Towards trait-based modeling for albacore tuna predator-prey interactions under climate change in the NE Pacific

Dr. Natasha Hardy

Postdoc in Biological Sciences @ U Alberta, AB, Canada

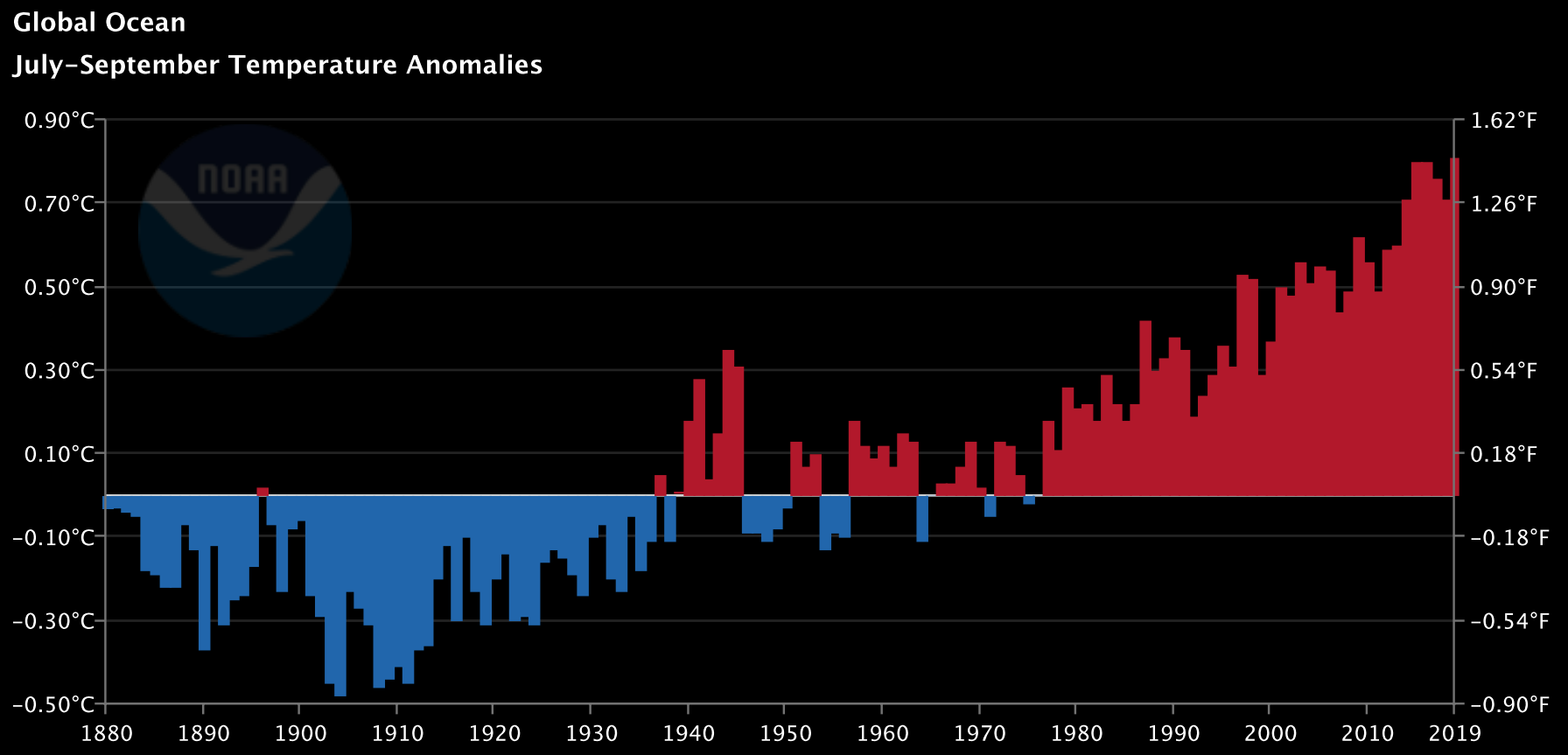
& Hopkins Marine Station @ Stanford, CA, USA

Collaboration with NOAA Environmental Research Division @ Monterey, CA, USA

LENFEST OCEAN PROGRAM

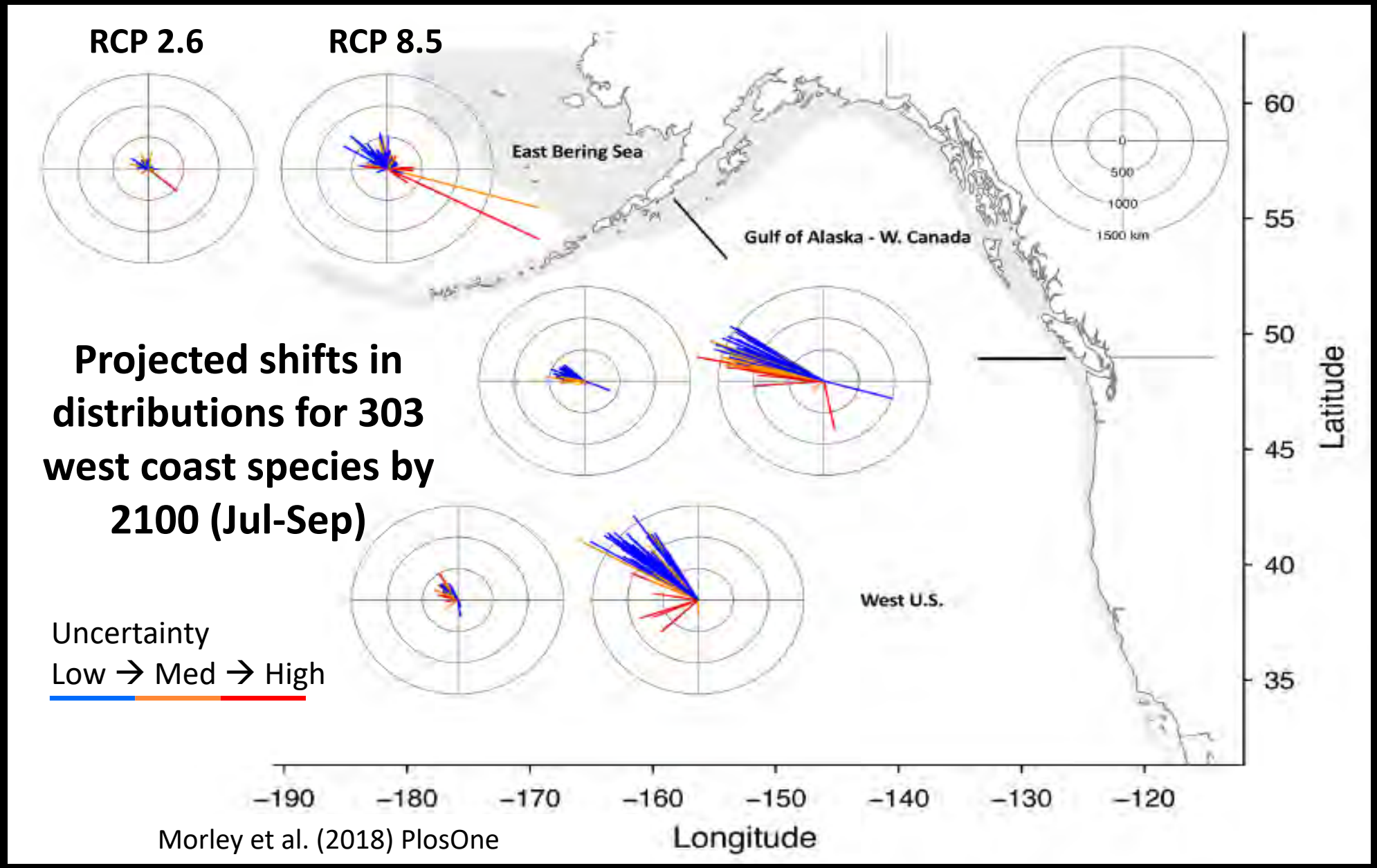
AQUATIC GLOBAL CHANGE ECOLOGY & CONSERVATION

Within a context of increasing climatic variability and warming mean climate states…



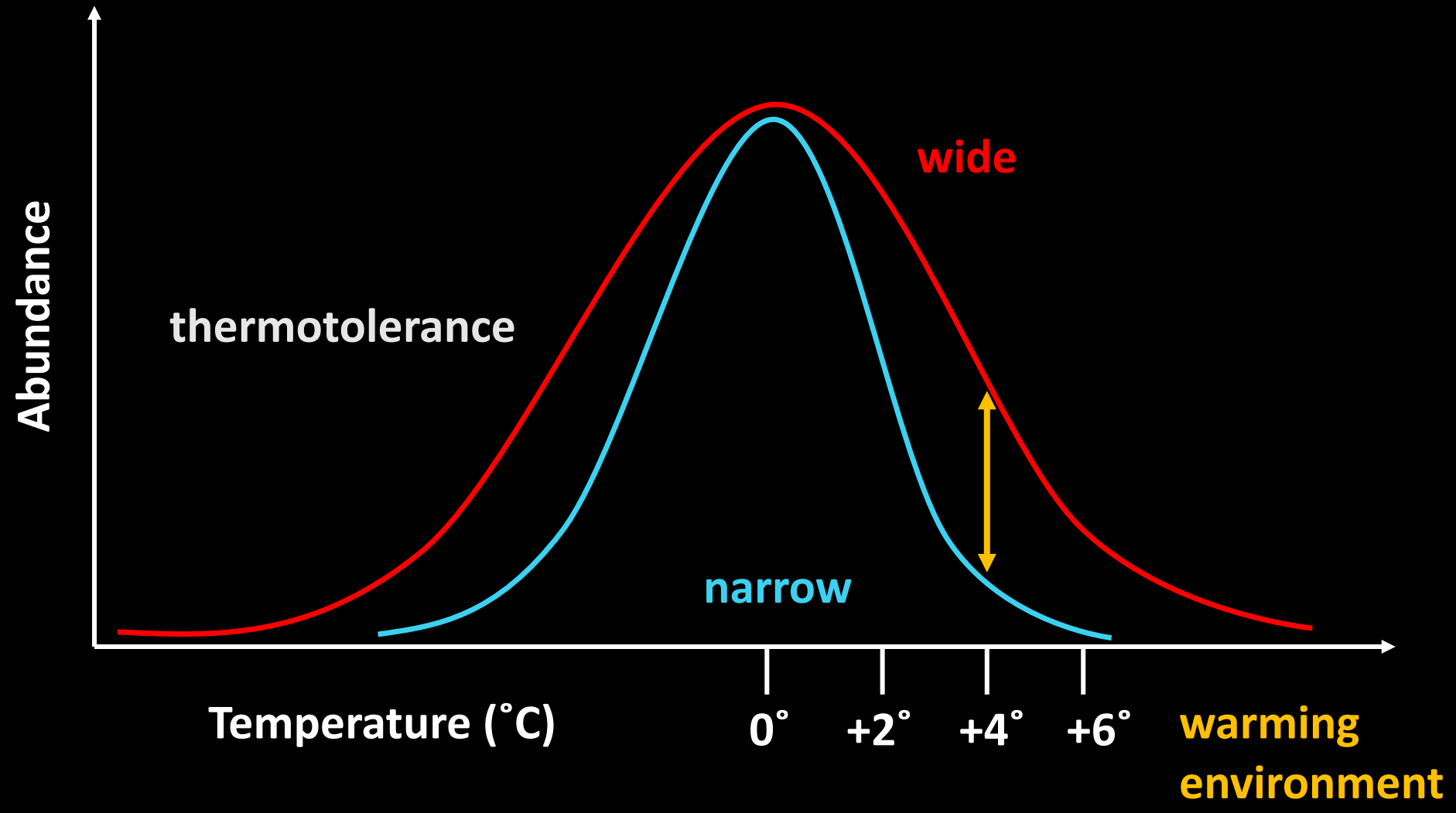
NOAA > Global climate series > Climate at a glance > Jul–Sep

…and shifts in thermal habitat causing species redistributions



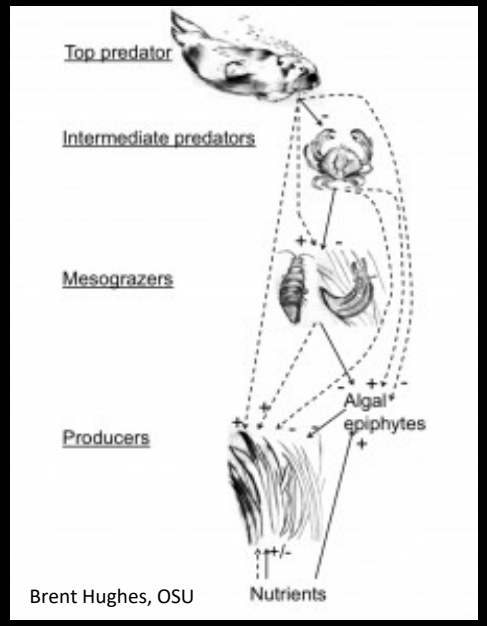
Morley et al. (2018) PlosOne

Use of traits to model species' vulnerability to climate change



But what about species effects on each other?

