

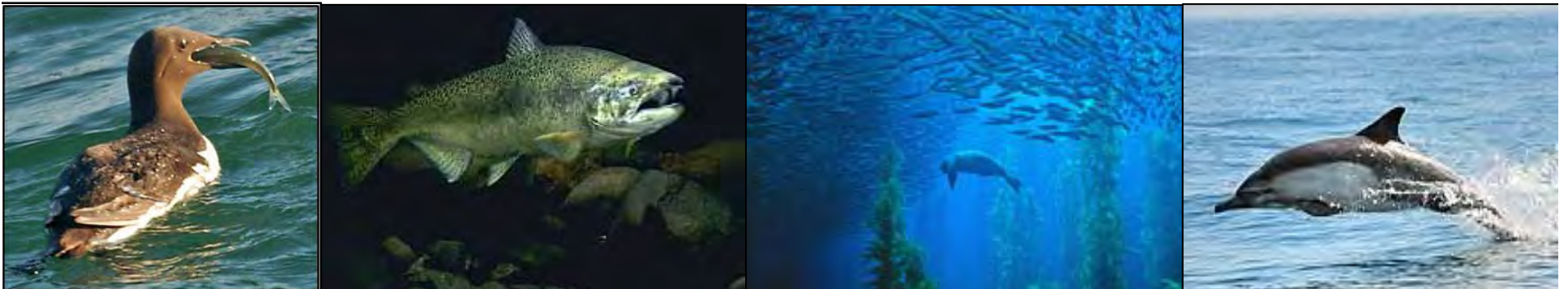
Predator Forage Needs: Comparison & Model Synthesis

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Outline

- **Numerical response models** - testing hypothesis of general relationships between prey abundance and predator productivity across marine vertebrate classes
- **Predator bio-energetic consumption models** of SPF (*anchovy*, *sardine*) for a broad suite of taxa
- **Synthesized results** from threshold models (species-limited due to substantial data requirements) with broader taxonomic results of bioenergetic models



Forage definitions

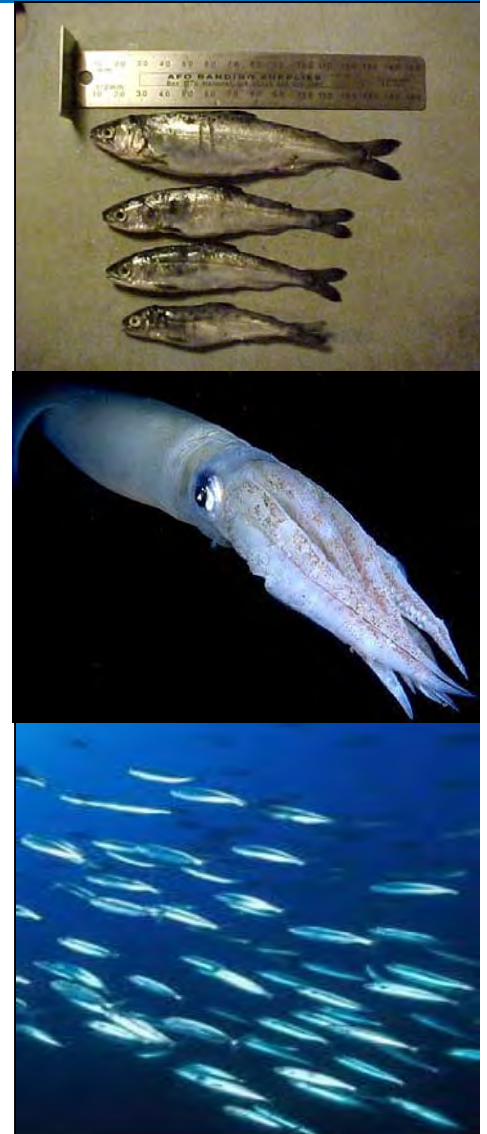
CC is not wasp-waist

- Small pelagics (*anchovy, sardine, herring*)
- Juveniles of predatory fishes (*rockfish, hake, salmon*)
- Invertebrates (*shrimp, squid*)

Comprehensive definition

1. Holds key role in the ecosystem
(*is important in predator diet*)
2. Feeds predominantly on plankton
3. Forms dense schools
4. Small size (<50cm)

