Predator Consumption of Forage Species in the California Current

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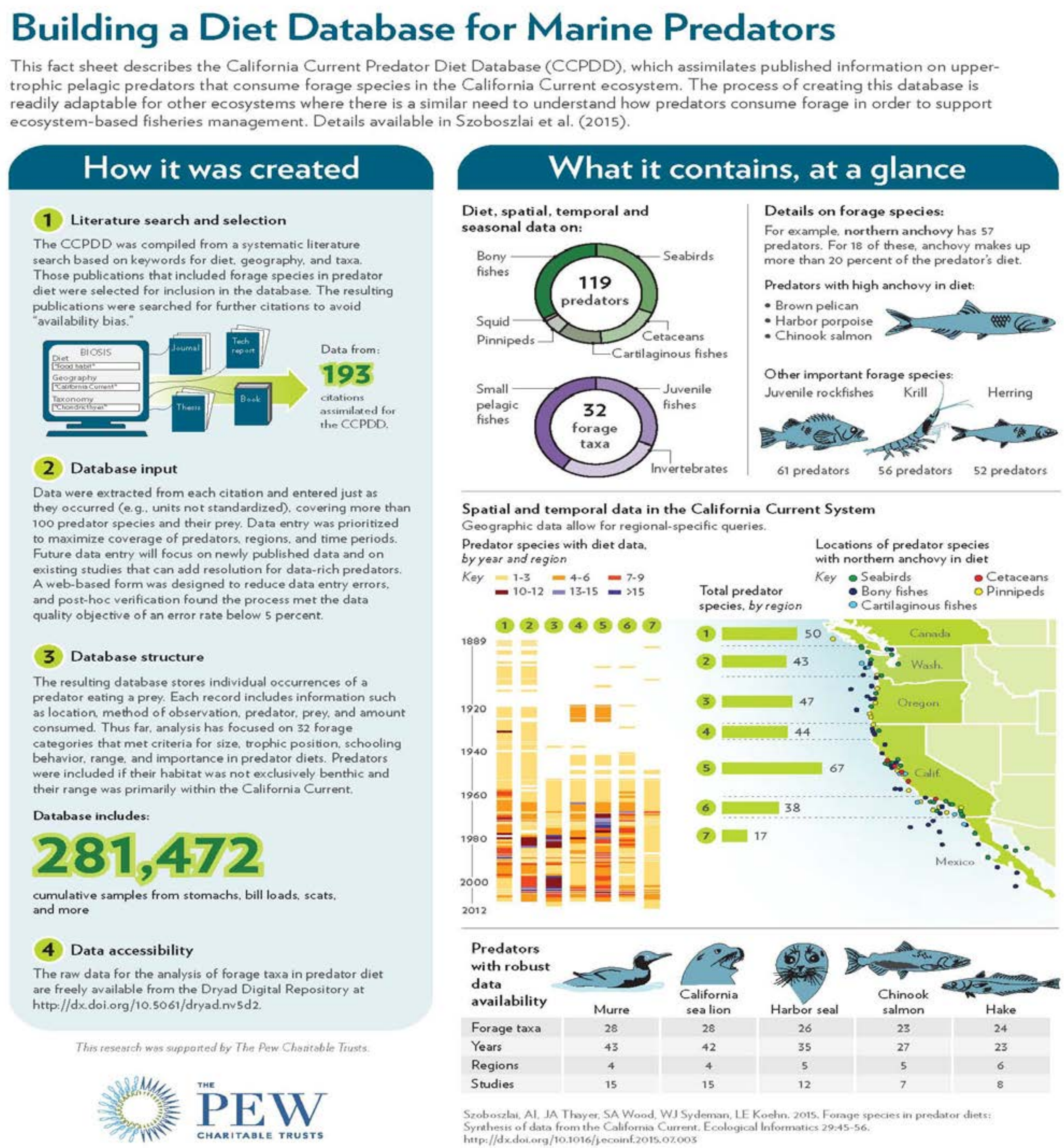
Obstacles

- Lack of synthesis of existing predator diet data *(data exist but not compiled, not accessible, data quality/type varies widely)*
- No standardized approach to predator diet composition
- Means do not accurately represent how predators respond to prey availability *(need to incorporate variance)*
- Spatio-temporal and ontogenetic differences in predators, prey *(appropriate scale, life stage)*




CA Current Predator Diet Database (CCPDD)



Building a Diet Database for Marine Predators

This fact sheet describes the California Current Predator Diet Database (CCPDD), which assimilates published information on upper-trophic pelagic predators that consume forage species in the California Current ecosystem. The process of creating this database is readily adaptable for other ecosystems where there is a similar need to understand how predators consume forage in order to support ecosystem-based fisheries management. Details available in Szoboszlai et al. (2015).

How it was created

1 Literature search and selection

The CCPDD was compiled from a systematic literature search based on keywords for diet, geography, and taxa. Those publications that included forage species in predator diet were selected for inclusion in the database. The resulting publications were searched for further citations to avoid "availability bias."

Data from:
193
citations assimilated for the CCPDD.

2 Database input

Data were extracted from each citation and entered just as they occurred (e.g., units not standardized), covering more than 100 predator species and their prey. Data entry was prioritized to maximize coverage of predators, regions, and time periods. Future data entry will focus on newly published data and on existing studies that can add resolution for data-rich predators. A web-based form was designed to reduce data entry errors, and post-hoc verification found the process met the data quality objective of an error rate below 5 percent.

3 Database structure

The resulting database stores individual occurrences of a predator eating a prey. Each record includes information such as location, method of observation, predator, prey, and amount consumed. Thus far, analysis has focused on 32 forage categories that met criteria for size, trophic position, schooling behavior, range, and importance in predator diets. Predators were included if their habitat was not exclusively benthic and their range was primarily within the California Current.

Database includes:

281,472

cumulative samples from stomachs, bill loads, scats, and more

4 Data accessibility

The raw data for the analysis of forage taxa in predator diet are freely available from the Dryad Digital Repository at http://dx.doi.org/10.5061/dryad.nv5d2.

This research was supported by The Pew Charitable Trusts.

THE PEW CHARITABLE TRUSTS

What it contains, at a glance

Diet, spatial, temporal and seasonal data on:

Details on forage species:

For example, northern anchovy has 57 predators. For 18 of these, anchovy makes up more than 20 percent of the predator's diet.

Predators with high anchovy in diet:

- Brown pelican
- Harbor porpoise
- Chinook salmon

Other important forage species:

Spatial and temporal data in the California Current System

Geographic data allow for regional-specific queries.

