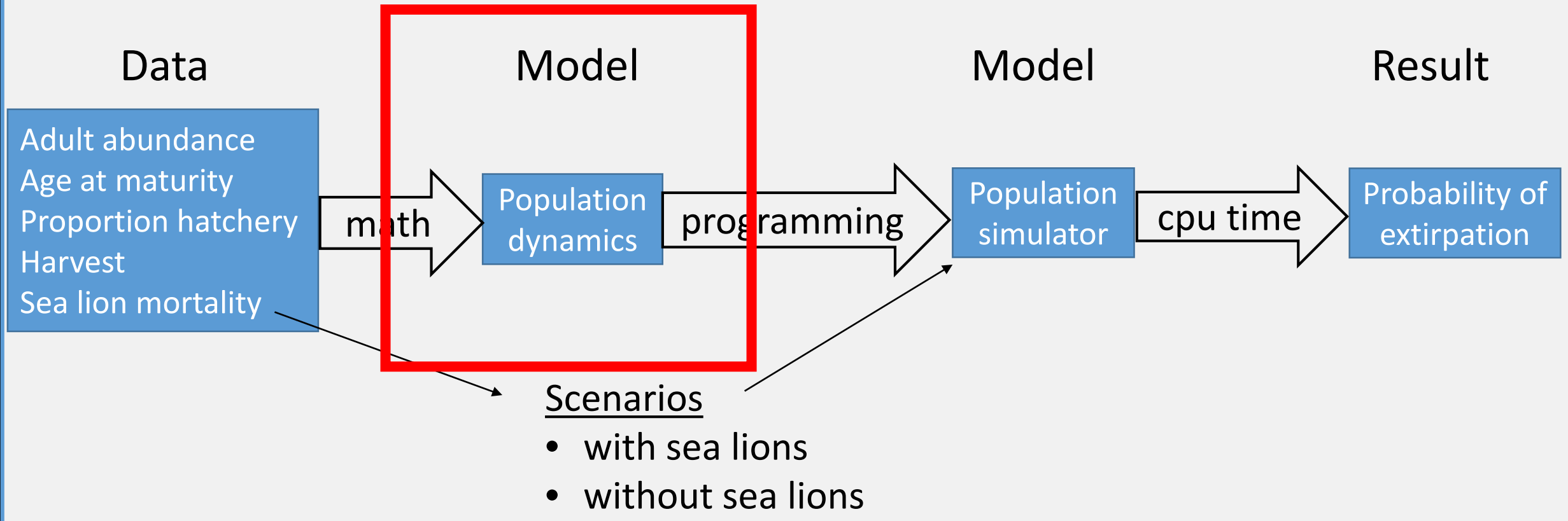

Population Dynamics

- Density-dependence
- Sea lion predation identical to fishing
- Multi-model inference

Bayesian analysis

- Yields probability-based inference for parameters.
- MCMC provides random draws of parameters that include covariance.

Three Ricker models

$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p} \varepsilon_{t,p}}$	Each pop separate, k=12, WAIC=224.8
$R_{t,p} = \alpha_p S_{t,p} e^{-\beta_p S_{t,p} \varepsilon_t}$	Shared error variance, k=9, WAIC=248.9
$R_{t,p} = \alpha S_{t,p} e^{-\beta_p S_{t,p} \varepsilon_{t,p}}$	Shared productivity, k=9, WAIC=217.6

