Evidence for selective mortality in marine environments: the role of fish migration size, timing, and production type.

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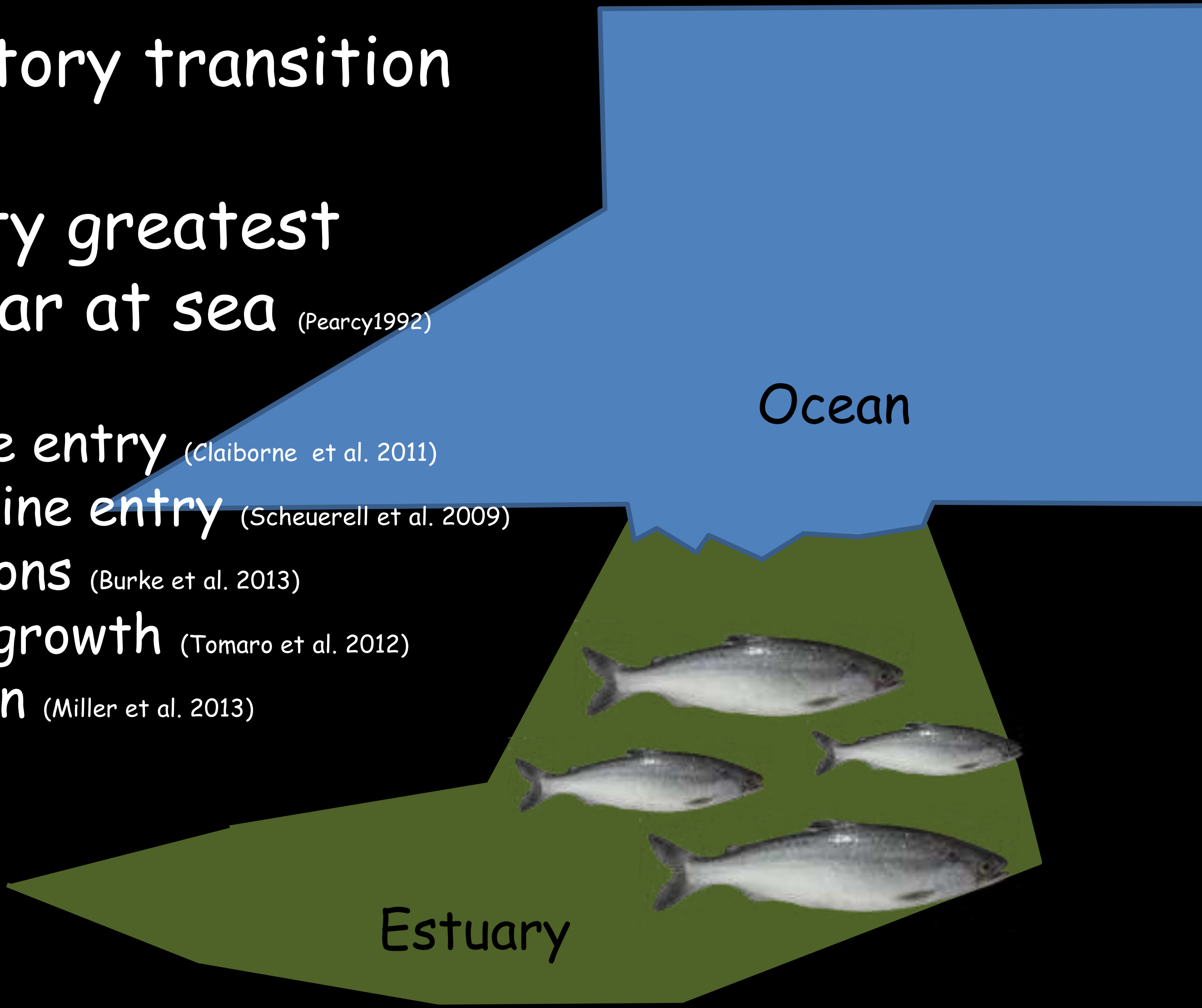
Salmon Early Ocean Ecology

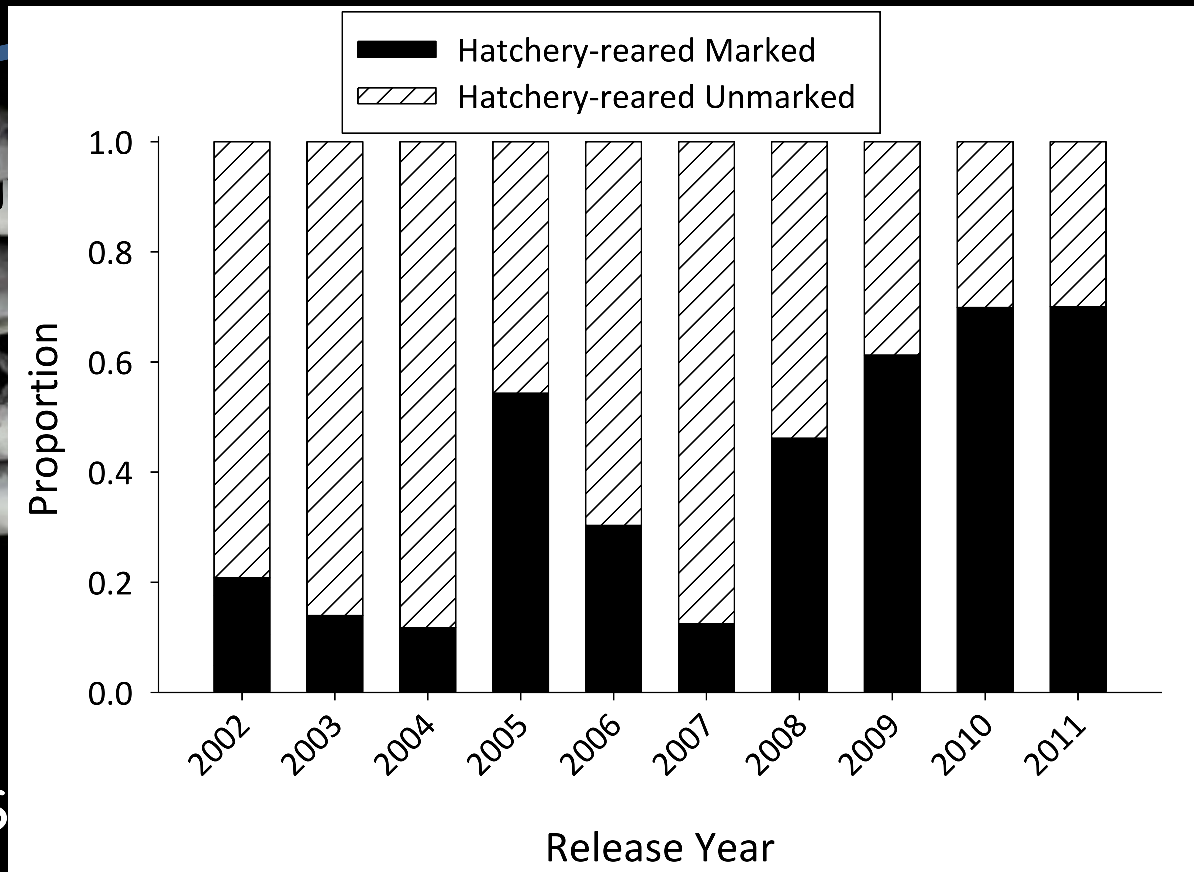
Critical life history transition

Marine mortality greatest during first year at sea (Pearcy1992)

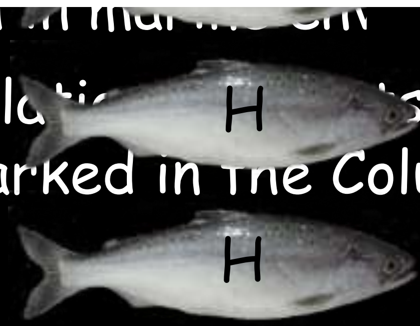
- size at marine entry (Claiborne et al. 2011)
- timing of marine entry (Scheuerell et al. 2009)
- ocean conditions (Burke et al. 2013)
- early marine growth (Tomaro et al. 2012)
- body condition (Miller et al. 2013)



What We Don't Know



- "S… hatchery fish in mar… env…
- In some popula… …s 30-80% H released unmarked in the Columbia River 2002-2011



Study Objectives

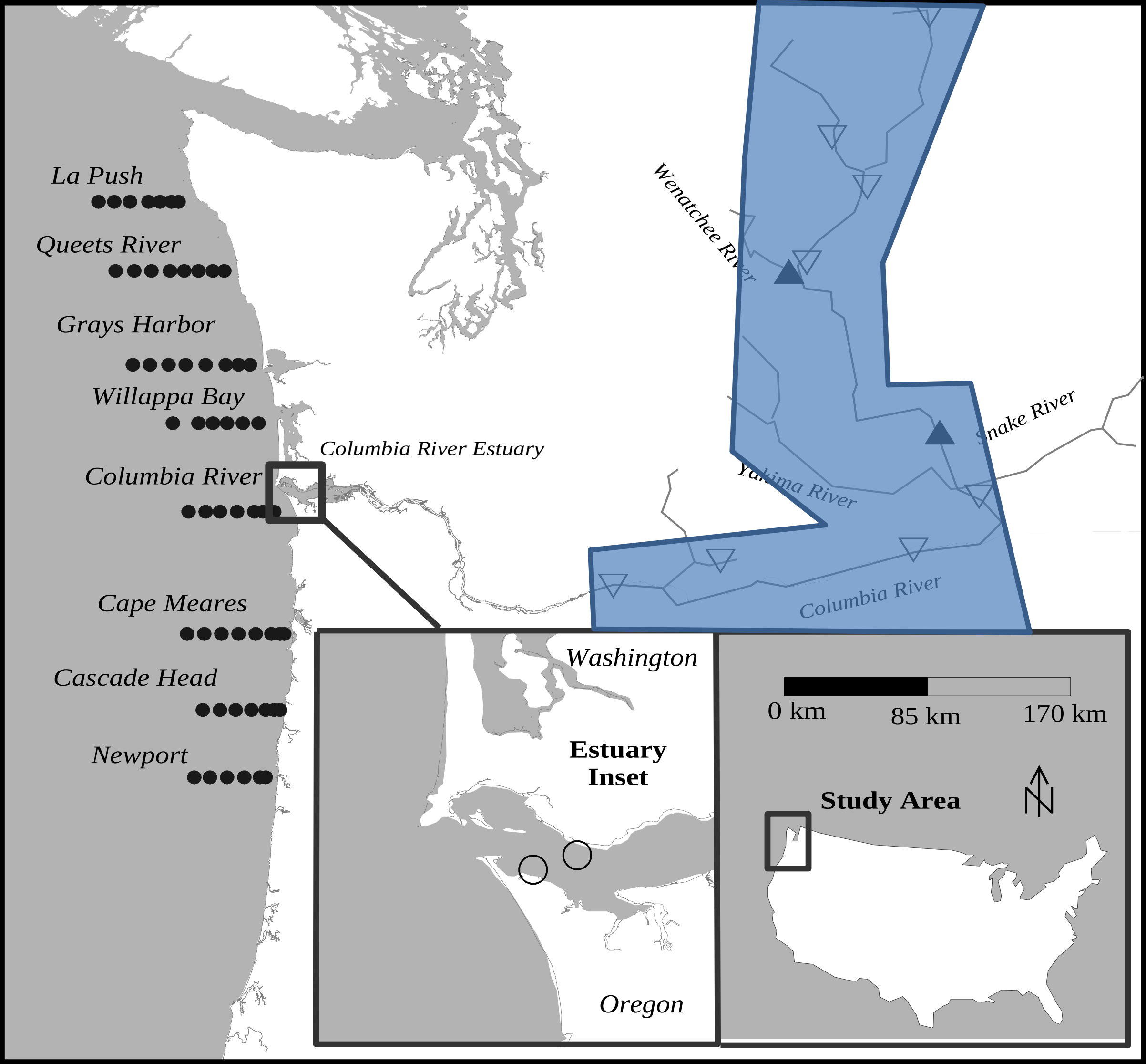
- Directly compare migratory patterns of hatchery and natural juveniles
- Determine if there is evidence for selective mortality during early marine residence related to production type, migration timing and size