Predators with robust data availability

	Murre	California sea lion	Harbor seal	Chinook salmon	Hake
Forage taxa	28	28	26	23	24
Years	43	42	35	27	23
Regions	4	4	5	5	6
Studies	15	15	12	7	8

Szoboszlai, AI, JA Thayer, SA Wood, WJ Sydeman, LE Koehn. 2015. Forage species in predator diets: Synthesis of data from the California Current. Ecological Informatics 29:45-56. http://dx.doi.org/10.1016/j.ecoinf.2015.07.003

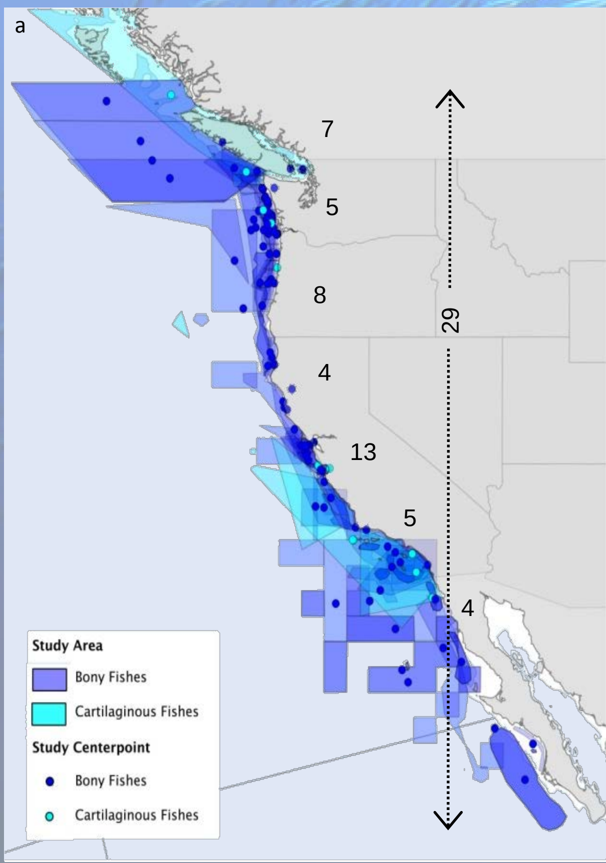
California Current Predator Diet Database

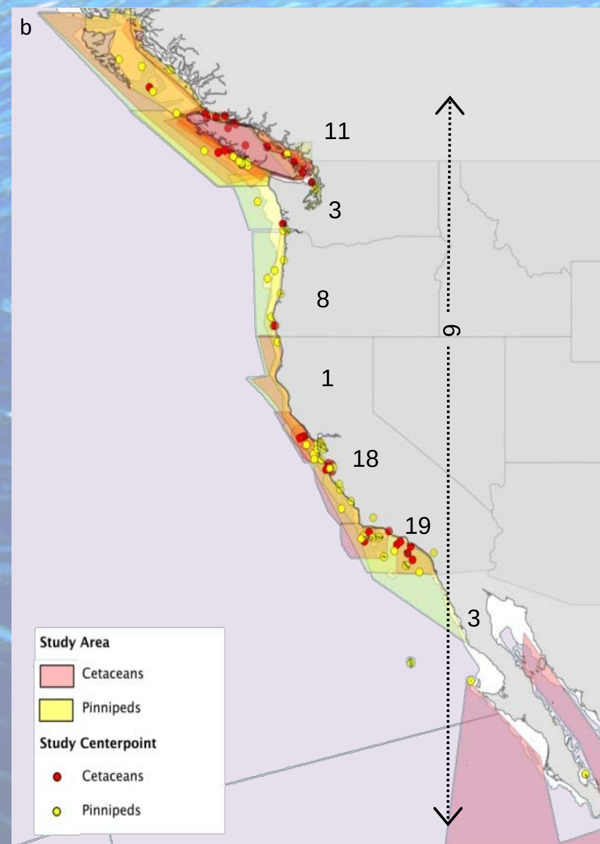
Szoboszlai et al. (2015) *Ecological Informatics* 29: 45

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

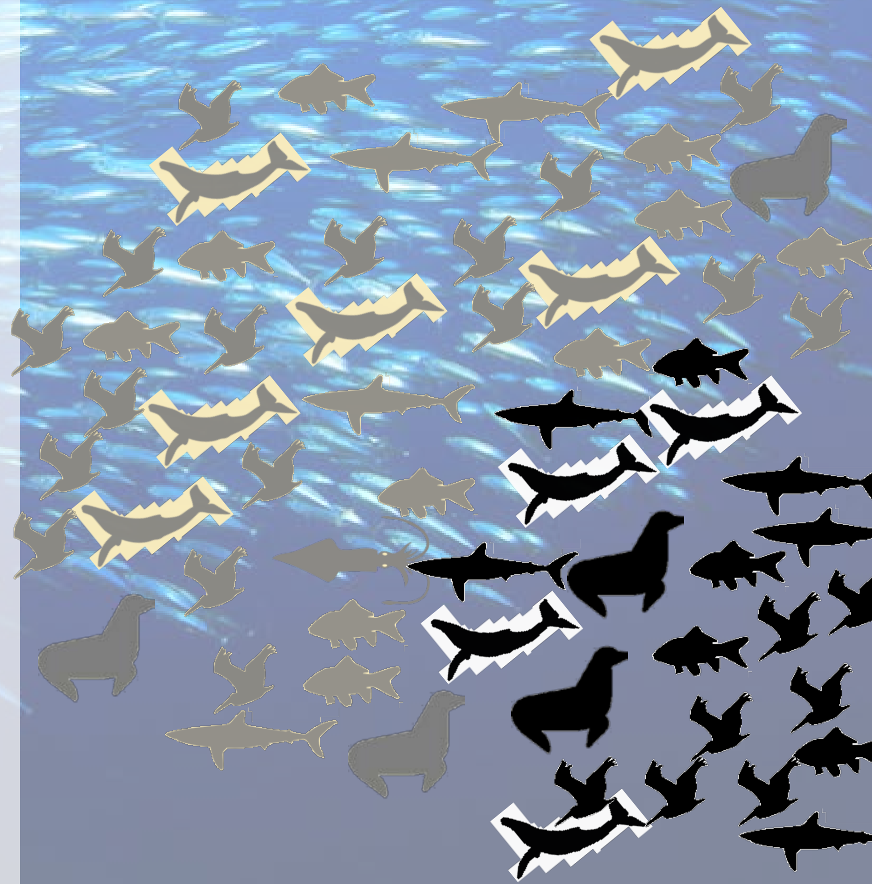
Bio-energetic model for predator consumption

METHODS

$$\text{Estimate Biomass Consumed (g)} = \sum_i P \times \frac{M}{A} \times R \times \frac{D_i}{E_i}$$

P = population size (abundance)
M = size-specific metabolic rate (kJ d^{-1} $animal^{-1}$)
A = assimilation efficiency (%)
R = residence time (days $summer^{-1}$)
D_i = diet portion of each prey (%)
E_i = energy density for each prey (kJ g^{-1})