Population Dynamics

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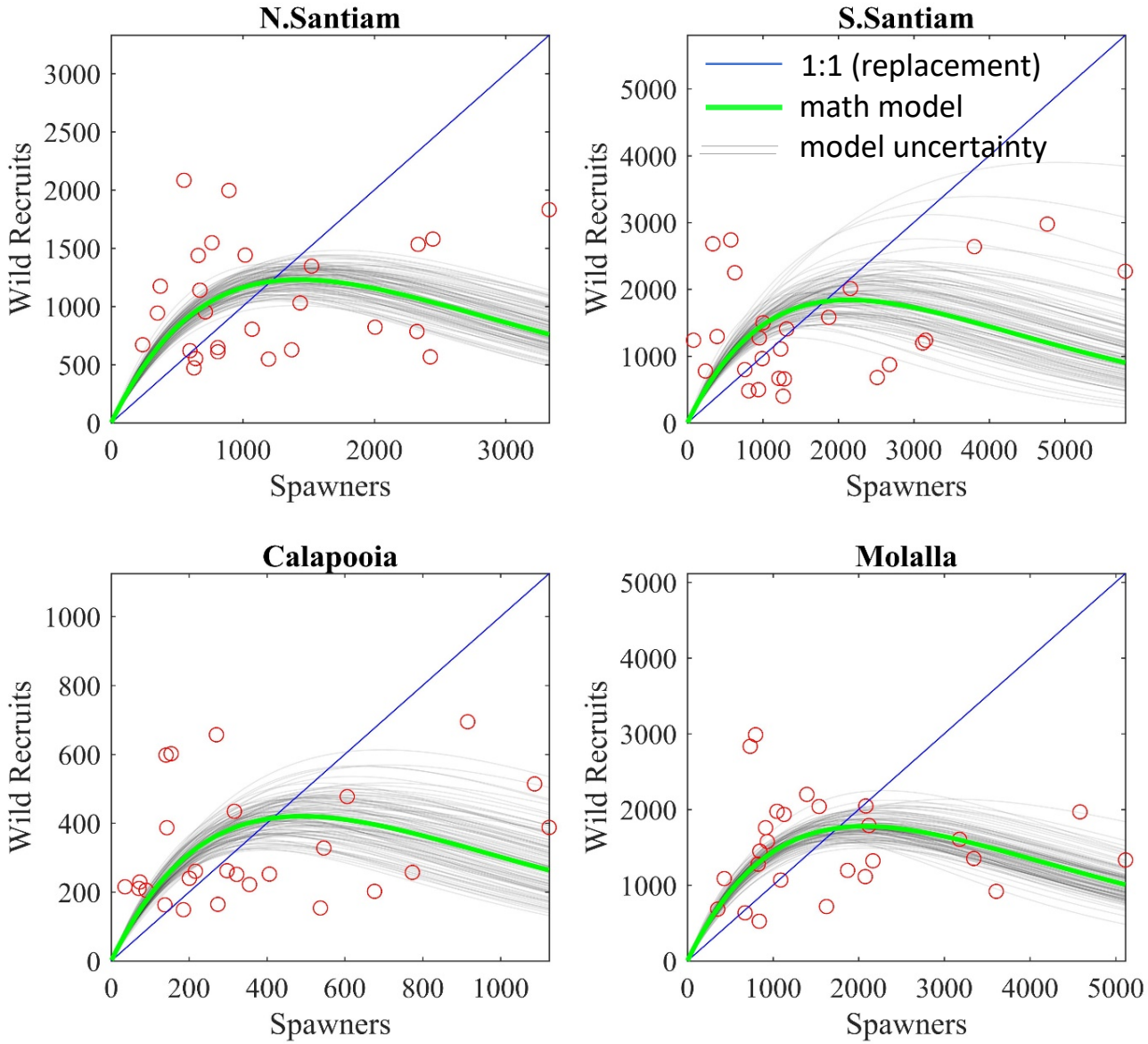