Predator-prey interactions from the coast to the open ocean



Brent Hughes, OSU


John Healey, Vancouver Aquarium

Albacore tuna as indicators for climatic & ecological change

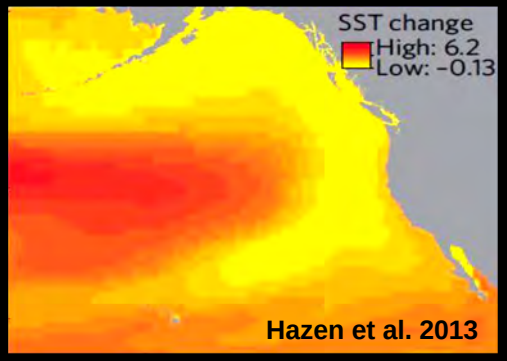
LENFEST OCEAN PROGRAM

- ❑ Albacore tuna as ecosystem samplers
- ❑ Move beyond taxonomy
- ❑ Identify trait-based parameters for diet shifts vs. environmental gradients
- ❑ Apply those parameters to project for future ecological & environmental change

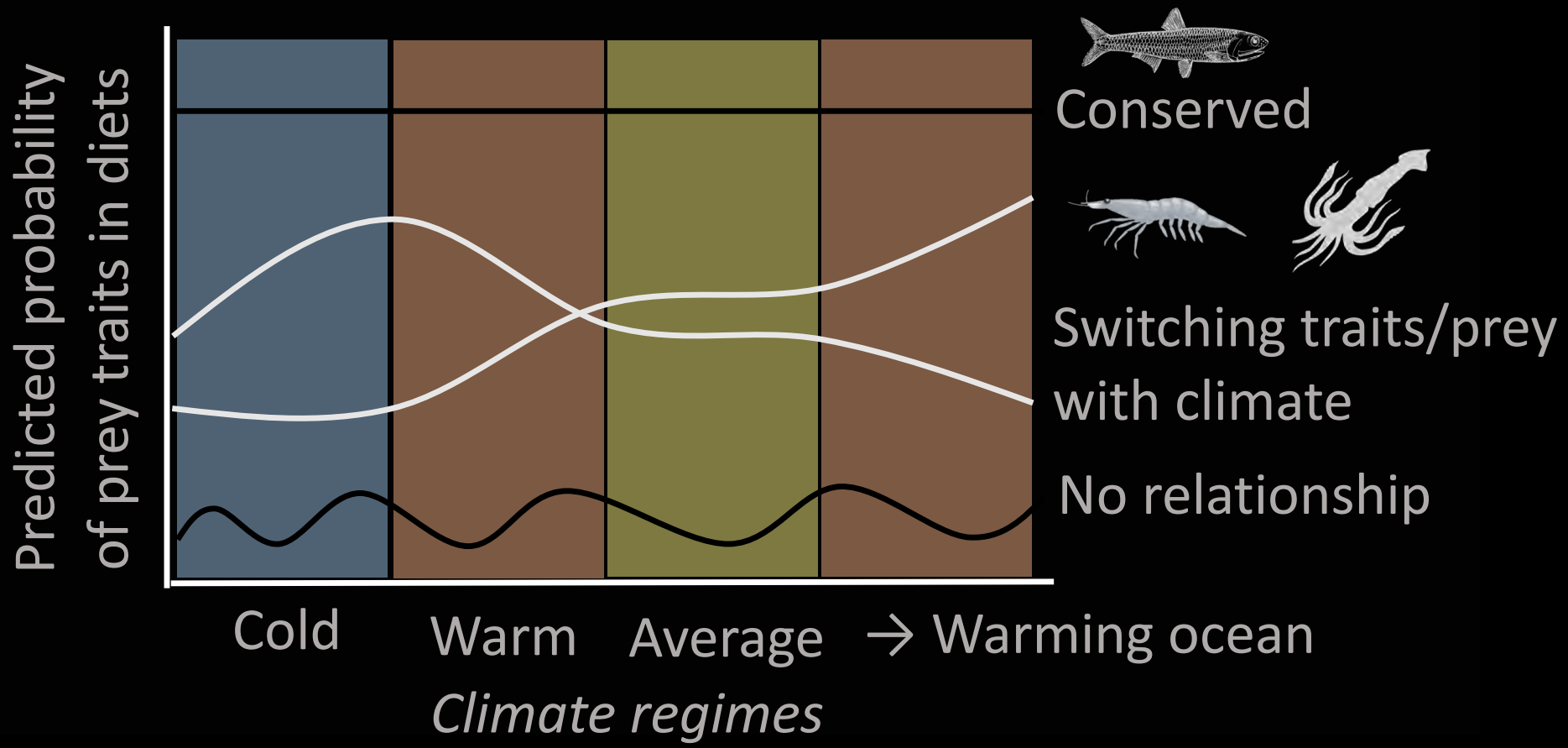
Albacore tuna as indicators for climatic & ecological change

LENFEST OCEAN PROGRAM

- ✓ Broad & variable diet composition across environmental gradients
- ✓ HMS – tracking change in thermal habitats
- ✓ Commercially valuable – NE Pacific with cross-jurisdictional CAN-US Treaty

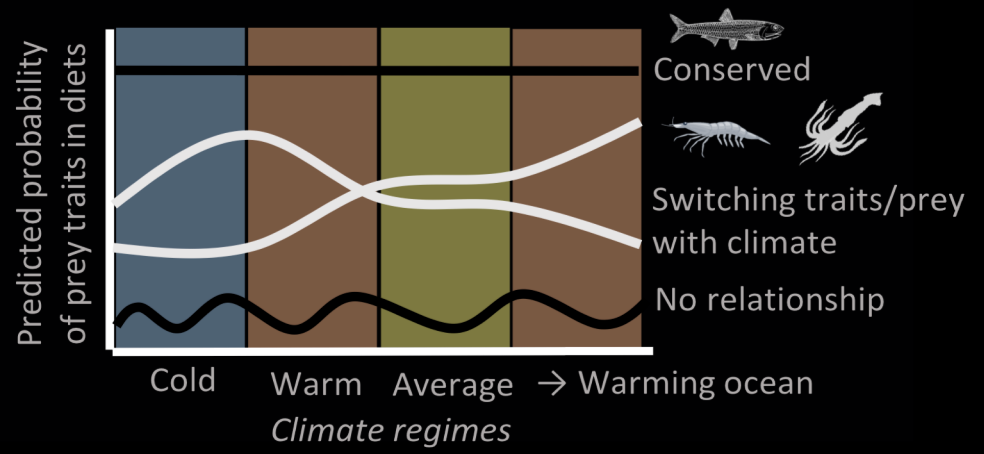


Trait-based predictions for future change

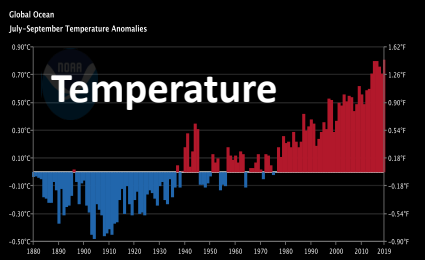


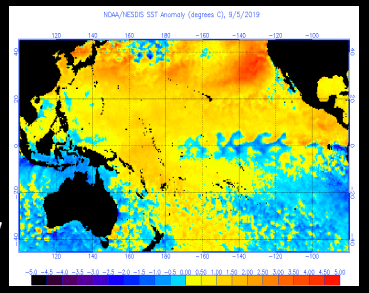
Towards trait-based predictions for future change

trait * environment relationship



Environment

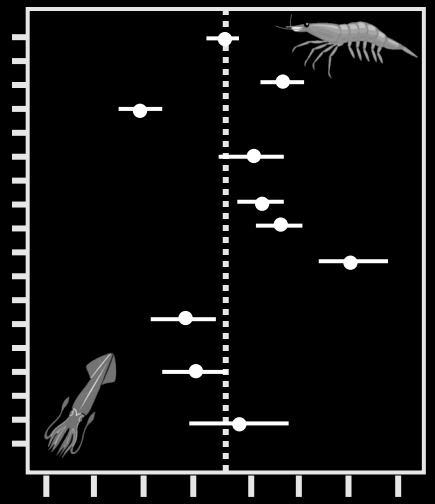




Geography

+

Predictive traits



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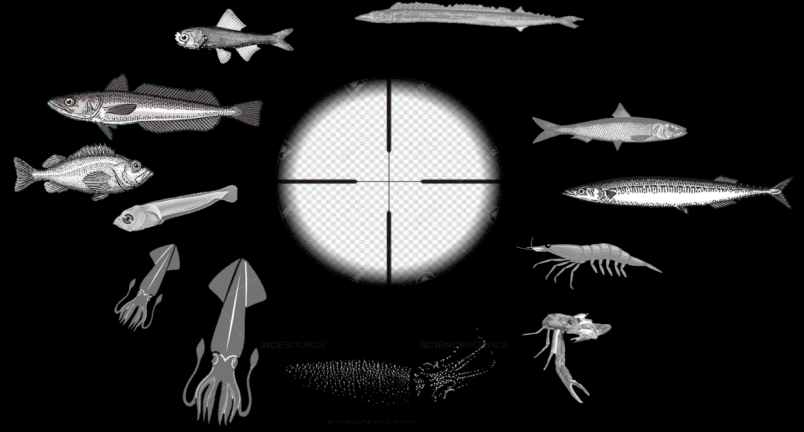
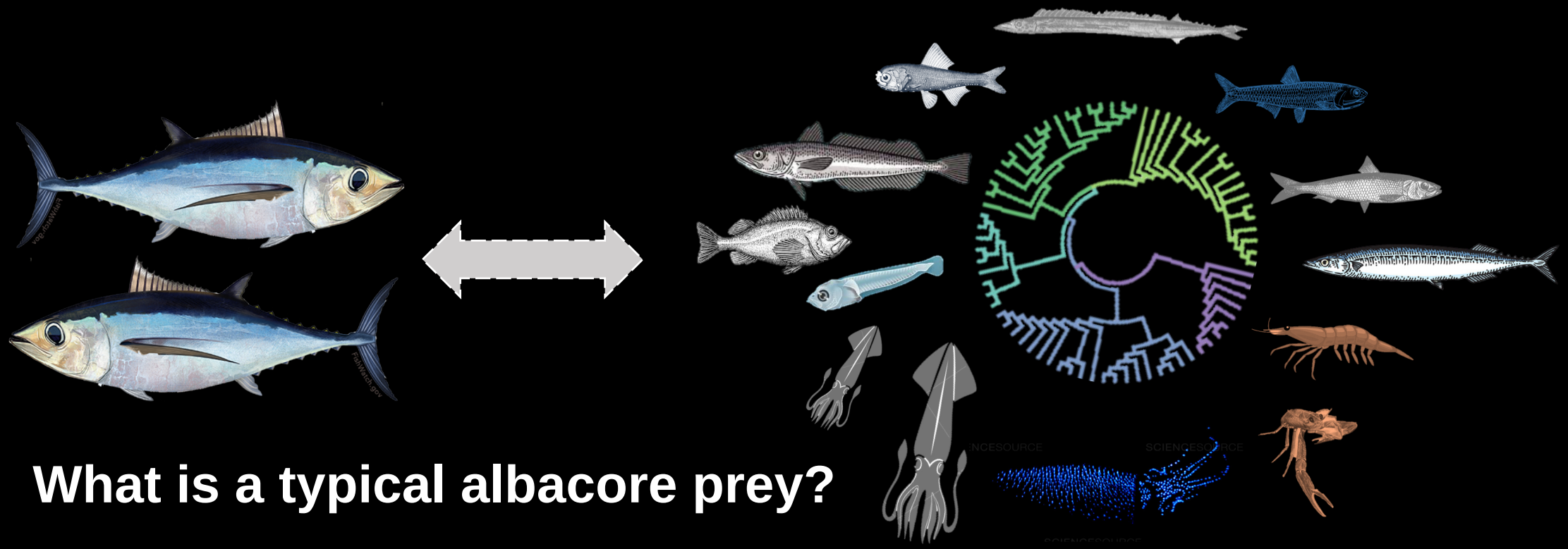
Taxonomic diet information



Not so fast…



- What is a typical albacore prey?
- Which strong predictors for diet shifts?

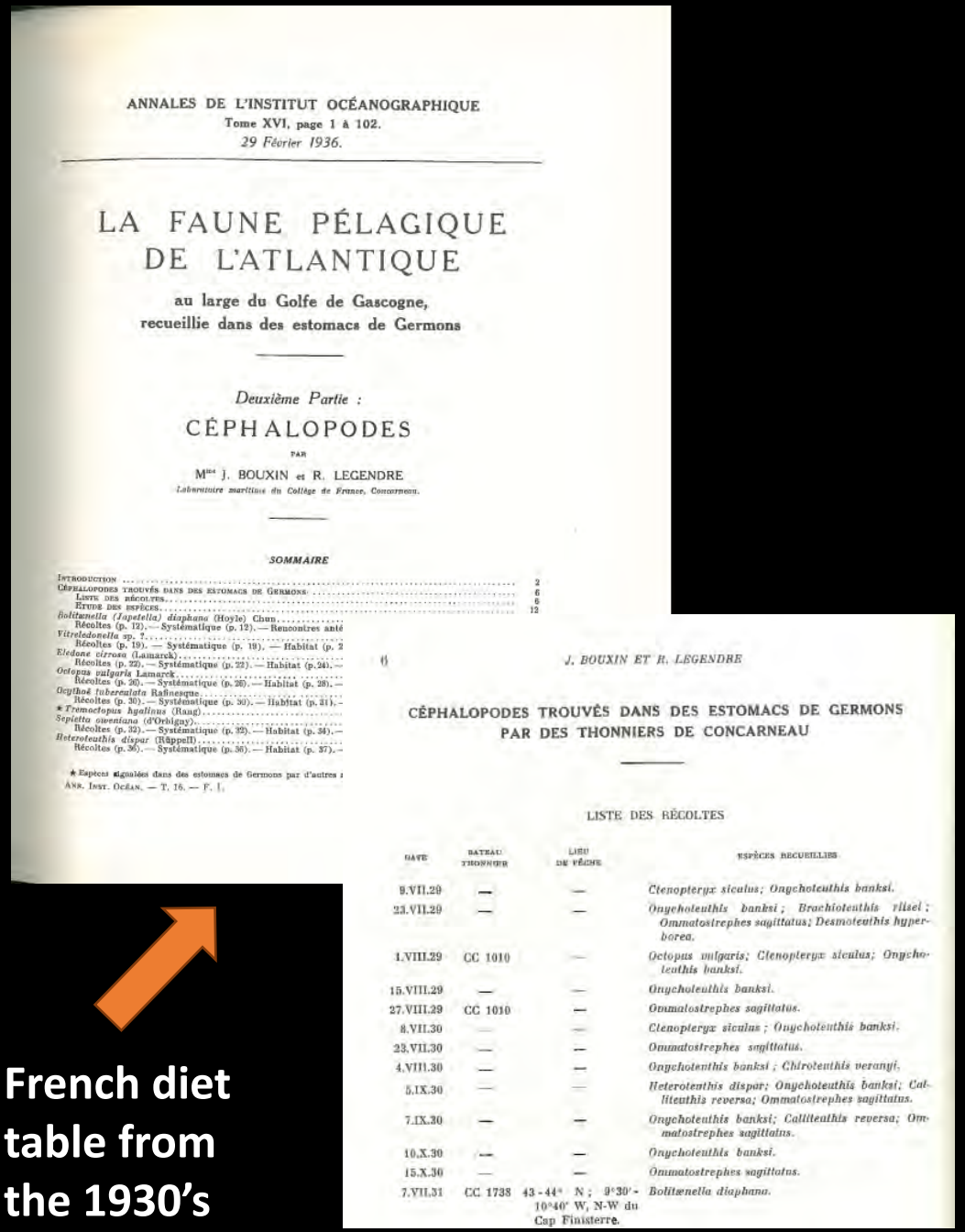
What is a typical albacore prey?