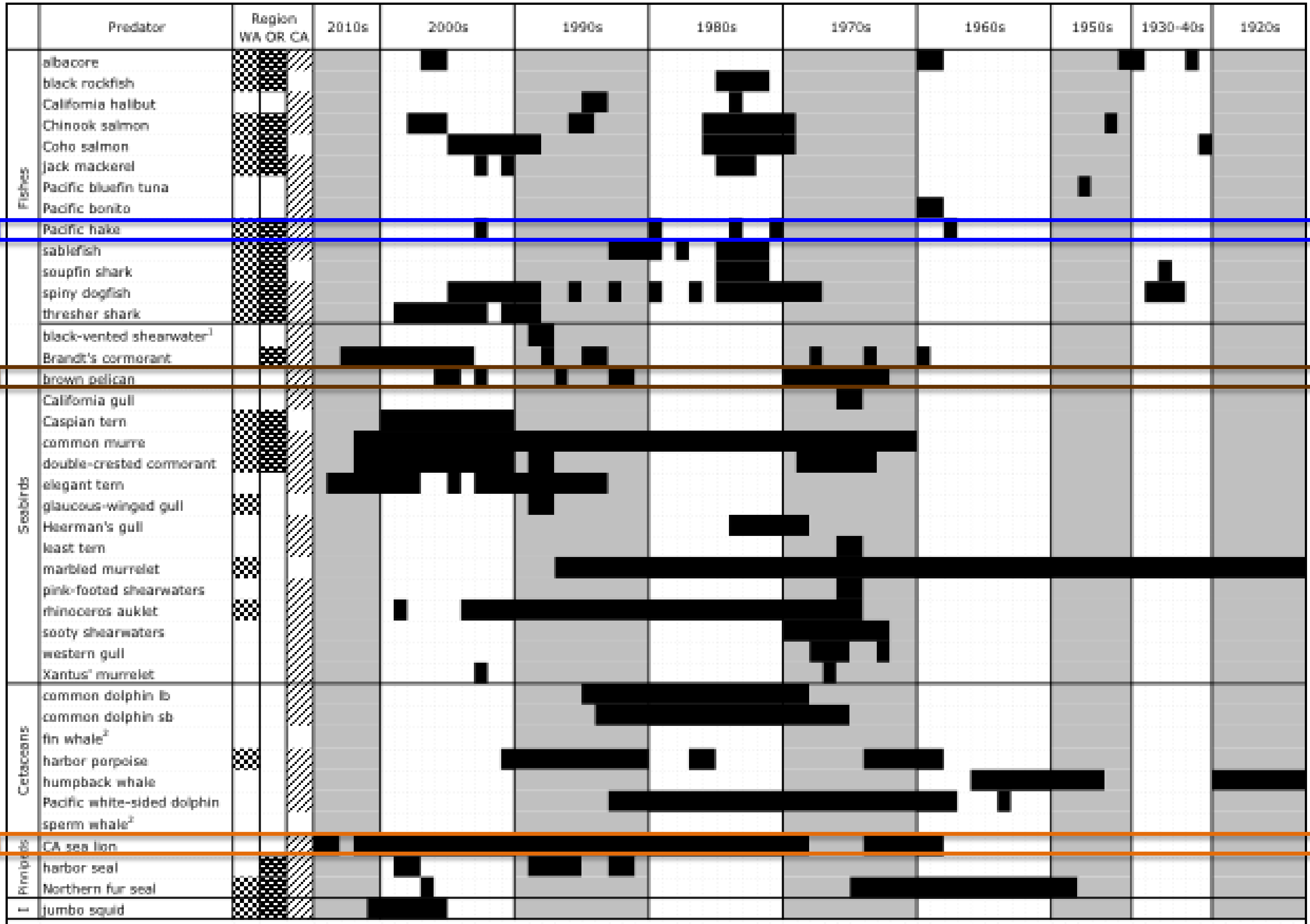
- Abundance/biomass data from recent stock assessments or other surveys
- Diet composition using ordered, weighted mean
    1. within a region
    2. among regions
    3. among life history stages
    4. weighted based on pop. distribution & number of years
- Assess total energy required by predator and provided by main prey types
- Generates a point estimate based on available diet data and recent population sizes
- Monte Carlo simulations to quantify error



Szoboszlai et al. *in prep*

20 of 43 preds only have diet data for one region

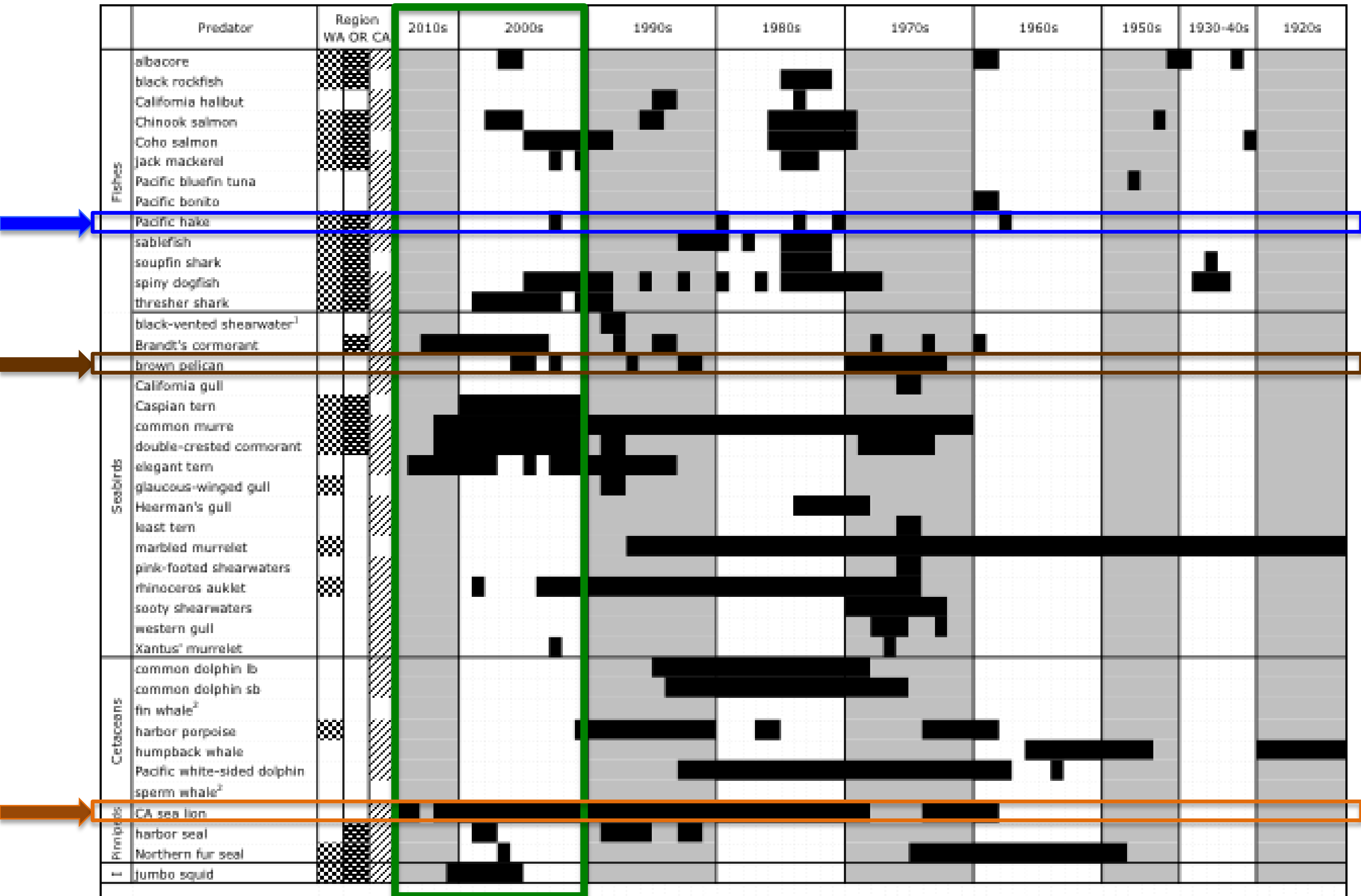
Szoboszlai et al. (2015) *Ecological Informatics* 29: 45



