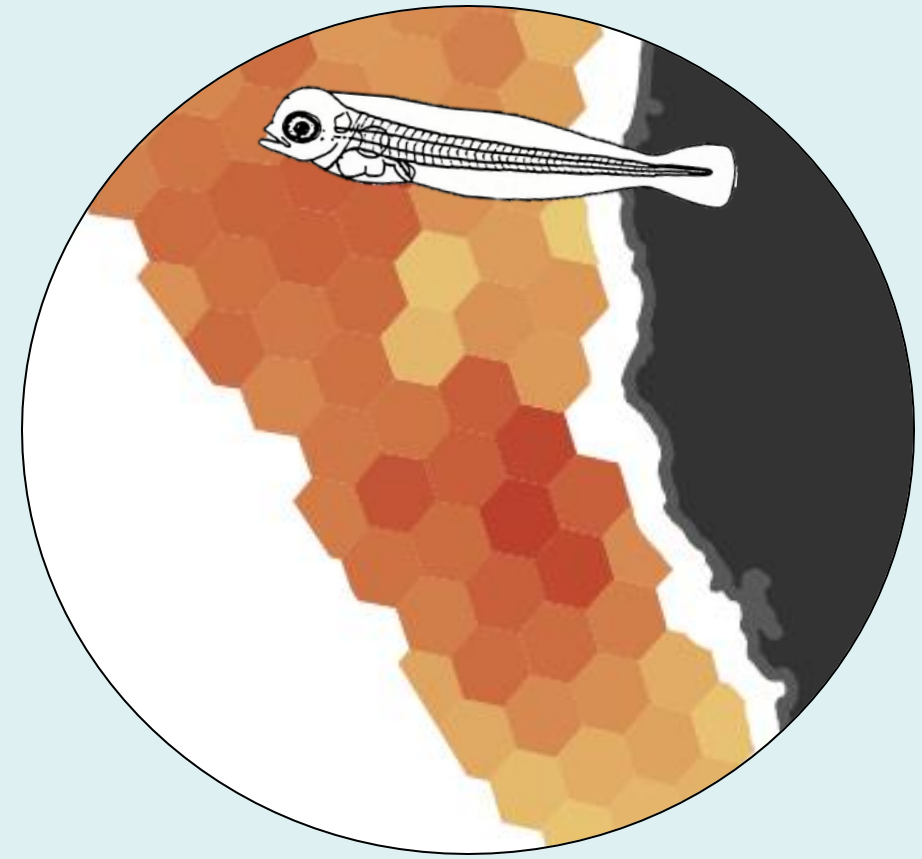# Eastern Pacific fish spawning patterns demonstrated mixed spatiotemporal tradeoffs in response to environmental changes

**Katherine Dale**, L. Ciannelli, J. Fiechter, M. Pozo Buil, R. Esteban García Gómez, S.P.A. Jiménez-Rosenberg, G. Aceves-Medina, A. Thompson, J.C. Field, T. Auth, R. Brodeur, R.I. Perry, L. Rogers, R. Howard, R. Asch

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# This project represents the efforts of many research teams!

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Rebecca Asch (ECU)

Jerome Fiechter (UCSC)

Rebecca Howard (OSU)

Mercedes Pozo Buil (UCSC)

Oregon State University

NOAA

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UNIVERSITY OF CALIFORNIA SANTA CRUZ
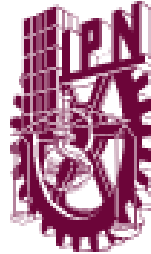
RUTGERS

IPN
Instituto Politécnico Nacional

CICESE

Fisheries and Oceans Canada

CalCOFI
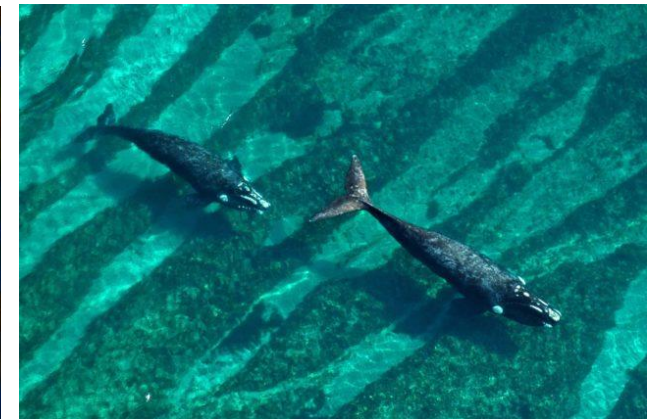Celebrating 70 Years
1949 - 2019

EcoFOCI
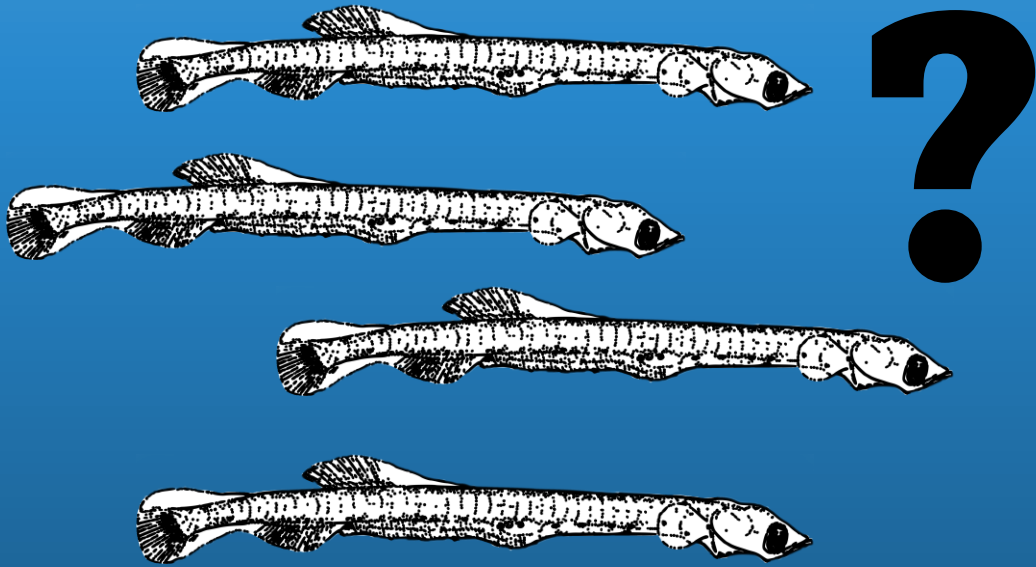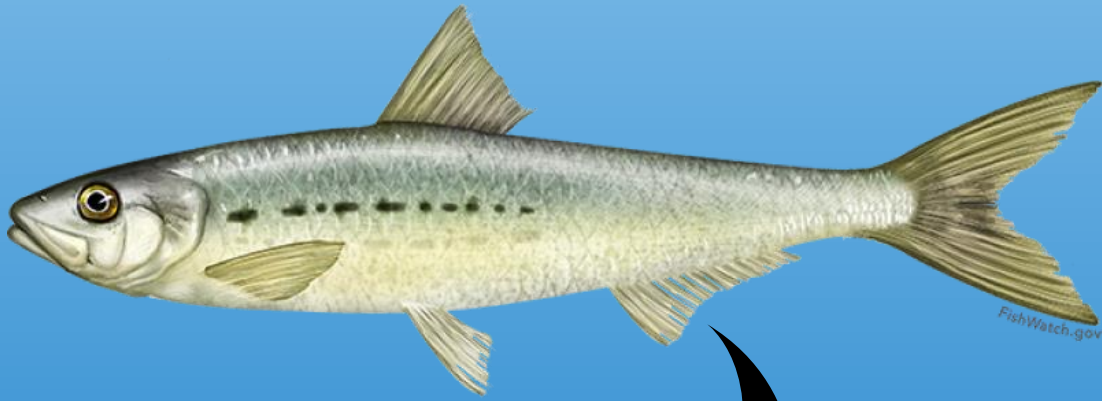Ecosystems & Fisheries-Oceanography Coordinated Investigations

# What is phenology?

## Phenology

Phenology is the study of periodic events in biological life cycles and how these are influenced by seasonal and interannual variations in climate, as well as habitat factors. **Wikipedia**
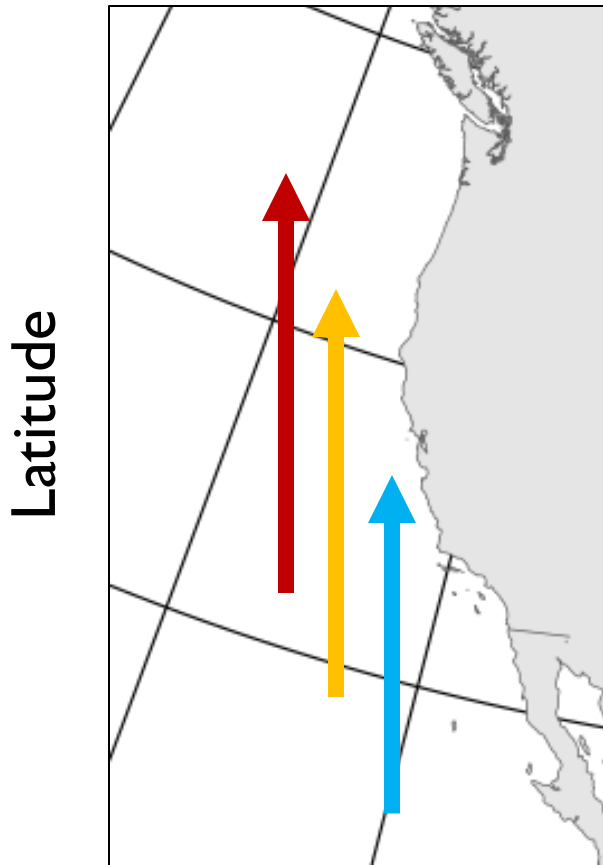
*Eggli & Giorgetta 2015*

What kind of food is available (and where is it?)
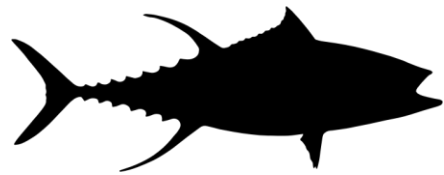
Are larvae close to suitable juvenile habitats?

