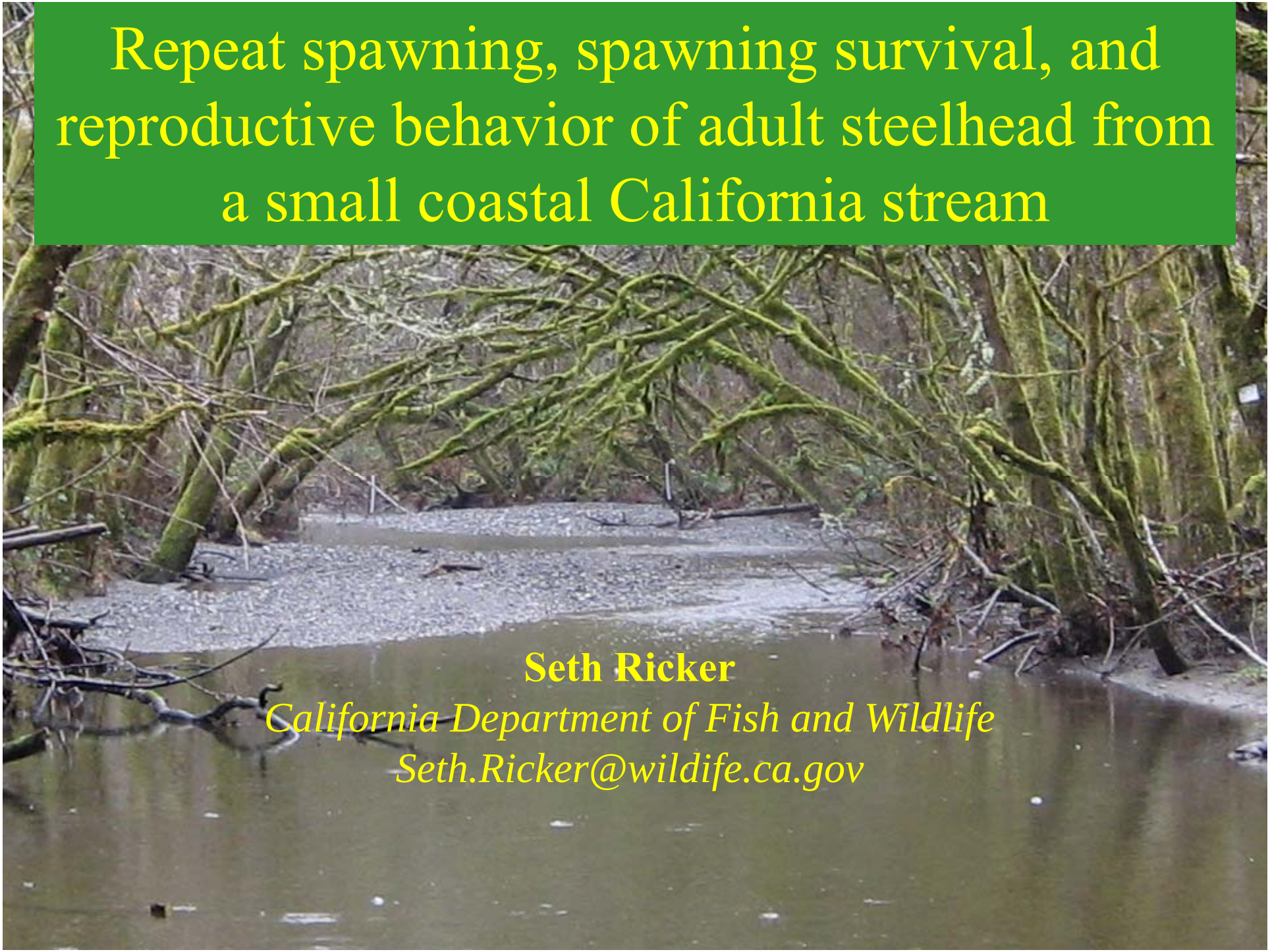
Repeat spawning, spawning survival, and reproductive behavior of adult steelhead from a small coastal California stream



Seth Ricker
California Department of Fish and Wildlife
Seth.Ricker@wildife.ca.gov

Freshwater Creek Life Cycle Monitoring

- Abundance
- Productivity
- Life History Diversity
- Relationships between habitat and productivity

Freshwater Creek Life Cycle Monitoring

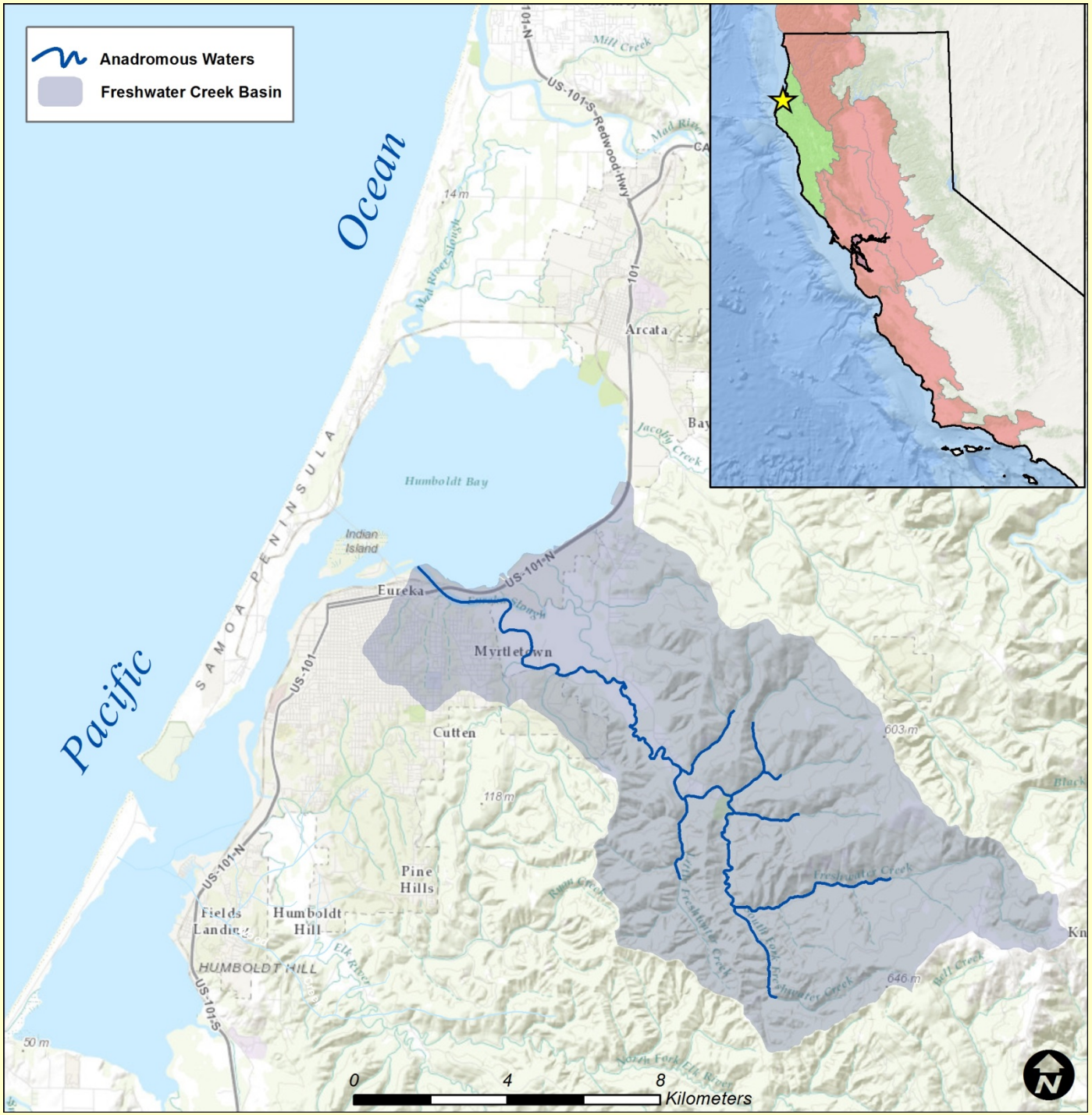
- Abundance
- Productivity
- Life History Diversity
- Relationships between habitat/environment and productivity