Study Approach

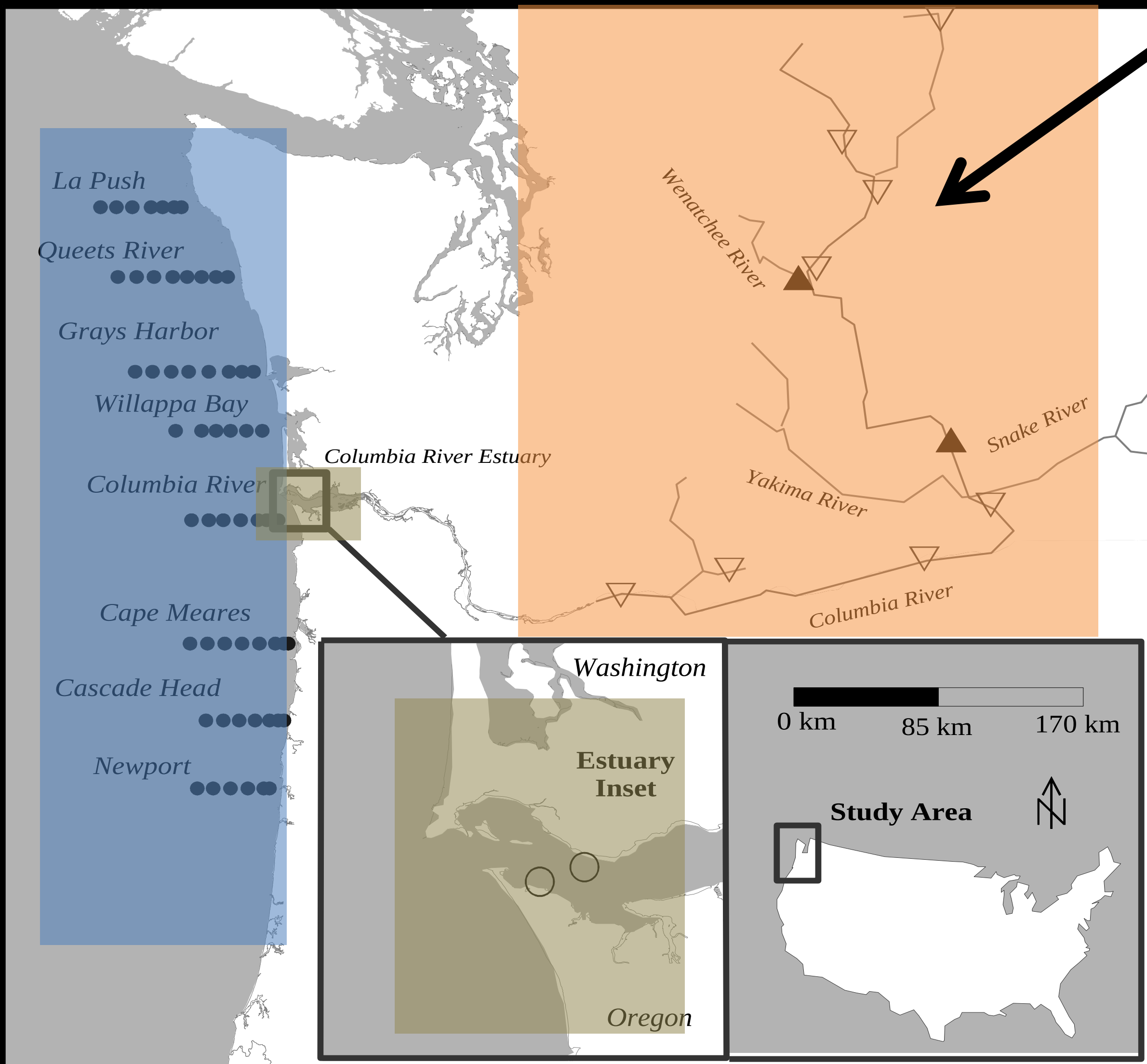
- Develop a model to discriminate between hatchery and natural juveniles using otolith structure i.e. Zang et al. 1998 & 2000, Barnett-Johnson et al. 2007
- Compare juveniles when they first enter marine waters with survivors after their first summer at sea
- Tools- stock of origin, size at and timing of marine entry, marine growth, and origin
  - genetic stock identification
  - otolith chemistry and structure
  - physical tags

UCR Su/F Stock

- GSI (D. J. Teel)
  - Mean probability of assignment 96% (7.2% SD)
- Subyearlings
  - Coastal residents
    (Fisher et al. 2007 and in press)
- Currently impossible to assess impact of hatchery production
  - 30% unmarked
    (Remis)



Fish Collections



sources (*n* = 48)

- NMFS EPS Study
- Agricultural Samples
  - 2010 & 2011
- ~60 individuals/yr

- NMFS Plume Study
- Sept 2010 & 2011
- ~60 individuals/yr

Primary Tool is Otoliths

- Otolith size related to fish size
- Otoliths are formed in daily increments
- Otoliths incorporate elements in relation to abundance in the environment

Production Type Classification (H vs N)

- H and N assignment of UNMARKED estuary and ocean fish using otolith structure

ared

ncrement widths (Claiborne 2013)

ach, model selection

* CVIW / $e^{-14.3+107.7* C}$

V.S.

ion type in 57% of

Hatchery-reared

H and N in

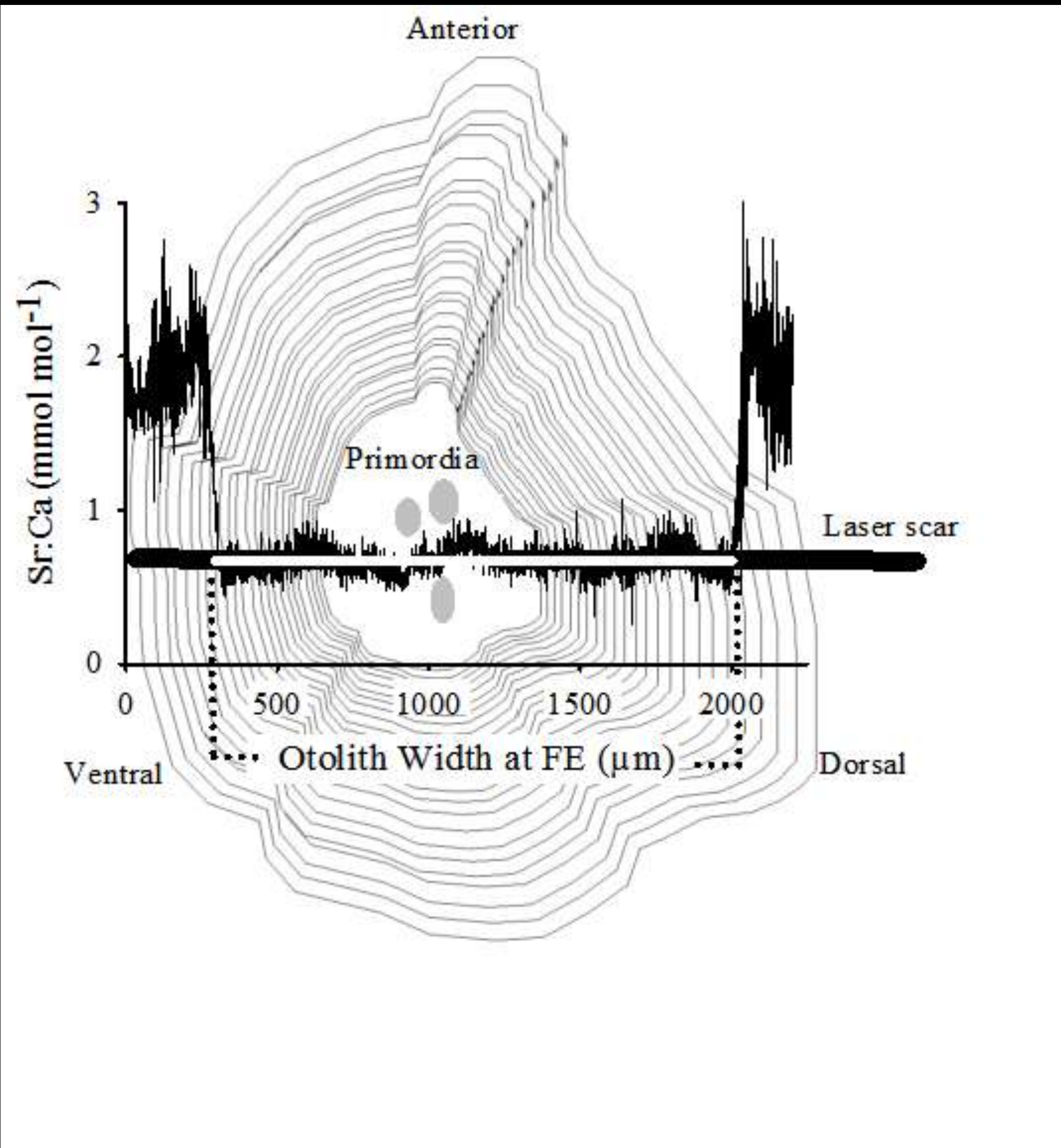
dividual assign

– Corrected % of unmarked H fish using classification model assignment (Claiborne 2013)

