Predation impact by juvenile salmon on early life stages of northern anchovy in the eastern North Pacific Ocean

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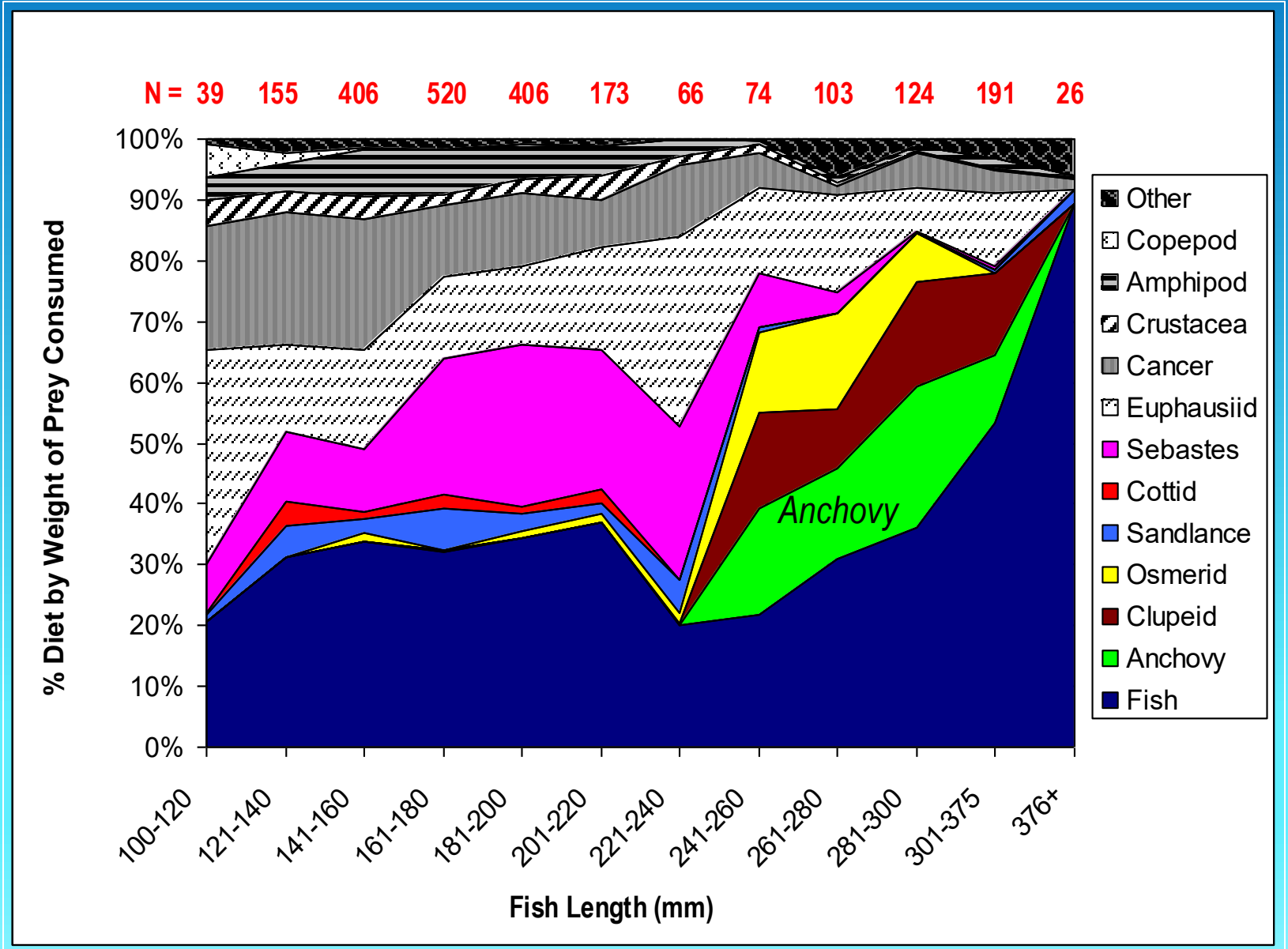
Rationale

1) Although predation is thought to be the major source of mortality for early life stages of fish, there have been few attempts to quantify levels of predation on juvenile fishes in marine systems

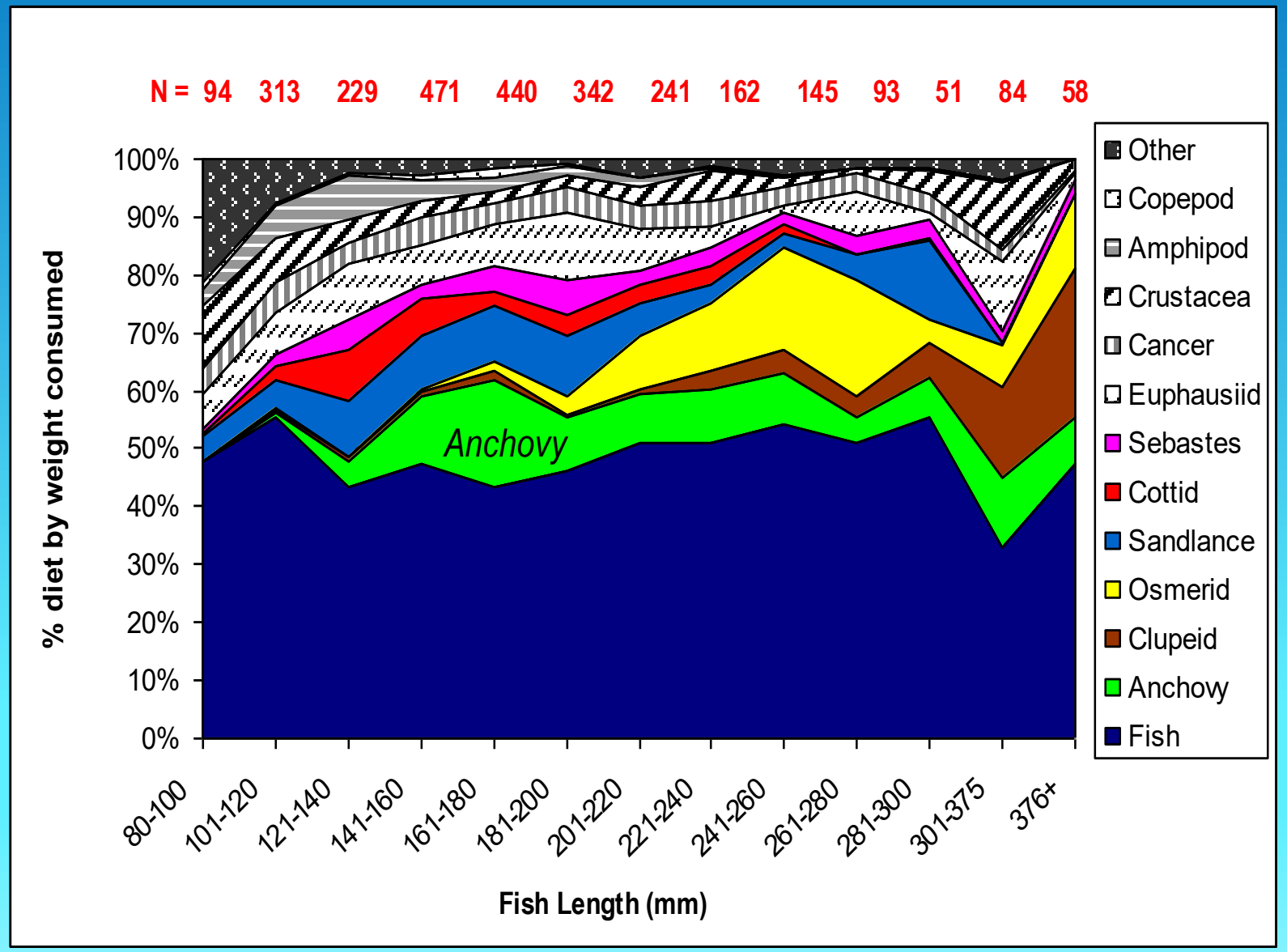
2) Surveys of the diets of pelagic marine fish such as juvenile salmon show much piscivory, with some concentrating on juvenile fish prey