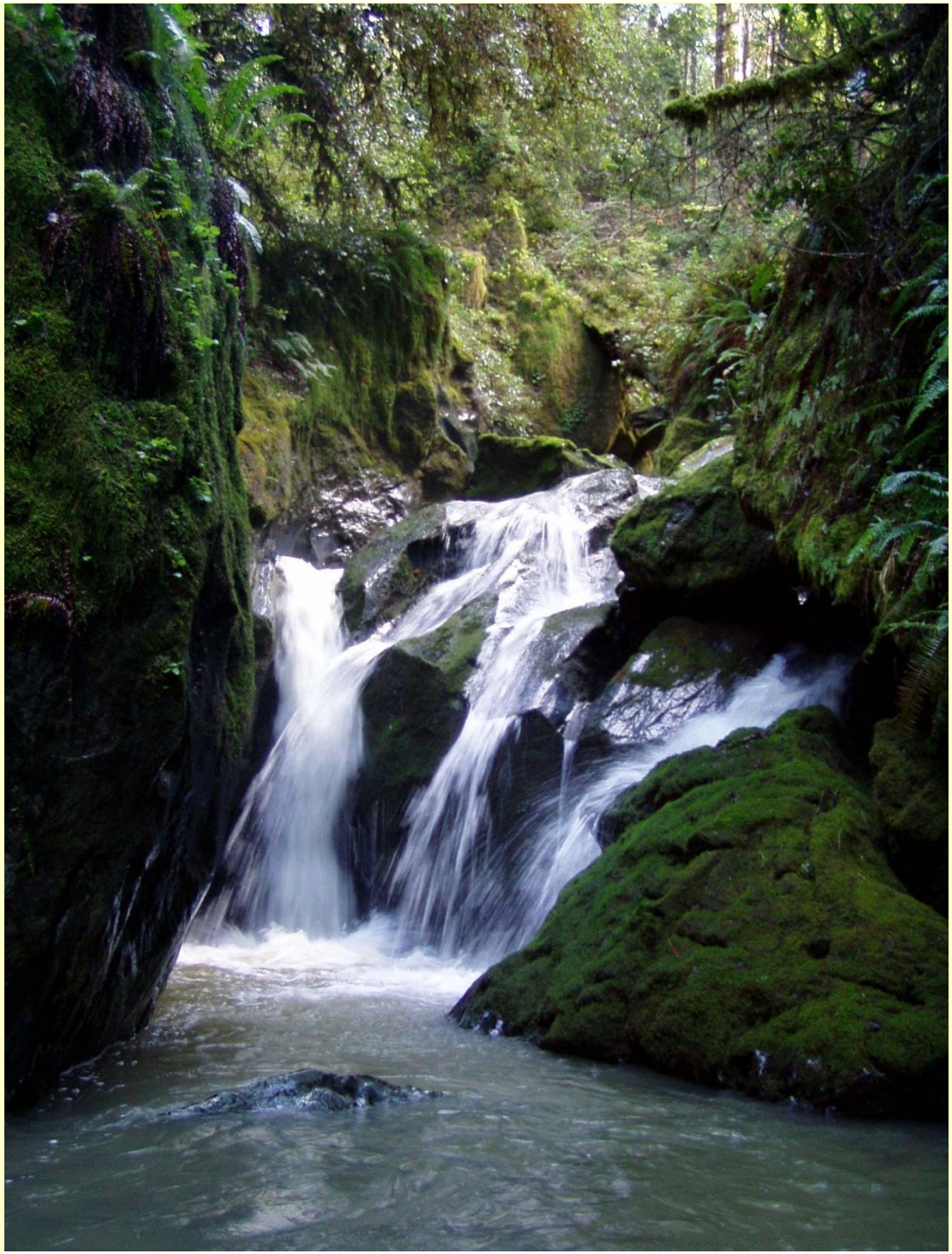
Iteroparity of steelhead

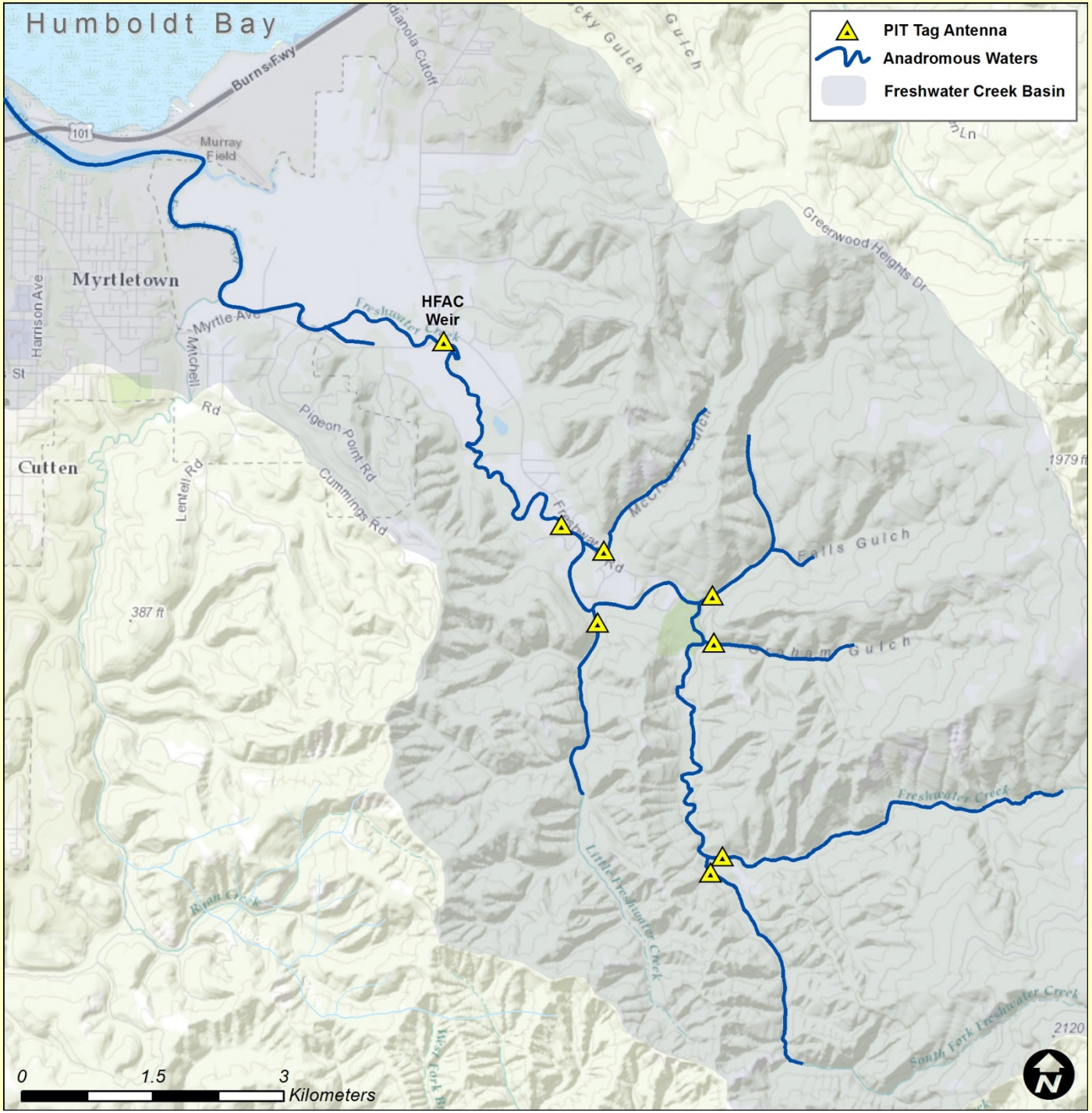
- Maximize lifetime reproductive success
  - Retirement goal
- Spread risk over cohorts
  - Diversify portfolio
  - Buffer against short term precipitous declines

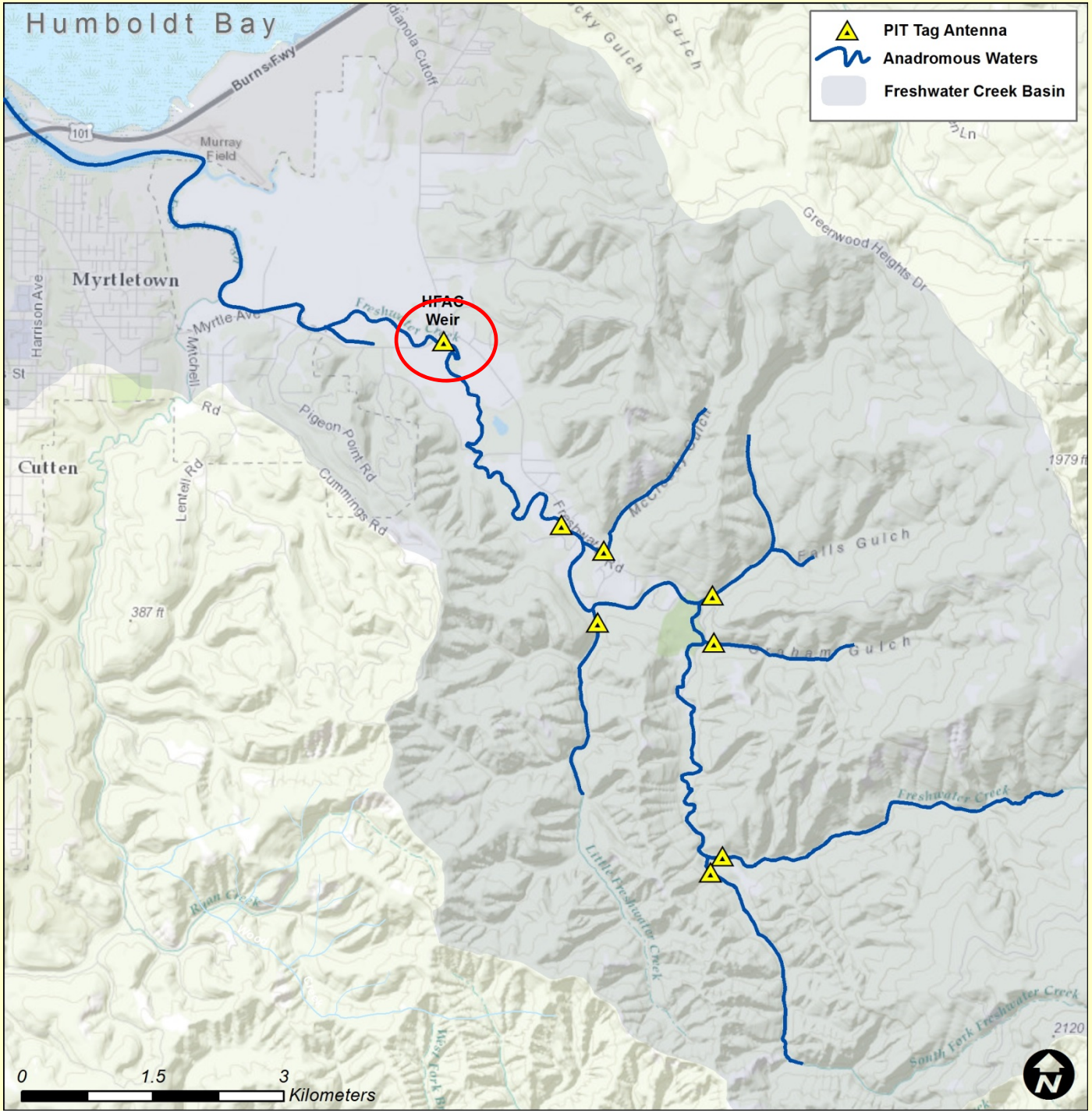
Presentation outline

- What is the incidence of repeat spawning in Freshwater Creek?
  - Scale pattern interpretation
- What is the range and magnitude of spawning and kelt marine survival?
  - PIT tag based CJS
- What is the relationship with behavioral, demographic and environmental processes?
  - Exploratory correlations


Anadromous Waters
Freshwater Creek Basin
Pacific
Ocean
SAMOA PENINSULA
Humboldt Bay
Indian Island
Eureka
Arcata
Myrtletown
Cutten
Pine Hills
Fields Landing
Humboldt Hill
HUMBOLDT HILL
Mad River Slough
Jacoby Creek
Elk River
Freshwater Creek
Ryan Creek
Bell Creek
North Fork Jacoby Creek
US-101-N
US-101-S-Redwood Hwy
US-101
US-101-S
14 m
118 m
603 m
646 m
50 m
0
4
8
Kilometers



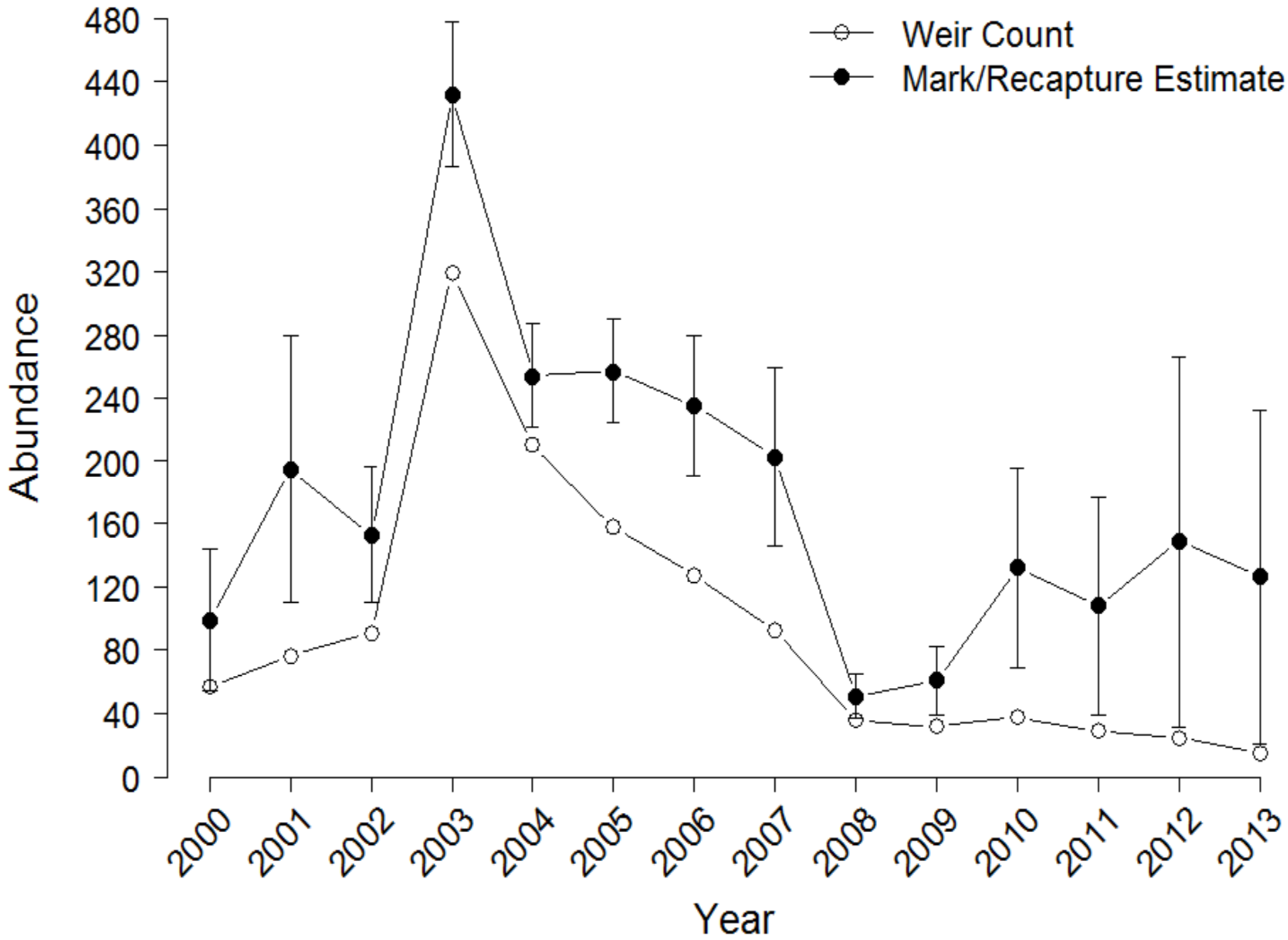

Humboldt Bay
PIT Tag Antenna
Anadromous Waters
Freshwater Creek Basin
HFAC
Weir
Myrtletown
Cutten
Murray
Field
Harrison Ave
Myrtle Ave
Mitchell
Rd
Pigeon Point Rd
Cummings Rd
Lentell Rd
Greenwood Heights Dr
Falls Gulch
Freshwater Creek
Little Freshwater Creek
South Fork Freshwater Creek
Ryan Creek
387 ft
1979 ft
2120
0
1.5
3
Kilometers
N

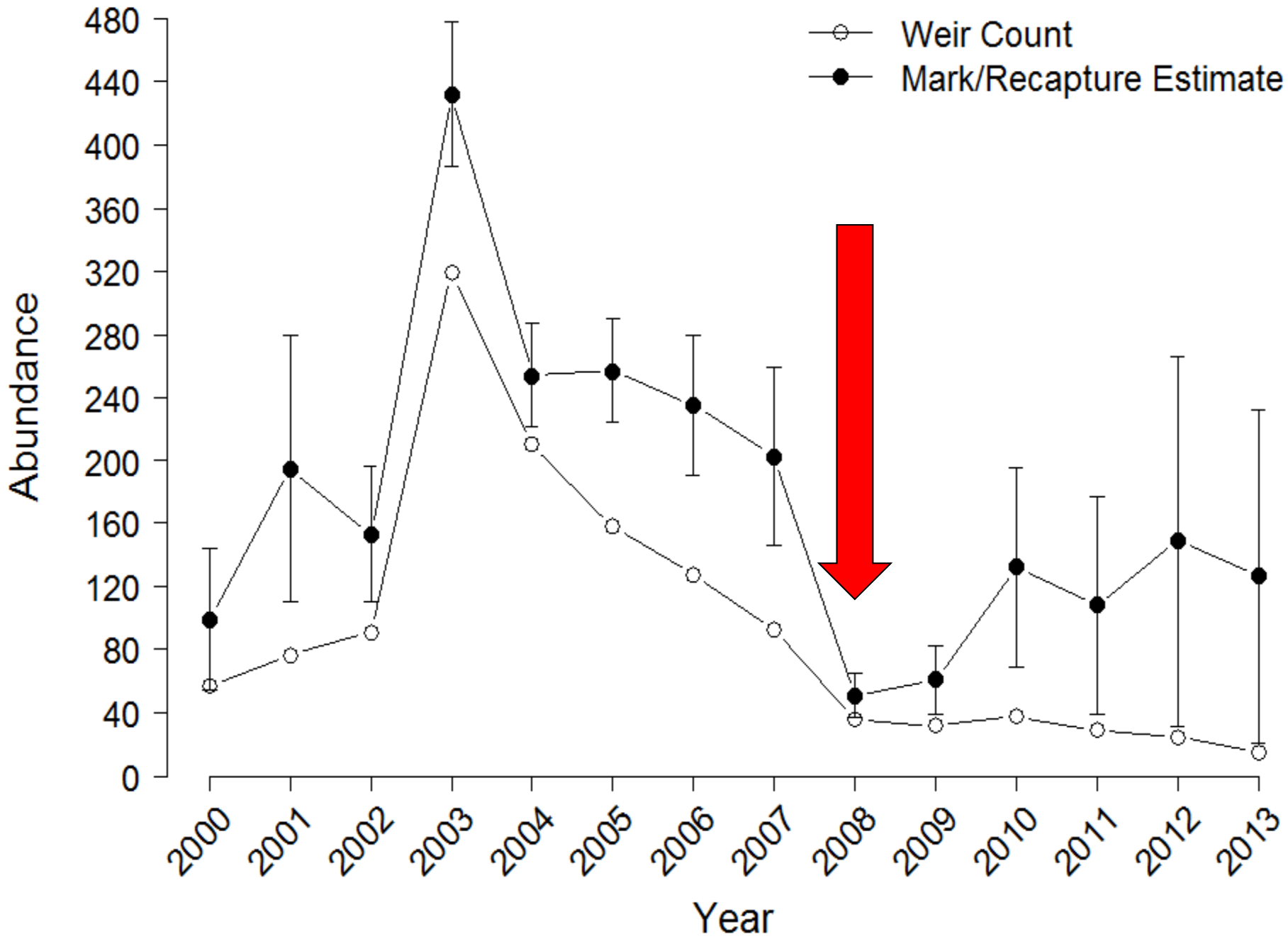

Humboldt Bay
PIT Tag Antenna
Anadromous Waters
Freshwater Creek Basin
HFAC Weir
Myrtletown
Cutten
Murray Field
Burns Fwy
101
Myrtle Ave
Harrison Ave
Mitchell Rd
Lentell Rd
Pigeon Point Rd
Cummings Rd
Greenwood Heights Dr
Falls Gulch
Freshwater Creek
Little Freshwater Creek
South Fork Freshwater Creek
Ryan Creek
387 ft
1979 ft
2120
0
1.5
3
Kilometers
N


