Genetic Analysis of Caspian Tern (*Hydroprogne caspia*) and Double Crested Cormorant (*Phalacrocorax auritus*) Salmonid depredation in the Columbia River Estuary 2006-2013

David Kuligowski[1], Laurie Weitkamp[1], Curtis Roegner[1], Daniel Roby[2], Ken Collis[3], Donald Lyons[4], Donald Van Doornik[1], Lauren Reinalda[4], Allen Evans[3] Tim Marcella[4], Peter Loschl[4], and David Teel[1].

[1]NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. E.,Seattle, WA 98112-2097.
[2]U.S. Geological Survey - Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331-3803.
[3]Real Time Research Inc. 1000 S.W. Emkay Drive, Bend, OR 97702.
[4]Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR 97331-3803.

NOAA FISHERIES

Objectives

- What salmon do Columbia R terns and cormorants eat?

  Genetic species and stock ID of bird diet samples

- Where do the birds forage?

  Comparison of bird diet species / stock ID results with data from adjacent juvenile salmon habitats:

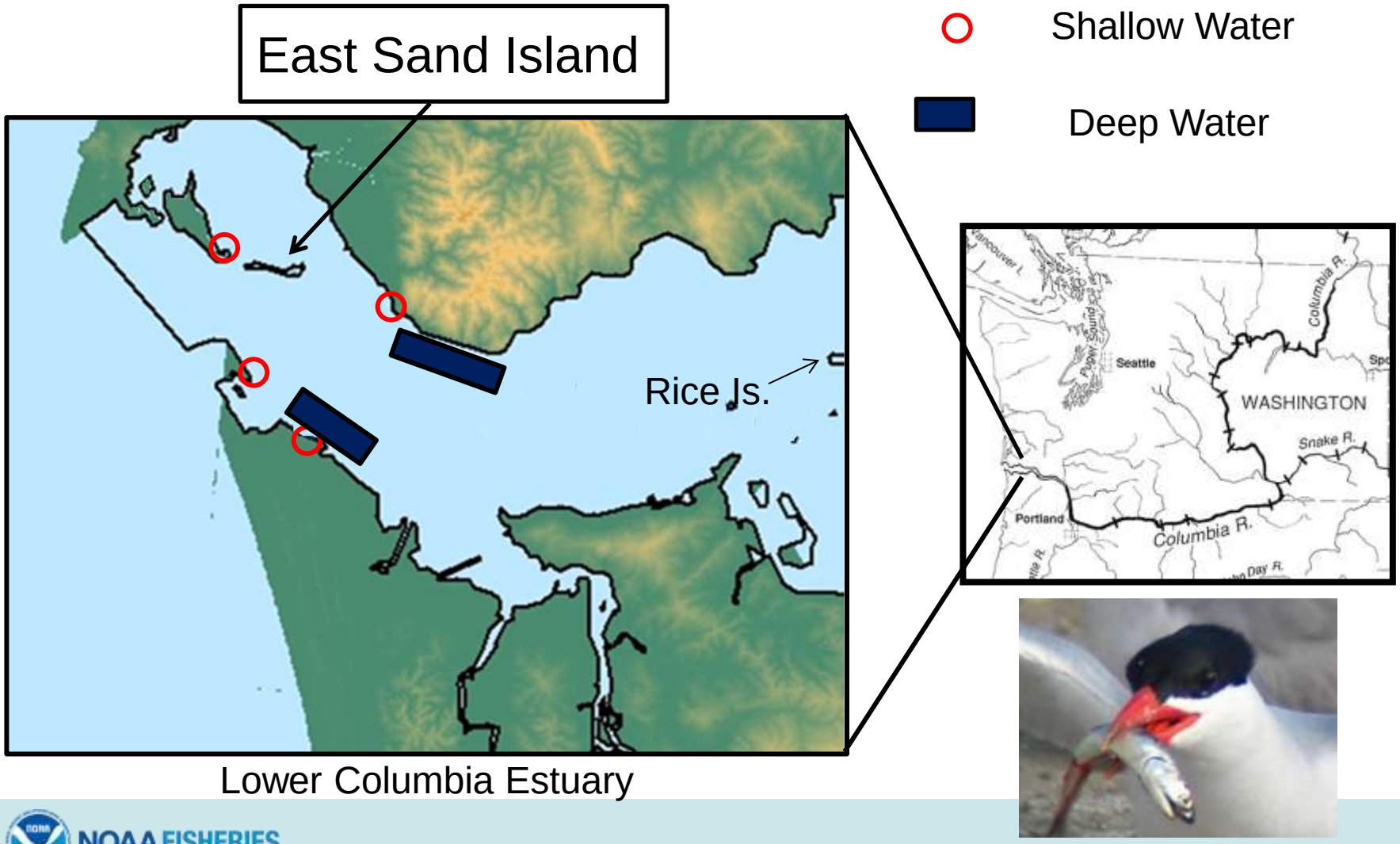
  1) Nearshore estuary, shallow water – Chinook (smaller) and chum

  2) Main river channel , deep water – Chinook (larger), coho, sockeye, steelhead

- What are the predation impacts on Columbia R juvenile salmon?

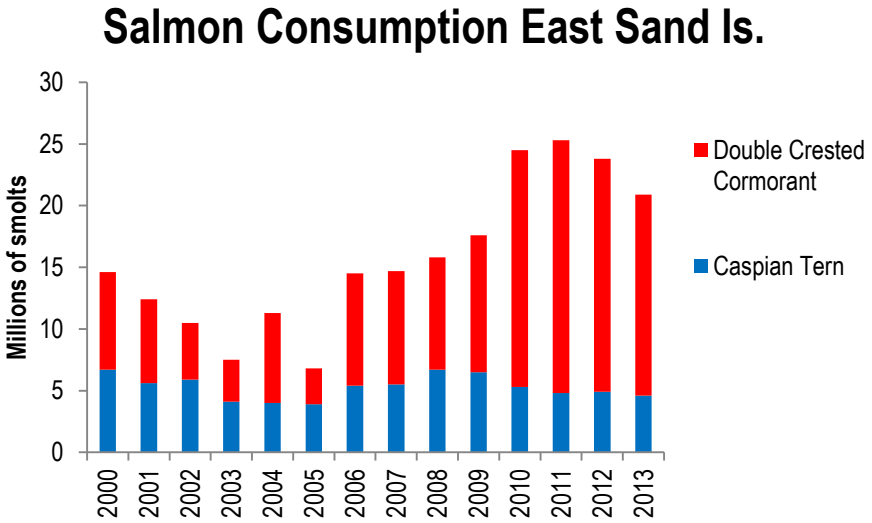
  Expansion of bird diet data using Columbia Basin smolt abundances

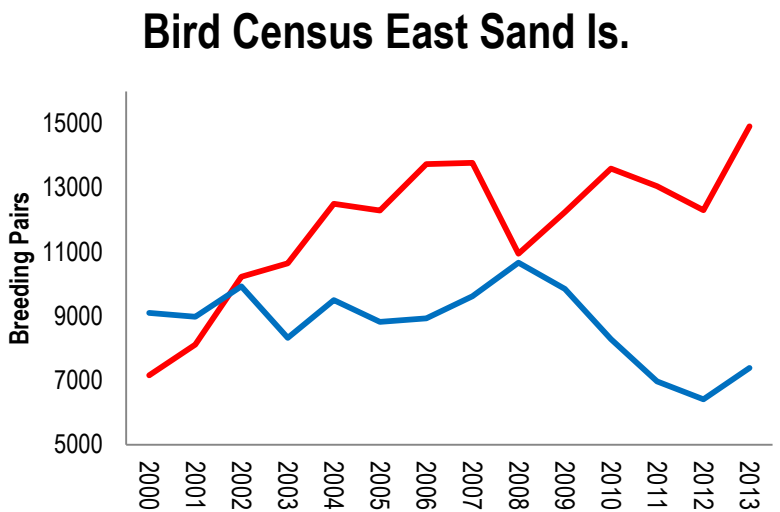
Study Area



Lower Columbia Estuary

Motivation for Genetic Assessment





- Previous diet composition methods
  - Caspian tern, visual id of bill loads carried back to nest
  - Double crested cormorant, gut samples determined by tissue characteristics and bone morphology
  - Smolts consumed estimated using bioenergetics methods
  - Mortality rates due to predation have been estimated using PIT tag recoveries
- Genetics can determine Species, Fish identity, Stock group ESU or DPS, relative consumption from an individual bird, forage habitat utilization and sharpen resolution to the bioenergetics methods

Collection Methods

- Prey takes occurred during nesting season
  - Late April to early July 2006 to 2013
  - Whole fish or tissues were collected
  - Lab or field identified as possible salmon

- Caspian tern were non-lethally sampled
  - Fish were taken from dropped beak loads
  - 15-20 bill loads per week

- Double crested cormorant were lethally sampled
  - 128 -137 birds per year
  - 5 -20 stomach samples per week
  - ~ 164 grams of fish per bird

Columbia River Estuary Juvenile Salmon Surveys

- Samples collected April to June 2010-2012
- Deep water sample
  - Purse seine collections in channel habitat (Weitkamp)
  - Sample depth 0-10 m
  - 2532 samples collected for visual species id
    - 1764 Chinook analyzed for GSI
- Shallow water sample
  - Beach seines in beach habitat (Roegner)
  - Sample depth 0-3 m
  - 4064 samples collected for visual species id
    - 3746 Chinook analyzed for GSI

