Environmental forcing on forage fish and apex predators in the California Current: Results from a fully coupled ecosystem model

Jerome Fiechter

Institute of Marine Sciences, UC Santa Cruz

Co-authors: K. Rose, E. Curchitser, K. Hedstrom, L. Huckstadt, D.Costa, C. Edwards, D. Huff, B. Wells, and many more…

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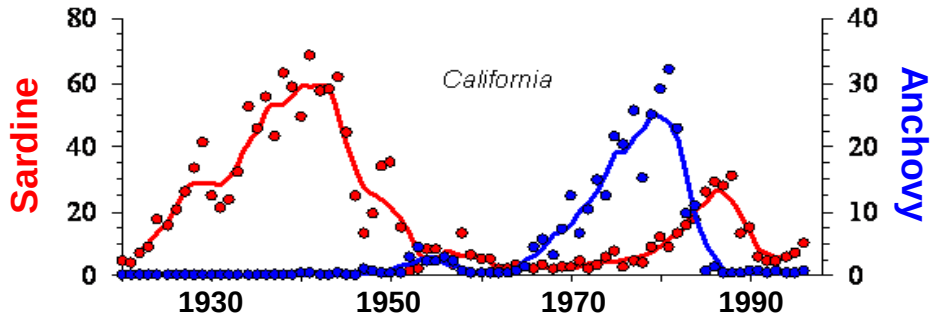
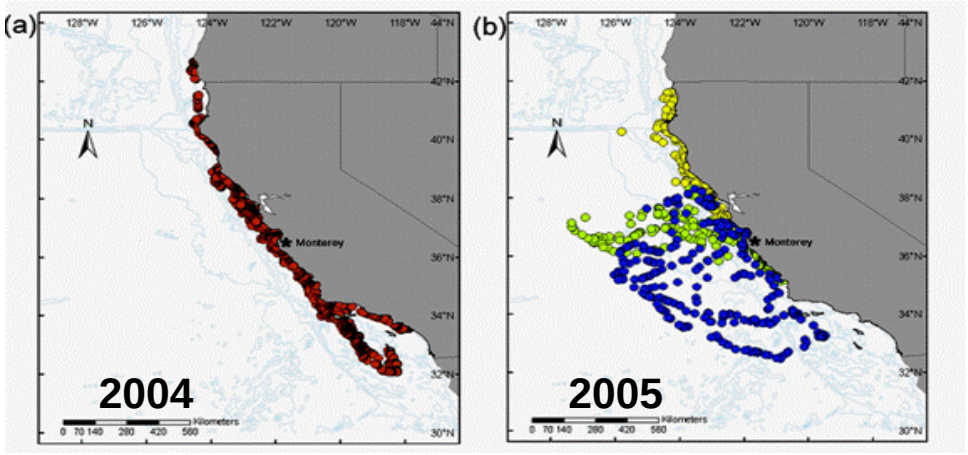
Ecosystem Variability in the California Current

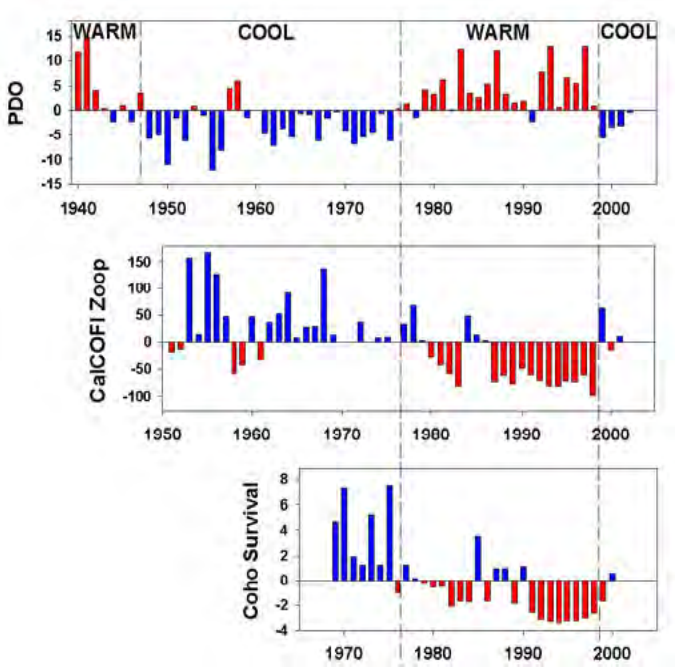
Goal: use fully coupled model to characterize environmental forcing on population dynamics of fish and top predators.



Sardine & Anchovy (Schwartzlose et al., 1999)



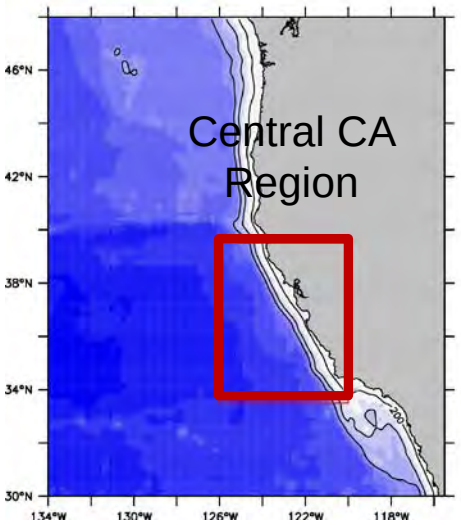
California Sea Lion (Weise et al., 2006)

