Conceptual framework for food web links between seabirds and fish in the estuary, plume, and nearshore ocean of the Columbia River

Presented by: Jeannette E. Zamon

Co-authors: Elizabeth M. Phillips, Troy J. Guy, Daniel D. Roby, Don E. Lyons, Ken Collis, Allen Evans, Jennifer M. Mannas and Josh Adams

TAKE HOME MESSAGES – Estuary/plume

1. The estuary/plume continuum supports <u>very large numbers</u> of fish-eating seabirds during April – September, and the numerically dominant bird & fish species change along this continuum

2. Anchovy, herring, smelt, and juvenile salmon provide most of the food resources to support birds in the estuary/plume.

3. These seabird-fish interactions create an "ecological hotspot" containing multiple issues of management & conservation concern.

CONCEPTUAL FRAMEWORK – Estuary/plume continuum
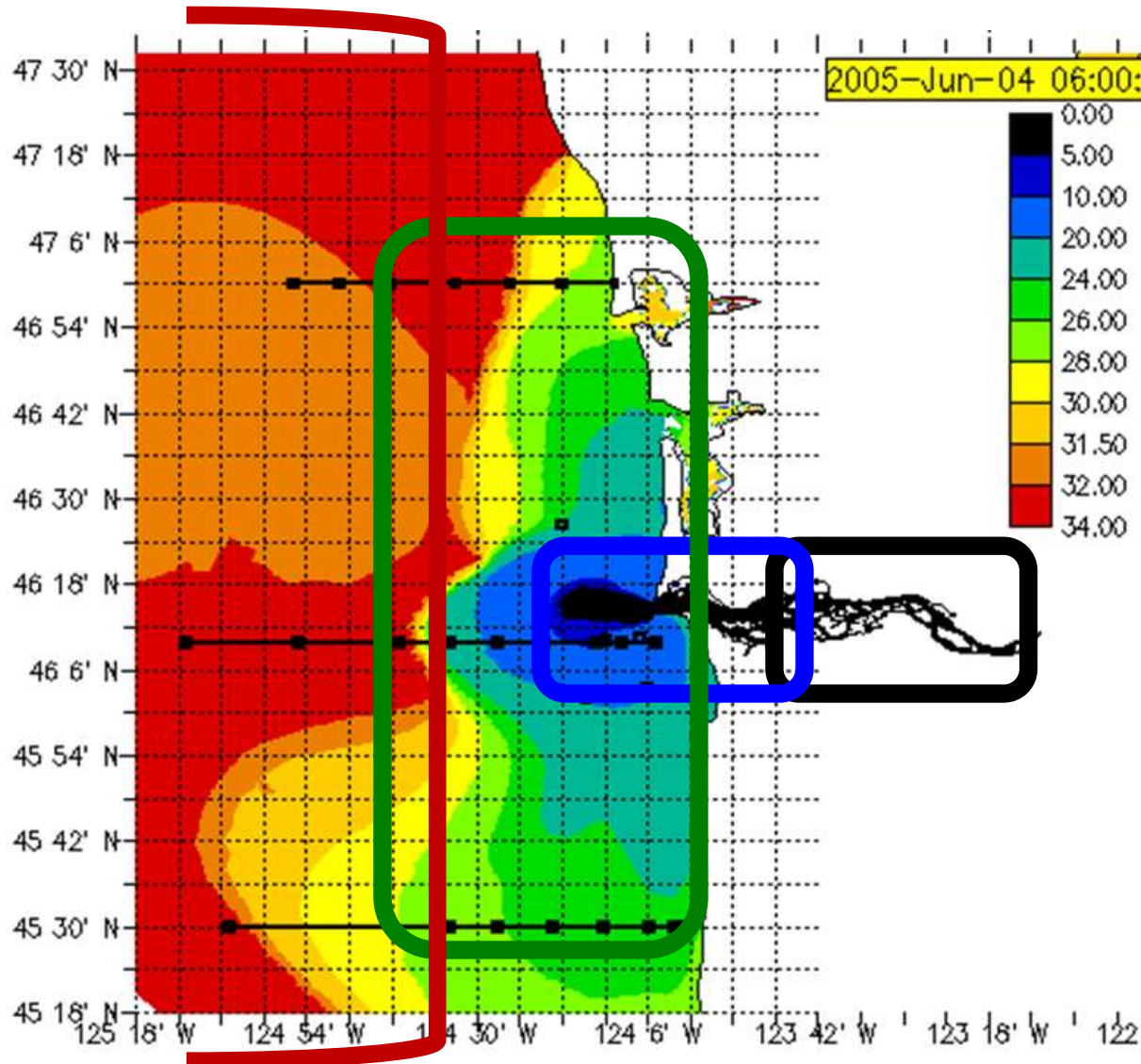
The estuary region:
Columbia River where salinity >1 often occurs on a daily basis (~ rkm 0 – rkm 50; see www.stcmop.org)

The plume region:
nearshore Pacific Ocean where salinity is often < 26 on a daily basis (~ 0-50 km offshore, Grays Harbor, WA to Cape Meares, OR; c.f. Horner-Devine et al. 2009)
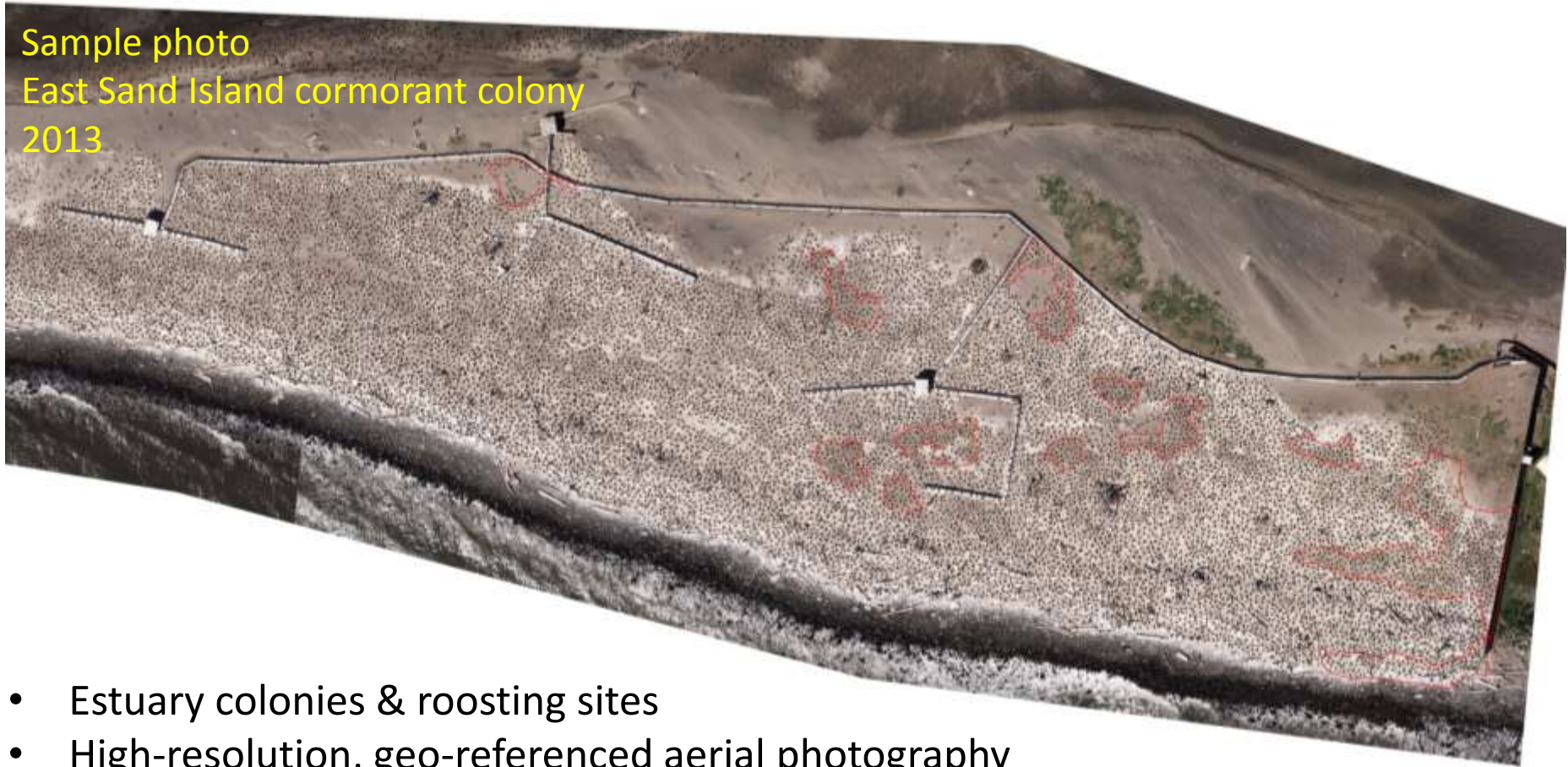
- **Pacific Ocean**   - **Plume**   - **Estuary**   - **Tidal freshwater**

