Distribution and Ecological Interactions off Forage Fishes in the Northern California Current

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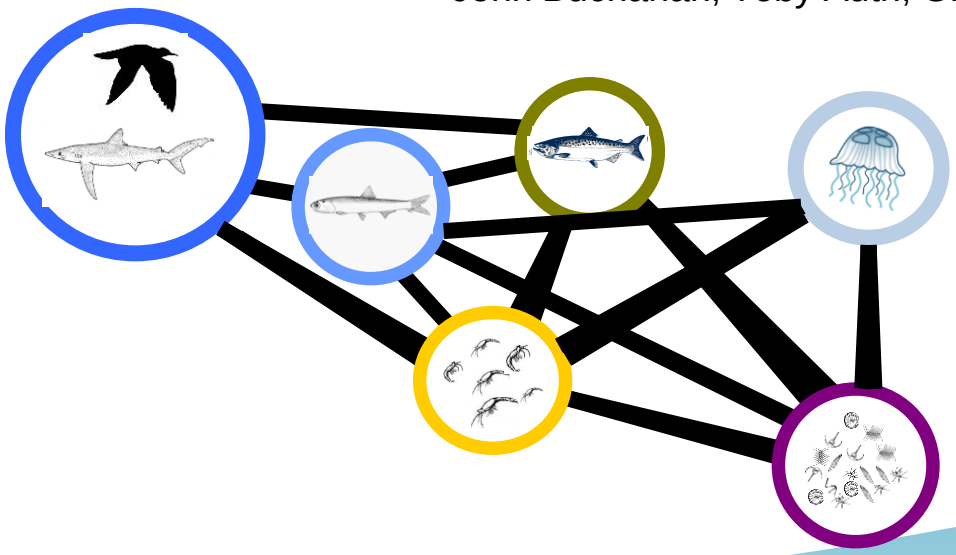
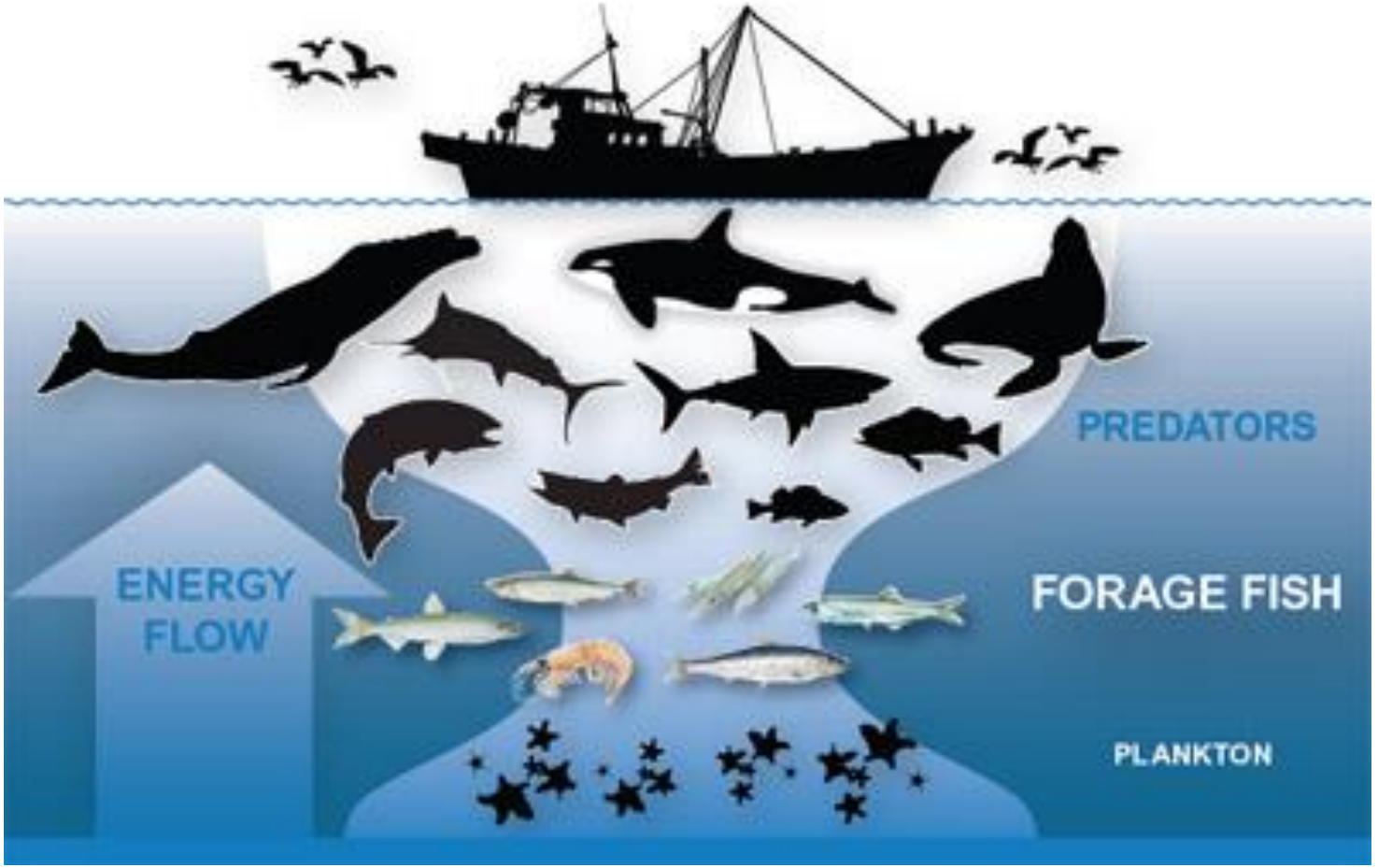
With help from Elizabeth Daly, Bob Emmett, Mary Hunsicker, Todd Miller, John Buchanan, Toby Auth, Greg Krutzikowski, Marisa Litz, and many others



Forage fish are key links in food webs



Talk Objectives –

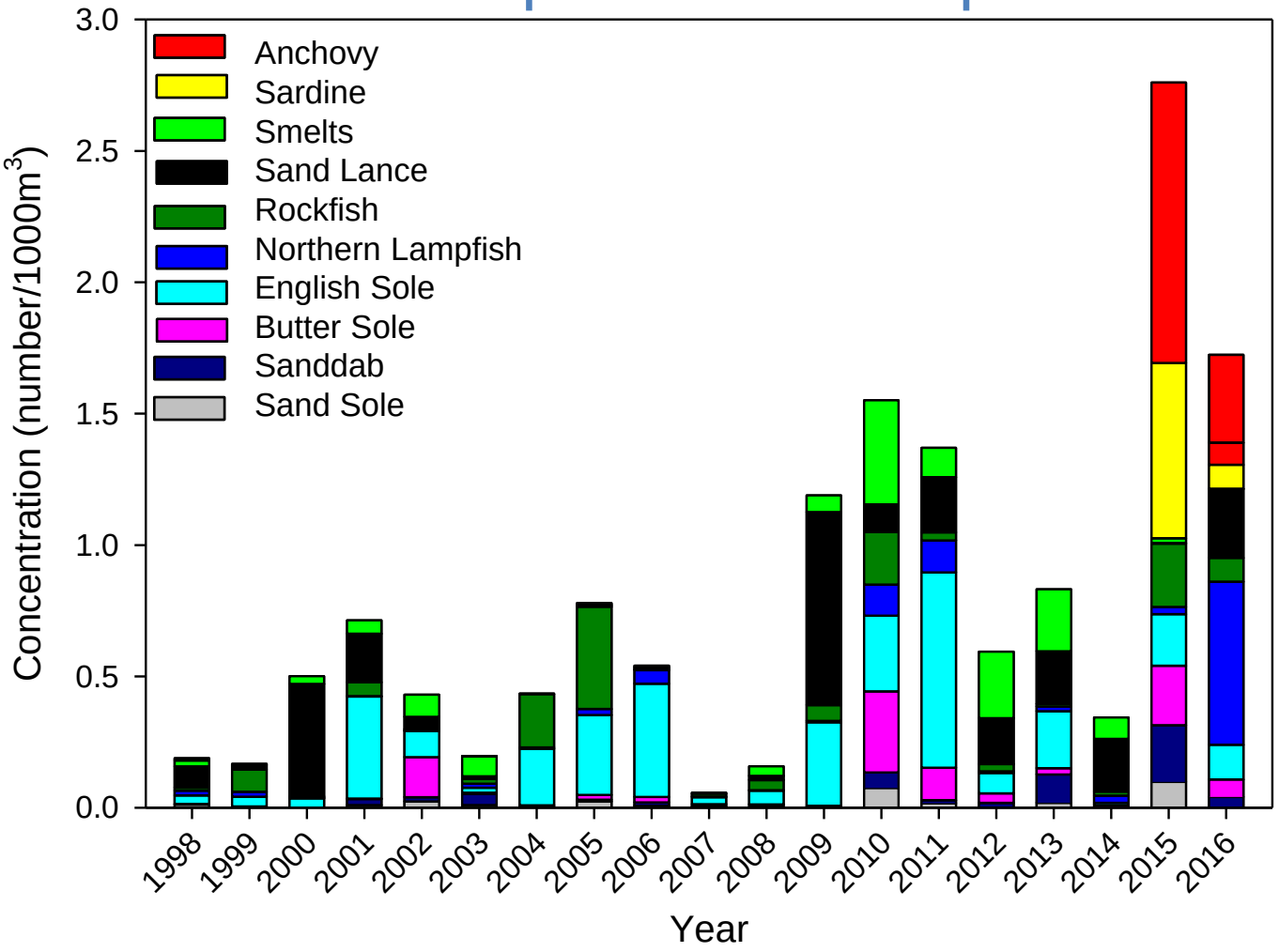
1) Examine changes in larval abundance of important forage fishes in relation to changing climate

2) Summarize surveys which examine distributions of key forage fishes

3) Examine diets of important forage fishes and diet overlap of other species that potentially compete with these forage fishes

4) Examine important fish predators and estimate consumption of forage fishes by pelagic fishes and salmon

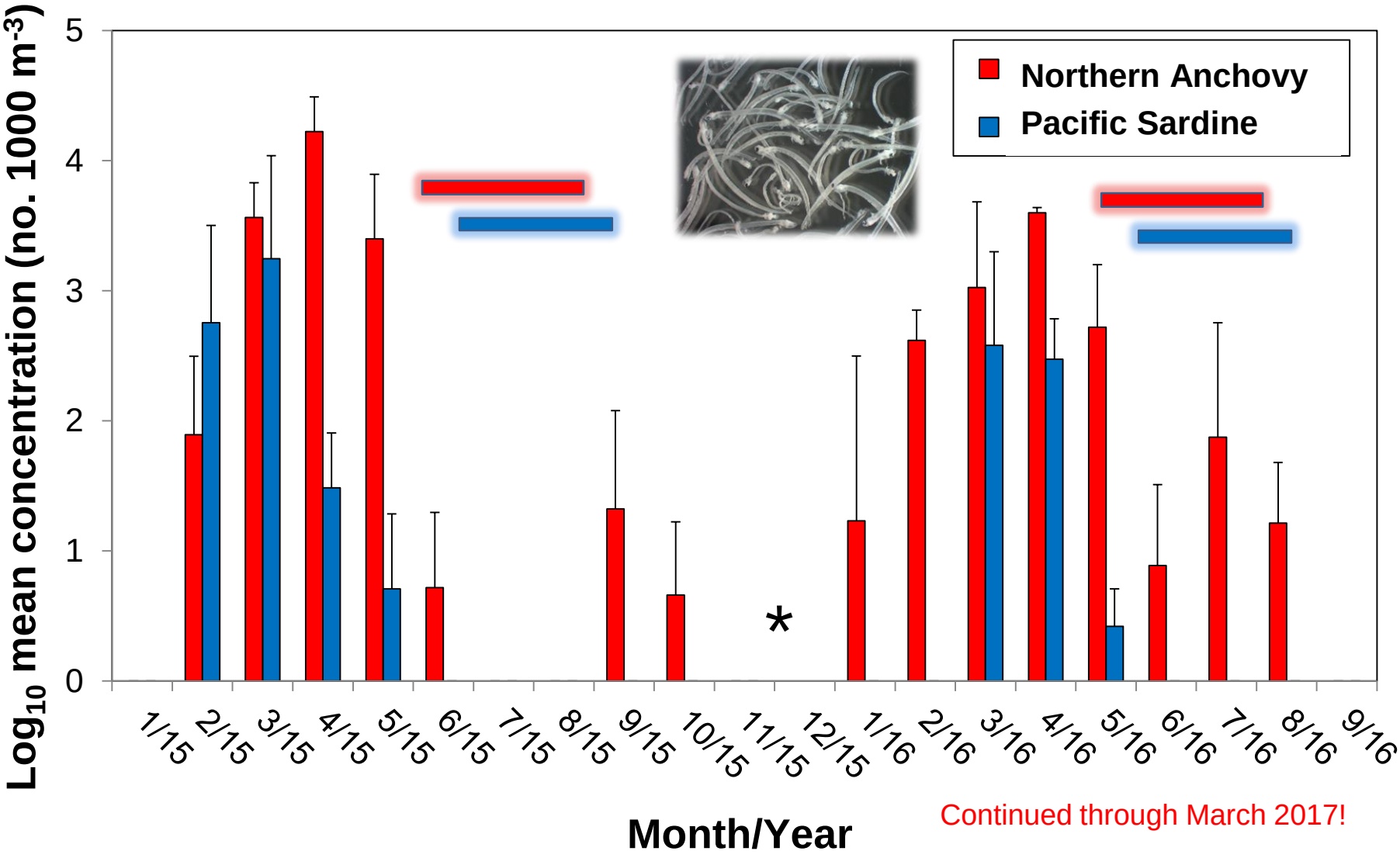
Winter (Jan. – March) Ichthyoplankton from Newport Line Samples