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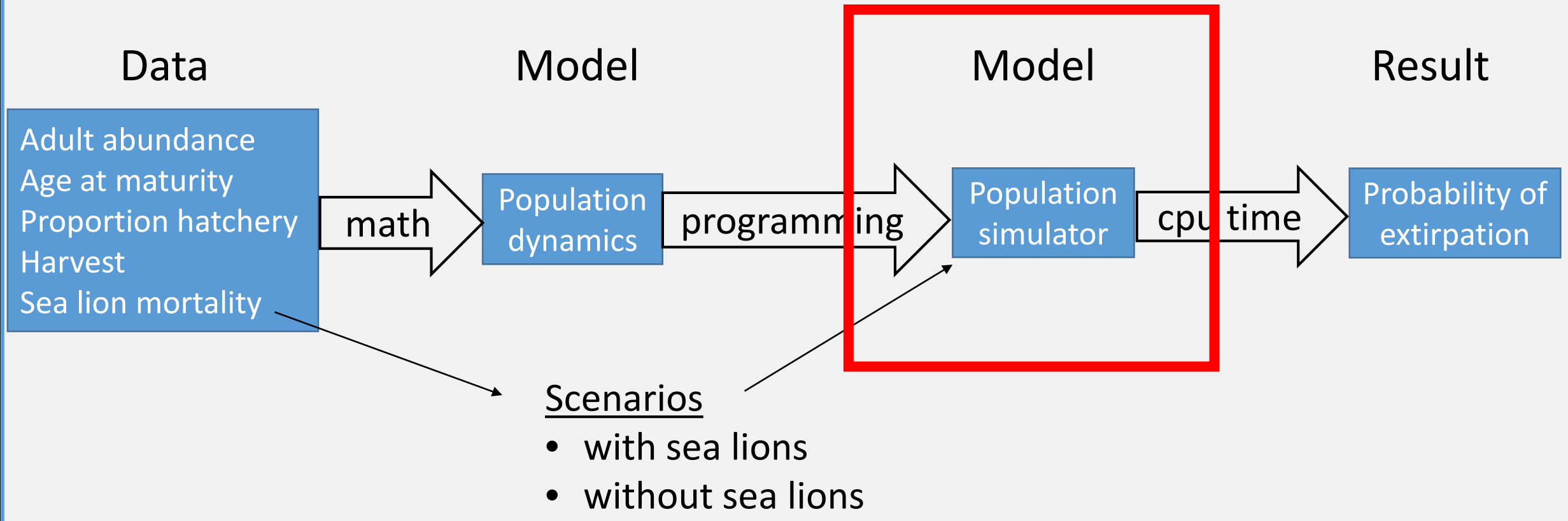
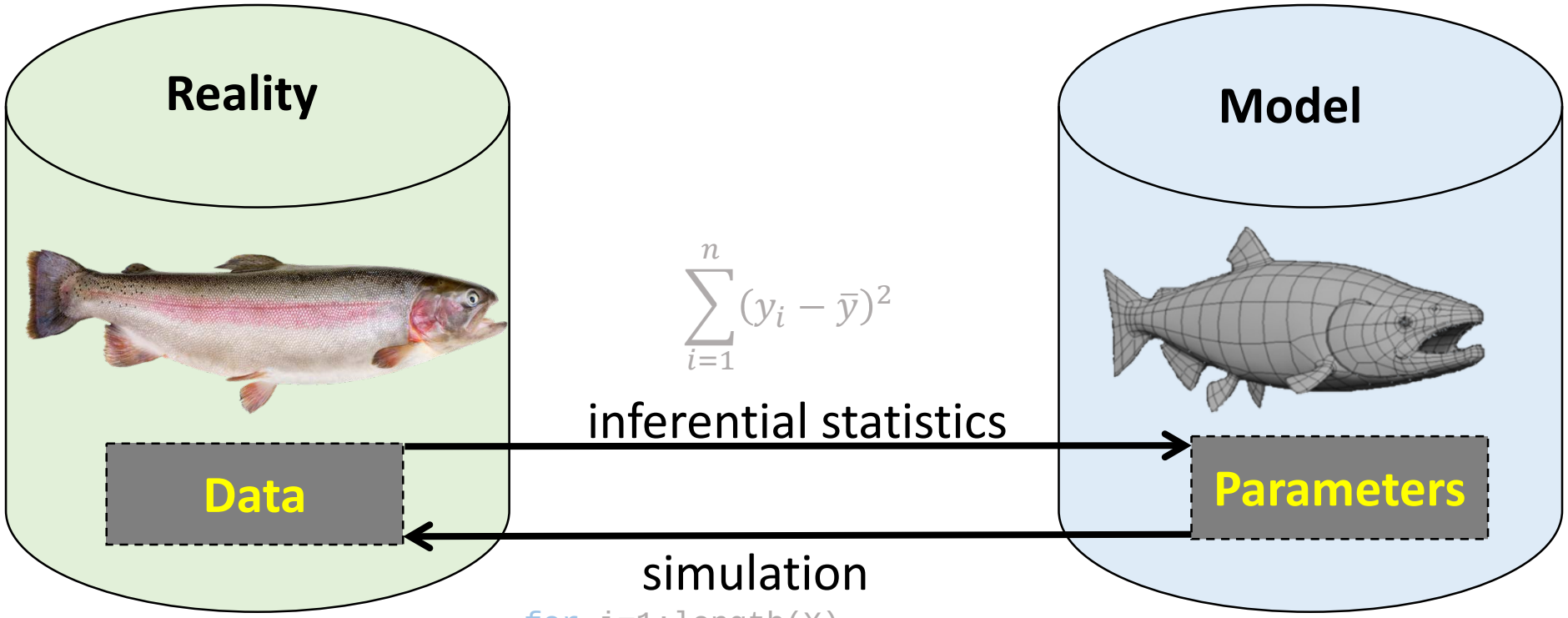