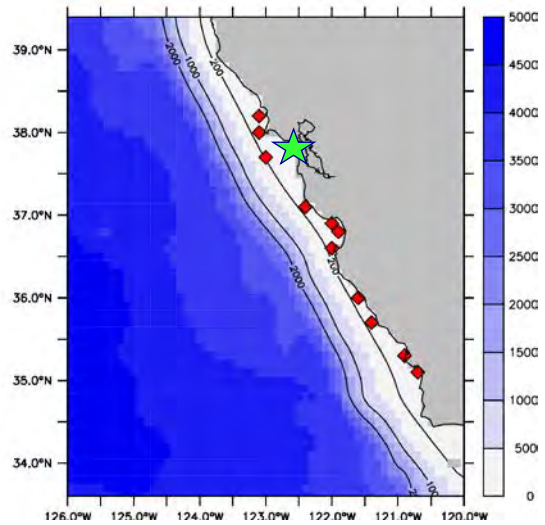


Coho Salmon Survival
(Peterson & Schwing, 2003)

Fully Coupled Ecosystem Model using ROMS Framework

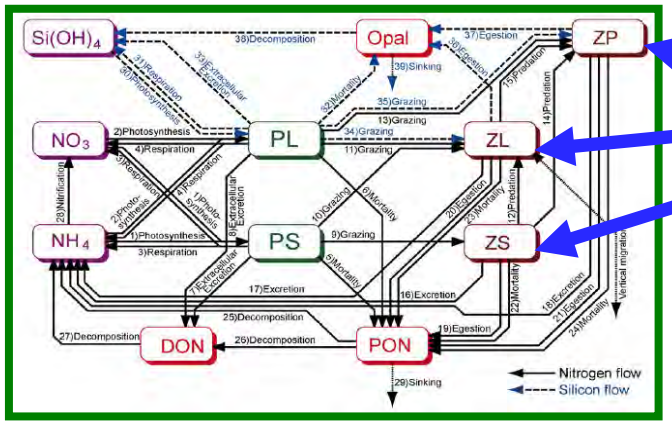
Regional Ocean Modeling System (ROMS)





- Ocean circulation
- Multi-decadal runs
- High-res. nesting
- Data assimilation
- Climate coupling

Biogeochemistry (NEMURO)



Multi-species Individual-Based Model

Fish IBM
Sardine
Anchovy
Juv. Salmon

Predator IBM
Sea Lions
Albacore

Fishing Fleet

Multi-species Individual-Based Model (IBM)

Individual-based Model

- Basic unit in nature; allows for complex life history/behavior.
- Main components: behavior, growth, mortality, reproduction.

Sardines and Anchovy (low frequency variability, 1964-2008)

- Dynamically feed on/compete for NEMURO zooplankton.
- Kinesis behavior combining temperature and food cues.

California Sea Lions (shifts in foraging patterns, 1989-2008)

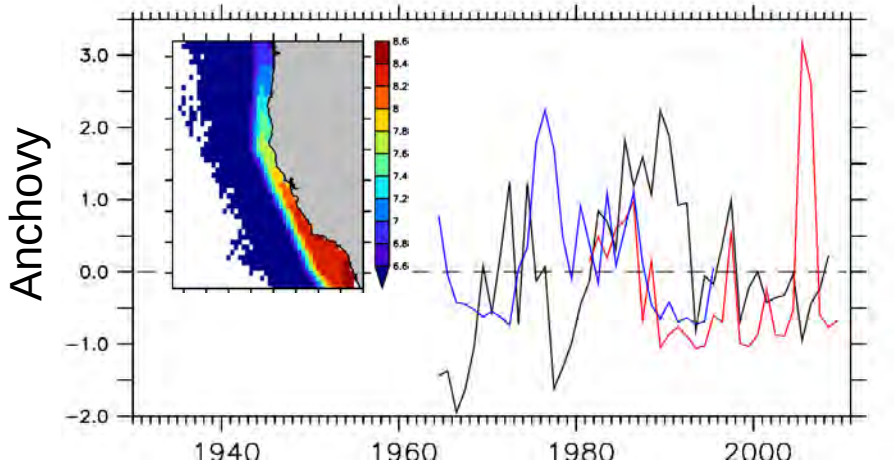
- Dynamically feed on sardine and anchovy from fish IBM.
- Additional predation on market squid and mackerel.
- Kinesis behavior using temperature cue of upwelled waters.

Juvenile Salmon (growth following ocean entry, 1980-2008)

- Dynamically feed on NEMURO predatory zooplankton (krill).
- Bioenergetics (growth) from dynamic energy budget model.
- Neighborhood search behavior based on prey availability.