Global, historical review of albacore diets from late 1880's to early 2000's

Table S5. Metrics showing prey species found in 86 albacore (*Thunnus alalunga*) stomachs in 2008, 2009, and 2010. Metrics are as follows: N is abundance, %N is relative abundance, FO is frequency of occurrence by stomach, %FO is % of stomachs containing that food item. Total mass is mass of prey items estimated from length, otolith size (fish), or beak metrics (cephalopods), and total kJ is estimated from mass using energy density values from Glaser *et al.(7)*. IRI is shown for the 4 most prevalent prey items. A hyphen (–) indicates that metric(s) could not be calculated because species were unidentified; 'nd' ('no data') indicates that conversion algorithms were not available for mass and kJ for that species.

Order/Family	Prey Category	N	%N	FO	%FO	Total mass (g)	Total kJ	IRI
FISHES								
Carangidae	*Trachurus symmetricus*	179	11	35	41	452	2894	23.44
Clupeidae	*Sardinops sagax*	51	3	25	29	122	887	4.97
Engraulidae	*Engraulis mordax*	6	<1	2	2	16	105	
Kyphosidae	*Medialuna californiensis*	1	<1	1	1	nd	nd	
Myctophidae	*Triphoturus mexicanus*	6	<1	6	7	nd	nd	
Scomberesocidae	*Cololabis saira*	7	<1	5	6	<1	3	
Scombridae	*Scomber japonicus*	4	<1	2	2	0.1	1	
Sebastidae	*Sebastes* spp.	29	2	9	10	21	90	
Fishes unid.		111	7	30	35	–	–	
CEPHALOPODS								
Argonautidae	*Argonauta argo*	13	1	8	9	nd	nd	
Enoploteuthidae	*Abraliopsis affinis*	1	<1	1	1	0.1	0.5	
	Abraliopsis felis	19	1	11	13	35	155	
Gonatidae	*Gonatus* spp.	176	11	44	51	154	678	13.50
Loliginidae	*Doryteuthis opalescens*	79	5	3	3	372	1639	
Octopodidae	*Octopus bimaculatus*	24	2	10	12	3	11	
Octopoteuthidae	*Octopoteuthis sicula*	19	1	7	8	10	46	
	Octopoteuthis spp.	2	<1	1	1	1	6	
Ocythoidae	*Ocythoe tuberculata*	1	<1	1	1	nd	nd	
Ommastrephidae	*Dosidicus gigas*	1	<1	1	1	55	240	
Onychoteuthidae	*Onychoteuthis borealijaponica*	17	1	4	5	13	59	
Ceph. unid.		143	9	31	36	–	–	
CRUSTACEA								
Amphipoda	*Hyperiidea* unid	20	1	6	7	nd	nd	
Decapoda	*Pleuroncodes planipes*	2	<1	1	1	3	10	
Euphausiacea	*Euphausiid*	540	33	45	52	384	1190	35.88
Crust. unid.		35	2	5	6	–	–	

Diet table



ANNALES DE L'INSTITUT OCÉANOGRAPHIQUE
Tome XVI, page 1 à 102.
29 Février 1936.

LA FAUNE PÉLAGIQUE DE L'ATLANTIQUE

au large du Golfe de Gascogne, recueillie dans des estomacs de Germons

Deuxième Partie :

CÉPHALOPODES

PAR

M^lles J. BOUXIN et R. LEGENDRE

Laboratoire maritime du Collège de France, Concarneau.

SOMMAIRE

★ Espèces signalées dans des estomacs de Germons par d'autres

ANN. INST. OCÉAN. — T. 16. — F. 1.

6 J. BOUXIN ET R. LEGENDRE

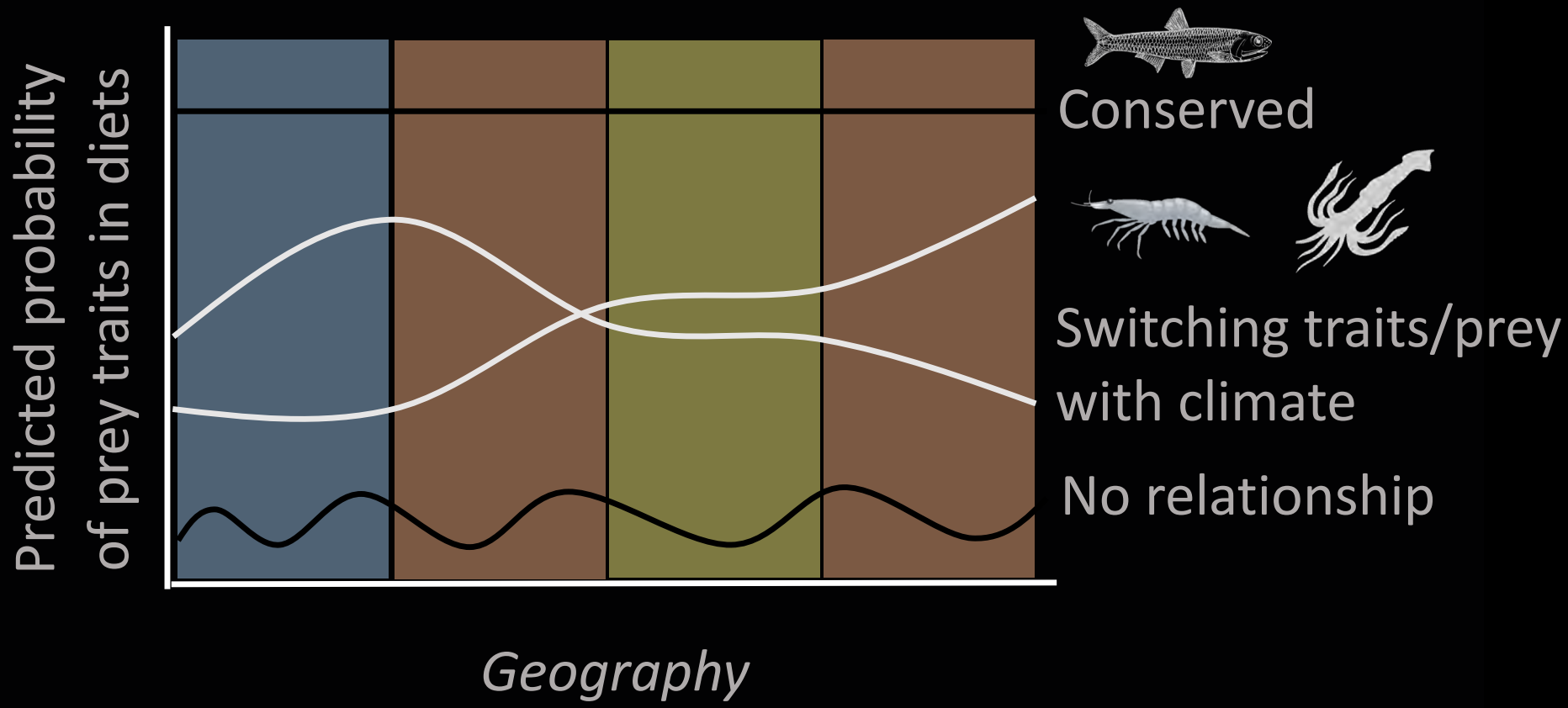
CÉPHALOPODES TROUVÉS DANS DES ESTOMACS DE GERMONS PAR DES THONNIERS DE CONCARNEAU

LISTE DES RÉCOLTES

DATE	BATEAU THONNIER	LIEU DE PÊCHE	ESPÈCES RECUEILLIES
9.VII.29	—	—	*Ctenopteryx siculus; Onycholeuthis banksi.*
23.VII.29	—	—	*Onycholeuthis banksi; Brachioteuthis riisei; Ommatostrephes sagittatus; Desmoteuthis hyperborea.*
1.VIII.29	CC 1010	—	*Octopus vulgaris; Ctenopteryx siculus; Onycholeuthis banksi.*
15.VIII.29	—	—	*Onycholeuthis banksi.*
27.VIII.29	CC 1010	—	*Ommatostrephes sagittatus.*
8.VII.30	—	—	*Ctenopteryx siculus; Onycholeuthis banksi.*
23.VII.30	—	—	*Ommatostrephes sagittatus.*
4.VIII.30	—	—	*Onycholeuthis banksi; Chiroteuthis veranyi.*
5.IX.30	—	—	*Heteroteuthis dispar; Onycholeuthis banksi; Calliteuthis reversa; Ommatostrephes sagittatus.*
7.IX.30	—	—	*Onycholeuthis banksi; Calliteuthis reversa; Ommatostrephes sagittatus.*
10.X.30	—	—	*Onycholeuthis banksi.*
15.X.30	—	—	*Ommatostrephes sagittatus.*
7.VII.31	CC 1738	43-44° N; 9°30'-10°40' W, N-W du Cap Finisterre.	*Bolitænella diaphana.*

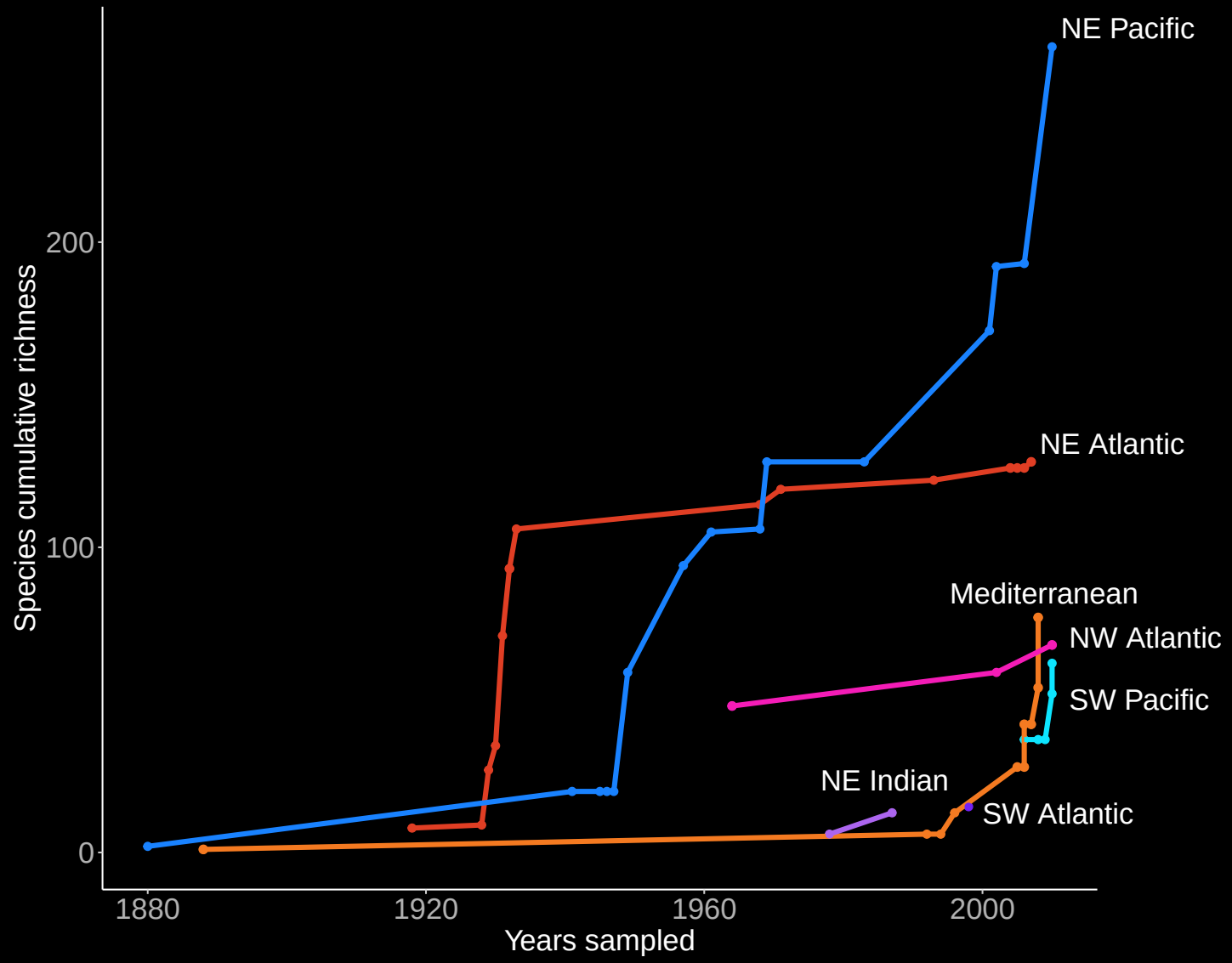
French diet table from the 1930's

Trait-variation in albacore diets across geography

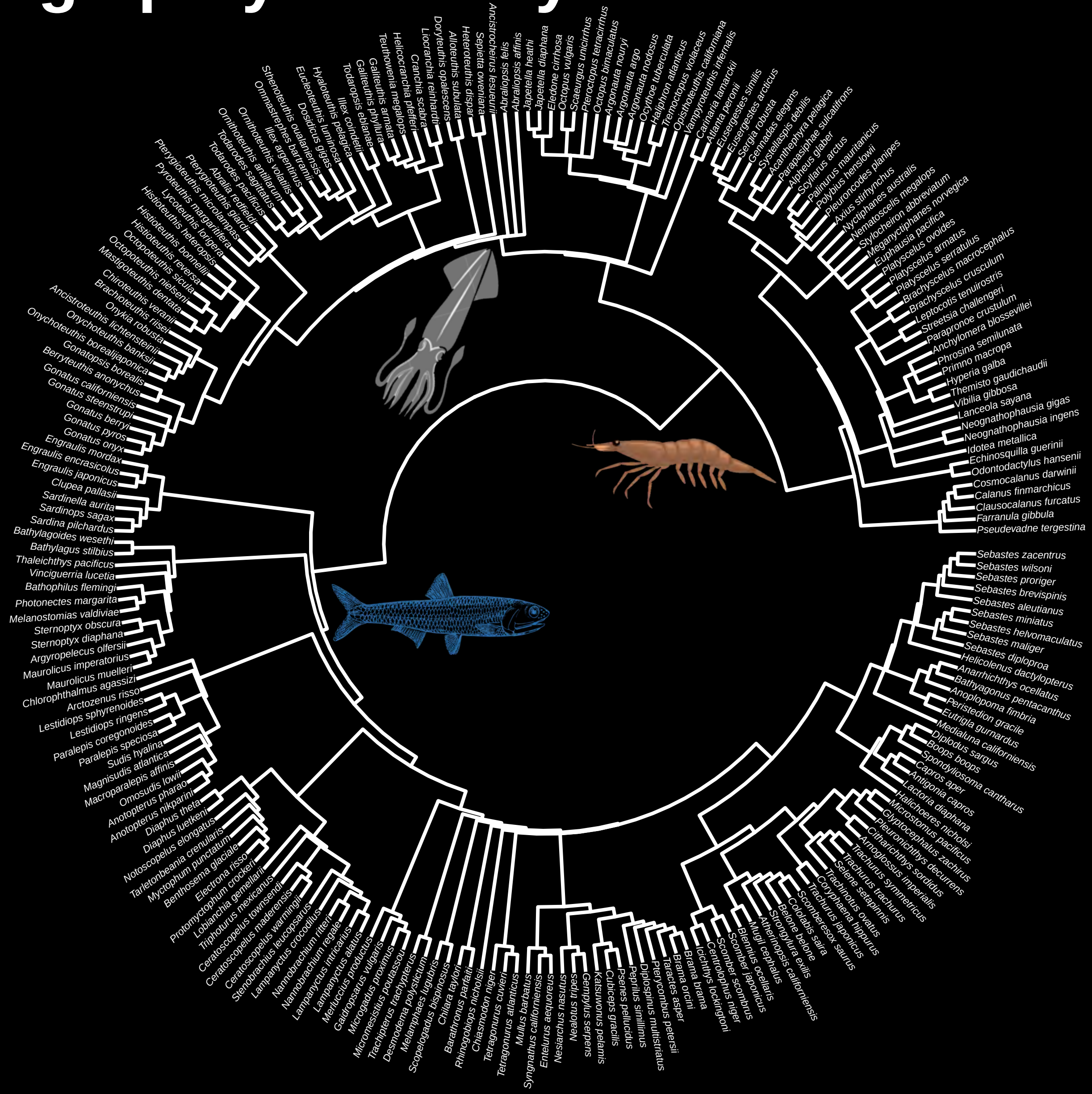


Global historical review of albacore tuna diets

- **31 published papers from 1880's to 2000's**
- **50 unique observations of albacore diet composition**