20 of 43 preds only have diet data for one region

From 2000 forward only 20 of 43 preds w/ diet data

Szoboszlai et al. (2015) *Ecological Informatics* 29: 45

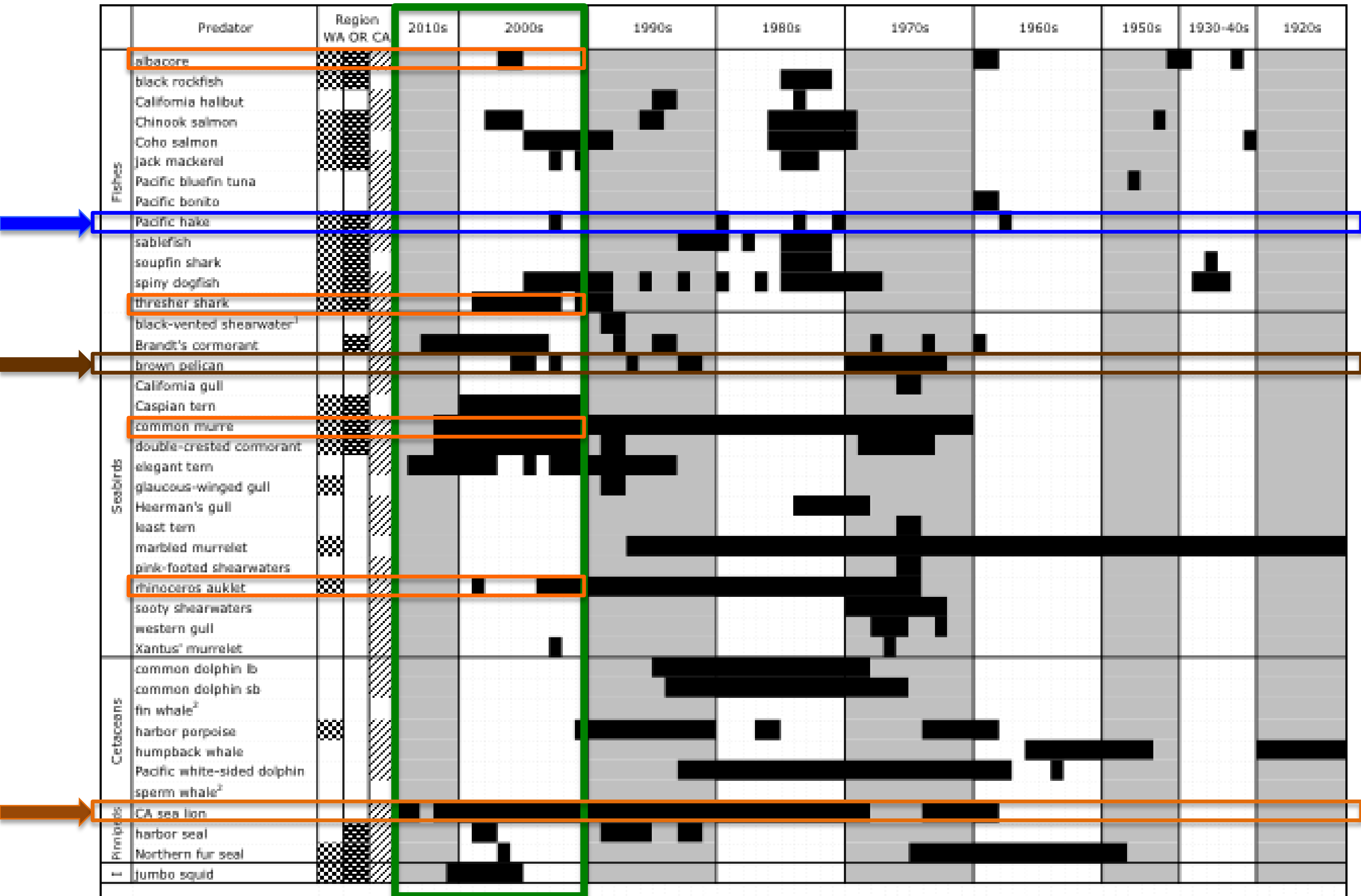


20 of 43 preds only have diet data for one region

From 2000 forward only 20 of 43 preds w/ diet data

Only 4 preds with recent and regional diet data

Szoboszlai et al. (2015) *Ecological Informatics* 29: 45



More spatio-temporal considerations

- Diet averages lose resolution crucial to the scale of predator-prey interaction

Temporal - predators have to survive through extremes

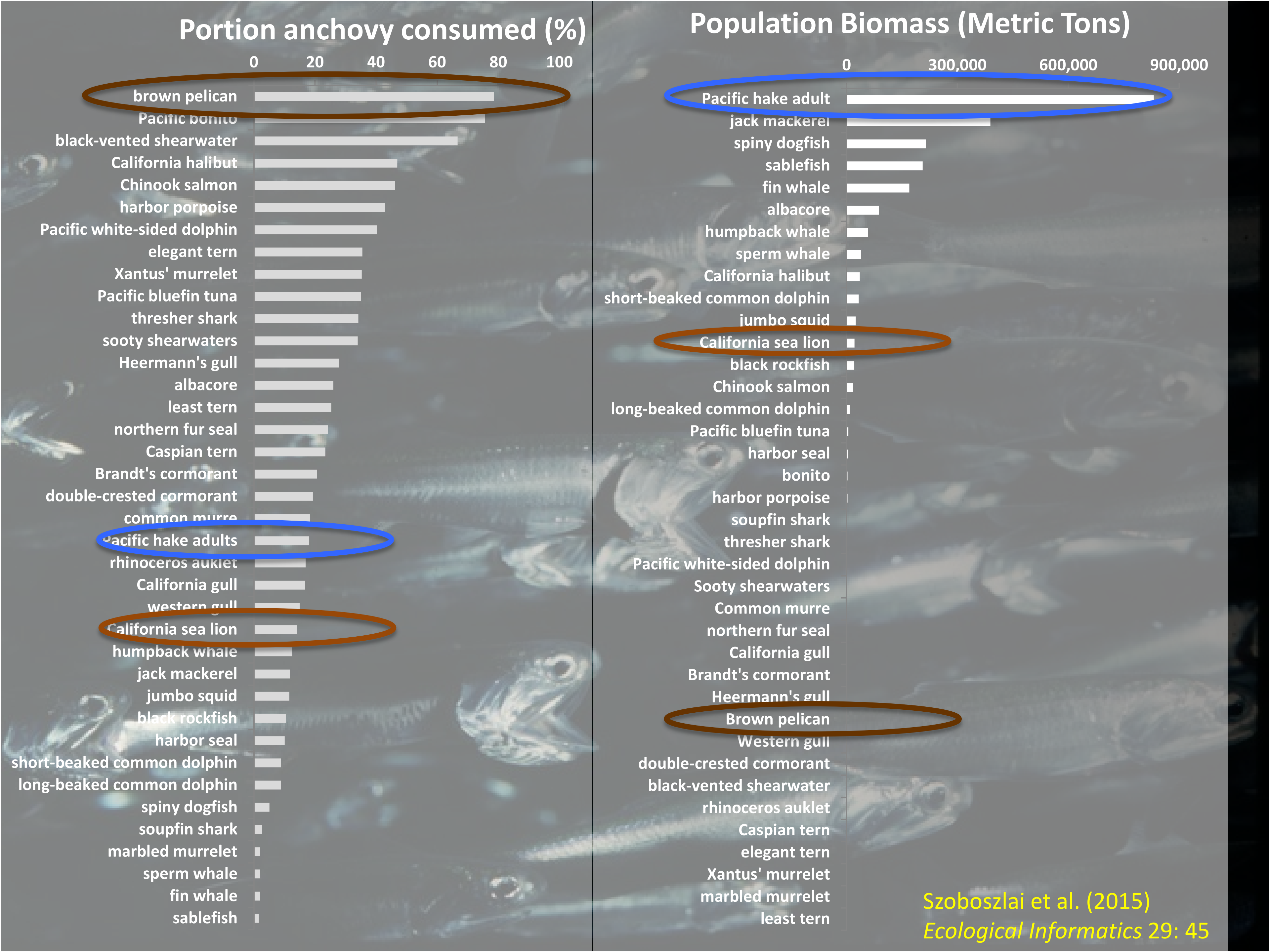
- seasonal prey pulses may be swamped when averaging at annual level
- annual variability is obscured when averaging over multiple years