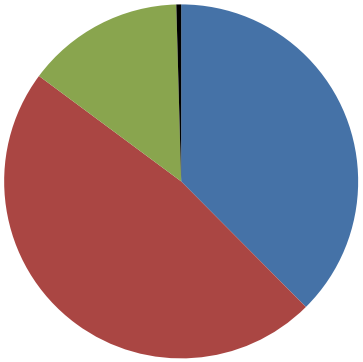
Species and Genetic Stock Identification Methods

- Species ID
  - Mitochondrial DNA ND3/COIII fragment analysis.
- GSI (Genetic Stock Identification)
  - Standardized Microsatellite Loci including Columbia River basin and Coastal populations.
  - Chinook 13 GAPS loci v2.1 (Seeb et al.)
    59 pops,12 reporting groups, 85%-99% assignment accuracy
  - Coho 11 loci (Van Doornik et al.)
    50 pops, 3 reporting groups, 95%-98% assignment accuracy
  - Steelhead 13 SPAN loci v2.3 (Blankenship et al.)
    233 pops, 7 reporting groups, 83%-98% assignment accuracy
  - Sockeye 12 Loci (Iwamoto et al.)
    3 pops, 3 reporting groups, 99% assignment accuracy
- PBT (Parentage Based Tagging) (Steele et al.) 96 SNP loci
  - Steelhead and Chinook dataset of Snake River Hatchery brood stock 2010-13
  - Offspring typed directly back to pair of sampled hatchery parents

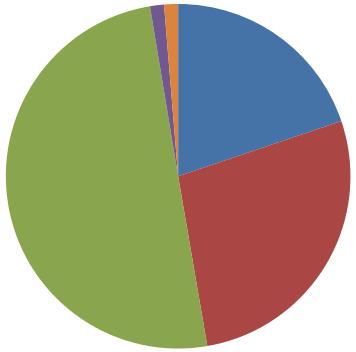
Species Identification 2006-2013

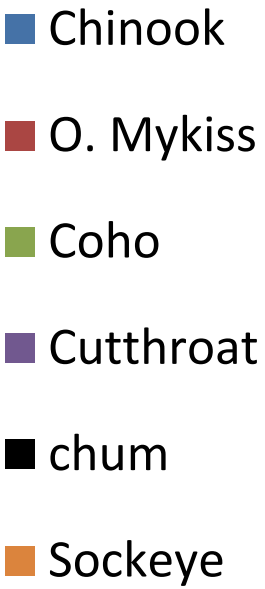
April-May

Tern n= 229



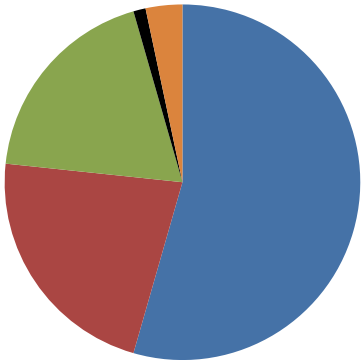
Cormorant n=535



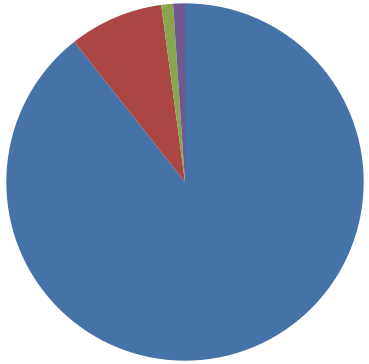


June-July

Tern n= 94



Cormorant n= 90



East Sand Island depredation (2006-2013)

(thousands of fish)

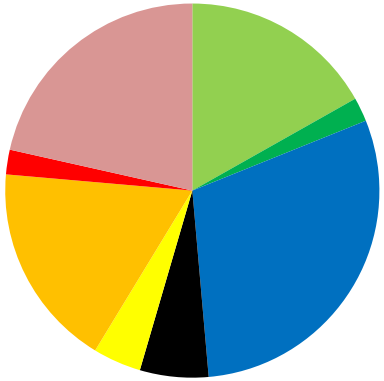
Salmon Species	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Chinook	2,211	9,852	12,063
Steelhead	1,050	1,318	2,368
Coho	2,086	2,948	5,034
Sockeye	31	57	88
Total			19,553

GSI Results Chinook

2006-2013

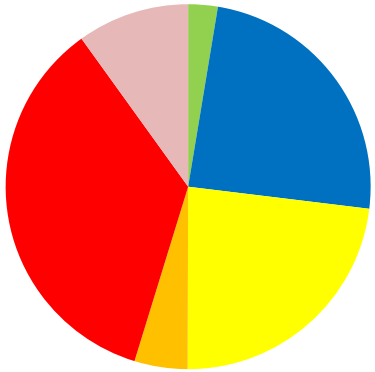
Tern April/May (n=84)

Tern June/July (n=47)

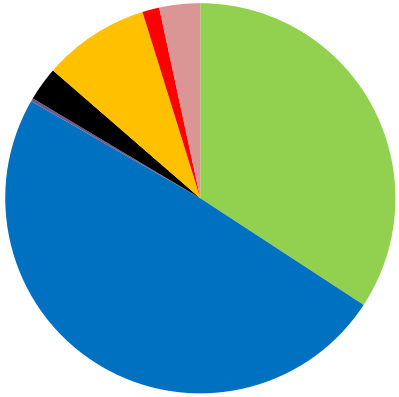


- West Cascade-Fall
- West Cascade-Spring
- Spring Creek Grp -Fall
- Willamette R- Spring
- Rogue R
- MCR&UCR- Spring
- Snake-Fall
- Snake-Spring
- UCR- Summer/Fall

Cormorant April/May (n=97)



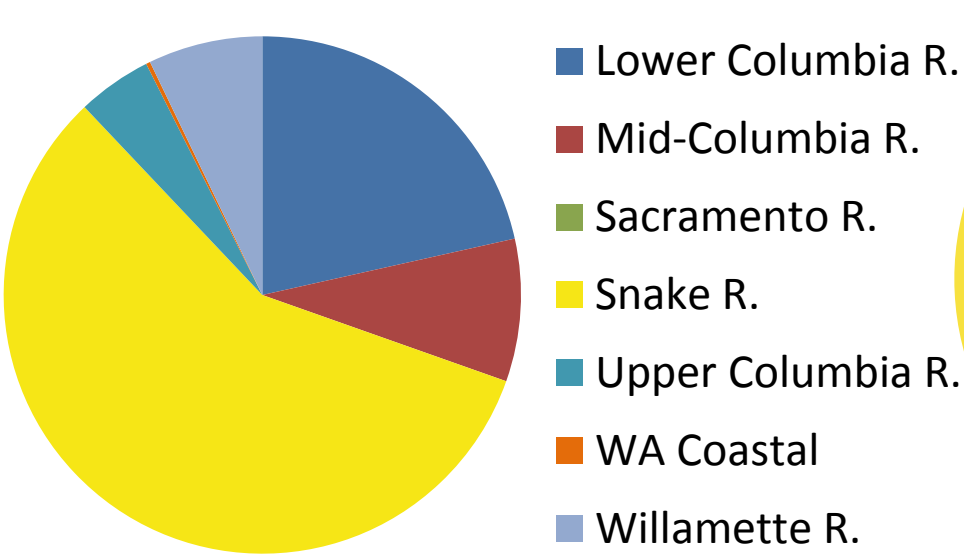
Cormorant June/July (n=72)



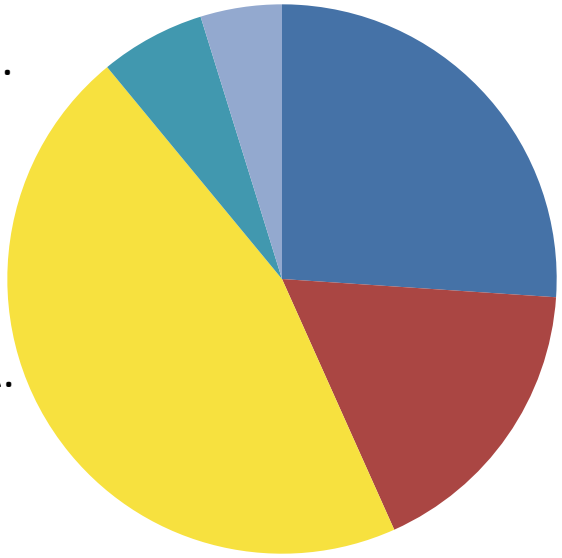
GSI results Steelhead

2006-2013

Tern n = 121

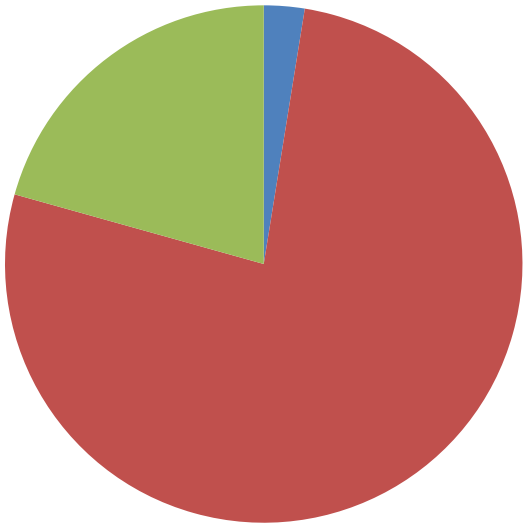


Cormorant n = 149



GSI results Coho
2006-2013

Tern n = 45

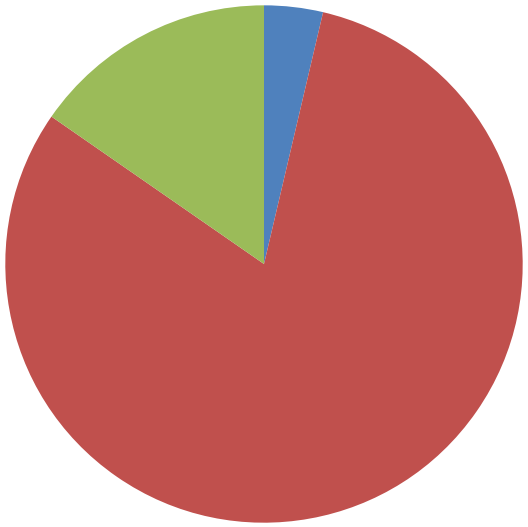


WA Coast

Columbia R.