- Earliest (by three months) and most widespread spawning of anchovies and sardines in NCC
- Also found Pacific hake and jack mackerel eggs and larvae off Newport

Auth et al. (2019) *Global Change Biology*

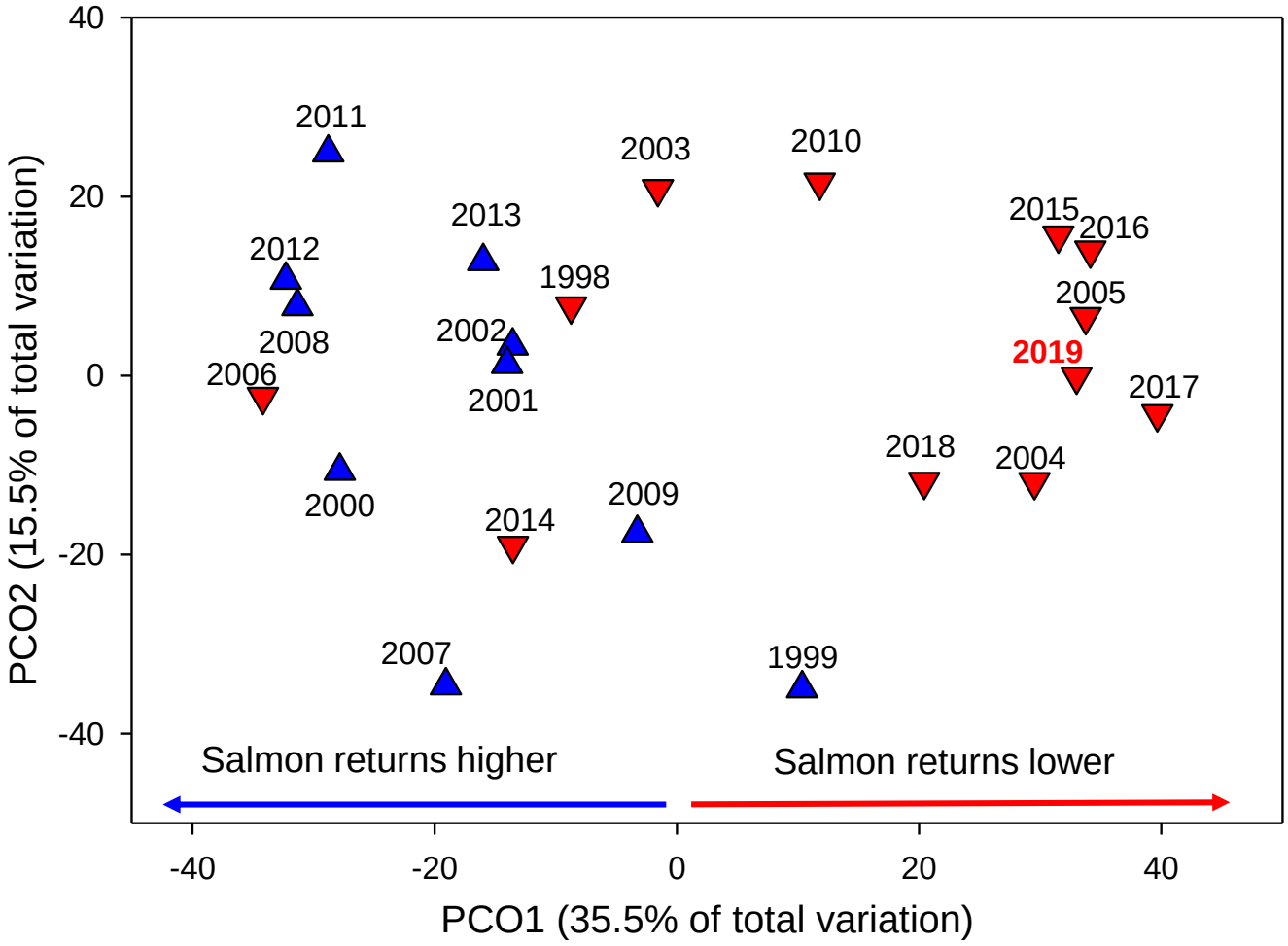
Nearshore (NH 1-15) Density



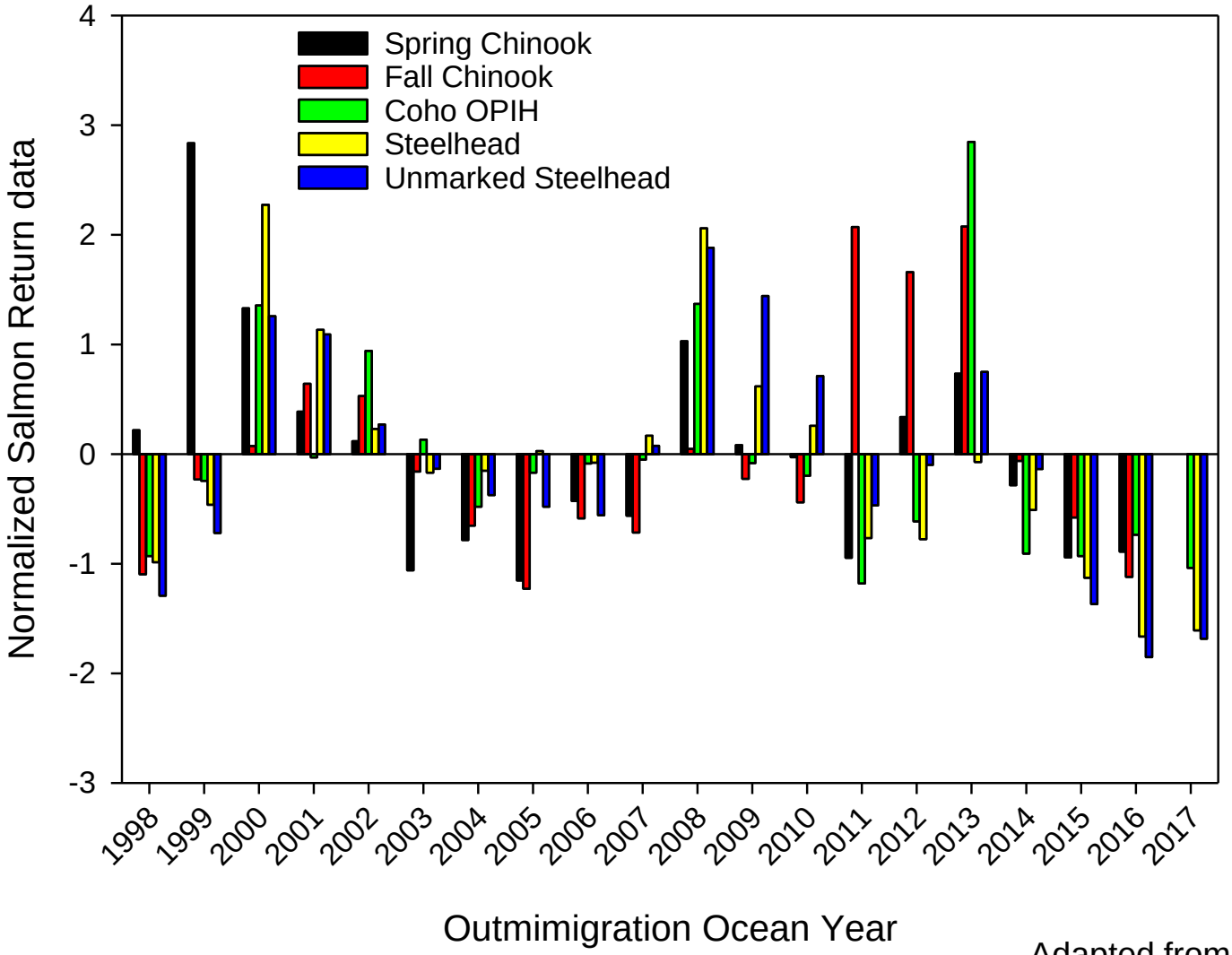
Continued through March 2017!

* No samples collected

Winter Ichthyoplankton composition
PCO axis 1 scores and juvenile salmon success



Juvenile salmon that have migrated into the ocean since the warm blob have all had poor subsequent adult salmon returns to the Columbia River

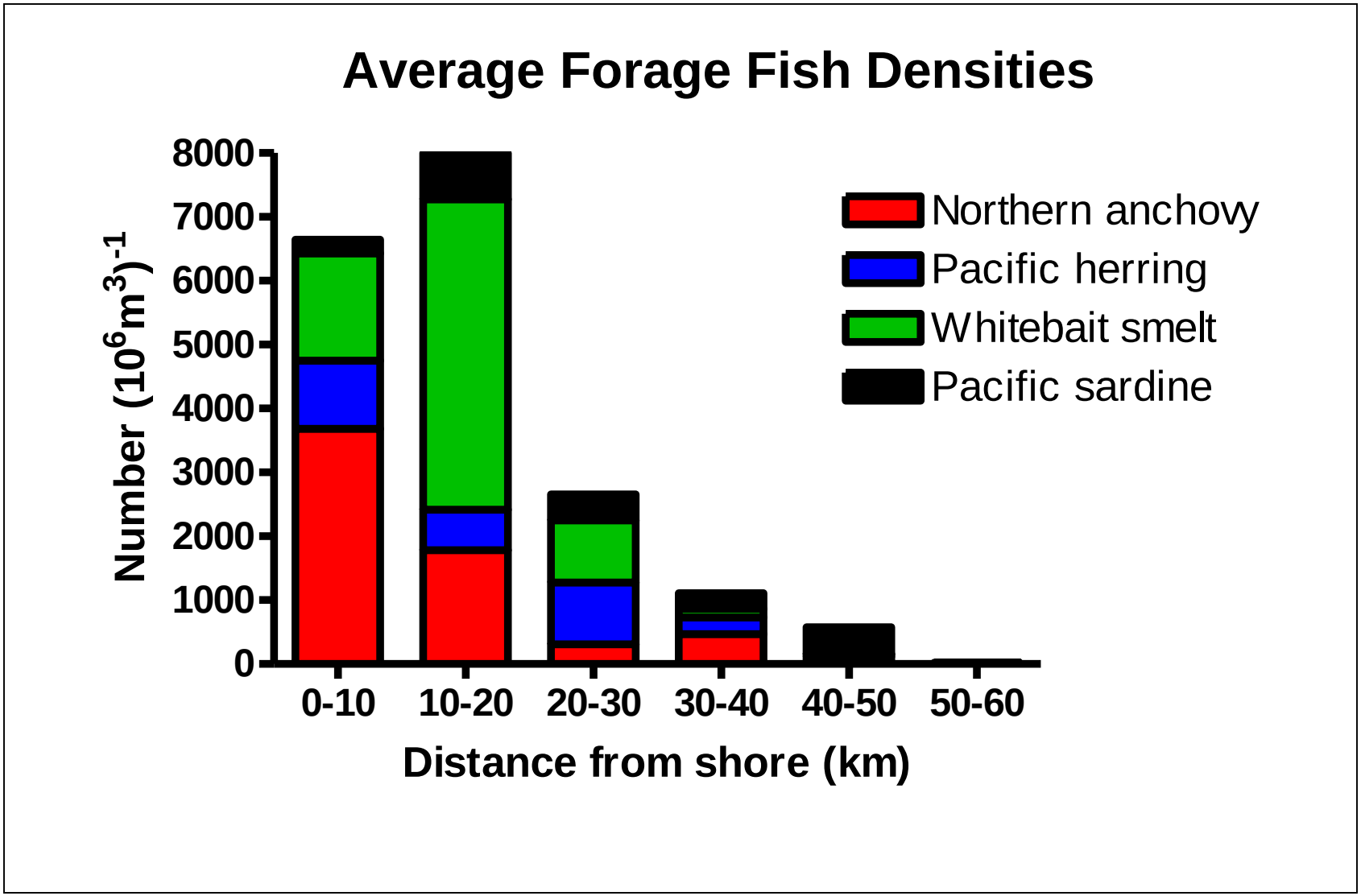


Adapted from Daly et al. (2019)