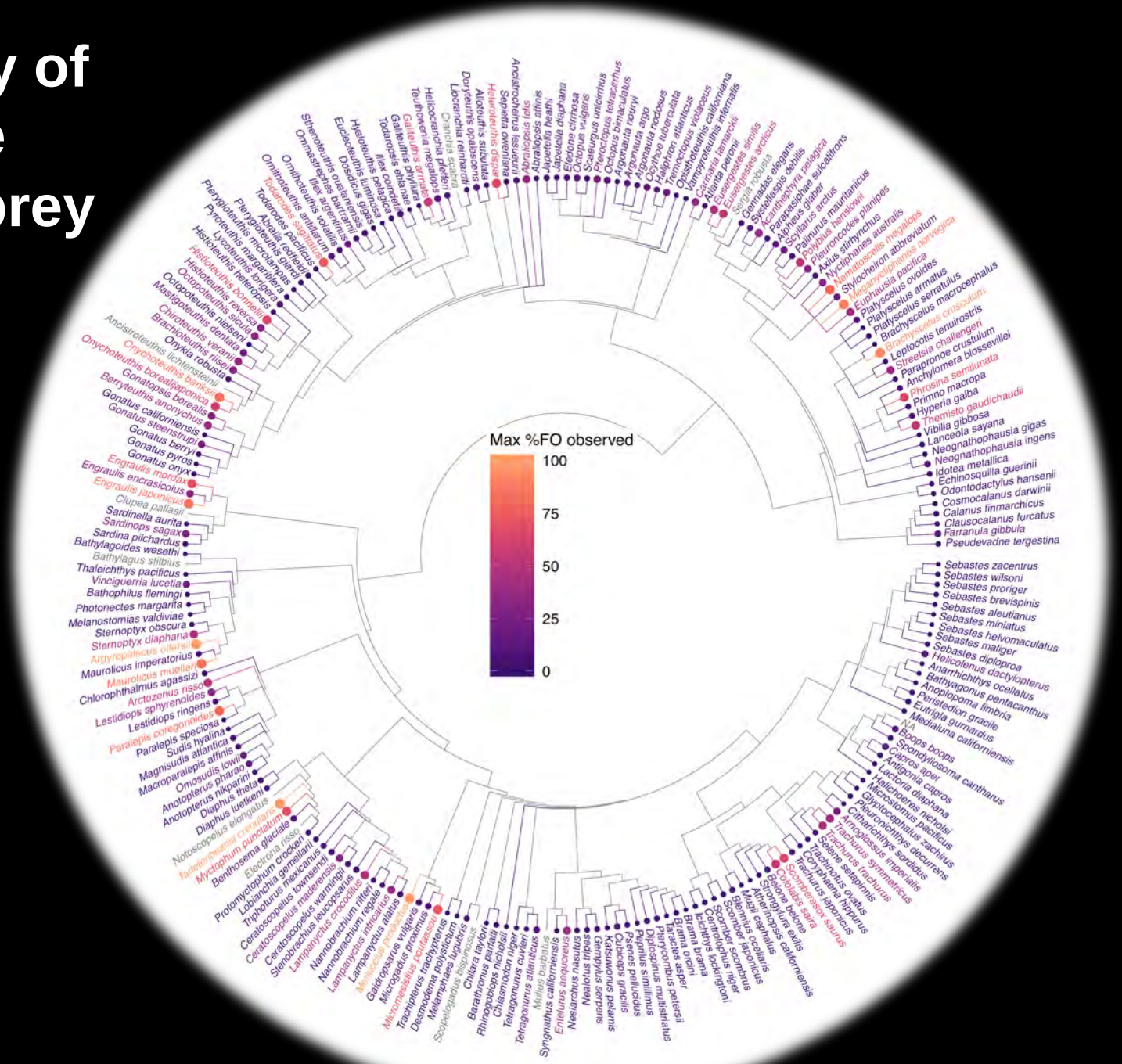


High prey diversity in albacore diets

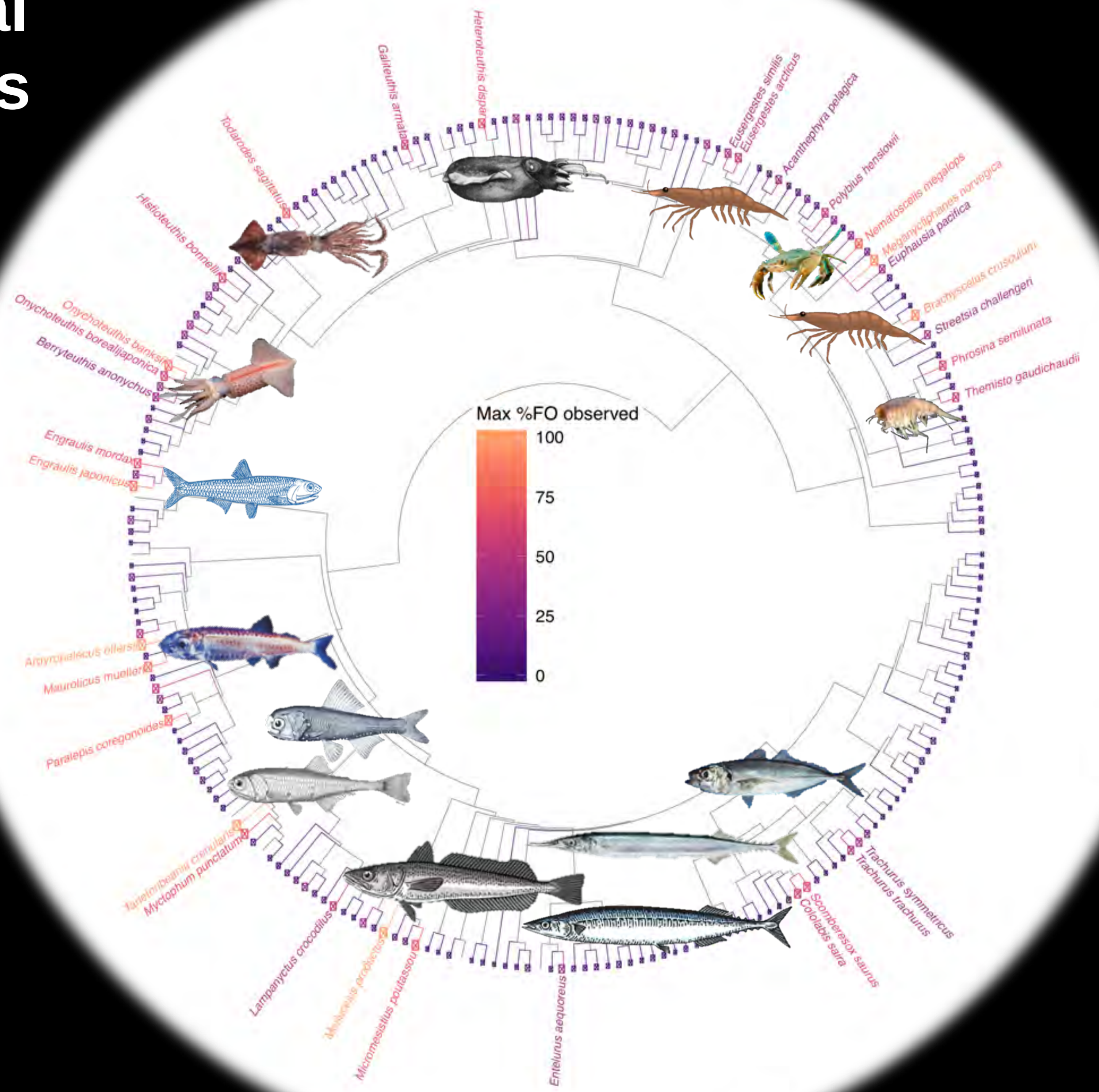


~240 unique species and ~460 unique taxa identified

Max frequency of occurrence observed for prey species

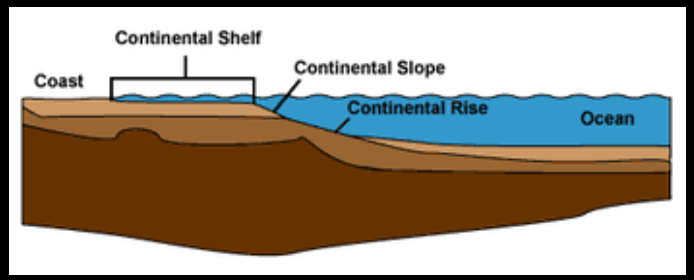


Typical focal prey species



There is a need to model change in complex ecological communities using generalisable traits

Traits for mediating predator-prey interactions



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Habitat position & diel migration