→ 32 forage groups



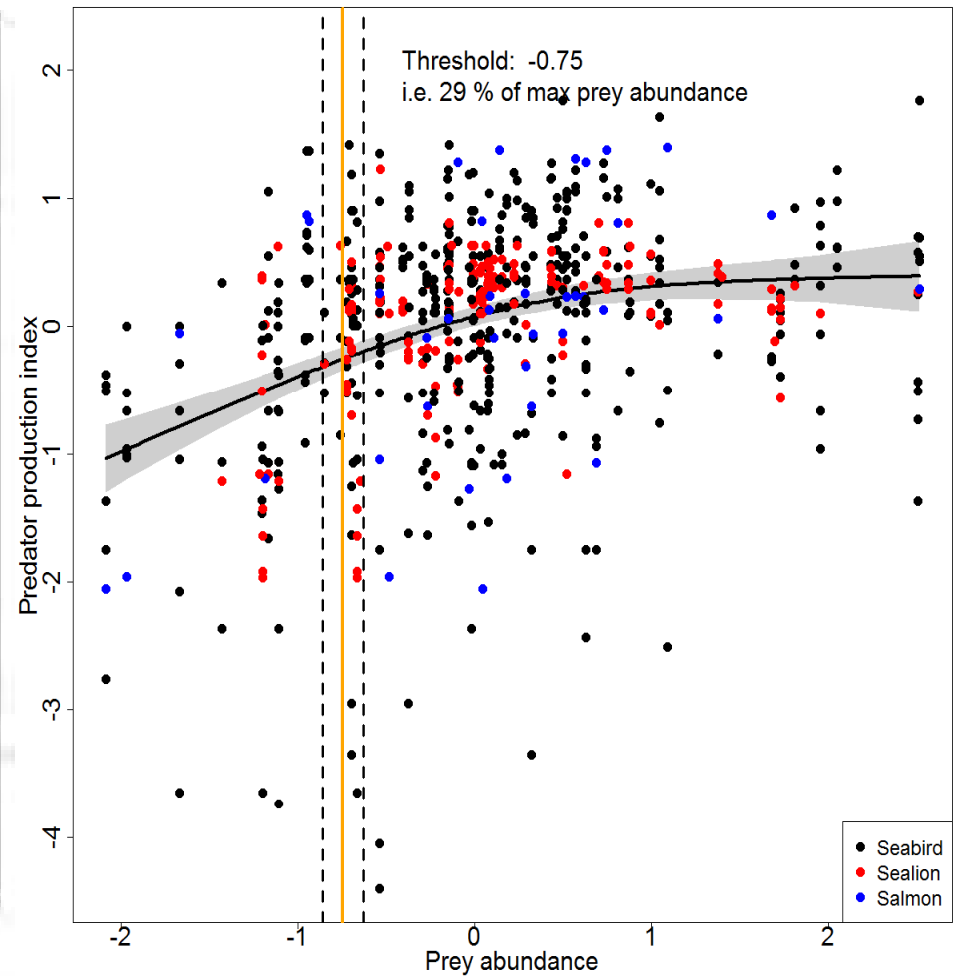
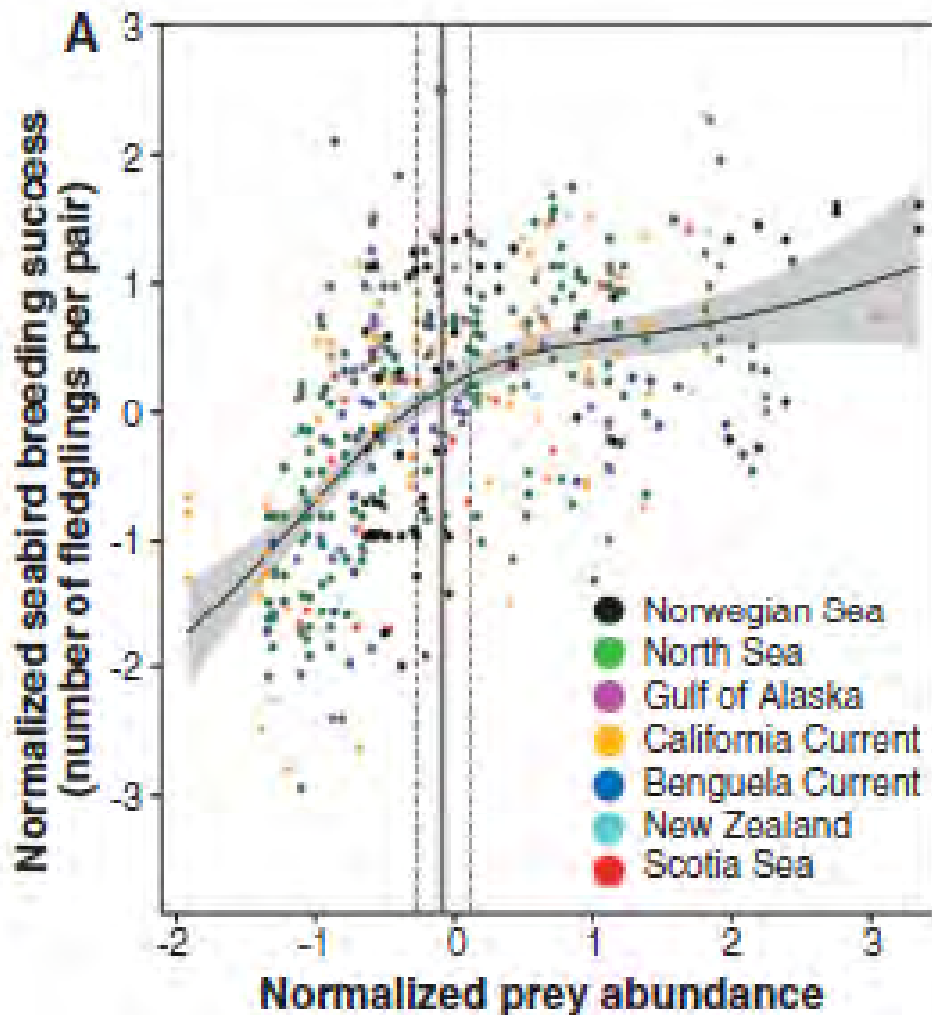
Numerical response models

- Used methodology of Cury *et al.* (2011) *Science*, expanding to multiple predator taxa
- Measures of predator productivity (between 1975-2013, southern to central California)
 - seabird breeding success
 - sea lion pup production
 - salmon survival (returns)
- Concurrent forage fish abundance time series
 - spawning biomass estimates
 - southern CC (1951-2011; NOAA CalCOFI Survey)
 - central CC (1983-2013; NOAA Rockfish Recruit. & Ecosyst. Survey)

One-third for the birds (global)
One-third for the predators (CC)