GRUNDENS
GRUNDENS

Data Collection at the Weir

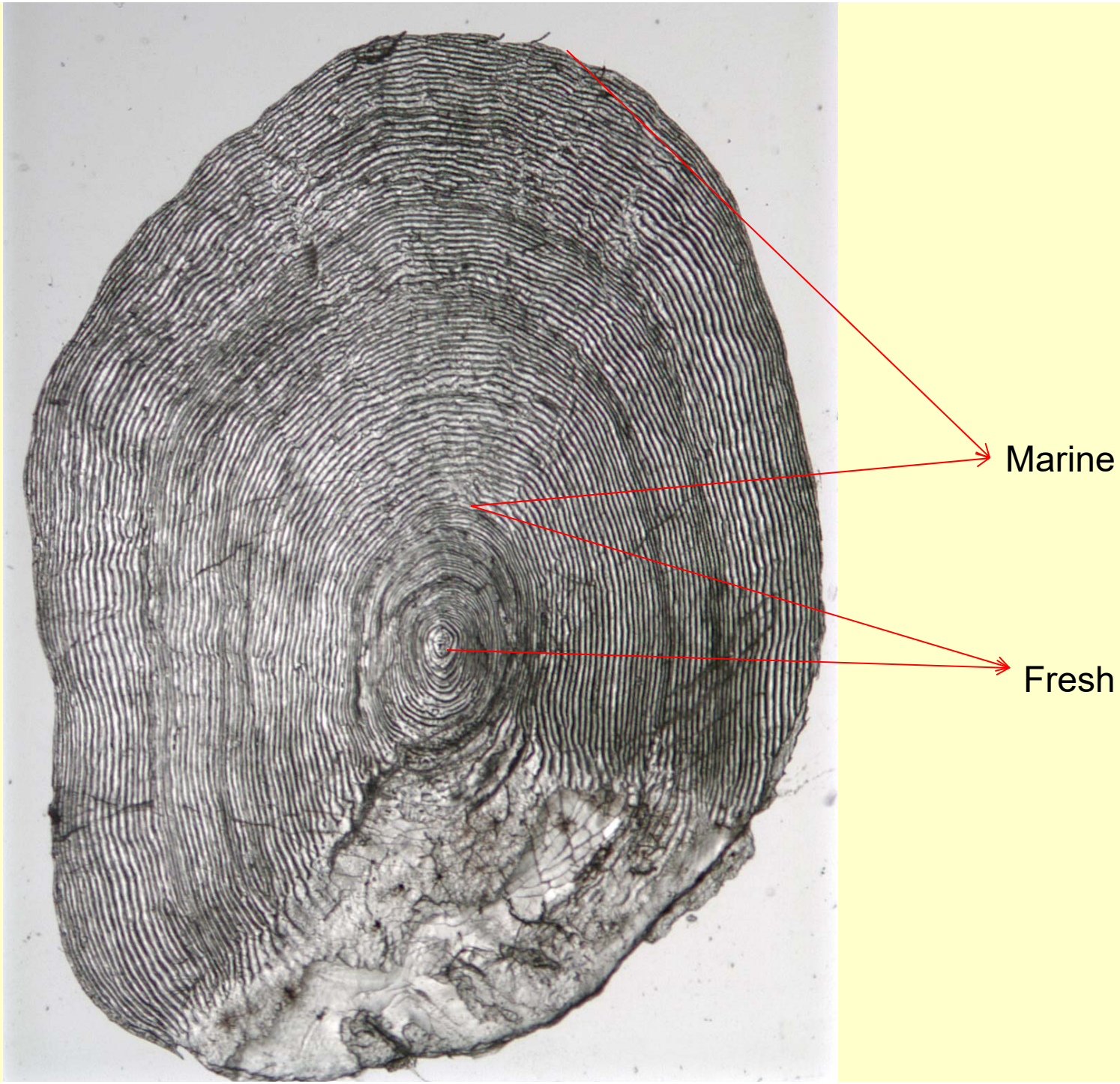
- Apply/check PIT tags
- Species
- Sex
- Length
- Scale/Tissue sample


Weir Count
Mark/Recapture Estimate
Abundance
0
40
80
120
160
200
240
280
320
360
400
440
480
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year


Weir Count
Mark/Recapture Estimate
Abundance
480
440
400
360
320
280
240
200
160
120
80
40
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Year

What is the incidence of repeat spawning in Freshwater Creek?

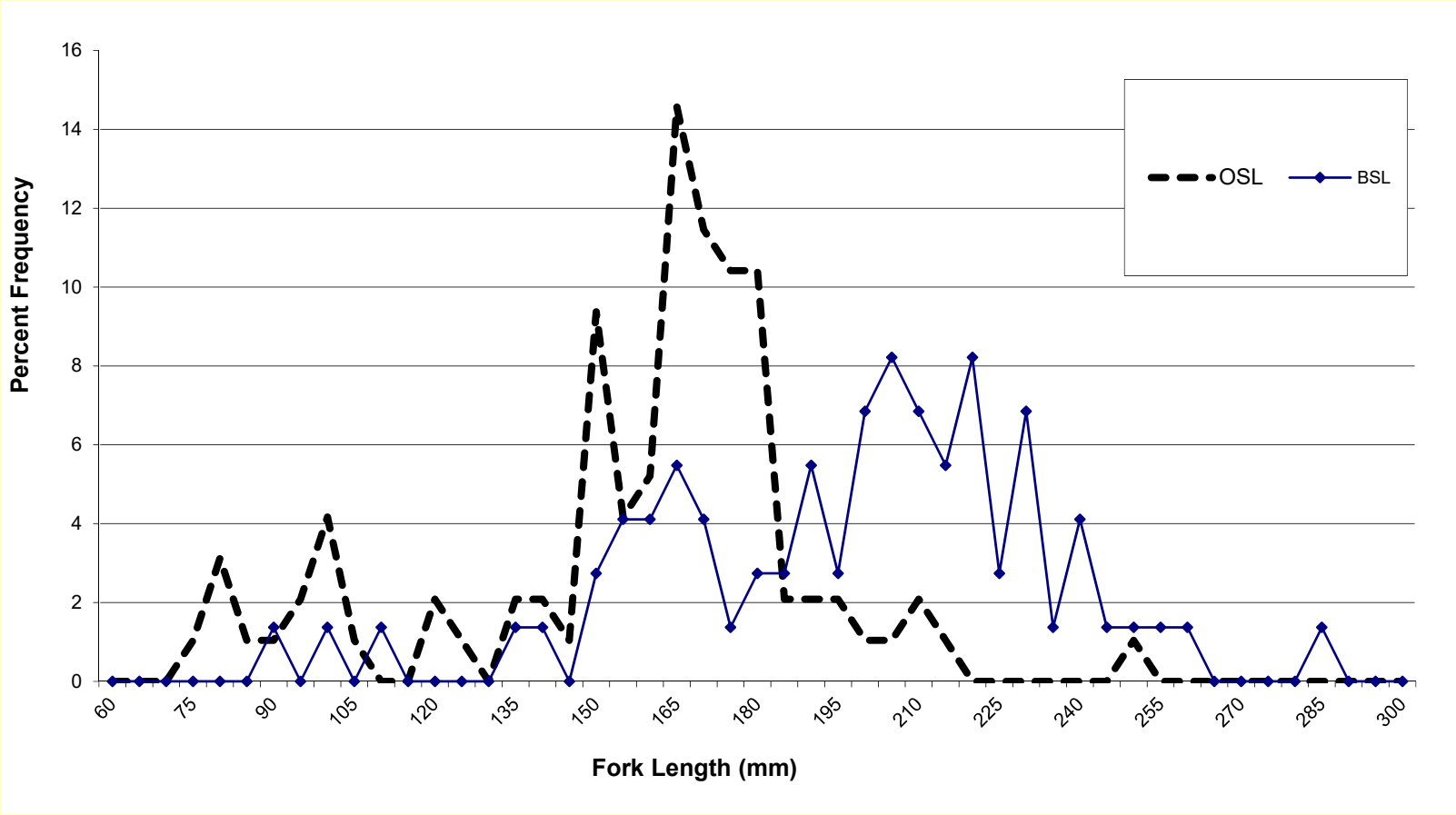
-Scale pattern interpretation

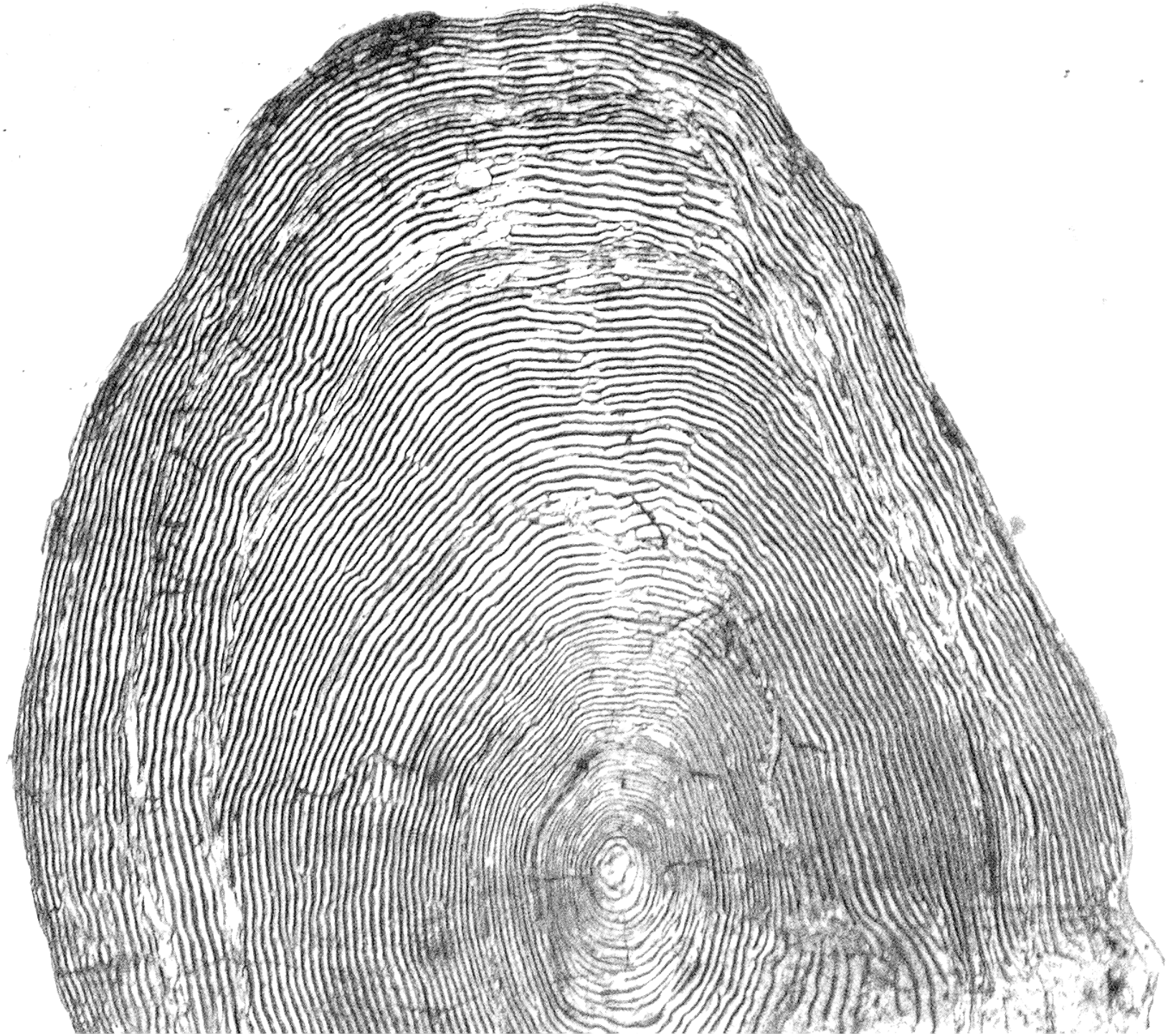

Marine
Fresh

$$\ln L_a = ((\ln L - c)\ \ln S_a / \ln S) + c$$

The variables are defined as:

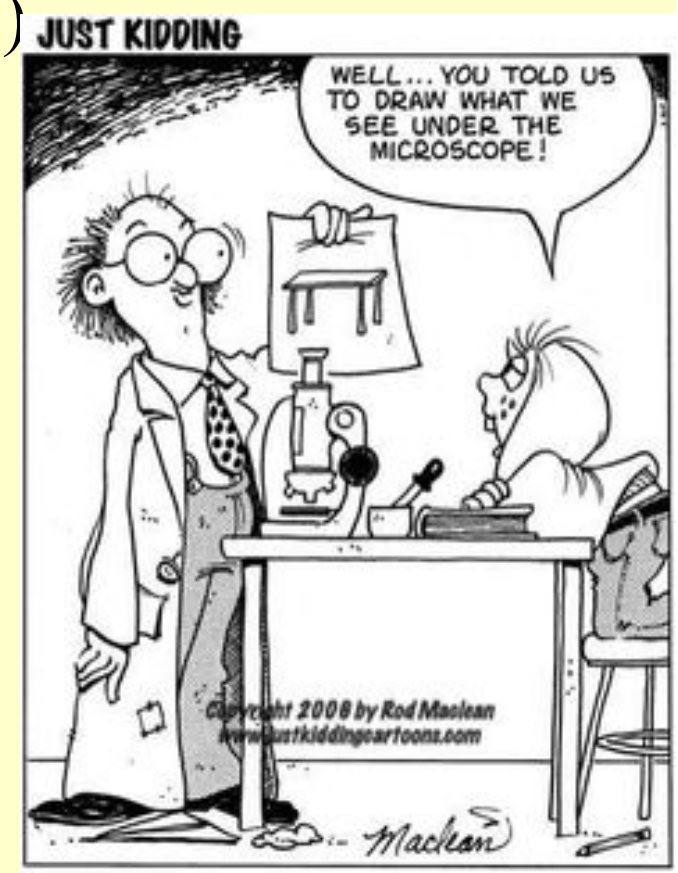
L = fork length (mm)
S = total scale radius (mm)
c = intercept of the body length and scale radius regression
S_a = scale radius at ocean entry check
L_a = fork length of fish at a given annulus

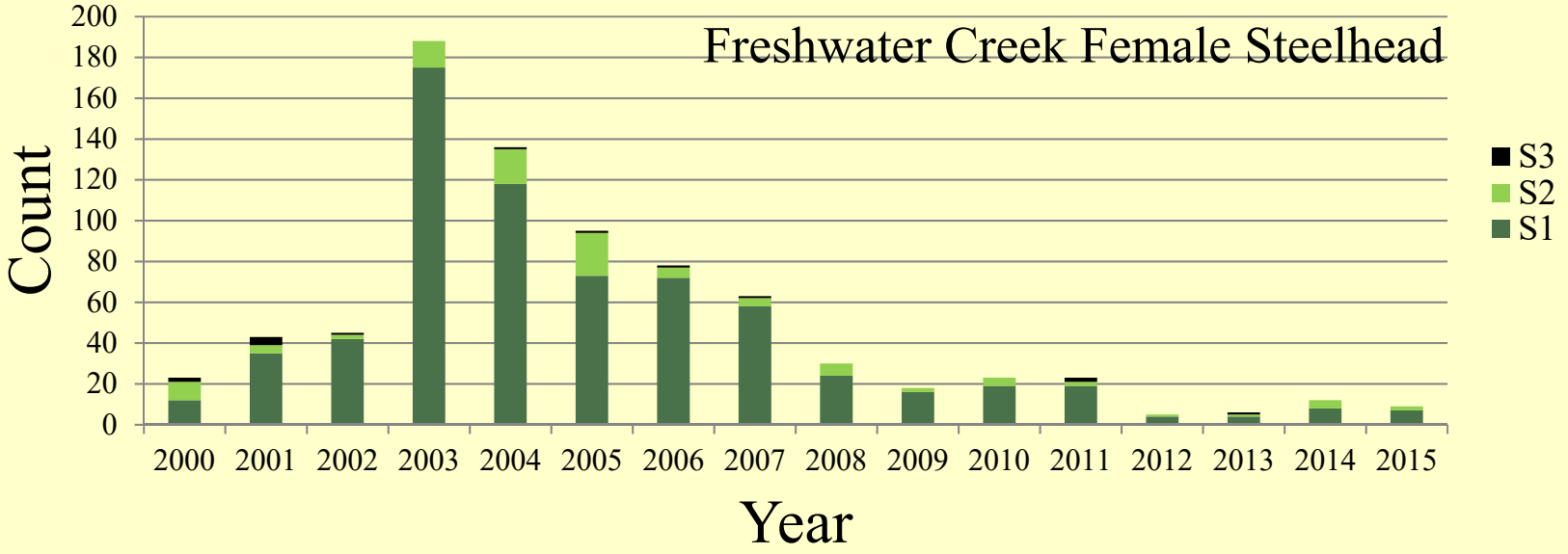




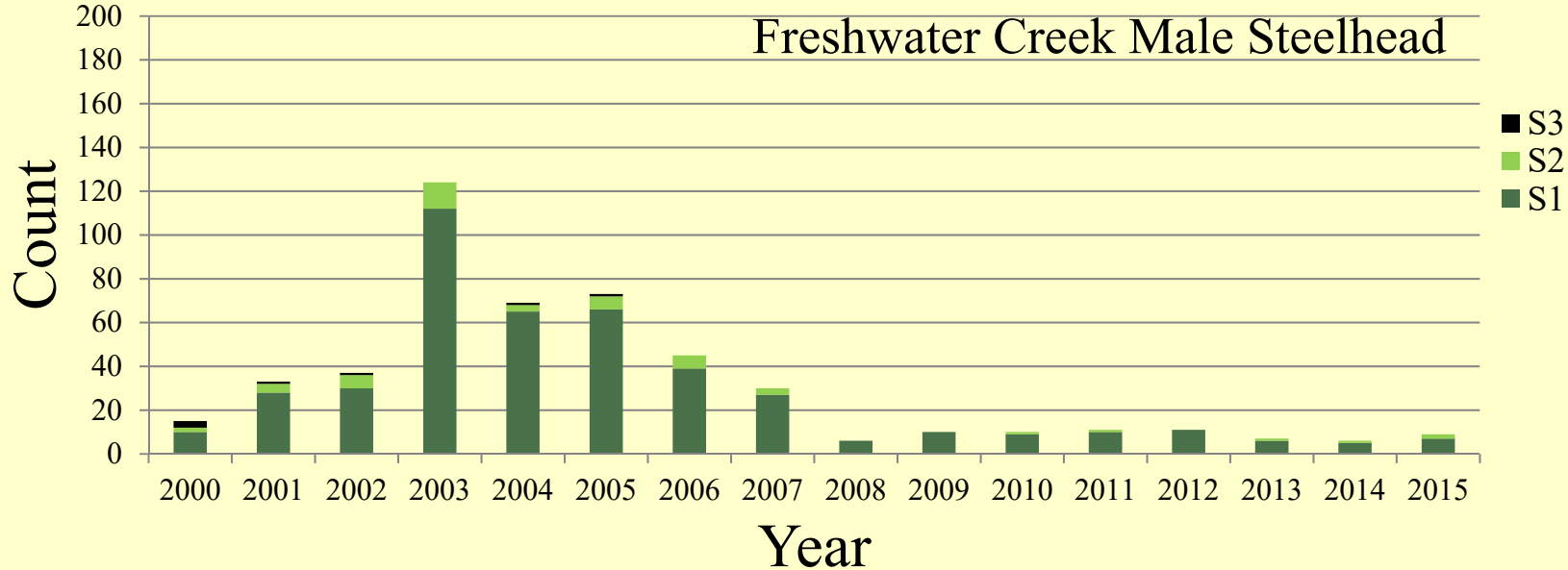
Scale pattern interpretation

- Two independent readers
- Train on ‘known’ set (PIT returns)
- 3rd read consensus
- Validate spawning ‘check’ ID
  with hidden known set
  - 1st reader 0.86
  - 2nd reader 0.97

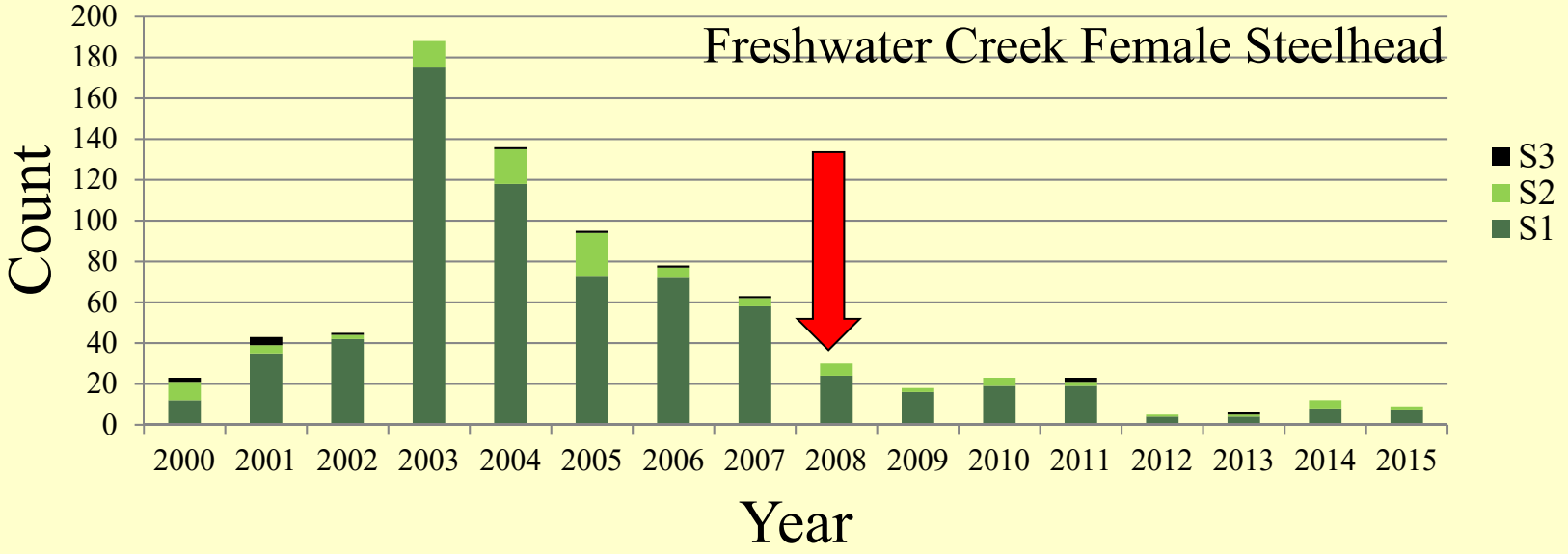




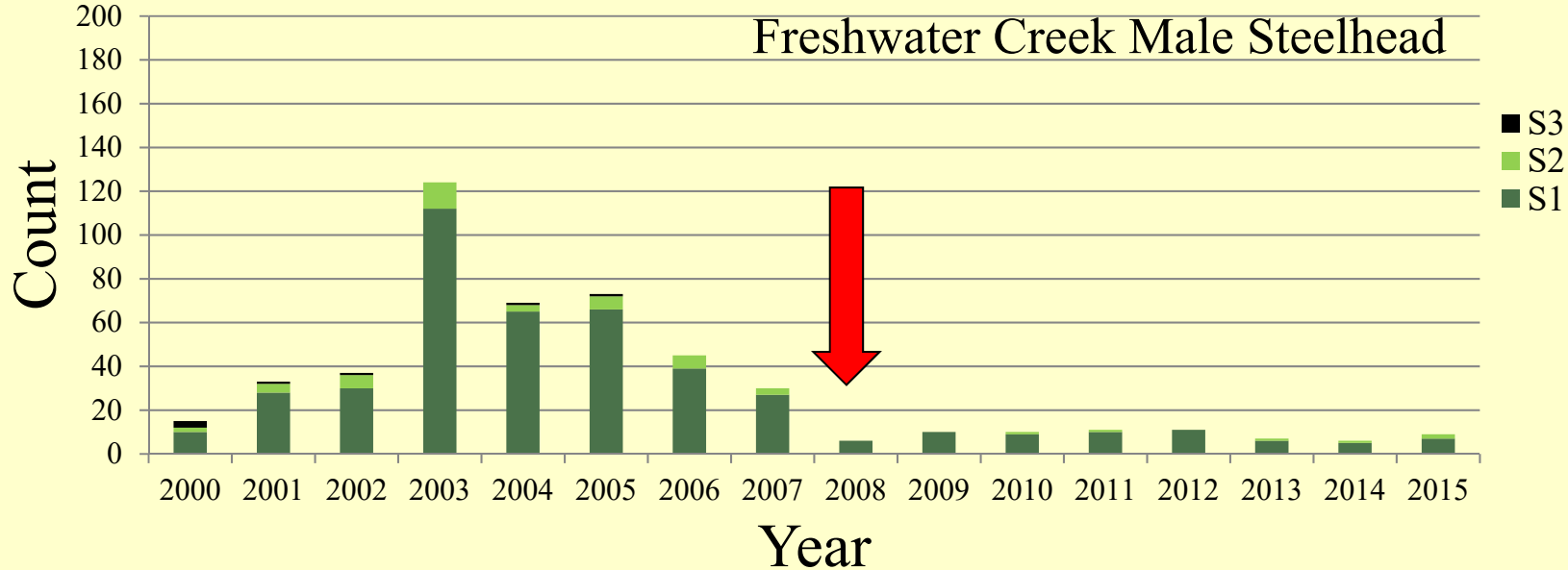
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Female	48	19	7	7	13	23	8	8	20	11	17	17	20	33	33	22