Are conditions optimal for growth?

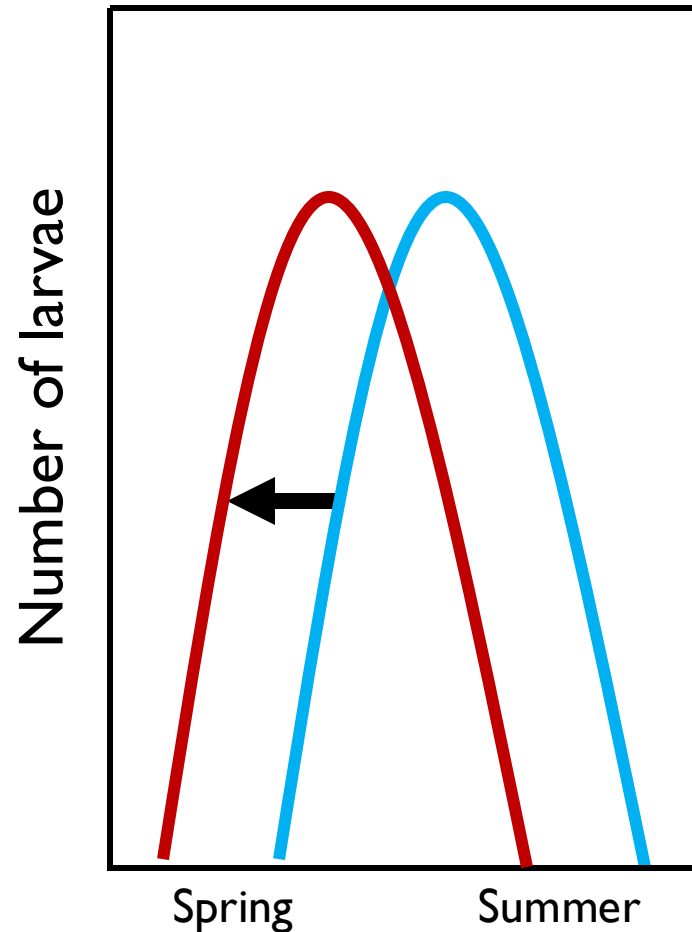# Fish can alter their spawning behavior to improve odds of larval survival in a warming ocean
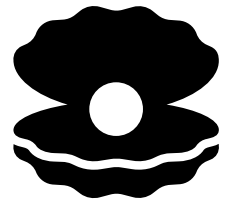
## *Shift geography*



Large, migratory species that **can easily move**, species with **longer lifespans**, or species with **wide niches**
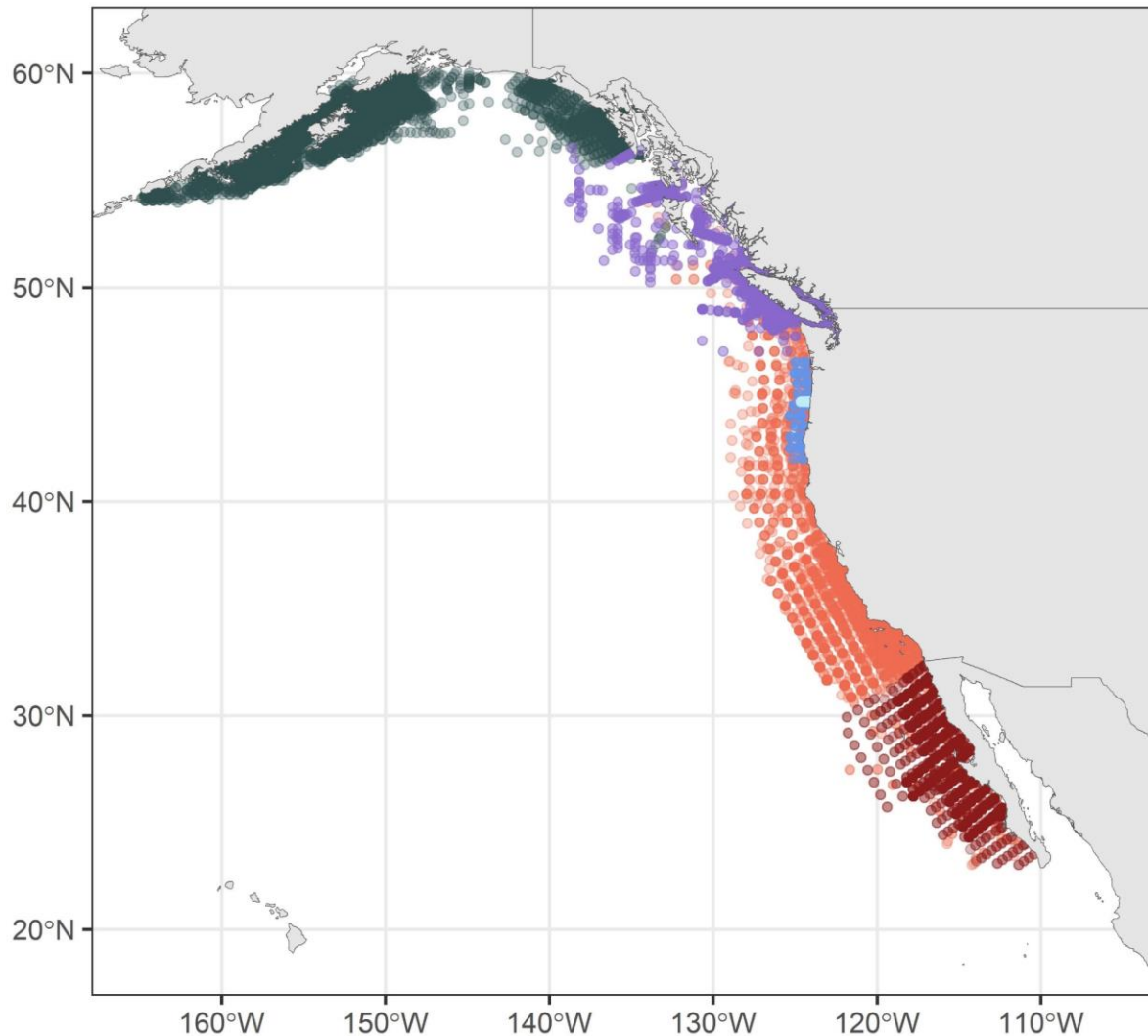
## *Shift seasonality (timing)*



Animals that **can't easily move**, animals with **specific habitat needs**, or animals that have **natal homing**

# We have combined data from 6 long-term larval fish sampling programs (across 3 countries!)



← **30,299** individual tows, subset to 1995-2019

- ● EcoFOCI
- ● Dept. of Fisheries & Oceans Canada
- ● NOAA Newport Hydrographic Line
- ● NOAA Prerecruit Larval Survey
- ● California Cooperative Oceanic Fisheries Investigations
- ● IMECOCAL

# We examined 16 species from three adult habitats

## Coastal pelagics
*Schooling fishes in the upper part of the ocean*

- Pacific sardine
- Northern anchovy
- Jack mackerel
- Chub mackerel
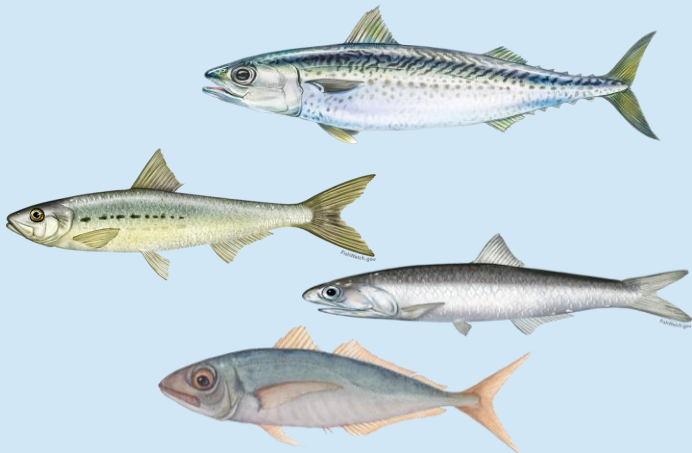
## Groundfish
*Often commercially-fished species associated with the bottom closer to the coast*

- Pacific hake
- English and rex soles
- Shortbelly rockfish
- Speckled sanddab
- Bocaccio rockfish

## Mesopelagics
*Abundant indicator fishes in the middle/deep water column*

- Blue lanternfish
- Northern lampfish
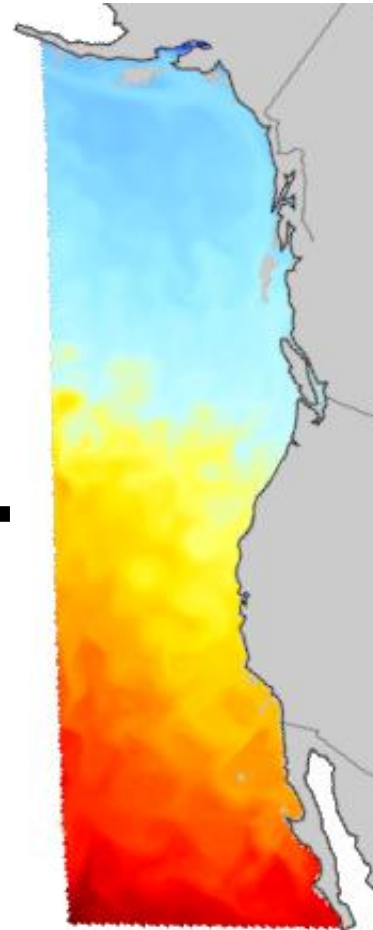- Mexican lampfish
- Panama lightfish

# We constructed species distribution models to test how fish navigate the geography-phenology tradeoff



Empirical catch
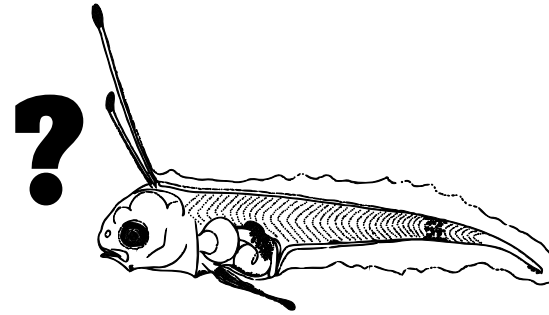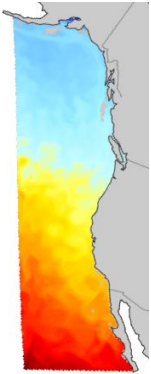data: log(N + 1)