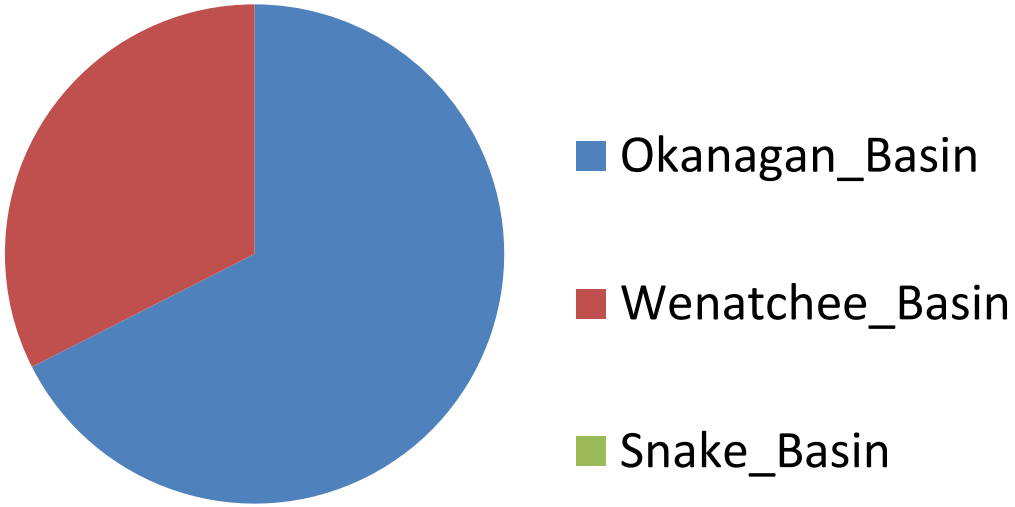
North Coast OR

Cormorant n = 170

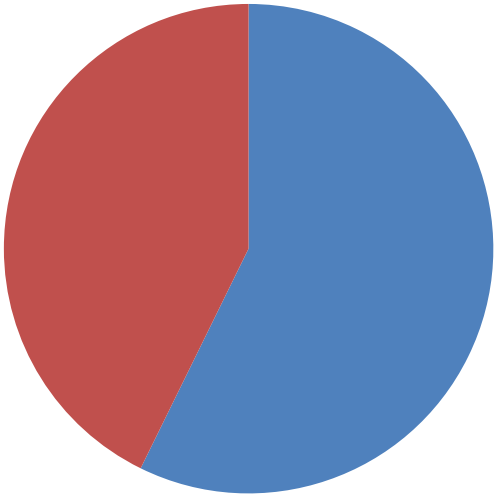


GSI results Sockeye
2006-2013

Tern n=3



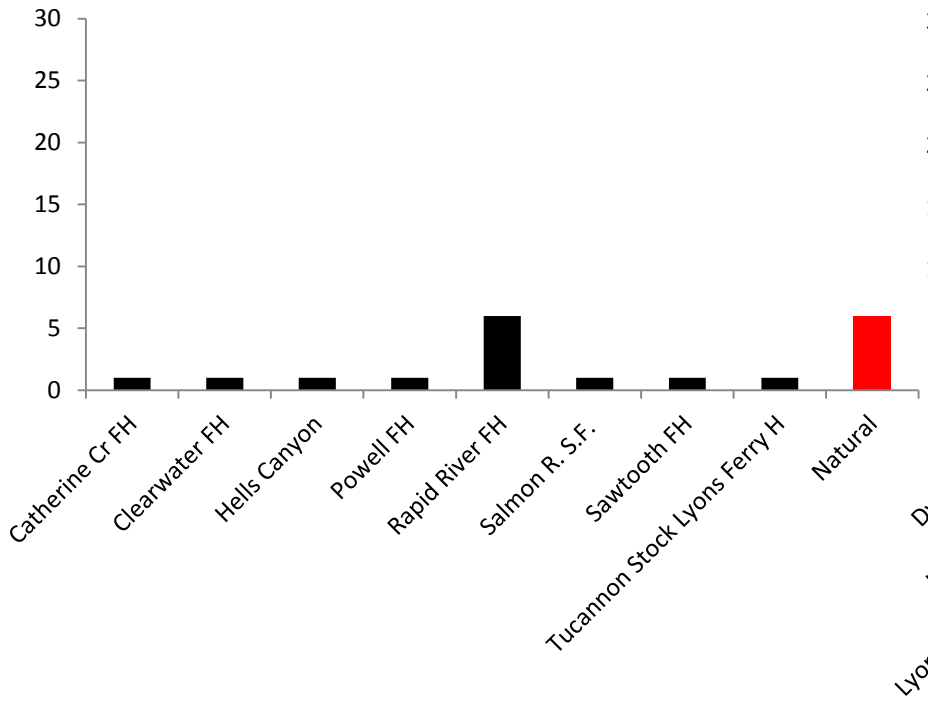
Cormorant n=7



Caspian Tern depredation Snake River basin Parentage Based Tagging

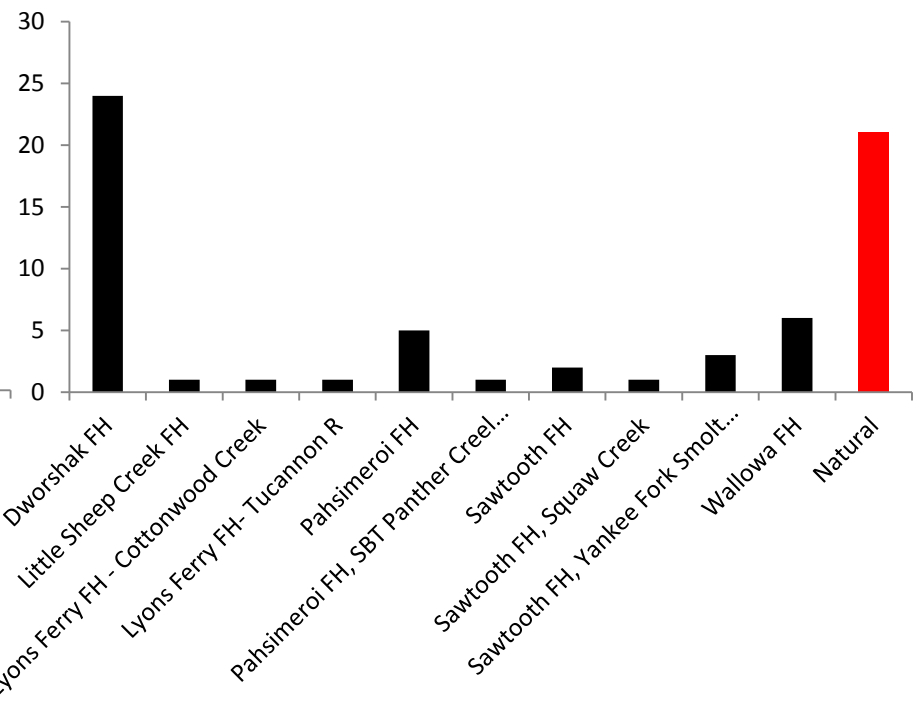
Chinook n=19 2012-13

(2:1) hatchery : natural



Steelhead n=66 2011-13

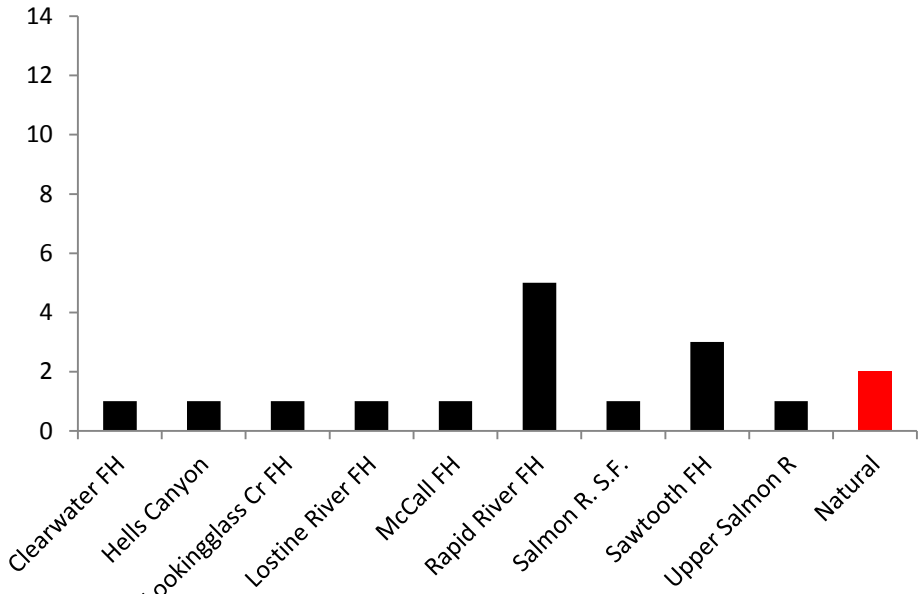
(2: 1) hatchery : natural