Zhang and Beamish 1998, Barnett-Johnson et al. 2007, Claiborne 2013

– Corrected %H in each year unmarked in each year (Daly et al. 2011, Weitkamp et al. 2012)

Size & Timing of Marine Entry, Growth



Size at freshwater emigration (FE)

- LA-ICPMS to quantify Sr:Ca
- Convert to FL FLFE = OWFE * 0.07 (± 0.004) – 7.22 (± 5.44) $R^2 = 0.77$; $p < 0.01$; $n = 133$

Timing of FE

- Daily increments & date of capture

Marine growth (%bl/d)

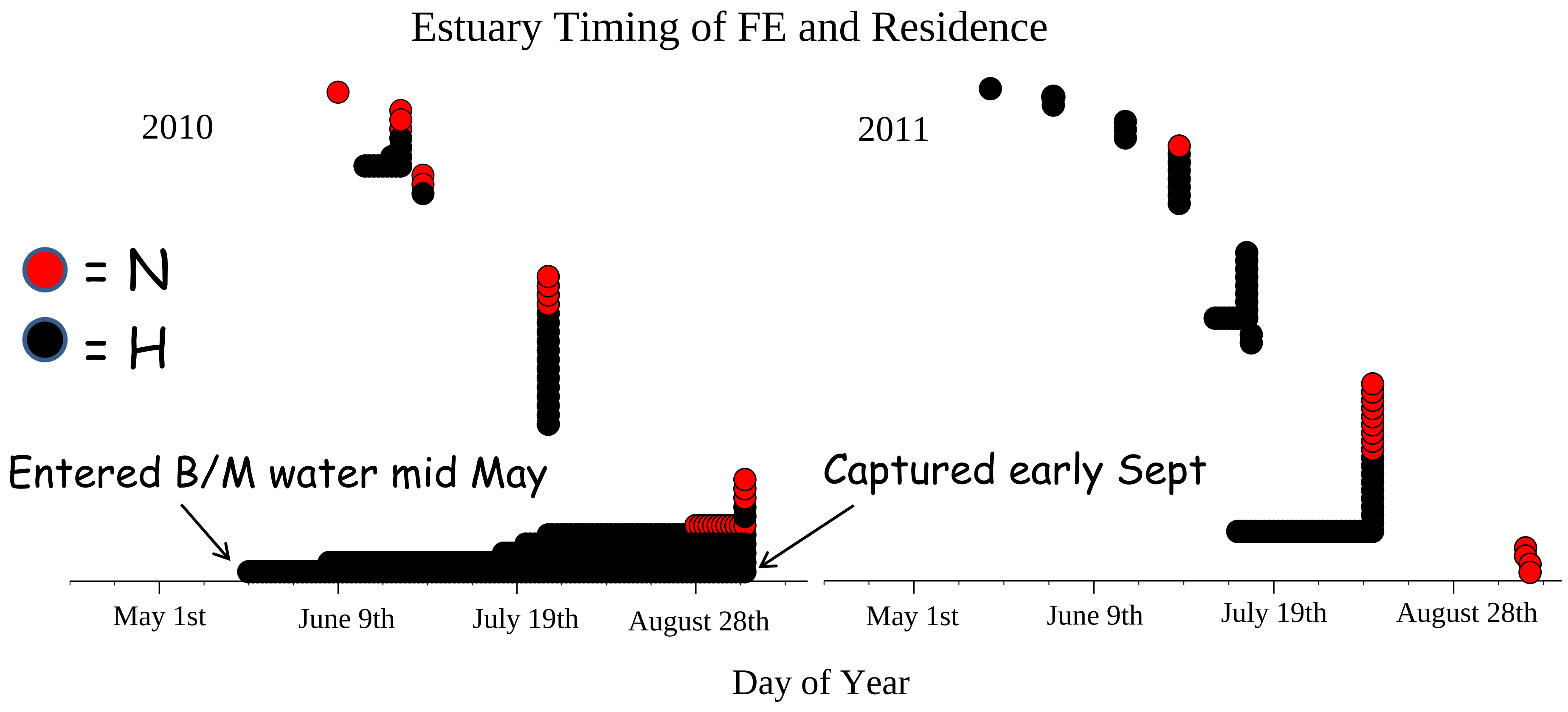
- Daily increments, size at FE & capture

Marine residence

- Daily increments

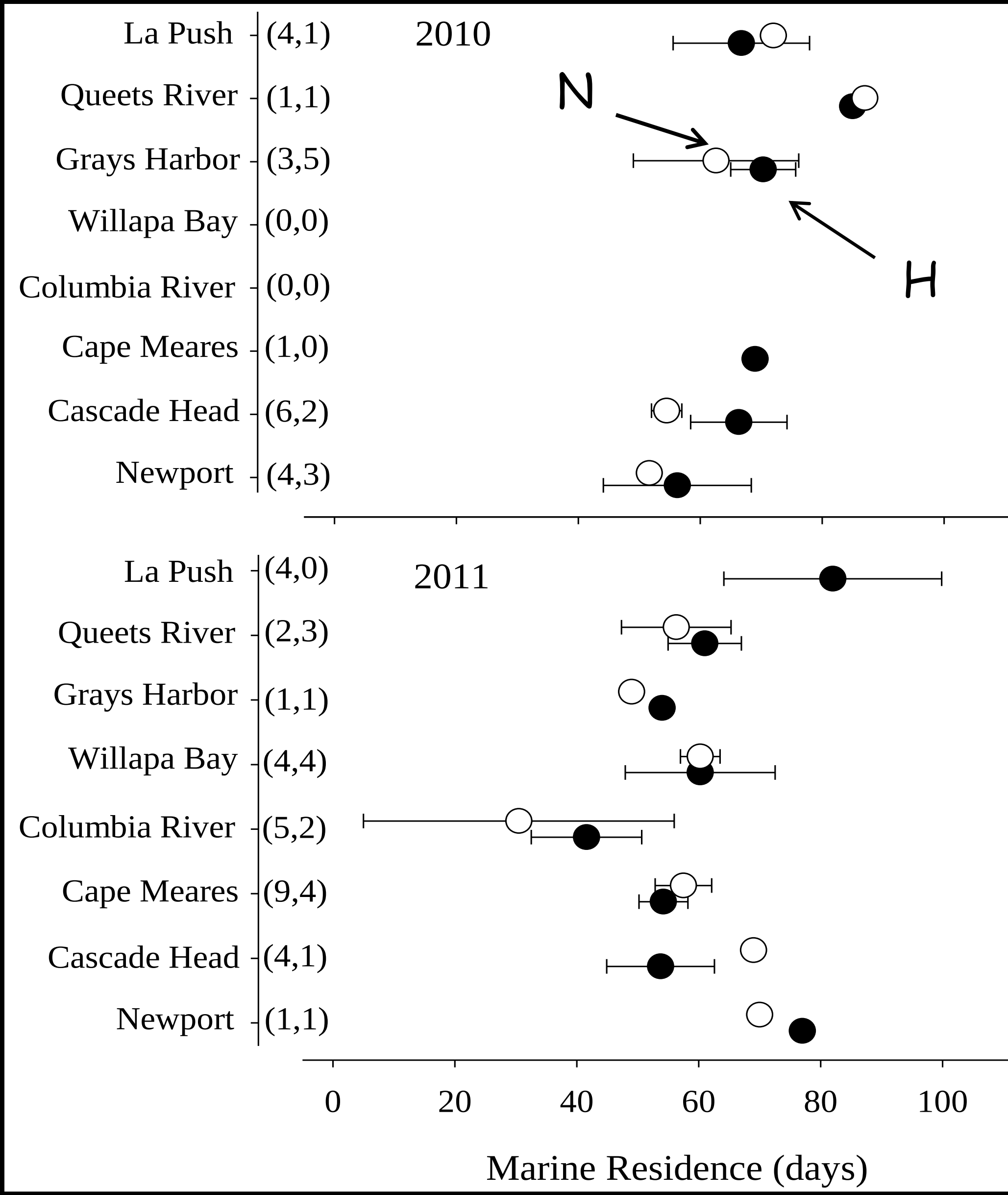
Hatchery vs Natural- Estuary

- Overall timing of freshwater emigration May-September
  - ~80% of fish < 3d residence, but residence can > 2 months
  - In 2011 FE of natural fish ~28 d later than H in 2011