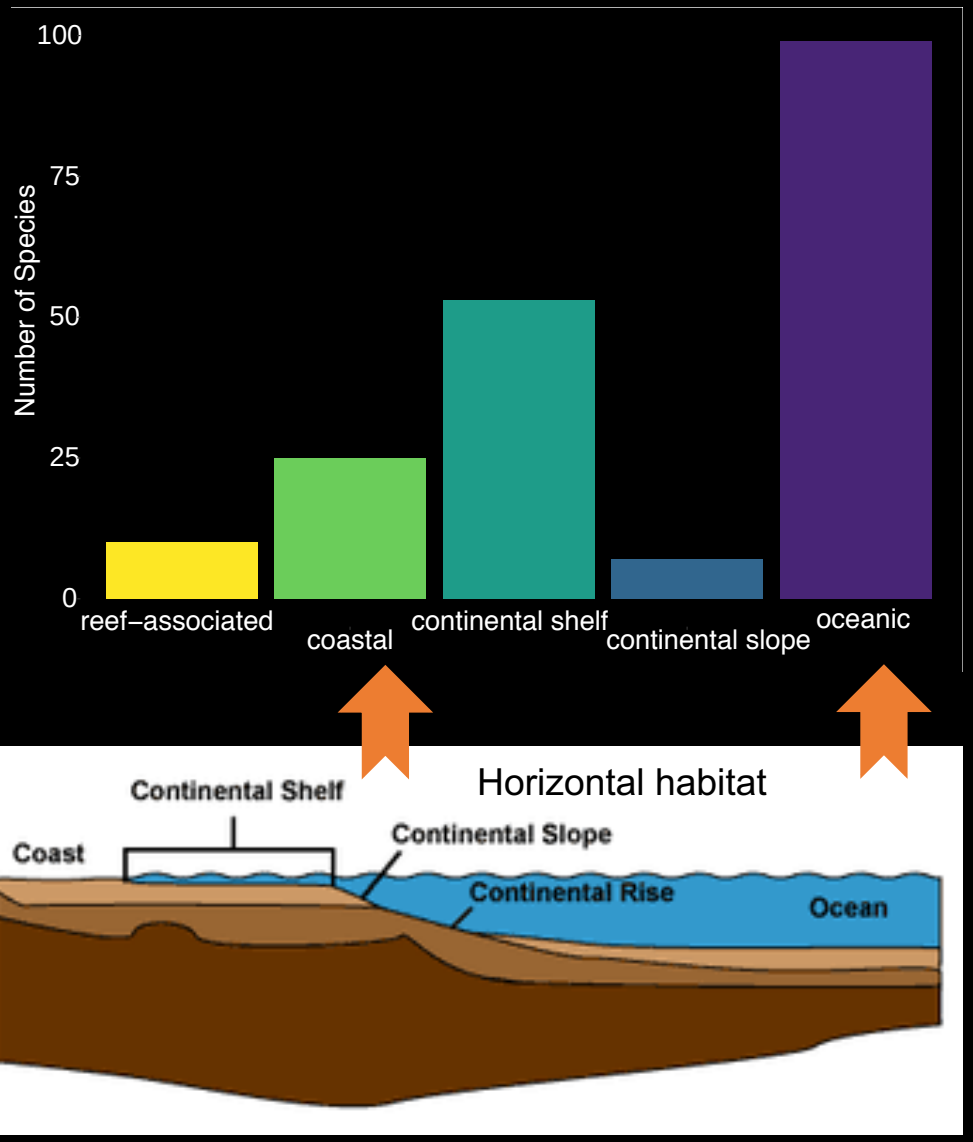
Refuge/ avoidance behaviour

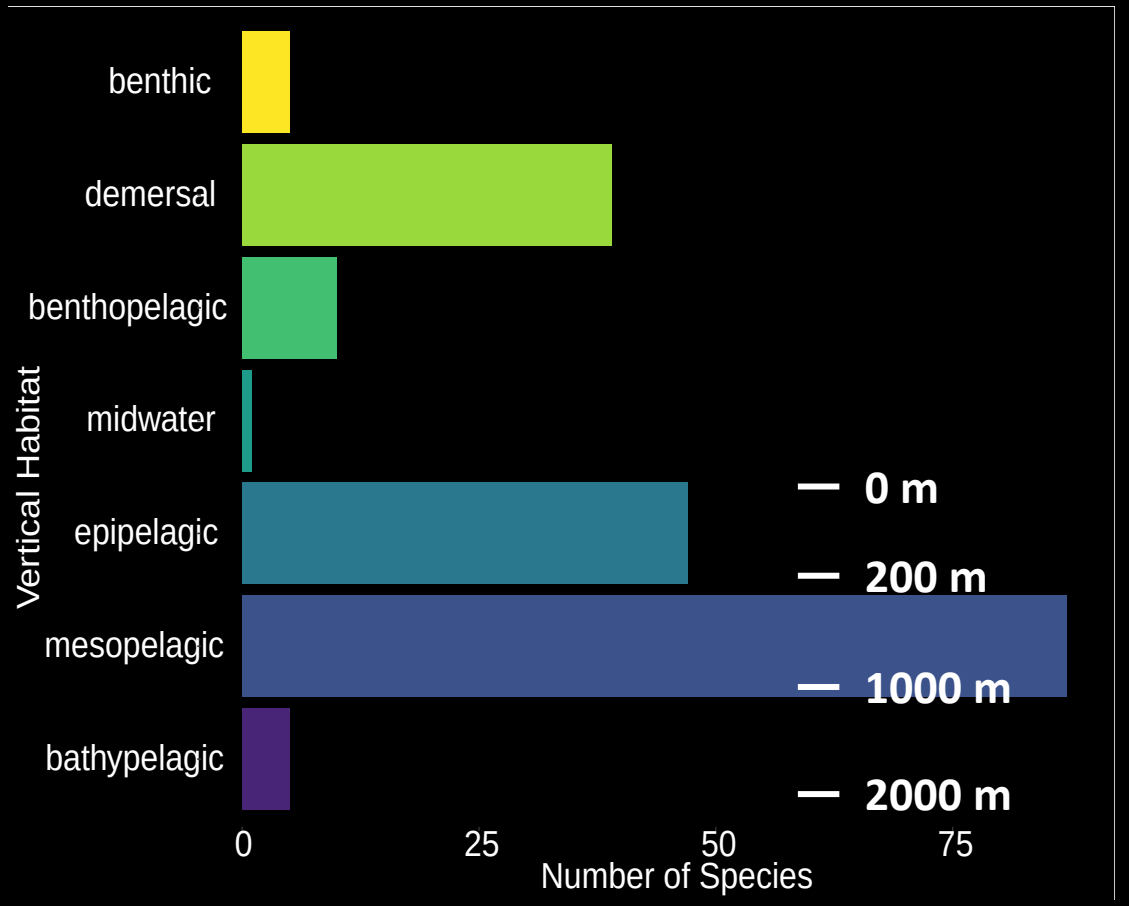
Physical defense

Body shape

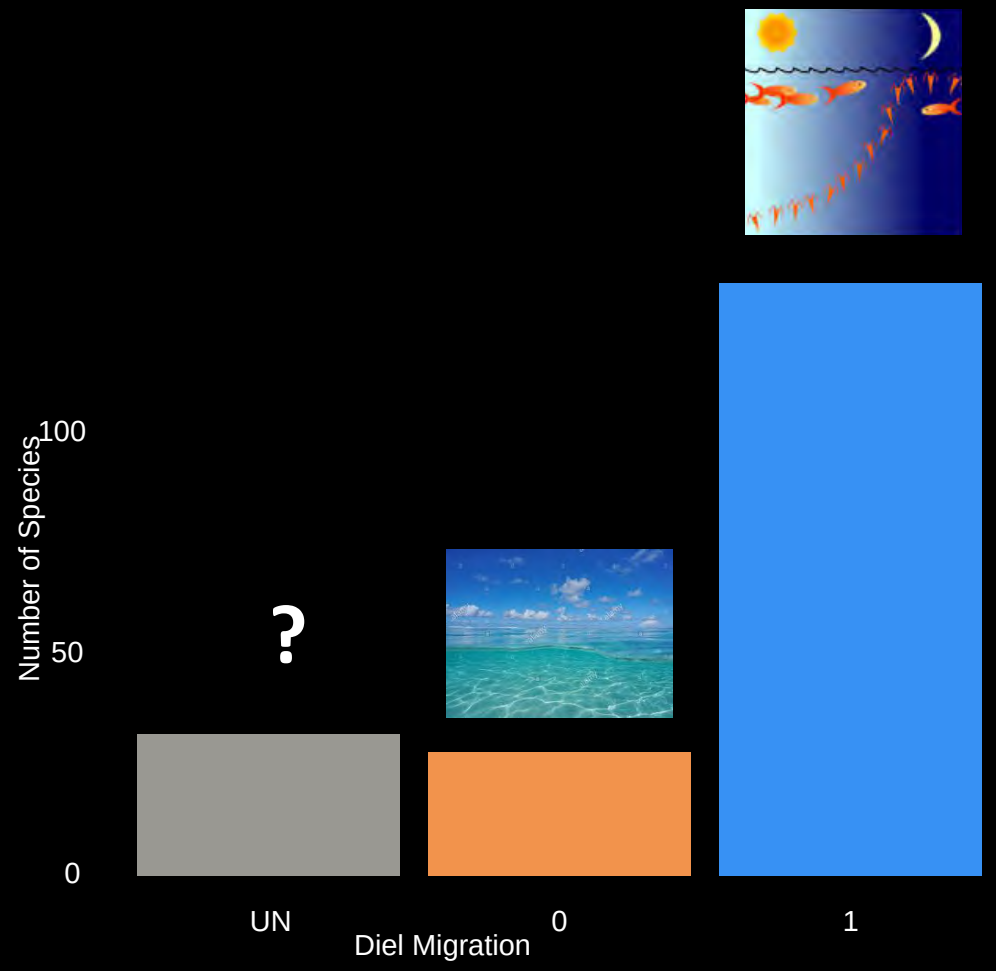
Using published, grey literature & FishBase + SeaLifeBase (Froese & Pauly 2000)