Double Crested Cormorant depredation Snake River basin Parentage Based Tagging

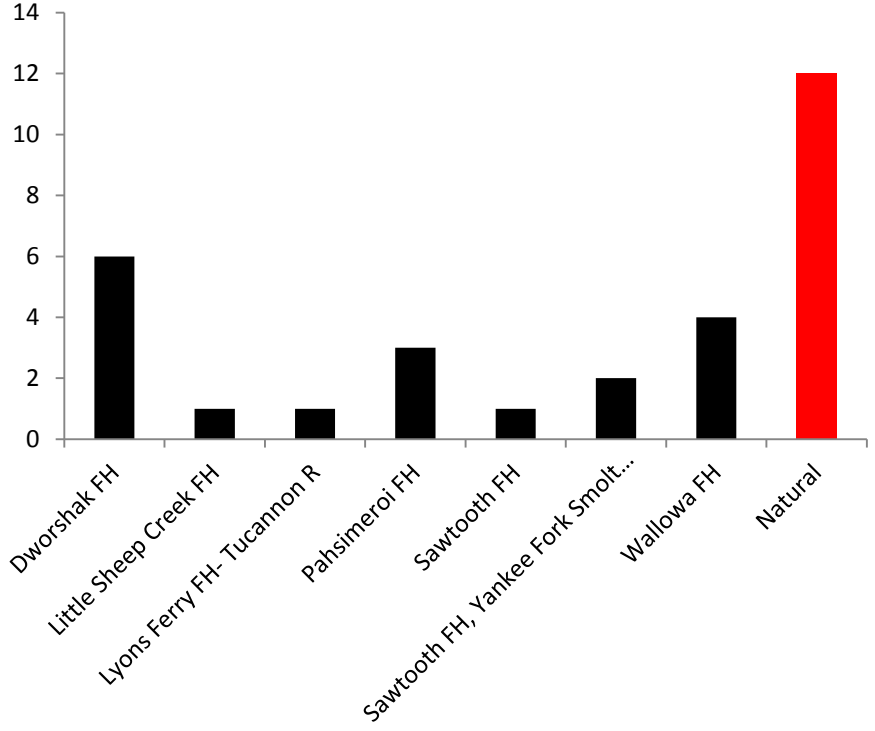
Chinook n=17 2012-13

(8:1) hatchery : natural

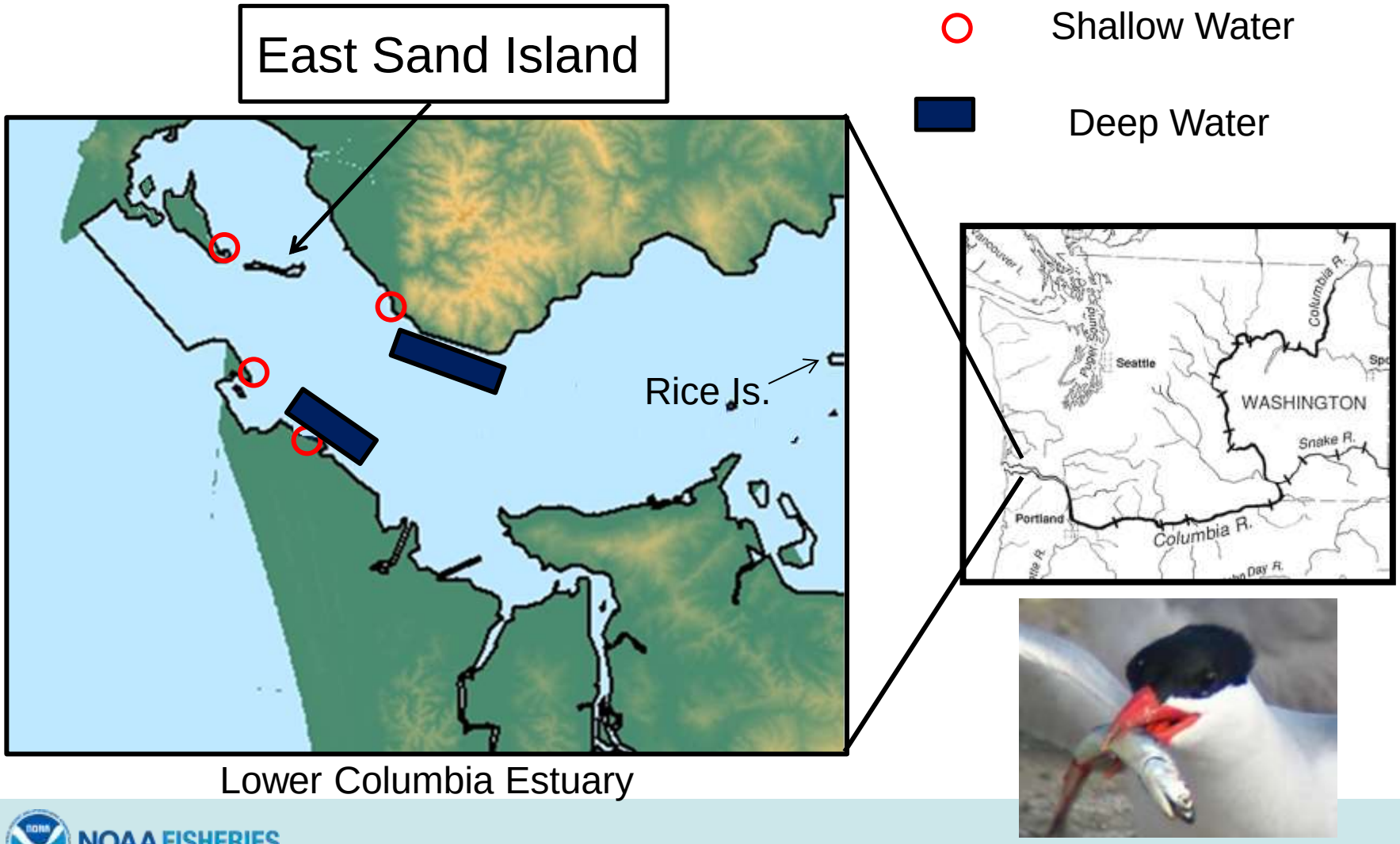


Steelhead n=30 2011-13

(2:1) hatchery : natural



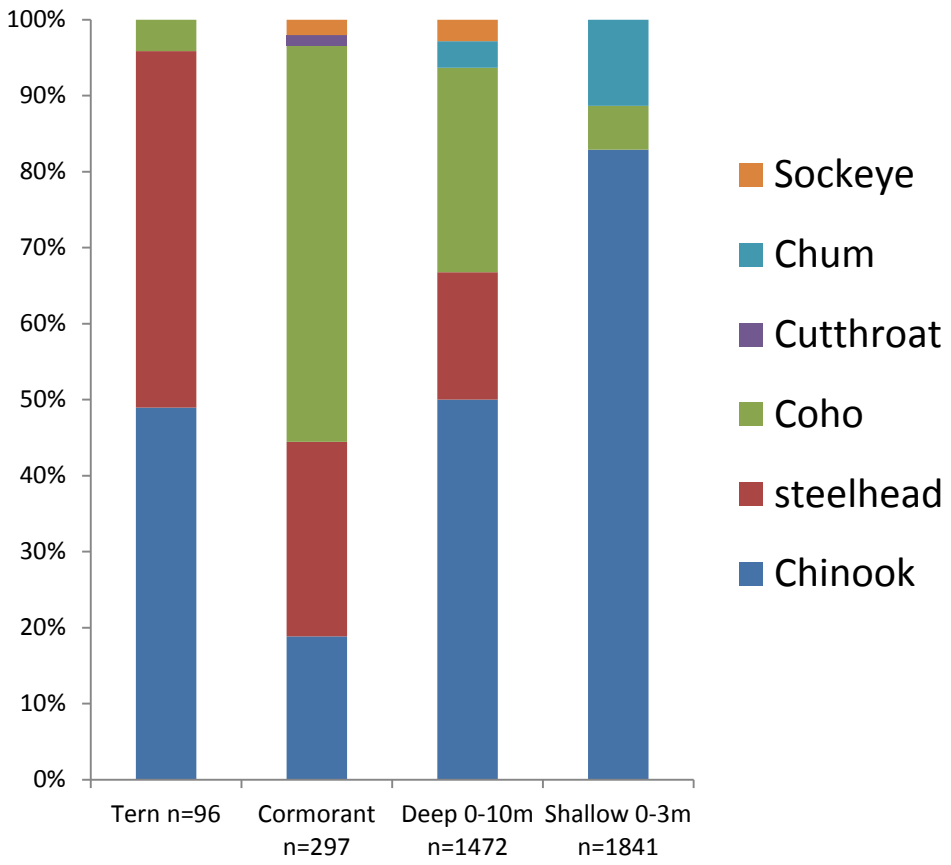
Study Area



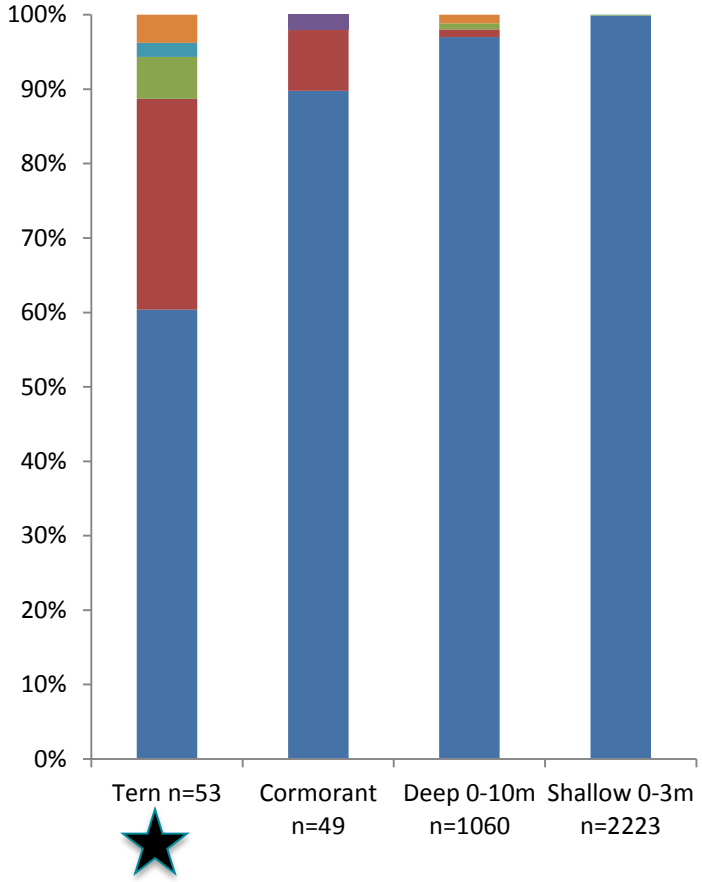
Lower Columbia Estuary

Species depredation by bird and location 2010-2012

Early (April-May)



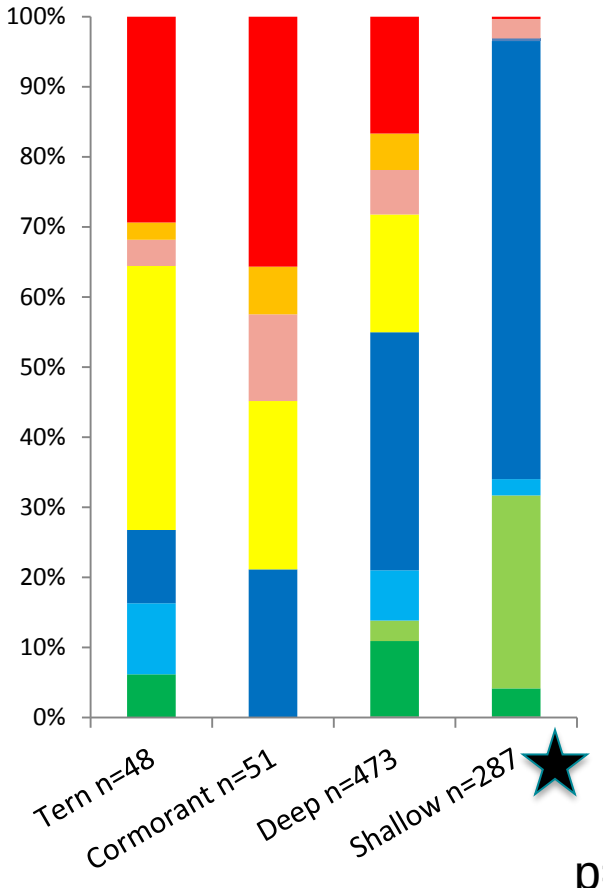
Late (June-July)



p=0.04