Ontogenetic Change in Coho Salmon Diet

Daly et al. (2009) TAFS



Ontogenetic Change in Chinook Salmon Diet

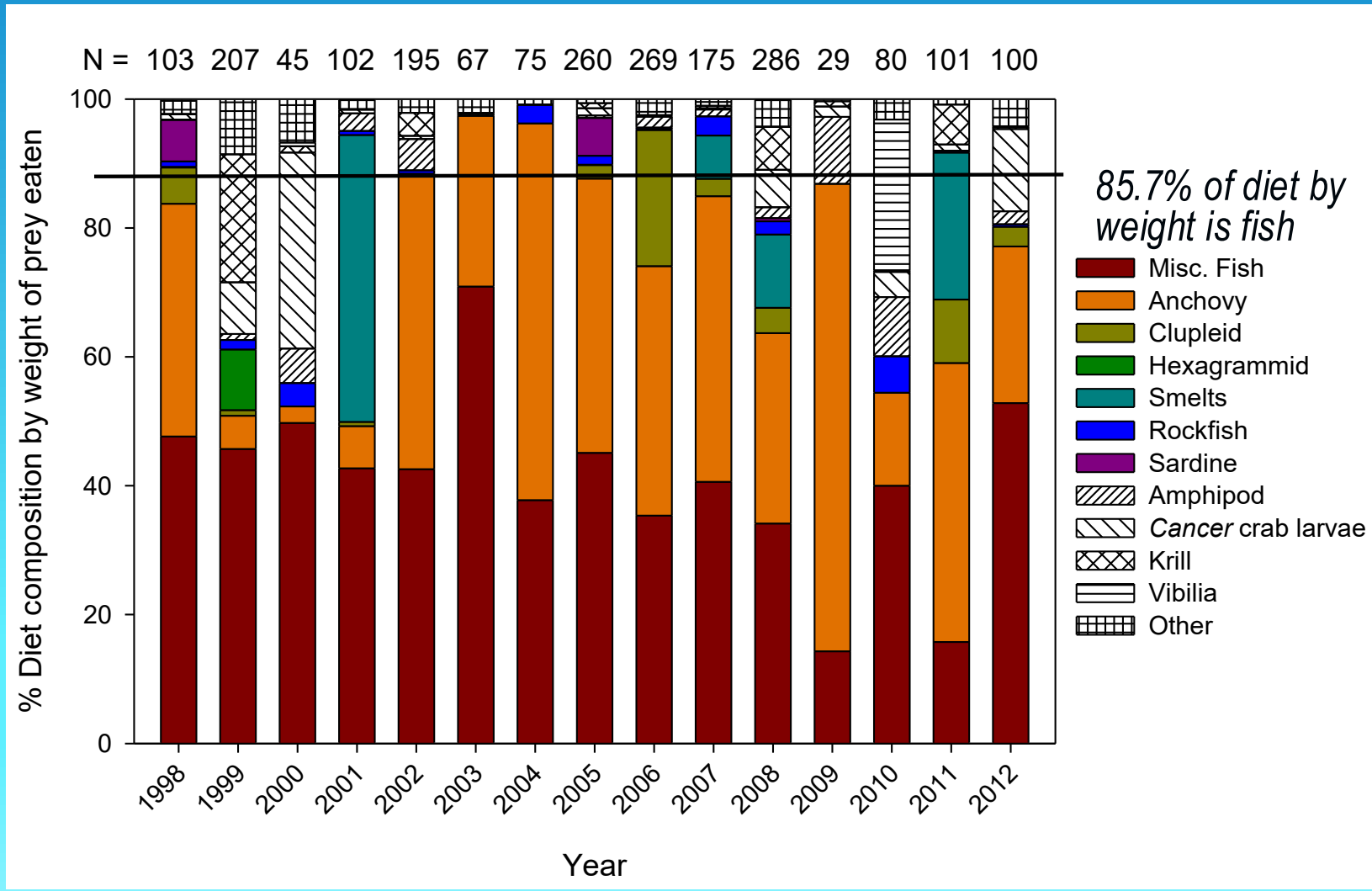


Daly et al. (2009) TAFS

Subyearling diet is dominated primarily age-zero forage fish, especially northern anchovies

Dale et al. (2017) Fish. Oceanog.

September Subyearling Chinook Salmon Diet



Objectives

The goal of this study is to examine predation by juvenile Chinook and coho salmon upon juvenile anchovy in coastal regions of the Northern California Current by examining:

1) proportions of anchovy prey in the diets of each predator by season and year and compare these to available prey anchovy from trawl sampling,

2) overall prey consumption using bioenergetics modeling and estimates of salmon and available prey present in coastal waters,

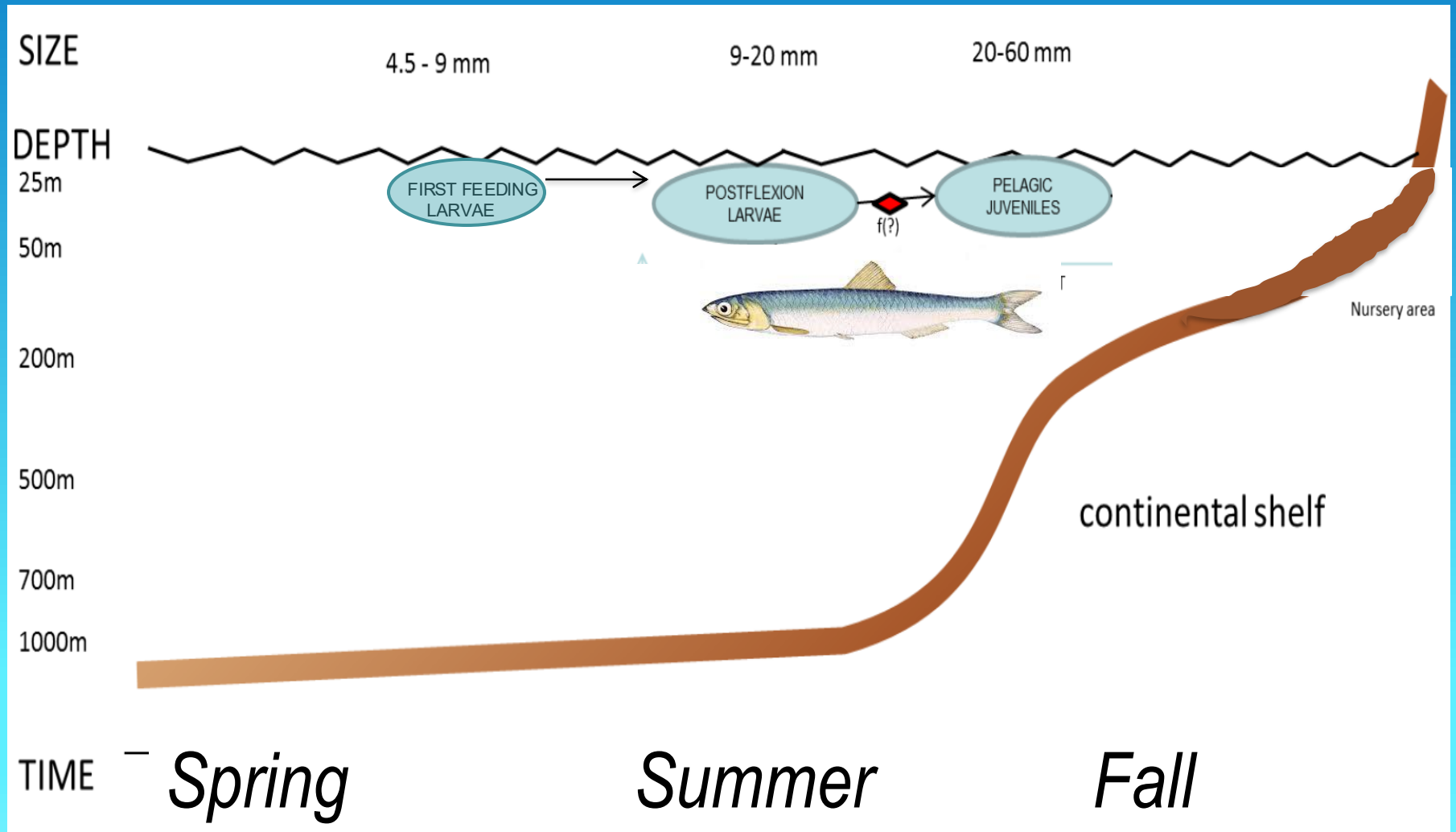
3) sizes of anchovy prey consumed compared to available sizes to examine size-selective predation.

Salmon Migration from Columbia River

The Columbia River is the major source of Coho and Chinook salmon along the US West Coast

The Columbia River Plume is the most important spawning are of the Northern Subpopulation of Northern Anchovy

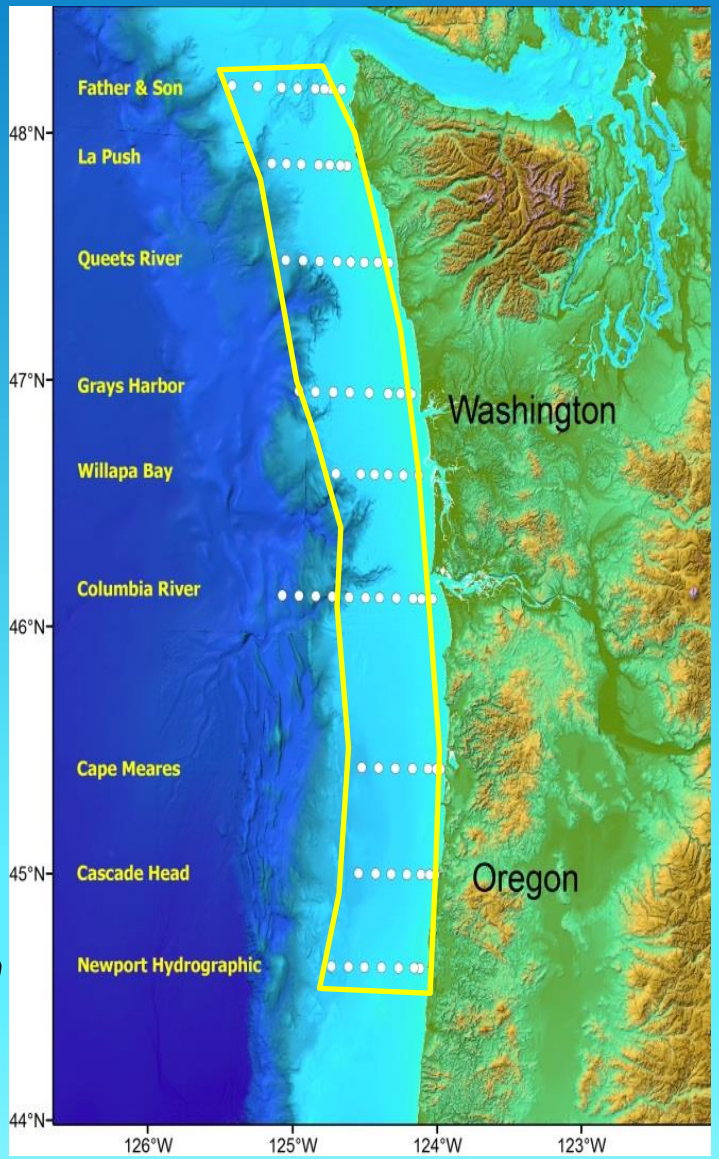
Northern Anchovy (*Engraulis mordax*)