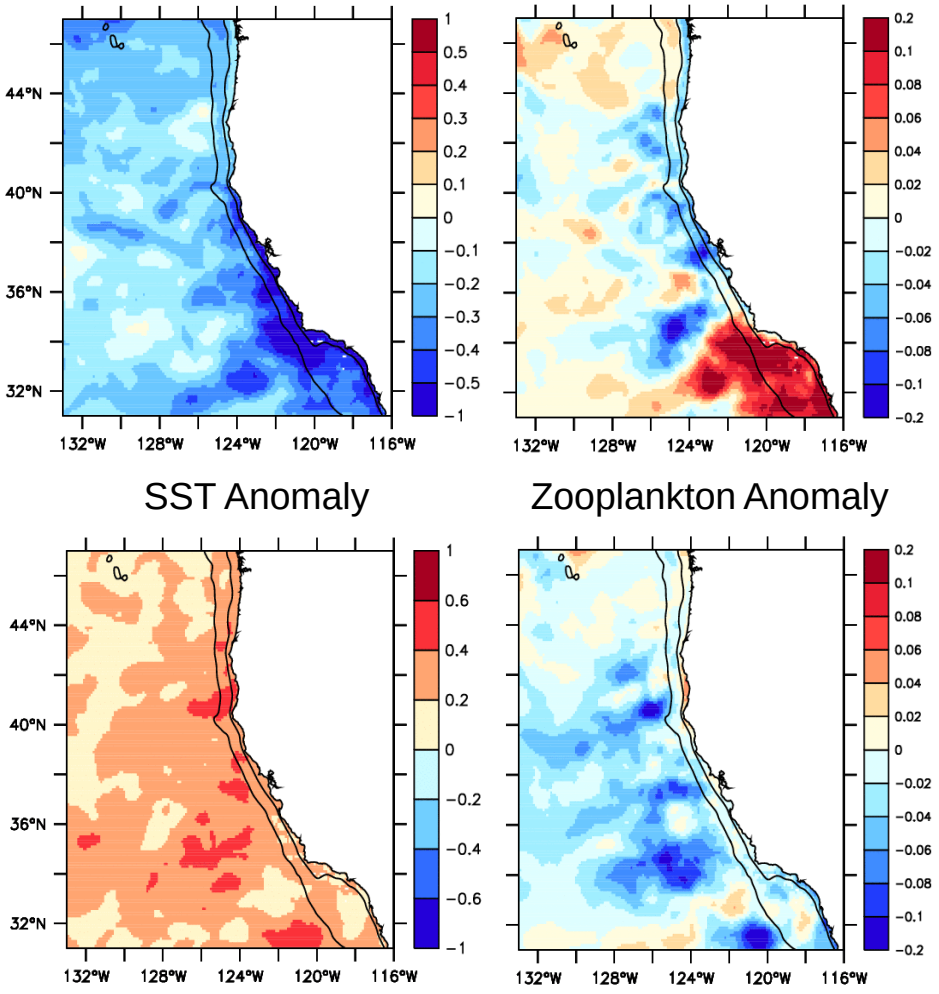
Sardine and Anchovy Population Dynamics

Adult Population Biomass



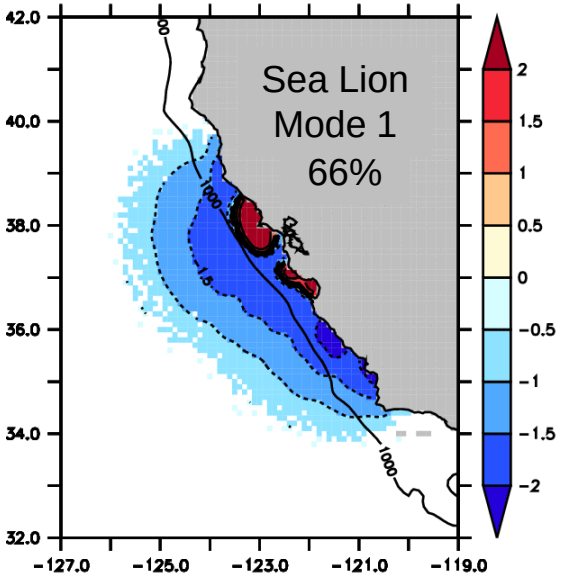
Rose et al., Prog. Ocean., 2015

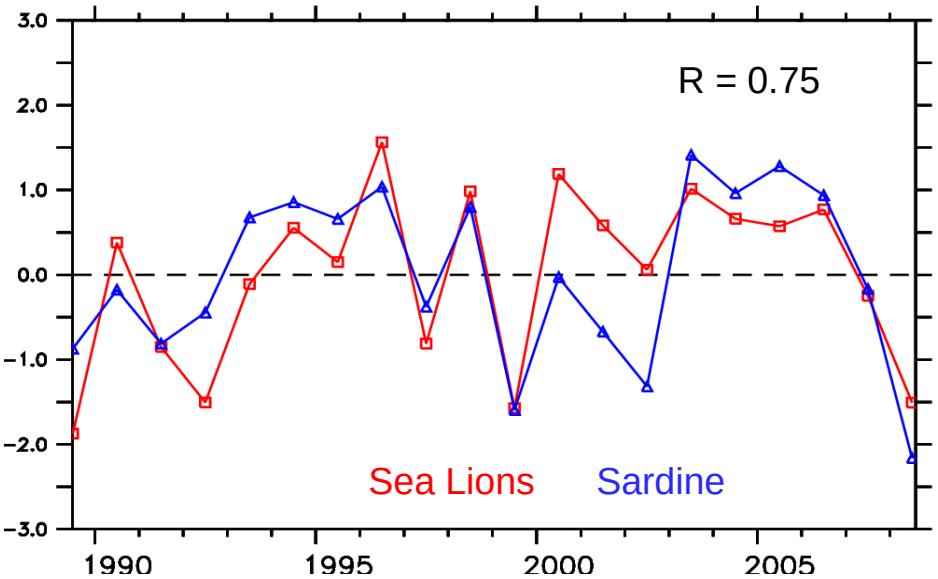
Favorable Environmental Conditions

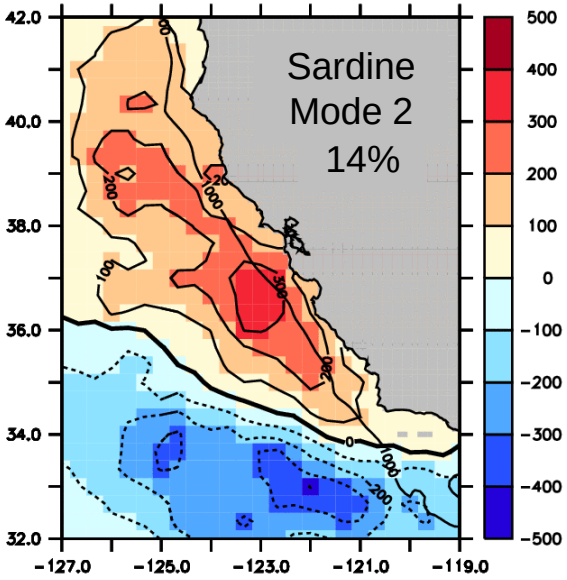


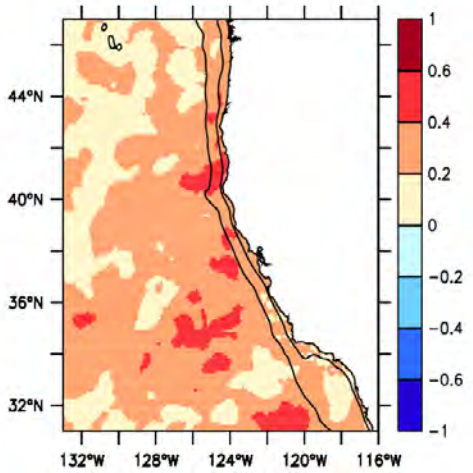
Fiechter et al., Prog. Ocean., 2015

California Sea Lion Feeding Success (EOF Mode 1)