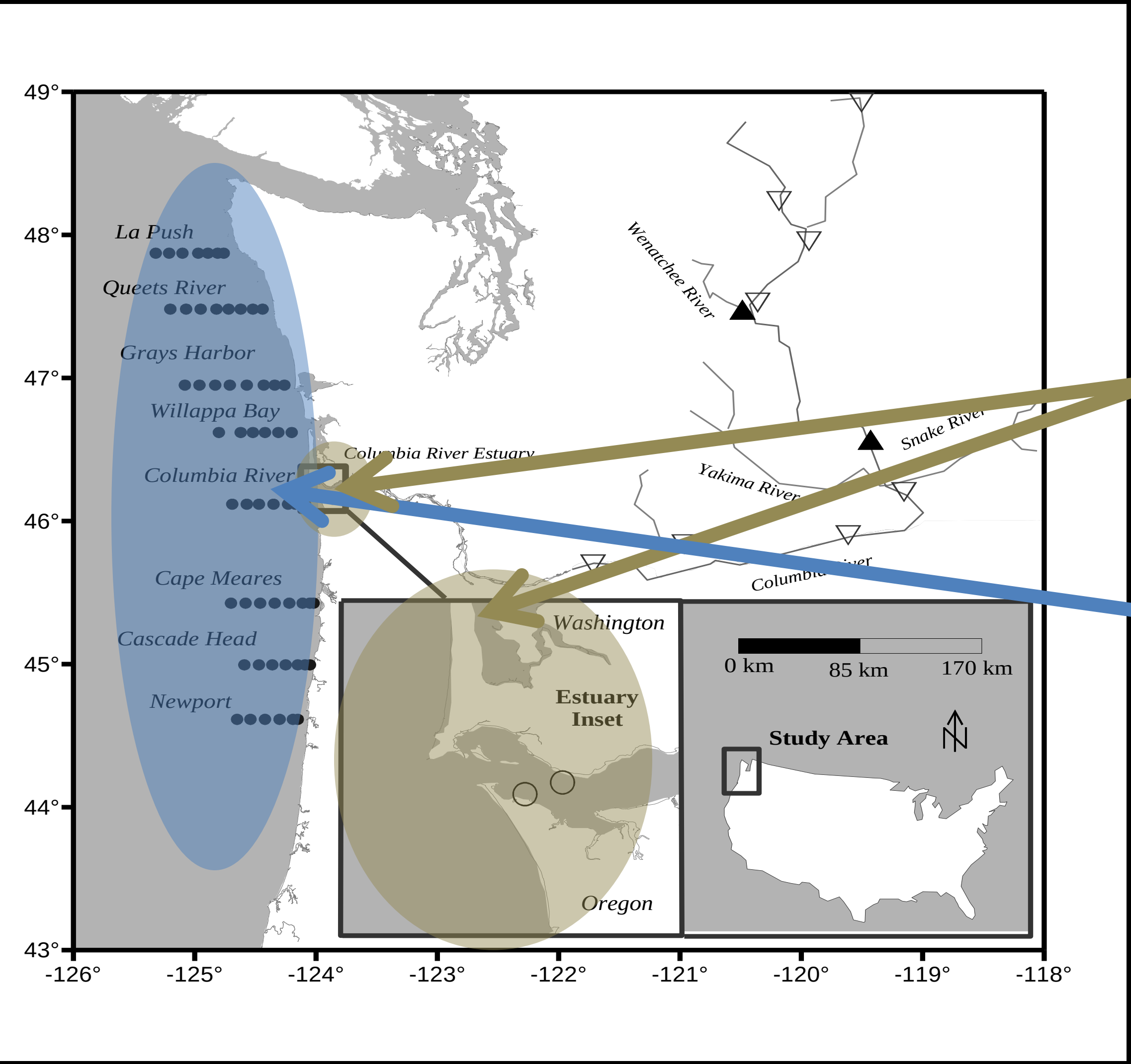


Hatchery vs Natural-Ocean

- Marine distribution similar
  - Newport to La push
- Overall size at freshwater emigration similar
  - ~100 mm at FE ranged 75 to 150
- Marine growth similar (0.9 ± 0.1 %bl/d)