Methods

- *Salmon collected in surface trawls at sea from May to September 2005-2011*
- *Stomachs removed in the laboratory*
- *Stomach contents identified to species, counted and weighed and length estimated for fish prey*
- *Available anchovy prey from juvenile fish surveys*

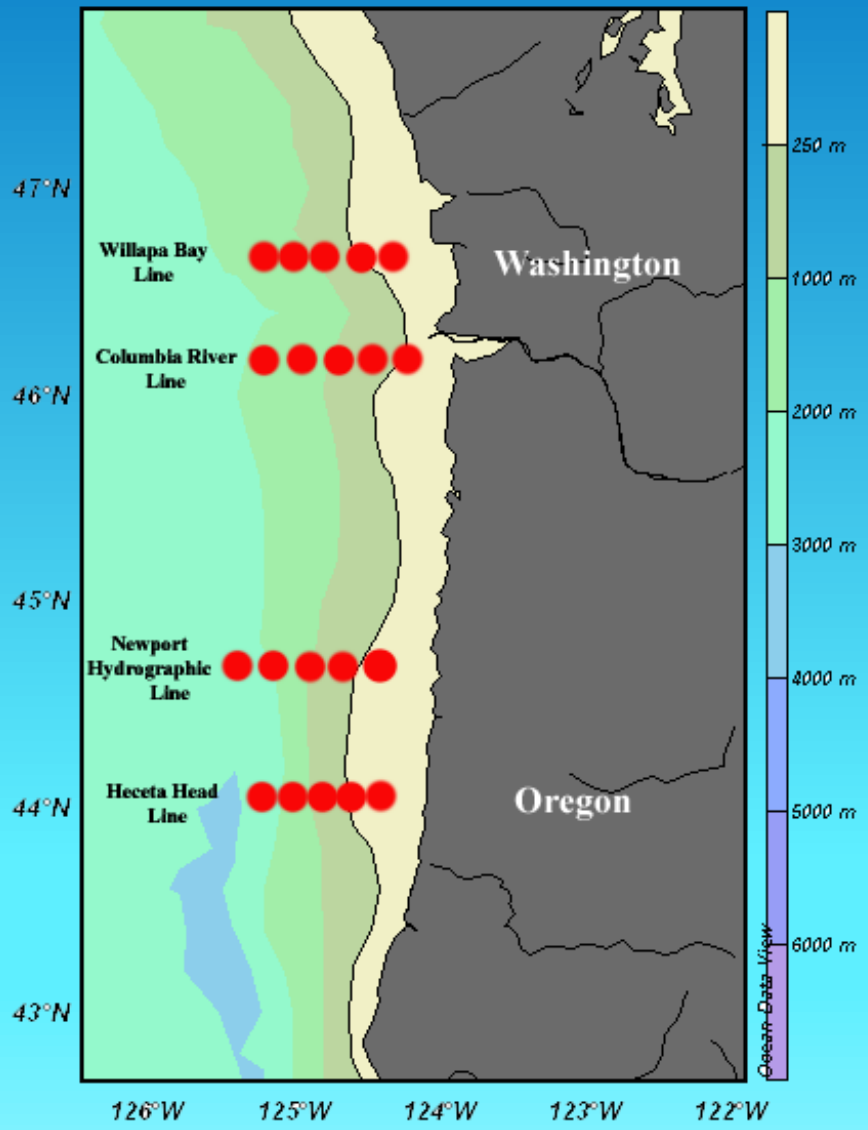
Salmon Sampling



May, June and September (n > 1000 trawls from 2005-2011)

Total Sample Area 17,846 km²

Juvenile Fish Sampling

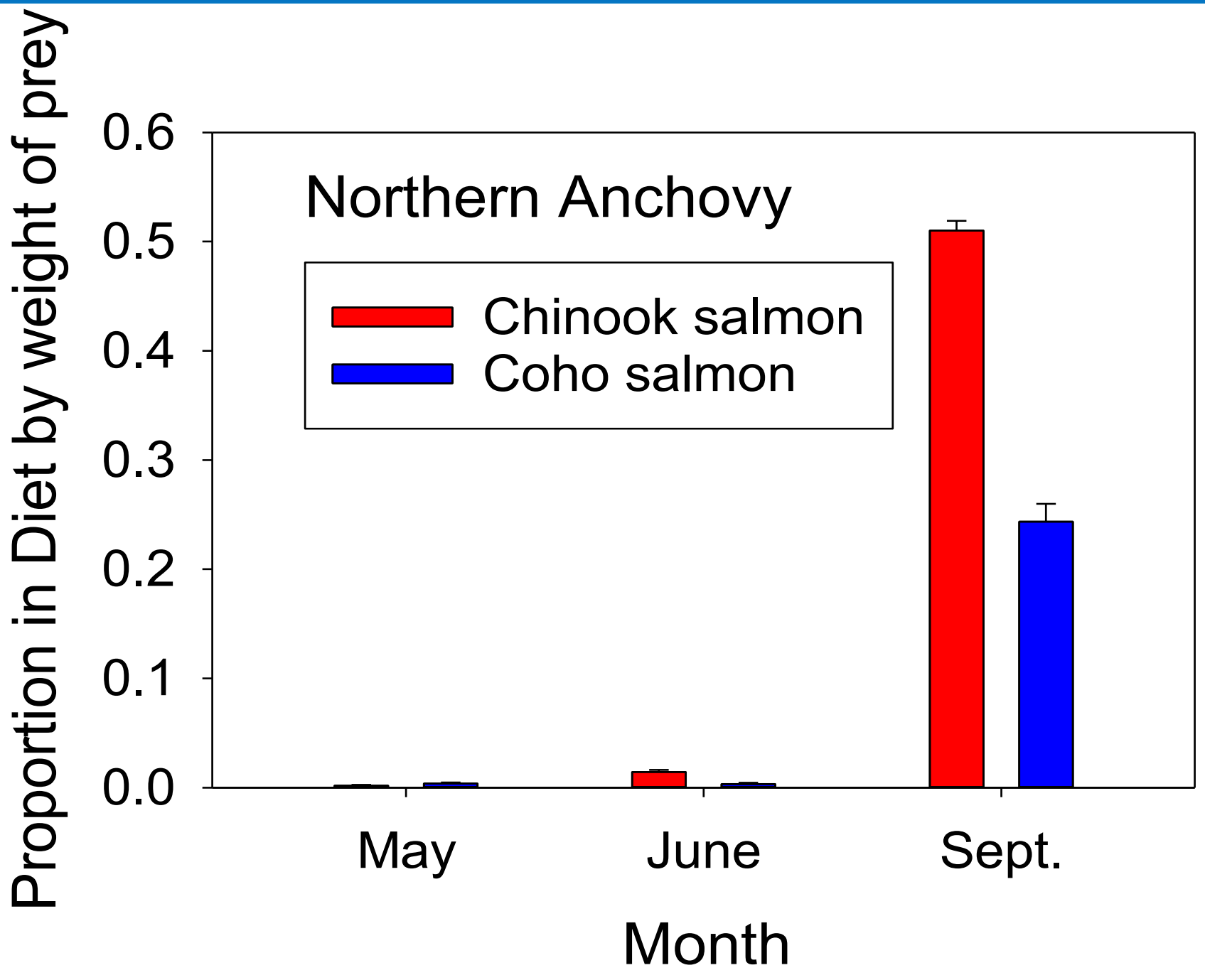


May through September (n = 585 trawls from 2005-2011)