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Male	33	15	19	10	6	10	13	10	0	0	10	9	0	14	17	22



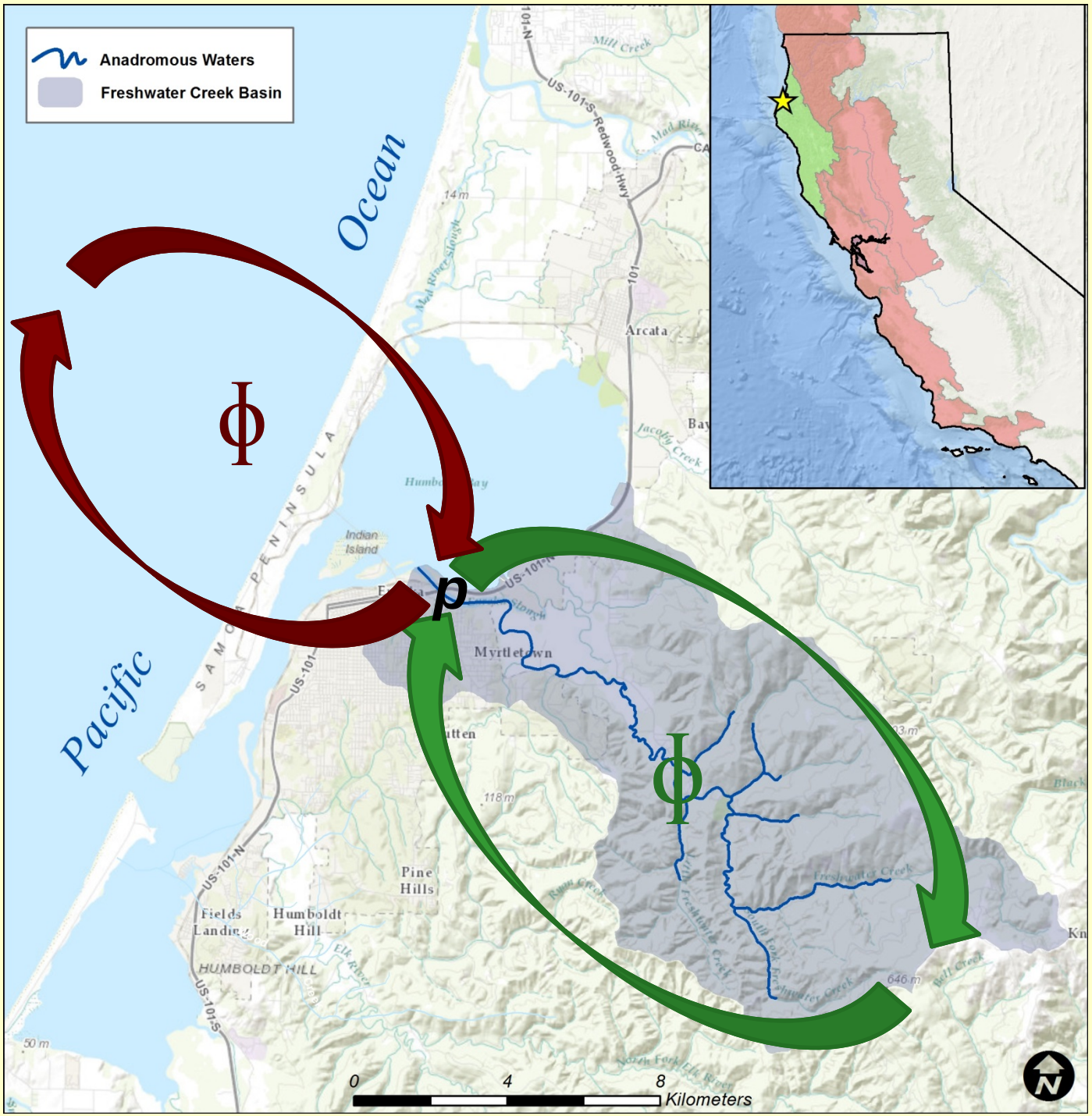
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
% Female	48	19	7	7	13	23	8	8	20	11	17	17	20	33	33	22



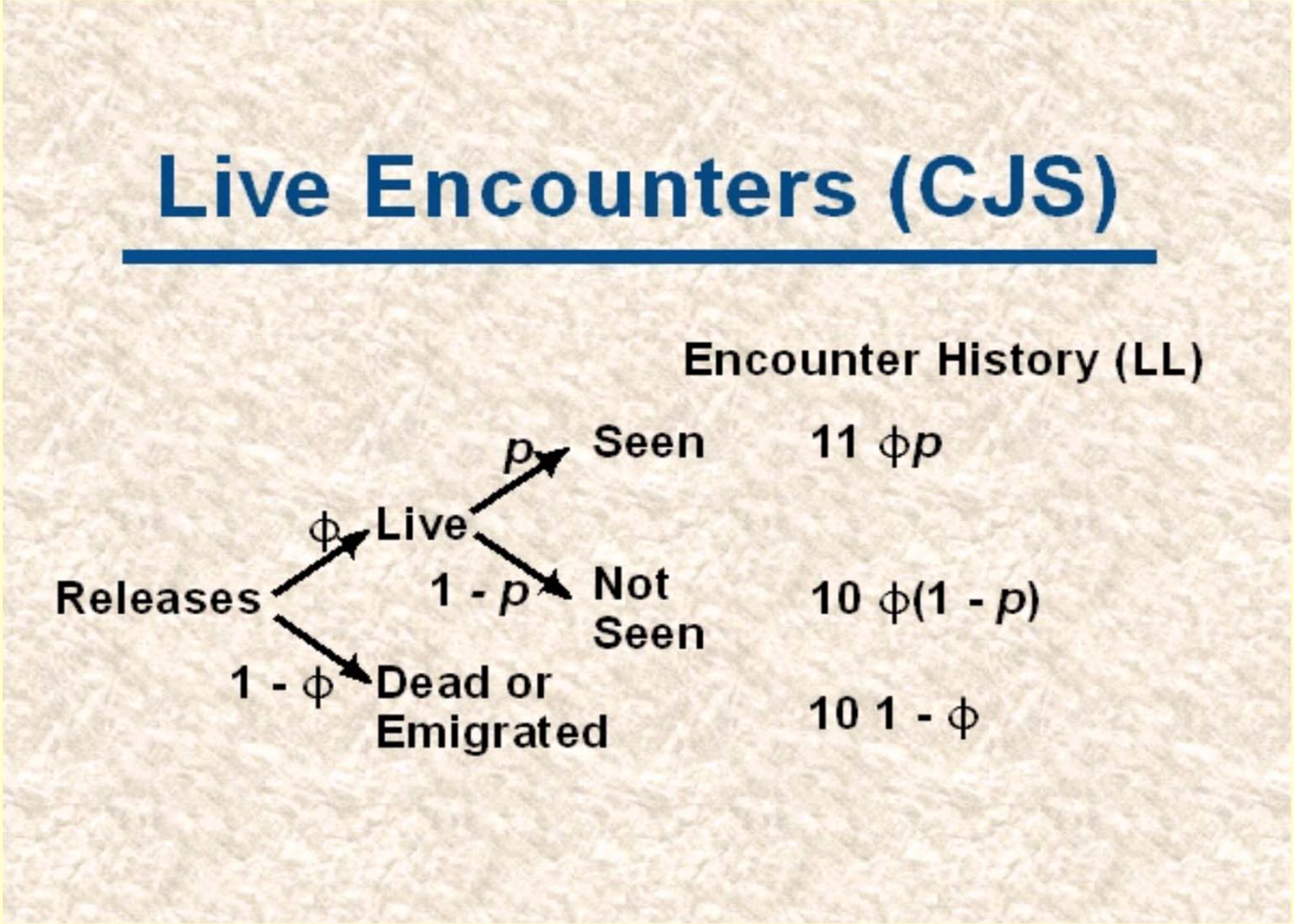
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
%Male	33	15	19	10	6	10	13	10	0	0	10	9	0	14	17	22

What is the range and magnitude of spawning and kelt marine survival?

PIT tag based CJS


Anadromous Waters
Freshwater Creek Basin
Ocean
Pacific
Φ
p
Φ
Arcata
Myrtletown
Pine Hills
Fields Landing
Humboldt Hill
HUMBOLDT HILL
Indian Island
SAMOA PENINSULA
US-101-N
US-101-S-Redwood Hwy
US-101
US-101-S
Mad River Slough
Jacoby Creek
Elk River
Freshwater Creek
14 m
118 m
646 m
50 m
0
4
8
Kilometers