Model data & images courtesy www.stcmop.org

DATA AVAILABILTY - Seabirds & fish in the estuary/plume

SURVEY	TAXA	YEARS WHEN SAMPLING TOOK PLACE
		80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14
CREDDP	Seabirds, fish	(80–81)
NOAA plume (day)	Seabirds, fish	no birds (99–02); (03–14) XXX - no birds
NW forest plan marbled murrelet	Seabirds	(91–14) XXX
BRNW colonial waterbirds	Seabirds	(97–14) XXX
NOAA lighthouse	Seabirds	(06–11) XXX
MMS/BOEM & OR/WA seabird catalogs	Seabirds	(89–90); (07–08); (11–12)
Fisher & Pearcy ocean purse seine	Fish	(82–86)
NOAA estuary purse seine	Fish	(07–13) XXX
NOAA plume (night)	Fish	(99–11) XXX

- Post-CREDDP, no studies captured estuary-plume continuum with spatially & temporally continuous sampling
- Most work driven by applied conservation concerns (e.g. species recovery)
- Several key data streams recently reduced or lost (XXX) due to federal budget cuts

METHODS: Estuary bird surveys
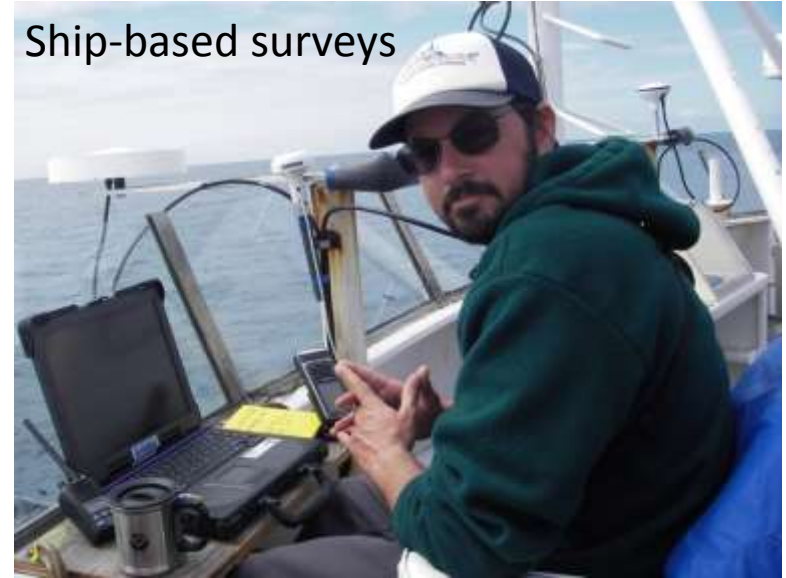

Sample photo