ROMS data 1995-
2019

Jerome Fiechter

Mercedes Pozo Buil

UNIVERSITY OF CALIFORNIA
SANTA CRUZ

We constructed species distribution models to test how fish navigate the geography-seasonality tradeoff

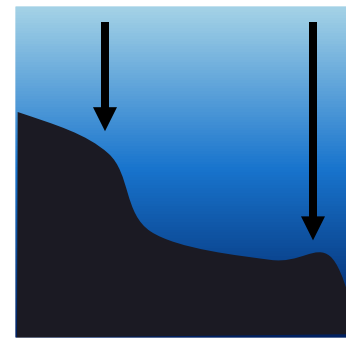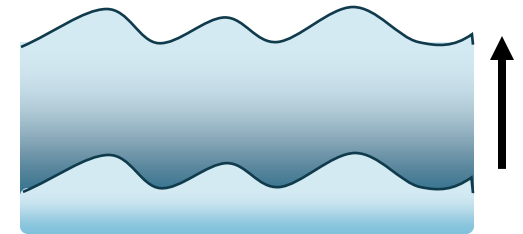Step 1: Determine the most predictive environmental covariates for each species

Salinity

Sea surface temperature

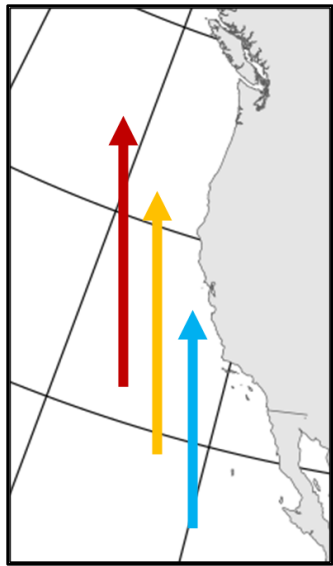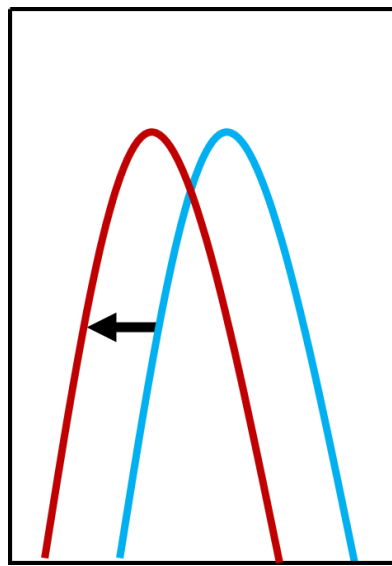"Spiciness" (warm/salty or cool/fresh)

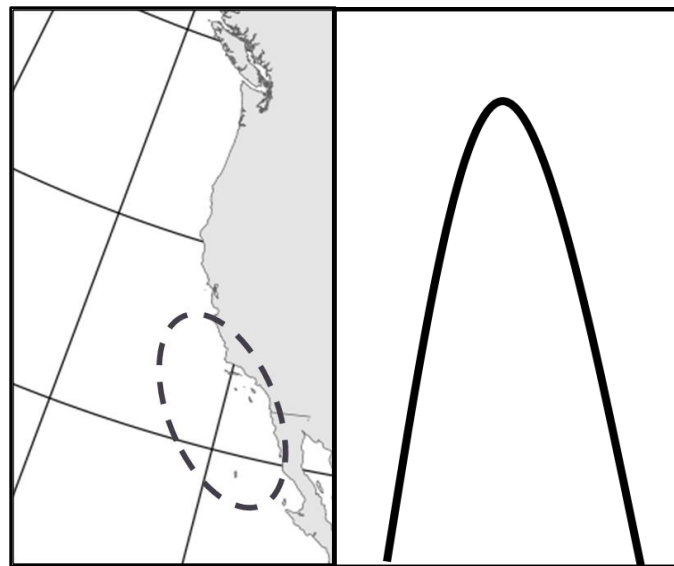Bottom depth

Sea surface height

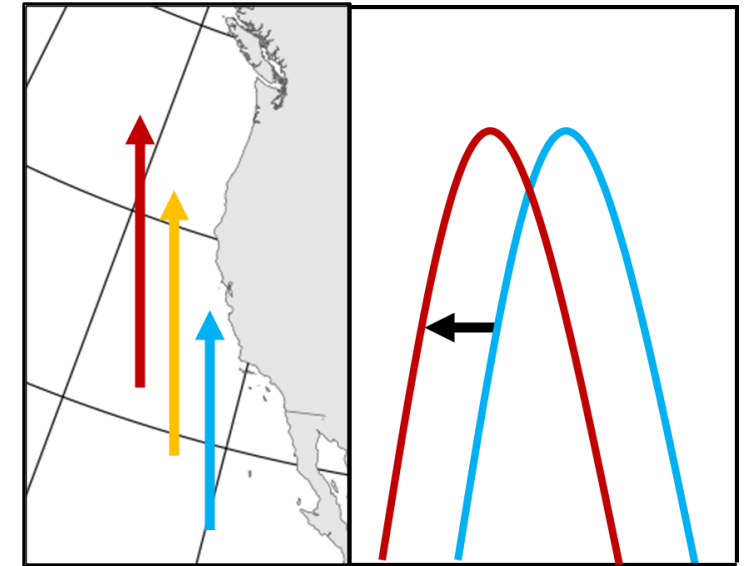# For each species, we compared four species distribution models, allowing shifts across 5-year timeblocks
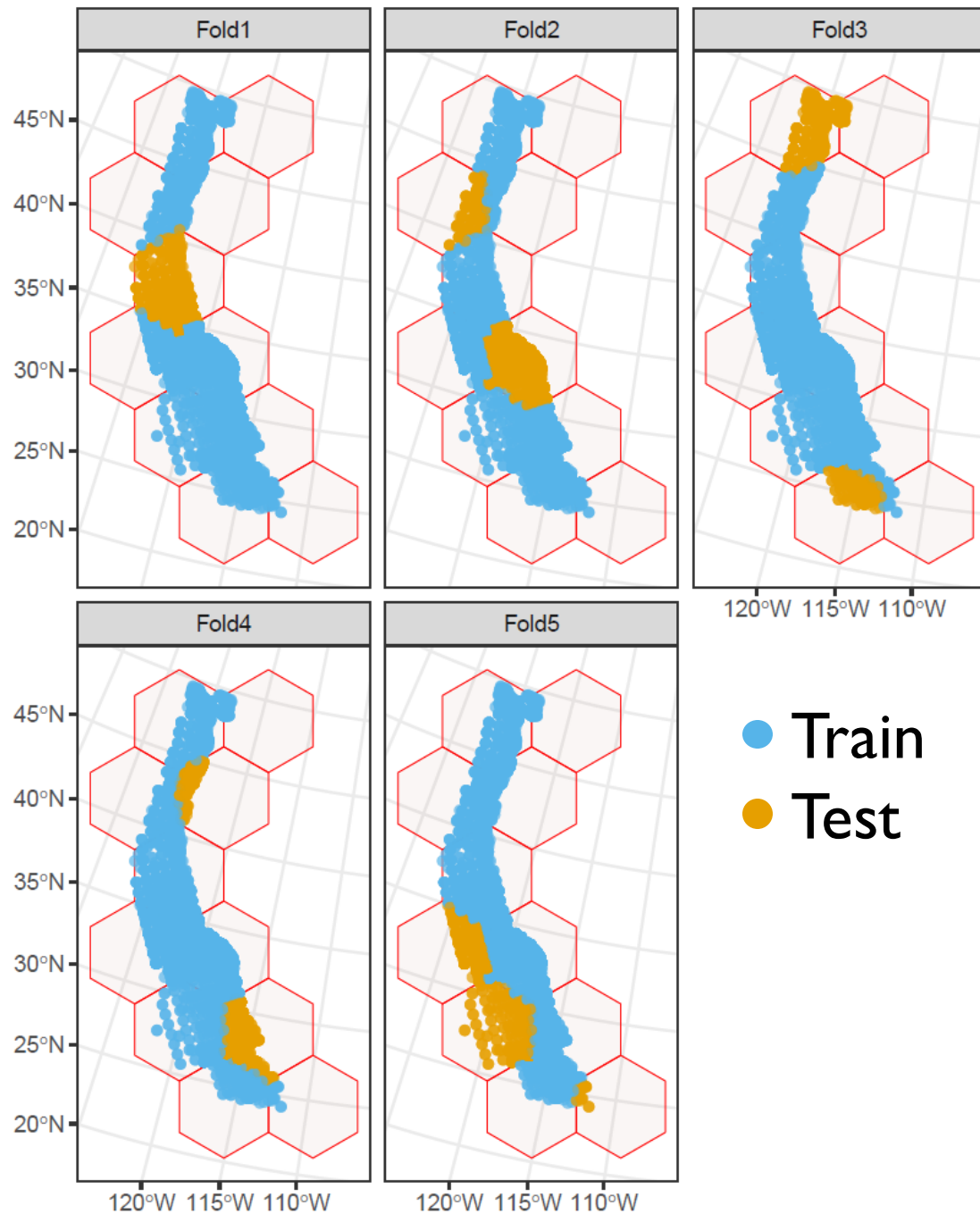