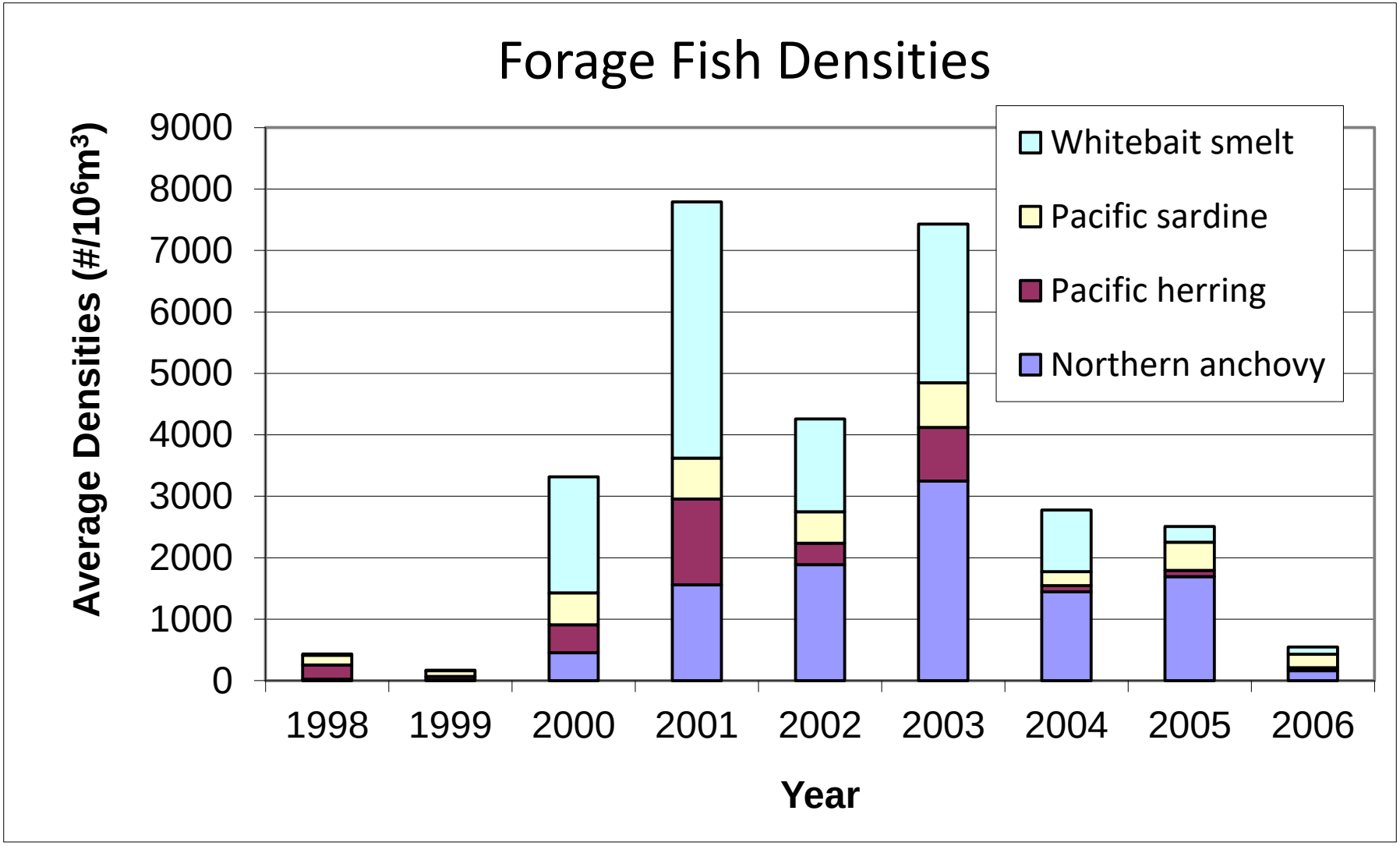
Forage Fish Study

Sampling Years:1998-2009

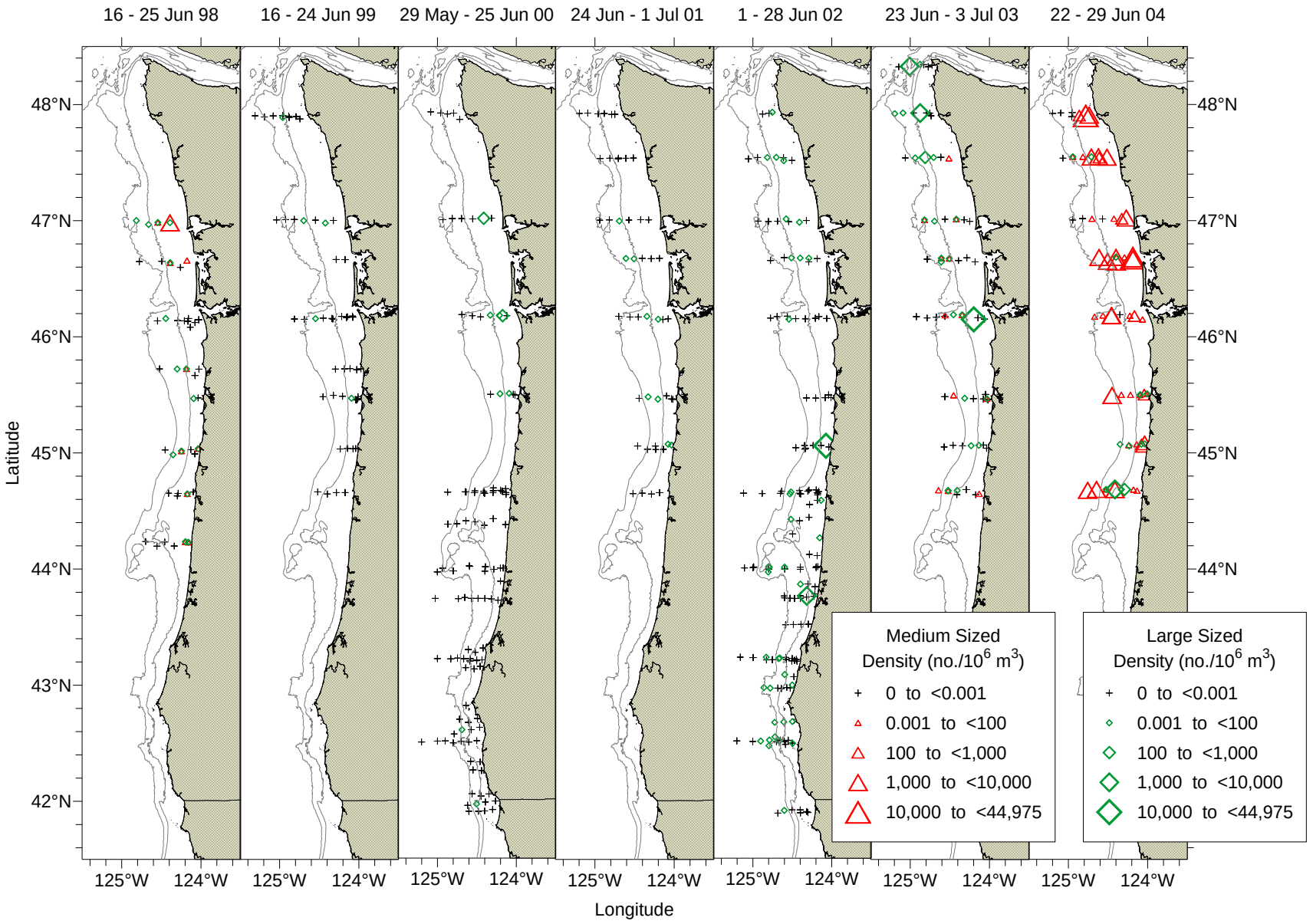
Sampled two transects off the Columbia River and Willapa Bay every 10 days from April to early August



Emmett et al. (2006) *Prog. Oceanogr.*

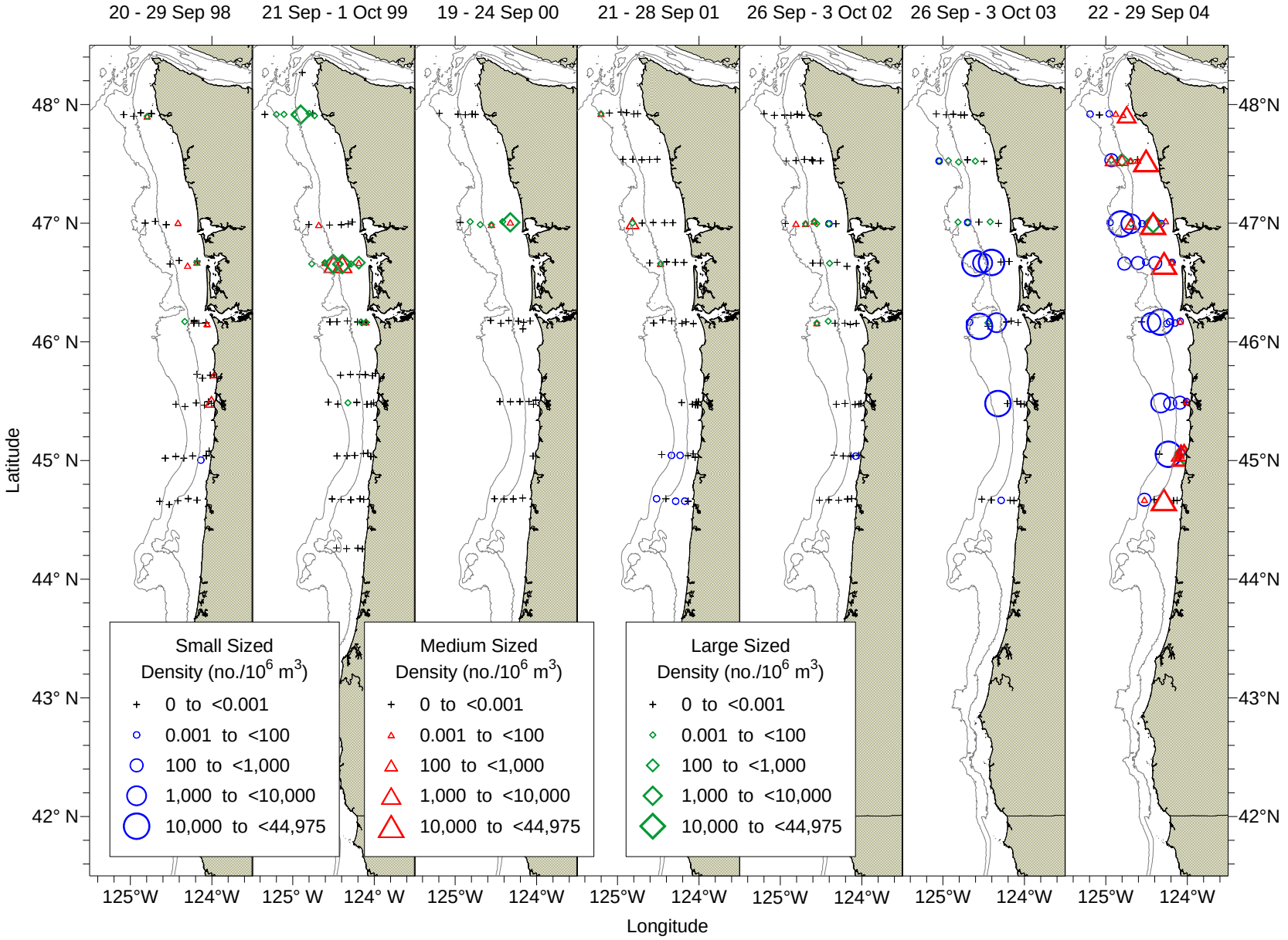

Forage Fish Densities
Average Densities (#/10⁶m³)
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
Year
Whitebait smelt
Pacific sardine
Pacific herring
Northern anchovy

Large-Scale Distribution of Pacific Sardines - June



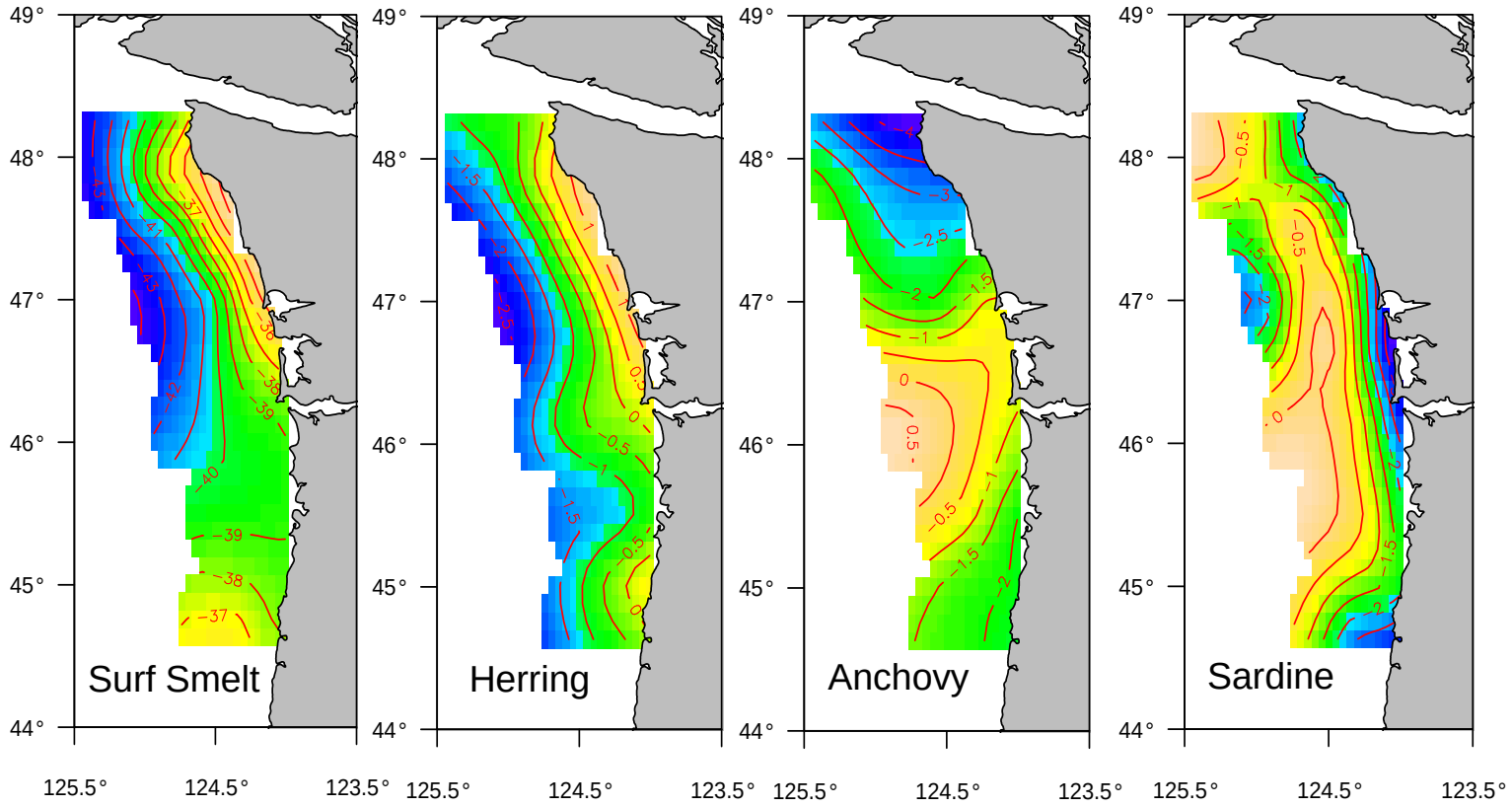
Emmett et al. (2006) *CalCOFI Reports*

Large-Scale Distribution of Pacific Sardines - September



Emmett et al. (2006) *CalCOFI Reports*

Predicted Probabilities of Occurrence in June



Fitted simple generalized additive models (GAMs) to each species separately. The response variable was presence/absence of a species at the selected stations and the explanatory variables included start lat, start lon, bottom depth and year. Using the models, calculated the predicted probabilities of occurrence of each species across the sampling area.