East Sand Island cormorant colony
2013

- Estuary colonies & roosting sites
- High-resolution, geo-referenced aerial photography
- Land & boat-based visual counts
- Only colonies/species of management interest (not community surveys)
- Primary data sets generated by Roby et al., 1997-present
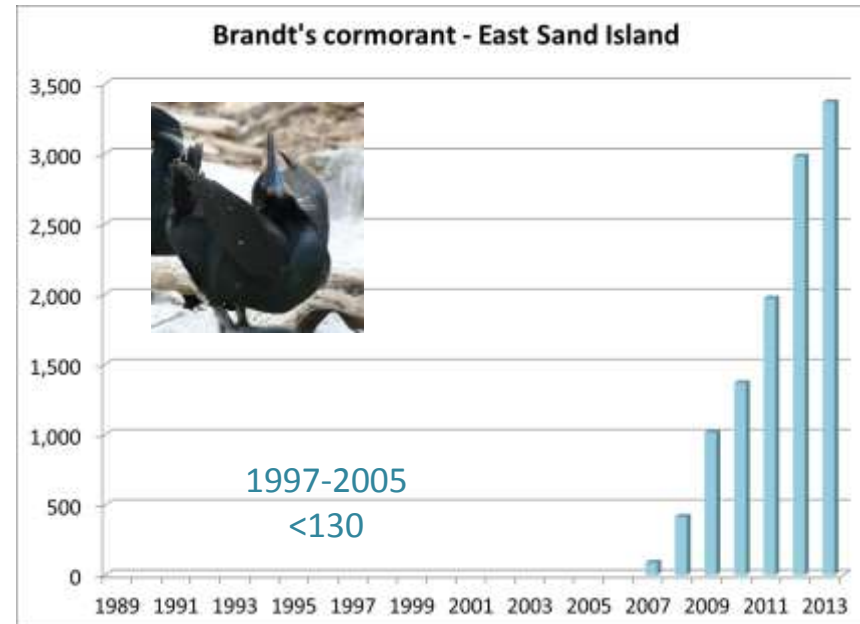
METHOD – Plume bird surveys
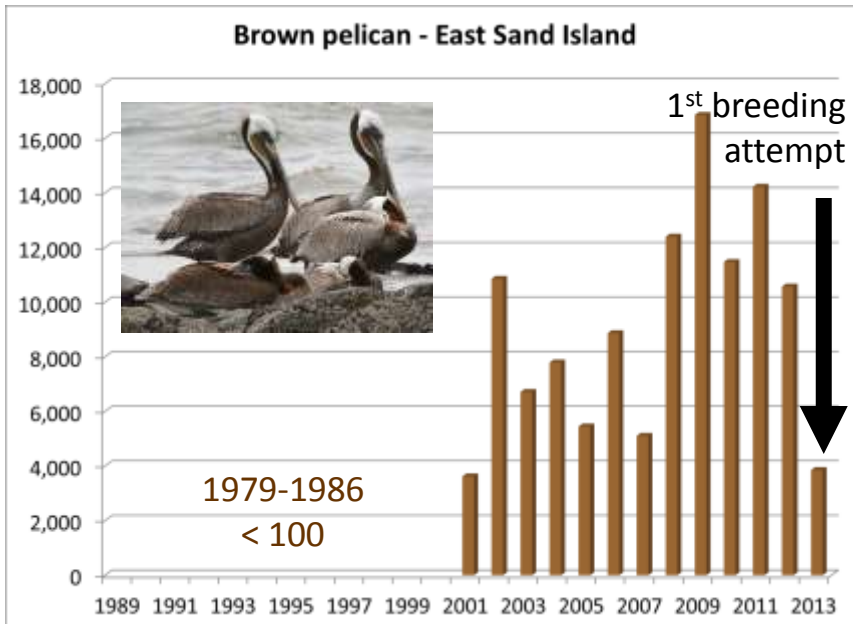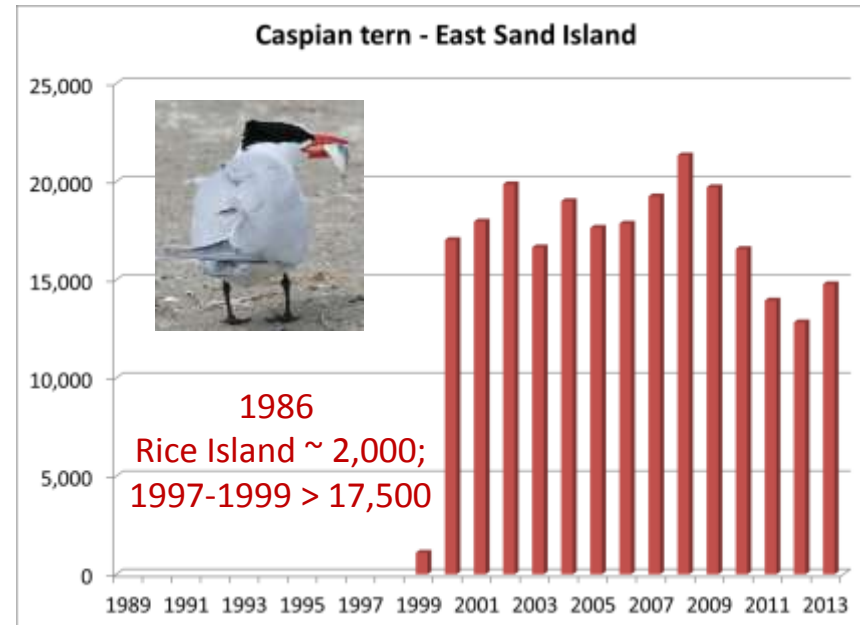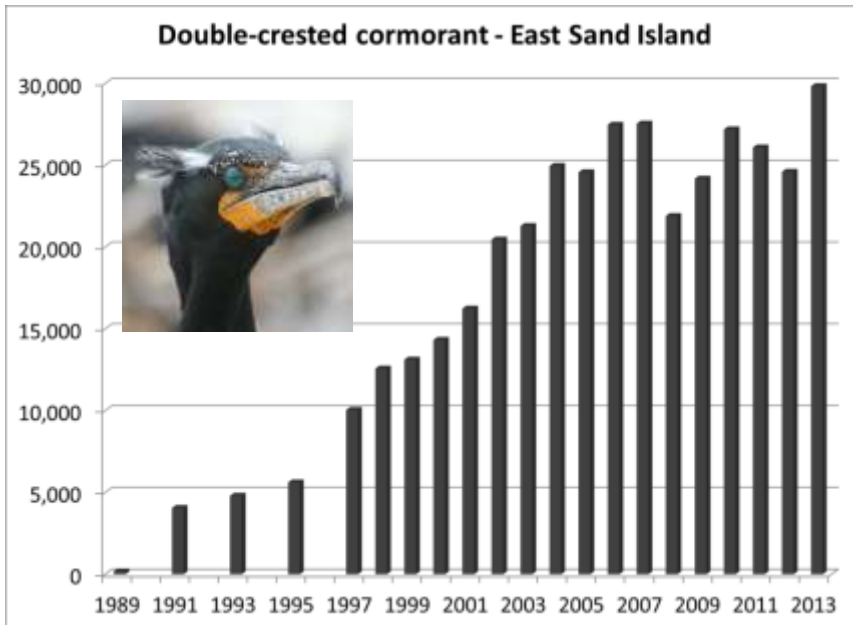
Land-based surveys

Ship-based surveys

- Birds at sea, on the water or flying
- Land-based, ship-based, & aerial visual surveys
- Counting all species encountered, not just those of management concern
- Primary plume data sets presented generated by Zamon et al. (land, ship)
- Additional plume data sets not included here (Strong et al., Pearson & Lance - very nearshore small boat surveys; Adams et al. - aerial surveys)
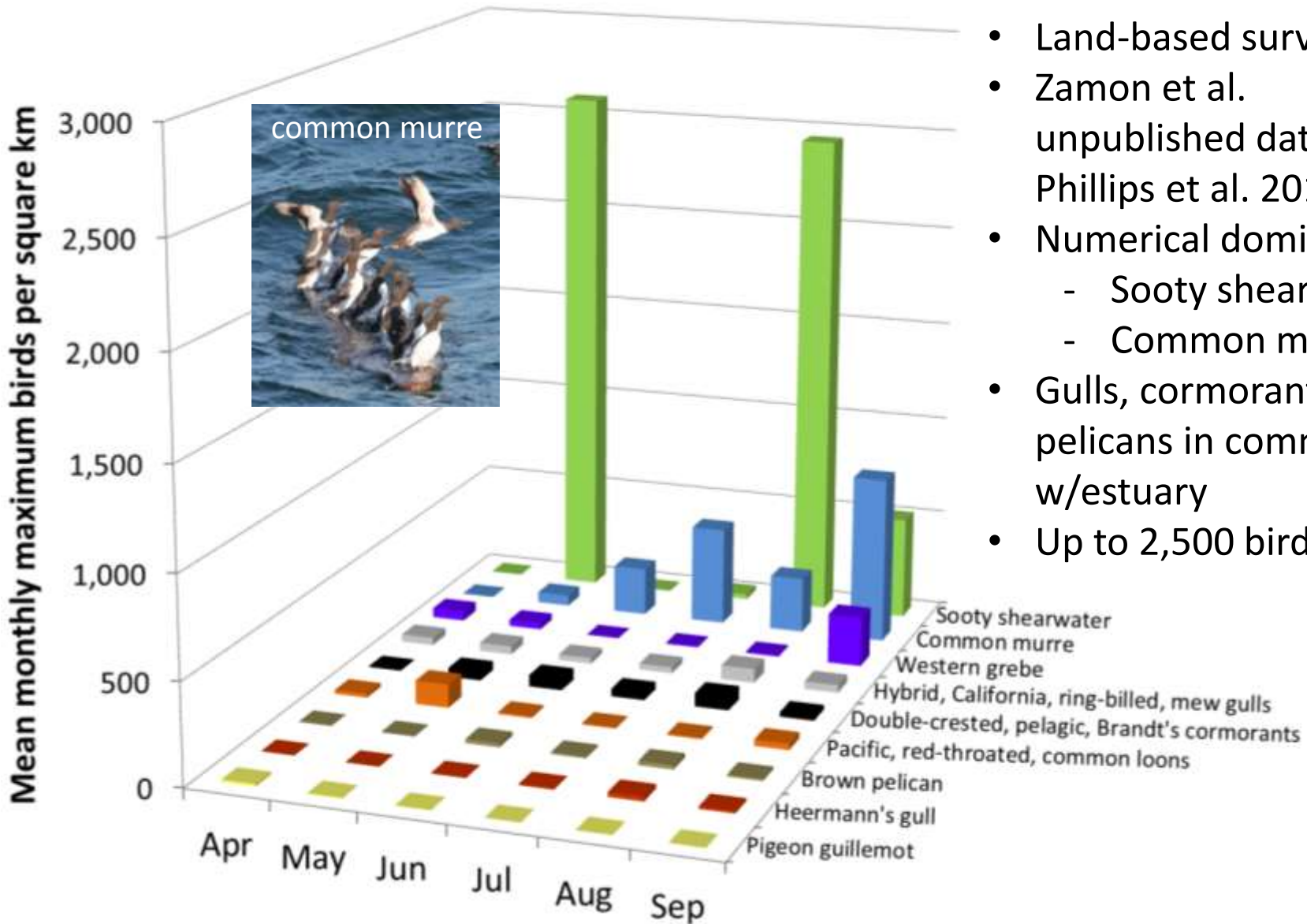
RESULTS: Estuary bird populations have changed – a lot