Chinook depredation by bird and location 2010-2012

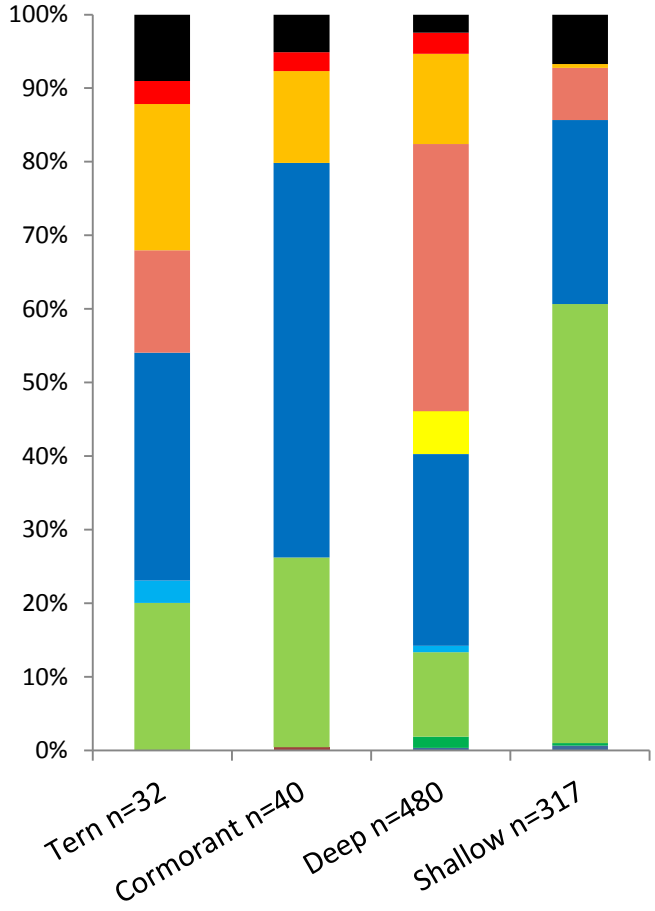
Early (April-May)



Rogue
Snake_Sp
Snake_F
UCR_Su/F
MCR&UCR_Sp
SCG_F
WC_Sp
WC_F
WR_Sp

p=0.036

Late (June-July)



Estimate of Depredation on Salmonid species and ESU

Estimate the relative numbers of depredated fish by species and reporting group (ESU) for each bird species using GSI proportional estimates of prey samples.

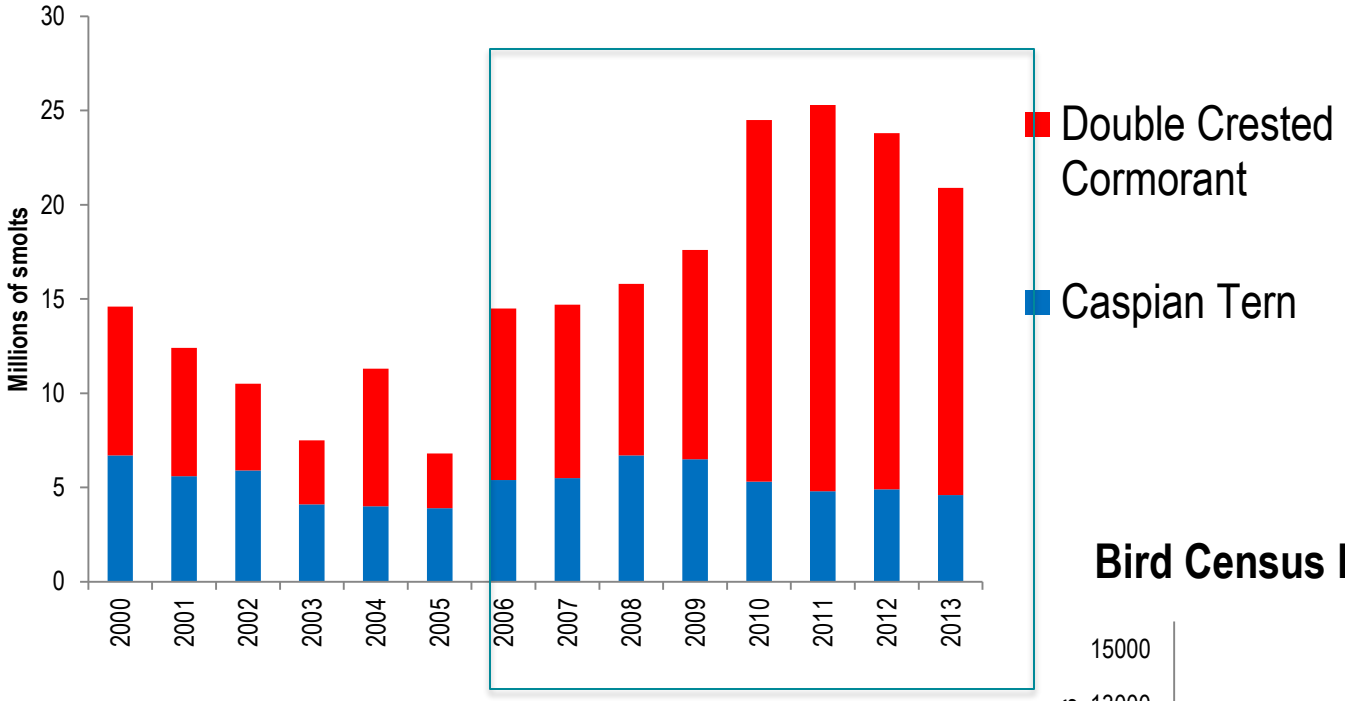
$$RSC_{ESU} = PESU \times RSCspe_{cies}$$