Spatial - prey may spatially be available in one area but not adjacent area

- What climate regime or top-down pressures?
  - e.g., 1960s-70s predator diet when sardine absent from CCE should not be used as "status quo"
  - TGAMS to investigate changes in predator-prey relationships through time

Changes in predator-prey relationships

- What happens when a prey disappears?
  - Predators can buffer (don't immediately die), but seabirds may be more sensitive
  - Seabirds more tightly coupled to prey resource
    - spatially (breeding colonies, migration routes near land for roosting)
    - size-limiting gape
- Prey-switching *(intra-seasonal to inter-annual)*
- Fundamental changes in predator-prey relationships through time



Portion anchovy consumed (%)
0
20
40
60
80
100
brown pelican
Pacific bonito
black-vented shearwater
California halibut
Chinook salmon
harbor porpoise
Pacific white-sided dolphin
elegant tern
Xantus' murrelet
Pacific bluefin tuna
thresher shark
sooty shearwaters
Heermann's gull
albacore
least tern
northern fur seal
Caspian tern
Brandt's cormorant
double-crested cormorant
common murre
Pacific hake adults
rhinoceros auklet
California gull
western gull
California sea lion
humpback whale
jack mackerel
jumbo squid
black rockfish
harbor seal
short-beaked common dolphin
long-beaked common dolphin
spiny dogfish
soupfin shark
marbled murrelet
sperm whale
fin whale
sablefish
Population Biomass (Metric Tons)
0
300,000
600,000
900,000
Pacific hake adult
jack mackerel
spiny dogfish
sablefish
fin whale
albacore
humpback whale
sperm whale
California halibut
short-beaked common dolphin
jumbo squid
California sea lion
black rockfish
Chinook salmon
long-beaked common dolphin
Pacific bluefin tuna
harbor seal
bonito
harbor porpoise
soupfin shark
thresher shark
Pacific white-sided dolphin
Sooty shearwaters
Common murre
northern fur seal
California gull
Brandt's cormorant
Heermann's gull
Brown pelican
Western gull
double-crested cormorant
black-vented shearwater
rhinoceros auklet
Caspian tern
elegant tern
Xantus' murrelet
marbled murrelet
least tern
Szoboszlai et al. (2015)
Ecological Informatics 29: 45

Diet data quality

- Scientific Coverage *(number of studies)*
- Sample Size *(aggregate samples among studies)*
- Spatial Coverage
- Temporal Coverage

Data Rich *(relatively)*	**Data Poor**
Brown pelican	Long-beaked common dolphin
Pacific white-sided dolphin	Short-beaked common dolphin
Harbor porpoise	Fin whale
Common murre	Humpback whale
California sea lion	Sperm whale
	Sooty shearwater

Estimate diet composition

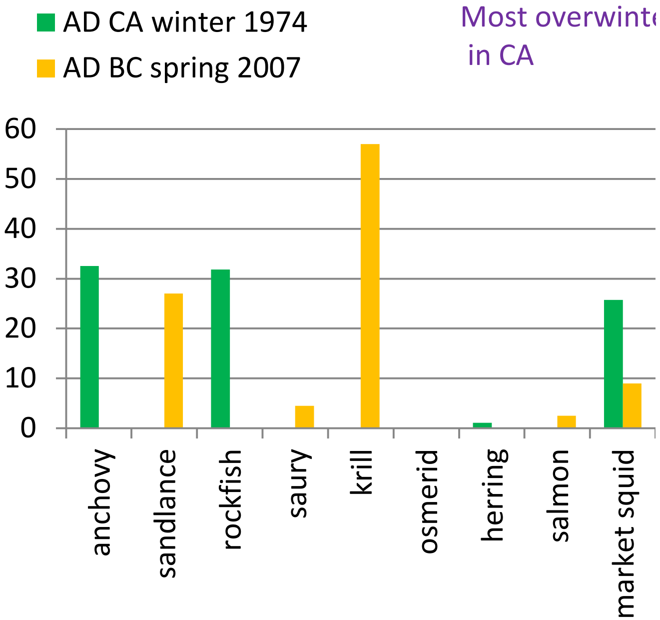
- Characterize all diet studies by predator age/stage, region, specific location, year, season, decade

- Decide on taxonomic resolution of interest for each prey based on lowest denominator between studies (*e.g., species, genus, family;* DO NOT USE higher taxonomic categories)

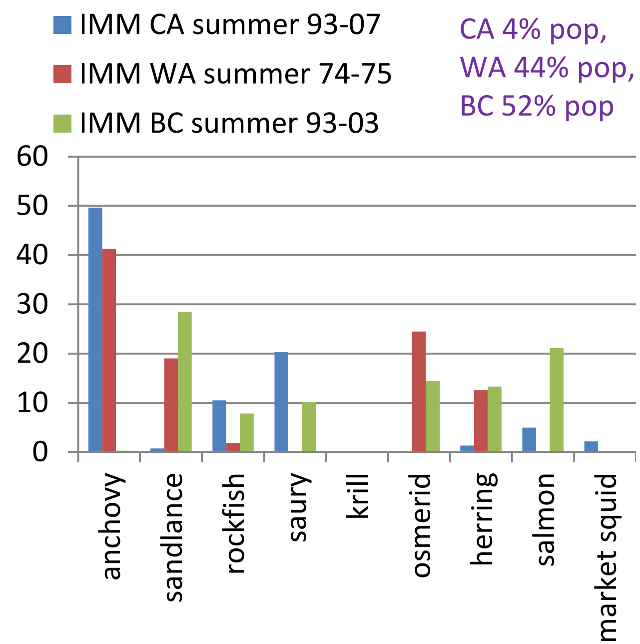
- Need %Mass (used %N if similar-sized prey consumed, or limited use of scaled %FO – sea lions soCA)

- Weighted averaging in certain order by specific locations/regions, seasons/years/decades, and across life stages, then scaling diet data relative to predator population distribution