Population Simulator




```
for i=1:length(X)
 y(i,:)=normrnd(X(i,1),X(i,2),[1,50]);
end
```

Population Simulator

Replication

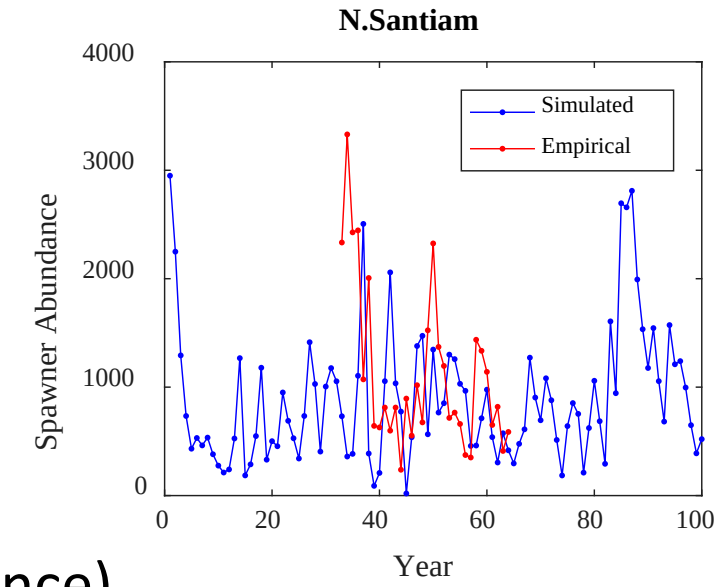
1000 random draws of parameters per population
each draw used to simulate 100 years
\+ process above replicated 100 times

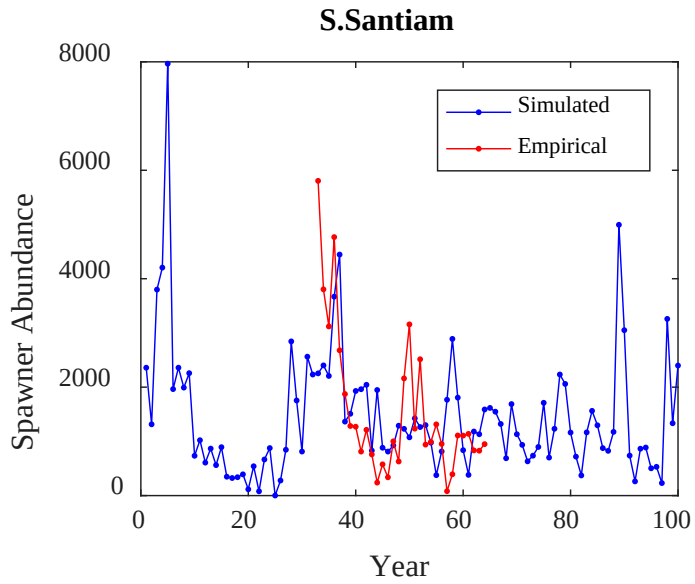
= 100,000 simulations of 100 years per population

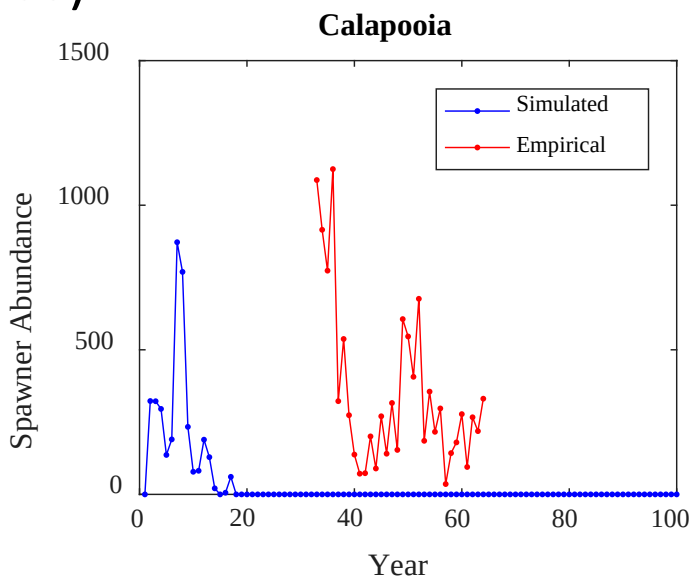
Allee effects (negative density dependence)