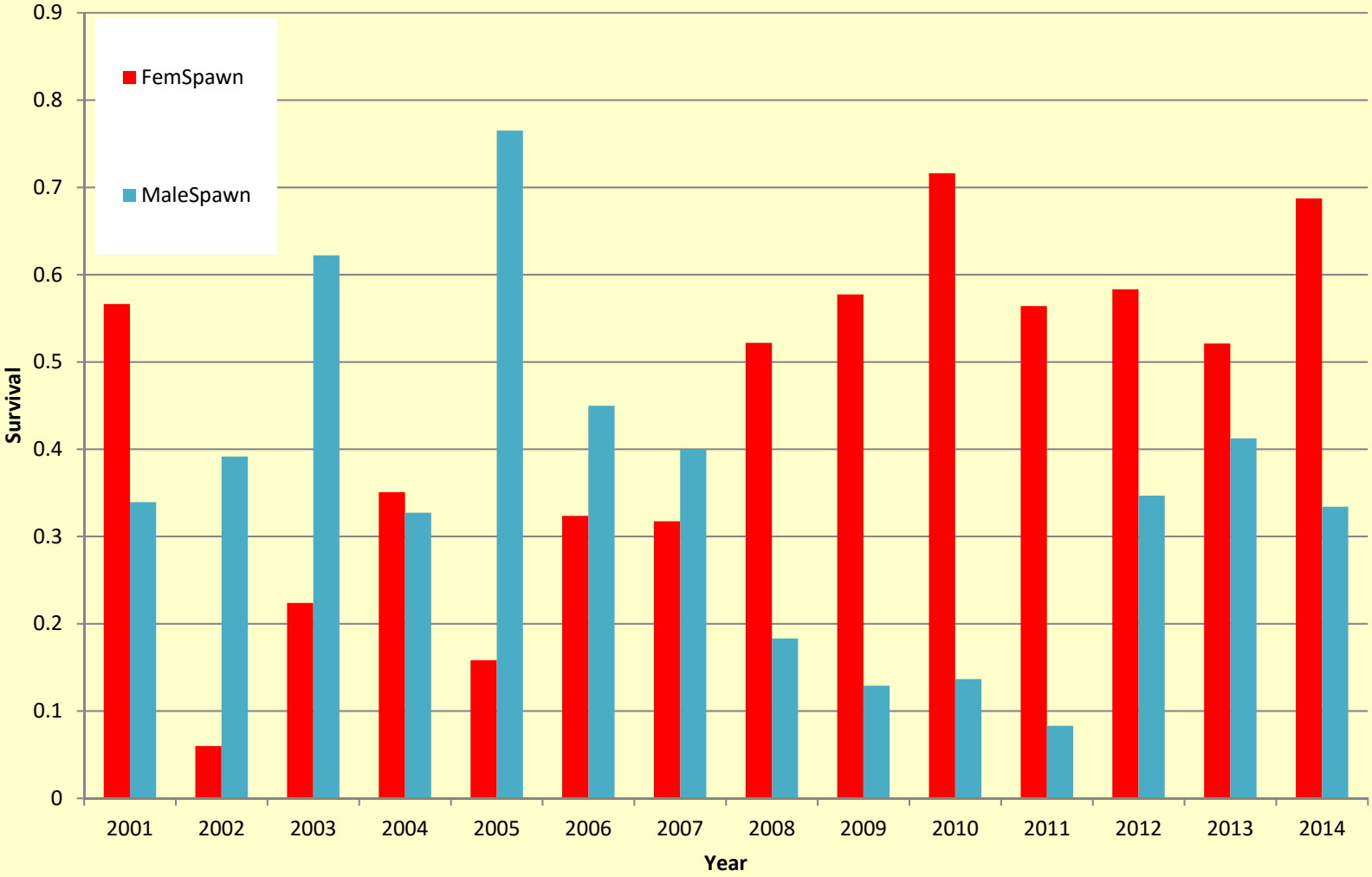
CJS estimates of survival rates



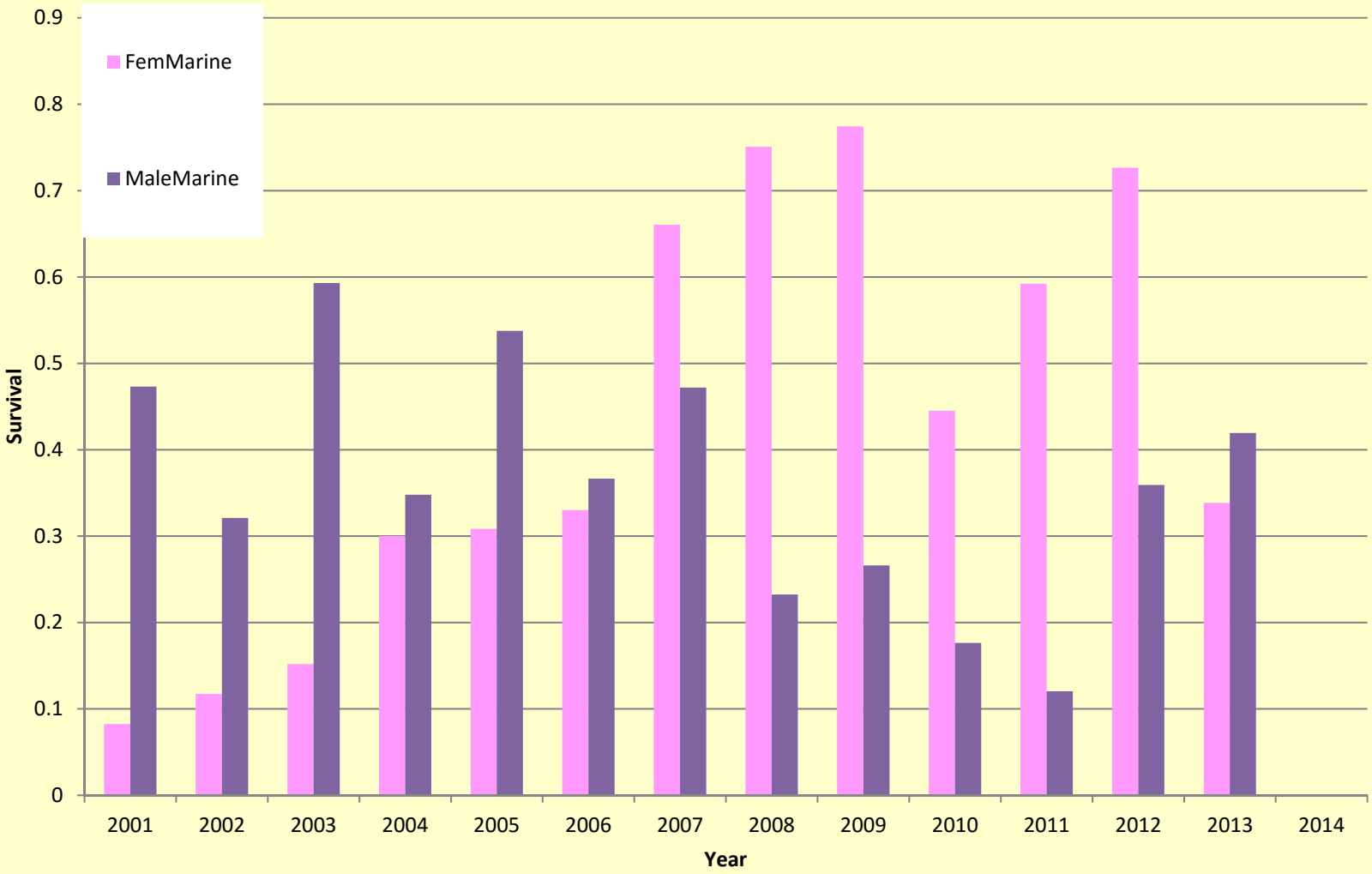
Mark Recapture Design

	Expected number of recaptures, $E(mij\|Ri)$ at time j				
Releases at time i	j=2 D/S (01-02)	3 U/S (02-03)	4 D/S (02-03)	5 U/S (03-04)	6…. D/S (05-06)
R1 (U/S 01-02)	$R_1(\Phi_1 p_2)$	$R_1(\Phi_1 q_2)(\Phi_2 p_3)$	$R_1(\Phi_1 q_2)(\Phi_2 q_3)$ $(\Phi_3 p_4)$	$R_1(\Phi_1 q_2)(\Phi_2 q_3)$ $(\Phi_3 q_4)(\Phi_4 p_5)$	$R_1(\Phi_1 q_2)(\Phi_2 q_3)$ $(\Phi_3 q_4)(\Phi_4 q_5)$ $(\Phi_5 q_6)$ $(\Phi_6 p_7)$
R2 (D/S 01-02)		R_2 $(\Phi_2 p_3)$	$R_2(\Phi_2 q_3)(\Phi_3 q_4)$ $(\Phi_4 p_5)$	$R_2(\Phi_2 q_3)(\Phi_3 q_4)$ $(\Phi_4 q_5)(\Phi_5 p_6)$	$R_2(\Phi_2 q_3)(\Phi_3 q_4)$ $(\Phi_4 q_5)(\Phi_5 q_6)$ $(\Phi_6 p_7)$
R3 (U/S 02-03)			$R_3(\Phi_3 q_4)(\Phi_4 p_5)$	$R_3(\Phi_3 q_4)(\Phi_4 q_5)$ $(\Phi_5 p_6)$	$R_3(\Phi_3 q_4)$ $(\Phi_4 q_5)(\Phi_5 q_6)$ $(\Phi_6 p_7)$
R4 (D/S 02-03)			$R_4(\Phi_4 p_5)$	$R_4(\Phi_4 q_5)(\Phi_5 p_6)$	$R_4(\Phi_4 q_5)(\Phi q_6)$ $(\Phi_6 p_7)$
R5 (U/S 03-04)				$R_5(\Phi_5 p_6)$	$R_5(\Phi_5 q_6)$ $(\Phi_6 p_7)$*
R6 (D/S 03-04) ….					R_6

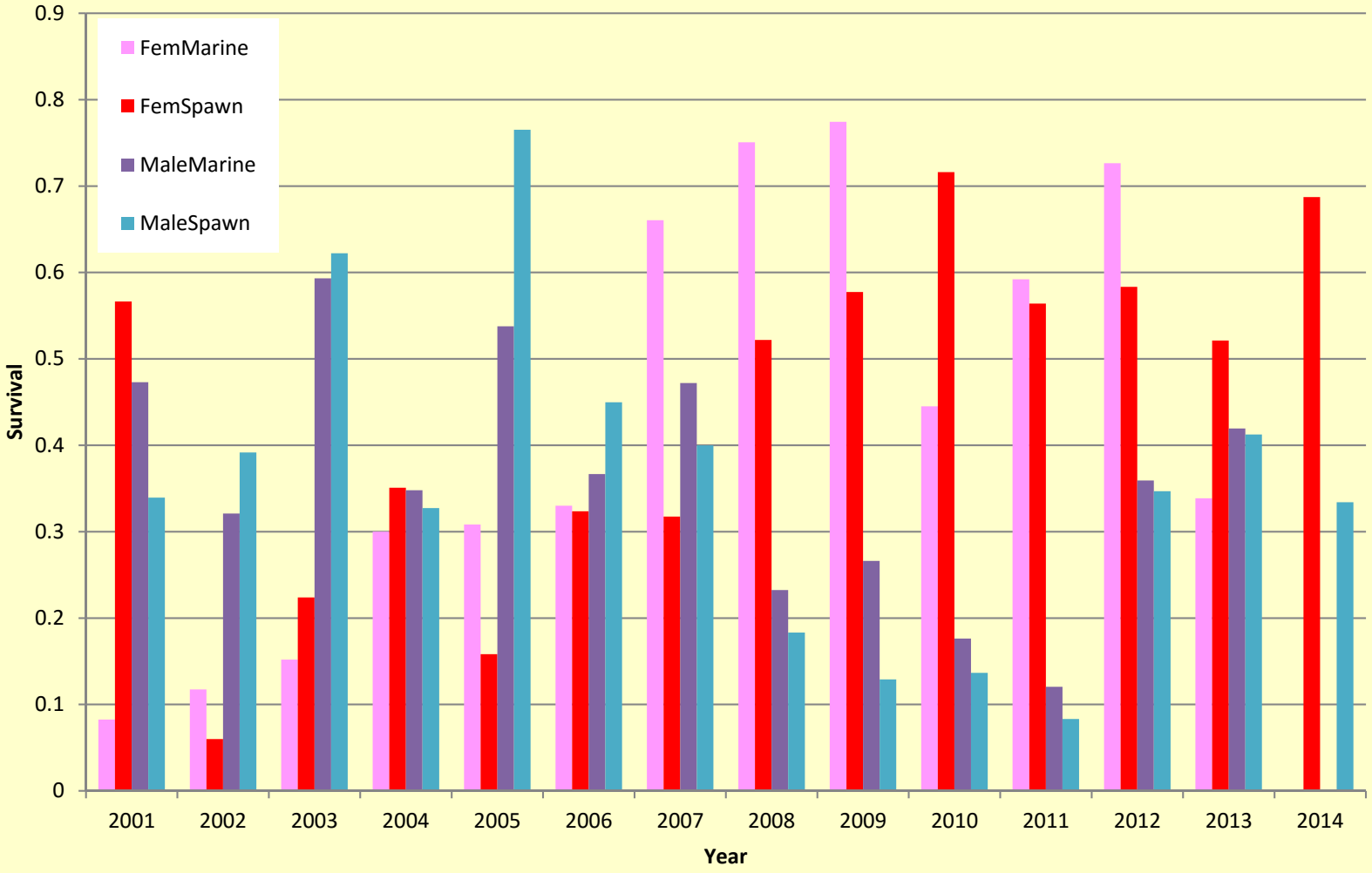
Gender specific Spawning survival model: *phi(t+sex)p(t)*



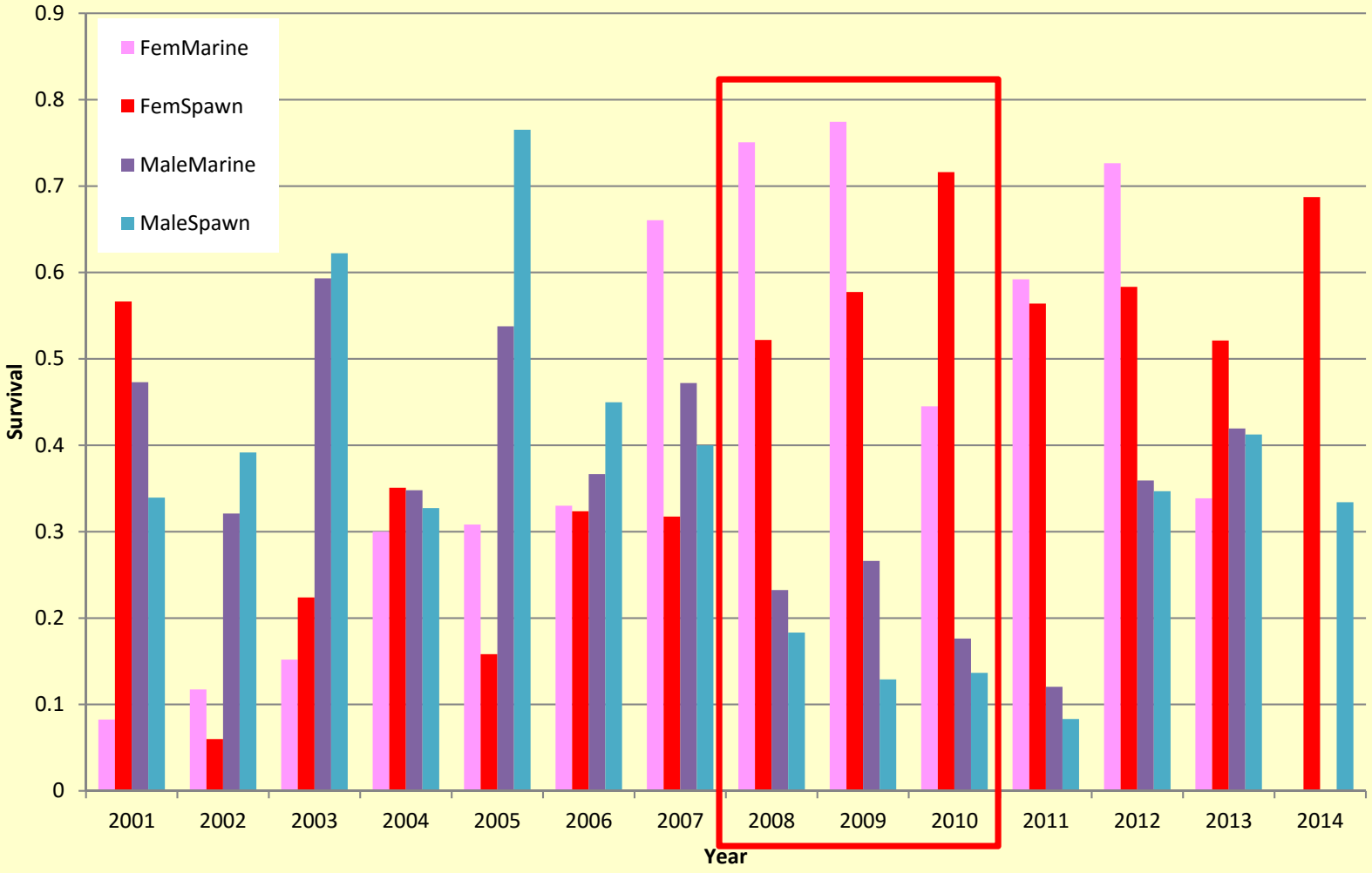
Gender specific marine survival model: *phi(t+sex)p(t)*



Gender specific Spawning and Marine survival model: *phi(t+sex)p(t)*



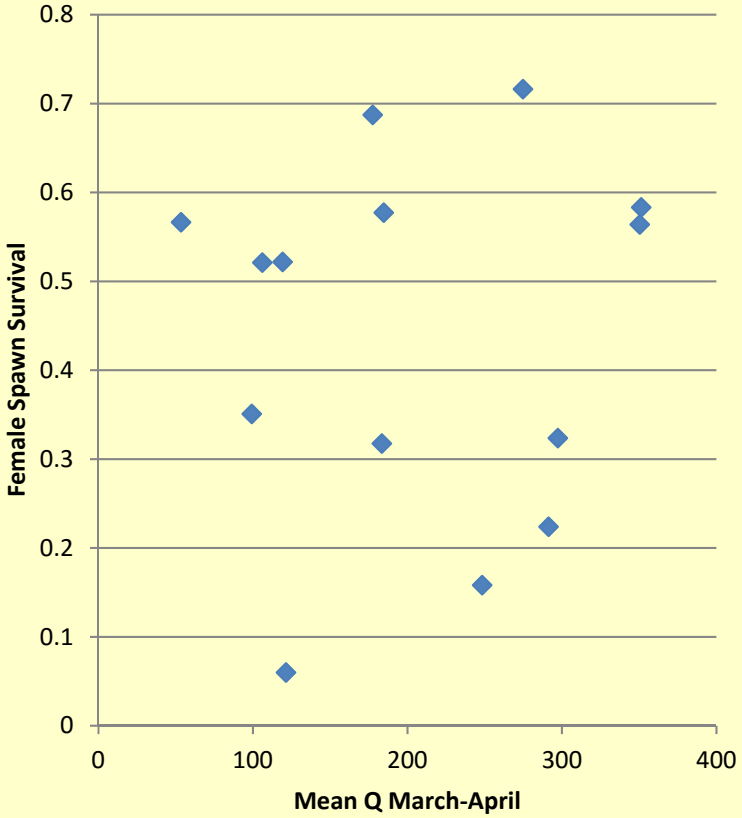
Gender specific Spawning and Marine survival model: *phi(t+sex)p(t)*