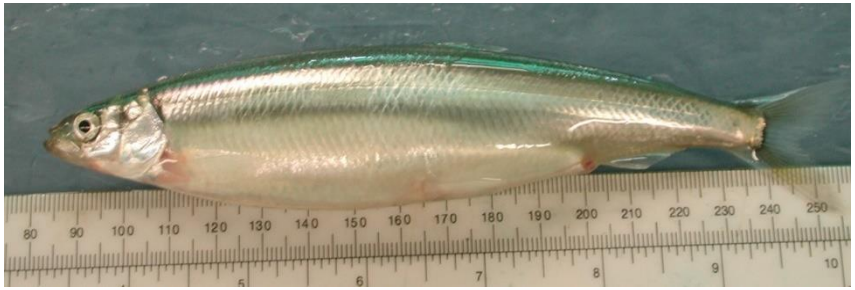
Provided by Mary Hunsicker

Interannual Variability in Diets of Forage Fishes

Northern anchovy (*Engraulis mordax*)

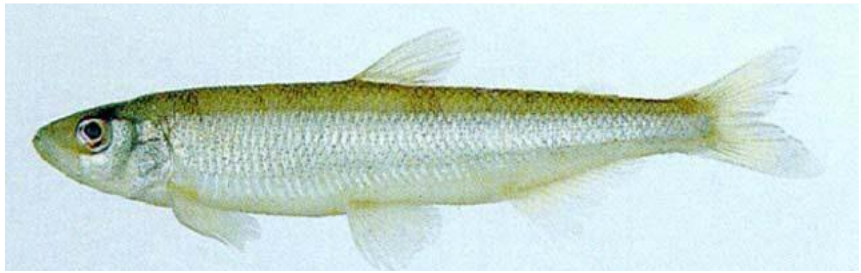
Pacific herring *(Clupea pallasii*)

Pacific sardine (*Sardinops sagax*)



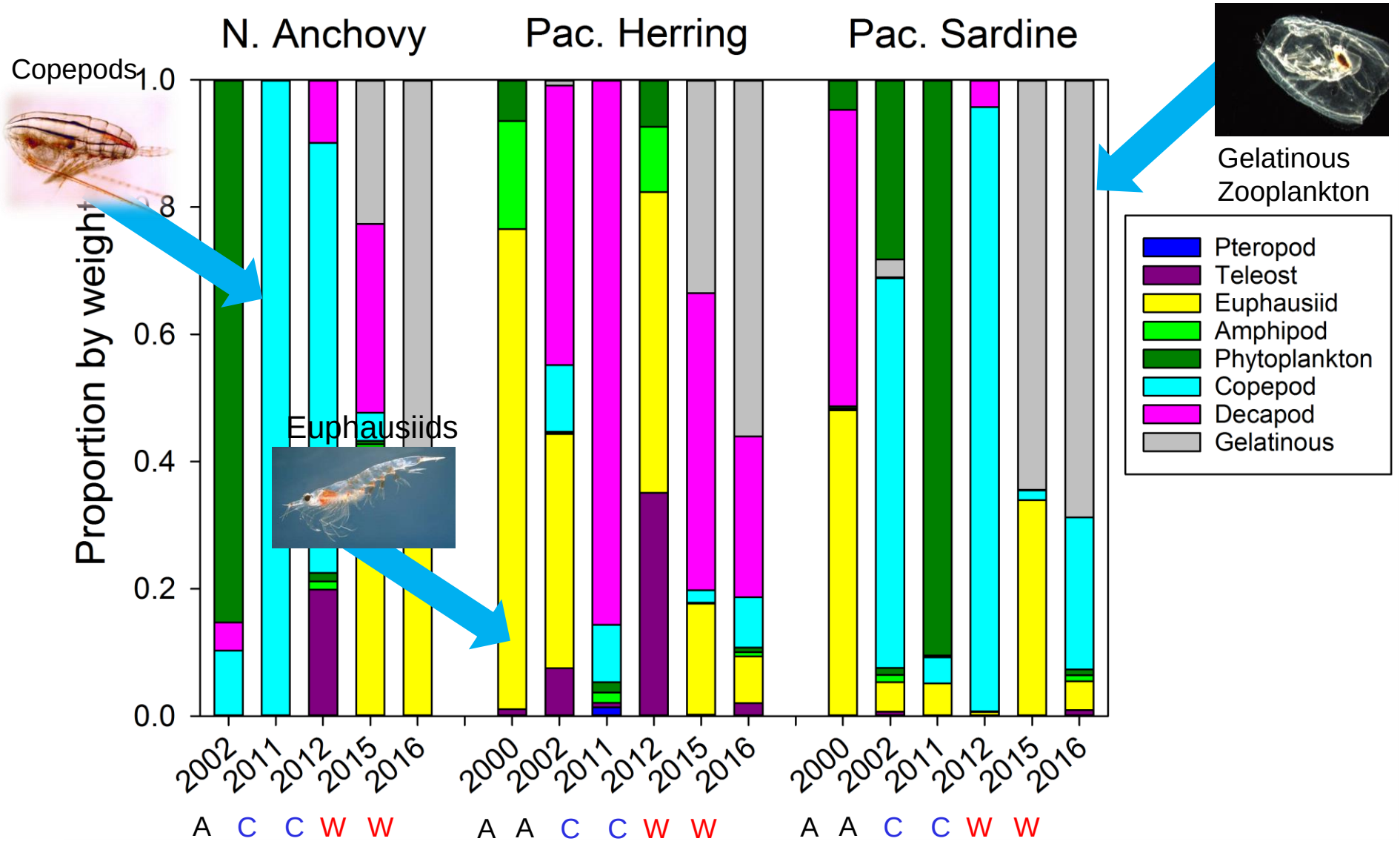
Surf smelt (*Hypomesus pretiosus*)

Jack mackerel (*Trachurus symmetricus*)



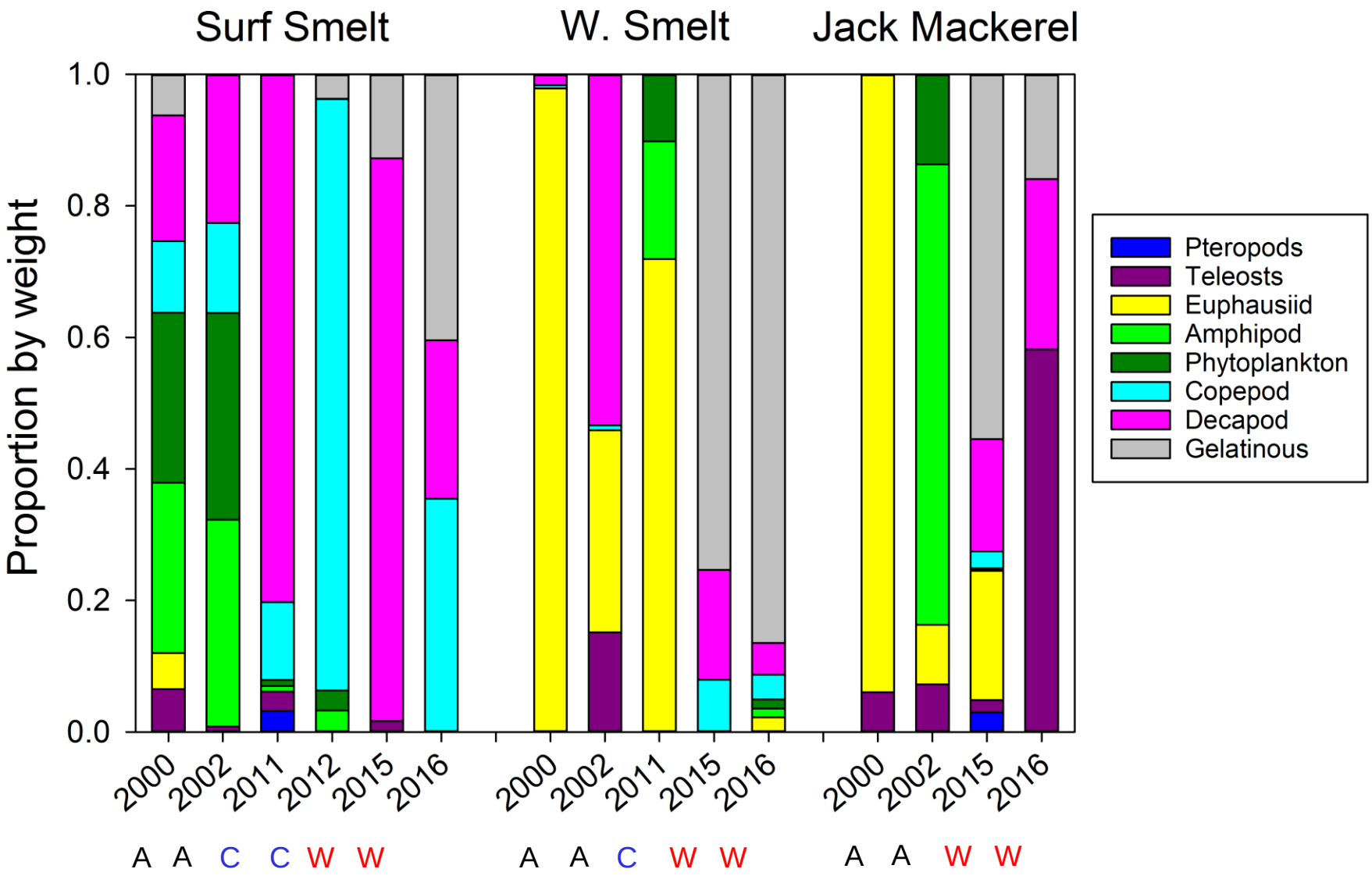
Whitebait smelt (*Allosmerus elongatus*)

Diet composition in June by weight



Brodeur et al. (2019) *Marine Ecology Progress Series*

Diet composition in June by weight



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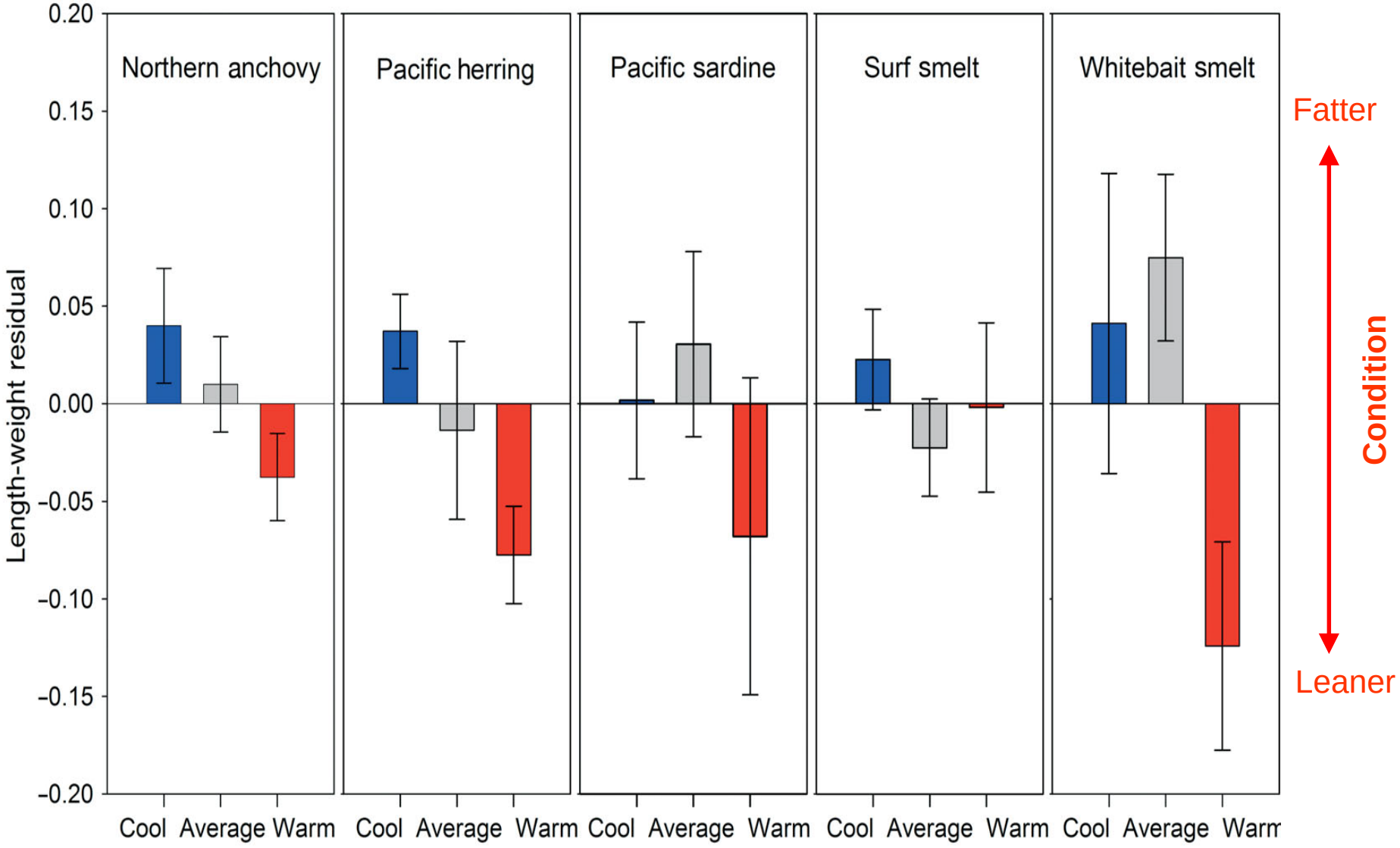
Brodeur et al. (2019) *Marine Ecology Progress Series*