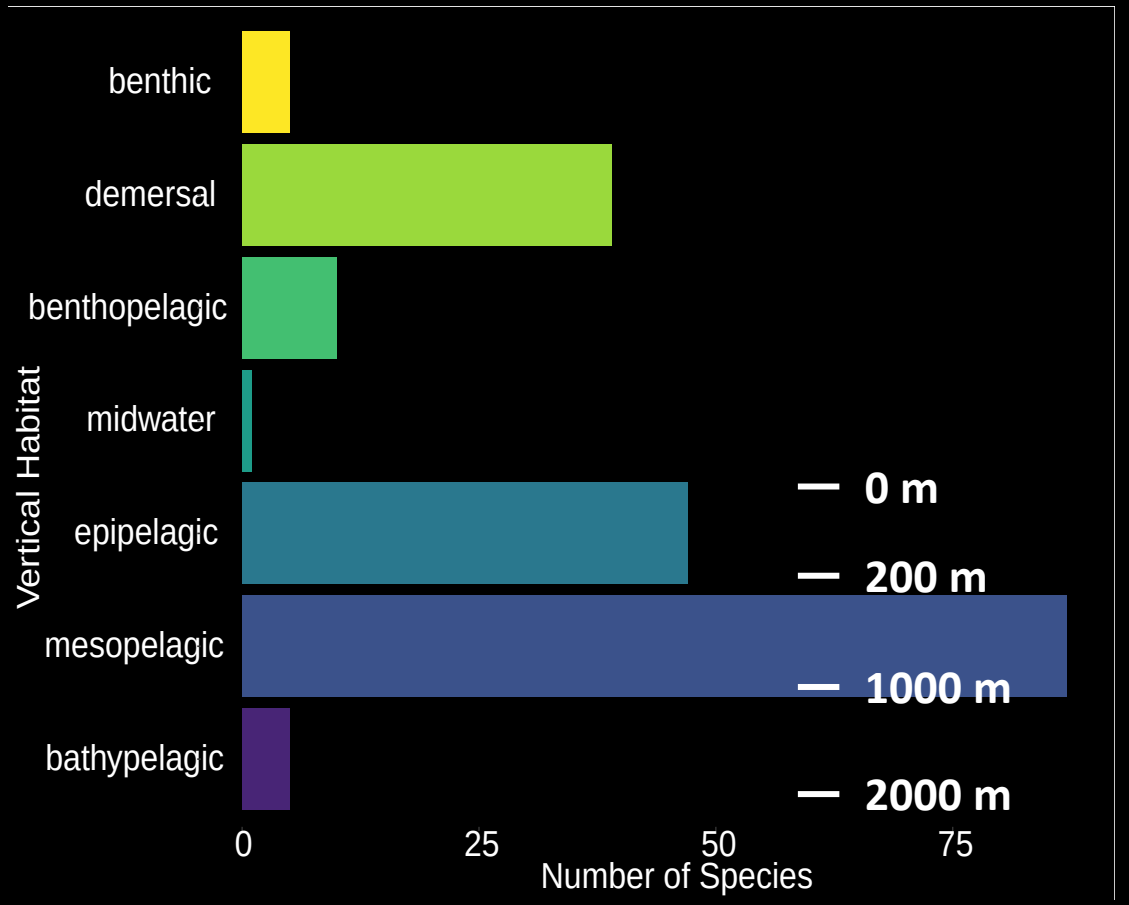
Habitat attributes



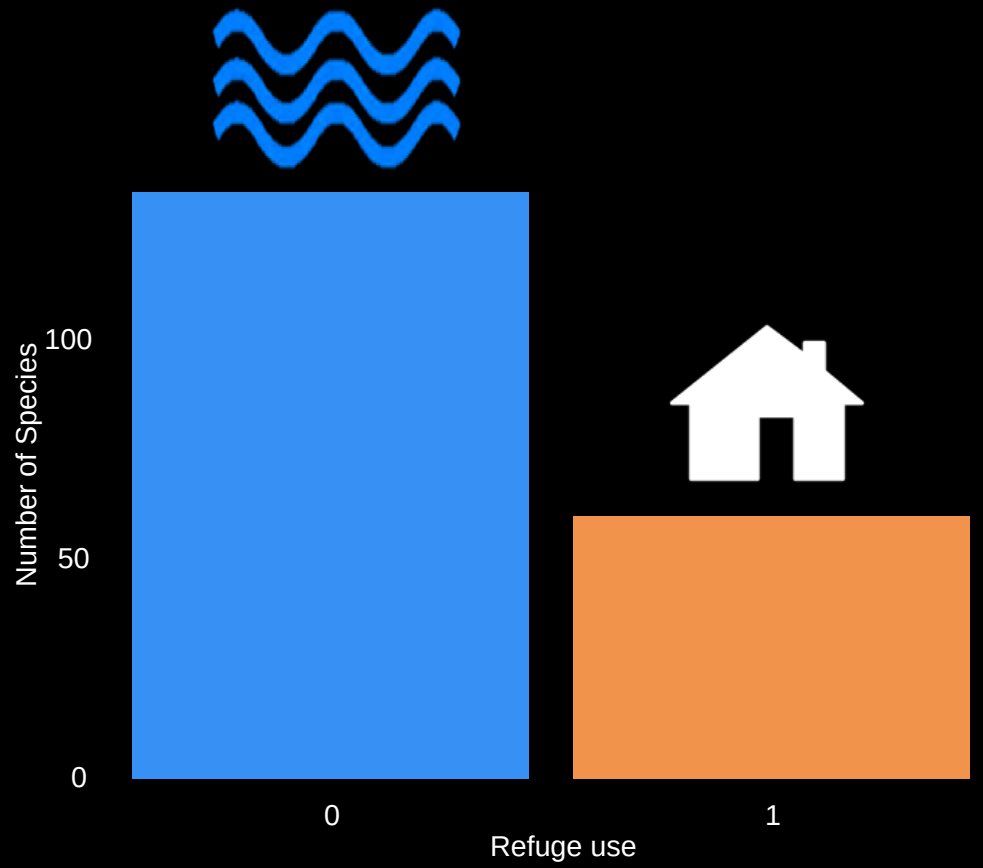


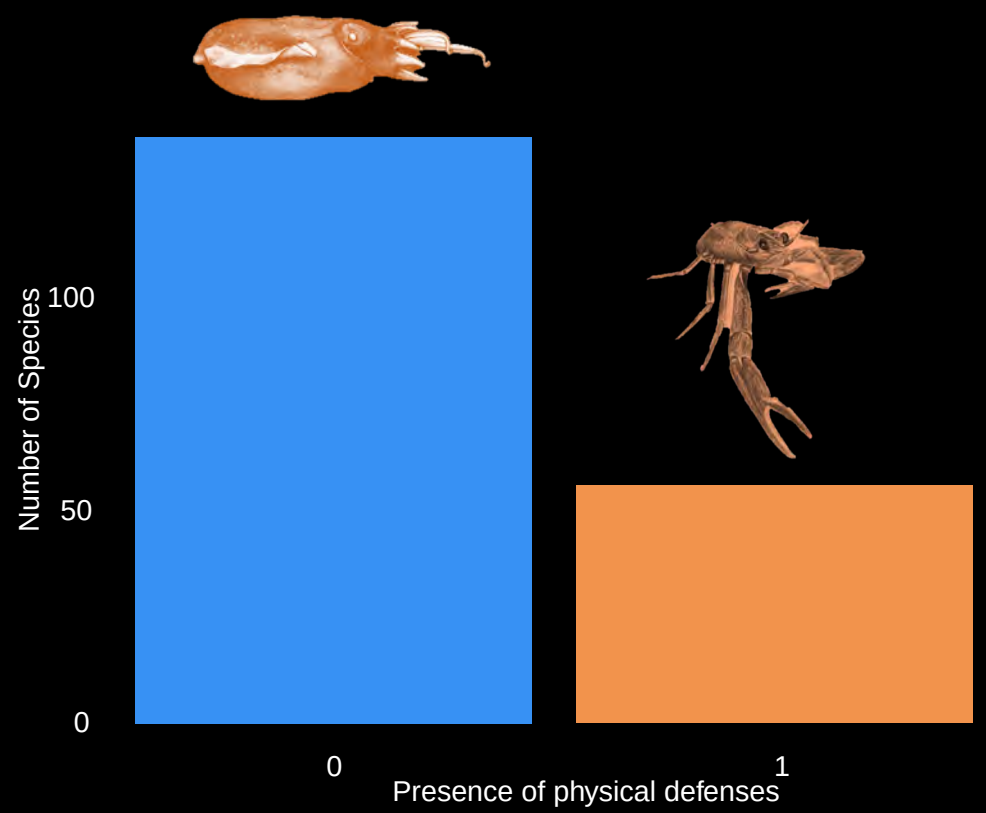
Habitat attributes





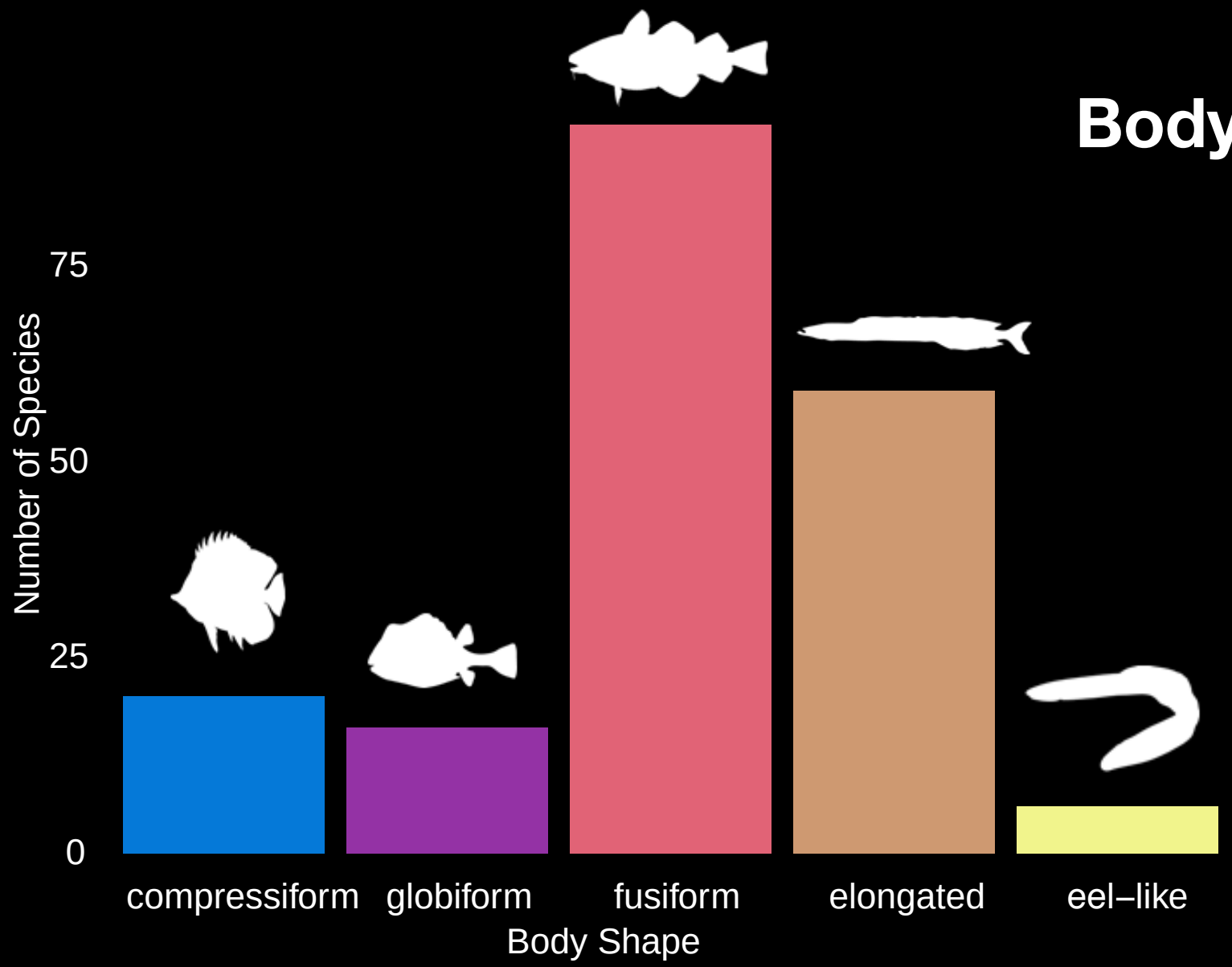
Physical defenses





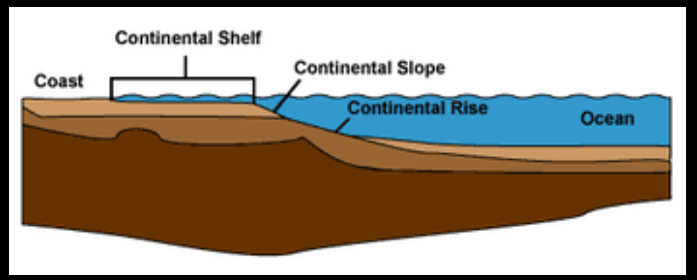
Predator avoidance/Refugia use

Body shape


Number of Species
75
50
25
0
compressiform
globiform
fusiform
elongated
eel–like
Body Shape

Traits for mediating predator-prey interactions

✓ ✓ ✗ ✗ ✓



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Habitat position & diel migration

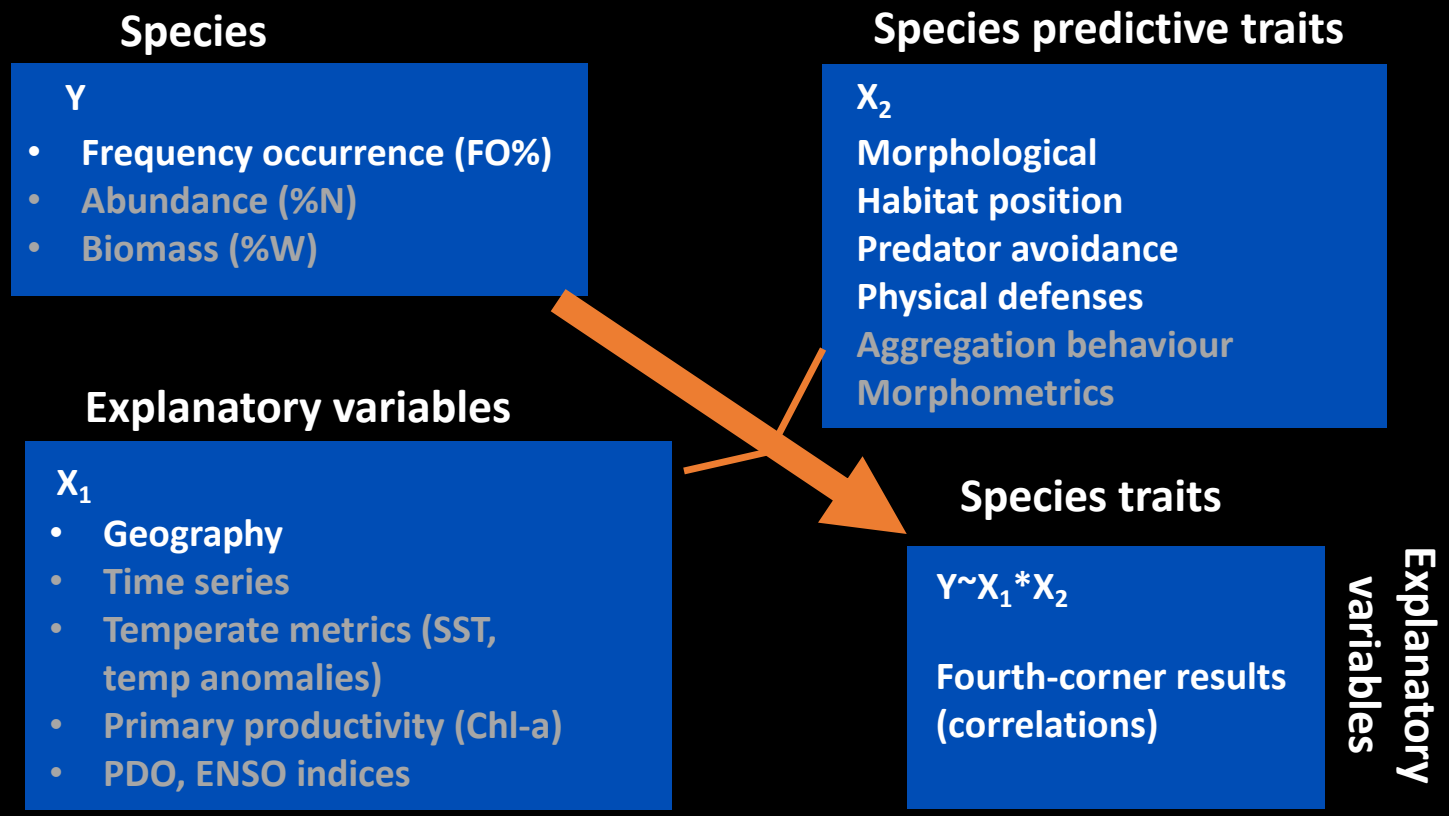
Refuge/ Avoidance behaviour

Physical defense

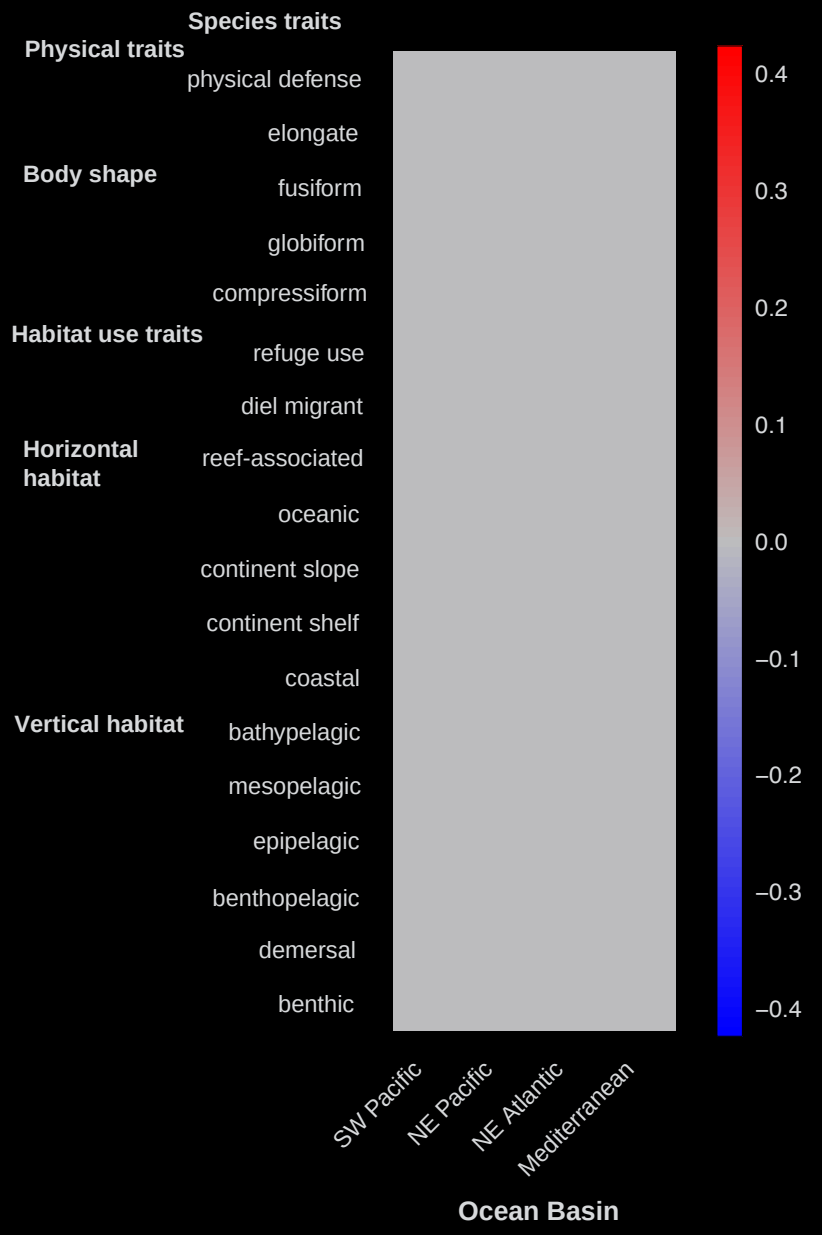
Body shape

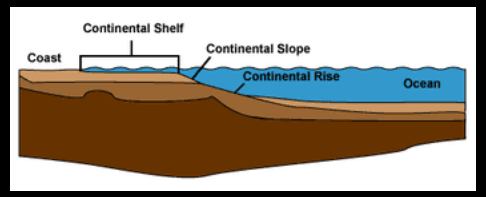
Multivariate trait-based analyses of tuna diets

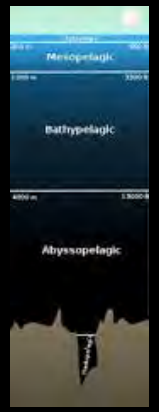
How much variation is explained by traits?