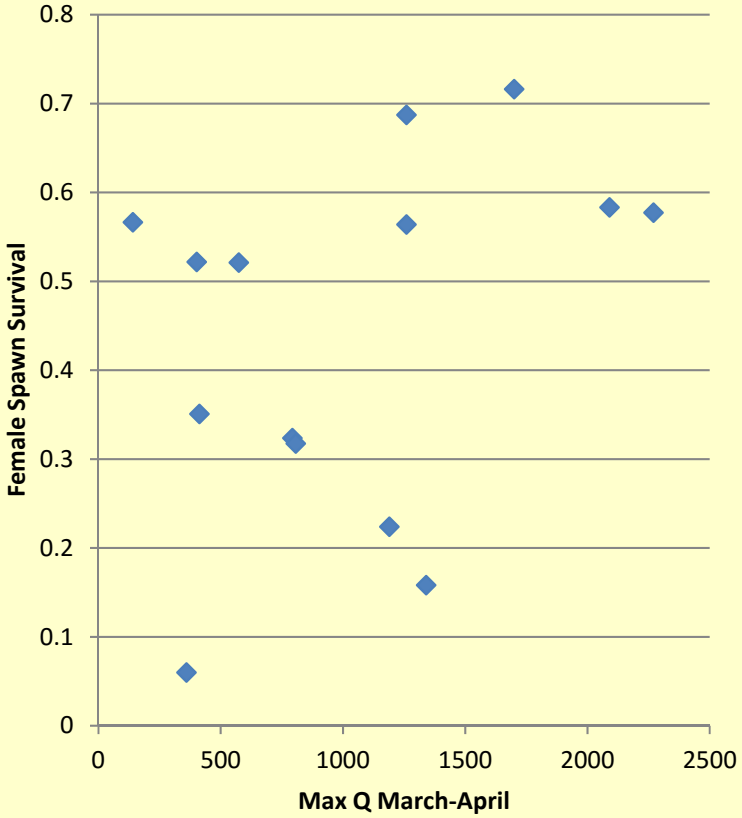


What is the relationship with behavioral, demographic and environmental processes?

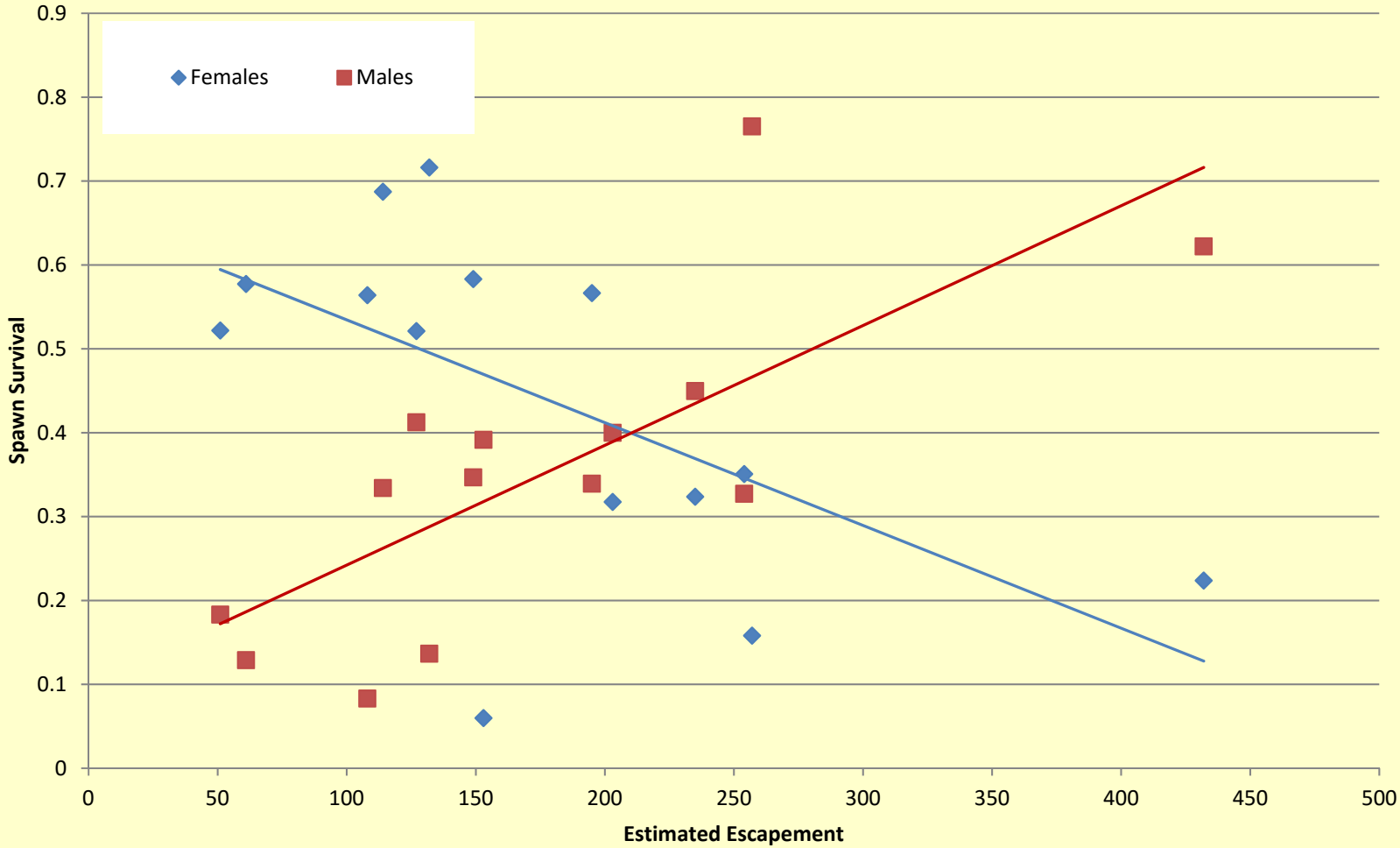
-Exploratory correlations

Stream Discharge during kelt migration?

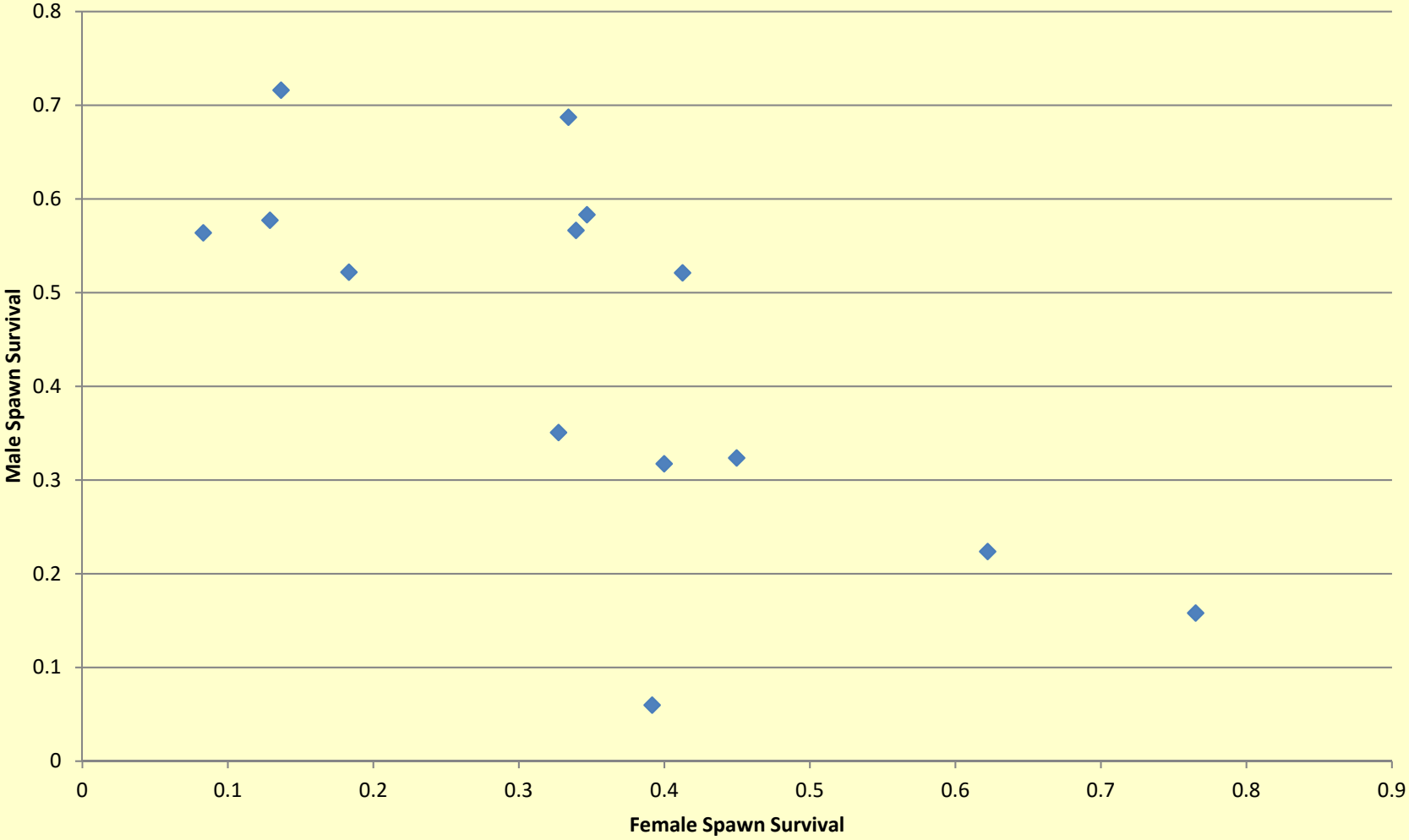




Demographic process



Demographic process

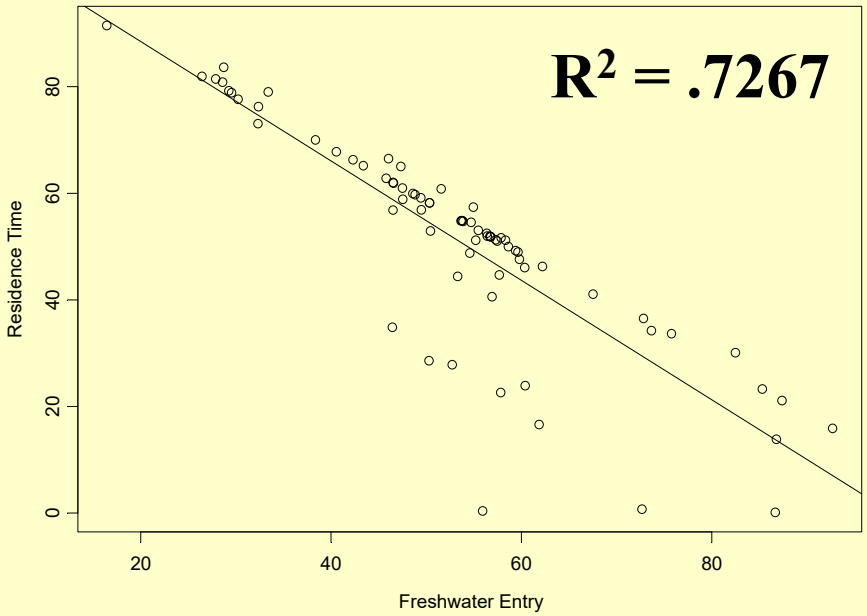


Spawning Behavior

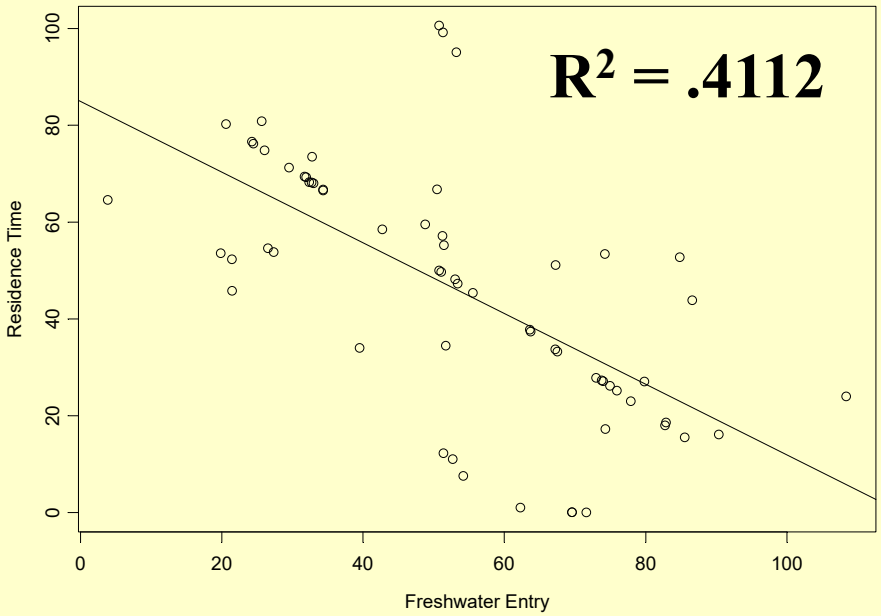
Gender vs. Residence Time

Year	Sex	Mean	n	t	p-value	CI
2003-04	Male	64.07	20	3.6	.0006	(7.46, 25.99)
	Female	47.35	55			
2004-05	Male	64.68	11	2.4	.02	(3.08, 34.51)
	Female	45.88	44			
2005-06	Male	79.91	19	5.13	<.0005	(17.31, 39.55)
	Female	51.48	35			