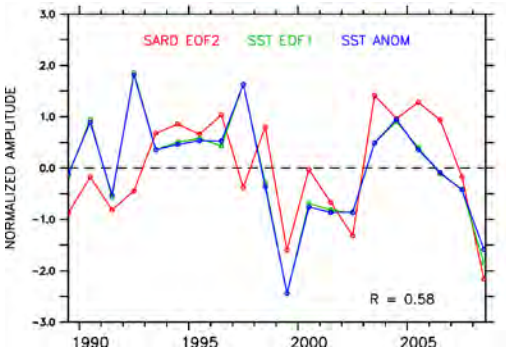






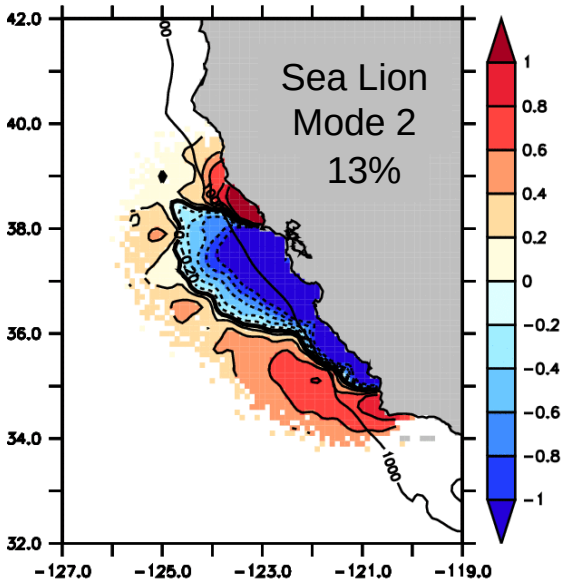


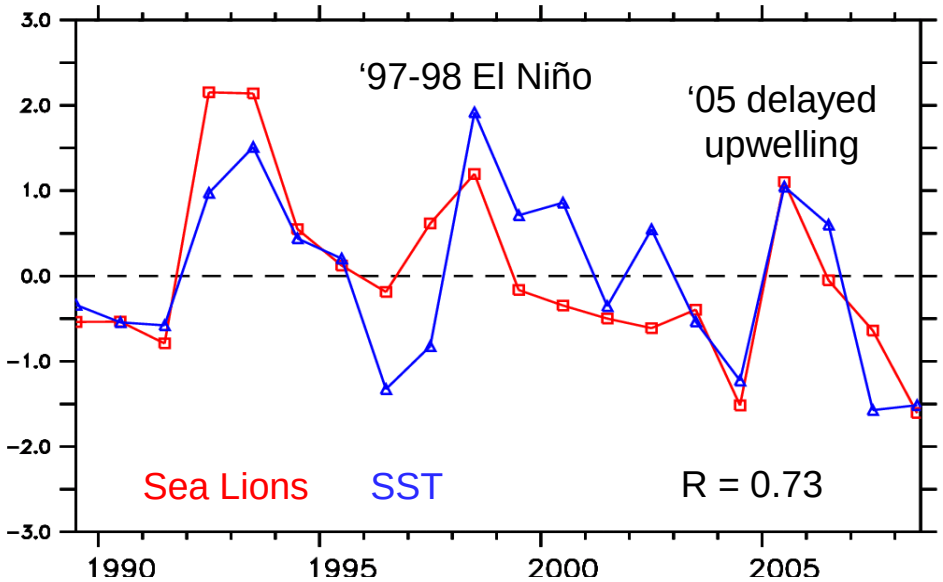
R_{PDO} = 0.7

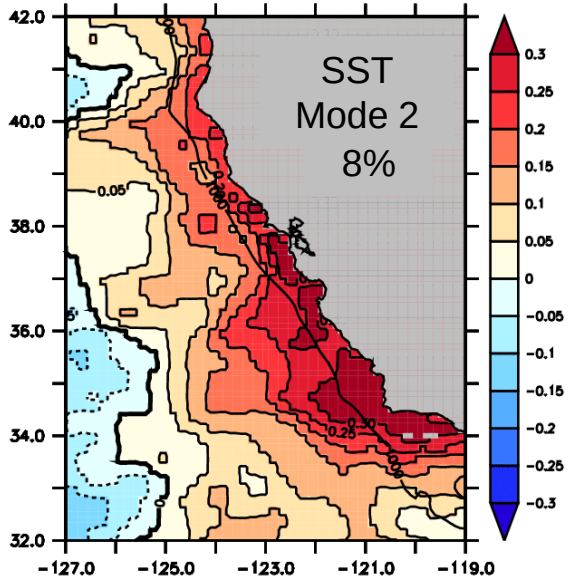


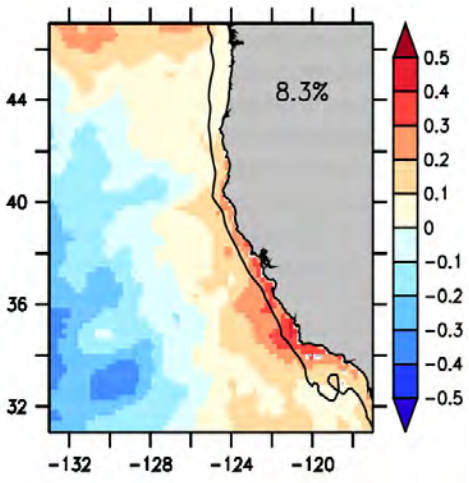
Fiechter et al., MEPS, 2016

California Sea Lion Foraging Patterns (EOF Mode 2)