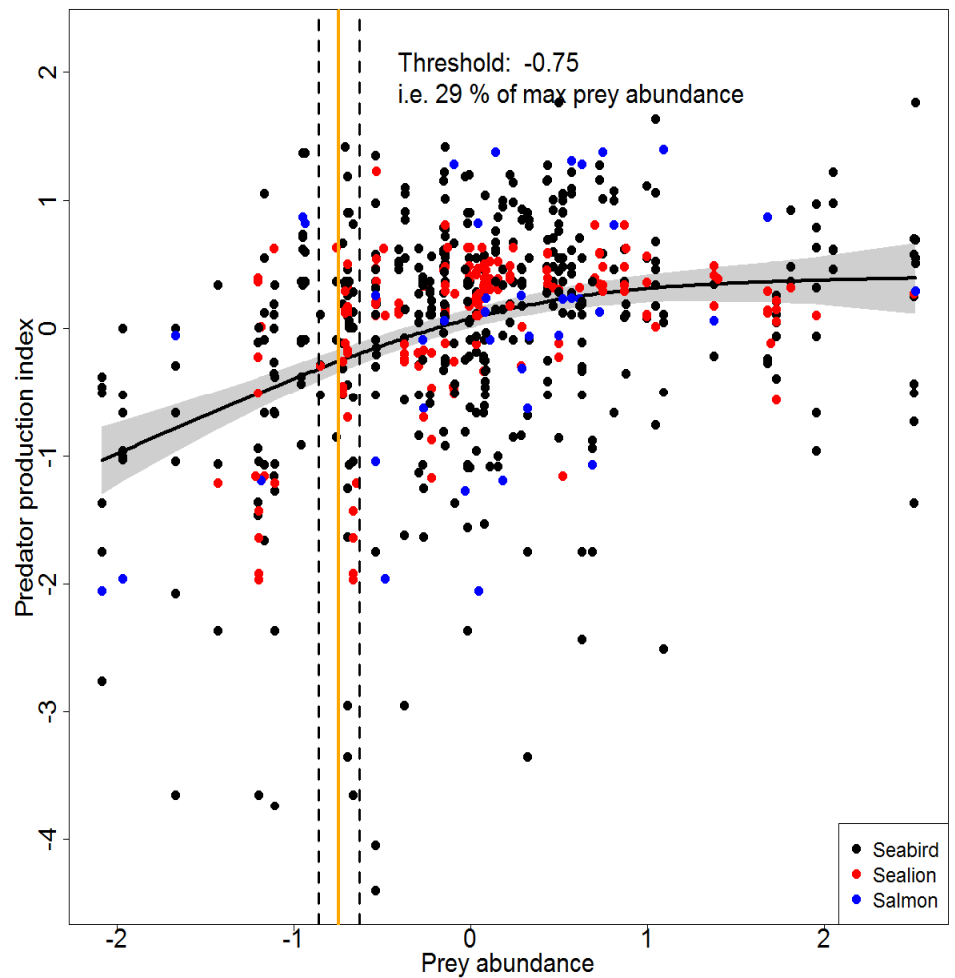
Cury et al. (2011) Science

Thayer et al. in revision



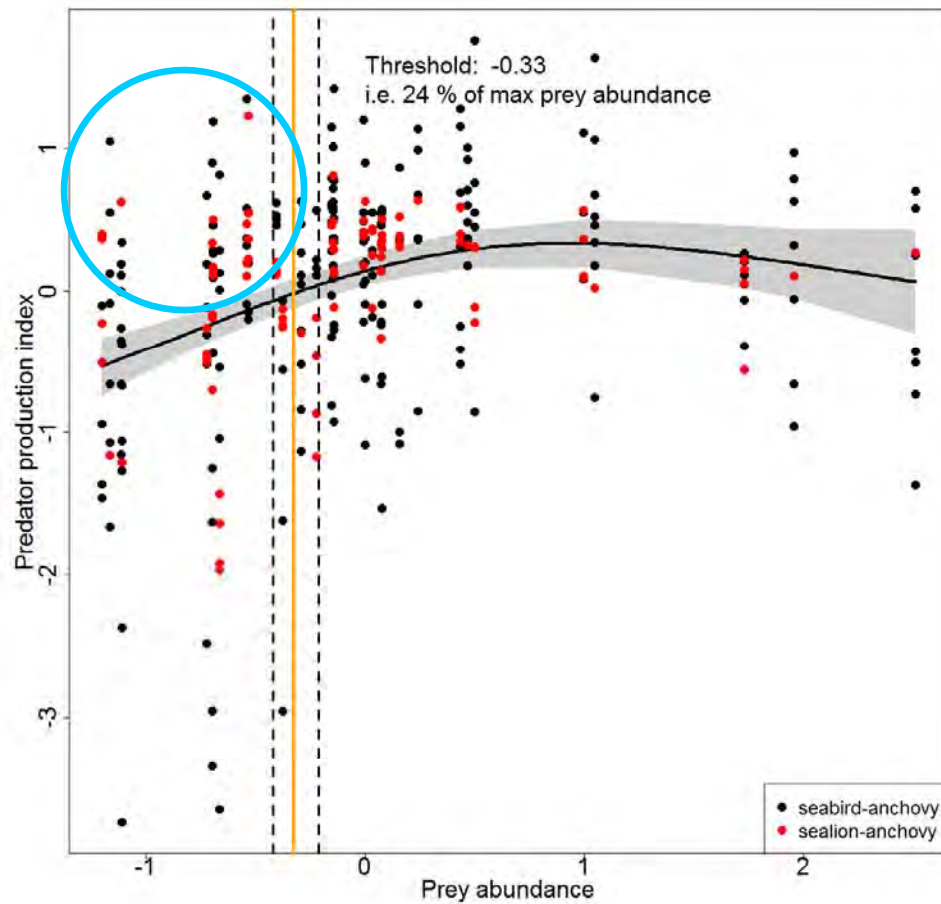
One-third for the predators (CC) *Thayer et al. in revision*

- Holds among multiple predator taxa
(3 classes, 9 spp.)
- Holds among 4 prey types
(schooling pelagics, inverts, juv. predatory fishes)
- Holds among regions
(soCA-cenCA, 10 locations)