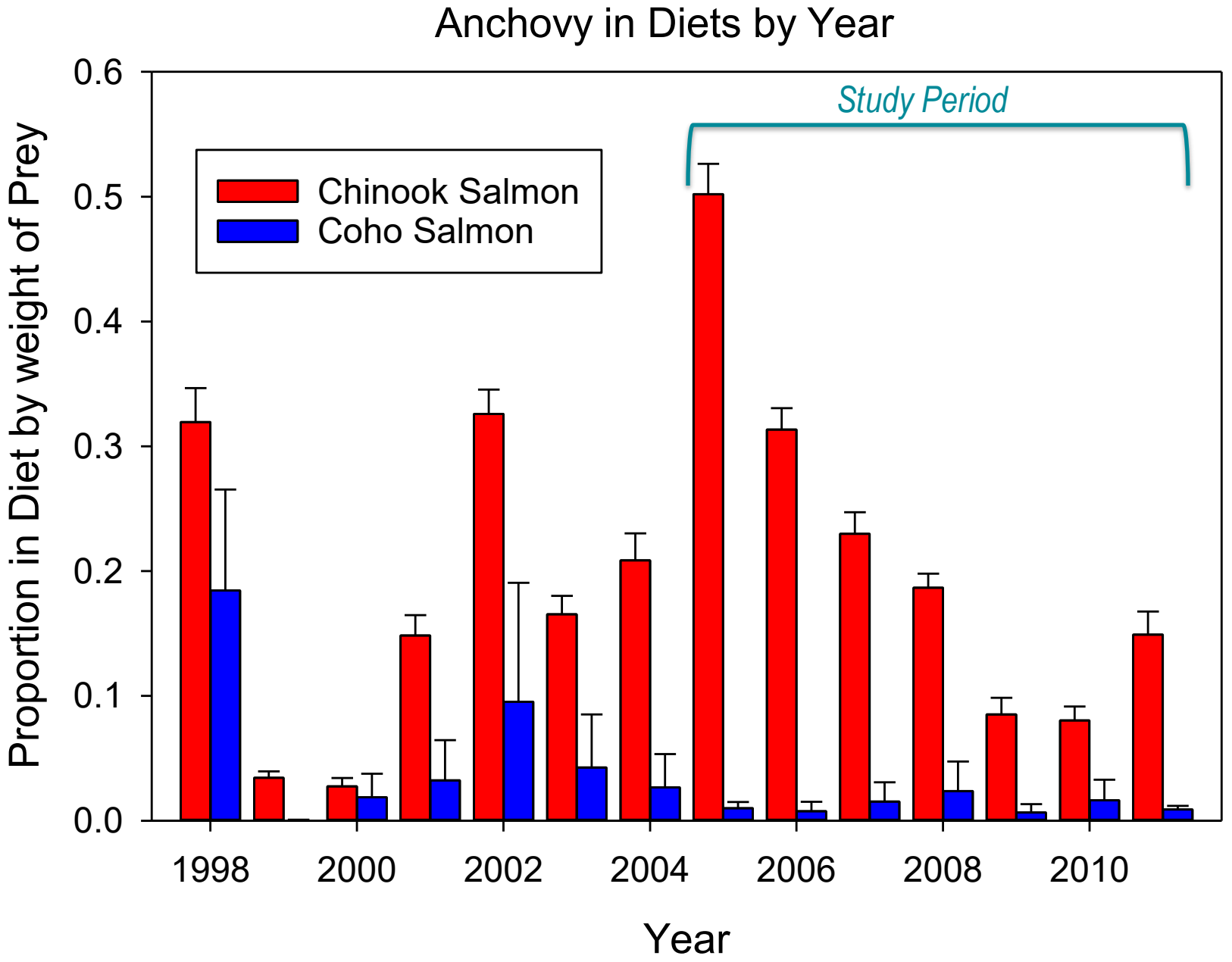
Data Required to Estimate Prey Consumption

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

Salmon diet analysis

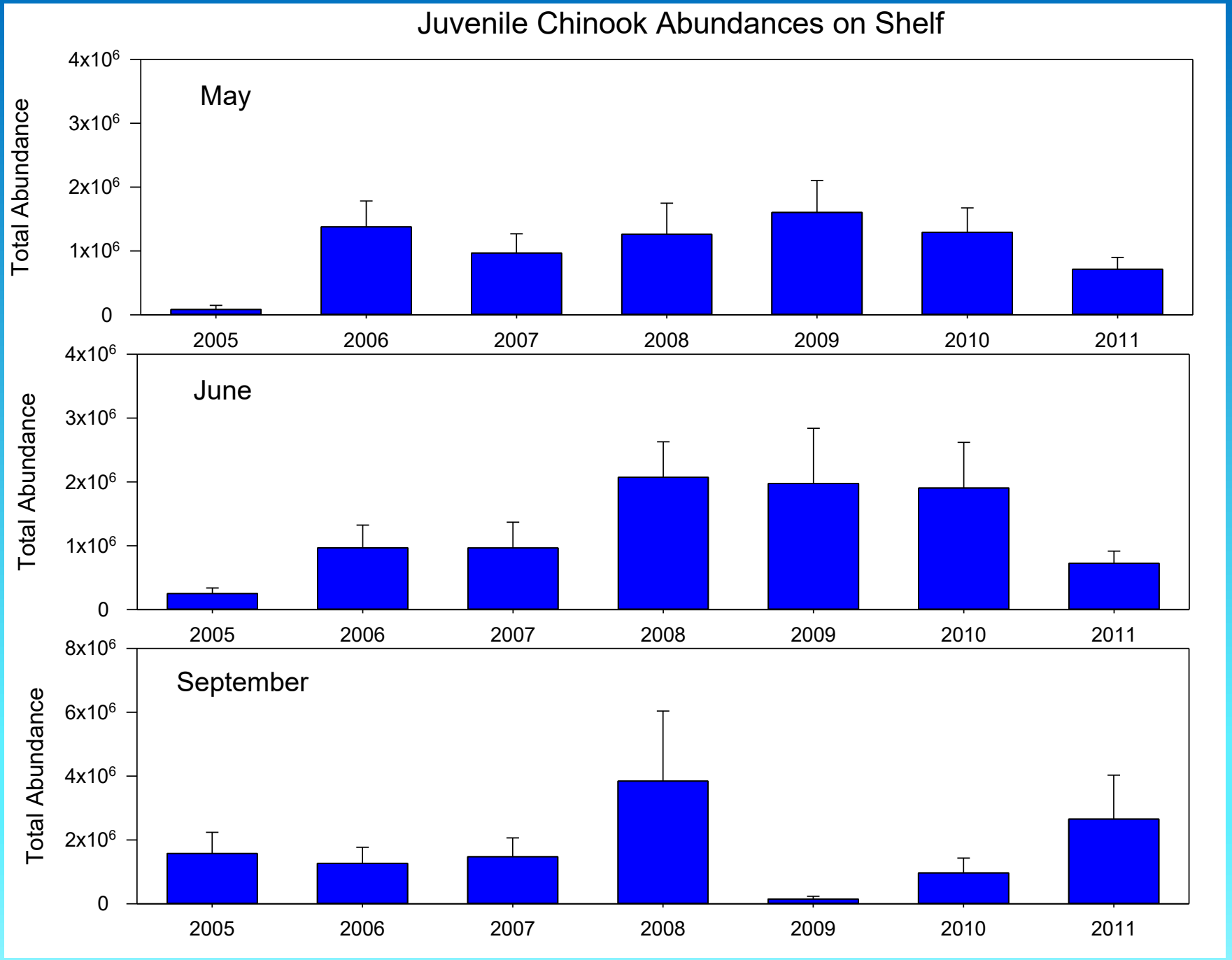


Salmon diet analysis



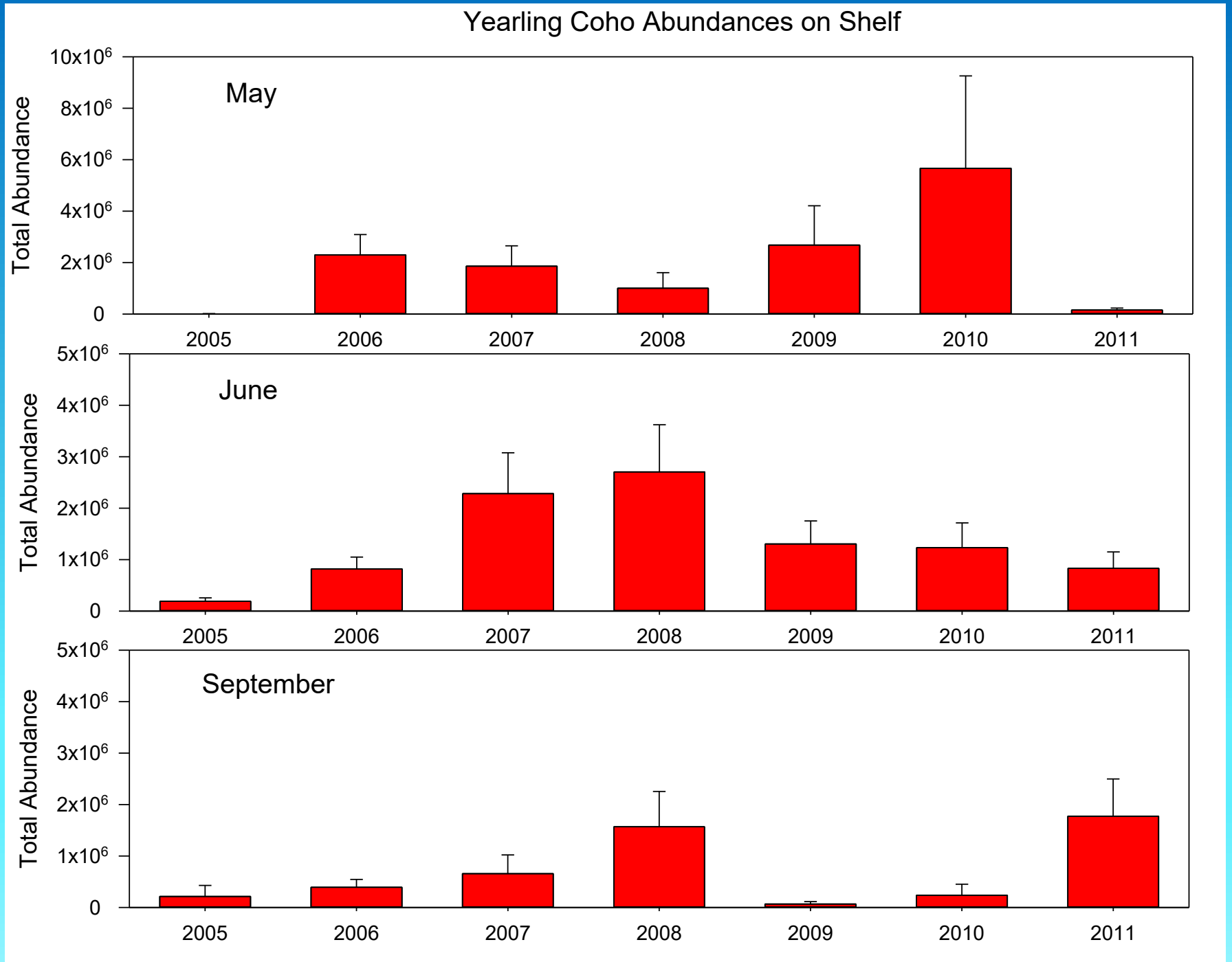
Juvenile Chinook Salmon abundance estimates by year