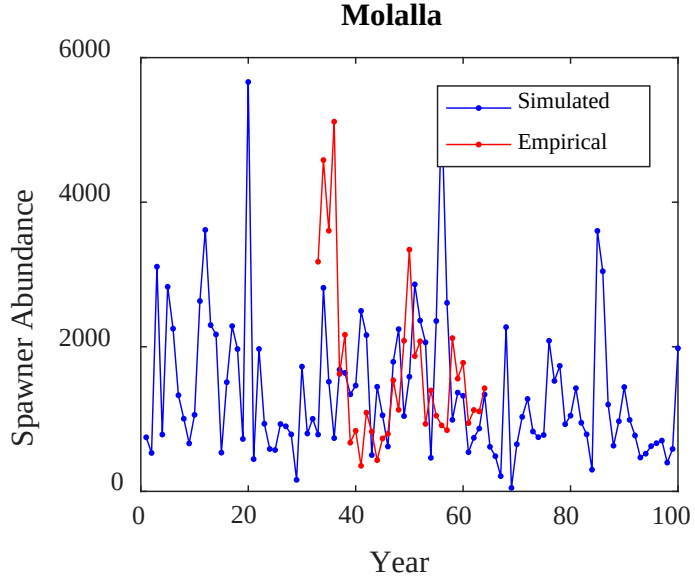
- If N_t < 100, then no reproduction
- If $N_{t:t+3}$ < 100 (4 consecutive years), then functionally extirpated