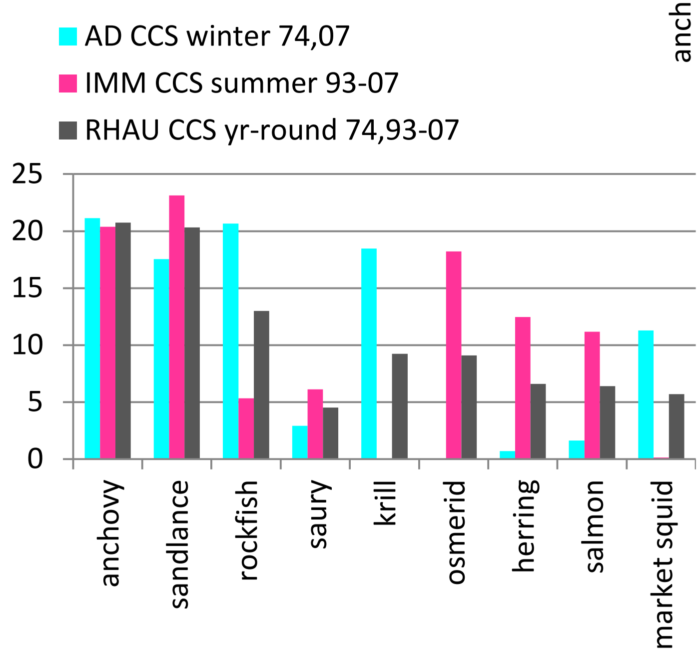
CCE seabird example



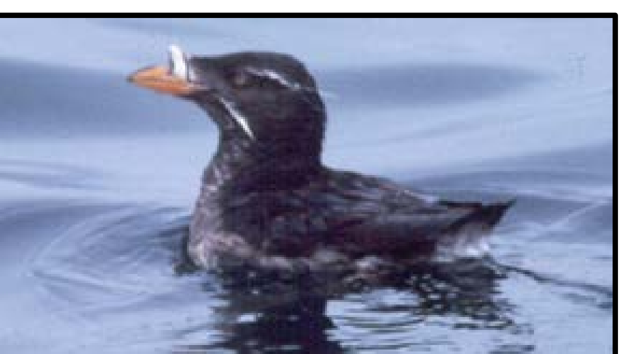
Most overwinte
in CA



CA 4% pop,
WA 44% pop,
BC 52% pop



Rhino auklet



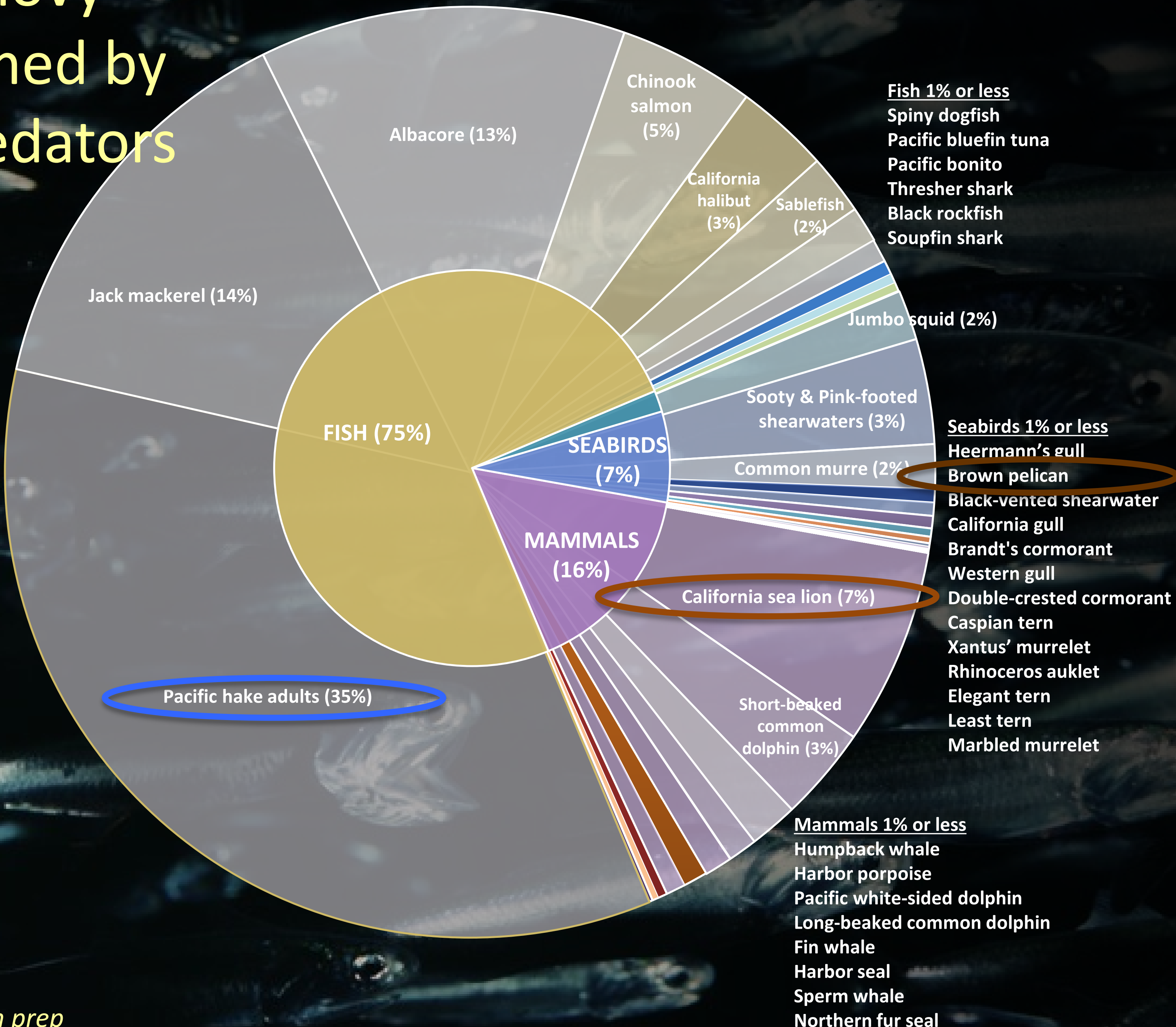
Diet - Maximum likelihood estimation

Ainsworth et al. (2010) Ecological Applications 20: 2188

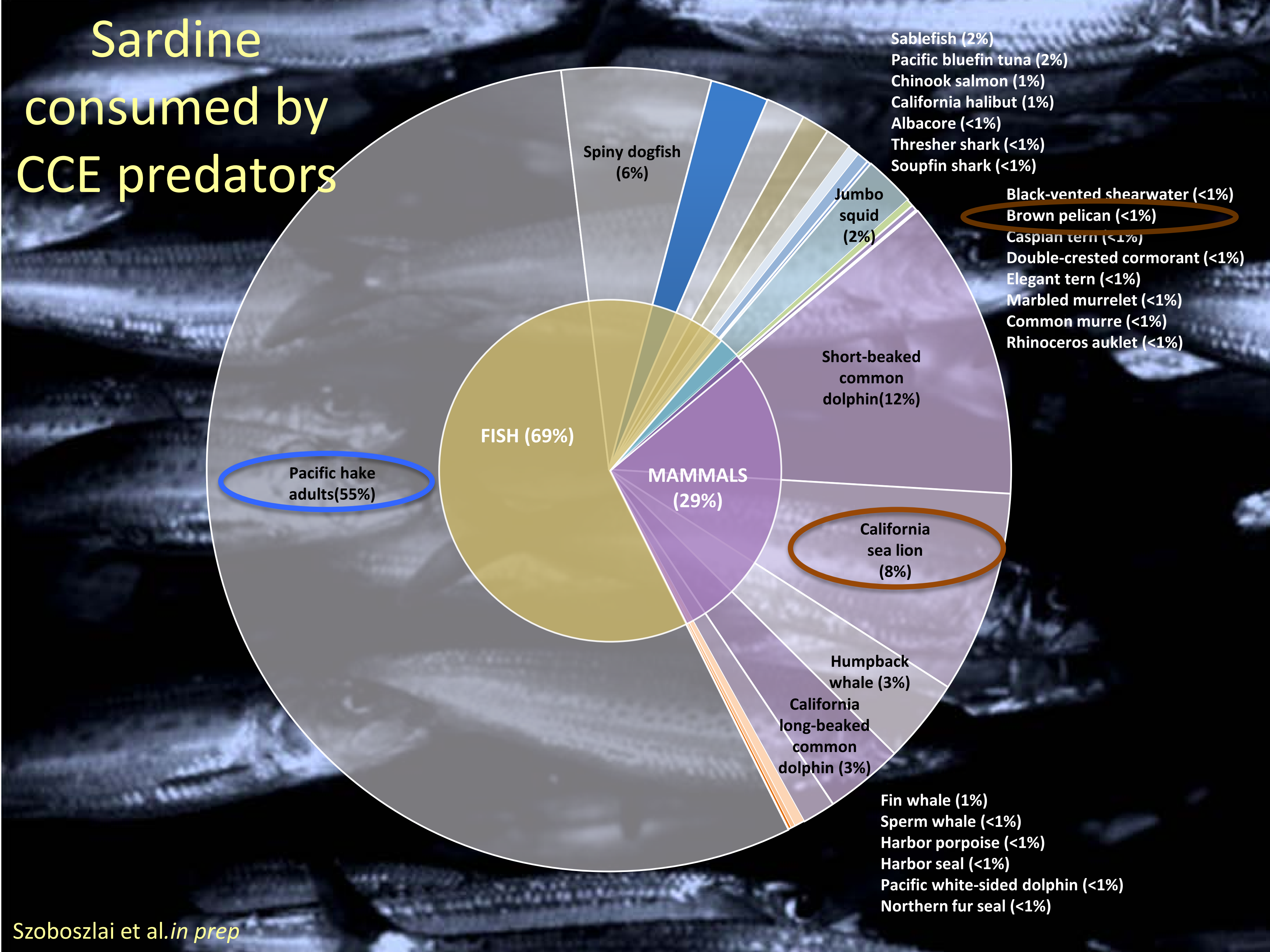
- Diet information (field samples & literature) averaged across samples to represent an average predator
- Data bootstrapped to generate likelihood profiles
- Liklihood profiles fit to Dirichlet function
- From resulting marginal distributions, MLEs are generated with confidence intervals representing the likely contribution to diet for each predator–prey combination

- Compared to the common method of straight averaging, the MLE method
  - is less influenced by rare prey so better suited to small data sets