Estuary vs Ocean: Contribution of H & N



Estuary 2010

N = 37-38%

H = 62-63%

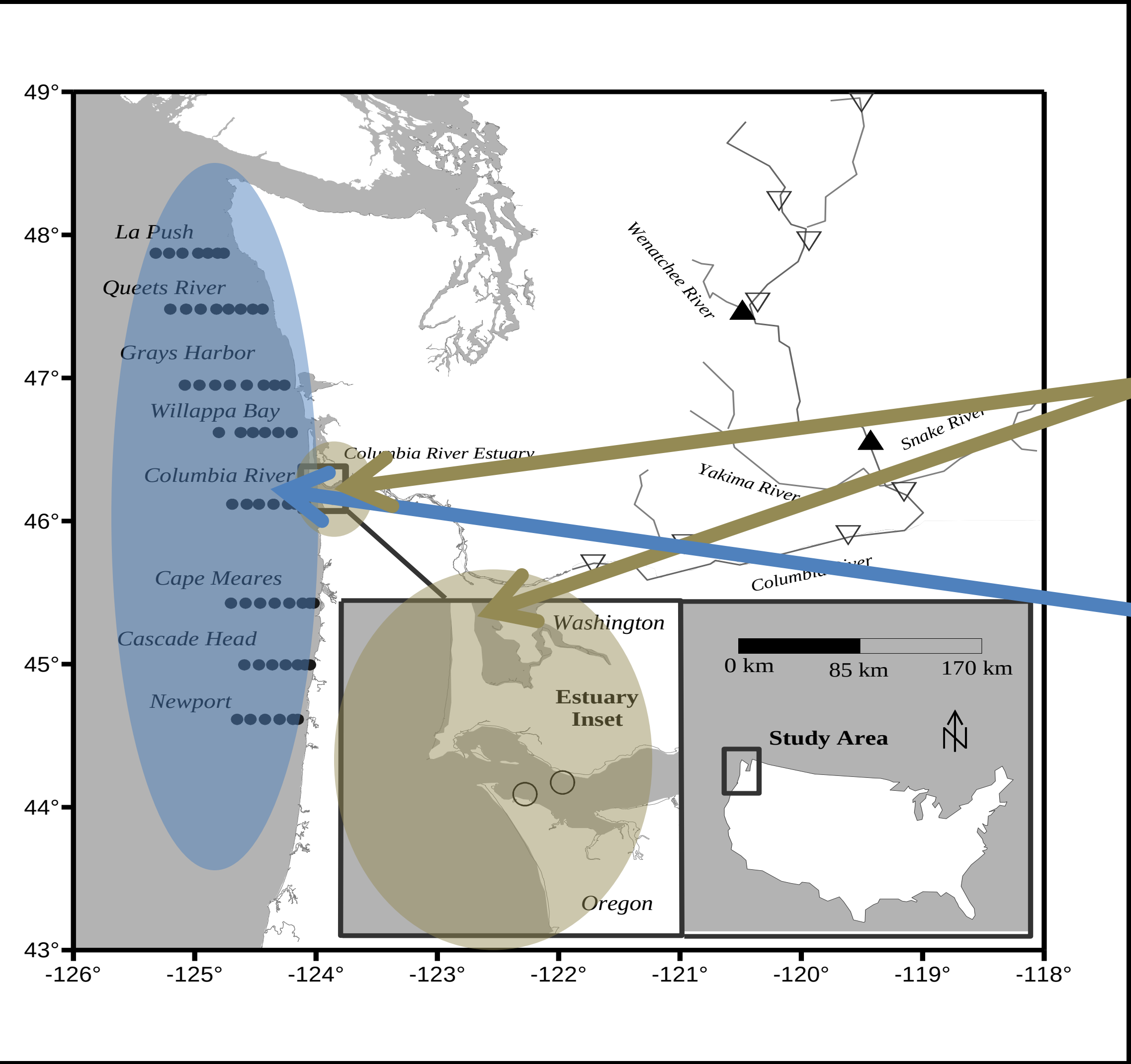
Ocean 2010

N = 41-59%

H = 41-59%

4-21% Increase in N

Estuary vs Ocean: Contribution of H & N



Estuary 2011

N =24-36%

H = 64-76%

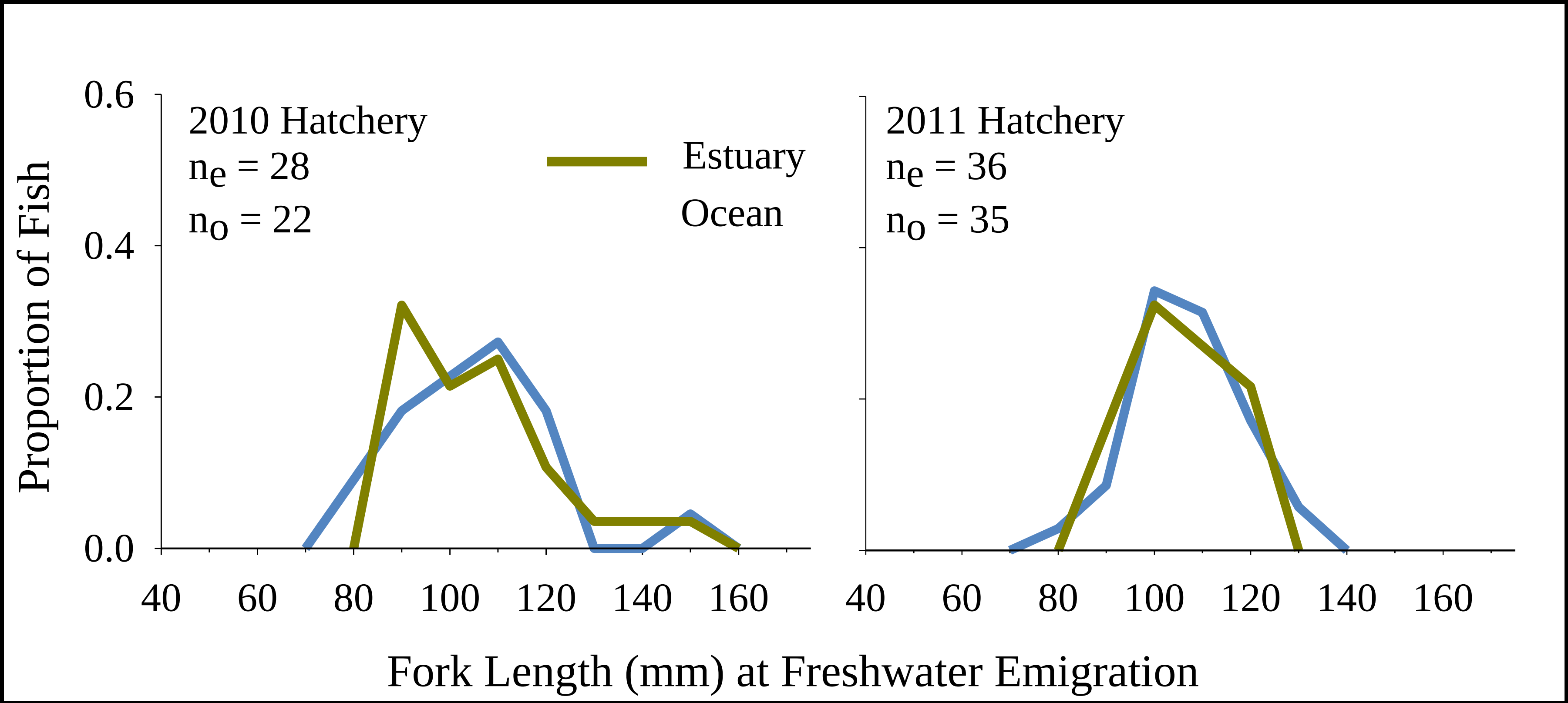
Ocean 2011

N =47-53%

H = 47-53%

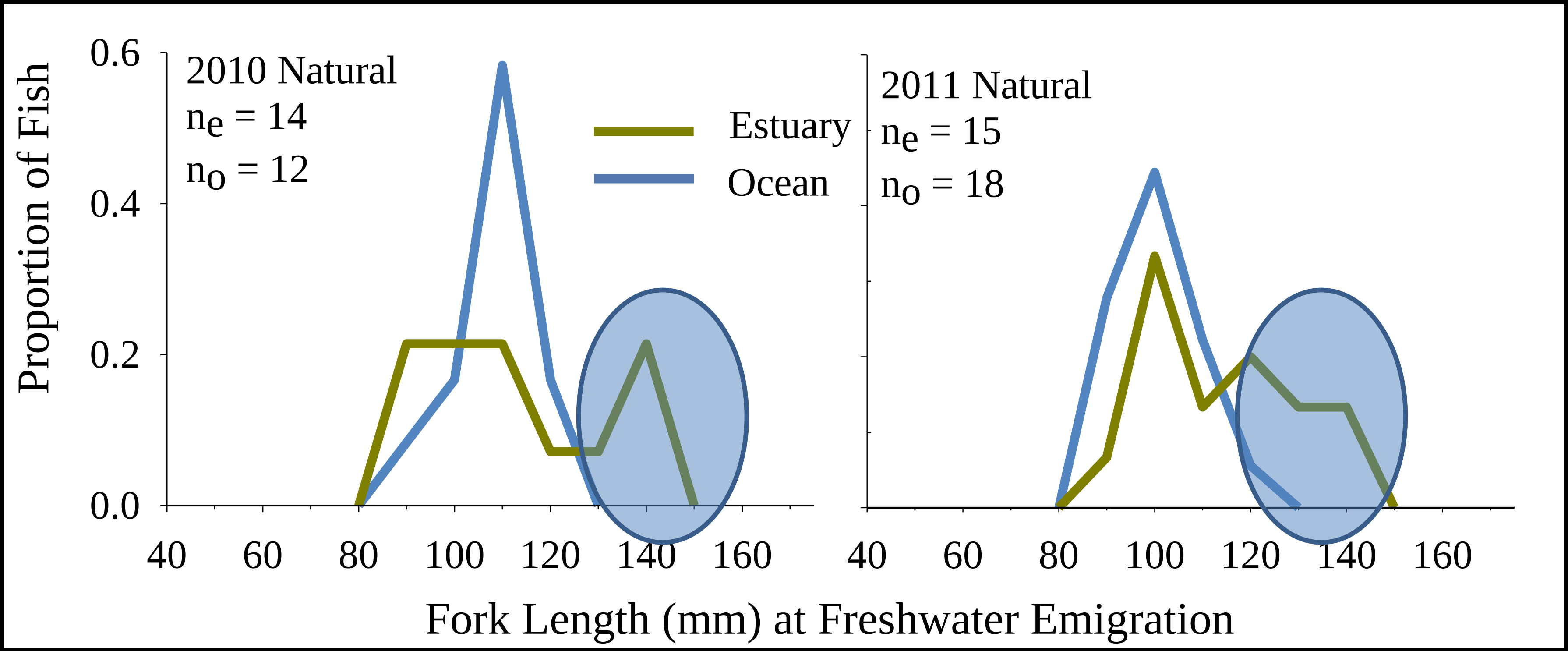
11-29% Increase in N

Estuary vs Ocean: Hatchery Size at FE



- No difference in distribution of size at FE (KS-Test $p > 0.40$)

Estuary vs Ocean: Natural Size at FE



- Suggestive difference in distribution of size at FE 2011 (p = 0.06 KS-Test)
- Large and later N fish in estuary not represented in ocean catches

Summary of Findings

- Suggestive evidence that the contribution of natural fish increased, particularly in 2011
  - Increased survival (consistent with higher fitness, differences in freshwater selection & behavioral differences)
- No evidence that bigger at marine entry is better
  - Only in years of record low adult survival i.e. 2005 (Woodsen et al. 2013)?
- In 2011 larger and later migrating natural fish not present later in ocean
  - Differential mortality? role of sample bias is unknown
- ~20% of UCR Su/F fish had resided > 3d before capture in estuary
  - Less residence than LCR stocks (Campbell 2010) but certainly a utilized habitat by an UCR stock

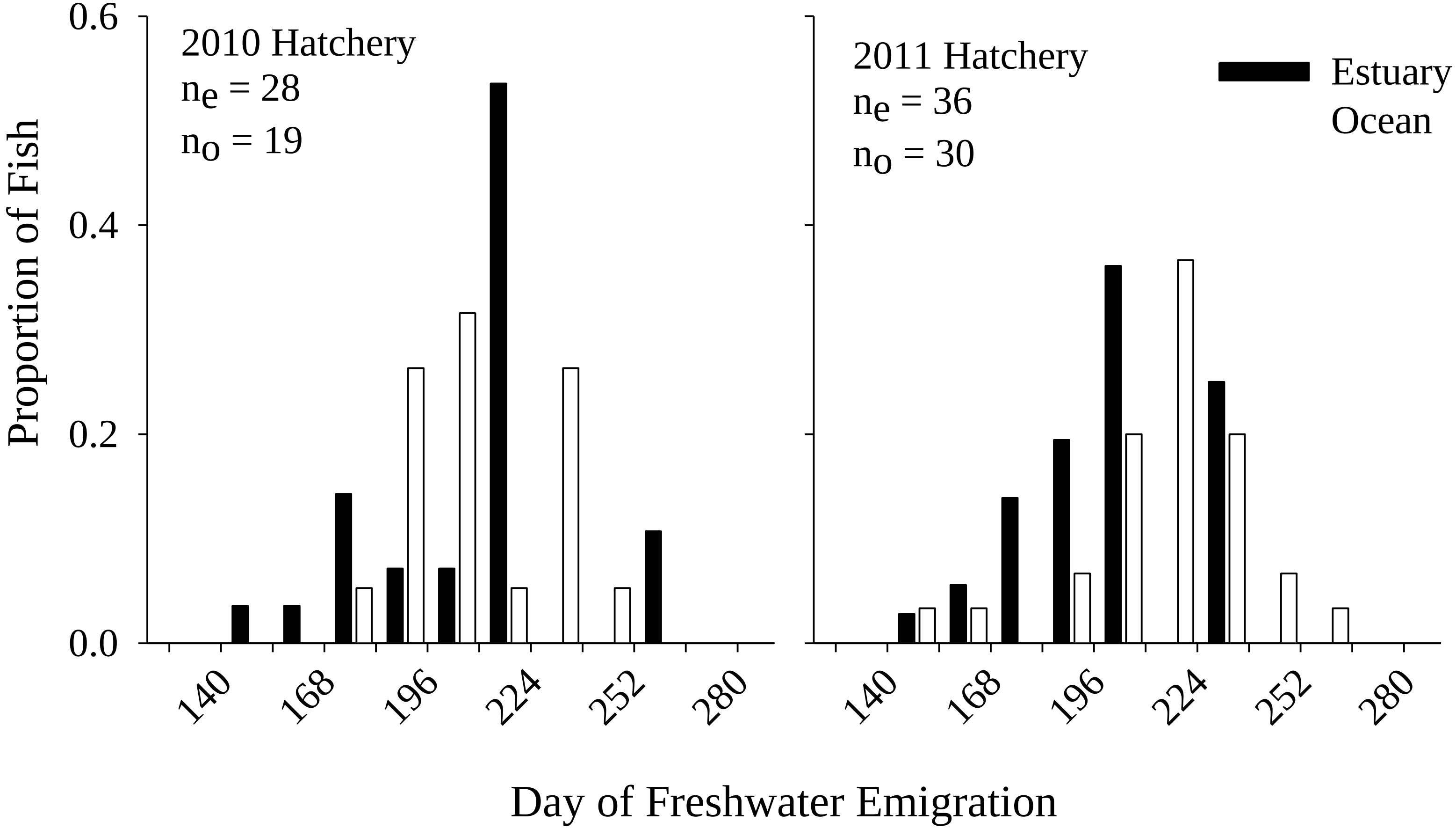
Acknowledgments

This research was supported by the Bonneville Power Administration; National Oceanic and Atmospheric Administration (NOAA) Fisheries; The Mamie Markham Research Award; Washington County Flyfishers; Washington Department of Fish and Wildlife; and the Flyfishers Club of Oregon

This work would not have been possible without the countless individuals in the plume and estuary group, and samples from WDFW

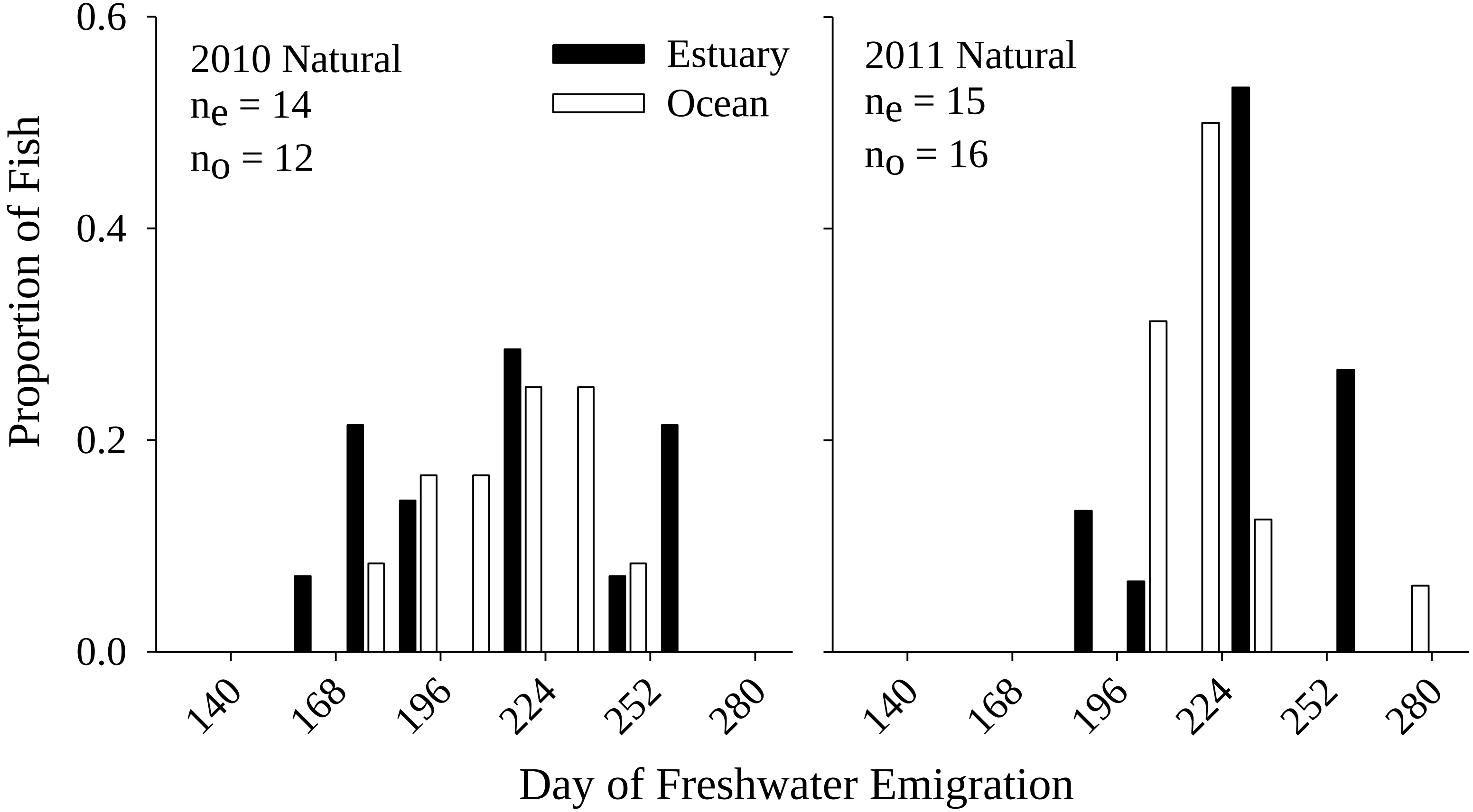
- Robert Emmett
- Marisa Litz
- Joe Fisher
- Cheryl Morgan
- Susan Hinton
- David Teel
- Laurie Weitkamp
- Paul Bentley
- Brian
- Rick Nelson
- Brian
- Jesse Lamb
- Paul Hoffarth
- Todd Miller
- Cindy Bucher
- Kym Jacobson
- Andrew Claxton
- James Losee
- Greg Hutchinson
- Lance Campbell
- And countless others……you know who you are