Pr[extirpation] = #extirpations/100,000









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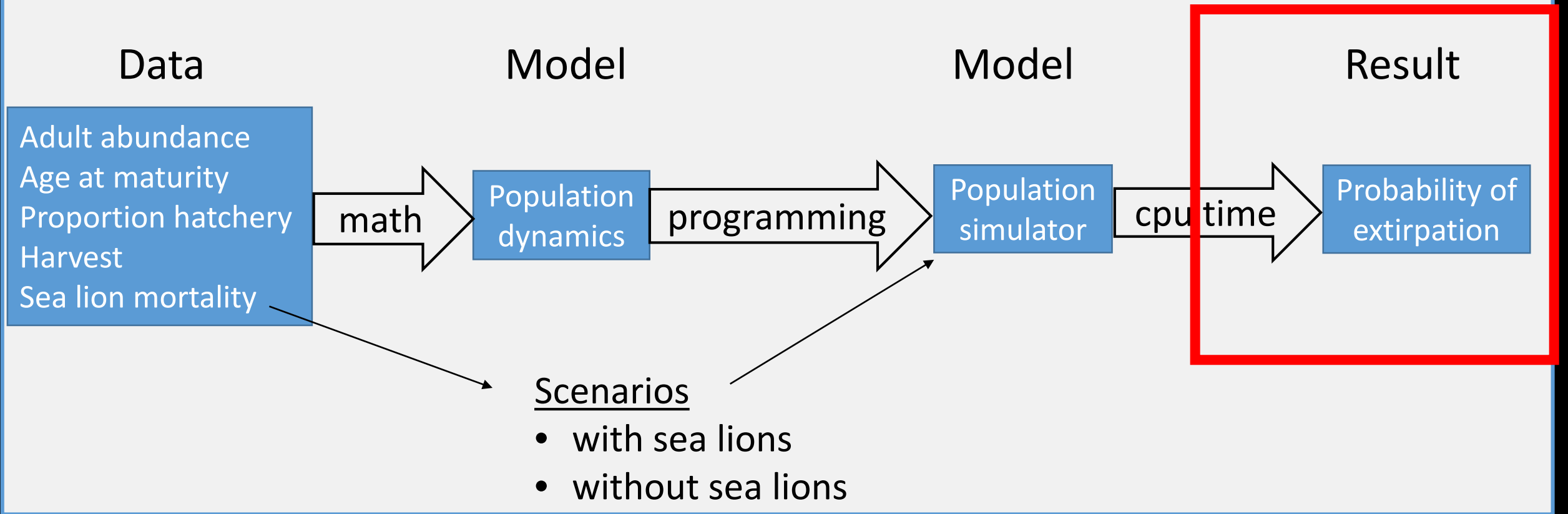
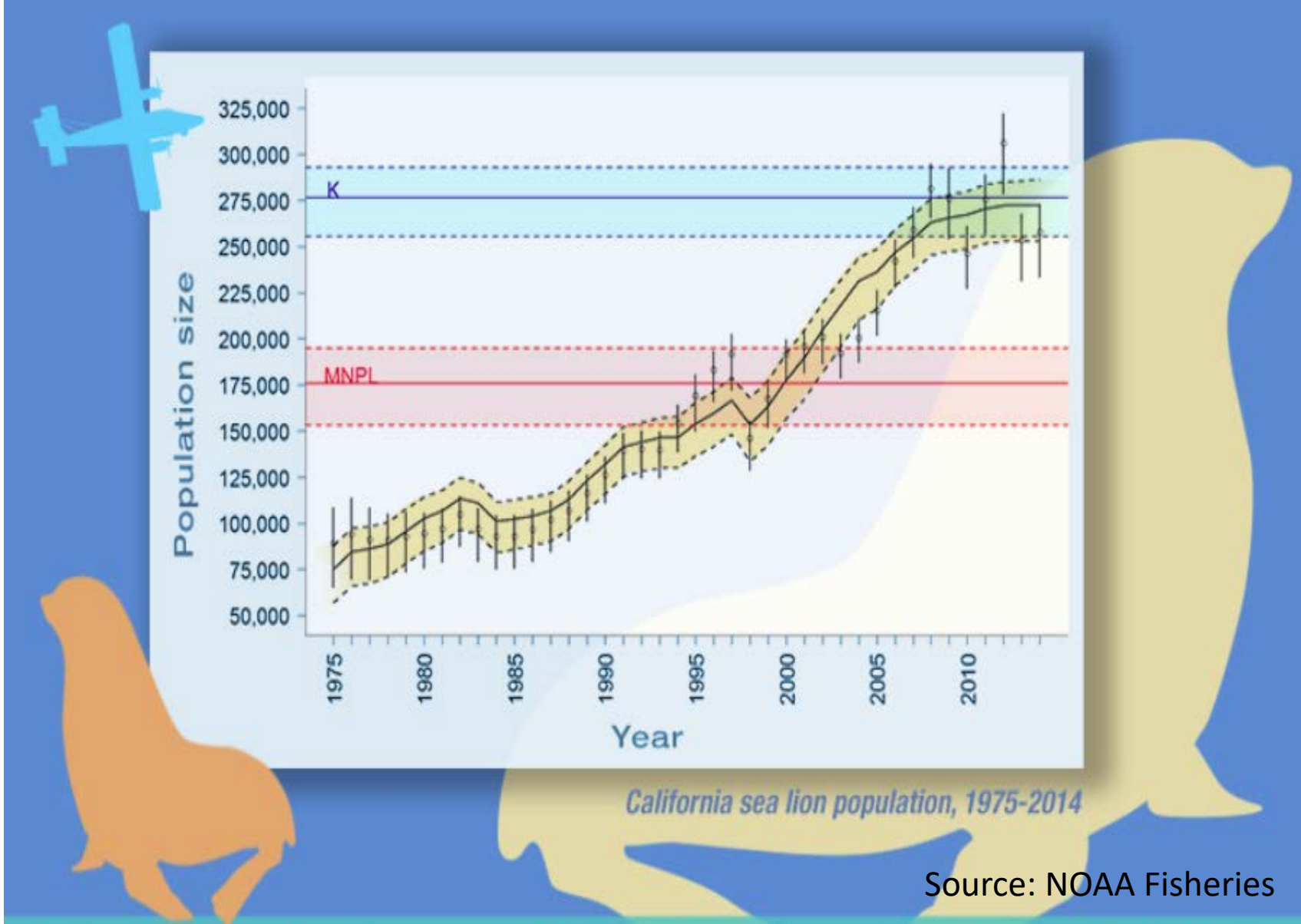


Probability of Extirpation

Scenario		Population			
		North Santiam	South Santiam	Molalla	Calapooia
Without Sea Lions:		2%	5%	0%	99%
With Sea Lions:	lowest observed predation (2015)	8%	16%	0%	99%
	average predation (2016)	27%	34%	2%	99%
	highest observed predation (2017)	64%	60%	21%	99%

Management

- Sea lions functionally extirpated steelhead at Ballard Locks, Seattle
- Non-lethal deterrence is ineffective (20+ years)
- “Take” under Marine Mammal Protection Act is a long process



California sea lion population, 1975-2014

Source: NOAA Fisheries

California sea lion numbers have grown steadily since the 1970s, the new study shows. The yellow band reflects the approximate population size, while K represents carrying capacity and MNPL is maximum net productivity level (the population level for maximum growth). The range above MNPL and below K is the optimum sustainable population, which the Marine Mammal Protection Act sets as the goal for protected species.

