Albacore and prey species distribution modeling in the California Current

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Project Motivation and Guidance

ALBACORE

1. Management Objectives / Stakeholder Priorities

HMS FMP objectives (as for swordfish)

Albacore as “insurance” fleet (not limited entry)

Understanding migration dynamics and impact of prey availability

Understanding changes in distribution (offshore/inshore and north/south)

2. Performance Metrics

International albacore Management Strategy Evaluation

Landings by port

Socio-economic metrics (revenue, harvester and processor engagement)

3. Management Strategies / Scenarios

No limited entry

Total allowable catch/effort at international level

West coast implementation of international TAC/TAE

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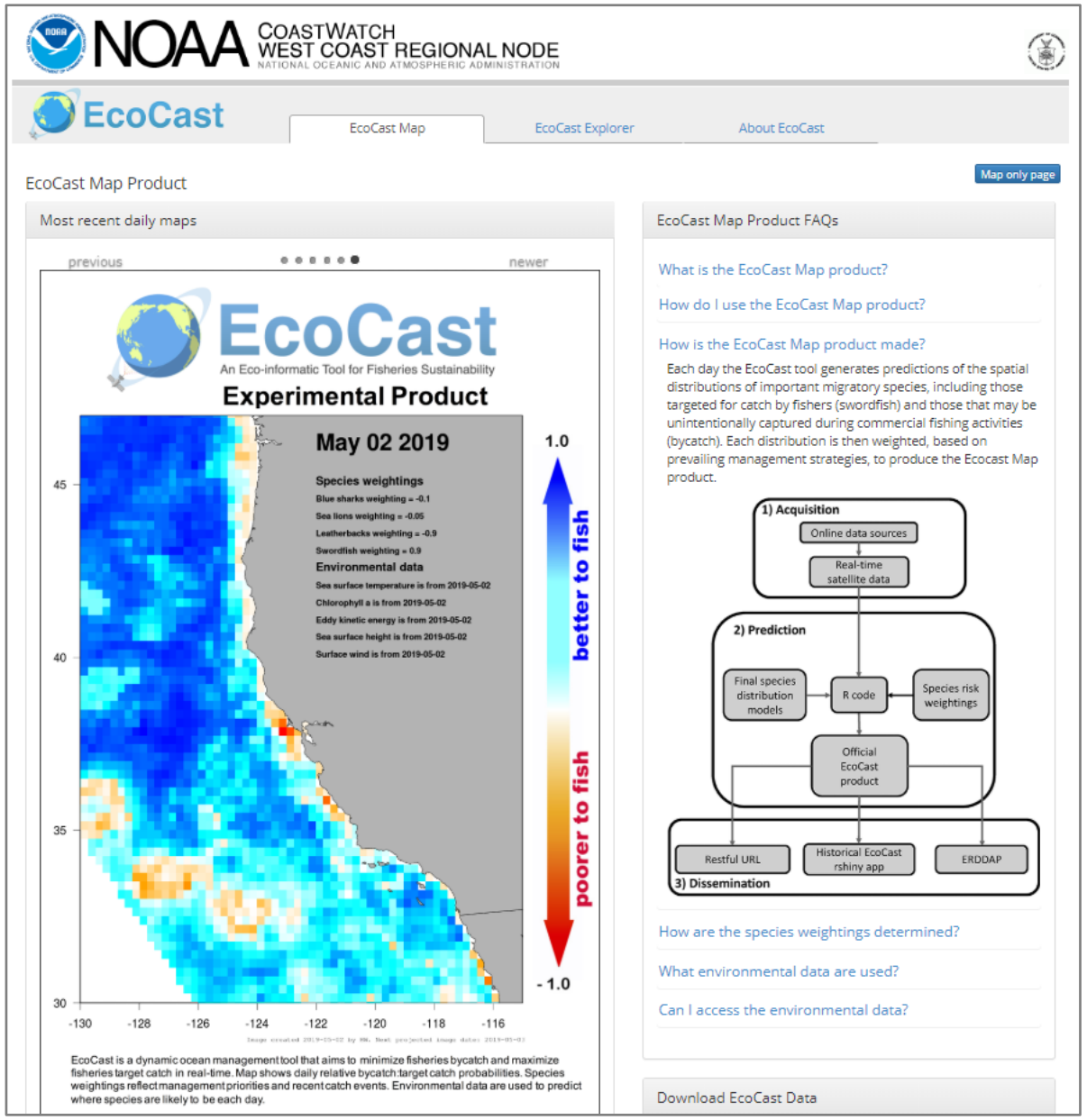
Ecocast