Estuary and Ocean: Hatchery Timing of FE



- 2011- earlier migrating H fish in estuary less represented later in the ocean ($p < 0.01$ KS-test)

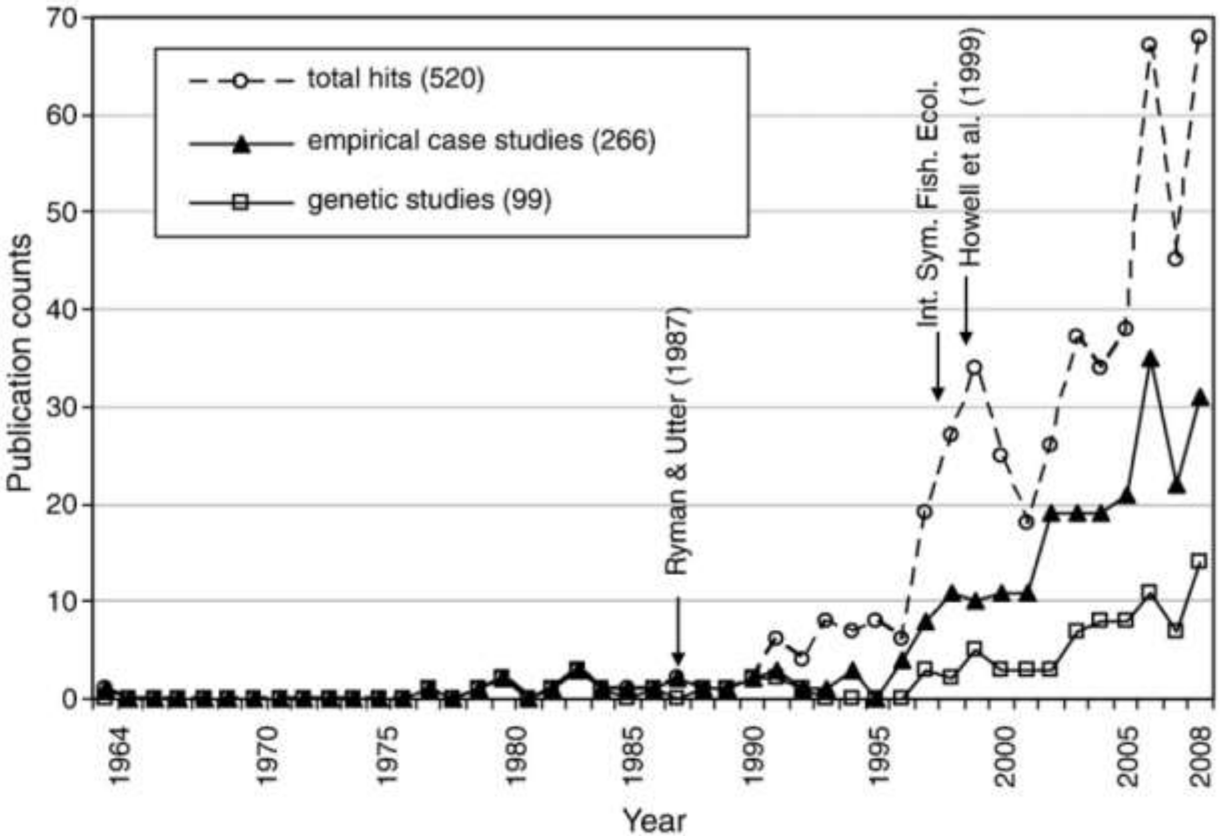
Estuary and Ocean: Natural Timing of FE



- 2011 later migrating N fish in estuary less represented later in the ocean (KS-Test $p < 0.01$)

Artificial Propagation Background

- Occurred for over 2000 years in Asia
- Stocking early life stages into natural environments

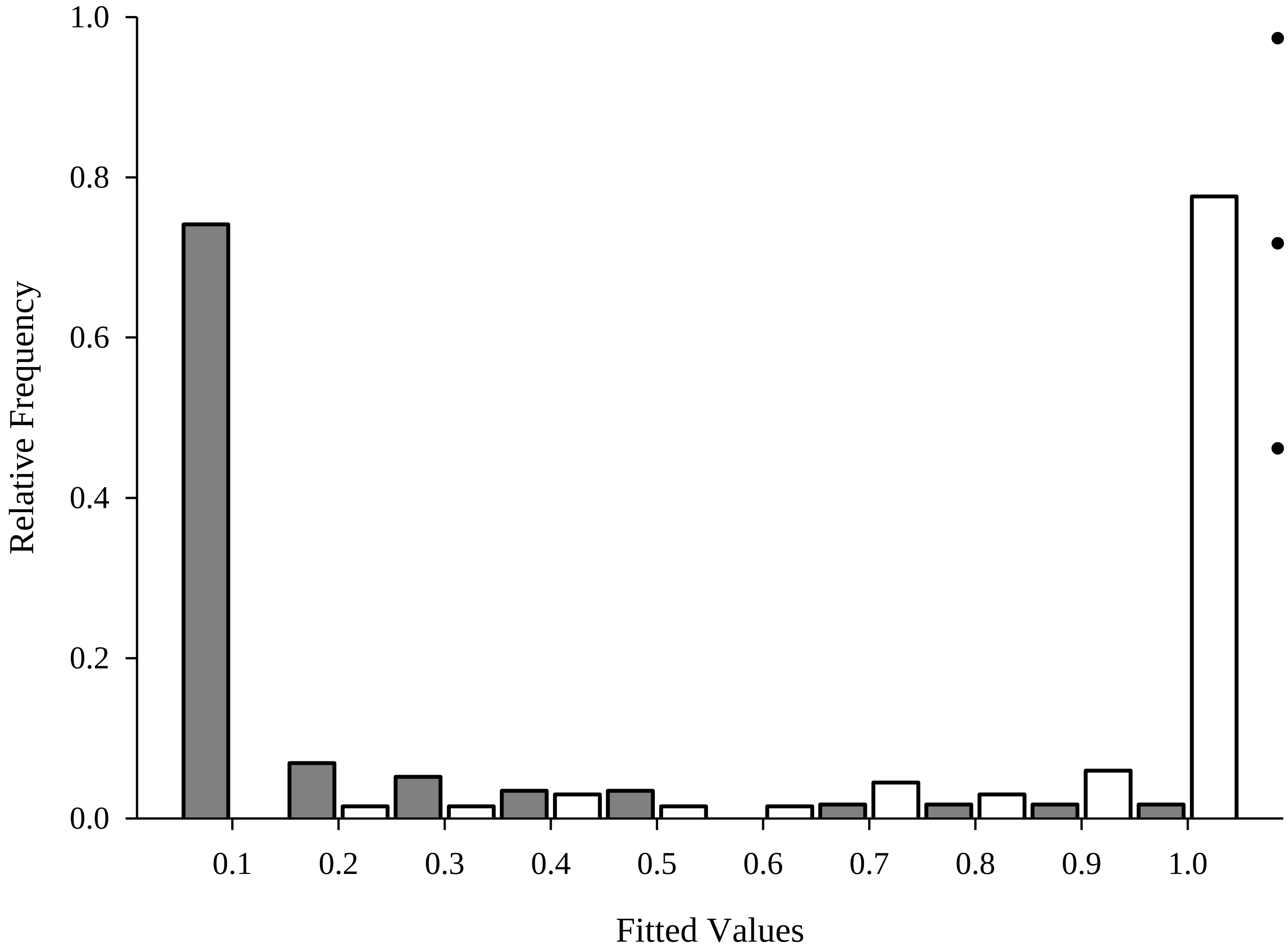


Araki and Schmid 2010

- Reduced fitness
- Behavioral changes
- Reduced survival

Results: Classification Model

Origin = $e^{\beta_0 + \beta_1 * CVIW +} / e^{\beta_0 + \beta_1 * CVIW} +1$



- Final model is CVIW
- Accuracy is 92% (jack knife)
- Independent validation 18 of 20 fish correctly classified