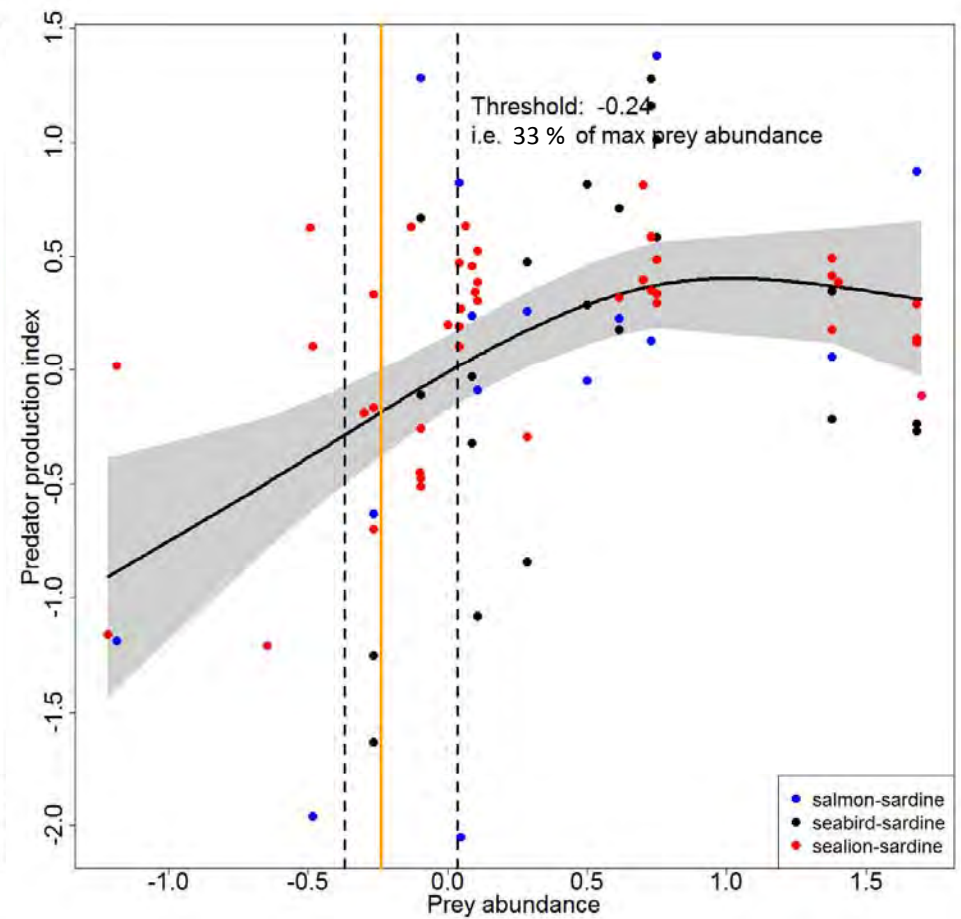


Predator productivity thresholds

N. Anchovy



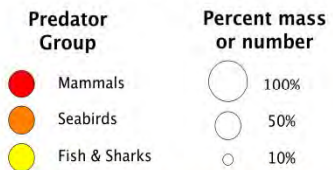
P. sardine



Bio-energetic models

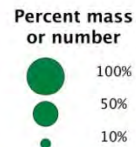
- Anchovy or sardine energy density for mean size
- Predator - diet composition
 - population size
 - metabolic rate
 - assimilation efficiency
 - days of occupancy in CC

Amount of Anchovy Consumed by CCS Predators



Sardines Consumed by CCS Predators

Presence/
Absence data



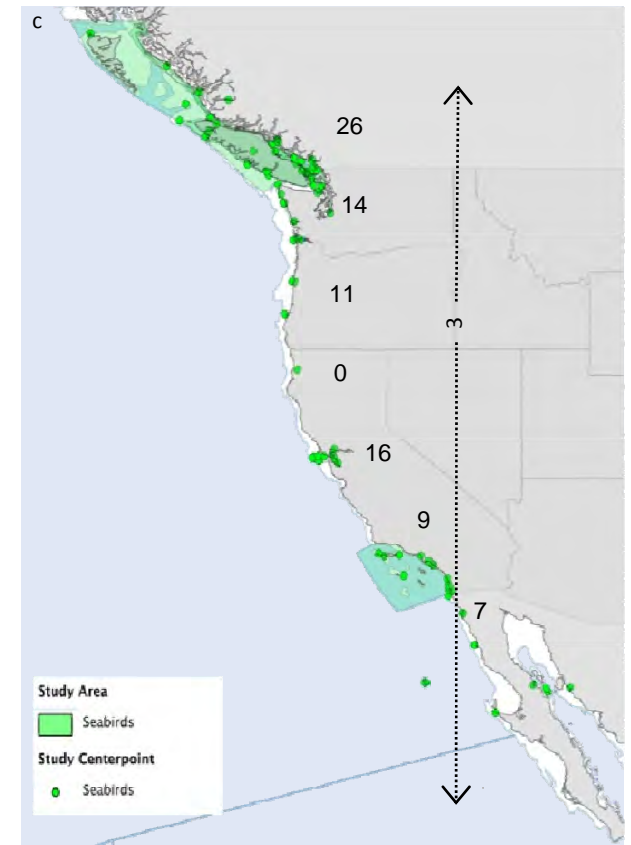
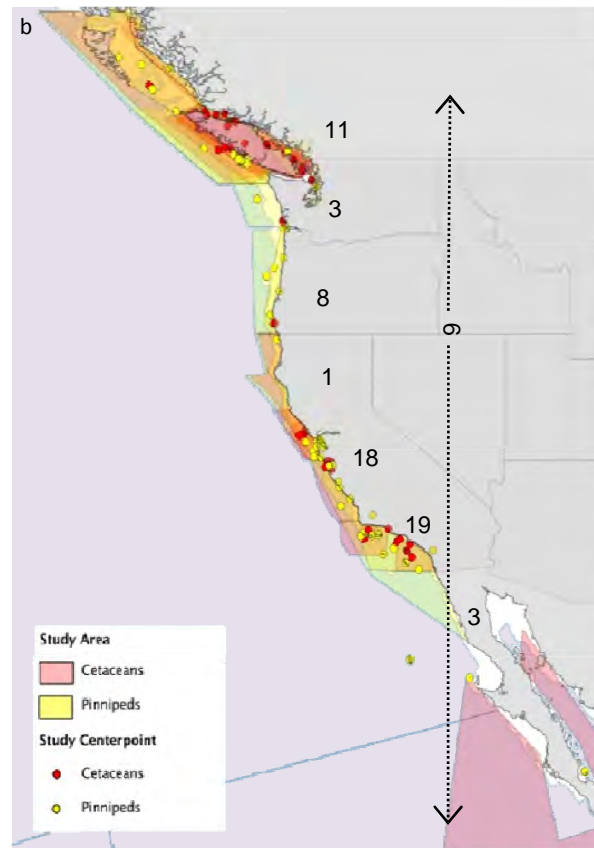
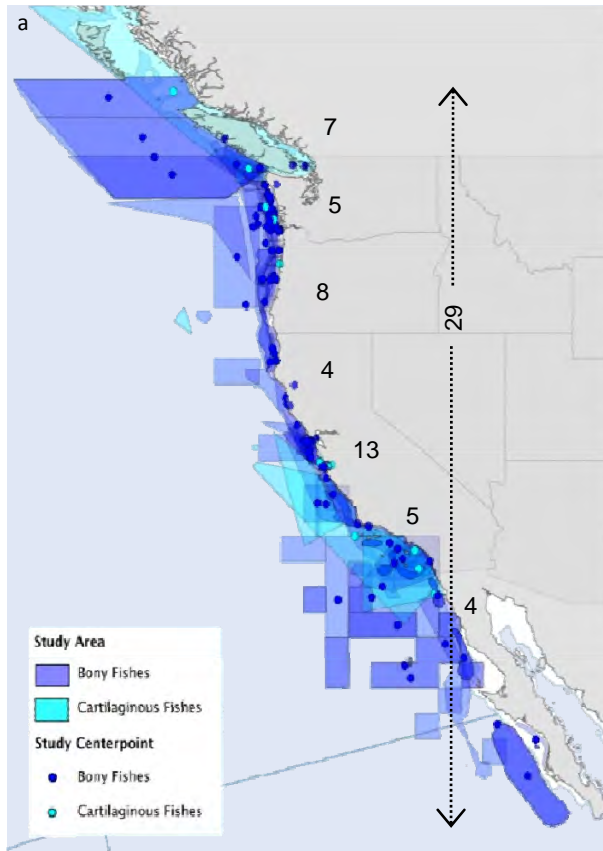
CA Current Predator Diet Database (CCPDD)