- Ecocast uses statistical Species Distribution Models for swordfish and multiple bycatch species
- Predicts optimal fishing locations to maximize target catch and minimize bycatch
- Not yet available for albacore or forage species

https://coastwatch.pfeg.noaa.gov/ecocast/map_product.html

SCIENCE ADVANCES | RESEARCH ARTICLE

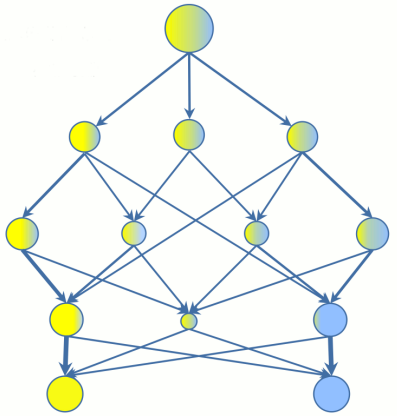
ECOLOGY

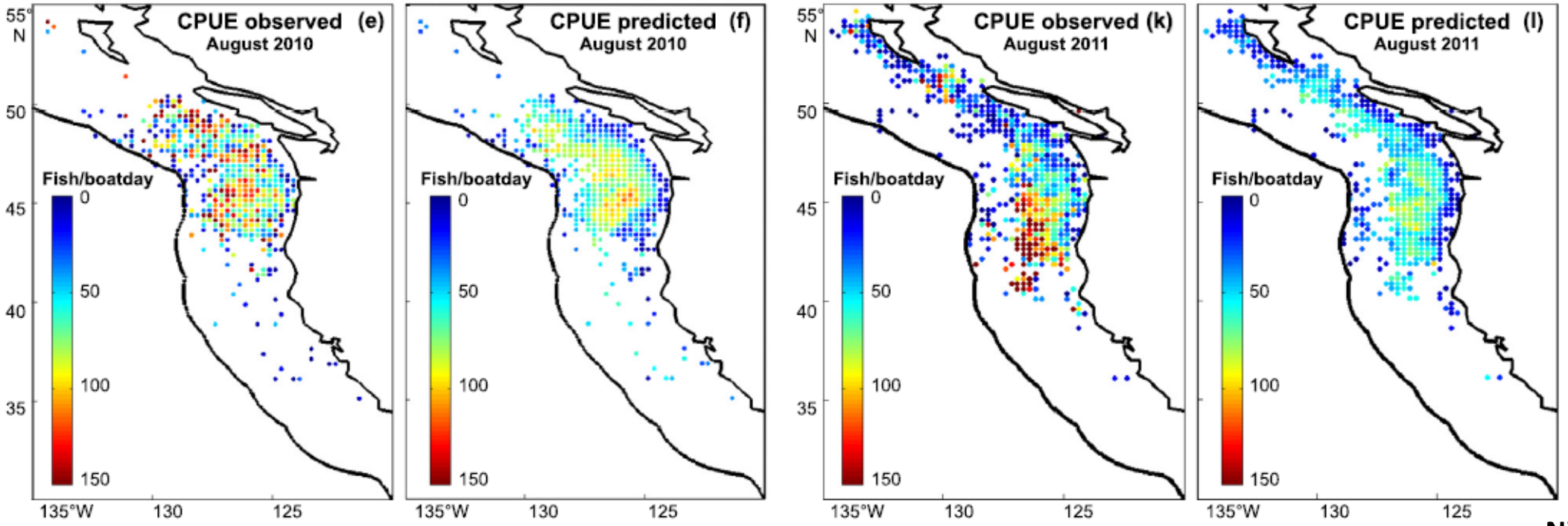
A dynamic ocean management tool to reduce bycatch and support sustainable fisheries

Elliott L. Hazen,[1,2,3]* Kylie L. Scales,[2,4] Sara M. Maxwell,[5] Dana K. Briscoe,[2] Heather Welch,[2] Steven J. Bograd,[1,2] Helen Bailey,[6] Scott R. Benson,[1,7] Tomo Eguchi,[1] Heidi Dewar,[1] Suzy Kohin,[1] Daniel P. Costa,[2] Larry B. Crowder,[8] Rebecca L. Lewison[9]