Forage Fish Condition Between Ocean Regimes



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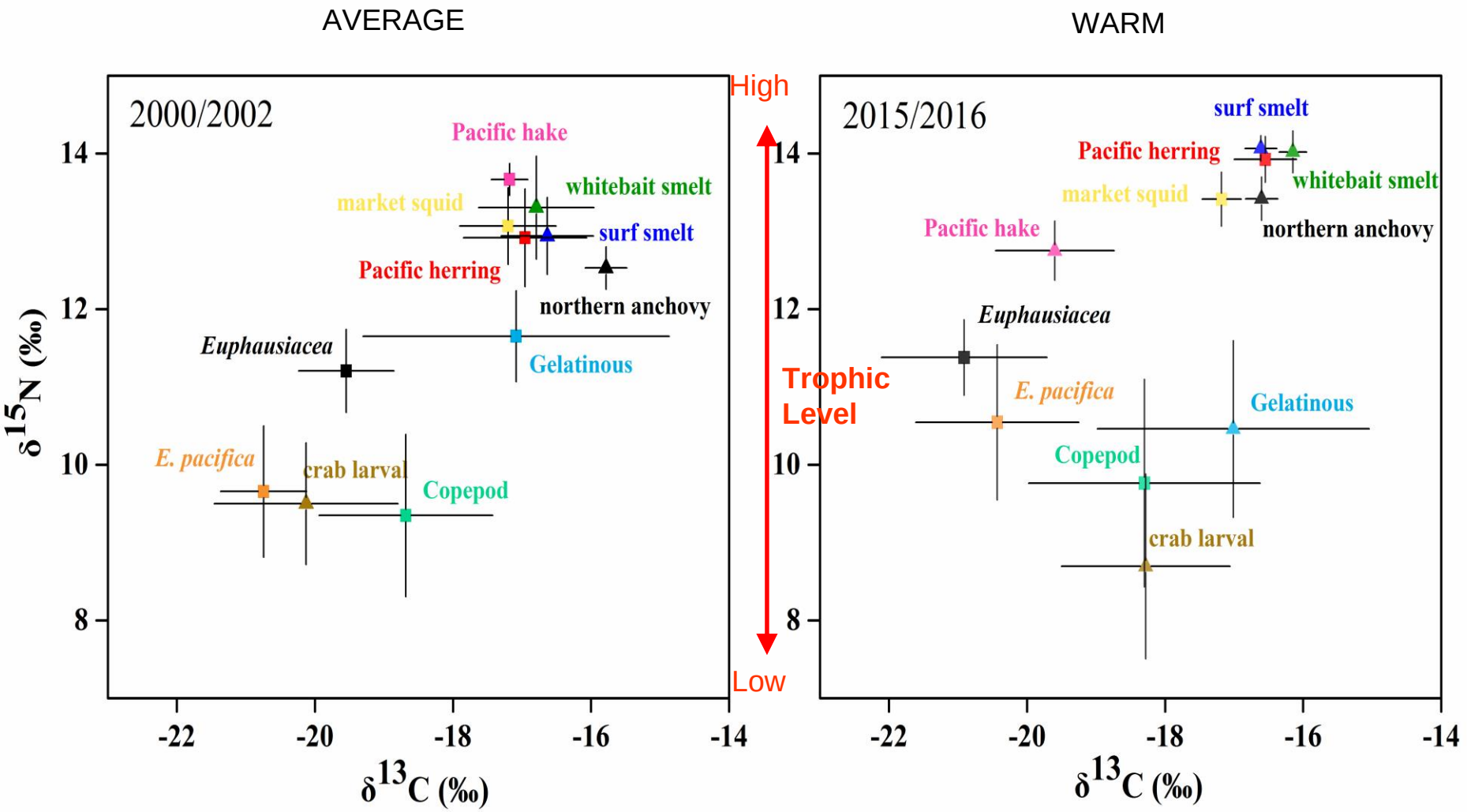
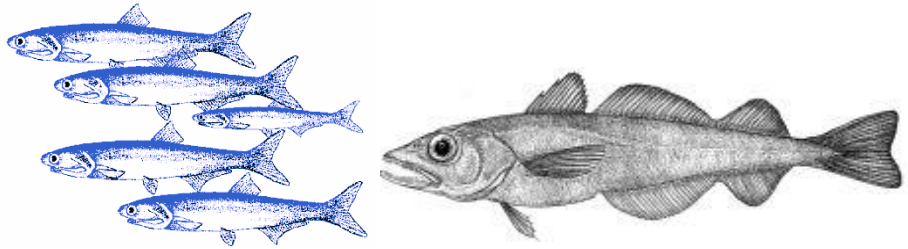
Brodeur et al. (2019) *Marine Ecology Progress Series*



Hunsicker et al. (In prep)



Pelagic and demersal fish predators on juvenile and adult forage fishes in the Northern California Current: Spatial and Temporal Variations

Richard Brodeur[1], John Buchanan[1], and Robert Emmett[2]

[1]Northwest Fisheries Science Center, NOAA Fisheries, Newport, OR

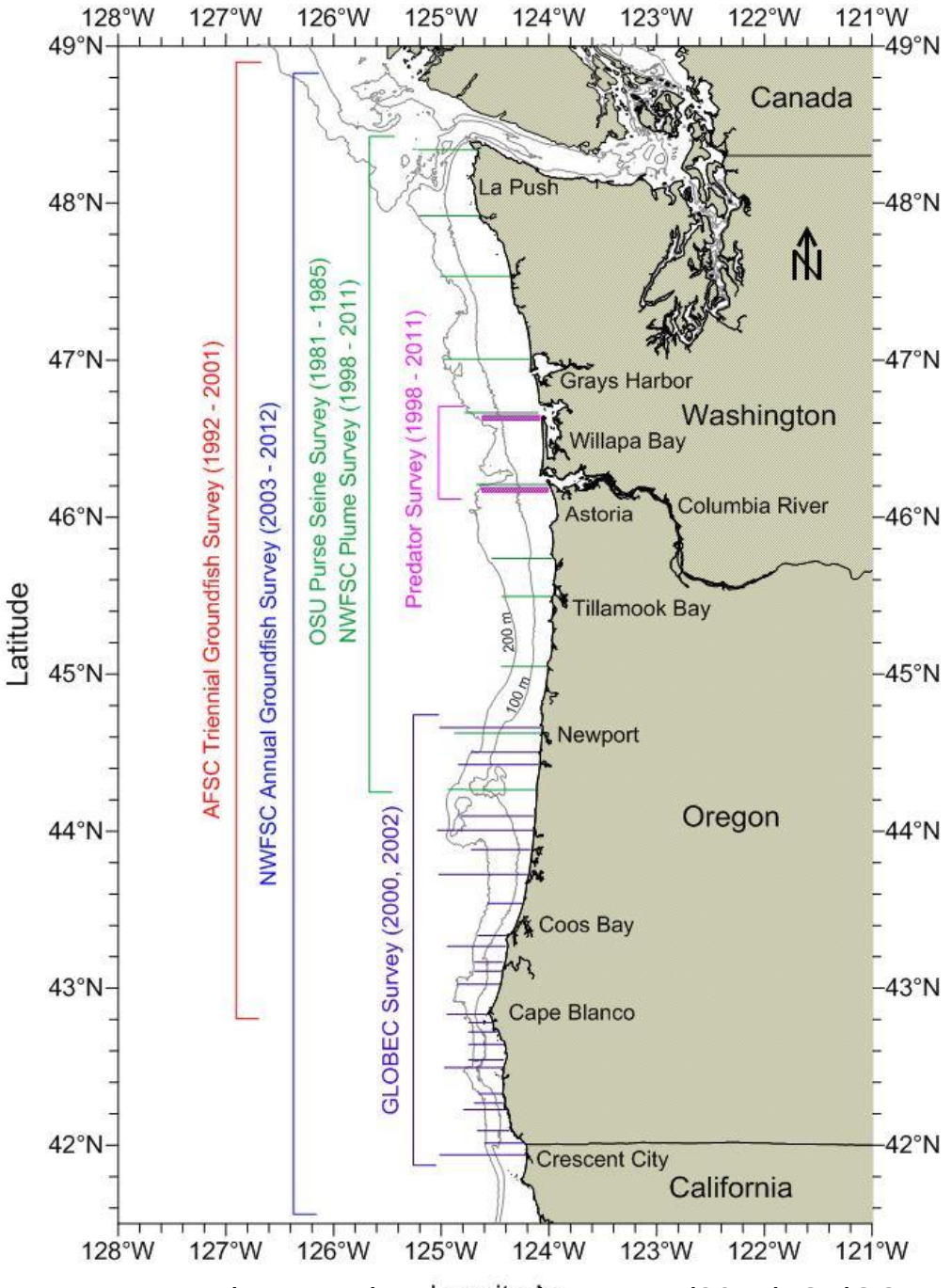
[2]Northwest Fisheries Science Center, NOAA Fisheries, Hammond, OR

CalCOFI Reports 2014

Methods

Conducted literature survey of diet studies along the coast of Washington, Oregon, and northern California.

- Multispecies surveys of diets
- Studies on individual species or related species in small geographic area
- Published and unpublished studies (theses)
- Potential pelagic, midwater, and demersal fish predators
- Summarized forage prey by percent of total weight in diet



Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

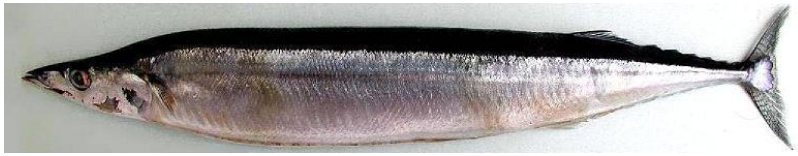
Forage Fishes Examined

Pacific herring (*Clupea pallasii*)

Pacific sardine (*Sardinops sagax*)

Northern anchovy (*Engraulis mordax*)

Smelt (Osmeridae)



Pacific saury (*Cololabis saira*)

Juvenile hake (*Merluccius productus*)

Juvenile rockfish (*Sebastes* spp.)

Predator Fishes Examined

Elasmobranchs

- Spiny dogfish
- Blue shark
- Soupfin shark

Pelagic fishes

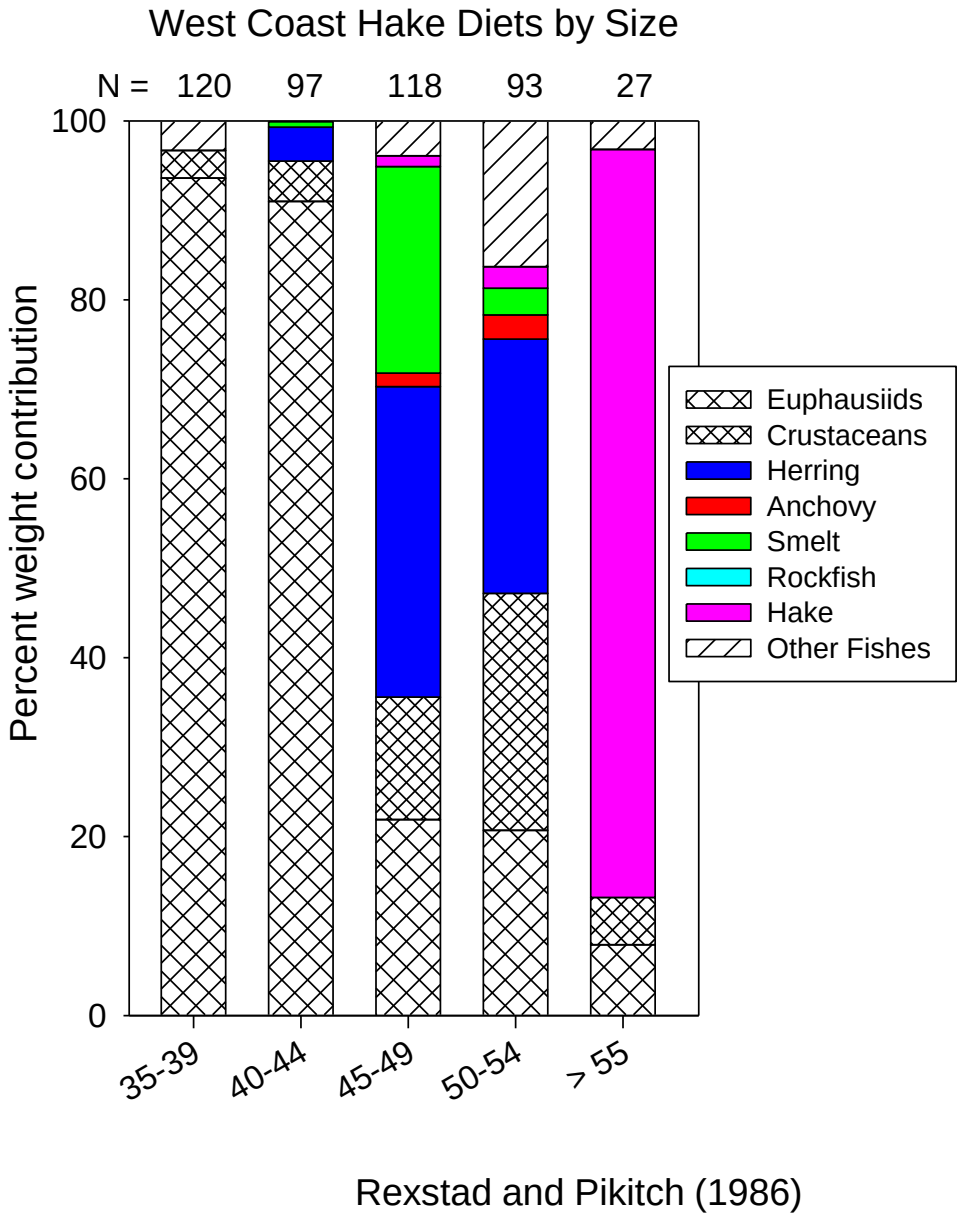
- Jack mackerel
- Pacific hake √
- Chinook salmon √
- Coho salmon
- Albacore