From Jim Ruzicka

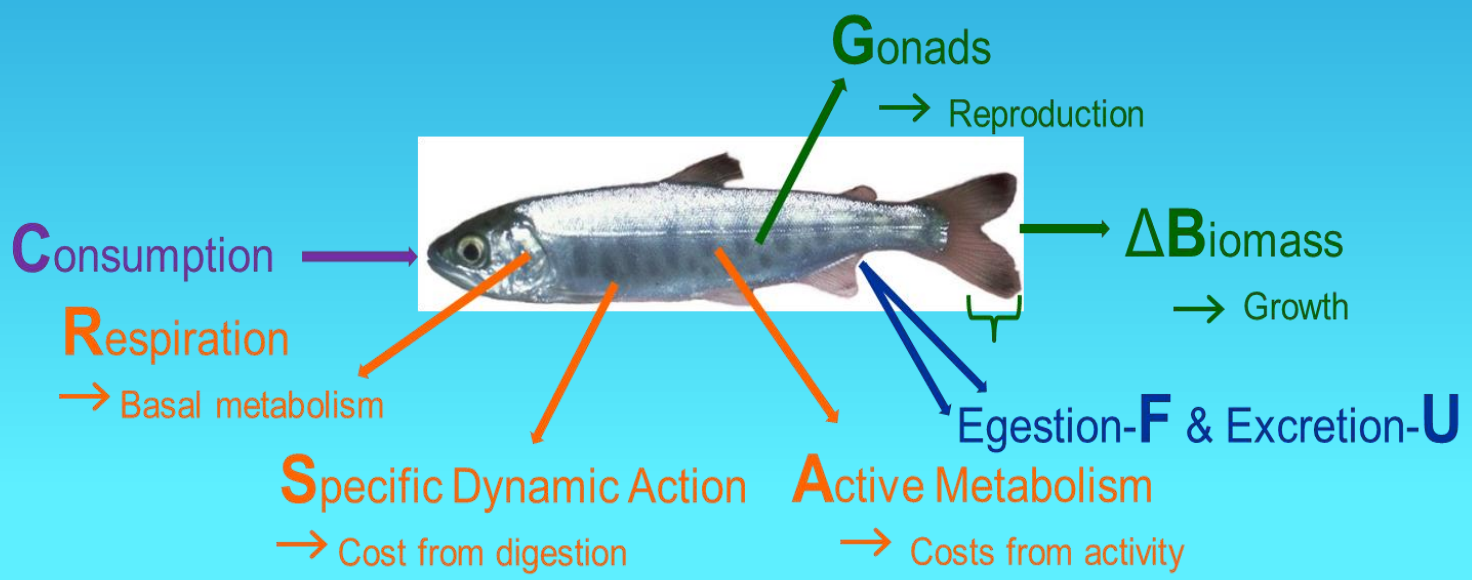


Juvenile Coho Salmon abundance Estimates

From Jim Ruzicka



Bioenergetic Modelling



Consumption:

- ✓ Prey Consumed (g)
- ✓ Diet Composition (%)
- ✓ Prey Energy Density (J g^{-1})

Growth:

- ✓ Initial Size (g)
- ✓ Change in Size (g)
- ✓ Salmon Energy Density* (J g^{-1})

Temperature:

- ✓ Daily Average (°C)

Bioenergetic Modelling Estimates

Individual consumption estimates

Used Wisconsin (V3.0) Fish Bioenergetic Model in R adjusting Chinook and Coho parameters based on recent studies

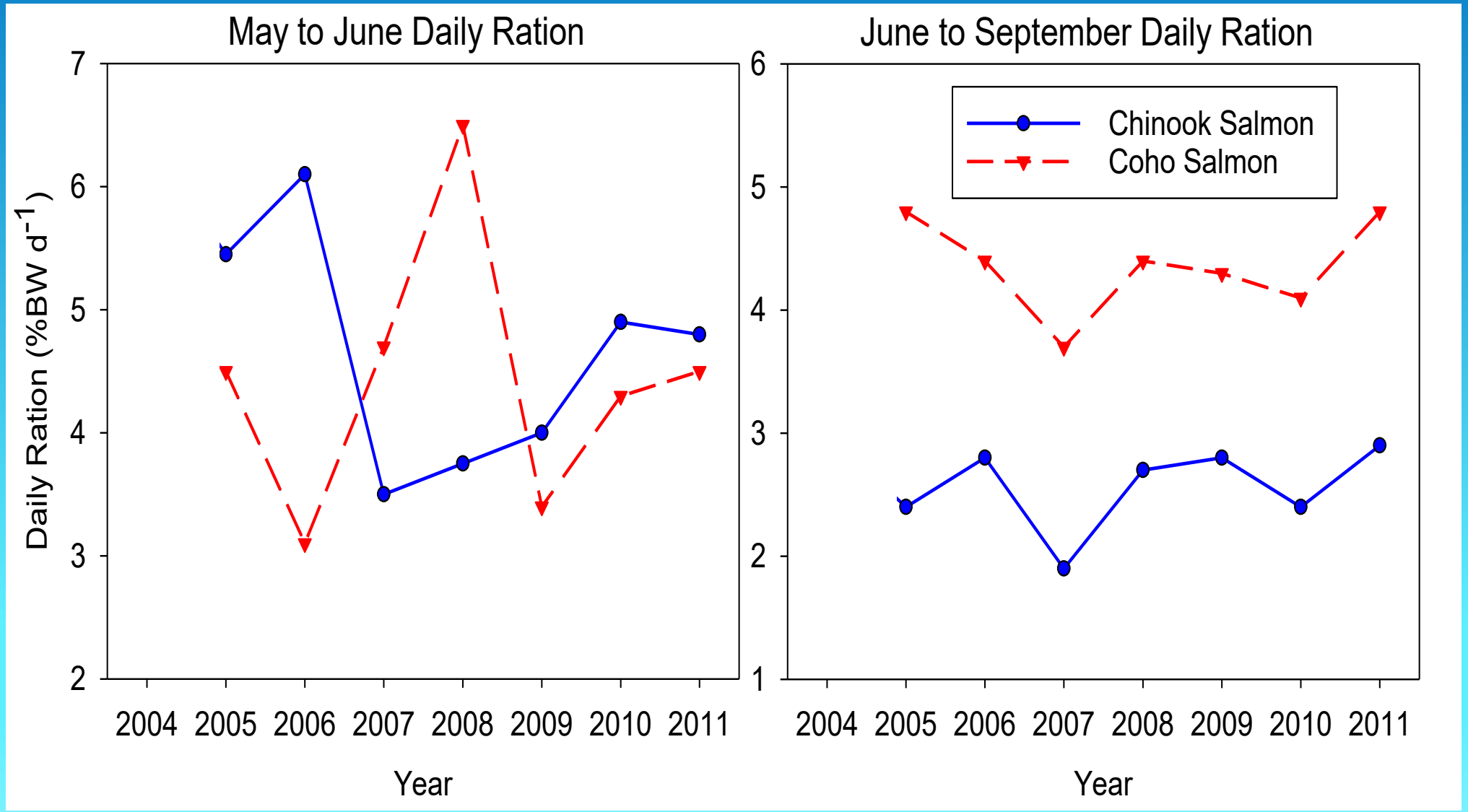
Used seasonal changes in predator weight, diet data, and mean temperature (upper 20 m) by year for May, June and September cruises from 2005-2011