Estimated total number of individual birds

Double-crested cormorant - East Sand Island

Caspian tern - East Sand Island

1986
Rice Island ~ 2,000;
1997-1999 > 17,500

Brown pelican - East Sand Island

1st breeding attempt

1979-1986
< 100

Brandt's cormorant - East Sand Island

1997-2005
<130

# RESULTS – Columbia River Plume, < 1.5 km offshore

- Land-based surveys
- Zamon et al. unpublished data, Phillips et al. 2011
- Numerical dominants
  - Sooty shearwaters
  - Common murres
- Gulls, cormorants, pelicans in common w/estuary
- Up to 2,500 birds/km^2 !

RESULTS – Columbia River Plume, > 4 km offshore

MAY
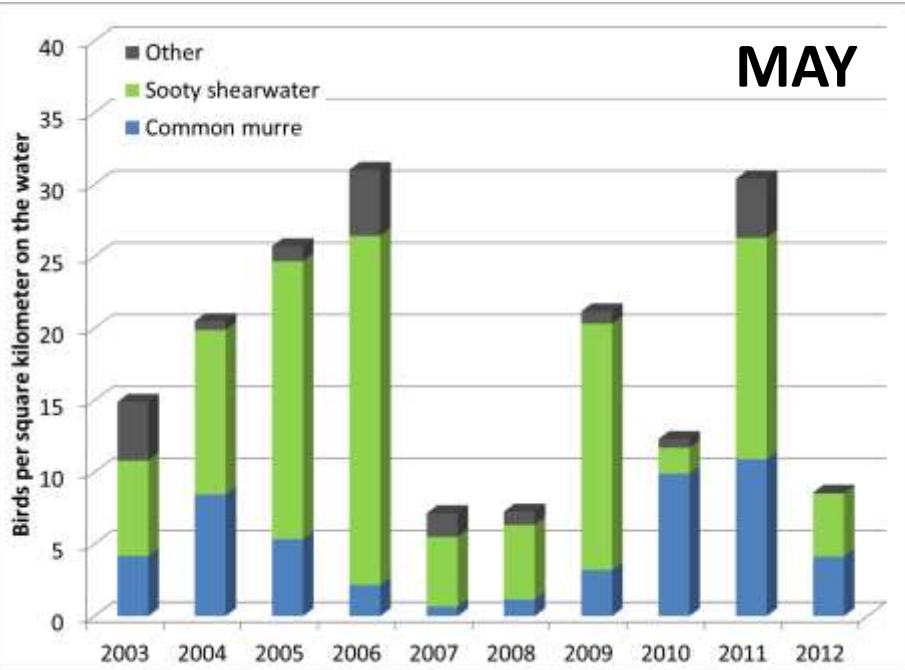
- Zamon et al. 2013, unpublished data
- Between Cape Meares, OR and Grays Harbor, WA
- Numerical dominants
  - Common murres
  - Sooty shearwaters
- 7-37 birds per km^2

sooty shearwater

common murre

JUNE
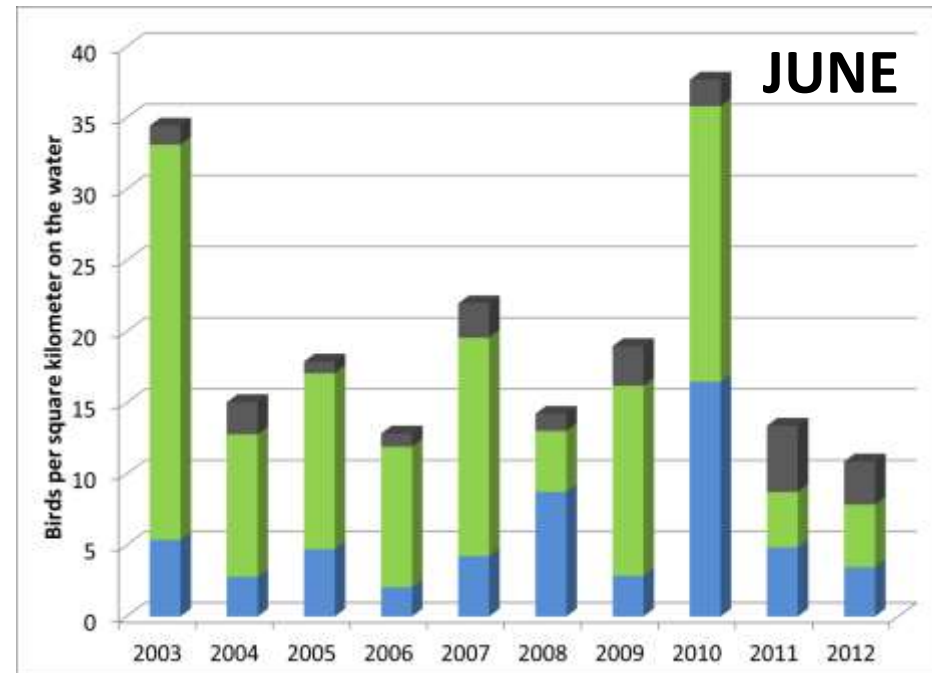
TAKE HOME MESSAGE
very large numbers of birds in estuary/plume

ESTUARY

- \> 65K breeding residents, non-breeding residents, non-breeding migrants

  – <u>Dominants:</u> Caspian tern, double-crested cormorant, western x glaucous-winged gull, brown pelican

PLUME

- \>300K breeding residents, possibly 2-4 million non-breeding residents/migrants

  – <u>Dominants:</u> sooty shearwater, common murre

Double-crested cormorants, East Sand Island

Mixed species feeding flock, Columbia River Plume

WHAT FISHES SUPPORT
SO MANY FISH-EATING BIRDS?