Demersal fishes

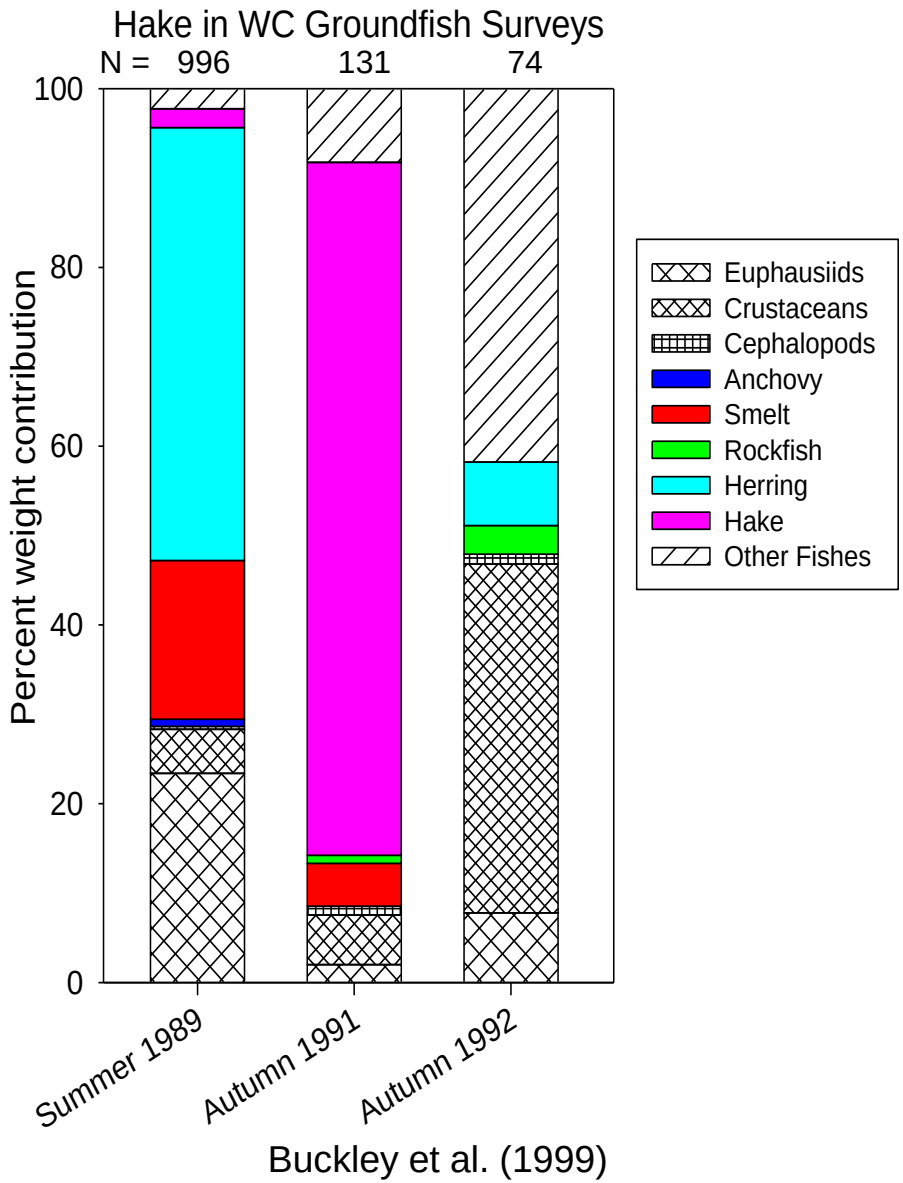
- Lingcod
- Black rockfish
- Yellowtail rockfish
- Bocaccio
- Yelloweye rockfish
- Rougheye rockfish
- Sablefish
- Pacific halibut
- Arrowtooth flounder

Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

Hake Diets from West Coast Bottom Trawl Surveys

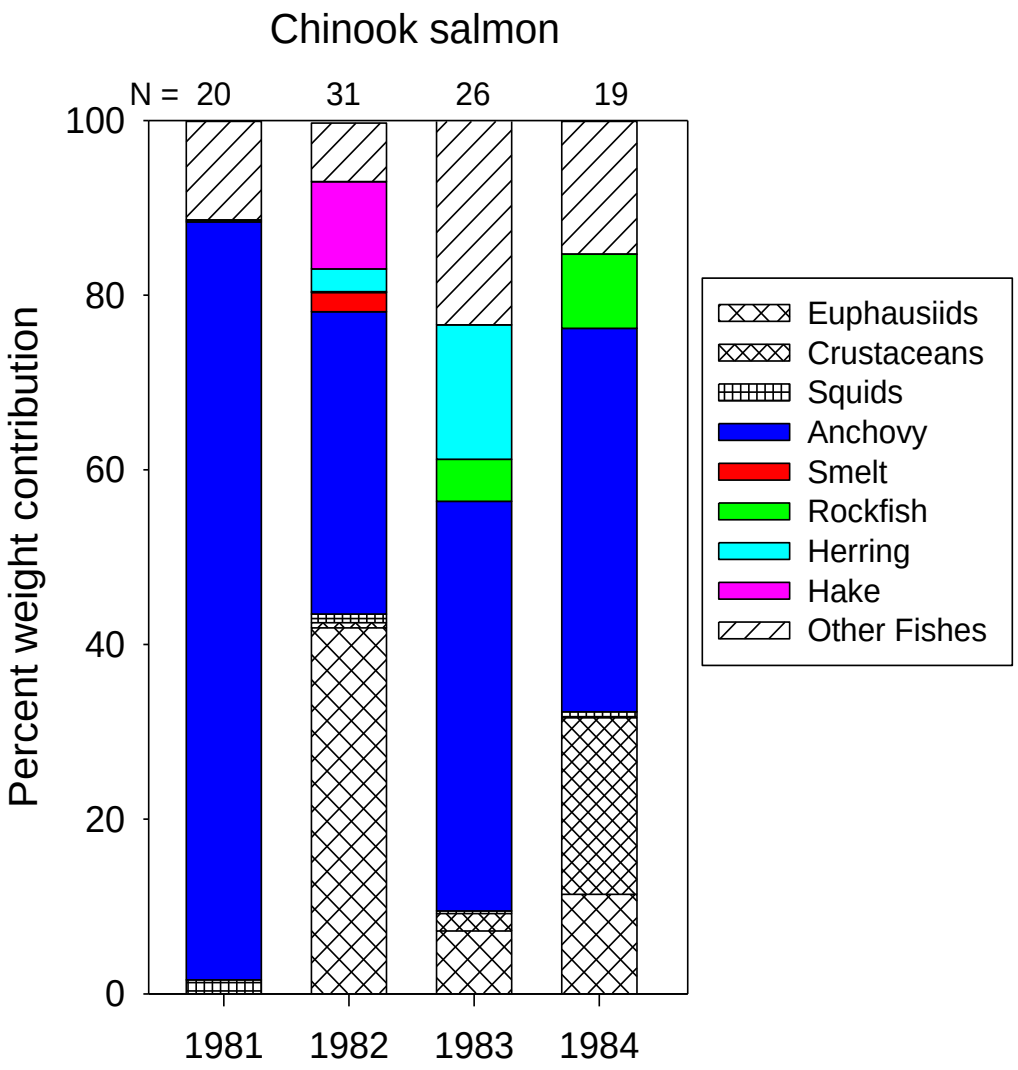


Rexstad and Pikitch (1986)

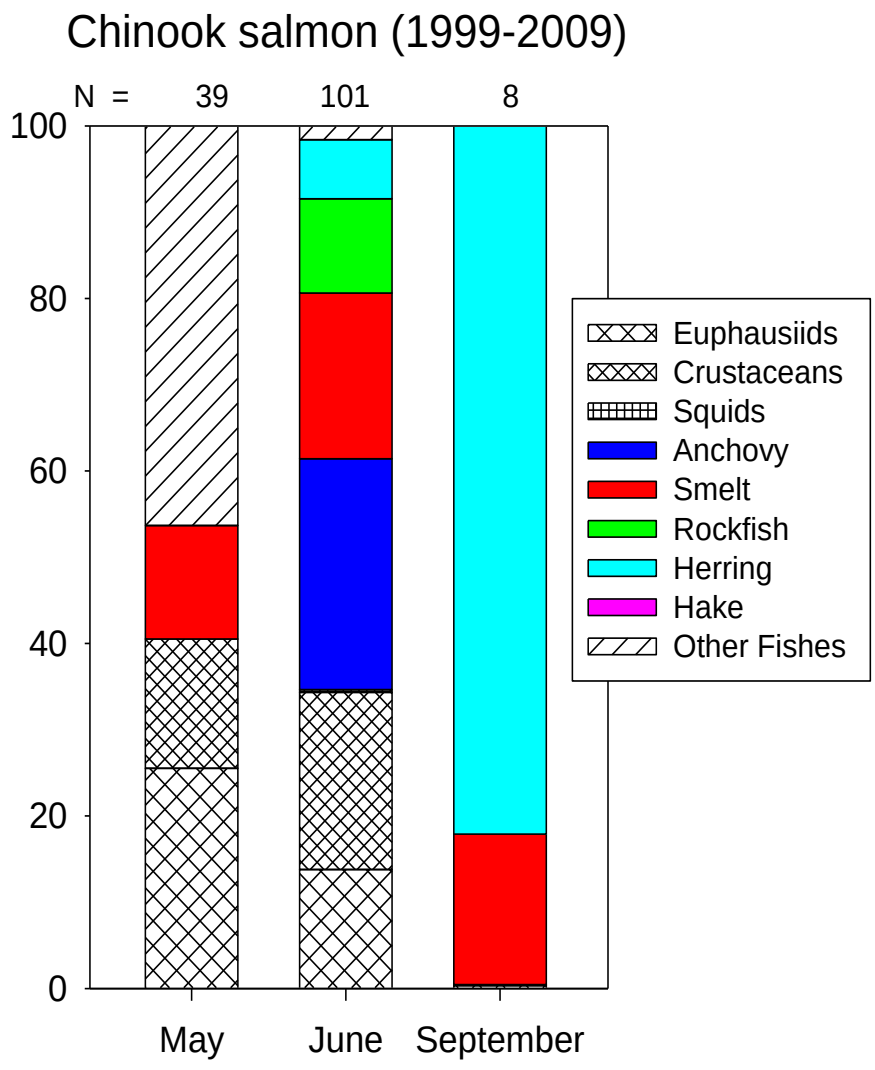


Buckley et al. (1999)

Adult Chinook Diets off Oregon and Washington

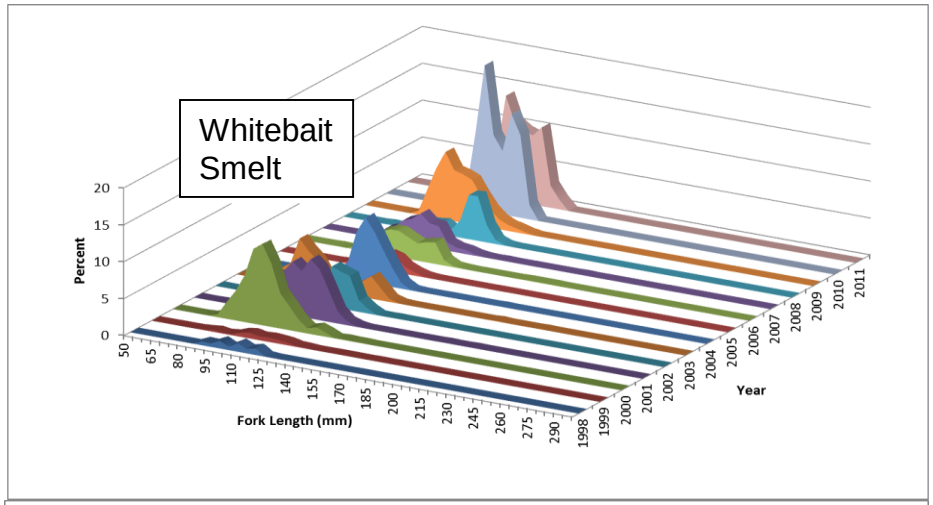


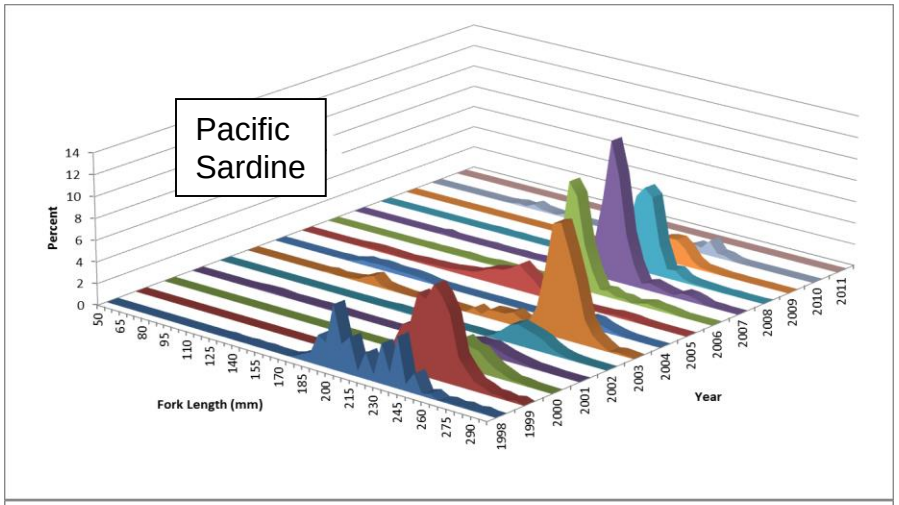
(Brodeur and Pearcy 1992)