Species distribution models

- Quantify relationships between species distribution and environment
- Extend previous studies on albacore and forage species by:
  - Including sub-surface predictor variables (ROMS)
  - Updating predictions to the present (including “blob” years)
  - Including biomass indicators to account for favorable but unoccupied habitat





Nieto et al. 2017

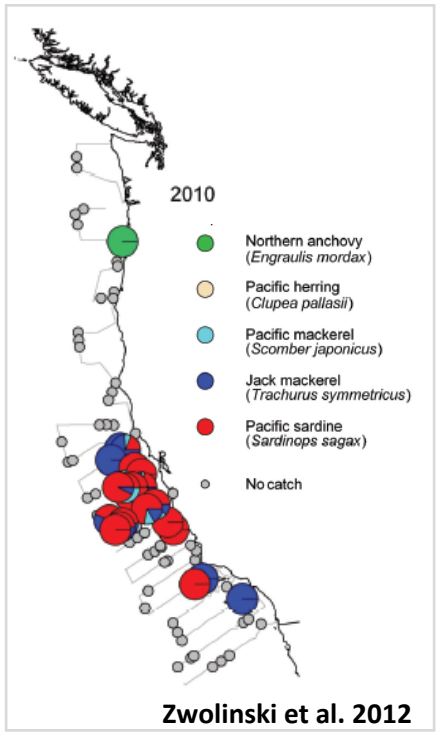
Biological data sources

Albacore

- Model training: CPUE from troll and pole-and-line fishery logbooks (Gaussian)
- Validation: Daily positions from archival tags

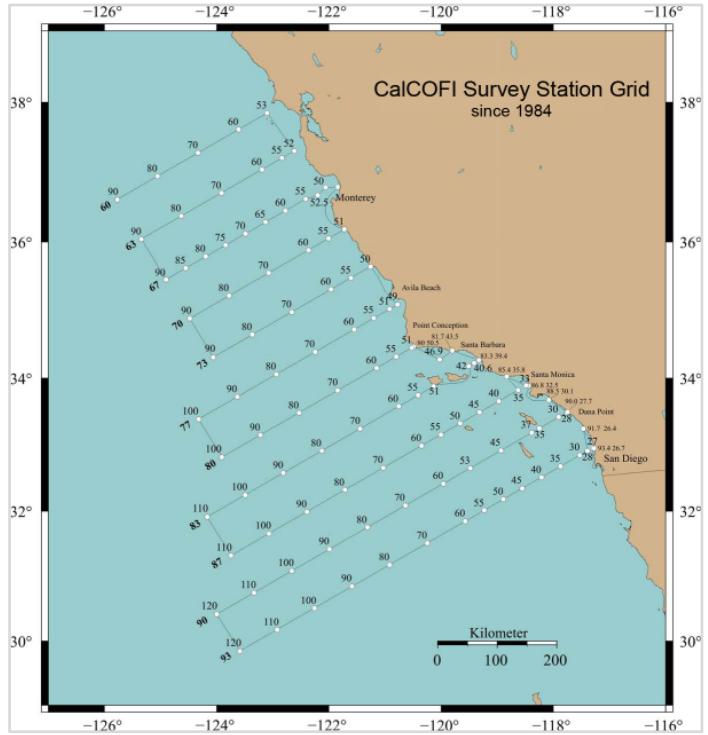
Prey species

- Model training: Presence/absence from SWFSC trawl surveys (Binomial)
- Validation: CalCOFI larval/egg surveys
- Picked 5 prey species based on diet studies and importance to Future Seas project:
  - Anchovy, hake, sardine, saury and boreal clubhook squid