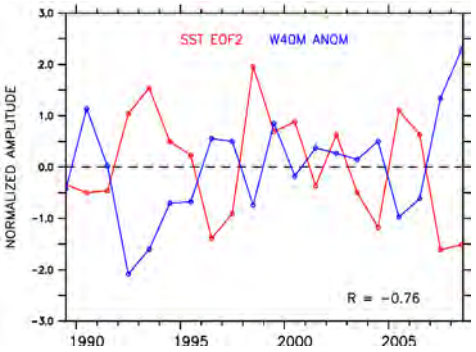






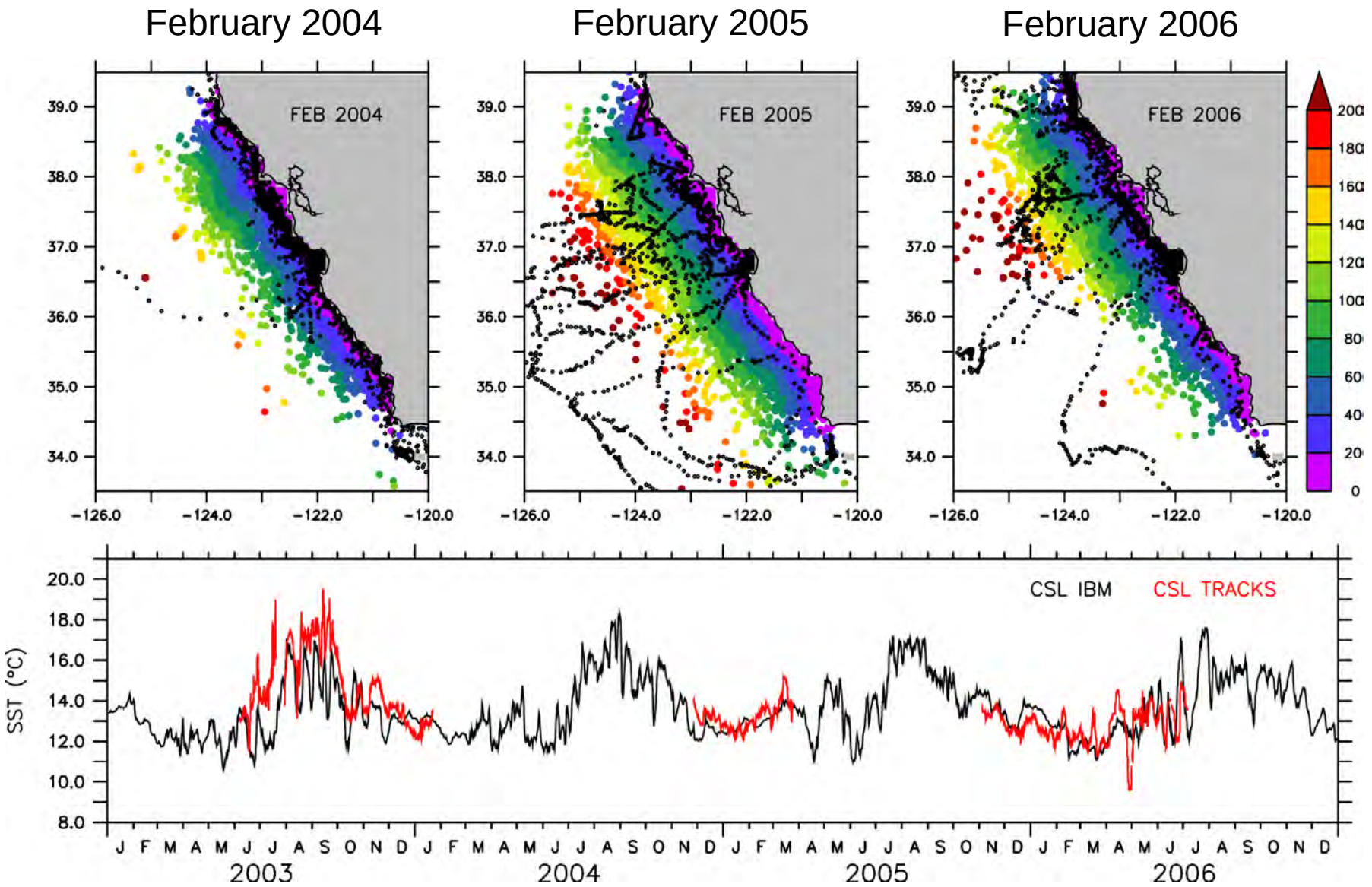


R_{ENSO} = 0.21 R_{UI36N} = -0.20