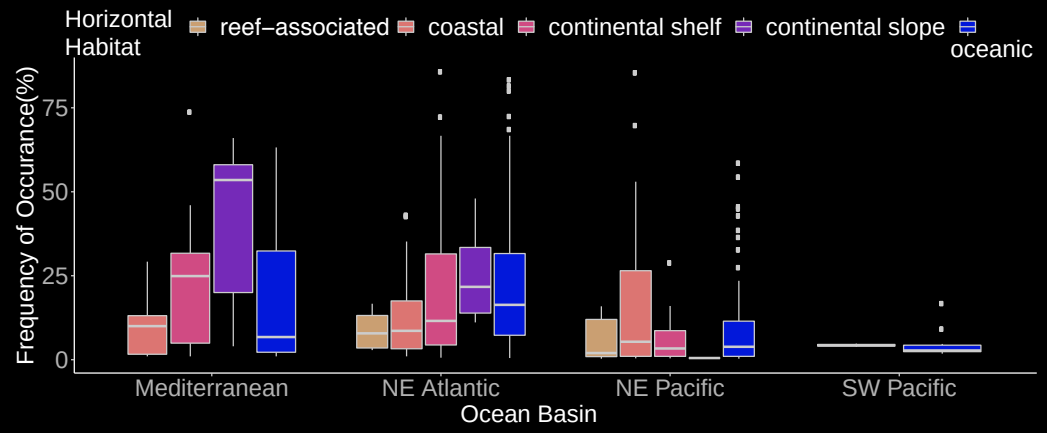
Fourth corner analyses using *mvabund* in R – Brown et al. (2014) *Methods Ecol Evol*

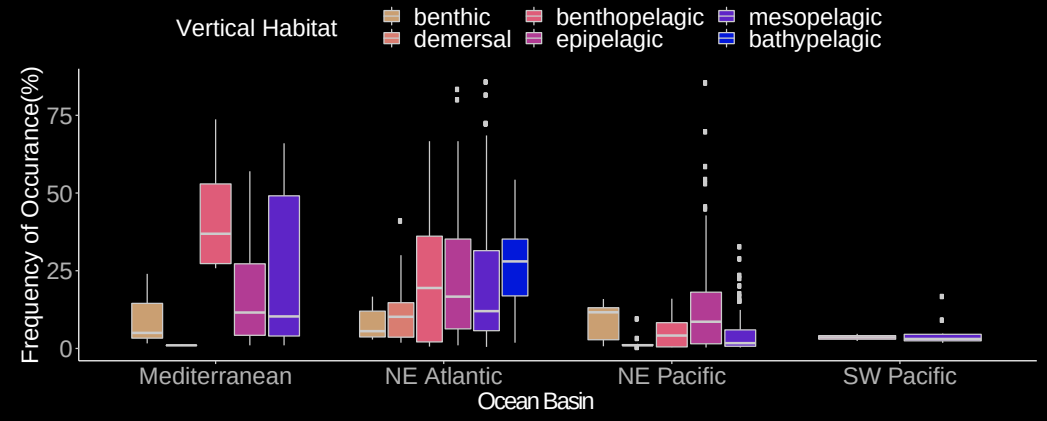

Species traits
Physical traits
physical defense
Body shape
elongate
fusiform
globiform
compressiform
Habitat use traits
refuge use
diel migrant
Horizontal habitat
reef-associated
oceanic
continent slope
continent shelf
coastal
Vertical habitat
bathypelagic
mesopelagic
epipelagic
benthopelagic
demersal
benthic
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
SW Pacific
NE Pacific
NE Atlantic
Mediterranean
Ocean Basin

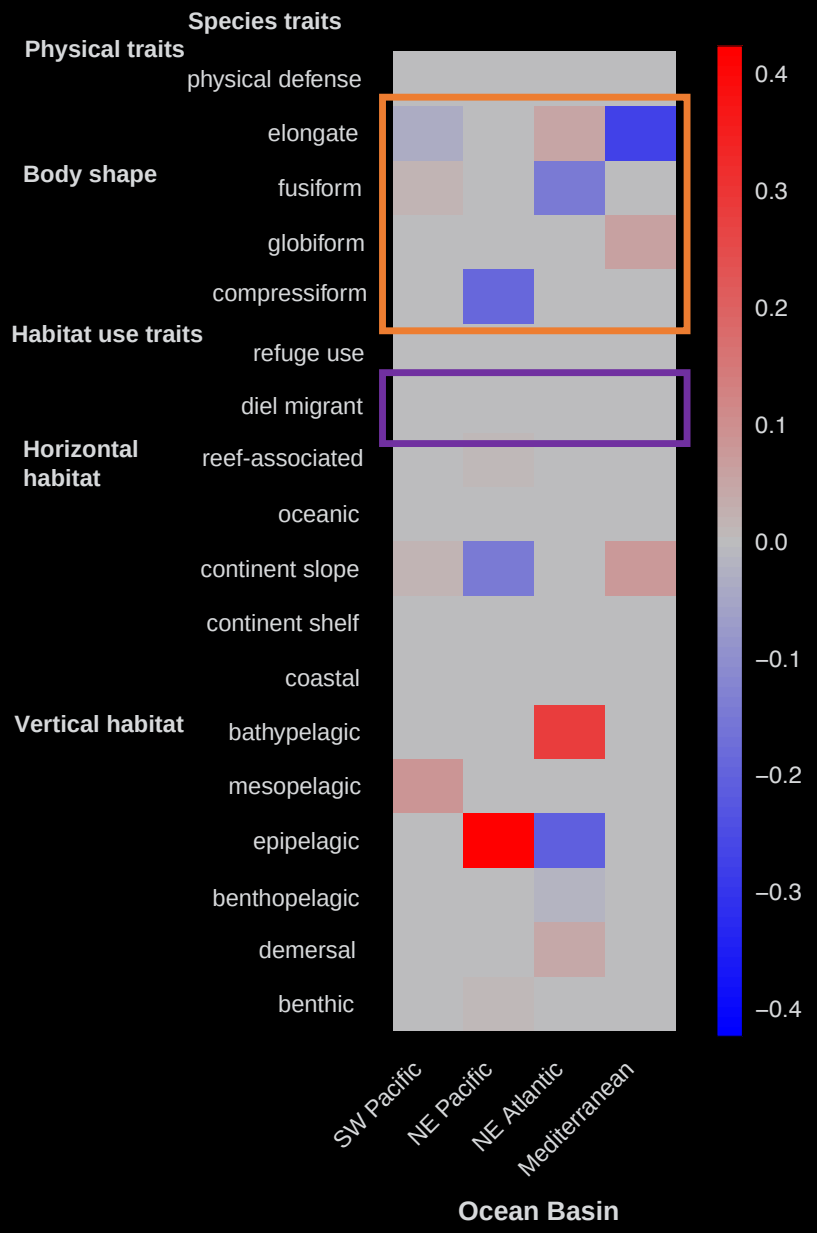

Continental Shelf
Coast
Continental Slope
Continental Rise
Ocean


Mesopelagic
Bathypelagic
Abyssopelagic

Species traits
Physical traits
physical defense
Body shape
elongate
fusiform
globiform
compressiform
Habitat use traits
refuge use
diel migrant
Horizontal habitat
reef-associated
oceanic
continent slope
continent shelf
coastal
Vertical habitat
bathypelagic
mesopelagic
epipelagic
benthopelagic
demersal
benthic
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
SW Pacific
NE Pacific
NE Atlantic
Mediterranean
Ocean Basin


Horizontal Habitat
reef−associated
coastal
continental shelf
continental slope
oceanic
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin


Vertical Habitat
benthic
benthopelagic
mesopelagic
demersal
epipelagic
bathypelagic
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin


Species traits
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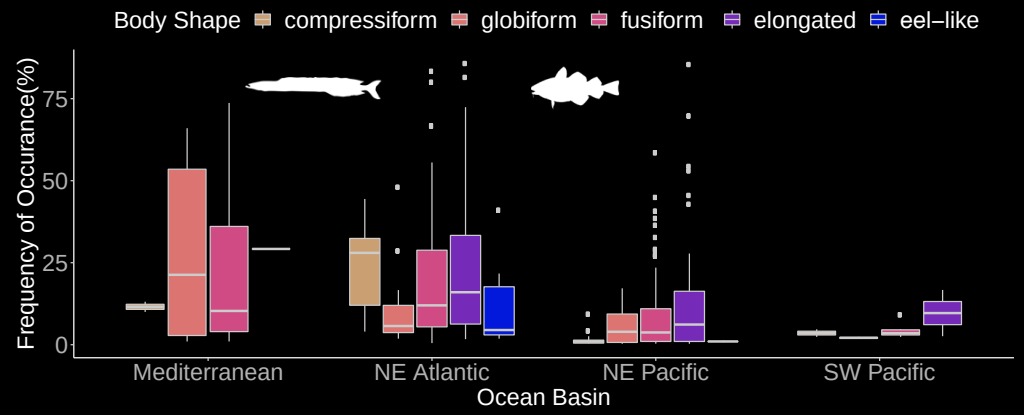
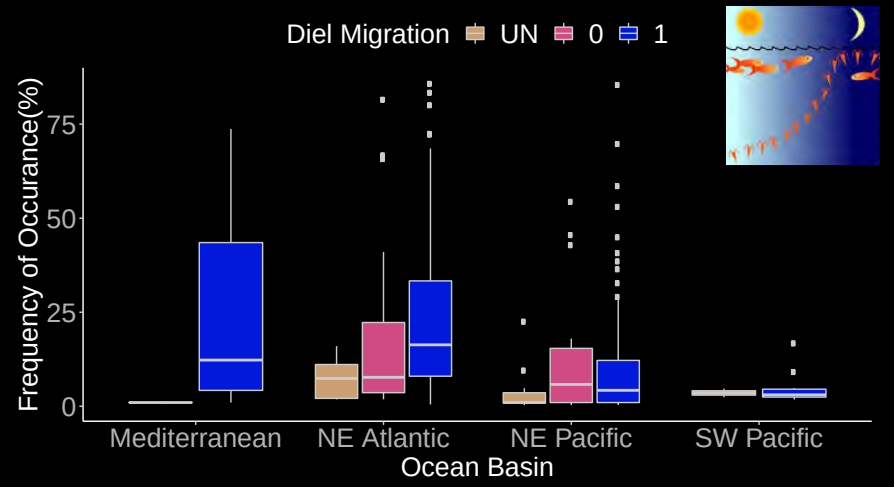
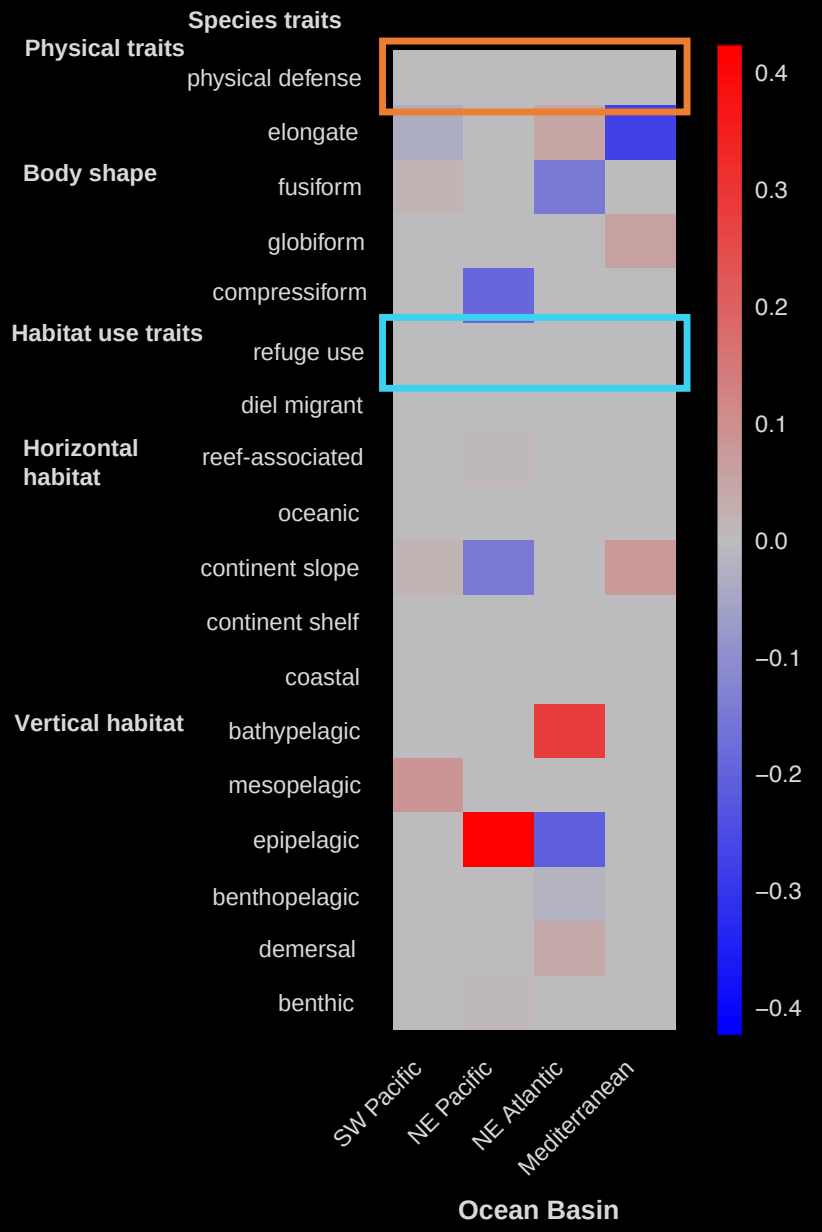
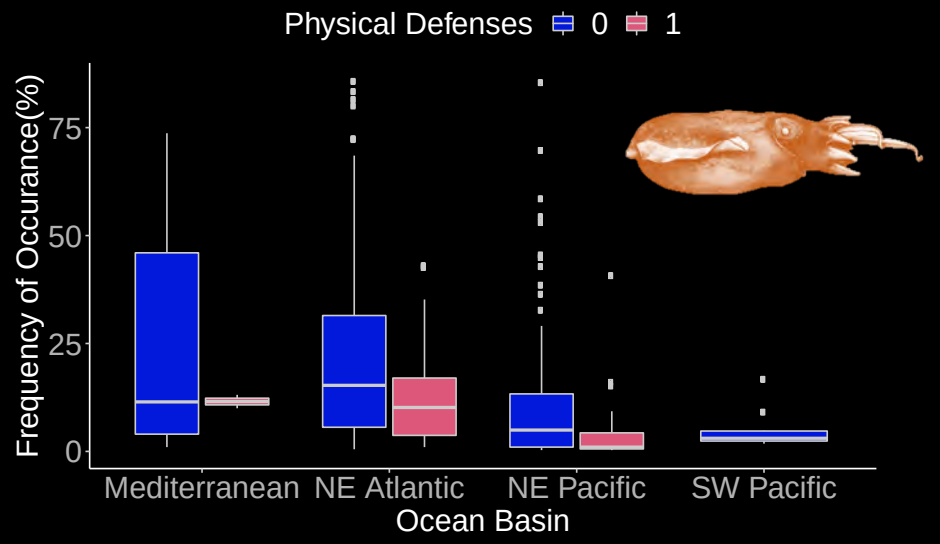
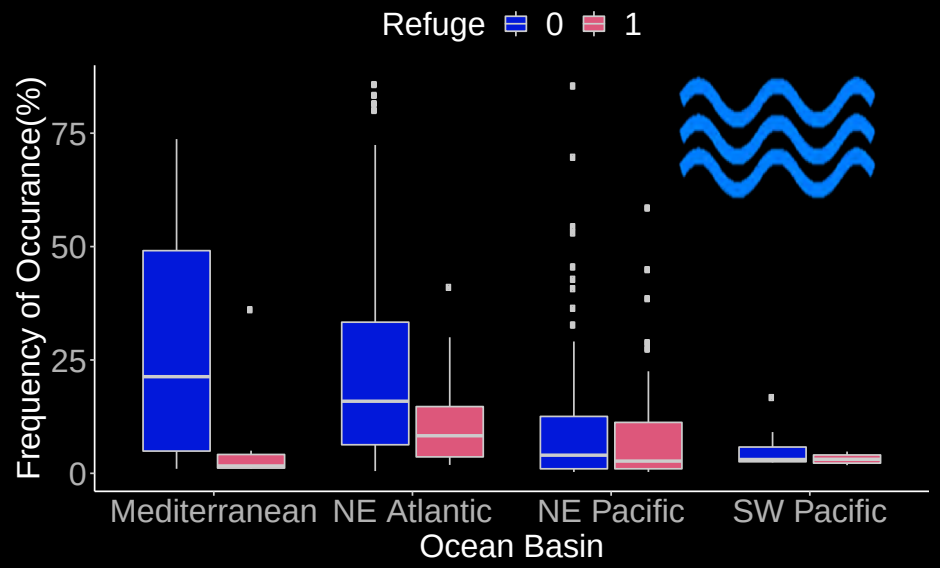
benthopelagic
demersal
benthic
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
SW Pacific
NE Pacific
NE Atlantic
Mediterranean
Ocean Basin