Szoboszlai et al. (2015) *Ecological Informatics*

120
predators: **39 fishes**
15 sharks/rays

21 cetaceans
6 pinnipeds

37 seabirds



**63 anchovy/
sardine**
predators:

22 fishes

11 cetaceans
5 pinnipeds

24 seabirds

... and 1 giant squid

More considerations

- Diet averages lose crucial detail

Temporal - predators have to survive through extremes

- annual variability is obscured when averaging over multiple years
- seasonal prey pulses may be swamped when averaging at annual level

Spatial - prey availability

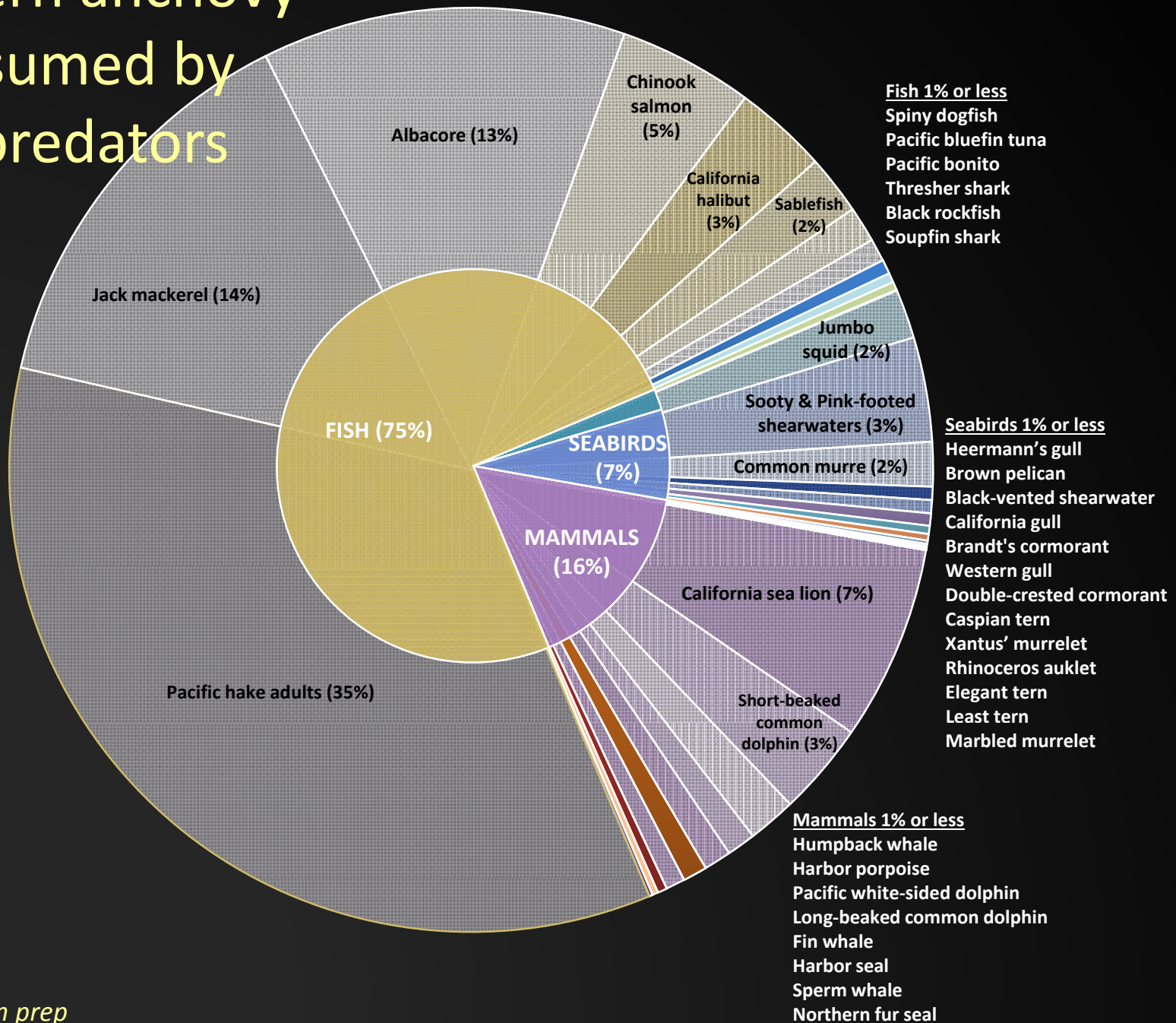
Ontogenetic - differences in diet

- What climate regime or top-down pressures present?