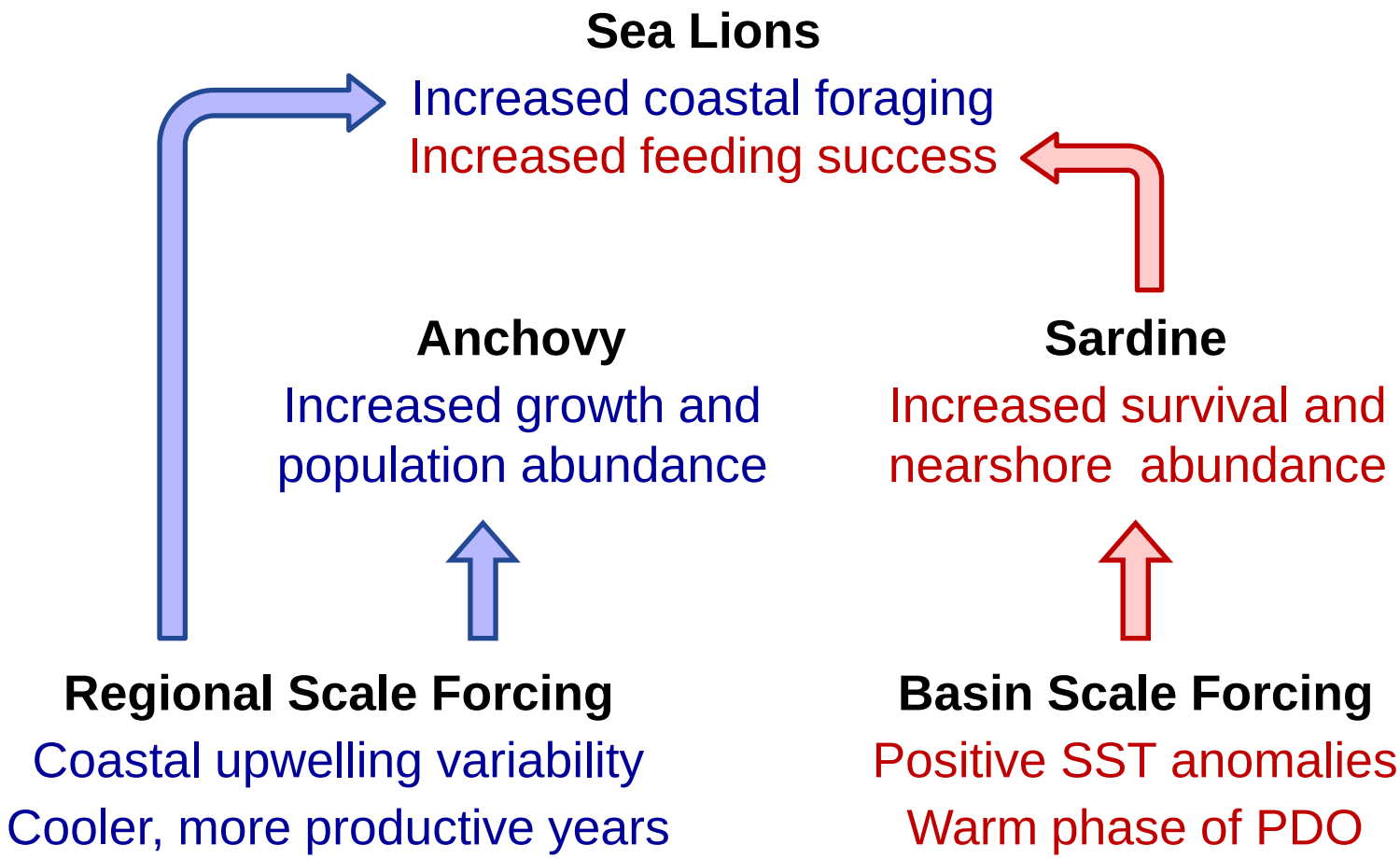


Fiechter et al., MEPS, 2016

Onshore-Offshore Shift in Foraging Patterns (Mode 2)