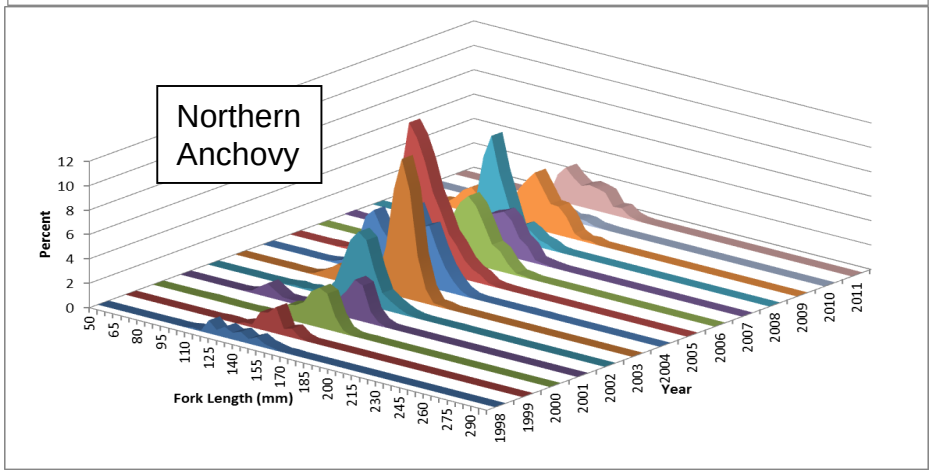


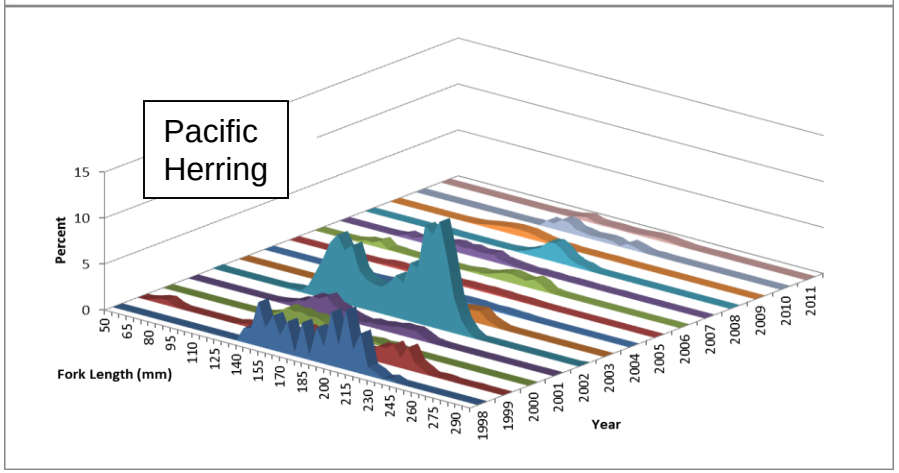
(Daly and Brodeur unpub.)

Available Forage Fish Prey Sizes from Trawl Surveys (1998-2011)







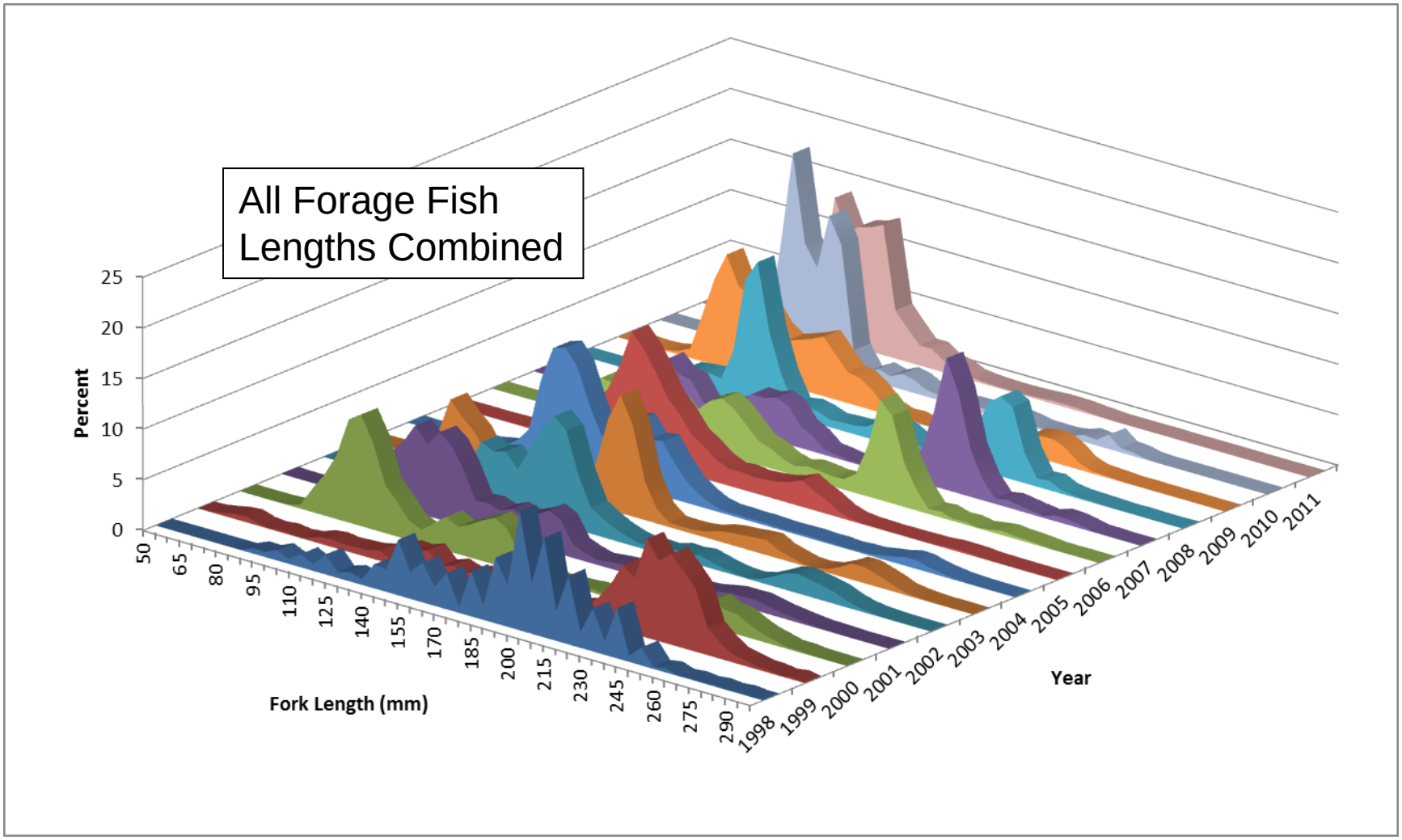


Represents > 90% of all forage fish collected in pelagic trawl surveys done off the Columbia River at night

Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

Overall Forage Fish Prey Sizes from Trawl Surveys (1998-2011)

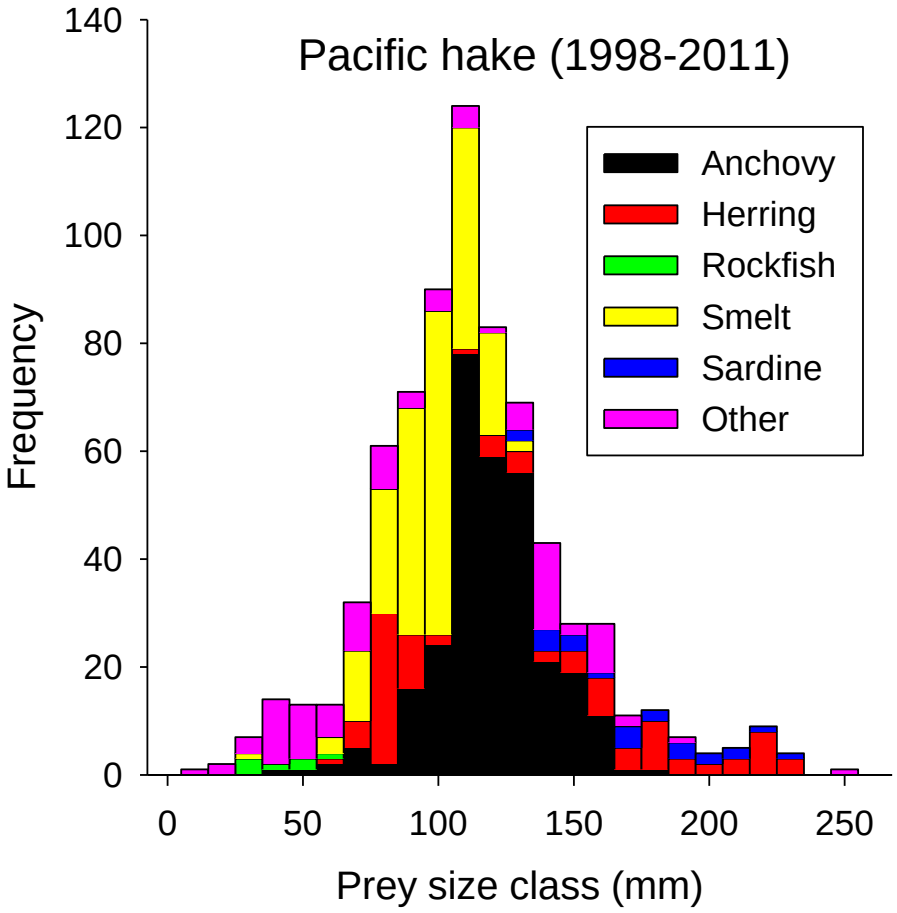
(Scaled to Relative Abundance)

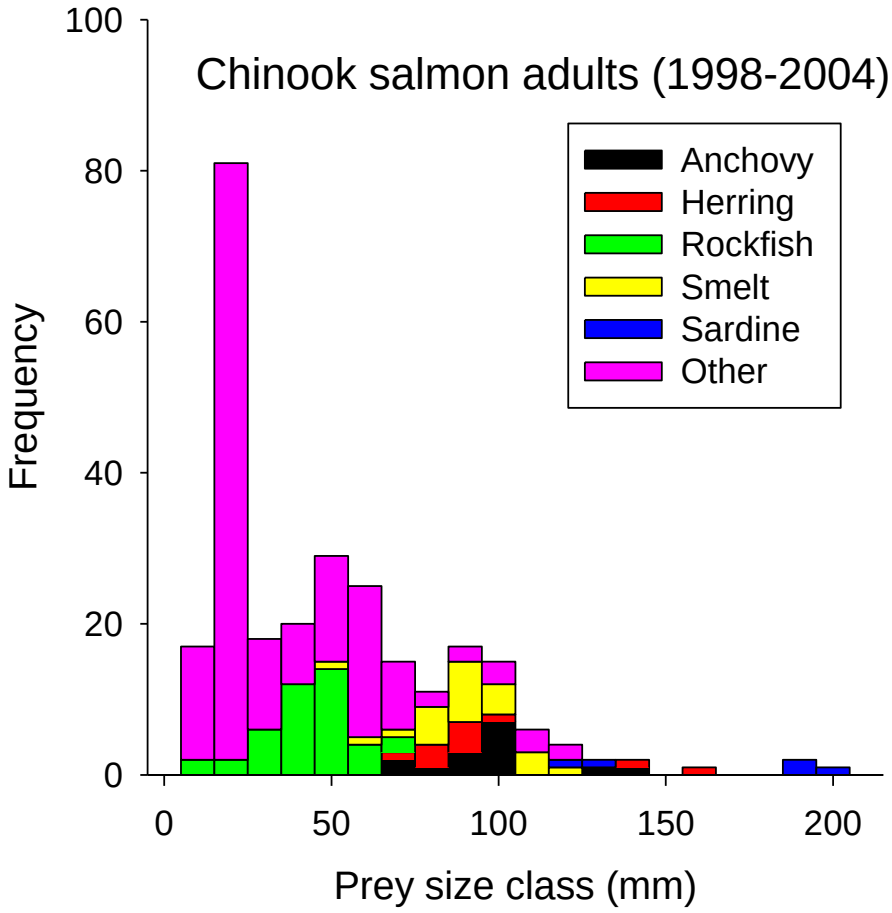


Represents > 90% of all forage fish collected in pelagic trawl surveys done off the Columbia River at night

Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

Fish Prey Sizes eaten by Pacific Hake and Chinook Salmon





Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

Ranking of Top Three Predators on Each Forage Fish

Pelagic Fishes Demersal Fishes Elasmobranchs

Based on proportion of diet made up by forage species

	Anchovy	Sardines	Herring	Smelt unid.	Hake juv.	Rockfish juv.
1	Albacore	Chinook	Boccacio	Black rockfish	Arrowtooth	Sablefish
2	Coho	Spiny dogfish	Spiny dogfish	Chinook	Soupfin shark	Yelloweye
3	Jack mackerel	Soupfin shark	Chinook	Yelloweye	Halibut	Halibut