$$RSC_{ESU} = Relative\ Salmon\ Consumption\ for\ each\ ESU$$

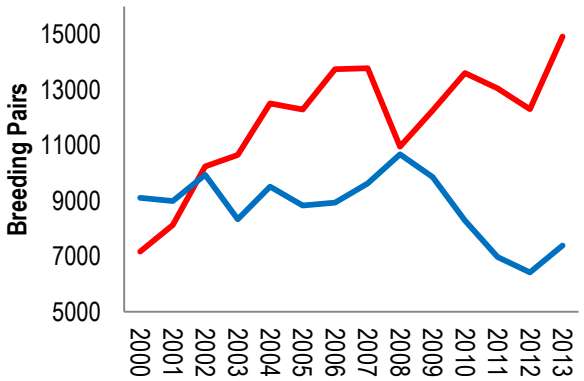
$$P_{ESU} = Genetic\ Stock\ Proportional\ Estimate\ for\ each\ ESU$$

$$RSC_{species} = Relative\ Salmon\ Consumption\ for\ each\ species$$

Salmon Consumption East Sand Is.



Bird Census East Sand Is.



Chinook (2006-2013)

(thousands of fish)

ESU	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Lower Columbia	628	4,988	5,616
Willamette spring	187	0	187
Deschutes summer/ fall	0	41	41
Mid-Upper Columbia spring (2)	519	1,247	1,766
Upper Columbia summer/ fall	246	759	1,004
Snake fall	170	548	718
Snake spring/ summer	401	2,098	2,499

Steelhead (2006-2013)

(thousands of fish)

DPS	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Lower Columbia	226	344	569
Willamette	75	63	138
Mid Columbia	93	227	321
Upper Columbia	49	82	130
Snake	604	603	1,207

Conclusions

- Soft tissues collected from cormorant stomachs provide DNA of adequate quality for species and genetic stock identification.
- Bird diet compositions suggests predation is occurring in deep water habitat where the birds have access to larger fish.
- PBT analysis suggests Snake River hatchery steelhead and Chinook salmon are a larger proportion of the birds diets and reflect greater abundance in the estuary.
- Caspian Terns and Double Crested Cormorants eat salmon from a large number of ESU's.

Acknowledgements

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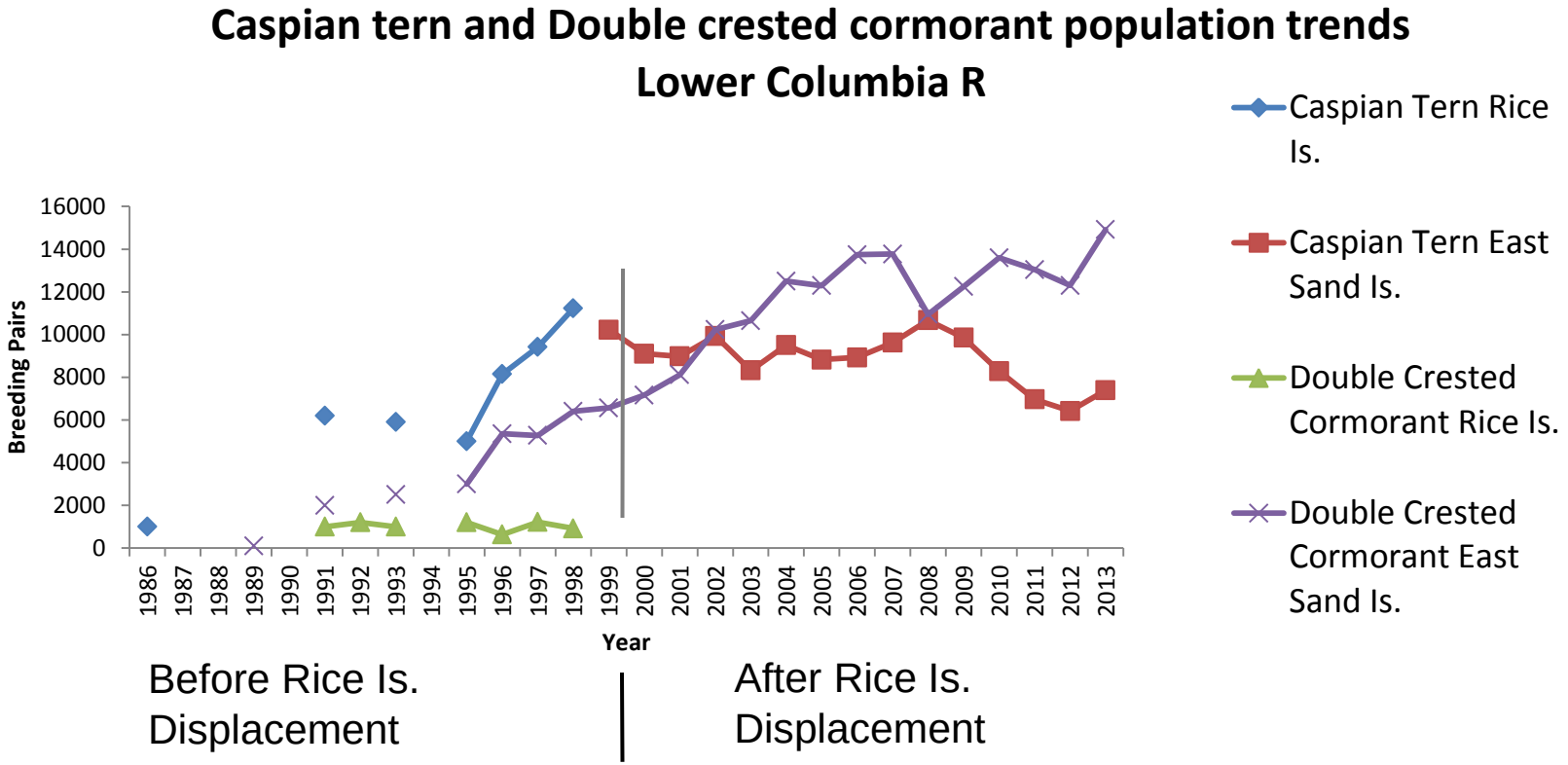
  - NOAA Fisheries
  - Oregon State University
    - Bonneville Power Administration
    - U.S. Army Corps of Engineers
- Genetic Baselines
  - GAPS Labs

Field work, bird collections and photo credits

- Bird Research Northwest staff
- Oregon State University, Real Time Research, USGS, Oregon Cooperative Fish and Wildlife Research Unit
- NOAA Fisheries

- EXTRA SLIDES

Background

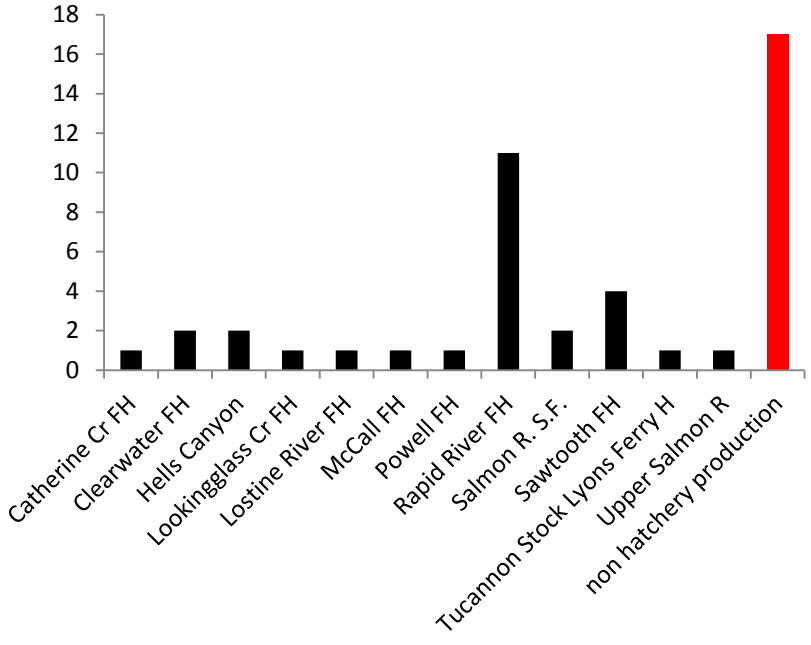

Caspian tern and Double crested cormorant population trends
Lower Columbia R
Breeding Pairs
16000
14000
12000
10000
8000
6000
4000
2000
0
1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Year
Caspian Tern Rice Is.
Caspian Tern East Sand Is.
Double Crested Cormorant Rice Is.
Double Crested Cormorant East Sand Is.
Before Rice Is. Displacement
After Rice Is. Displacement