METHODS – Fish surveys

Plume survey vessel *Frosti*

- Boat-based net sampling
- Daytime estuary purse seine, entire water column except benthic fish
- Daytime plume surface trawl, upper 20 m
- Nighttime plume trawl, upper 20 m
- NEW PILOT WORK: estuary/ocean mobile hydroacoustics, ~3 m to the bottom (not presented here)
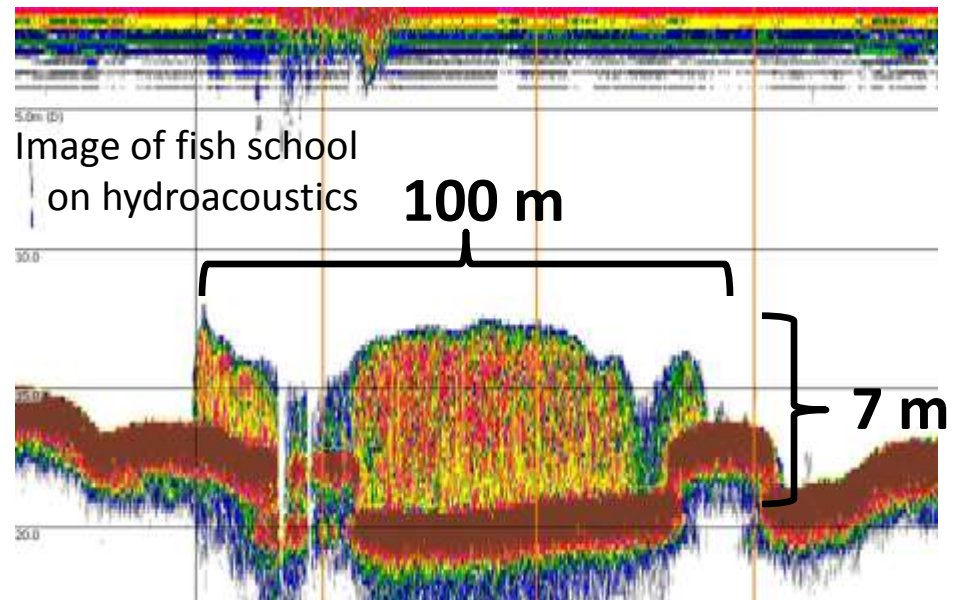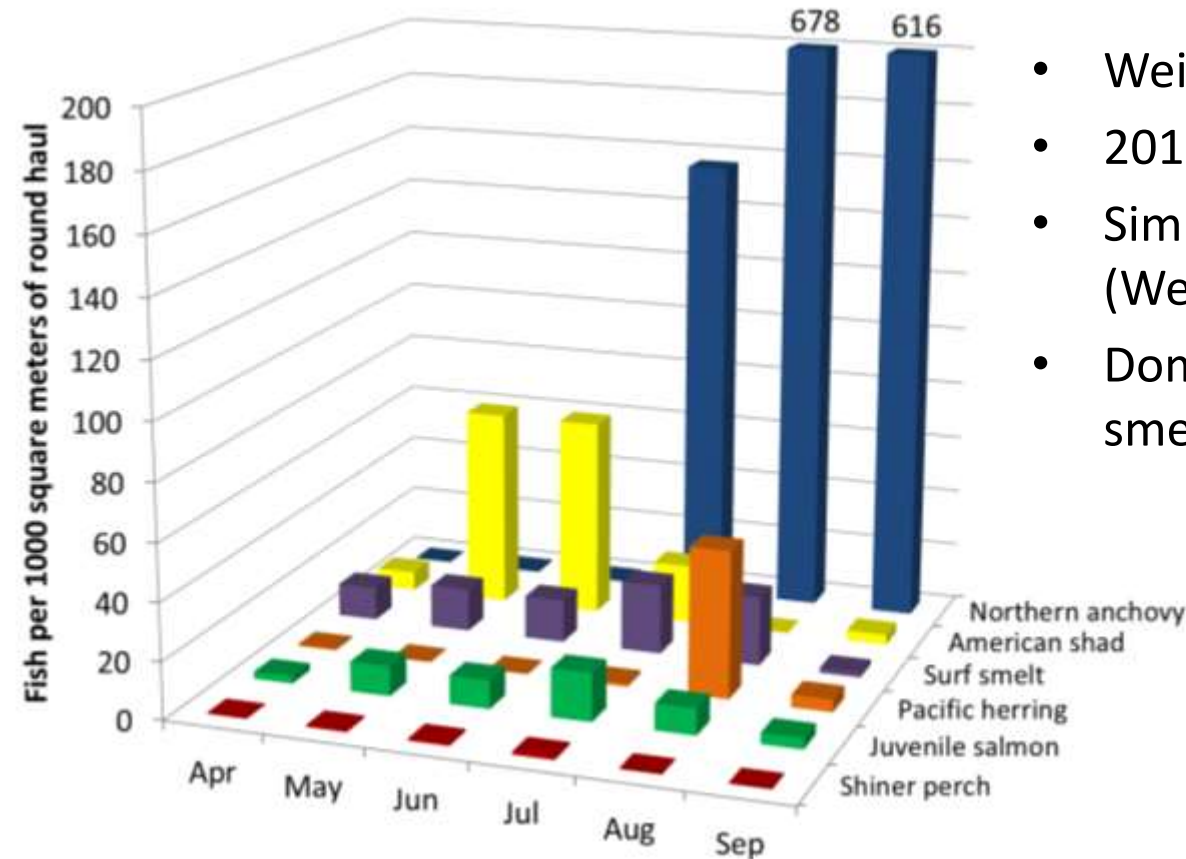- Data presented today are for fish of size birds can eat (<250 mm)

Image of fish school on hydroacoustics

100 m

7 m

RESULTS – Dominant fishes in estuary

northern anchovy

juvenile American shad

surf smelt

- Weitkamp et al. unpublished data
- 2010-2012, ~27 taxa in total
- Similar rankings as 2007-2010 (Weitkamp et al. 2012)
- Dominated by anchovy, shad, surf smelt, herring