Shift **geography**
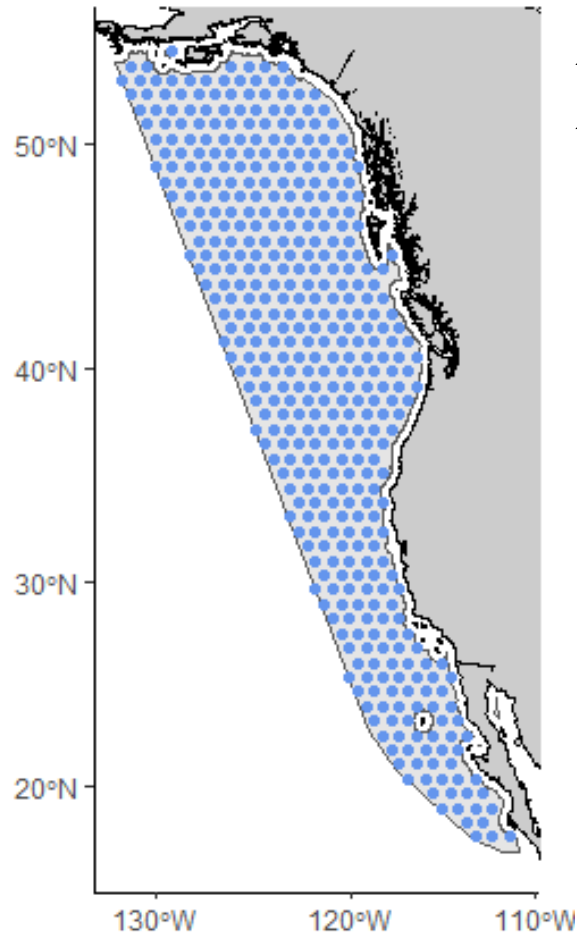
Shift **seasonality**
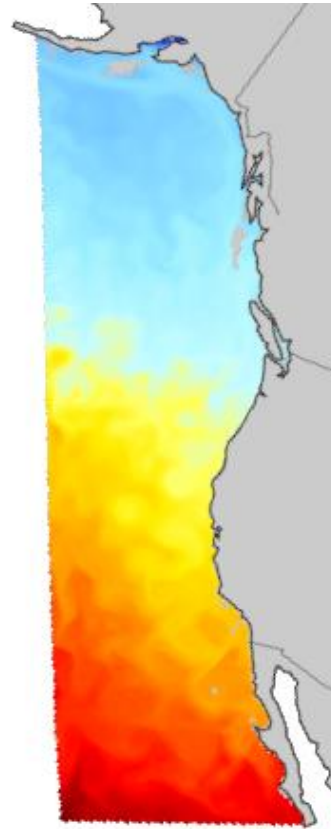
Shift **neither**

Shift **both**

We compared models using 5-fold leave-one-out cross validation, and calculated performance weights for each model

We predicted larval abundance across a regular grid over the same range of years using all models and stacking by model weight…
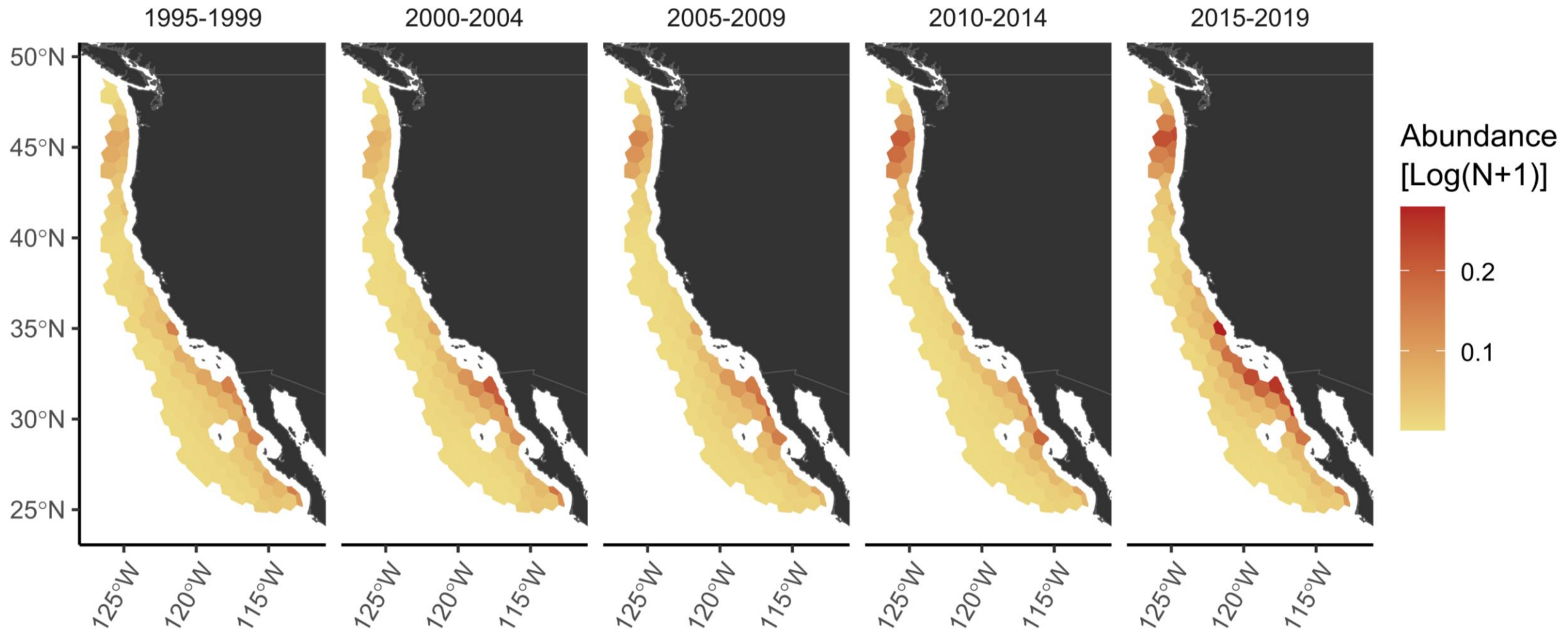


X 12 months
X 23 years
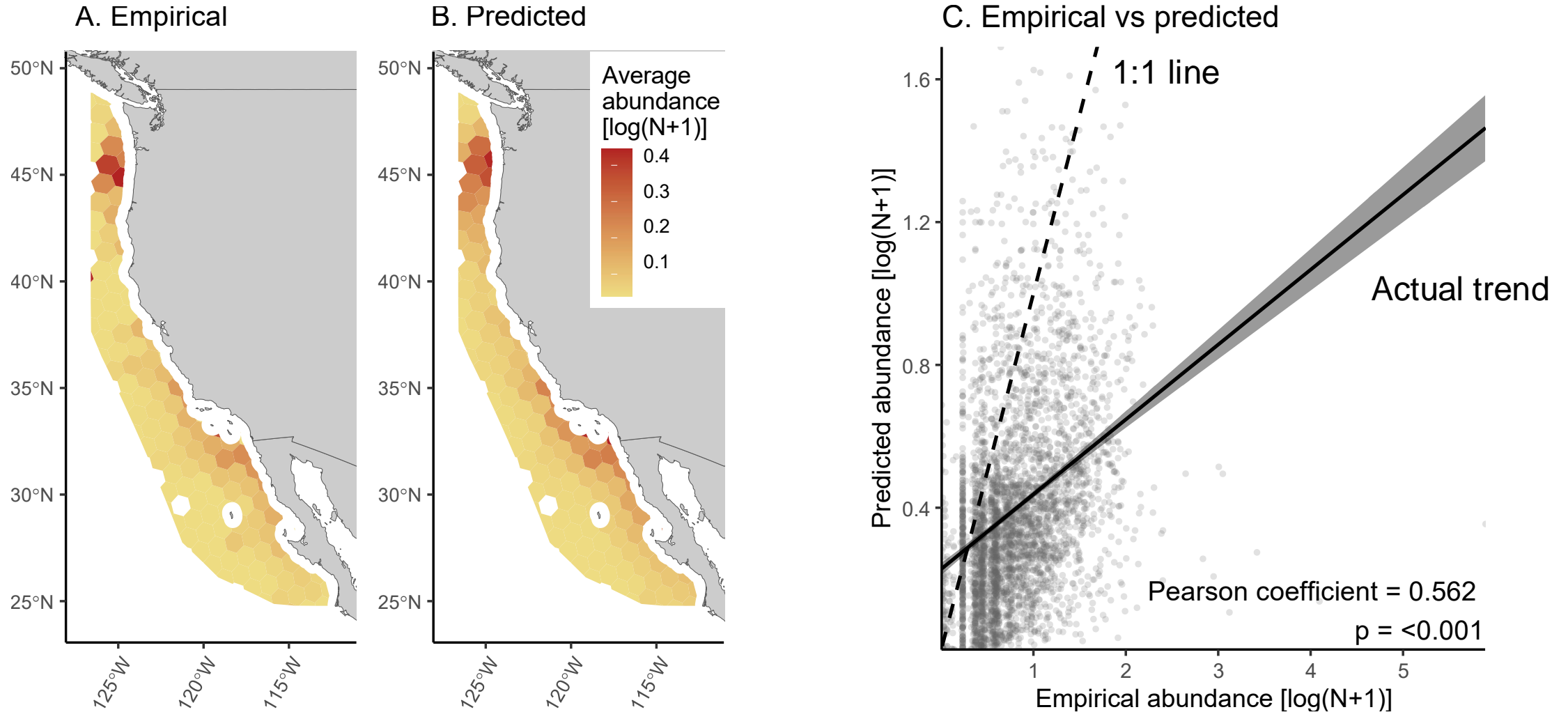(1995-2019)