Body Shape
compressiform
globiform
fusiform
elongated
eel–like
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin

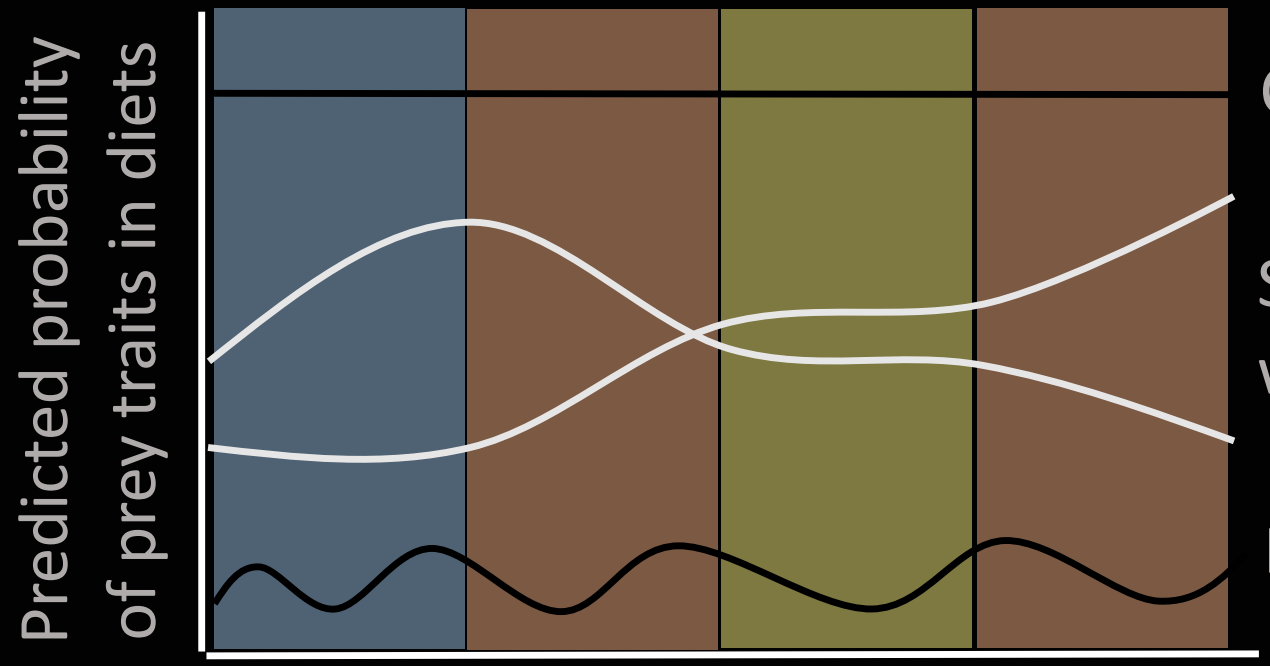

Diel Migration
UN
0
1
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin


Species traits
Physical traits
physical defense
Body shape
elongate
fusiform
globiform
compressiform
Habitat use traits
refuge use
diel migrant
Horizontal habitat
reef-associated
oceanic
continent slope
continent shelf
coastal
Vertical habitat
bathypelagic
mesopelagic
epipelagic
benthopelagic
demersal
benthic
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
SW Pacific
NE Pacific
NE Atlantic
Mediterranean
Ocean Basin

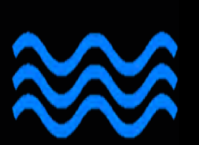

Physical Defenses 0 1
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin


Refuge 0 1
Frequency of Occurance(%)
75
50
25
0
Mediterranean
NE Atlantic
NE Pacific
SW Pacific
Ocean Basin

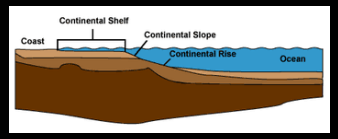
Trait-based predictions for future change



Conserved

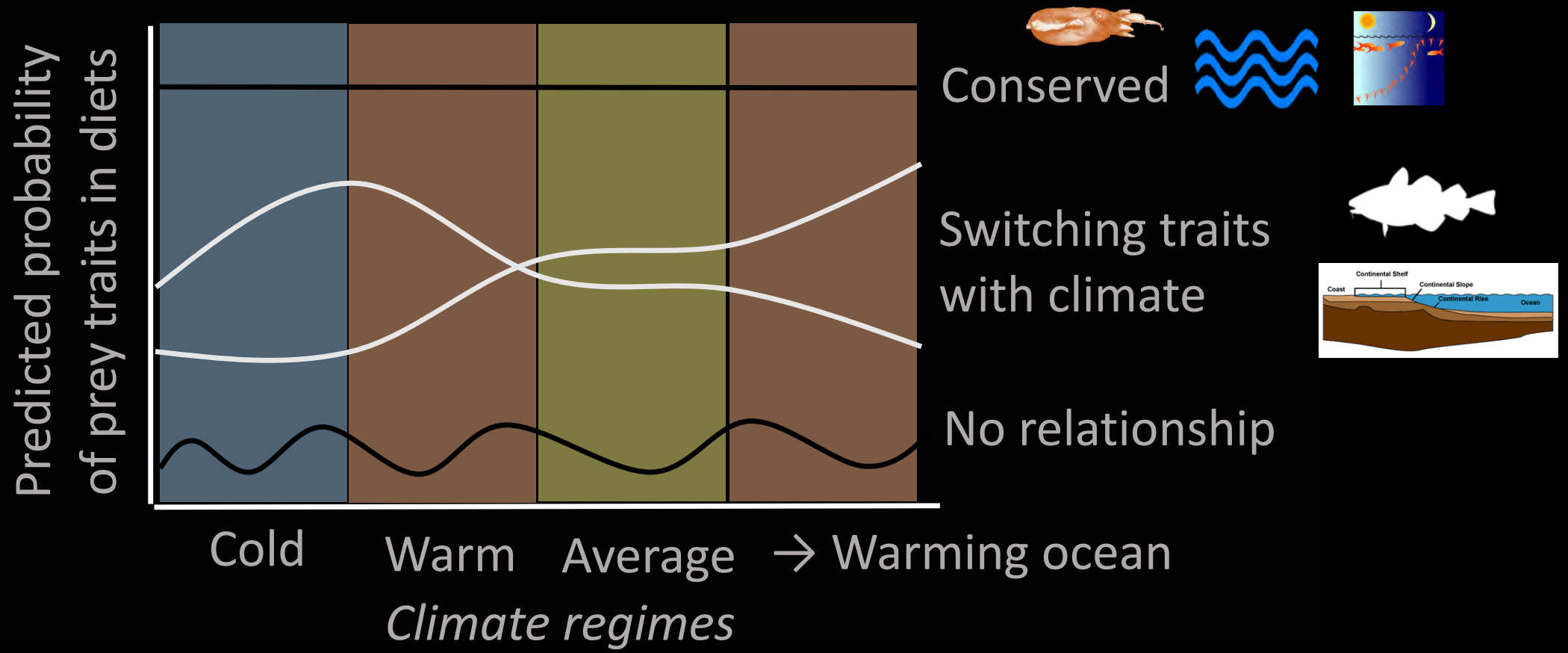


Switching traits with climate

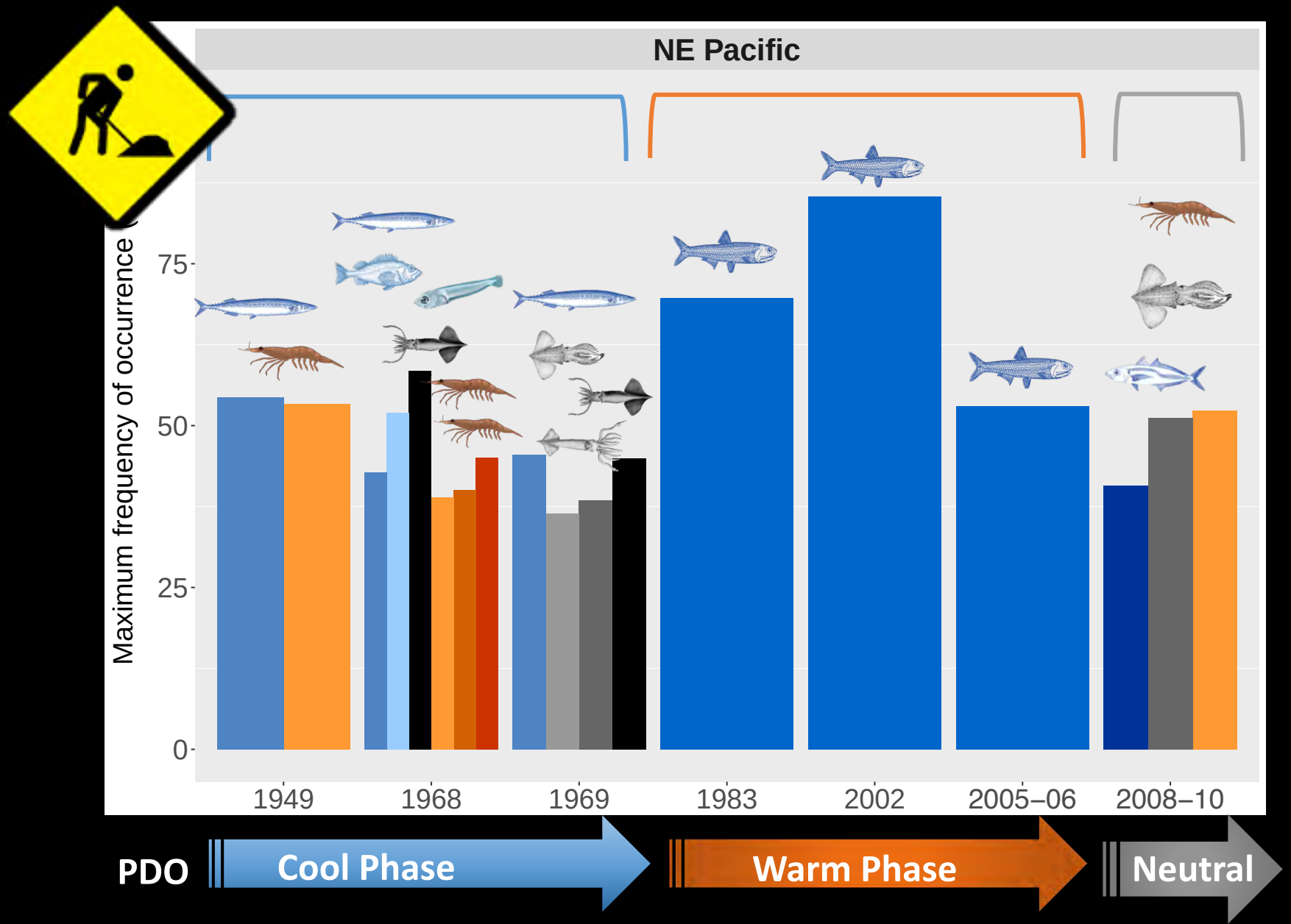


No relationship

Trait-based predictions for future change



Next steps: trait-mediated diet shifts in the NE Pacific



Take home points

- ❑ Trait-based diet assessment can be done for tuna
- ❑ Numerous complementary models to add to our analytical framework
- ❑ Requires diet data at the level of inference
- ❑ Ongoing effort for trait database on which to build analyses

Stephanie Green
& Cole Brookson
@ U Alberta

Larry Crowder
@ Hokpins
Marine Station

Michael Jacox, Elliott Hazen & Steven Bograd
@ NOAA Environmental Research Division

Poster session tonight @ 6pm

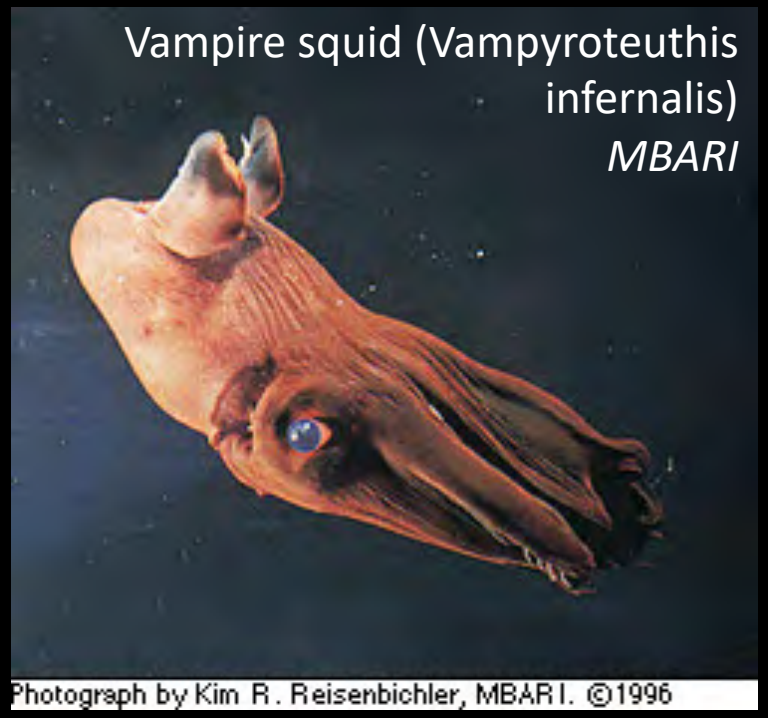
Cole Brookson → on

trait-based mechanistic models for predator-prey interactions

Questions?

Piglet squid (Helicocranchia pfefferi)
E/V Nautilus

Black swallower (Chiasmodon niger)
NOAA Okeanos Explorer Program



Vampire squid (Vampyroteuthis infernalis)
MBARI

Diaphanous hatchet fish (Sternopyx diaphana)
Arturo Angulo, Research Gate