Zwolinski et al. 2012


L. Vasquez NOAA



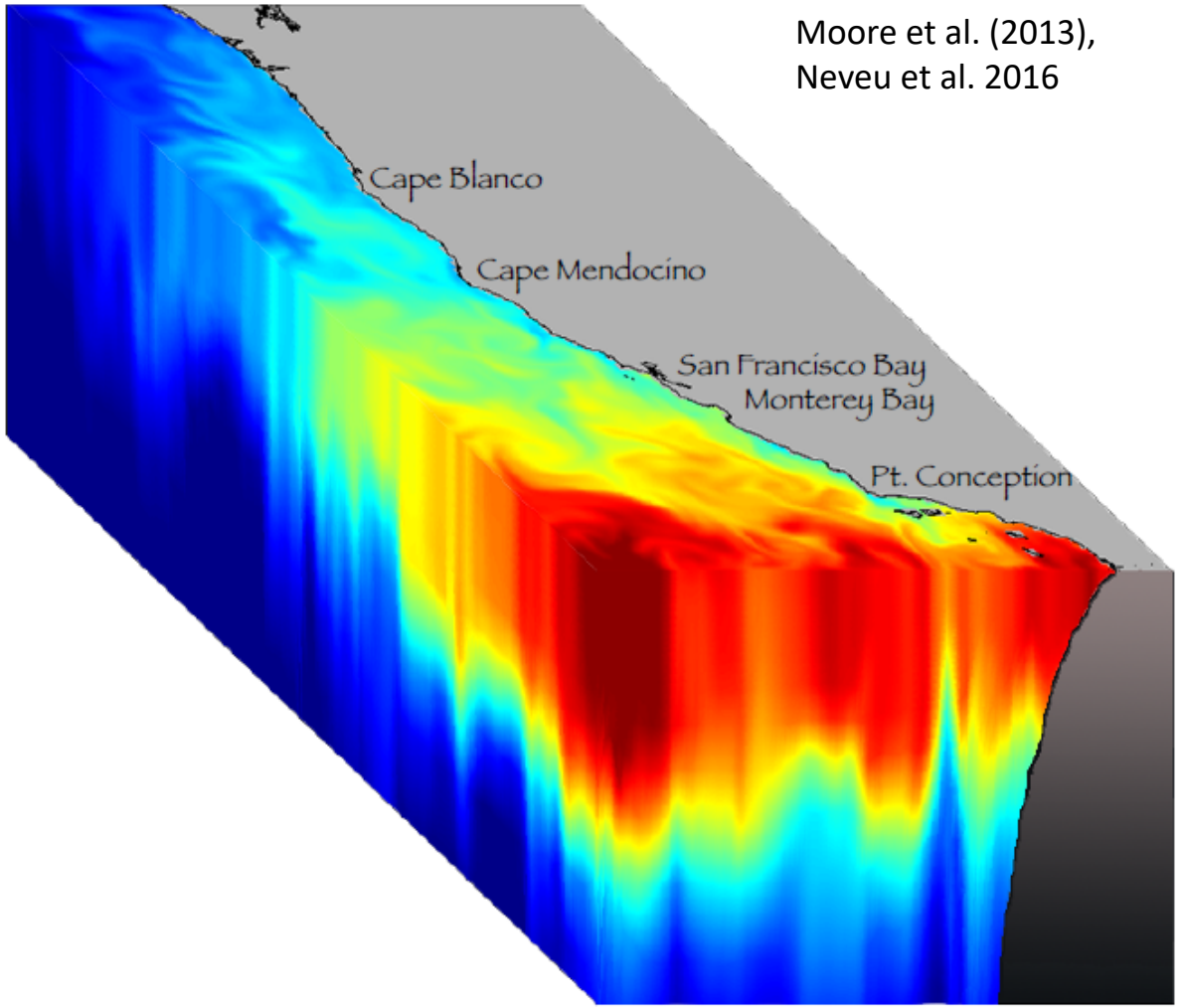
Environmental predictors

- Sourced from data-assimilative ROMS
- Surface chlorophyll also included from satellite observations (SeaWiFS, MODIS-Aqua, VIIRS, ESA reanalysis)

ROMs Variable	Biological Relevance
Moon phase	Foraging behavior and depth distribution
Sea surface temperature	Metabolic processes, thermal niche
SD of sea surface temperature	Dynamic temperature variability
Sea surface height	Mesoscale current and eddy features
SD of sea surface height	Dynamic mesoscale feature variability
Eastward surface current flow	Inshore/offshore transport
Eastward surface wind stress	Nearshore dynamics, retention
Northward surface current flow	Alongshore transport
Northward surface wind stress	Upwelling proxy
Wind stress curl	Tendency for convergence/divergence at surface
Eddy kinetic energy	Eddy dynamics
Isothermal layer depth	Depth of surface mixing
Bulk buoyancy frequency	Stratification and stability in upper water column