ROMS data 1995-2018

+ + **Stacked models** ___

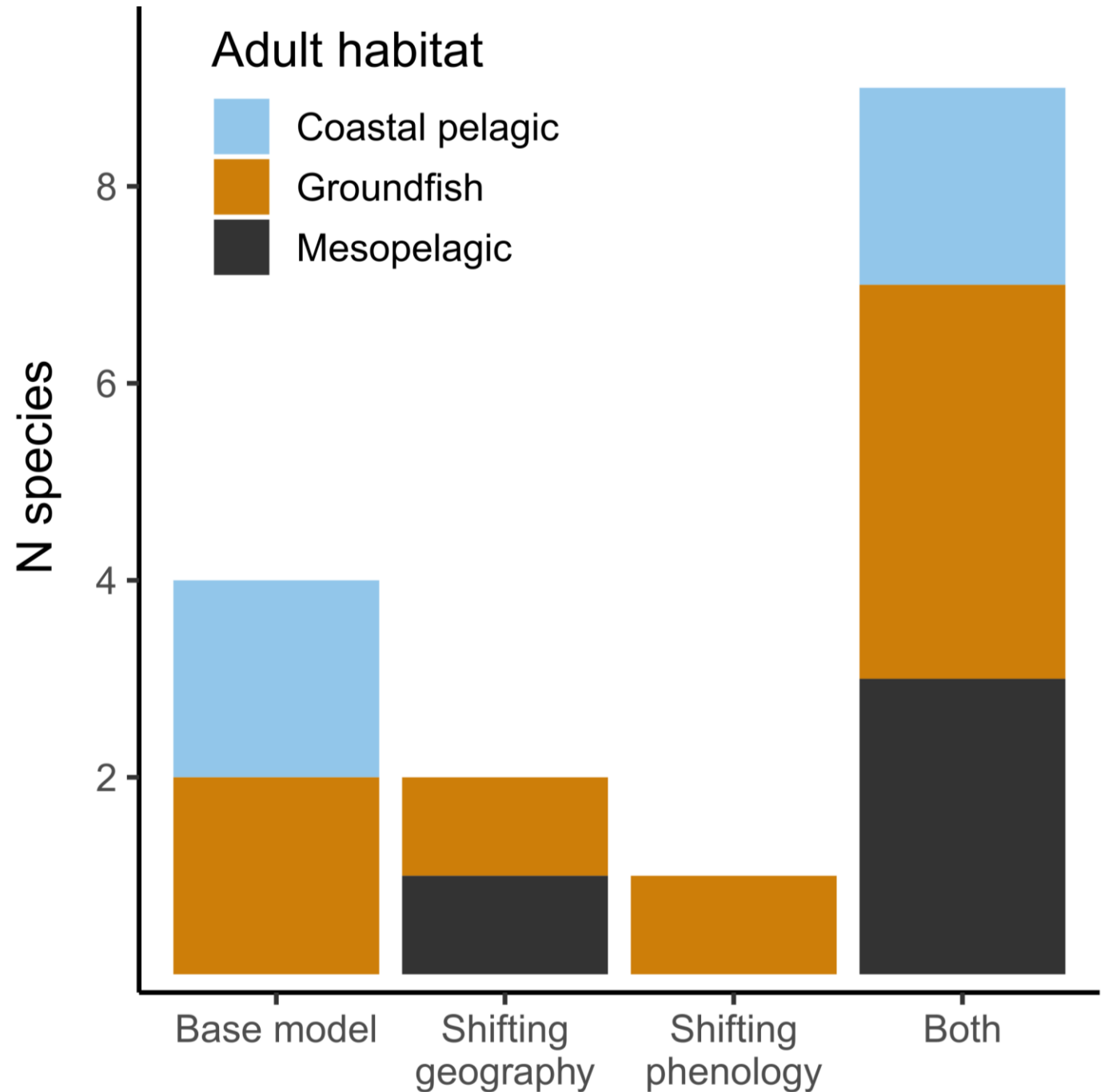# …giving us a more complete picture of predicted larval abundance!

# How do models perform?

Modeling output tracks geographic trends…
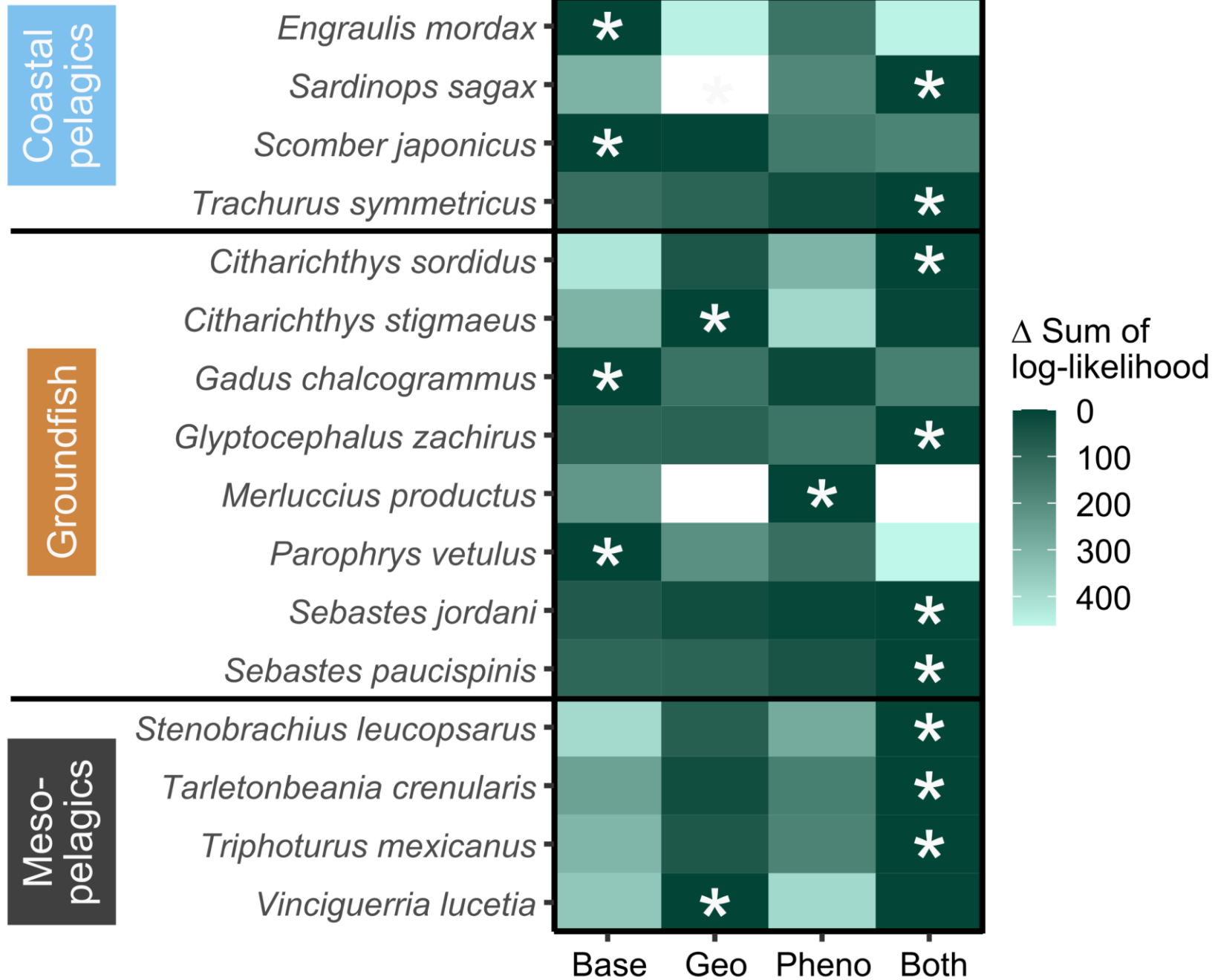…but is more conservative with abundance estimates

How do species **navigate the tradeoff** between shifting geography versus phenology?

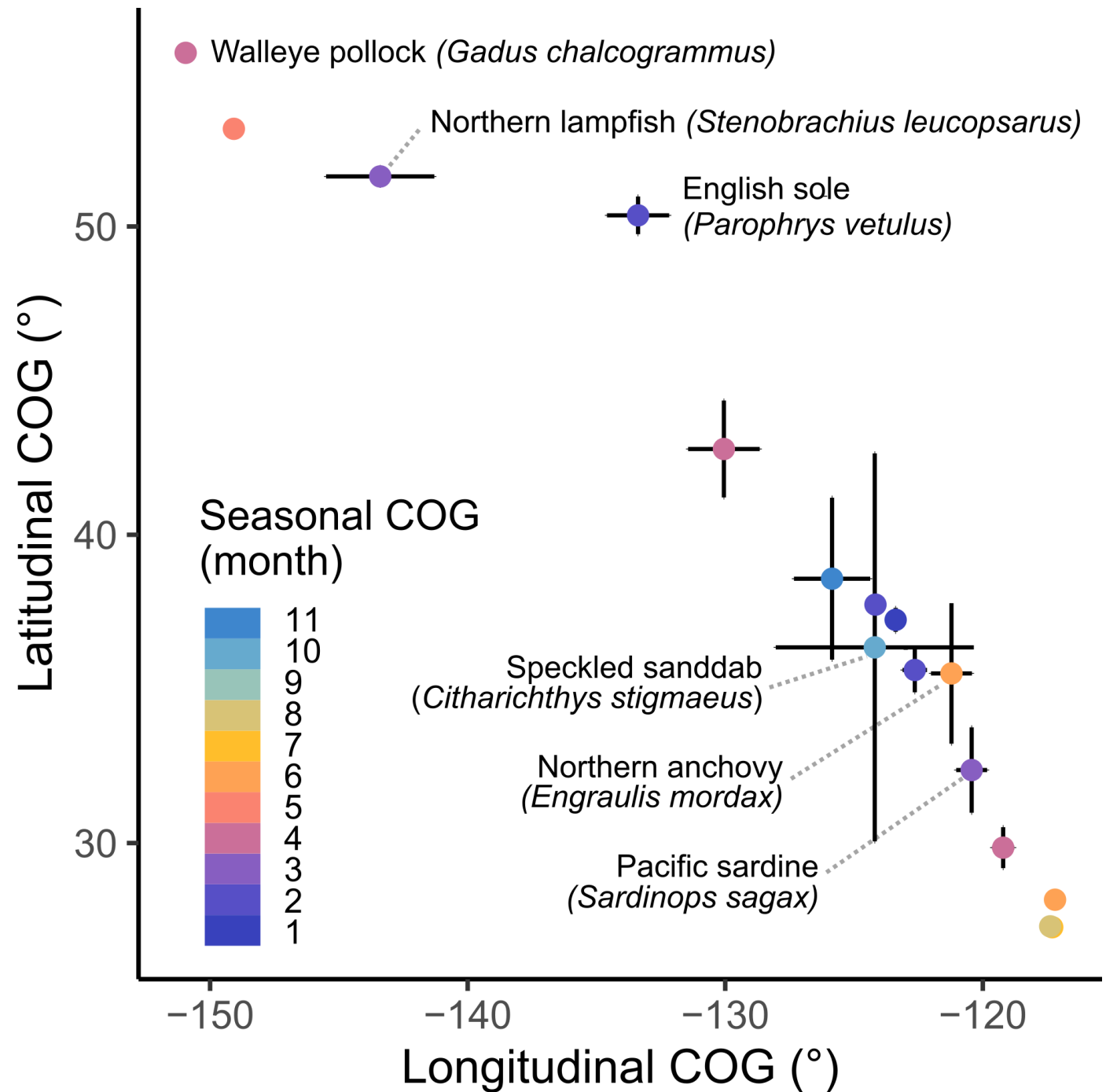Most species shifted both phenology and geography

How do species **navigate the tradeoff** between shifting geography versus phenology?