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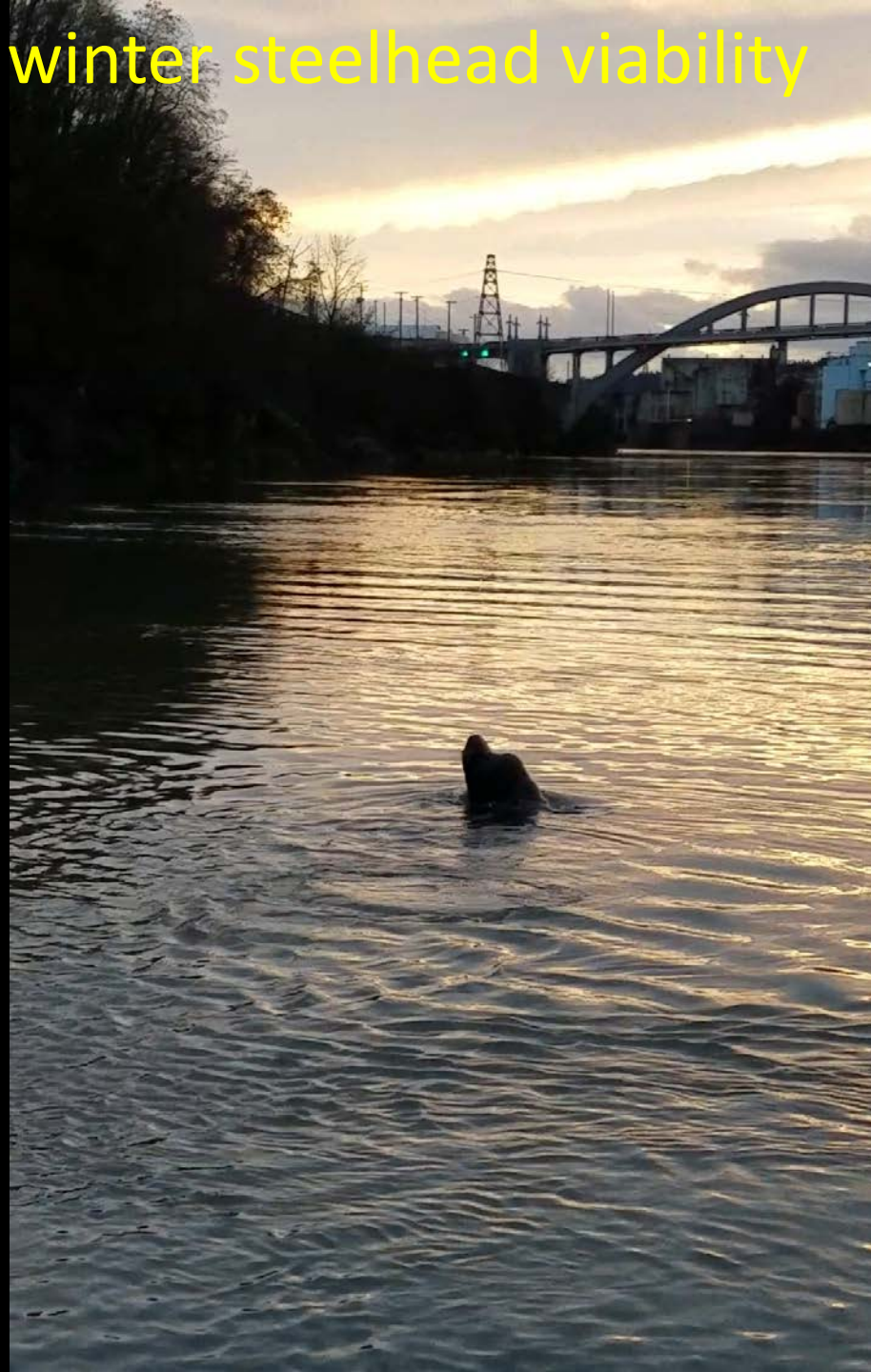
Reproducible results: www.falcy.weebly.com/pva
(data and code)



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