Pacific herring

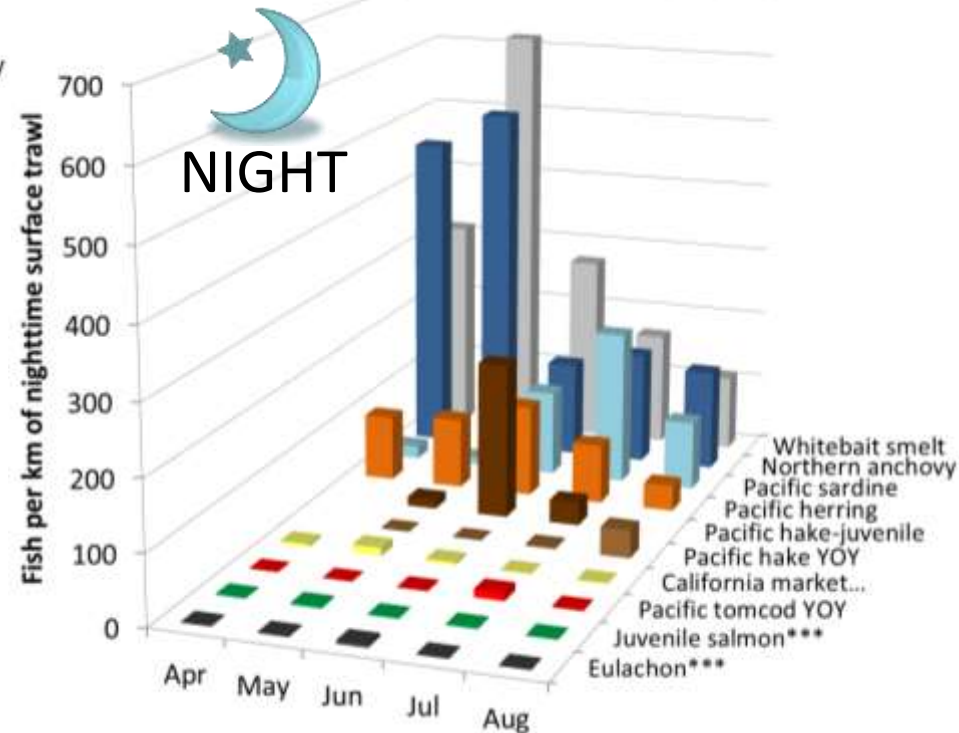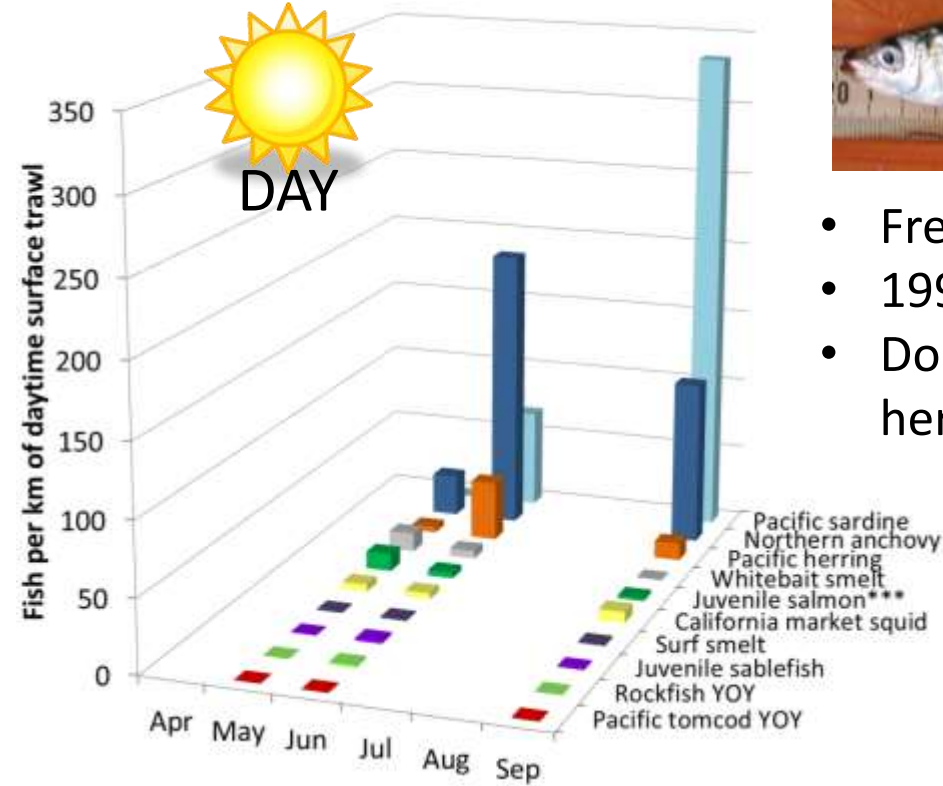# RESULTS – Dominant fishes in plume

DAY

Pacific sardine

Whitebait smelt

- Fresh et al. unpublished data
- 1999-2013, ~ 100 taxa in total
- Dominated by sardine, anchovy, herring, whitebait smelt

NIGHT

- Emmett et al. unpublished data
- 1999-2011, similar to 1999-2009 (see Litz et al. 2013), ~ 100 taxa in total
- Dominated by whitebait smelt, anchovy, sardine, herring

RESULTS – dominant fish across estuary/plume continuum

- Species common to estuary & plume regions
  - Northern anchovy
  - Surf smelt
  - Pacific herring
  - Juvenile salmon

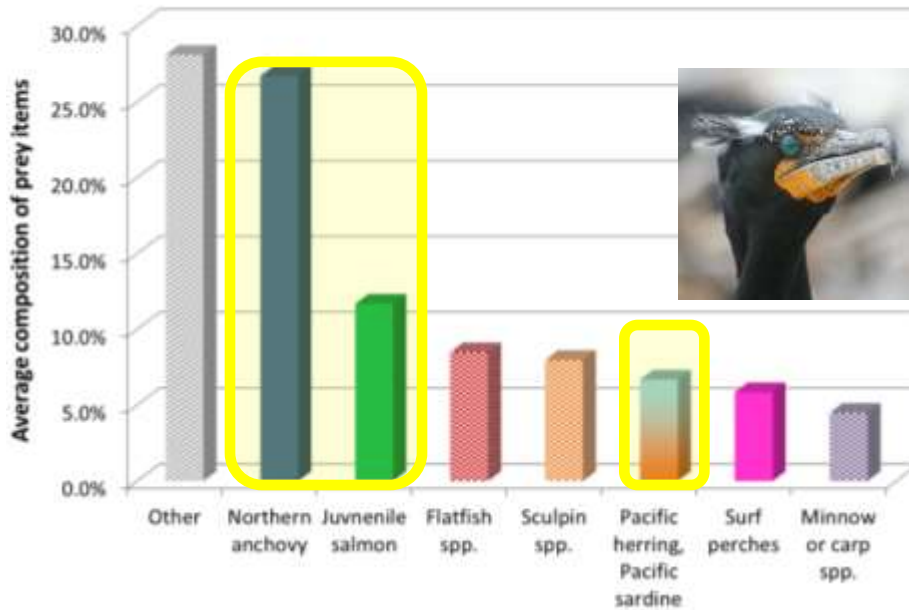# METHODS – Bird diet

- Diet samples
  - Bill loads for chicks
  - Stomach samples
    - Necropsy, lavage, regurgitation
  - Fecal samples
  - PIT tag recovery on colonies
    - Primarily for juvenile salmonids
- Prey identification
  - Visual
    - Soft tissue
    - Bones, hard tissue
  - Genetic
  - PIT tag decoding

12 mm PIT tag , Caspian tern colony

common murre with stomach & fecal samples

stomach contents

northern anchovy

Chinook salmon

RESULTS – Estuary bird diet


Double-crested cormorant

- Average composition, 2000-2013
- Over 45% of cormorant diet, 67% of tern diet contains anchovy, salmon, herring
- PIT tag recoveries from East Sand Island colonies verifies estuary birds consume millions of salmon each year