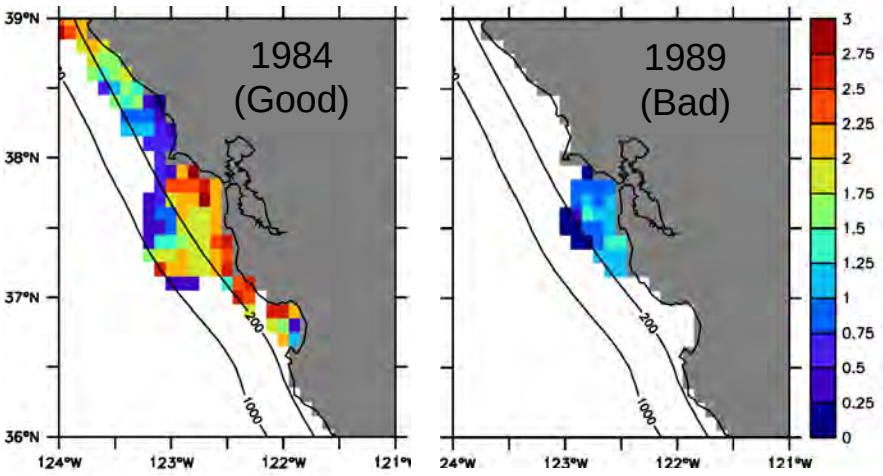


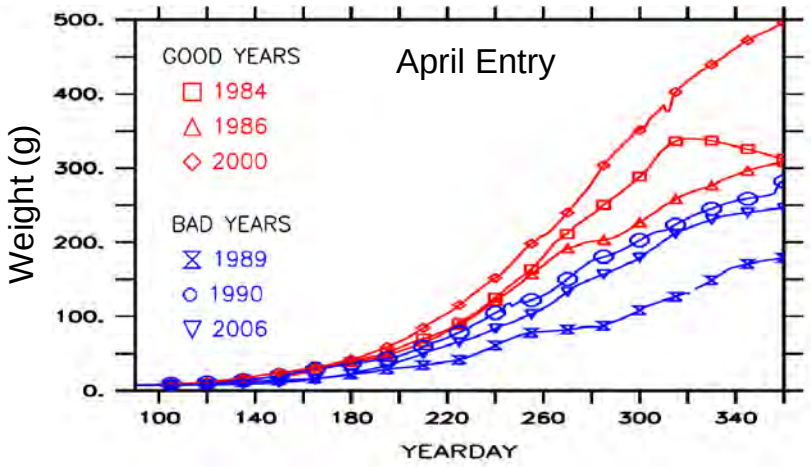
Environmental Forcing across Trophic Levels