  - consistently predicts higher contributions to predator diet for major prey (> 12% of predator diet) and lower contributions for minor prey

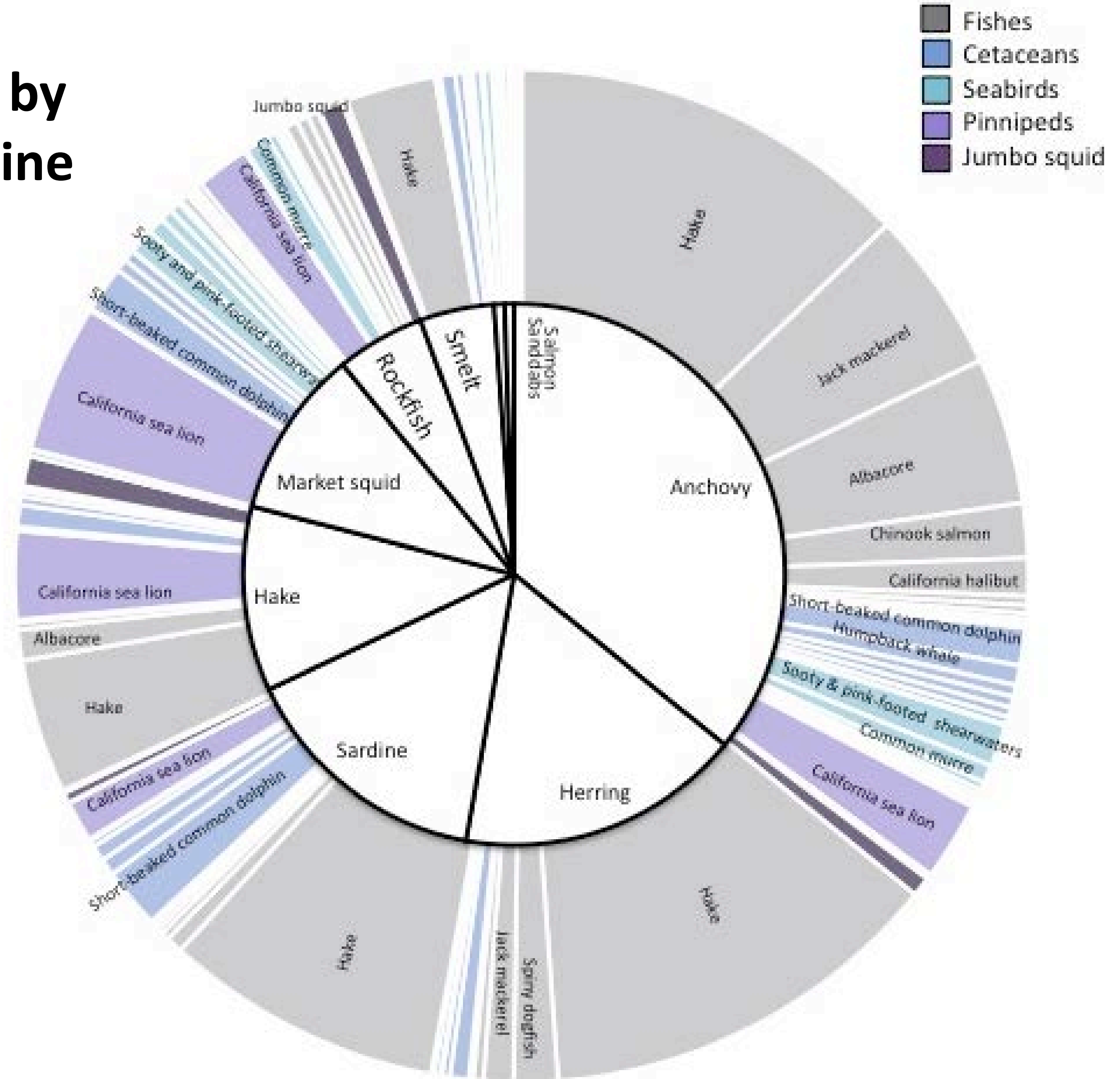
Anchovy consumed by CCE predators



Szoboszlai et al. *in prep*


Sardine consumed by CCE predators
Sablefish (2%)
Pacific bluefin tuna (2%)
Chinook salmon (1%)
California halibut (1%)
Albacore (<1%)
Thresher shark (<1%)
Soupfin shark (<1%)
Black-vented shearwater (<1%)
Brown pelican (<1%)
Caspian tern (<1%)
Double-crested cormorant (<1%)
Elegant tern (<1%)
Marbled murrelet (<1%)
Common murre (<1%)
Rhinoceros auklet (<1%)
Spiny dogfish (6%)
Jumbo squid (2%)
Short-beaked common dolphin(12%)
FISH (69%)
MAMMALS (29%)
Pacific hake adults(55%)
California sea lion (8%)
Humpback whale (3%)
California long-beaked common dolphin (3%)
Fin whale (1%)
Sperm whale (<1%)
Harbor porpoise (<1%)
Harbor seal (<1%)
Pacific white-sided dolphin (<1%)
Northern fur seal (<1%)
Szoboszlai et al. *in prep*