Ran simulations over 30 days (May 25 to June 25) and 93 days (June 25 to Sept. 25)

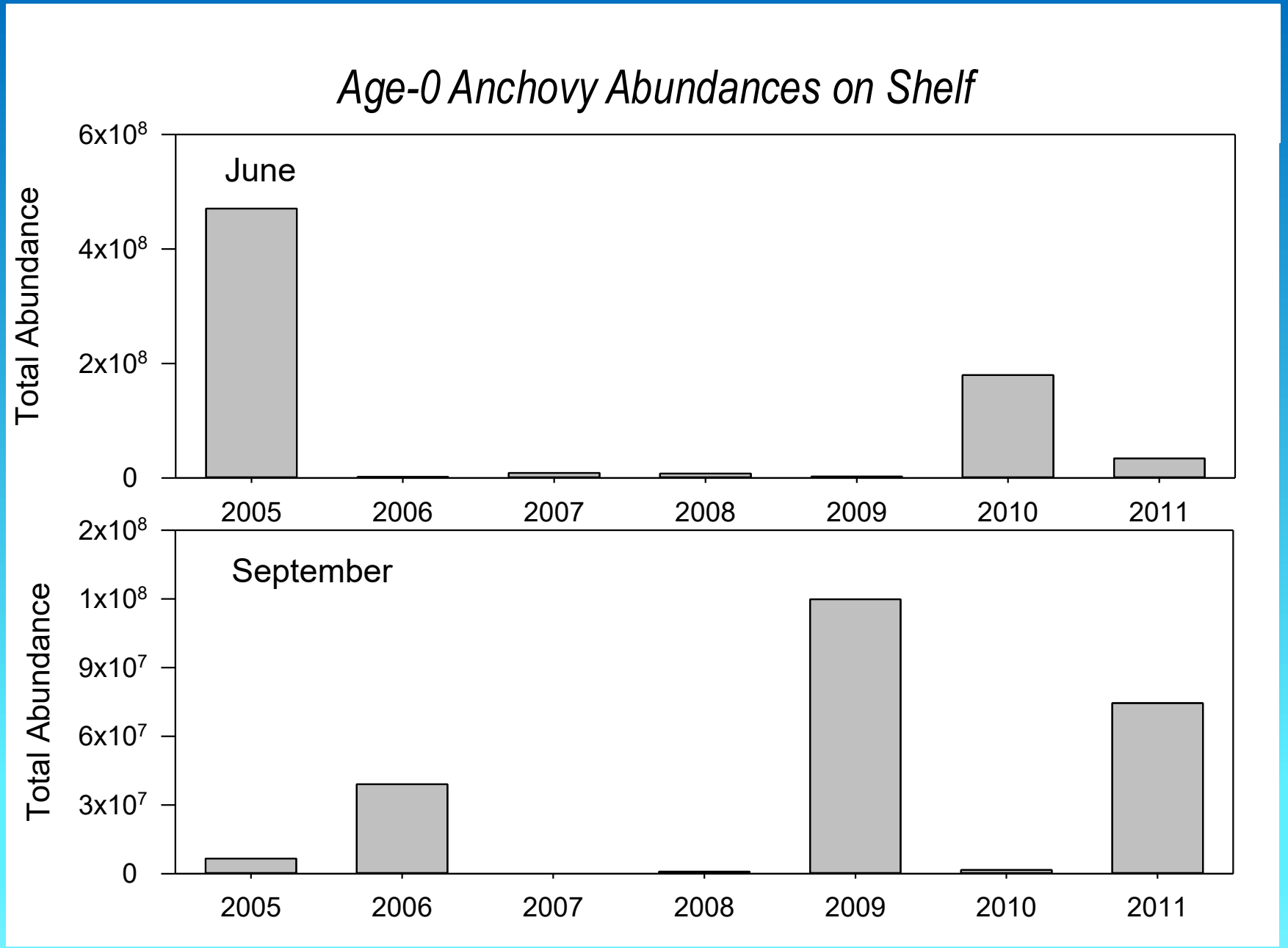
Converted weight to number consumed per day using mean prey weights