Juvenile Salmon Growth and Early Upwelling Intensity

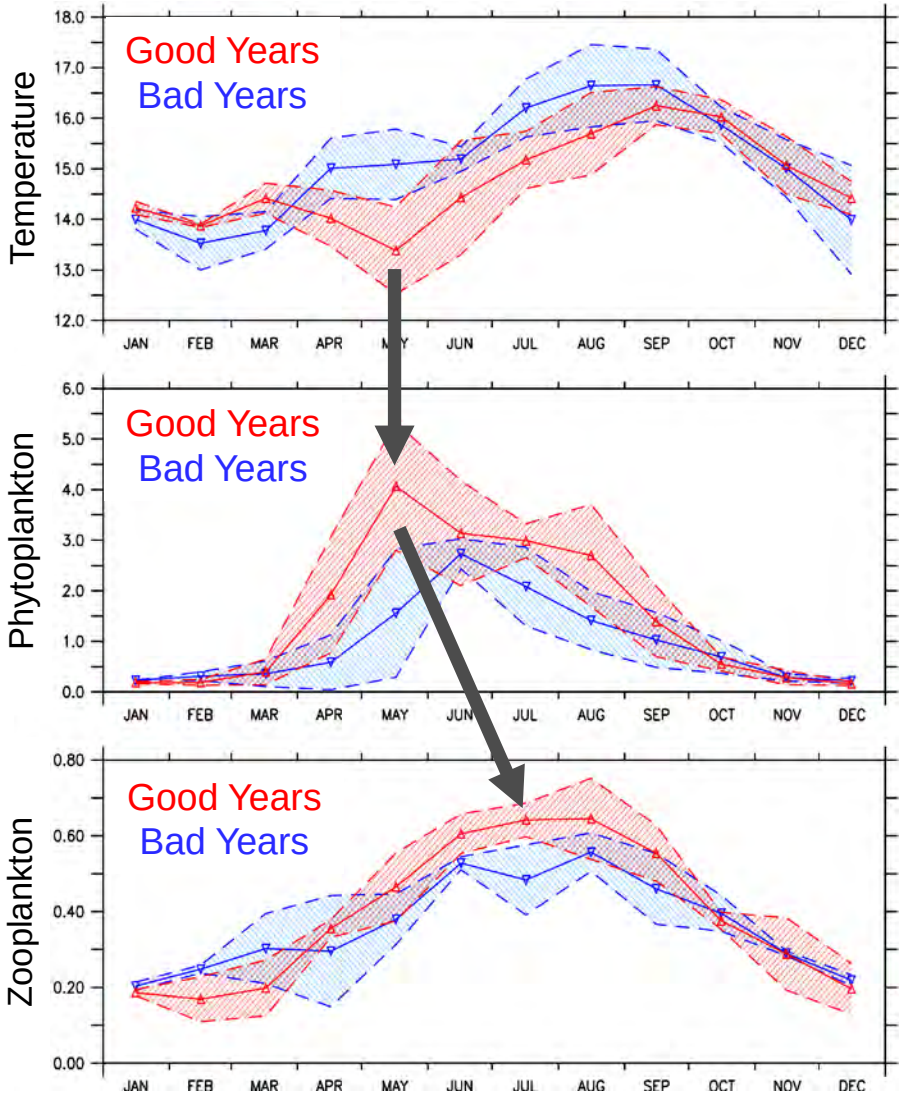
Growth Potential





Fiechter et al., GRL, 2015

Environmental Conditions



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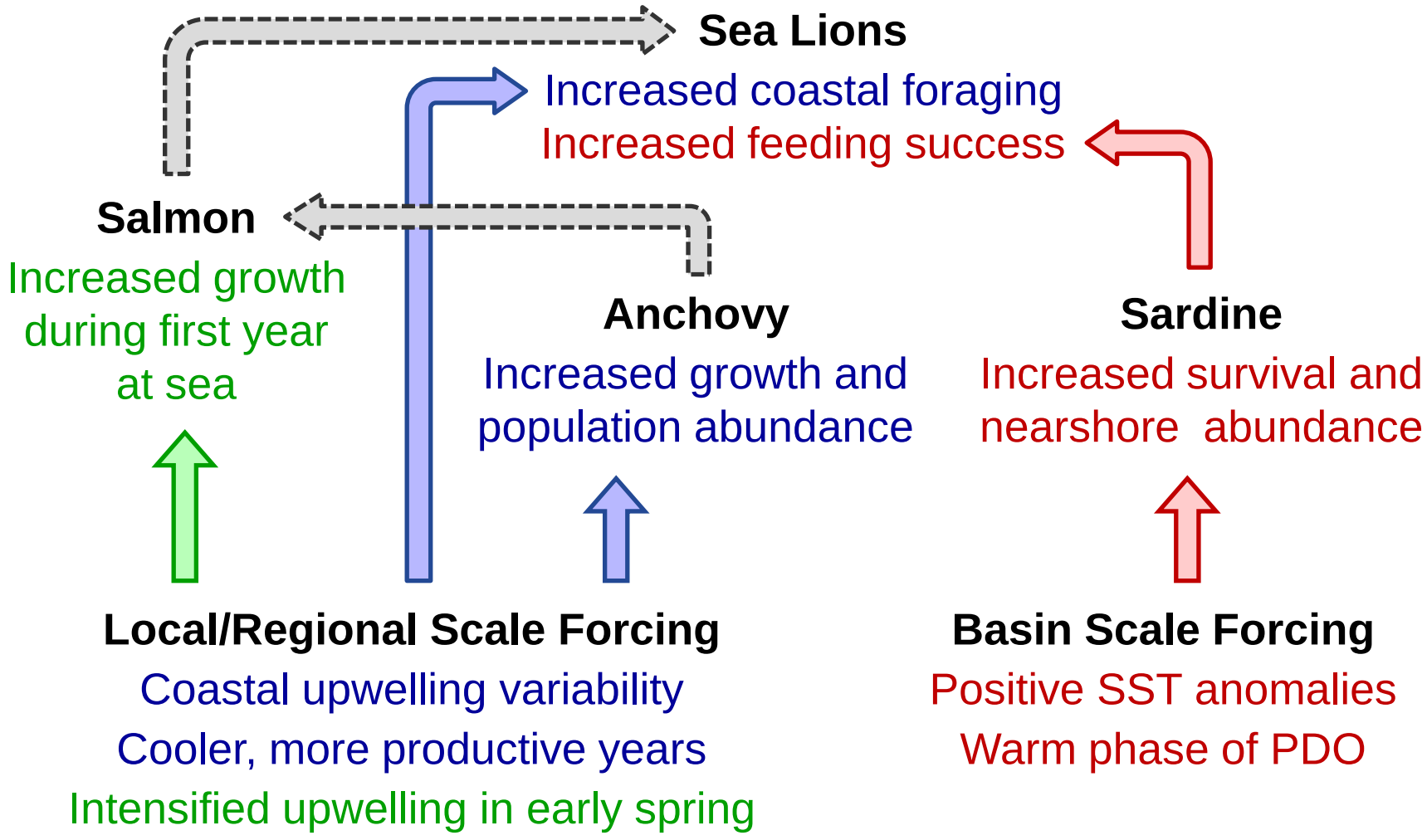

Summary

Proof of principle (it can be done)

- 3 days of CPU time for 20 years at 10km resolution.
- 20,000 fish super-individuals and 1,000 predator individuals.

Model calibration and evaluation

- Very challenging: physics, NPZ, fish, and predators.
- Behavior: must include realism without “overtuning”.

Is it useful?

- Low-frequency cycles in sardine and anchovy populations.
- Shifts in sea lion foraging patterns (e.g., onshore vs. offshore).
- Environmental conditions favoring juvenile salmon growth.
- Mechanistic approach to understanding ecosystem variability.

Fully-coupled food web model?

Not quite there yet, but getting closer…