Other top consumption by anchovy/sardine predators



Szoboszlai et al. *in prep*

Caveats

- This model demonstrates potential for overall consumption, and relative consumption between predators *(not useful for results of consumption amounts, because uses average over time)*
  - Which predator species are most important to model in detail

- Model is most sensitive to which parameter?
  - **Diet data?** *Some predators have no diet data in this ecosystem*
  - **Population?** *Perhaps for marine mammals (high-biomass individuals), but maybe not as sensitive for seabirds (low-biomass)*

… BUT, IT'S A FISH'S WORLD OUT THERE, IN TERMS OF CONSUMPTION!

Model comparisons

BIOENERGETIC **CONSUMPTION vs.** ***THRESHOLD*** **PREY IN OCEAN**

(MANY SPP.) **(FEW SPP. – data intensive)**

- Prey thresholds needed for predator production may be orders of magnitude higher than bioenergetic predator consumption

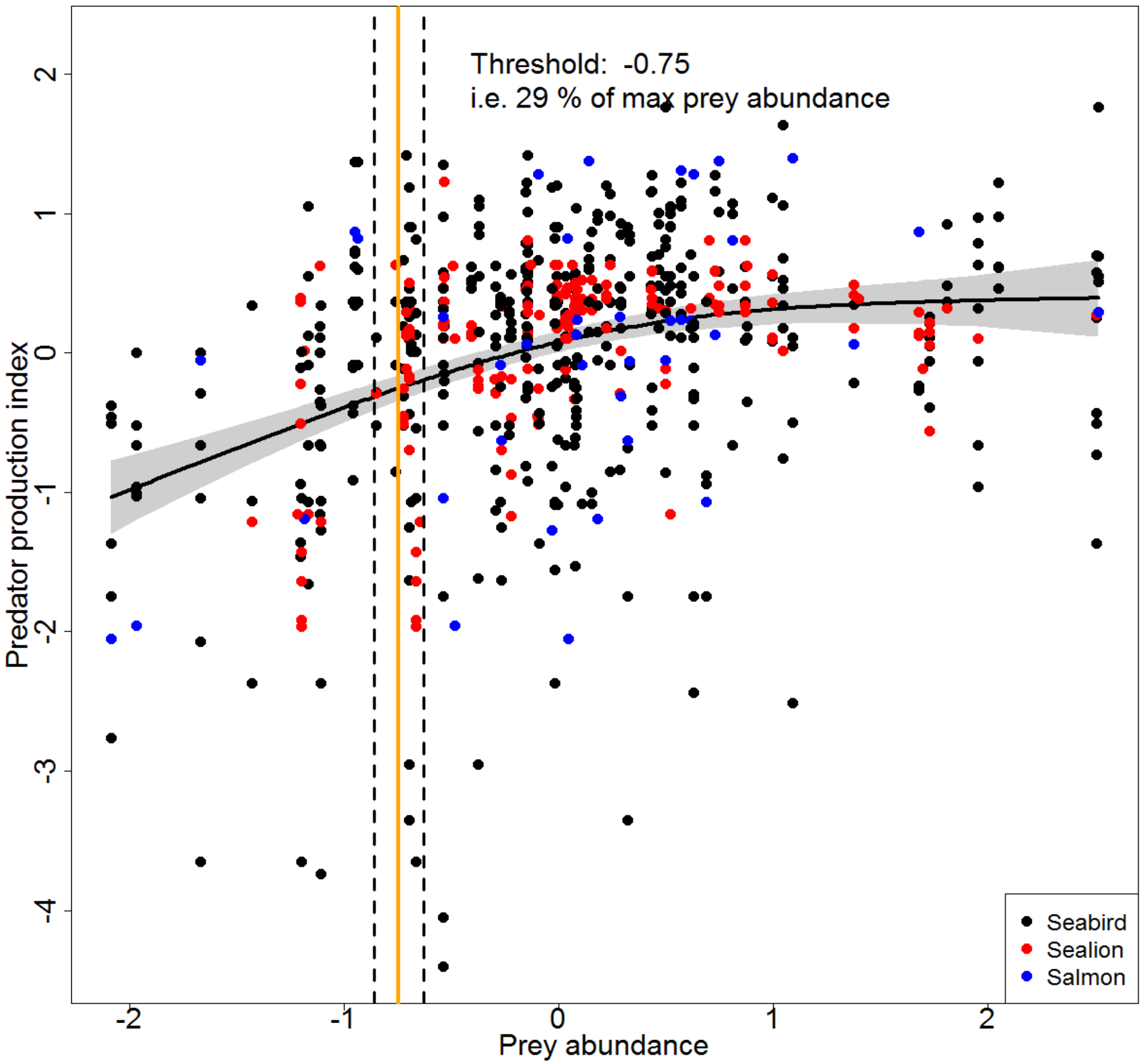
- Shown for seabirds - *Arctic skuas, North Atlantic* - consume ~65 MT/yr sandeel yet require ~30,000 MT sandeel in the system to prevent decline in productivity (*R. Furness et al*.)

- Discrepencies likely due to schooling and patchy distribution of forage fish *(i.e., minimum abundances for schools to form, for predators to encounter schools, for predators to be successful at capture)*

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

Cury et al. 2011

Thayer et al. in review



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

Conclusions

- This model important for big picture
  - Consumption by predator community
  - Which predators to focus on for more detailed models, how those may be scaled upwards to community level
- Don't just average the diet
  (VERY different than weighting spatio-temporal, ontogenetic differences)
- Changes in predator-prey relationships through time
- Sensitivity analysis to determine most important parameters overall?
- Put bioenergetic models into context

Acknowledgements

**Authors of the 193 citations included in the database **

Collaborators

Spencer Wood, Stanford University
Sarah Ann Thompson, Farallon Institute
Kristin Marshall, University of Washington
Laura Koehn, University of Washington
Isaac Kaplan, NOAA
Tim Essington, University of Washington

Funders

The Pew Charitable Trusts
The Marisla Foundation
The National Fish and Wildlife Foundation

Seabird Abundance Data shared by:

1) US Fish and Wildlife Service, 2013, Oregon Seabird Colony Database – computer database and Colony Status Record Archives, USFWS, Oregon Coast National Wildlife Refuge, Newport, Oregon, 97365
2) Vandenburg Airforce Base
3) Washington Department of Fish and Wildlife