Estimation of Daily Food Consumption

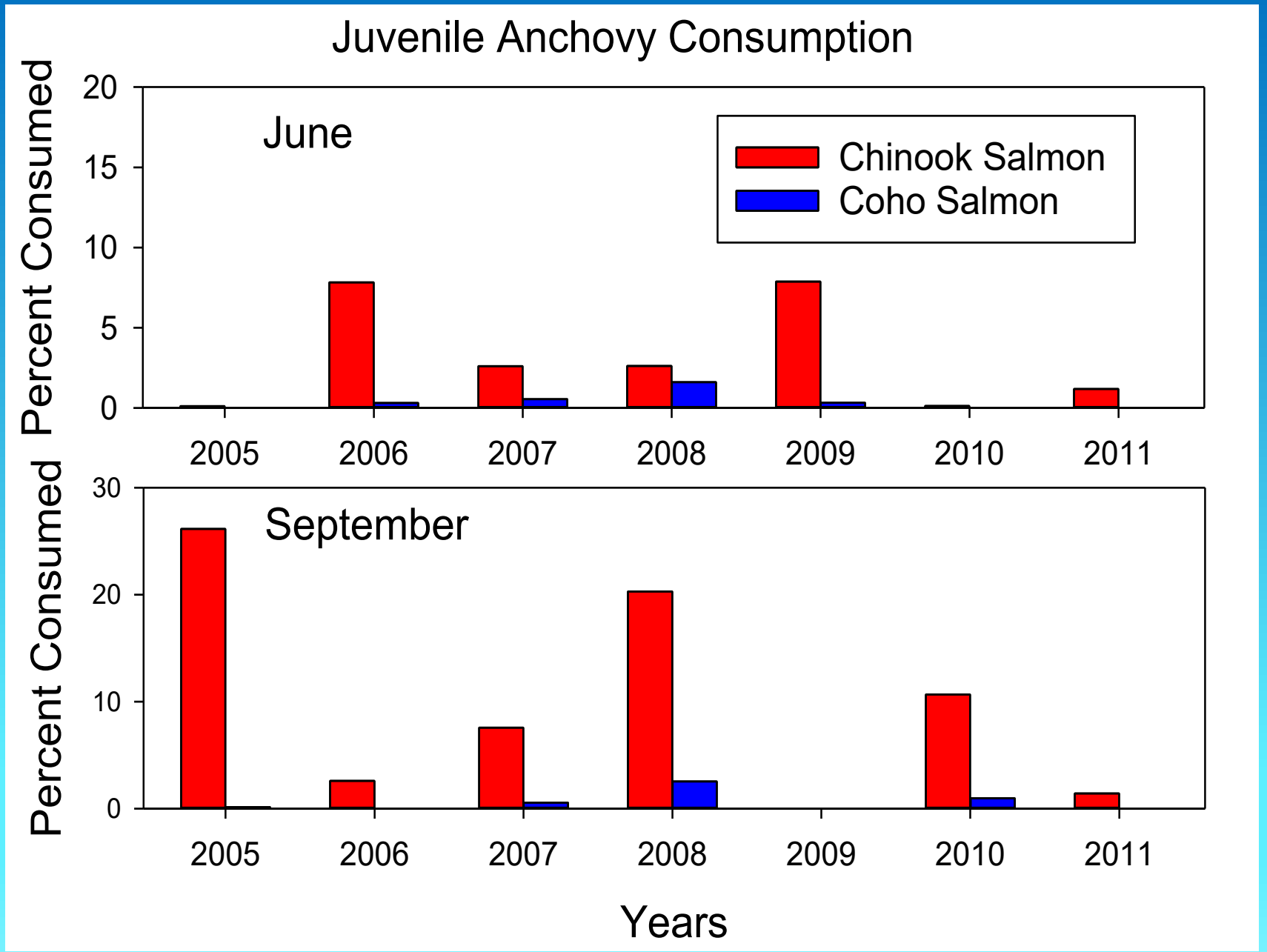
Individual consumption estimates



Prey abundance



Total Consumption by Year and Predator



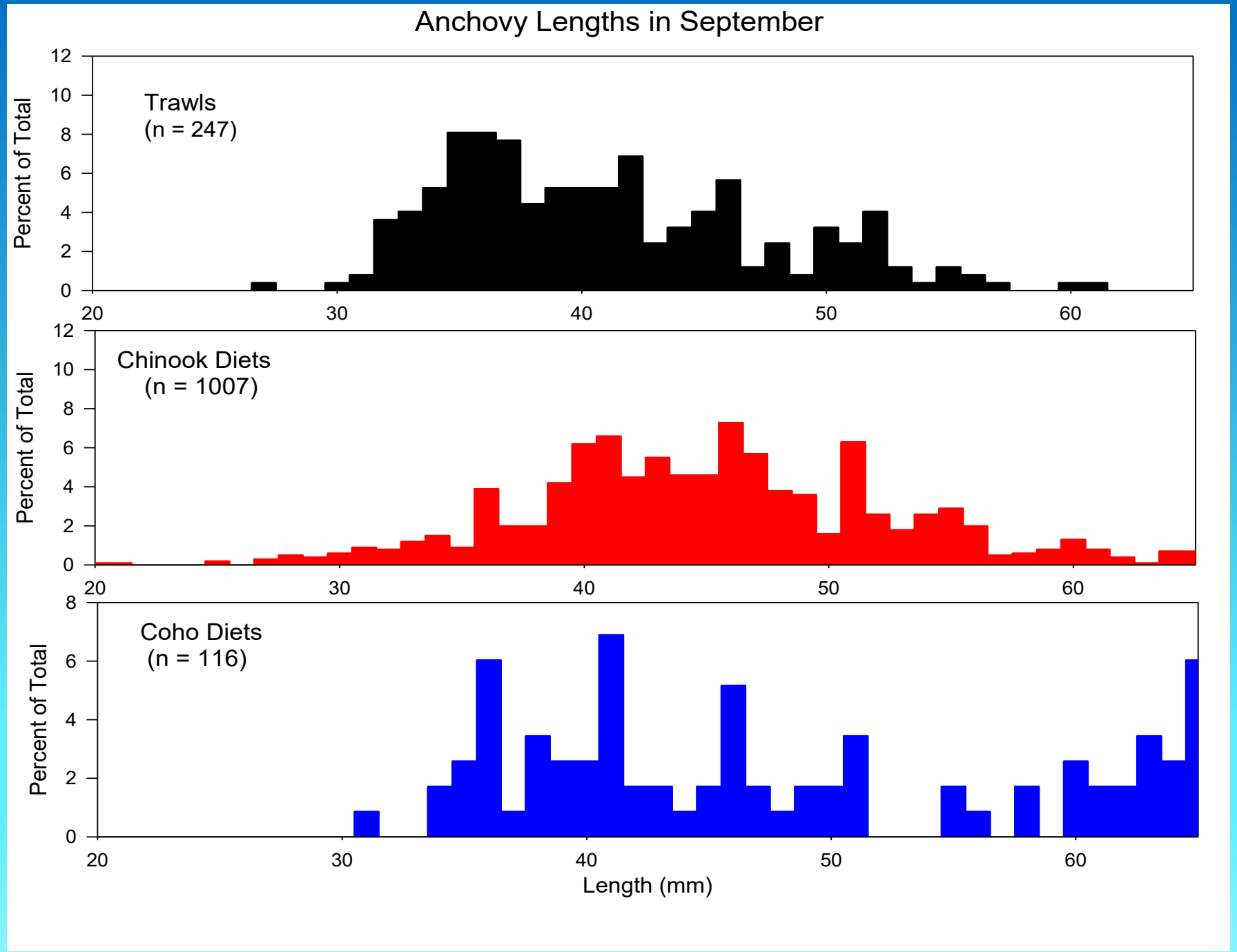
Mean

$\bar{X} = 3.9$

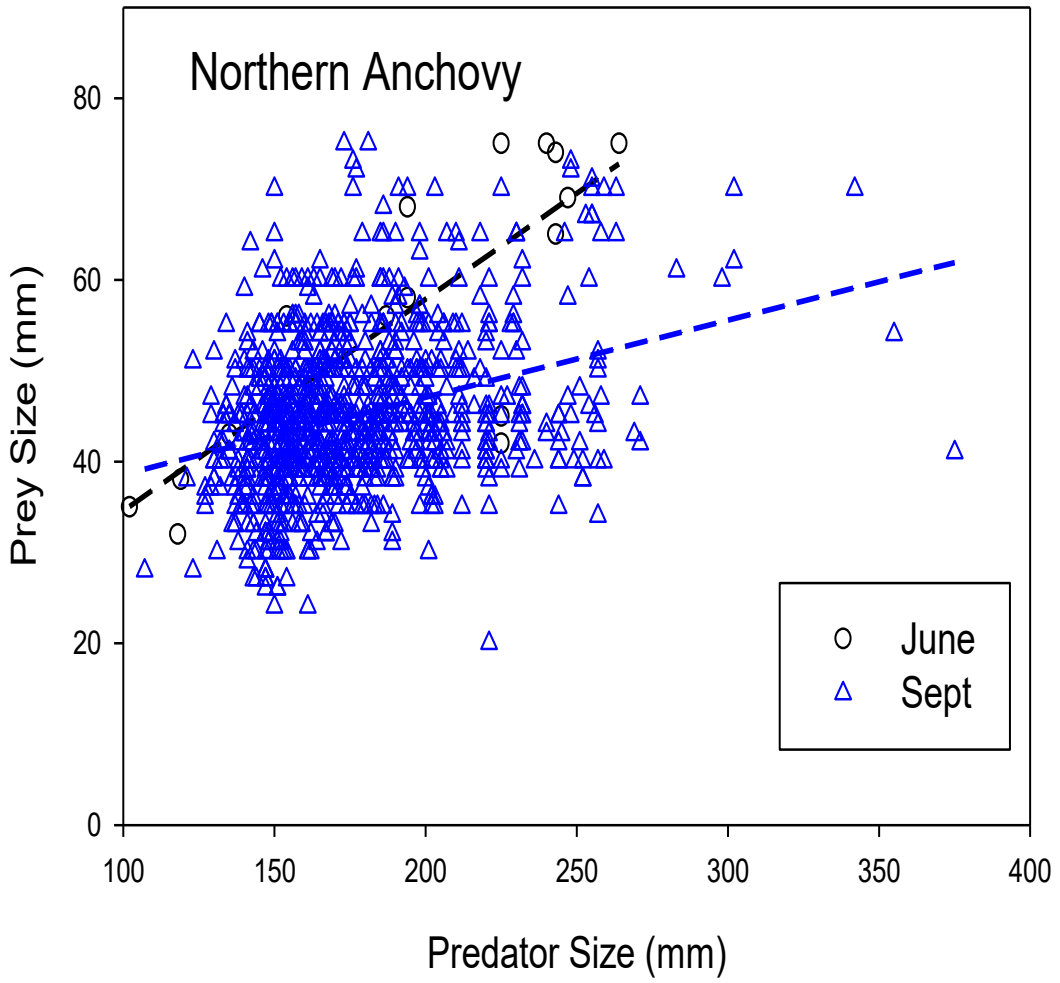
$\bar{X} = 1.8$

$\bar{X} = 12.9$

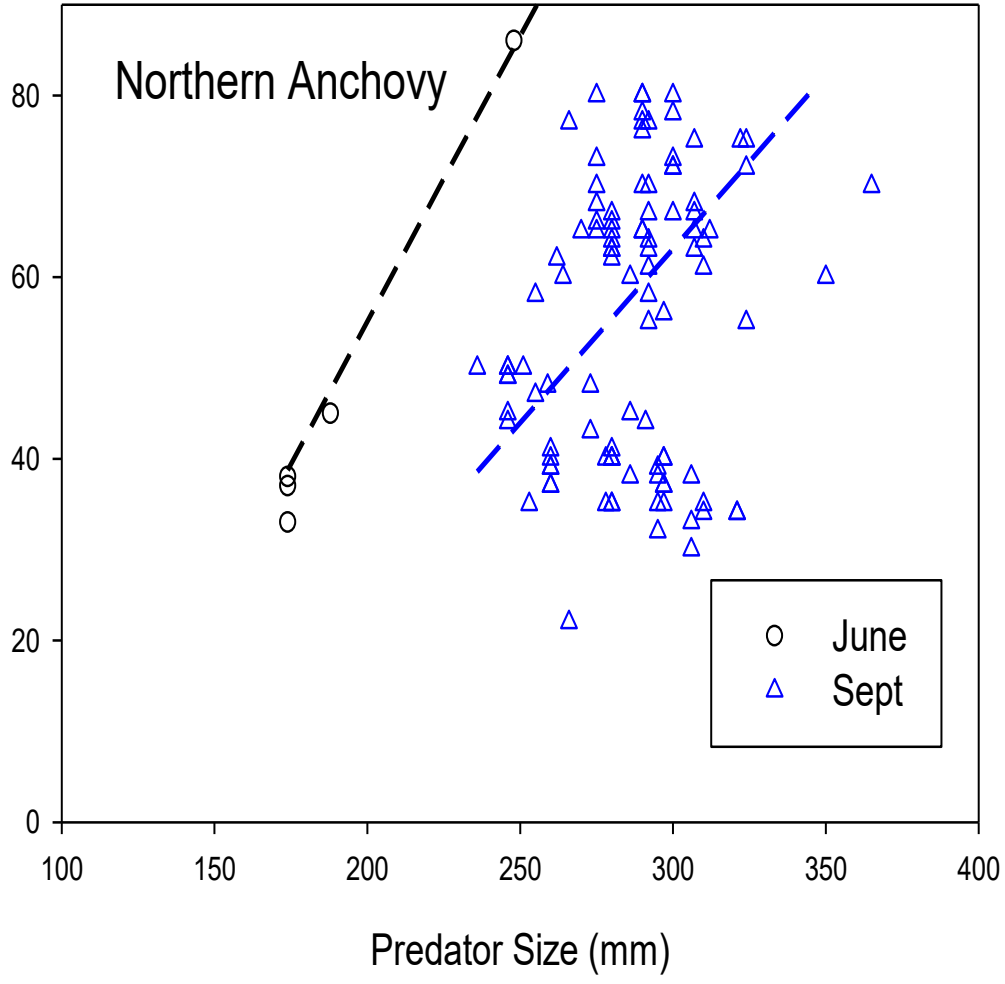
$\bar{X} = 2.1$


Anchovy Lengths in September
Trawls
(n = 247)
Chinook Diets
(n = 1007)
Coho Diets
(n = 116)
Percent of Total
Length (mm)
0
2
4
6
8
10
12
20
30
40
50
60