Proportion of diet scaled to total biomass in NCC

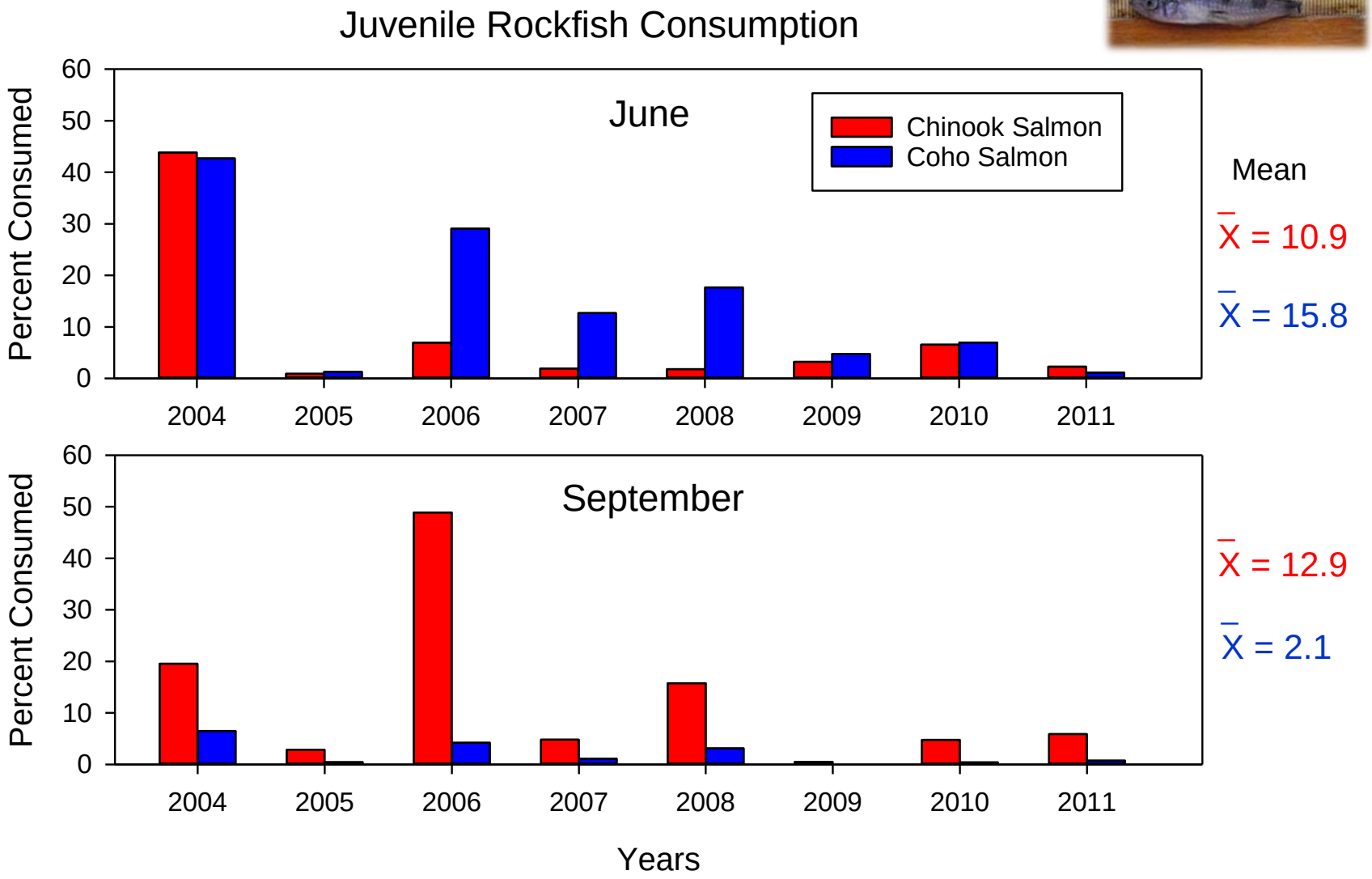
	Anchovy	Sardines	Herring	Smelt unid.	Hake juv.	Rockfish juv.
1	Albacore	Hake	Hake	Hake	Hake	Sablefish
2	Jack mackerel	Spiny dogfish	Spiny dogfish	Black rockfish	Spiny dogfish	Hake
3	Spiny dogfish	Albacore	Jack mackerel	Lingcod	Albacore	Jack mackerel

Brodeur, Buchanan, and Emmett (2014) *CalCOFI Rep*.

Data Required to Estimate Salmon Forage Fish Consumption

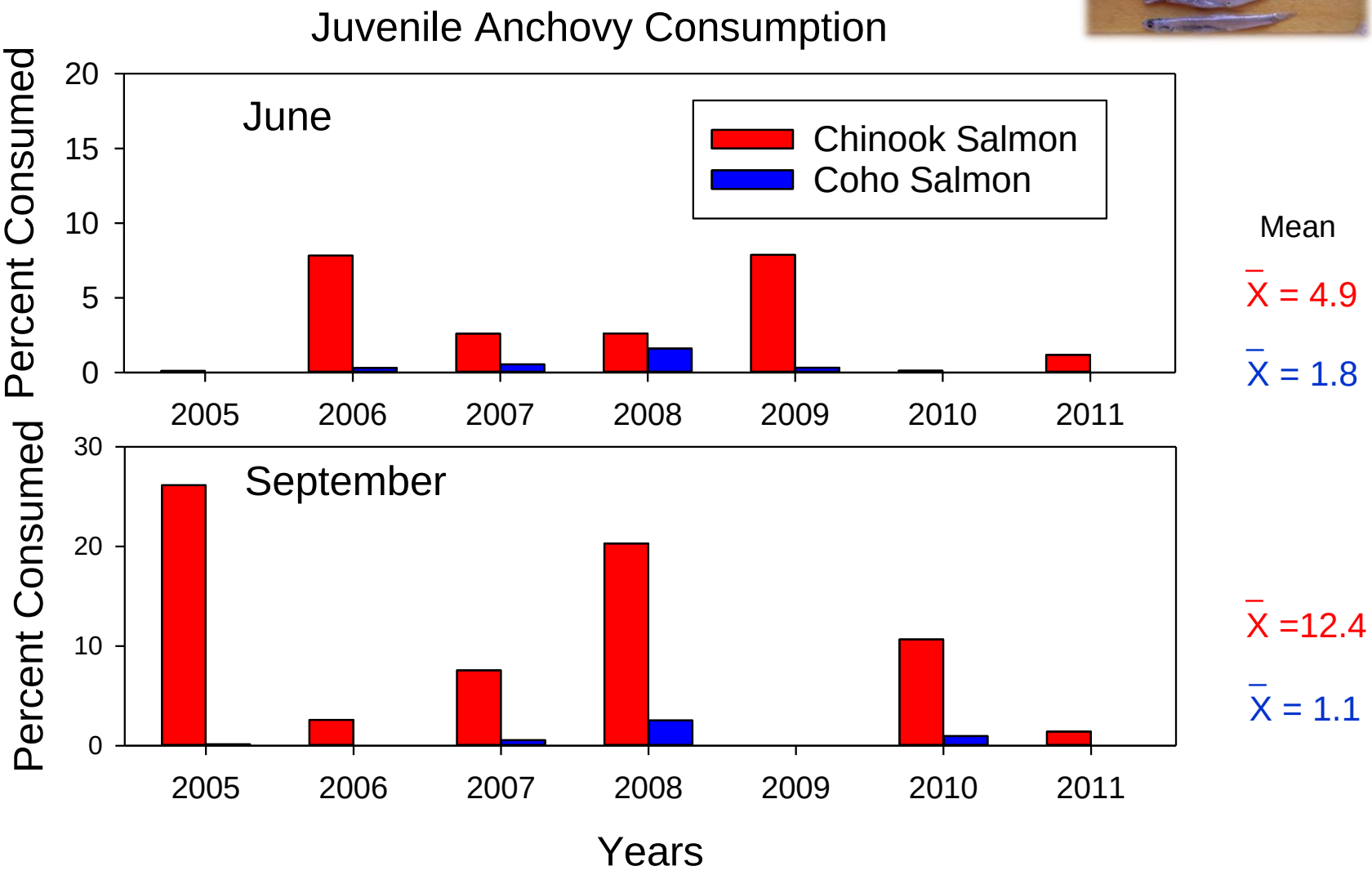
- Salmon diet analysis: annual time series of prey types consumed from BPA seasonal surveys for Chinook and Coho, 2004-2011.
- Salmon abundance: annual time series of abundance for 3 months from BPA seasonal Salmon Surveys, 2004-2011.
- Prey abundance: annual time series of late larval/juvenile rockfish and anchovies abundance per tow from NMFS Juvenile Surveys, 2004-2011.
- Individual consumption estimates: annual (2004-2011) time series of bioenergetic model runs using prey abundance, growth rates, and temperature in the upper 20 m integrated across the shelf.

Top-down effects by salmon on focal prey



Brodeur and Daly (unpub.)

Top-down effects by salmon on focal prey

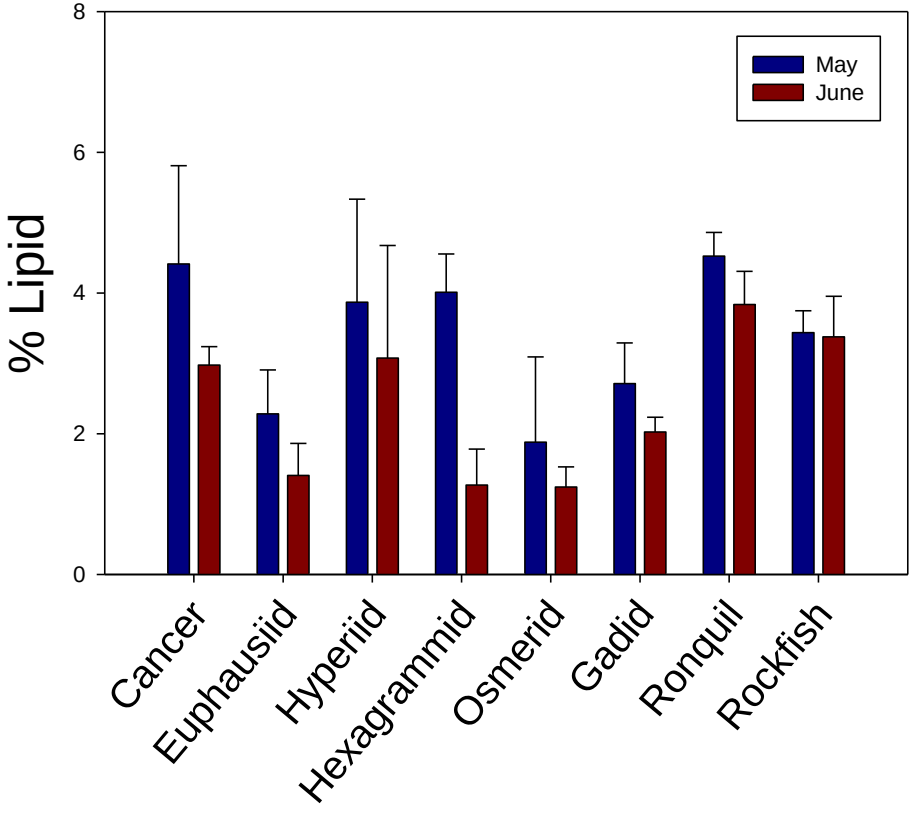


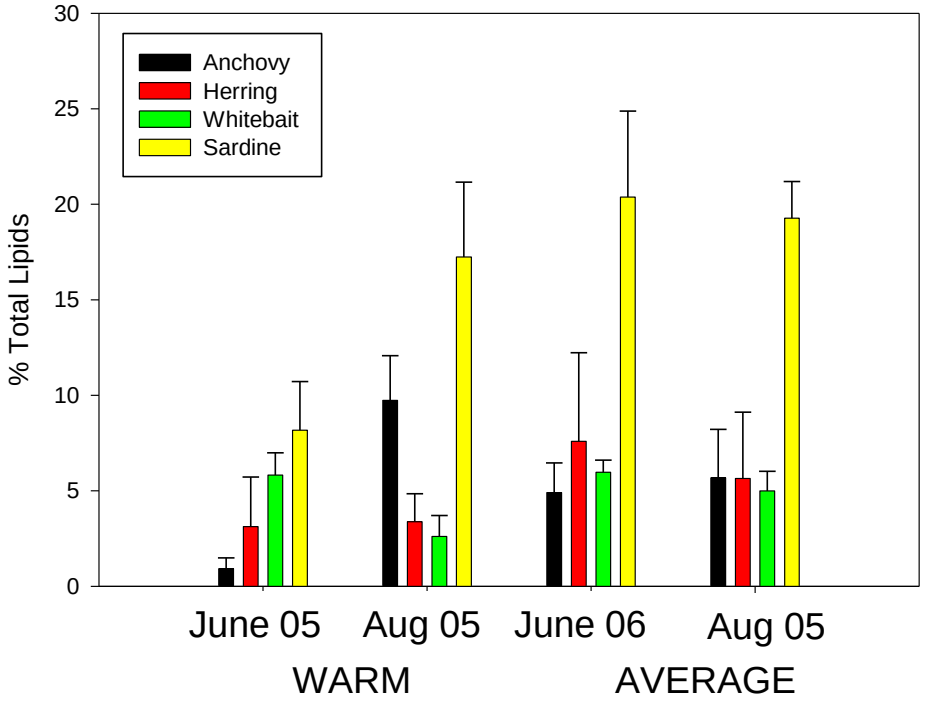
Brodeur and Daly (unpub.)

Data Gaps

- Diet information available only through ancillary collections so big data gaps in space and time (i.e., few dedicated process surveys to look at predator-prey interactions)
- Little sampling outside of summer season and in nearshore ecosystem
- No information on prey selectivity by predators and how that changes with prey availability
- Need more information on prey quality in terms of spatial and temporal variability

Lipid Densities Vary Between Months and Years





Marine Biology (2010) 157:1975–1987

Fatty acid profiles of juvenile salmon indicate prey selection strategies in coastal marine waters

Elizabeth A. Daly · Cassandra E. Benkwitt · Richard D. Brodeur · Marisa N. C. Litz · Louise A. Copeman

Vol. 405: 71–85, 2010
doi: 10.3354/meps08479

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Effects of variable oceanographic conditions on forage fish lipid content and fatty acid composition in the northern California Current

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