Caspian tern

- Detailed look at bird diet & fish availability - including seasonal diet changes – to be presented by Weitkamp et al. in next talk
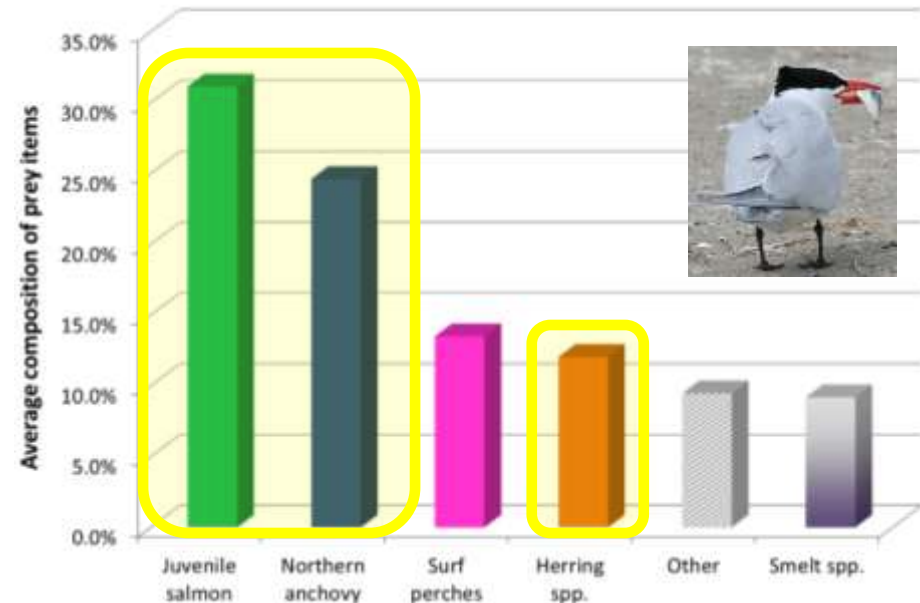
# RESULTS – Plume bird diet
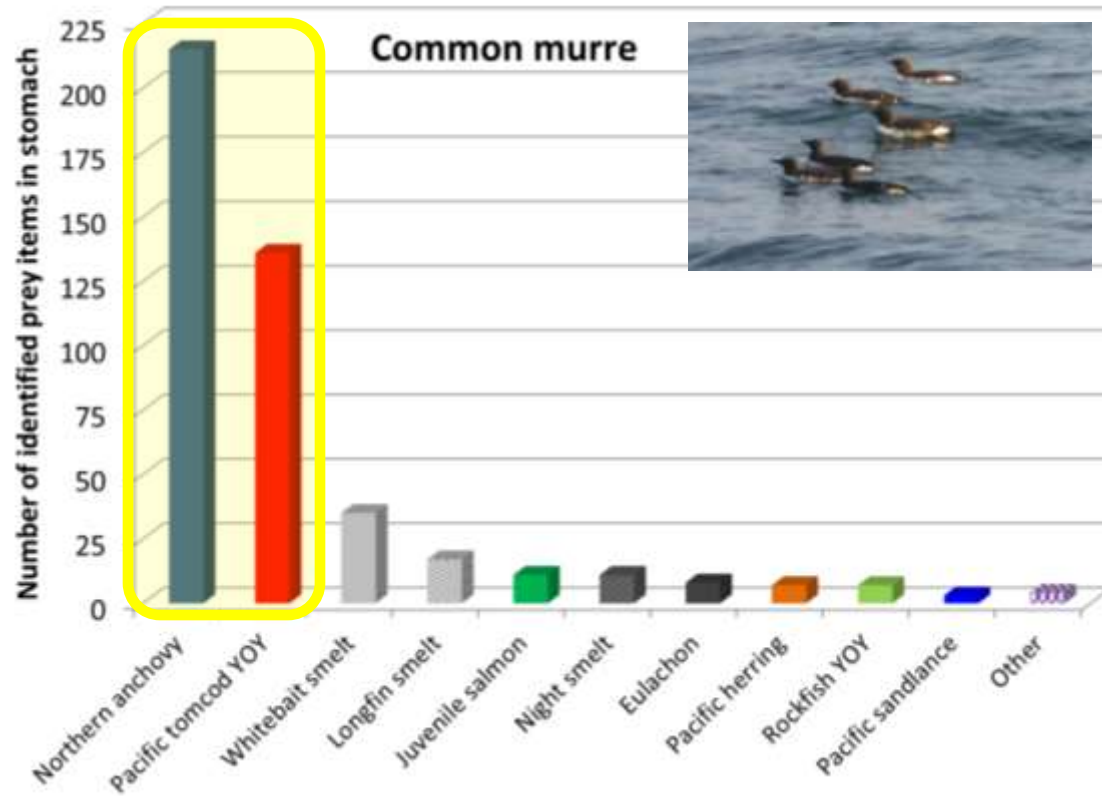
Common murre

- Very few data available
- Varoujean & Matthews 1983
  - Common murre (n=77)
  - Over 75% anchovy, tomcod
  - 13% birds had juvenile salmon
- Zamon et al. unpublished proof-of-concept work
  - Anchovy most prevalent prey in shearwater & murre samples
  - Additional species in murre diet

	Frequency of occurrence in diet samples			
	2005	2008	2009	2010
Common murre	n = 5	n = 6	n = 17	n = 16
Juvenile salmon	20.0%	16.7%	11.8%	0%
Northern anchovy	20.0%	33.3%	58.8%	81.3%
Pacific sandlance, Pacific herring, Pacific sardine, surf smelt, other	0%	16.7%	35.3%	31.3%
Sooty shearwater	n = 2	n = 9	n = 9	n = 15
Juvenile salmon	0	0	0	0
Northern anchovy	100.0%	66.7%	100.0%	100.0%
Unidentified fish/crustacean	0.0%	33.3%	0.0%	40.0%

MANAGEMENT & CONSERVATION APPLICATION

- Recovery of ESA-listed Columbia River juvenile salmon & steelhead populations
  - Estuary avian predation is significant factor
  - Effects modulated by alternative fish prey
  - Plume predation ???
- Ecosystem science/models/management
  - Provide data for models of bioenergetics, salmon survival, food webs, energy flow
  - Identify California Current "ecological hotspots"
  - Inform forage fish harvest management