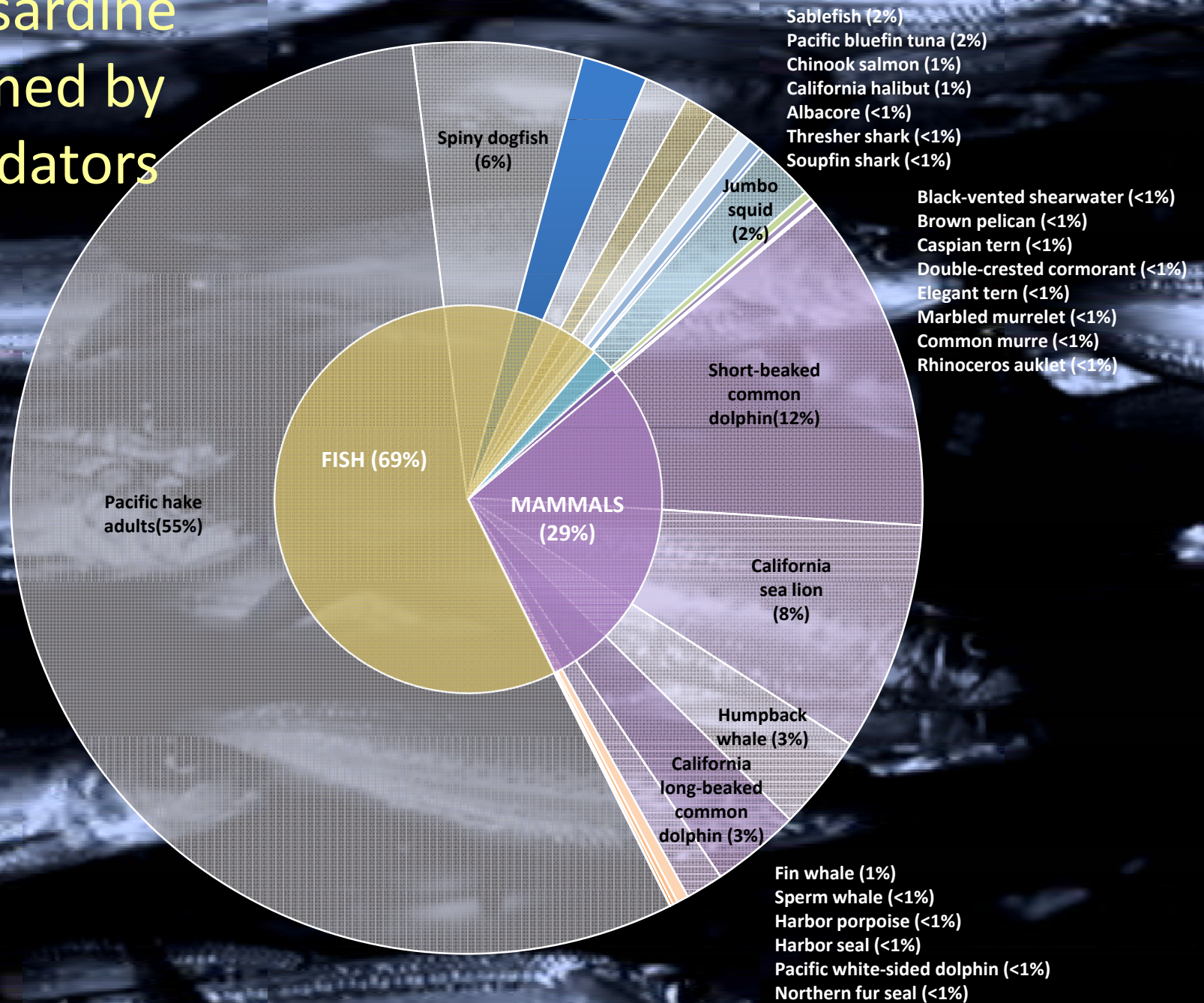
- e.g., 1960s-70s predator diet when sardine absent from CC should not be used as “status quo”
- Changes in predator-prey relationships
 - *prey-switching*
 - *fundamental changes through time*