Chinook Salmon

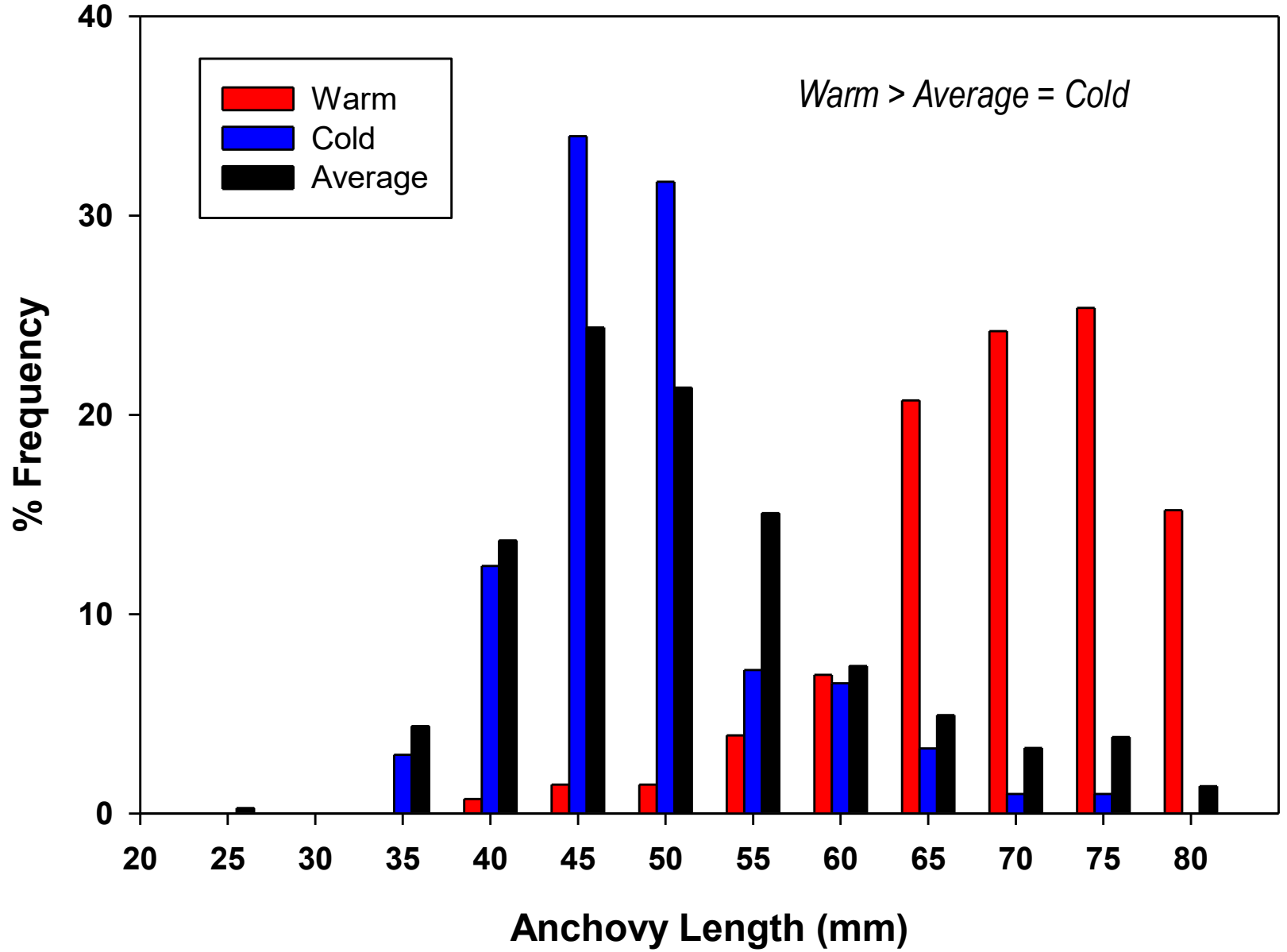


Coho Salmon

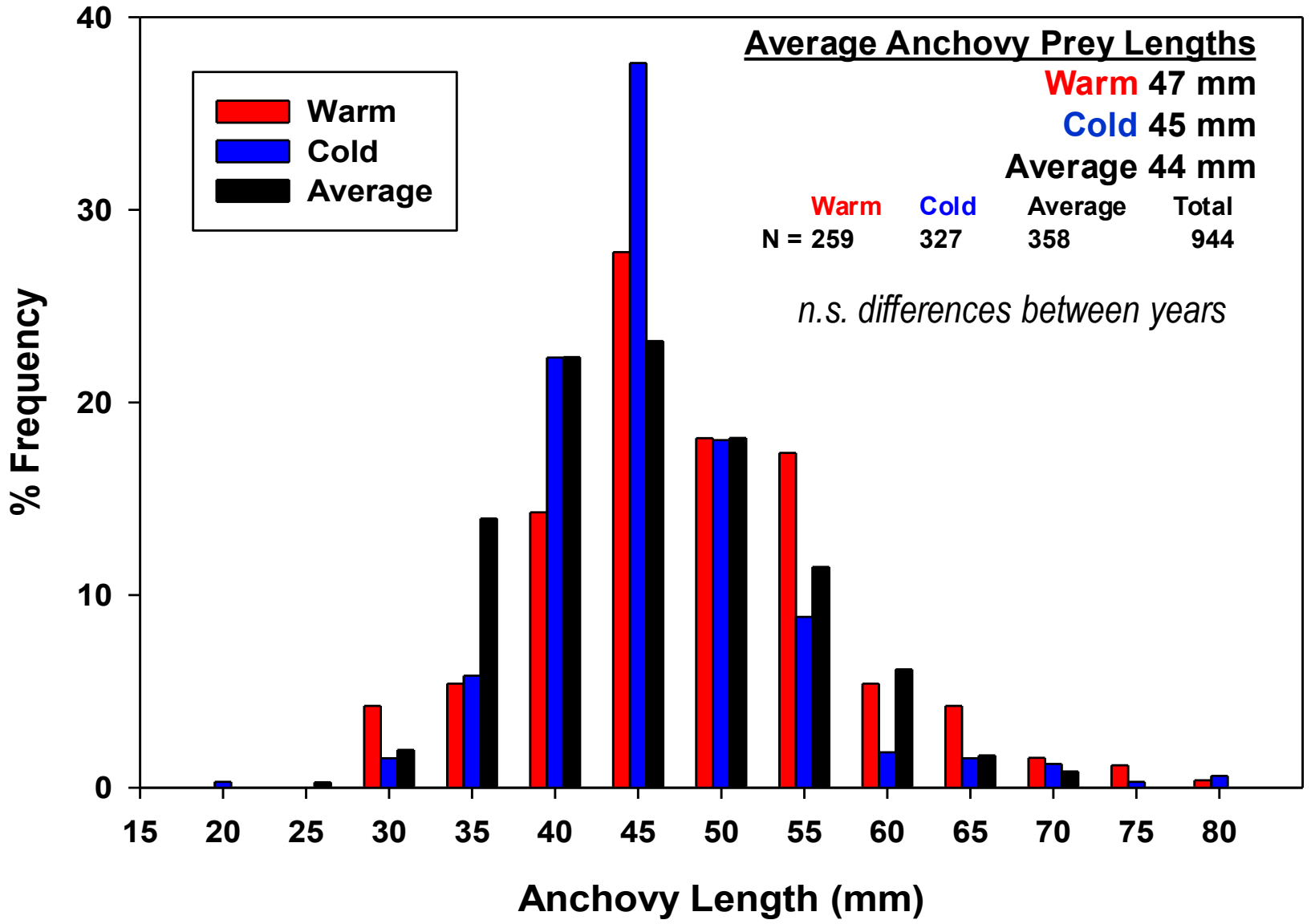


September BPA Catch Data For <80mm Anchovy

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
N =	19	2	0	174	64	107	554	10	322	43	66	164	1506



Length Frequency of Anchovy Prey Consumed



Summary

- Chinook and coho salmon are highly piscivorous and have the potential to impact anchovy populations in the NCC (estimated average consumption 6-15%)

Salmon are not the only predators….

Summary

- Chinook and coho salmon are highly piscivorous and have the potential to impact anchovy populations along the West Coast
- Can be substantial interannual and seasonal variability in utilization of these prey by juvenile salmon
- Similar prey size range between size of prey consumed and those available but some apparent selection for larger prey available for both predators

Implications

- Age-0 northern anchovy occur in the right size range at a critical period of juvenile salmon survival during these study years. However, recent sampling (Auth et al. 2018, GCB) shows that anchovy spawning season has shifted several months earlier due to ocean warming and may lead to a mis-match in available prey
- Juvenile salmon growth is 2x higher in years when anchovy are most abundant (Litz et al. 2018, FO).

Acknowledgements

- Crew and scientists aboard research vessels
- Drs. Marisa Litz and Jim Ruzicka for providing data
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