Chapter 2

Fish Collection Estuary

- Compared UCR Su/F subs
  - FL at capture
  - % UCR Su/F
  - % marked UCR Su/F

Intertidal

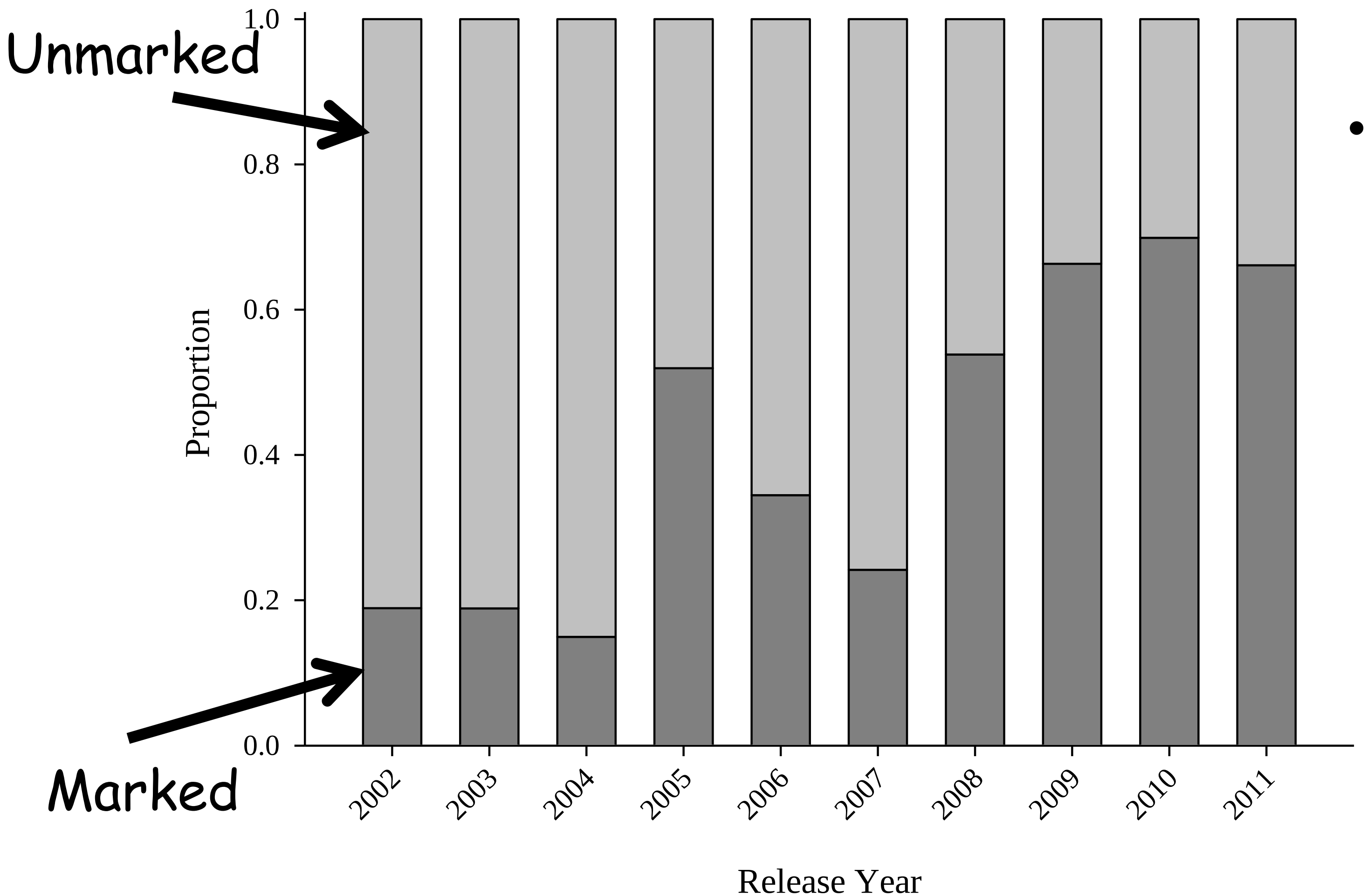
VS

Channel

Study	Year	Months Sampled	*n*	FL_C (mm)	% Catch	% Marked
Estuary Channel	2010	April-July, September	53	110	25	43
Estuary Intertidal	2010	April-September	5	118	4	50
Estuary Channel	2011	April-September	75	106	33	52
Estuary Intertidal	2011	April-September	14	77	7	50

Chapter 3

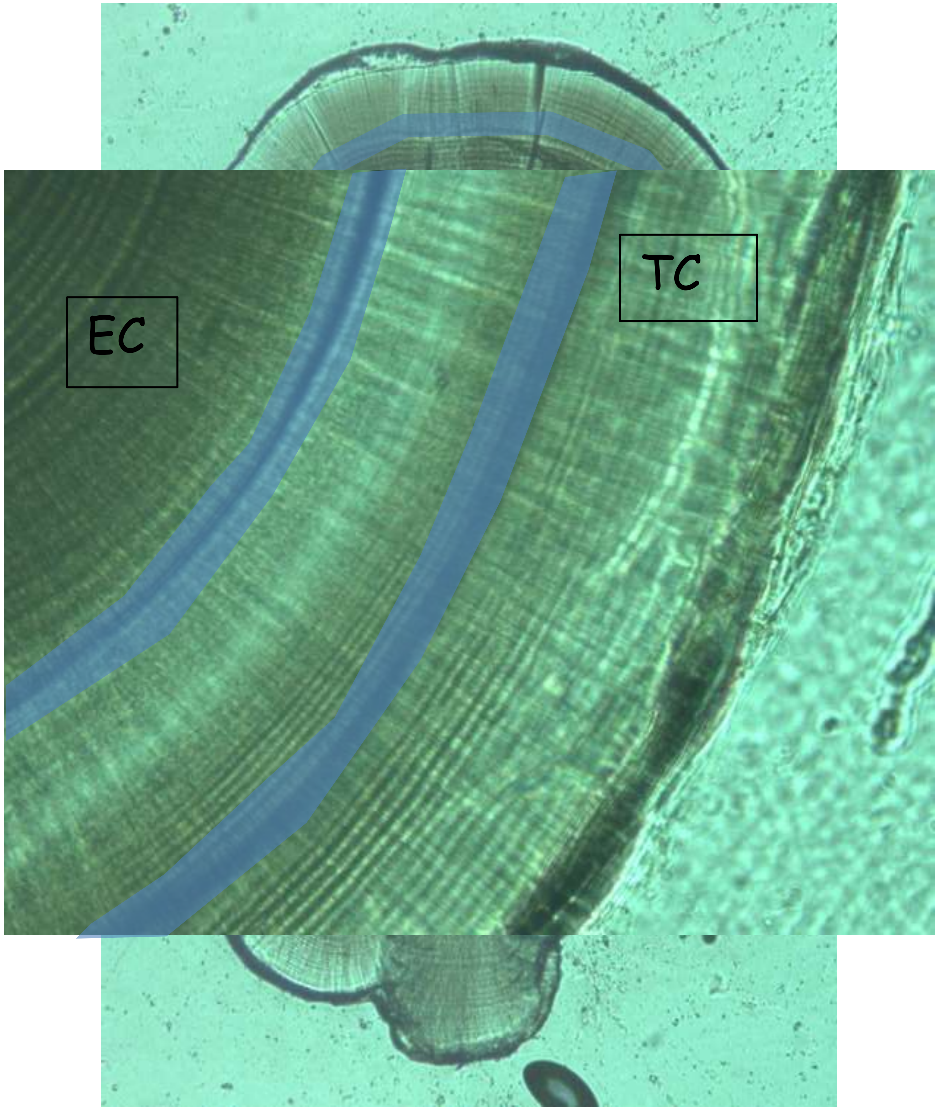
Unmarked Hatchery Fish



- Subyearlings

- 2002-2011 30-80% released unmarked in the Columbia River

Otolith Structure I Measured



1. Otolith width at transition check (TC)

2. Otolith width at exogenous feeding check (EOW)

3. Distance to first feeding check (FC)

4, 5, &6. Mean, SD, CV of daily increments (first 20 post exogenous feeding check)

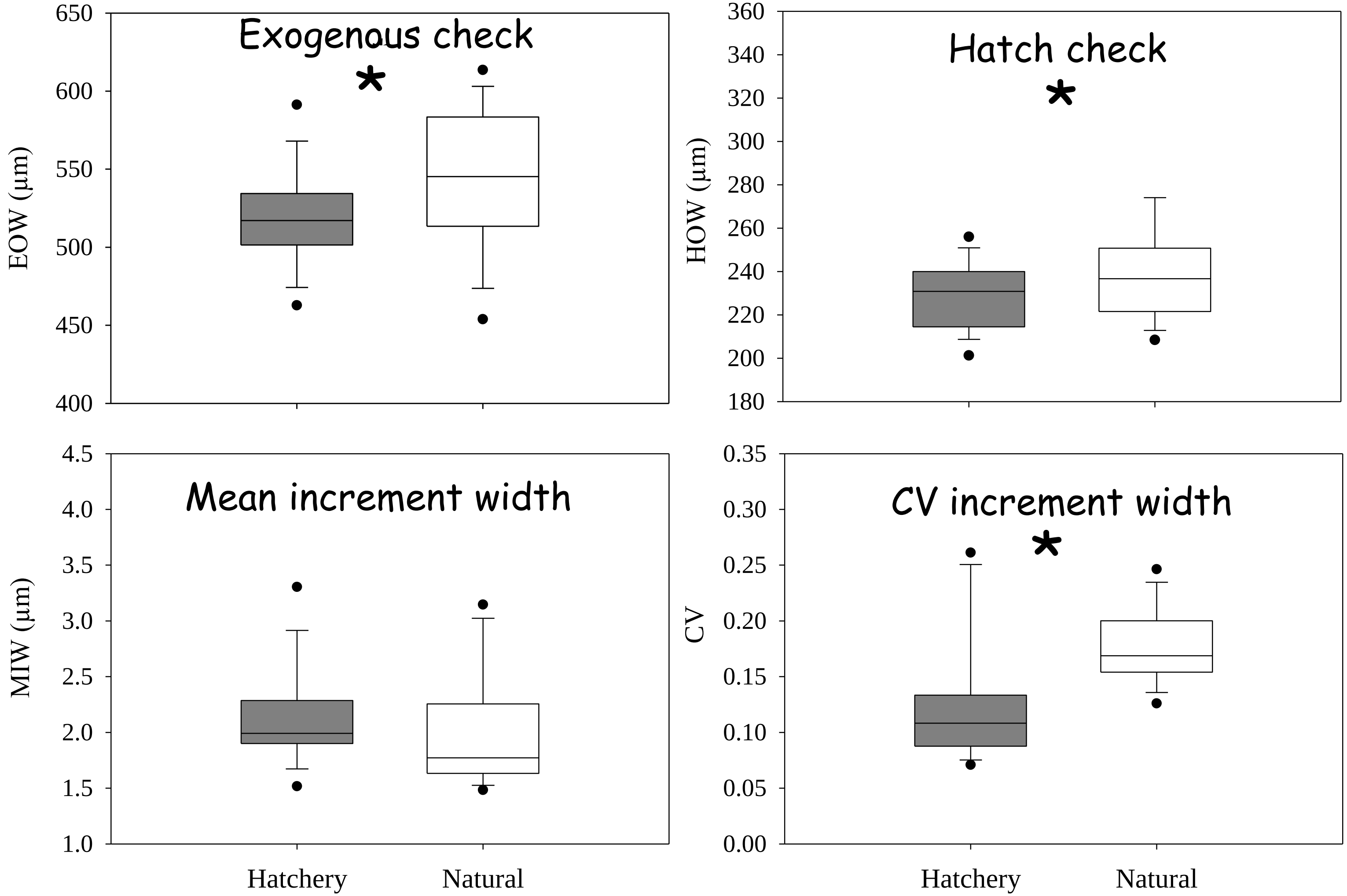
7. Otolith width at ...