Annual Diet Composition
100%
50%
0%
Caspian Tern Rice Is. 1986-2000
Caspian Tern East Sand Is. 2001-2013
Double Crested Cormorant East Sand Is. 1999-2013
other
Surf Perch
Herring
Anchovy
Salmonid

Parentage Based Tagging

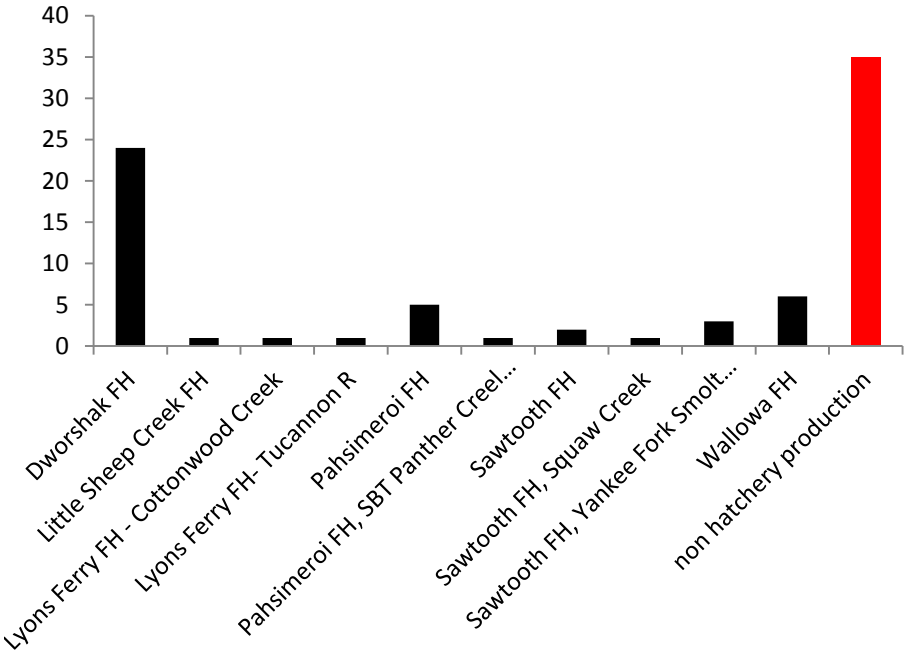
Chinook n=45 2012-13

- 28:17 hatchery:natural



Steelhead n=80 2011-13

- 45:35 hatchery:natural



MtDNA and uSAT Results

- Tissue quality variability
  - Soft tissues (muscle)
    - 85 of 1033 were excluded from Species
      - Mixed sample or unresolved
    - 90 of 948 were excluded from GSI analysis
      - Unresolved for fish with < 7 loci genotyped
- Samples of mixed fish
    - 7 samples contained more than one fish or mixed species
- Identical Samples
    - 3 samples were determined to be identical or likely identical Pid range ($3.7x10^{-12}$ to $1.4x10^{-17}$)

Genetic Analysis Methods

- Genetic Identity
  - (P_{id}) function in GenAIEx 6.4
    - (Peakall and Smouse)
  - 8 locus cut-off criteria
- Mixture analysis performed using computer program ONCOR (Kalinowski et al.)
  - Baselines were assessed for assignment accuracy
  - EM algorithm to estimate mixture proportions
  - 95% CI calculated by bootstrap 100 iterations with resampling.
- Parentage Based Tagging (PBT) performed using computer program SNPPIT (E. Anderson)

Predators become prey

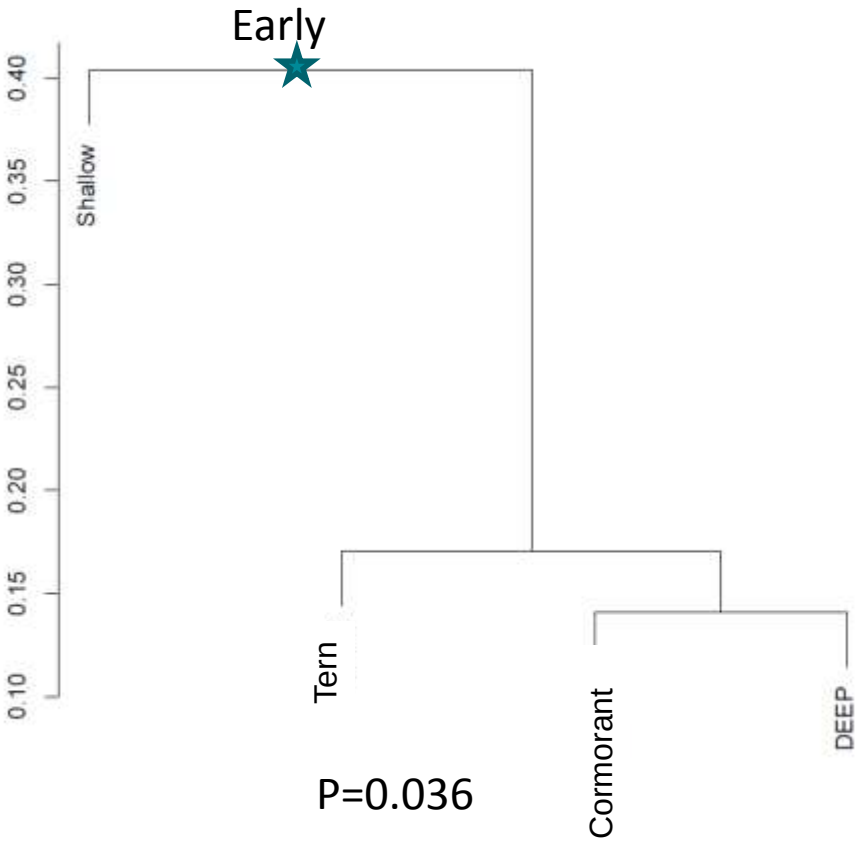
East Sand Island Bird Populations

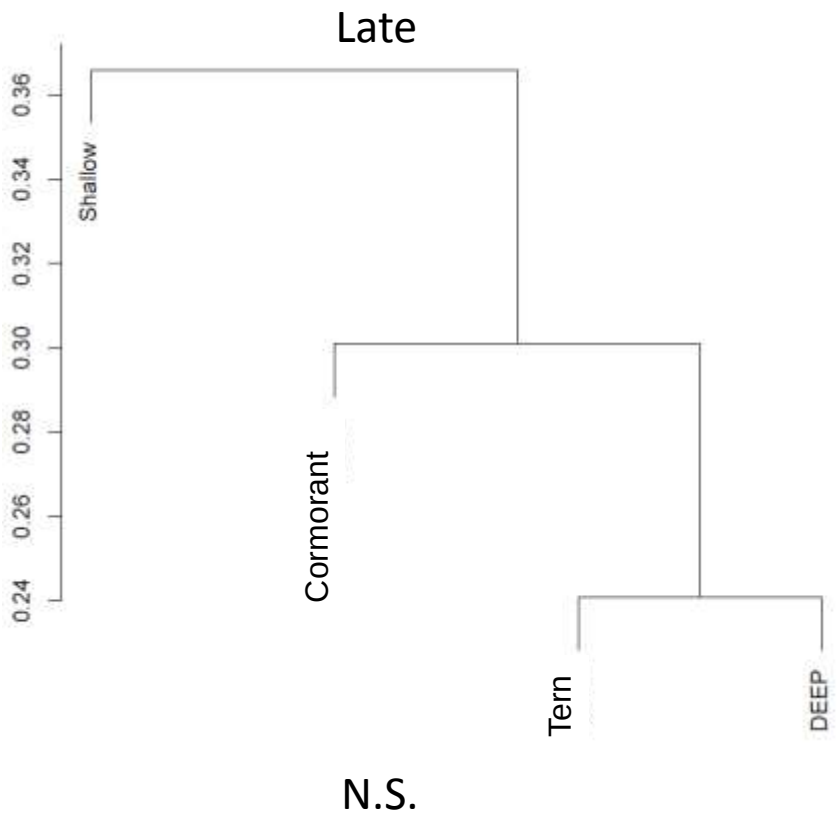
- Area is about 62 acres
- 2013 Census
  - Caspian terns 7387 nesting pairs
  - Double crested cormorants 14,916 nesting pairs
  - Brown Pelicans 3850 nighttime roosting birds
  - Brandt's Cormorant 1523 breeding pairs
  - Ring-billed gulls 2,680
  - Glaucous-winged/ western gulls 4,580

~58,762 fish eating birds

Chinook reporting groups UPGMA tree based on Bray

Curtis ecological distance Arcsine transformed proportional estimates statistical significance based on 999 permutations