Habitat use, satellite-tracked common murres
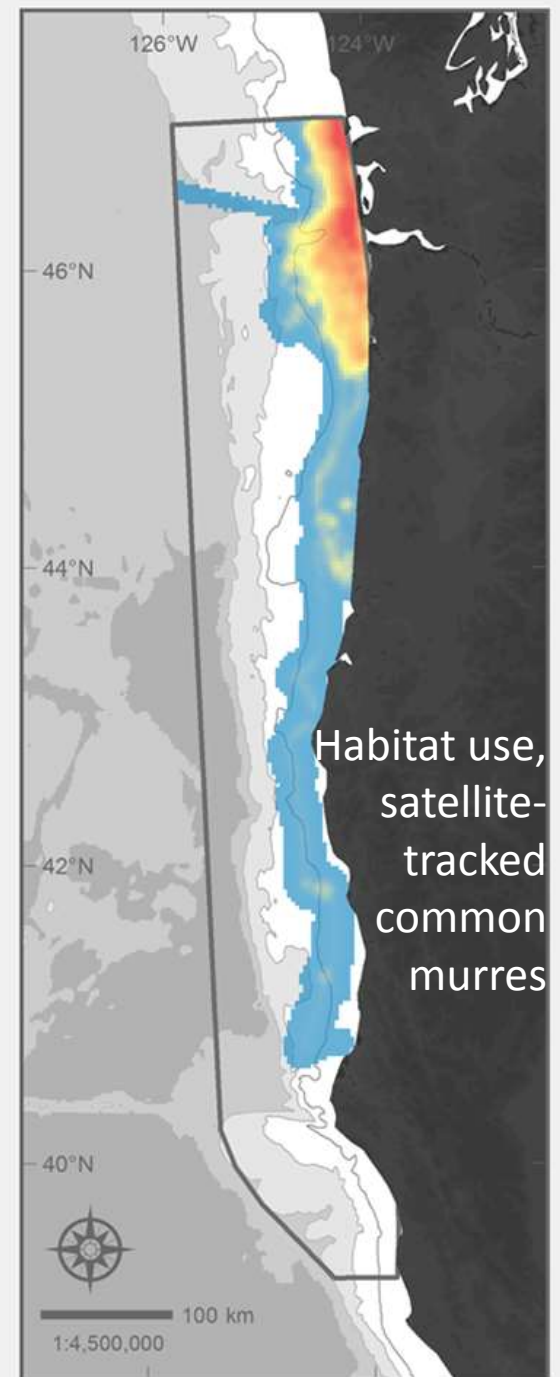
MANAGEMENT & CONSERVATION APPLICATION

- Marine spatial planning data
  - Wind/wave/tidal energy development
  - Oil spill planning & response
  - Critical, sensitive, or protected habitat for birds & fish (sanctuaries, reserves, MPAs, IBAs, estuarine nursery areas)
- Monitoring ecosystem/climate change
  - Species distribution/abundance
  - Reproductive patterns
  - Ecosystem production

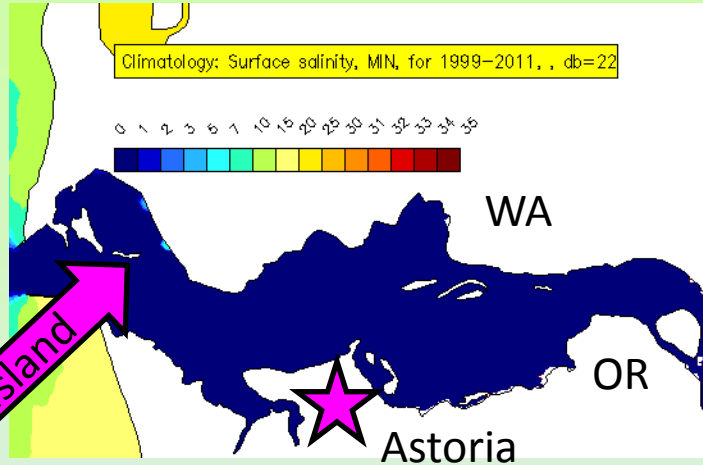Wreck of oil barge *Millicoma*, Columbia River mouth, 2005

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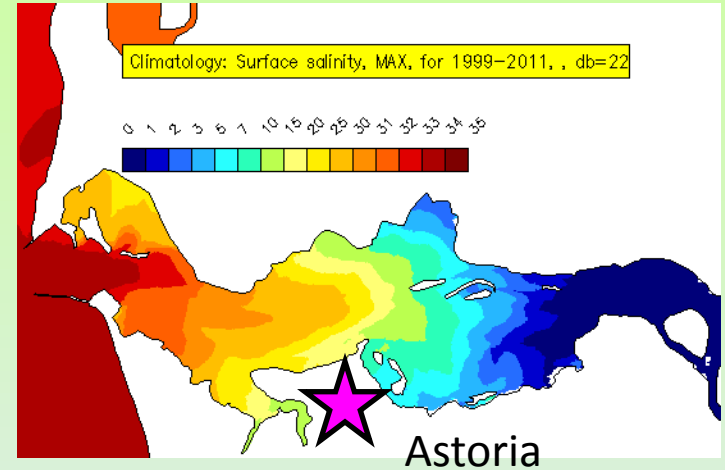
Data gaps, future work

- Bird-fish interactions in the plume – a data gap
- Studies/surveys/syntheses with river-to-ocean coverage across the entire estuary-plume continuum
- Multi-scale, mechanistic understanding of mechanisms driving forage fish dynamics in estuary/plume continuum
  - Tidal, seasonal, interannual variation in distribution/abundance
  - Dynamics critical to estuary/plume ecology, ecosystem models
  - High potential for mechanistic understanding, predictive capability due to strong physical forcing
- Defining time & space scales of management forecast/action/response needs for estuary/plume
  - When, where, what data types available in time to inform adaptive management

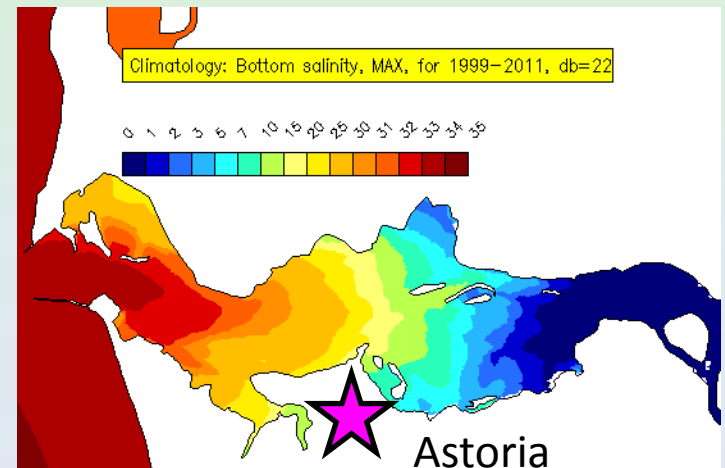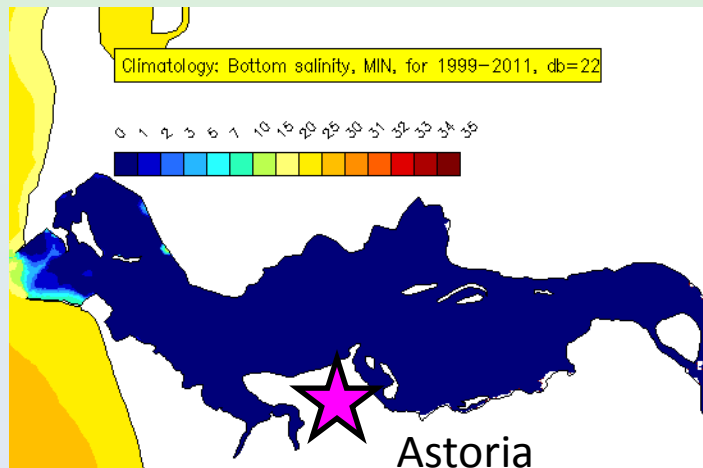# CONCEPTUAL FRAMEWORK –
Daily changes of entire water column

MINIMUM SALINITY, 1999-2011
LOW TIDE

MAXIMUM SALINITY, 1999-2011
HIGH TIDE

SURFACE

BOTTOM

East Sand Island

Model data & images courtesy www.stcmop.org

ACKNOWLEDGMENTS