Northern anchovy consumed by CC predators



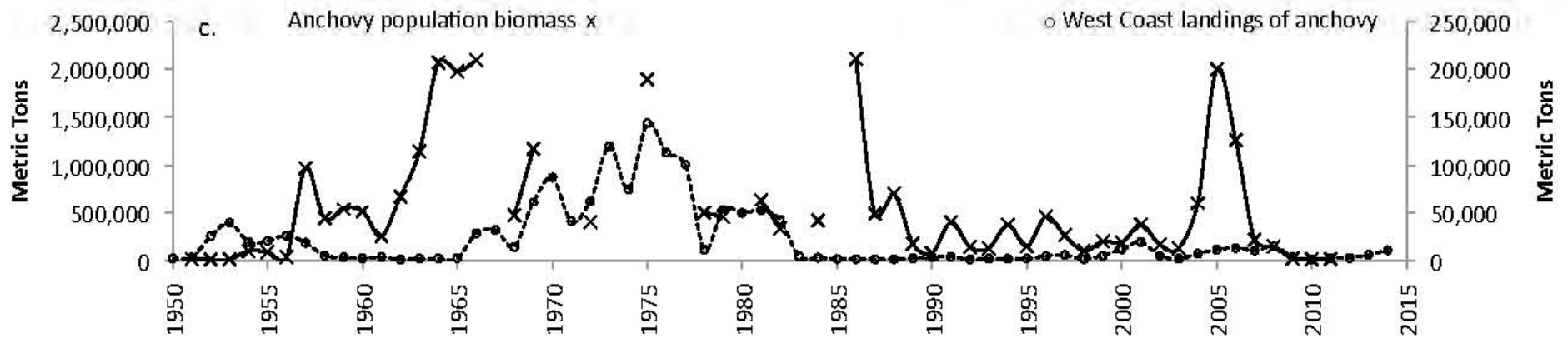
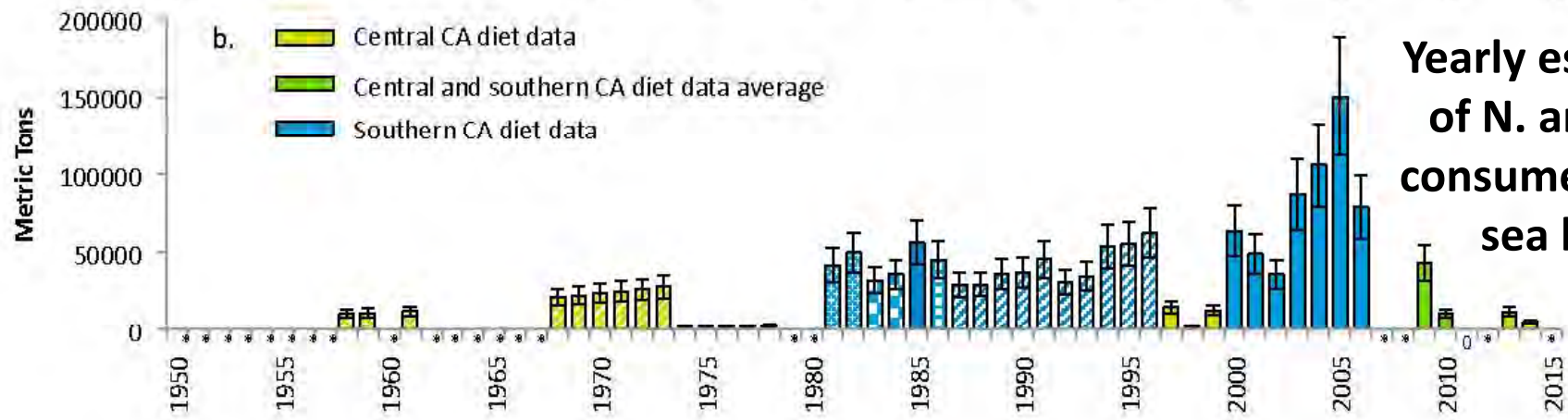
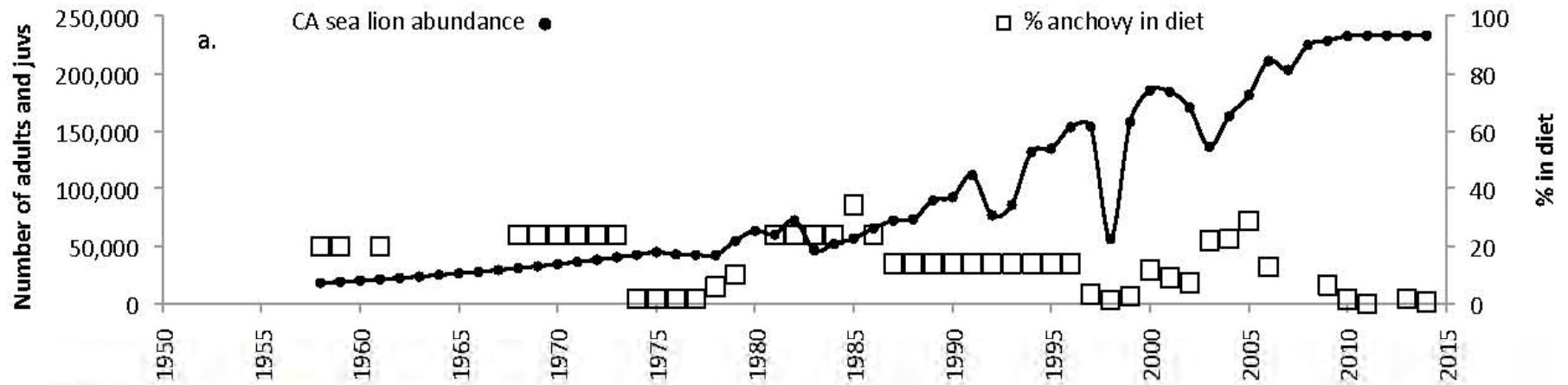
Pacific sardine consumed by CC predators



Interpretation

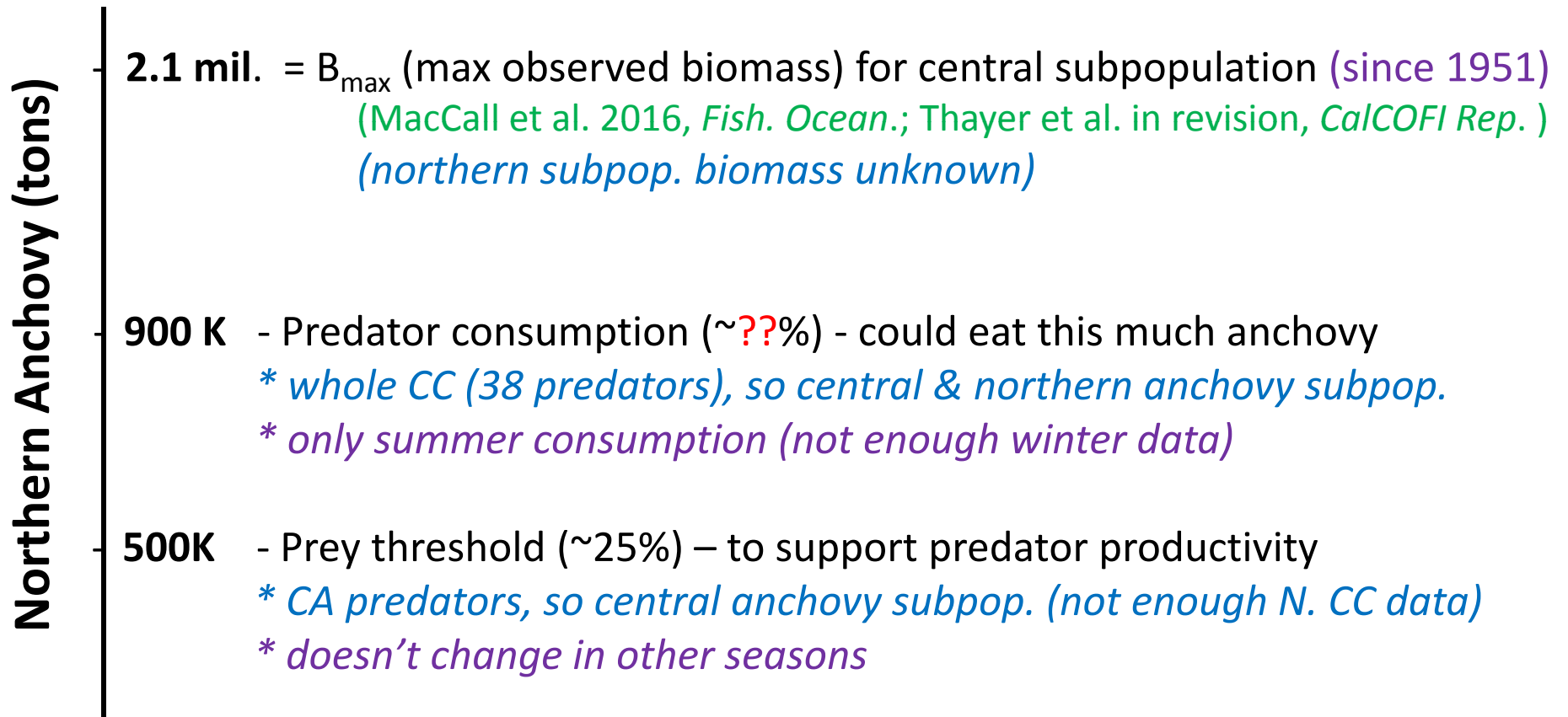
- Bio-energetic model demonstrates potential for overall consumption, and relative consumption between predators
 - consumption estimated at current high predator biomass (*after anchovy and sardine peaks in 2000s*)
 - does not illustrate inter-annual variability
 - can provide focus on predator species to model in detail
- Most sensitive to which parameter(s)?
 - **predator population size** (*e.g., hake*)
 - **diet data**
 - *some predators have no diet, or patchy data*
 - *problem of averages*