Zhang et al. 1995

Marshall and Parker 1982

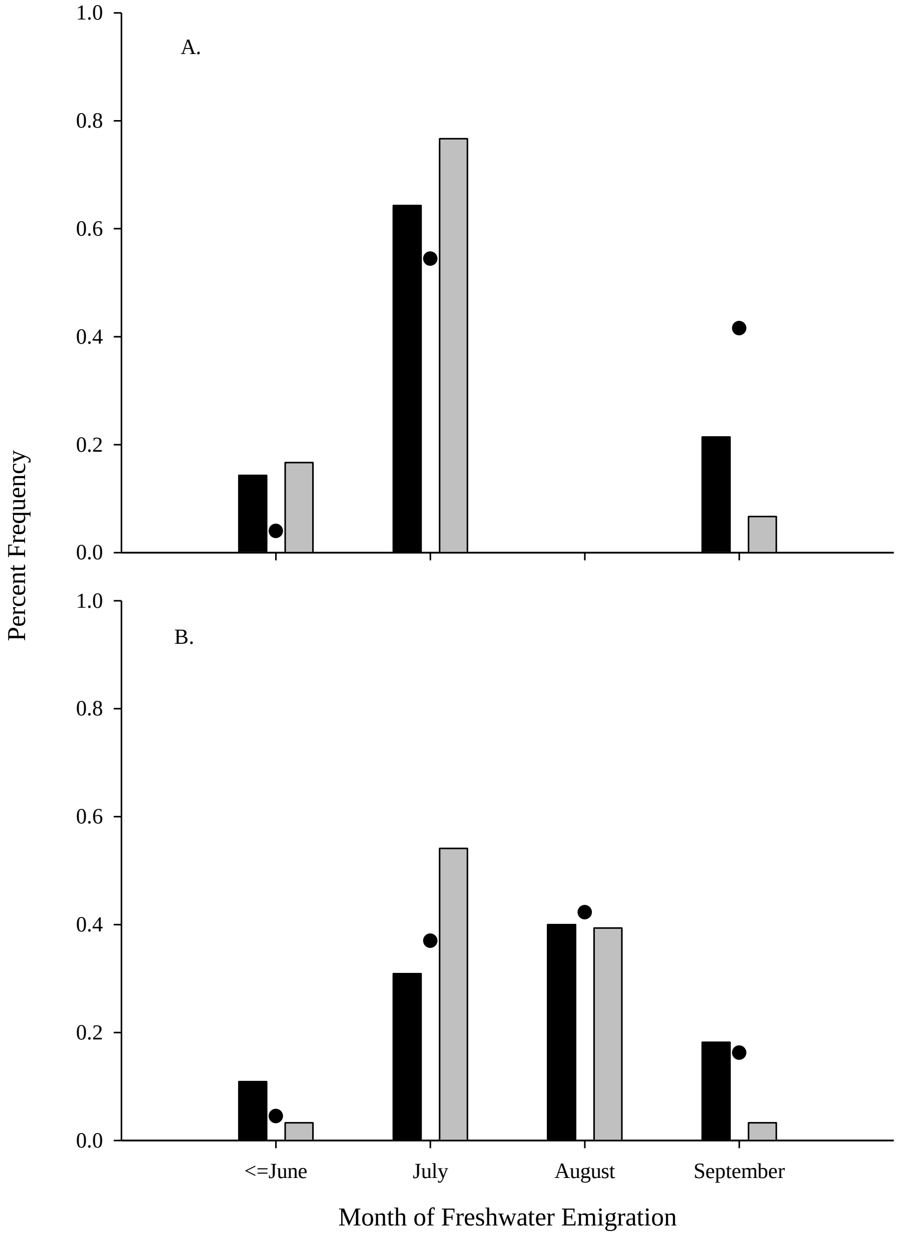
Barnett-Johnson et al. 2007

Results: Otolith Structure



- HOW, EOW, TC, SD, CVIW different between H and N ($p < 0.05$)
- PE, MIW not different ($p > 0.05$)

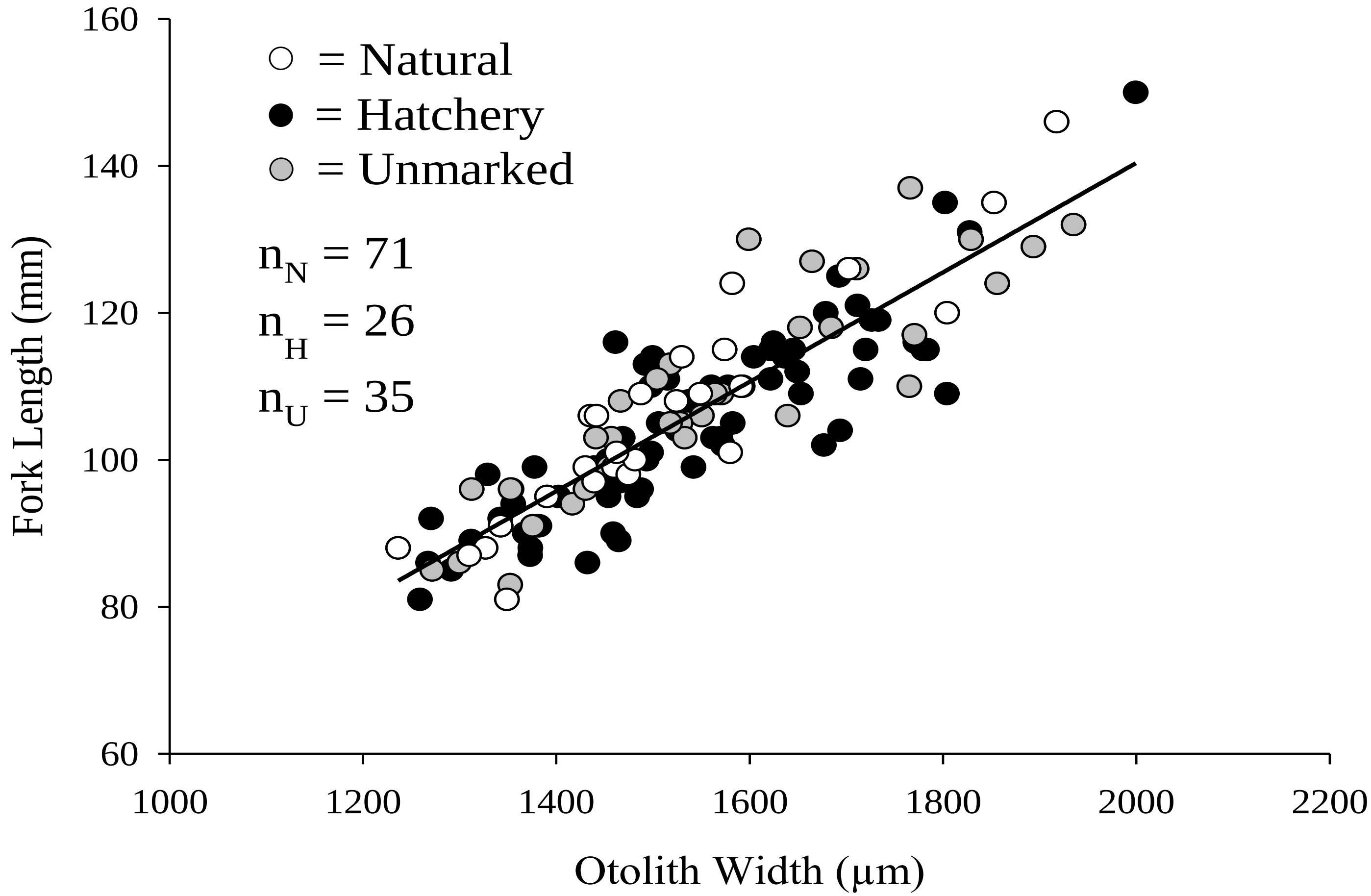
Chapter 2


A.
B.
1.0
0.8
0.6
0.4
0.2
0.0
Percent Frequency
<=June
July
August
September
Month of Freshwater Emigration

Chapter 3

Fish Collections for Classification Model

Rearing Area	*n*	Source	Adult Run Time	FL (mm)	Emigration Year	Origin
Lower Wenatchee River	50	R	Su	40 (3.6)	2011	N
Hanford Reach Columbia River	17	R	Fa	44 (3.3)	2012	N
Carlton Rearing Pond	9	H	Su	37 (4.1)	2011	H
Priest Rapids Hatchery	2 (2)	CWT	Fa	167 (22.1)	2010	H
Umatilla Hatchery	3 (2)	CWT	Fa	134 (39.7)	2010 & 2011	H
Klickitat Hatchery	2 (2)	CWT	Fa	99 (27.7)	2010 & 2011	H
Little White Salmon Hatchery	2 (2)	CWT	Fa	115 (29.5)	2010 & 2011	H
Similkameen Rearing Pond	7	H	Su	42 (4.3)	2011	H
Wenatchee Rearing Pond	20	H	Su	43 (3.1)	2011	H



- % Hatchery = ((NM / PM_{HR}) / TI) * 100

- % Hatchery = ((NUM * PH) + NM) / TI) * 100

Study Hypothesis

- Hatchery fish experience negative size selection during early marine residence

- Natural-origin fish will be smaller than hatchery conspecifics at marine entry but do not experience negative size-selective mortality

- The timing of marine entry will be more protracted for natural-origin Chinook salmon

Chapter 3