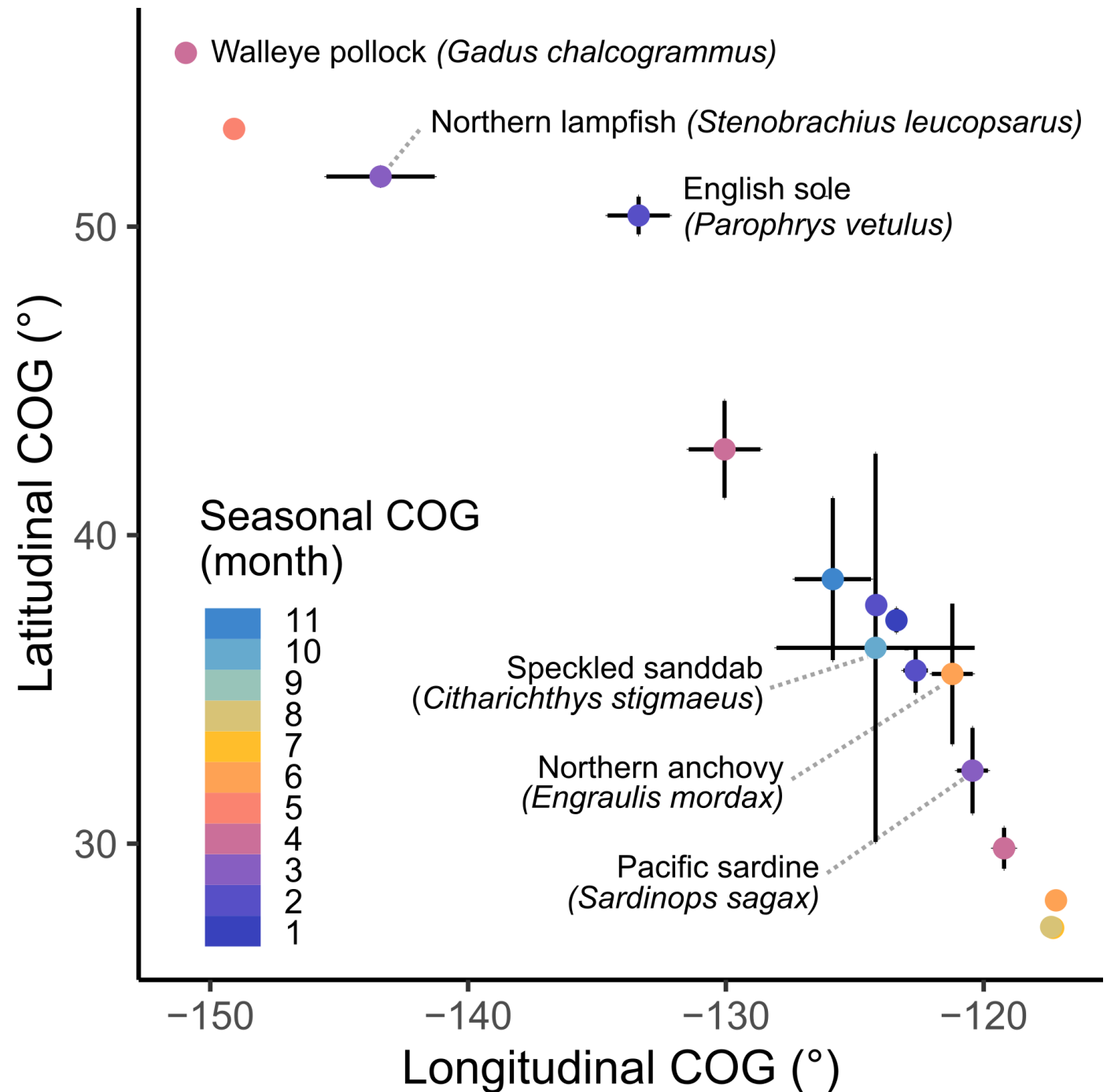However, species could be described by multiple models!

# How do longitudinal, latitudinal, and seasonal center of gravity co-vary?

Species with wide variance in geographic COG don't spawn at a consistent time of year

How do longitudinal, latitudinal, and seasonal center of gravity co-vary?

Wide variation is more likely in the southern California Current!

# Does **environmental sensitivity/niche breadth** track tradeoffs?

We calculated a niche hypervolume (Smith's measure) for each species:

$$\text{Hypervolume} = \sum \sqrt{p_j a_j}$$

Frequency of the species in a given environmental bin (salinity, sst, ssh, bottom depth)

Frequency of that bin overall in the study region

Does **environmental sensitivity/niche breadth** track tradeoffs?

*Hypothesis:* Species with broader niches may tend to shift geography over phenology.

Does **environmental sensitivity/niche breadth** track tradeoffs?

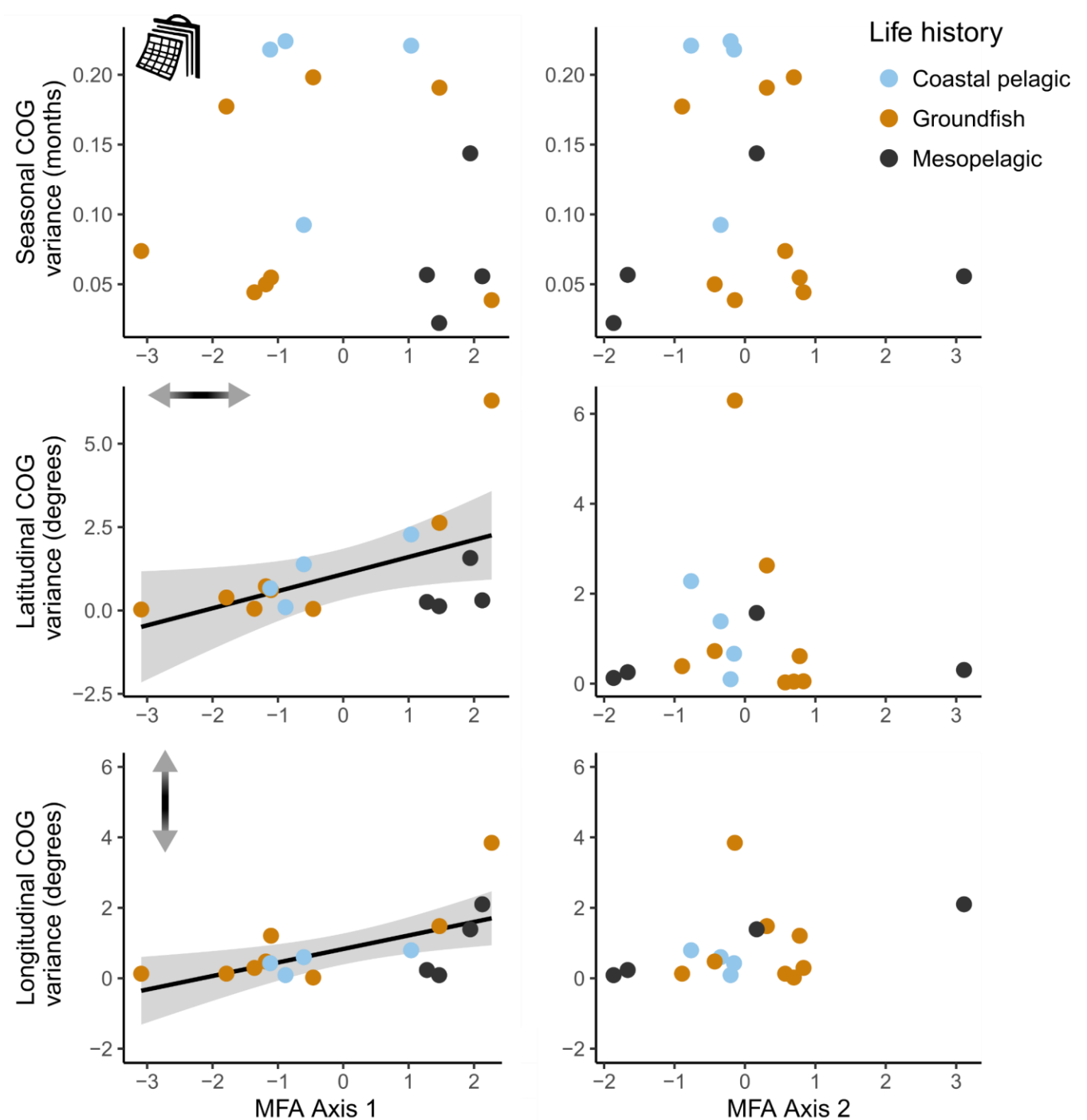No evidence for direct relationship between niche breadth and the top-performing tradeoff model
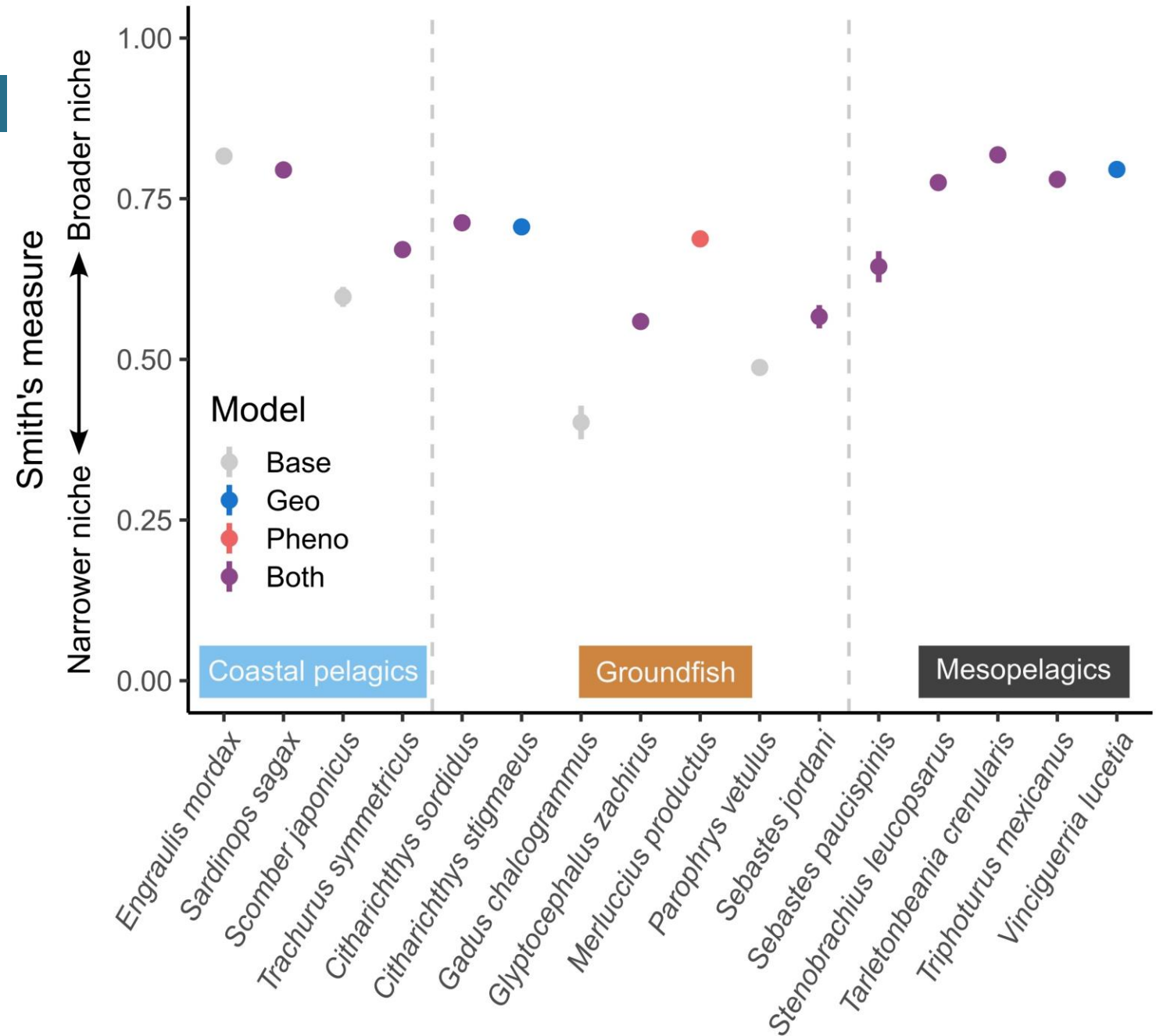
Can additional life history characteristics explain trends with seasonal or geographic center of gravity variance?