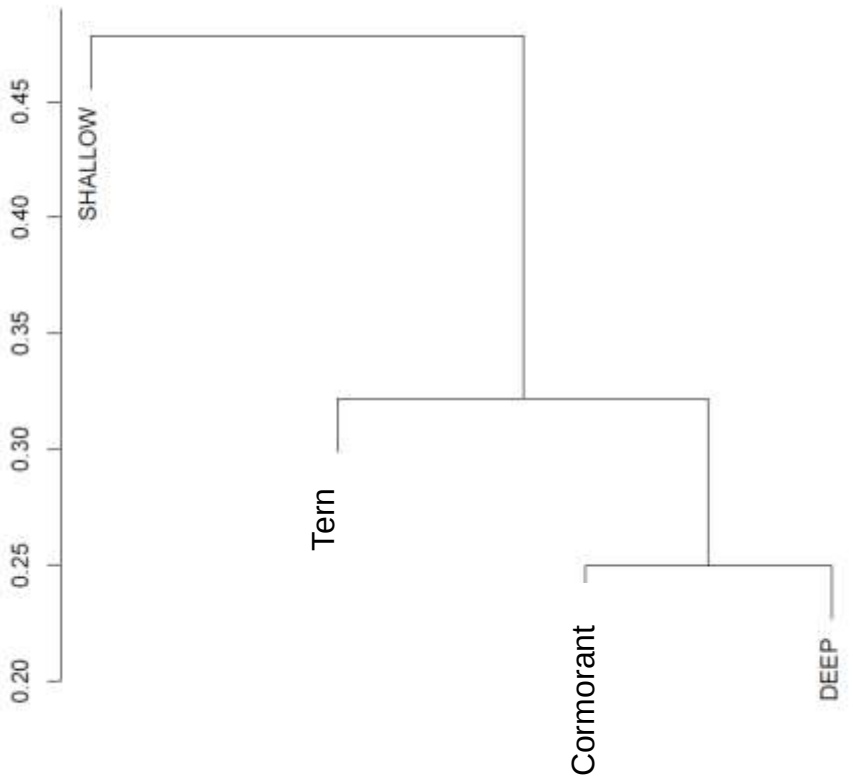




Species groups UPGMA tree based on Bray Curtis ecological distance

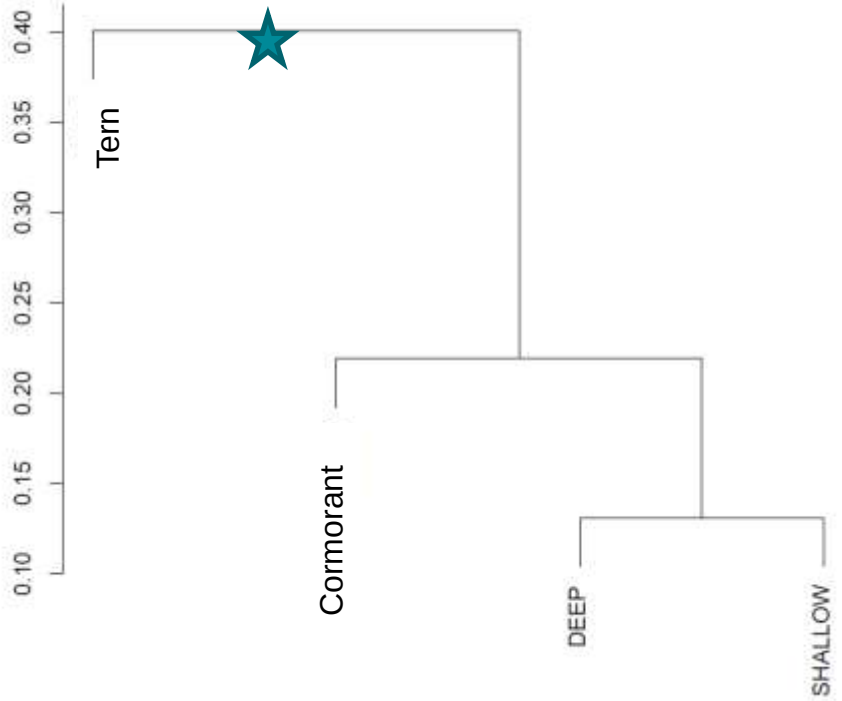
Arcsine transformed proportional estimates statistical significance based on 999 permutations

Early



N.S.

Late



P=0.041

$$\overline{TSC} = \frac{\sum SC_{BioE}}{Year}$$

$$P_{sc} = \frac{\overline{SSC}}{\overline{TSC}}$$

$$RSC_{species} = \overline{TSC} \times \mathrm{P_{sc}}$$

$$RC_{ESU} = PESU \times RSCspe_{cies}$$

$$\frac{\sum SC_{BioE}}{Year}$$

$$\left(\frac{\sum SC_{BioE}}{Year}\right)$$

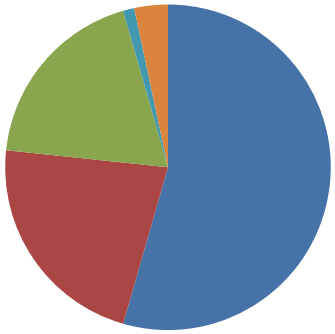
$$RSC_{ESU} = PESU \times RSCspe_{cies}$$

Habitat Comparison Late June-July 2010-2012

Bird depredation

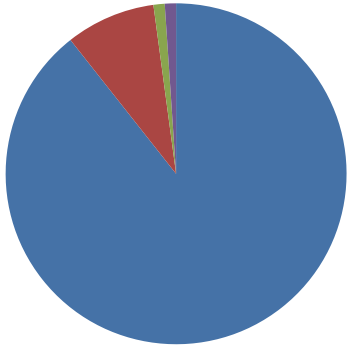
Tern

n= 53 ★ P=0.04



Cormorant

n= 49



Chinook

steelhead

Coho

Cutthroat

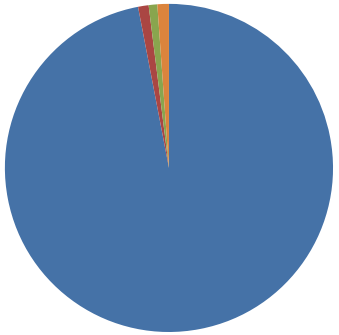
Chum

Sockeye

Habitat profiles

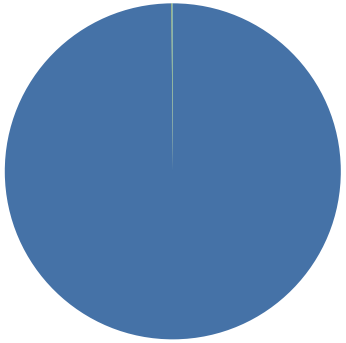
Deep 0-10 m

n = 1060



Shallow 0-3 m

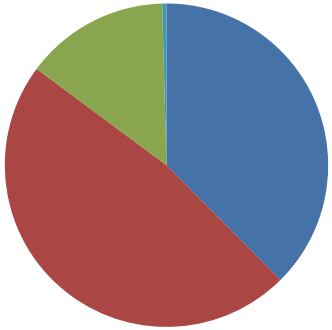
n= 2223



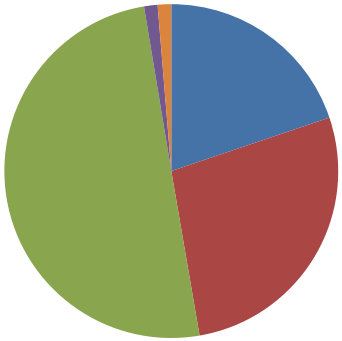
Habitat Comparison Early April-May 2010-2012

Bird depredation

Tern
n= 96

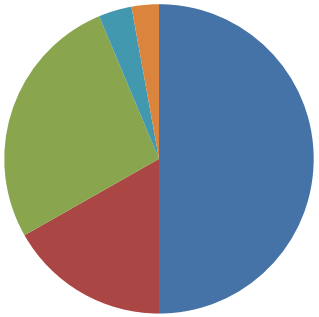


Cormorant
n= 297

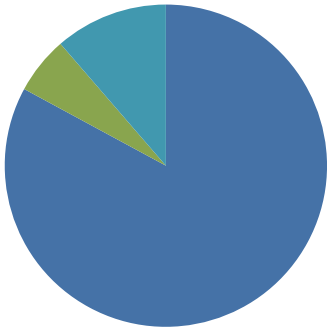


Habitat profiles

Deep 0-10 m
n = 1472



Shallow 0-3 m
n= 1841



Columbia River Basin (2006-2013)

(millions of fish)

Salmon Species	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Chinook	2.21	9.85	12.06
Steelhead	1.05	1.32	1.72
Coho	2.09	2.95	5.03
Sockeye	0.03	0.05	0.08
Total			18.89

Chinook (2006-2013)

(millions of fish)

ESU	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Lower Columbia	0.85	4.99	5.23
Willamette spring	0.19	0.00	0.19
Deschutes summer/ fall	0.01	0.00	0.01
Mid-Upper Columbia spring (2)	0.52	1.25	1.77
Upper Columbia summer/ fall	0.25	0.76	1.01
Snake fall	0.17	0.55	0.72
Snake spring/ summer	0.40	2.10	2.50

Steelhead (2006-2013)

(millions of fish)

DPS	Caspian Tern depredation	Double Crested Cormorant depredation	Sum Bird depredation
Lower Columbia	0.23	0.34	0.57
Willamette	0.08	0.06	0.14
Mid Columbia	0.09	0.23	0.32
Upper Columbia	0.04	0.08	0.13
Snake	0.60	0.60	1.21

Species Identification 2006-2013