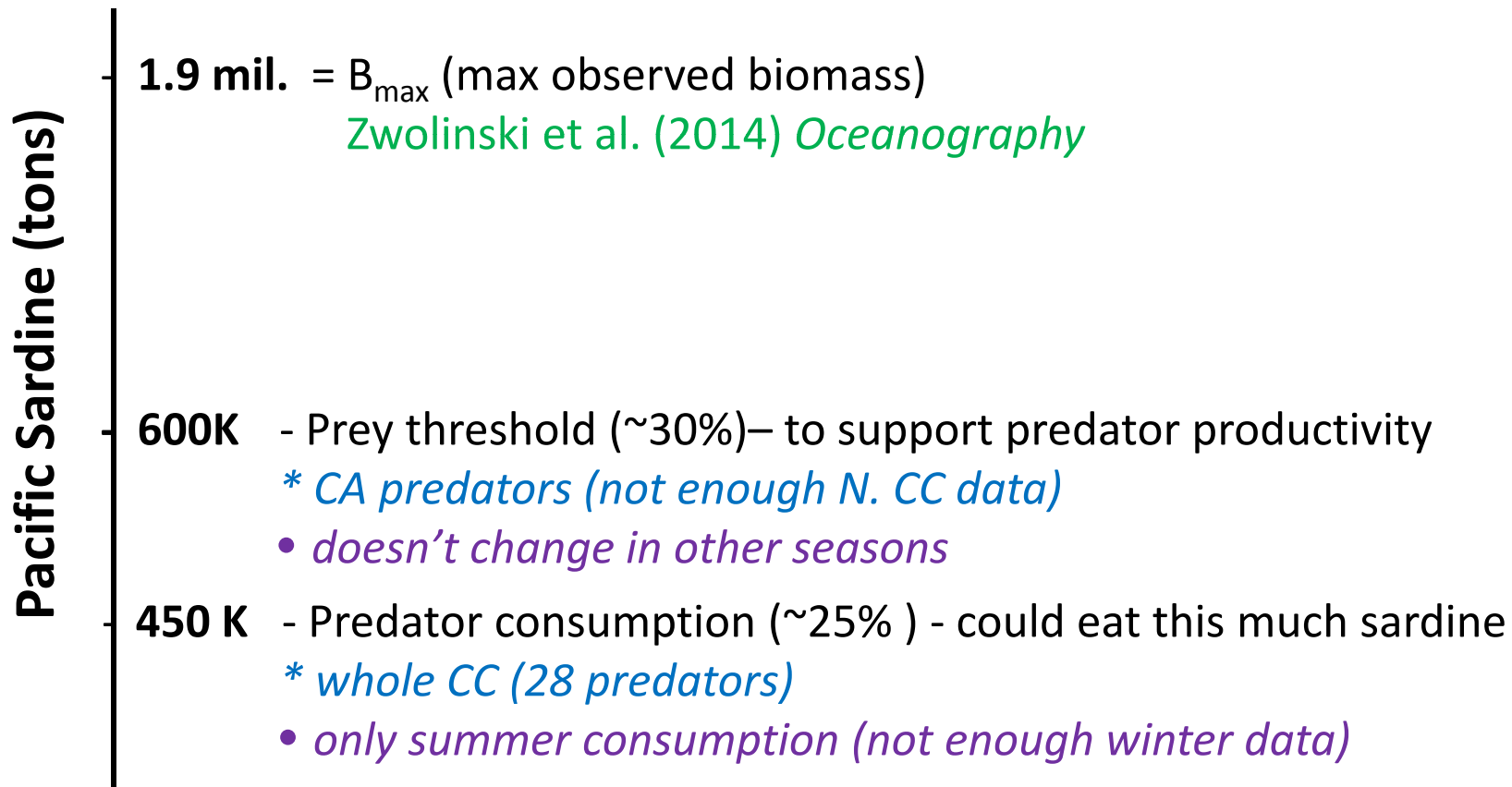
Northern anchovy

BIOENERGETIC CONSUMPTION vs. **THRESHOLD PREY IN OCEAN**
(MANY PREDATOR SPP.) (FEW PREDATOR SPP. – data intensive)



Pacific sardine

BIOENERGETIC CONSUMPTION vs. **THRESHOLD PREY IN OCEAN**
(MANY PREDATOR SPP.) (FEW PREDATOR SPP. – data intensive)



Conclusions

- Numerical response and bioenergetic consumption approaches exhibited similar results *for the predator community*
- Important for big picture predator forage needs
 - Which predators or regions to focus on for more detailed models
 - “Natural mortality rate” of course varies inter-annually, but this is a start using real data
 - Informative for mgmt. reference points to satisfy needs of predators
- Additional data will enable threshold models for northern CC, and to fill other data gaps; CA-only bioenergetic model can also be attempted



Acknowledgements

Thank you to:

Authors of the 193 citations included in the CC predator diet database,

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