We ran a **multiple factor analysis** on different life history characteristics
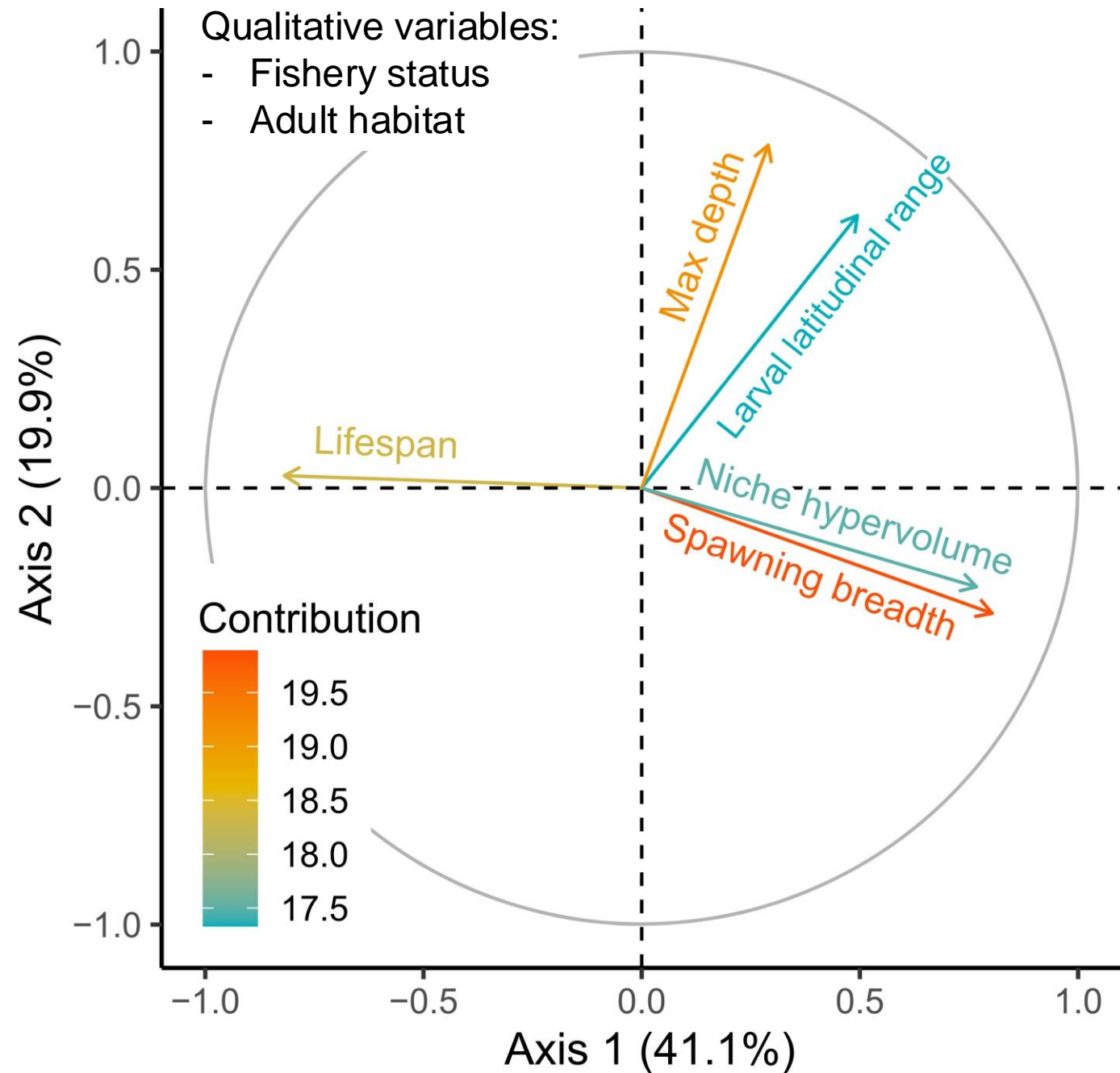
Can additional life history characteristics explain trends with seasonal or geographic center of gravity variance?

Latitudinal and longitudinal COG were correlated with MFA axis 1

Can additional life history characteristics explain trends with seasonal or geographic center of gravity variance?

Species with **longer spawning seasons**, **short lifespans**, and **wider niches** had more geographic variability



… these didn't fall into a single general adult habitat category!
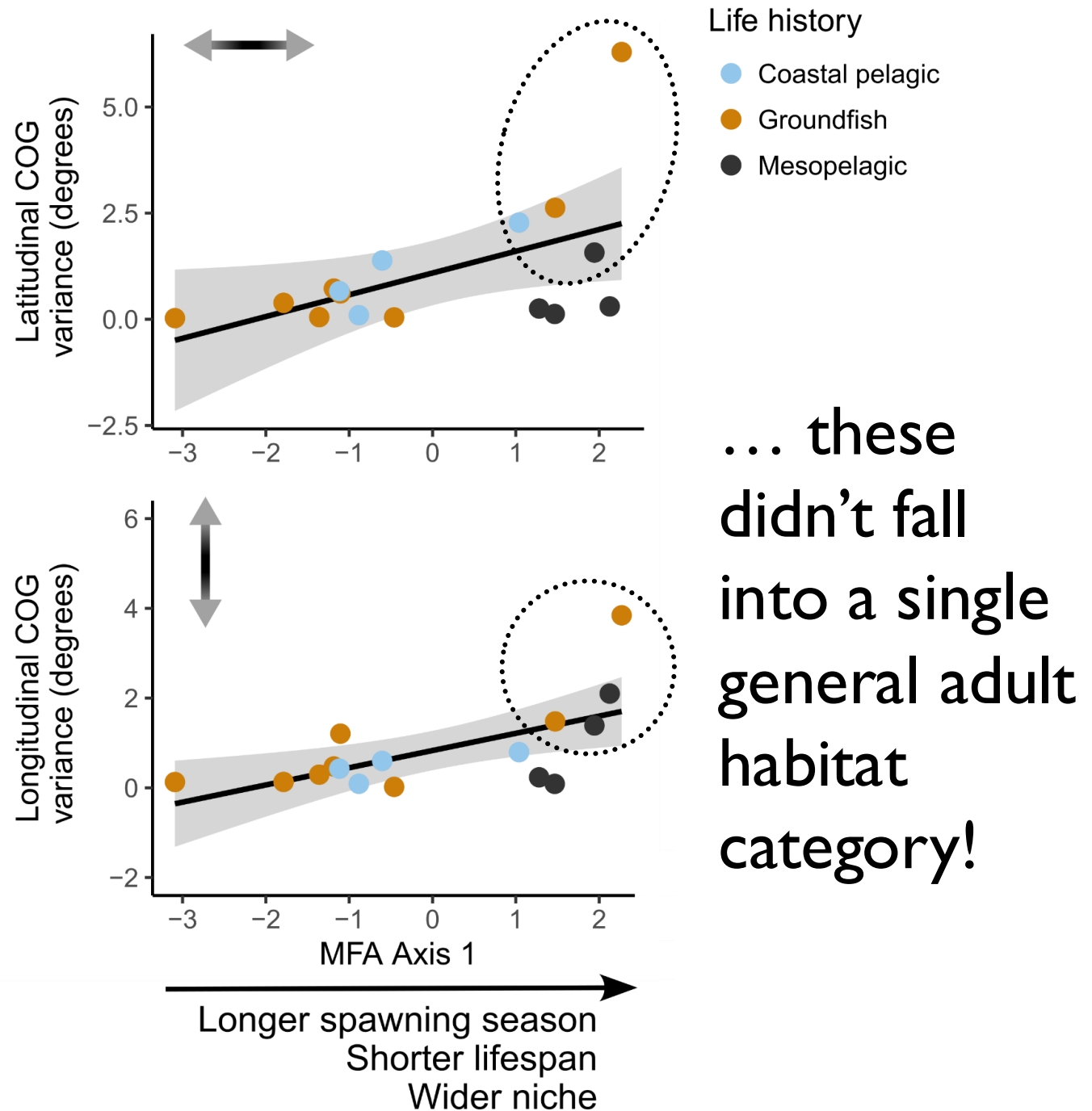
**In conclusion:** Most species we examined have the capacity to shift both phenology and geography, with species characteristics predicting geographic COG variance
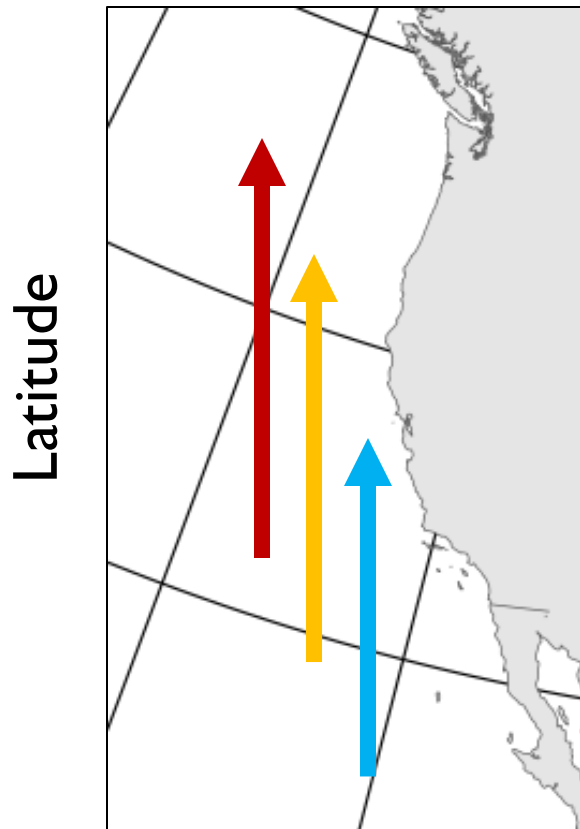