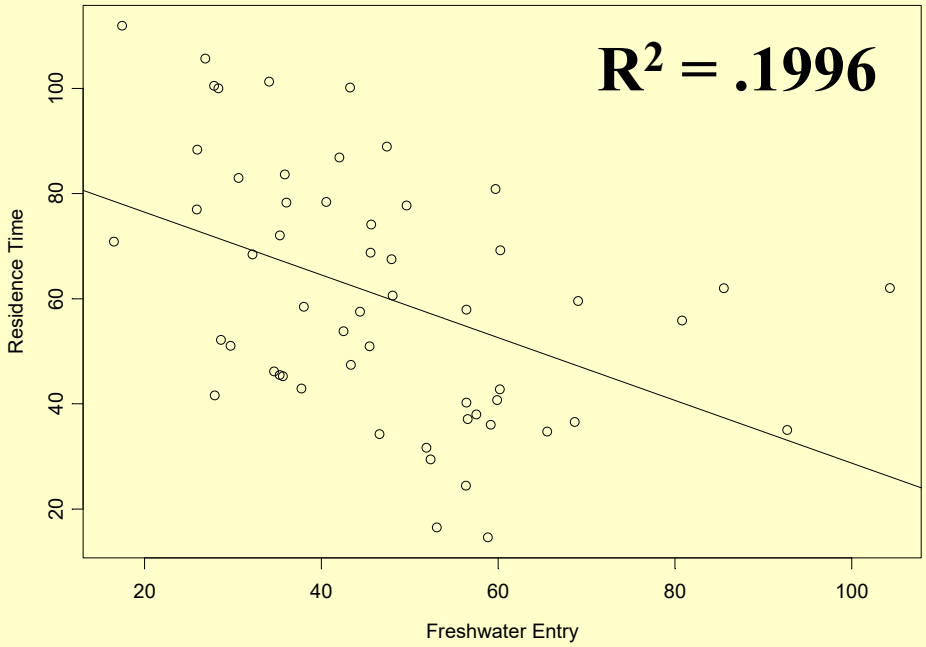
2003-04: Steelhead Residence Time vs. Entry Date

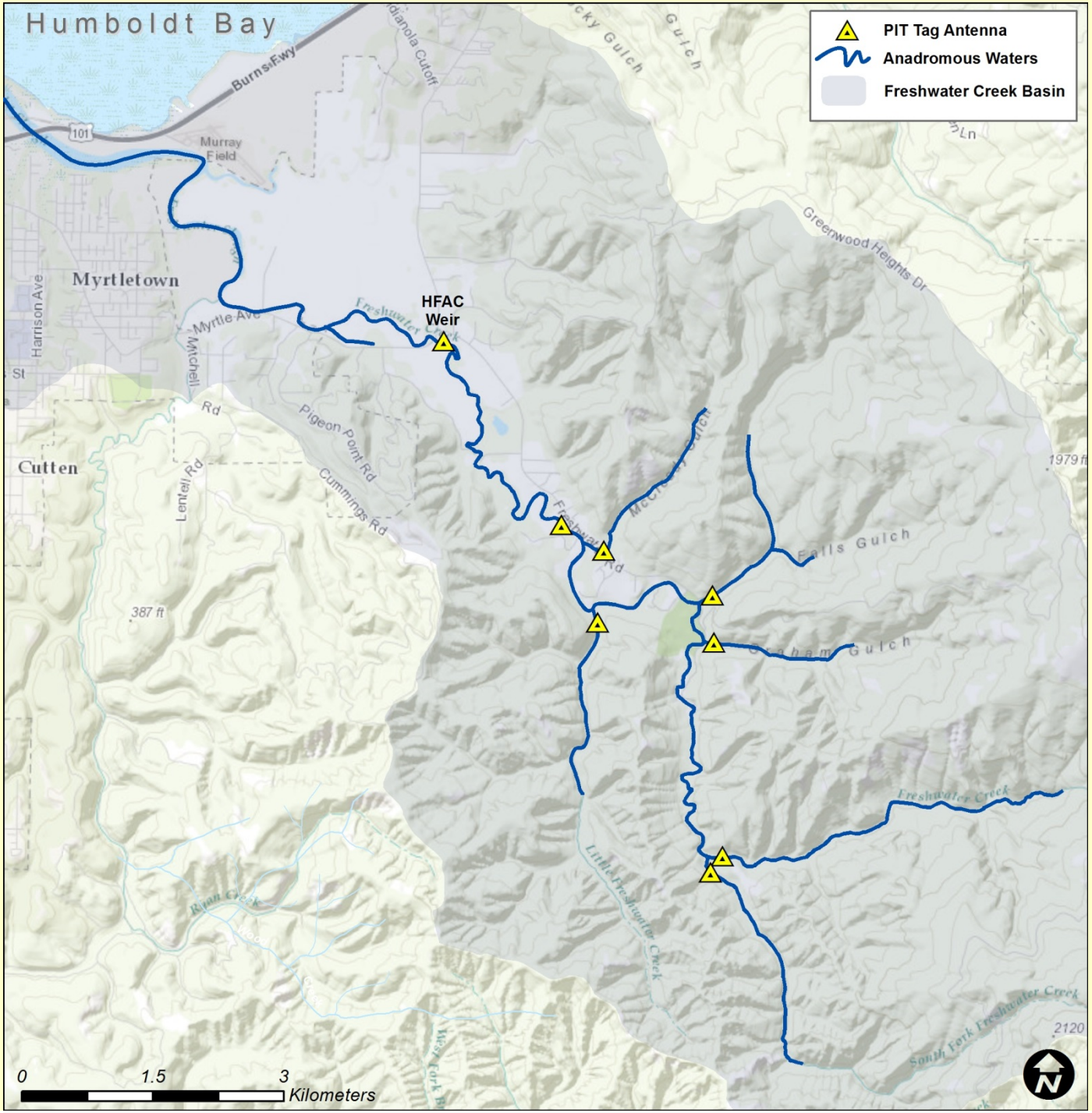


2004-05: Steelhead Residence Time vs. Entry Date



2005-06: Steelhead Residence Time vs. Entry Date

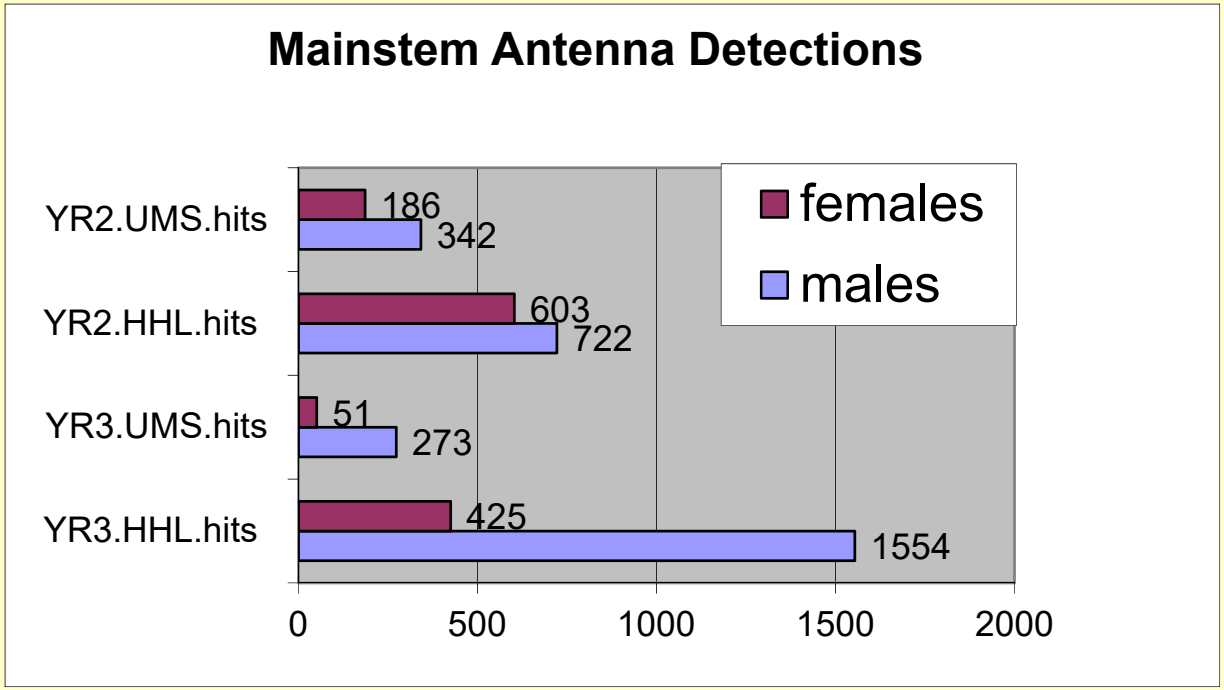


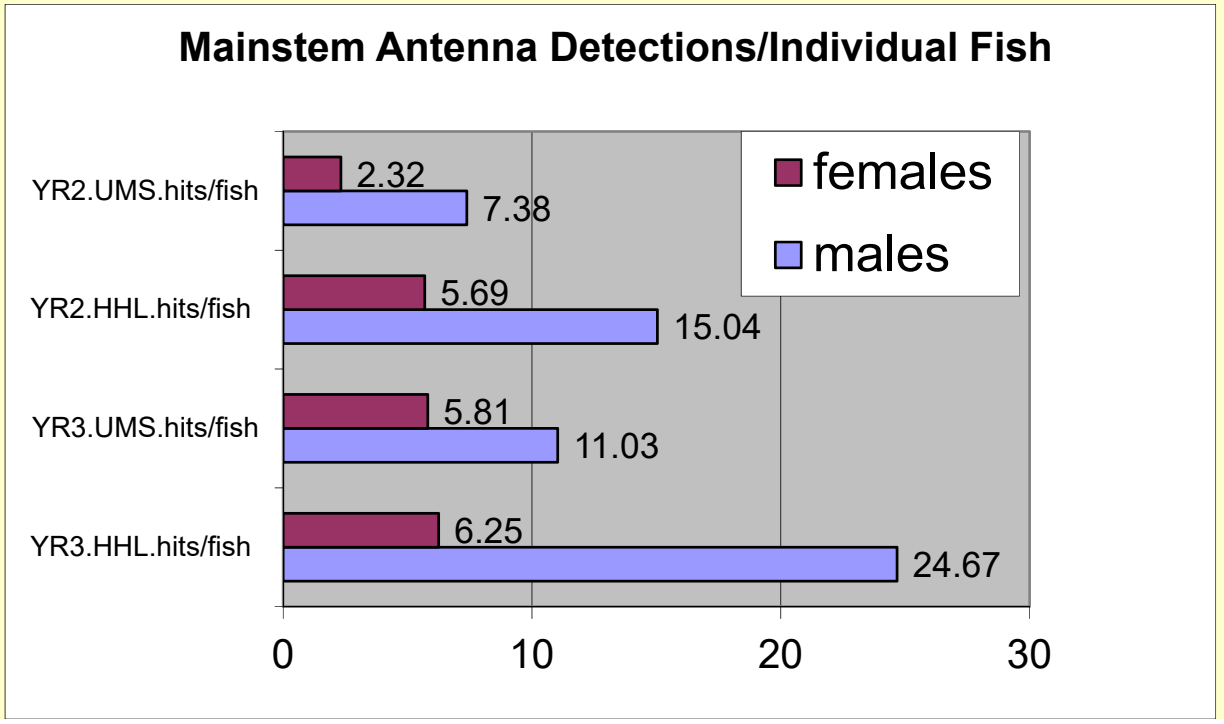

Humboldt Bay
PIT Tag Antenna
Anadromous Waters
Freshwater Creek Basin
HFAC
Weir
Myrtletown
Cutten
Murray
Field
Harrison Ave
Myrtle Ave
Mitchell
Rd
Pigeon Point Rd
Cummings Rd
Lentell Rd
Greenwood Heights Dr
Falls Gulch
Freshwater Creek
Little Freshwater Creek
South Fork Freshwater Creek
Ryan Creek
387 ft
1979 ft
2120
0
1.5
3
Kilometers
N

Stationary Antennas

paired antennas located:

- at mouth of tributaries
- in mainstem to separate lower, middle, and upper reaches


Mainstem Antenna Detections
YR2.UMS.hits
YR2.HHL.hits
YR3.UMS.hits
YR3.HHL.hits
186
342
603
722
51
273
425
1554
females
males
0
500
1000
1500
2000


Mainstem Antenna Detections/Individual Fish
YR2.UMS.hits/fish
YR2.HHL.hits/fish
YR3.UMS.hits/fish
YR3.HHL.hits/fish
2.32
7.38
5.69
15.04
5.81
11.03
6.25
24.67
females
males
0
10
20
30

Conclusions

- There is variability in both spawning and marine survival between years.
- Female iteroparity buffers abundance during poor smolt to maiden spawning (S1) survival
- We hypothesize male survival is reduced because males expend more effort spawning with as many females as possible in a single spawning event AND males may work harder to find/ensure reproduction at lowered abundance.
- ?? your interpretation ??

Acknowledgments

Dr. Terry Roelofs
Dr. David Hankin
Dr. Darren Ward
Humboldt State University Sponsored Programs Foundation
CDFW Fisheries Restoration Grants Program
Freshwater Field Crew
Colin Anderson
Jon Goin
Americorps Watershed Stewards Project

Questions