Species that can **easily move**, species with **longer lifespans**, or species with **wide niches**
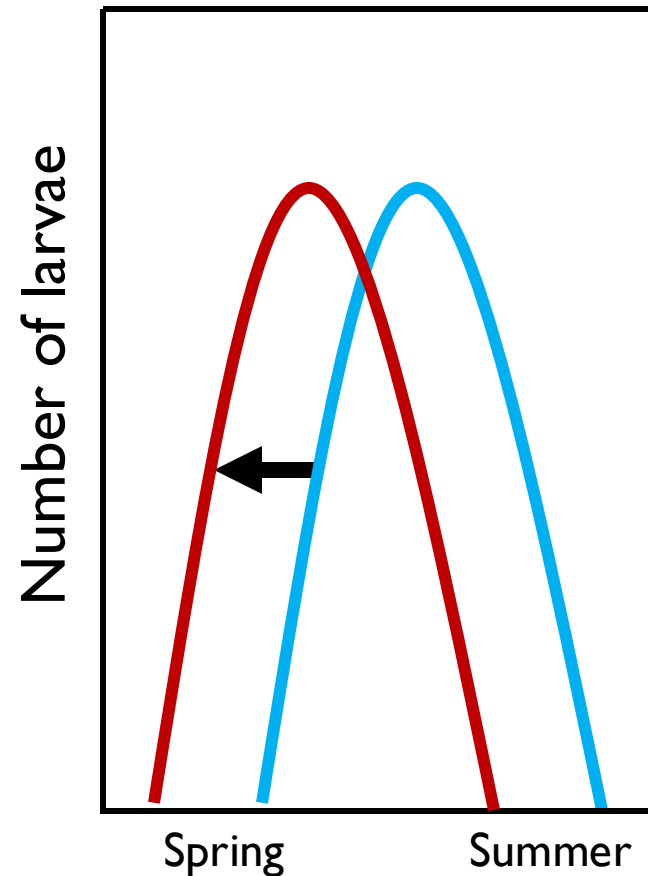
Species with **specific habitat needs**
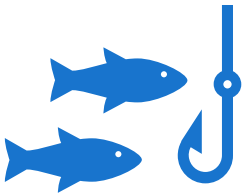
# Why does this matter?

- Species that are more likely to *rapidly* shift geography could be more vulnerable to climate impacts (Chaikin et al. 2024)

- Species that already have long spawning seasons and wide niches may be better prepared for future change

- Larvae that aren't in the "right place, right time" may face higher mortality rates
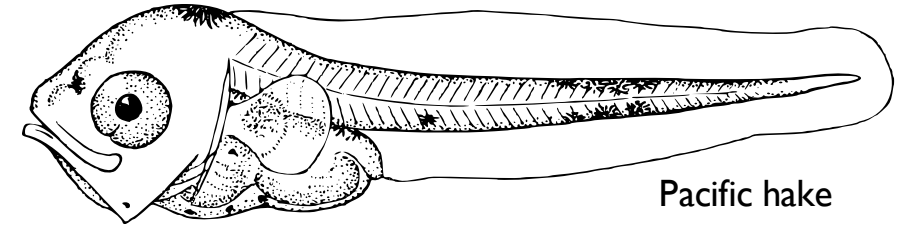
- Geographic and seasonal shifts of spawning adults could have an impact on fisheries, especially when distributions shift across country borders!

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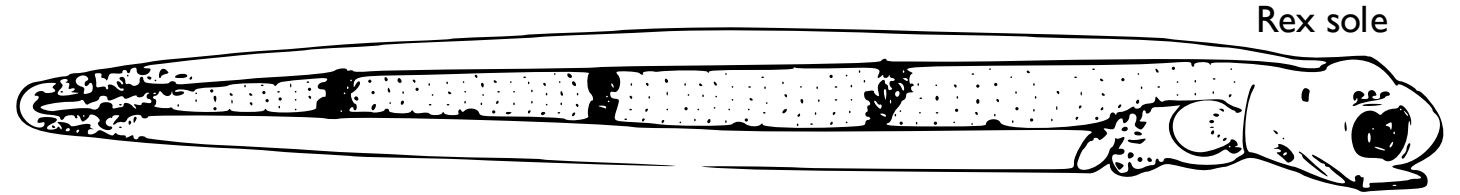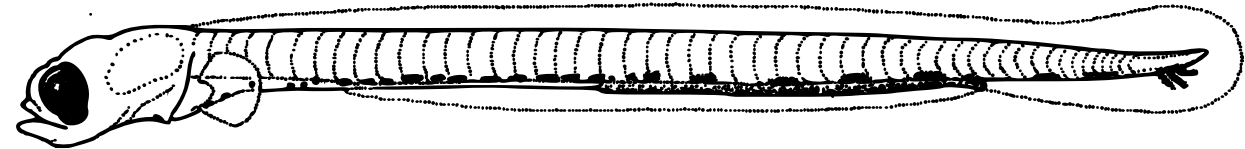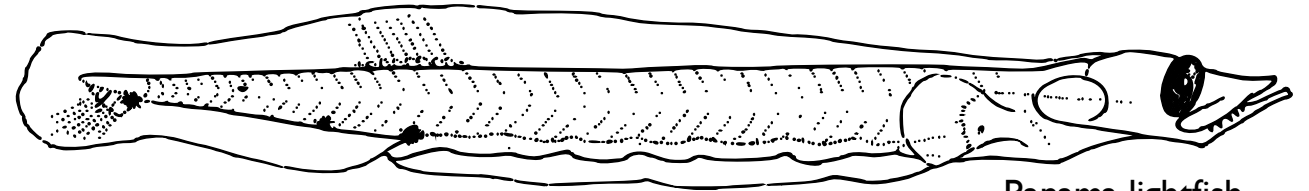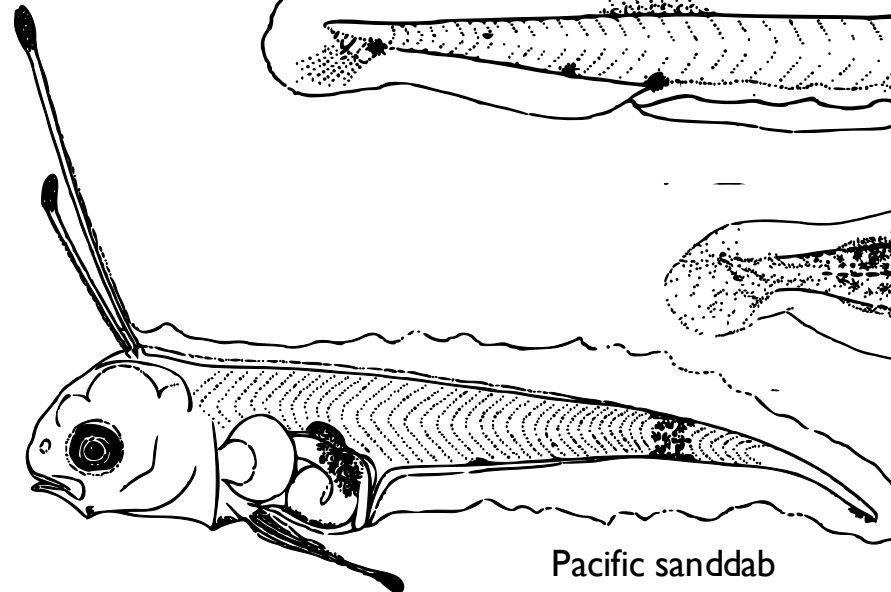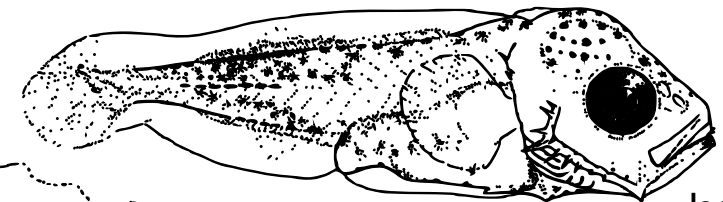Pacific hake

Rex sole

Sardine

Panama lightfish

Jack mackerel

Pacific sanddab

# Feedback welcome!

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*Drawings from CalCOFI Atlas 33*