0.1 horizontal resolution, 42 vertical levels

Moore et al. (2013),
Neveu et al. 2016



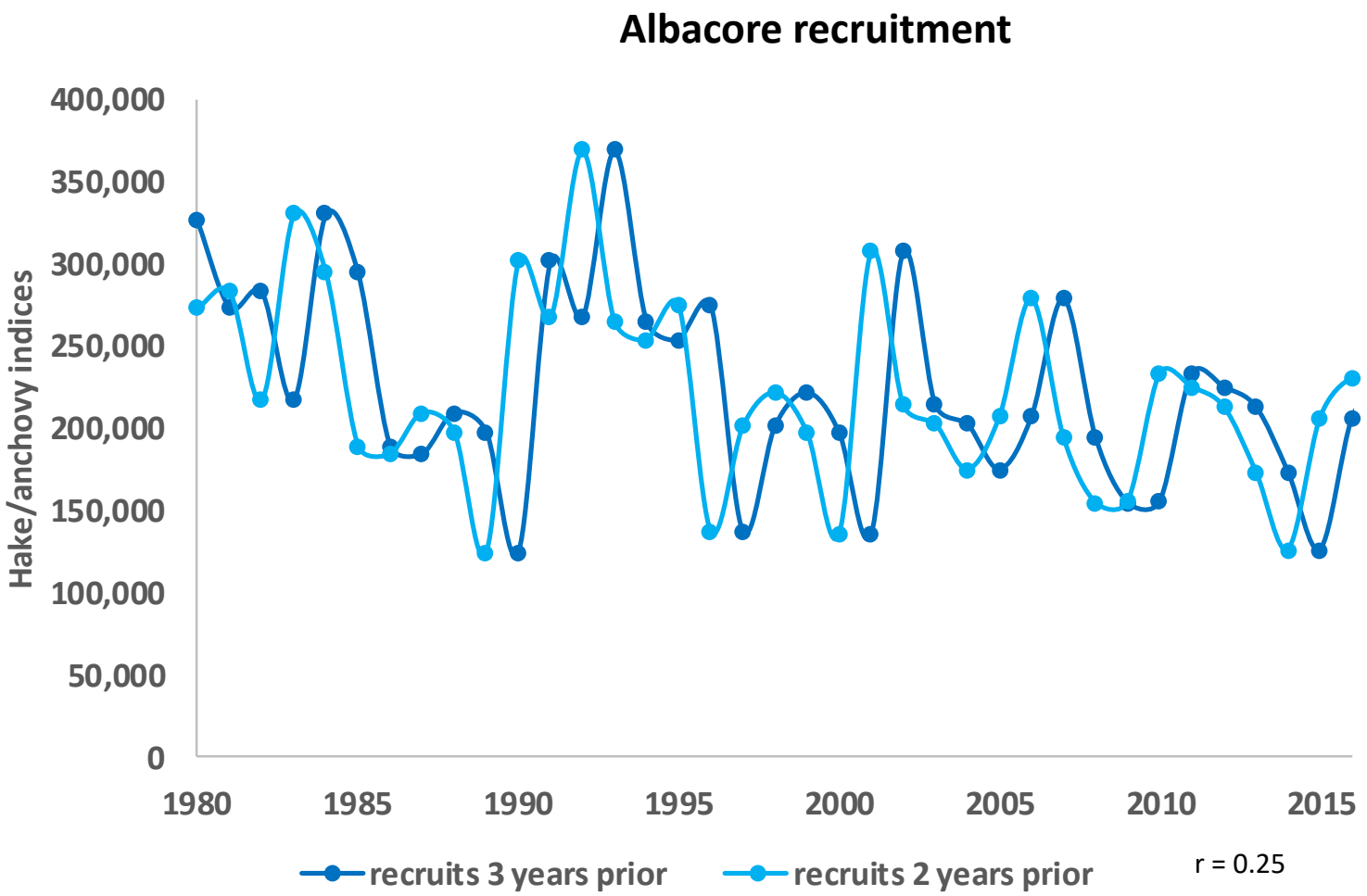
frontiers in Marine Science

Integrating Dynamic Subsurface Habitat Metrics Into Species Distribution Models

Stephanie Brodie[1,2], Michael G. Jacox[1,2,3], Steven J. Bograd[1,2], Heather Welch[1,2], Heidi Dewar[4], Kylie L. Scales[5], Sara M. Maxwell[6], Dana M. Briscoe[1], Christopher A. Edwards[1], Larry B. Crowder[7], Rebecca L. Lewison[8] and Elliott L. Hazen[1,2]*

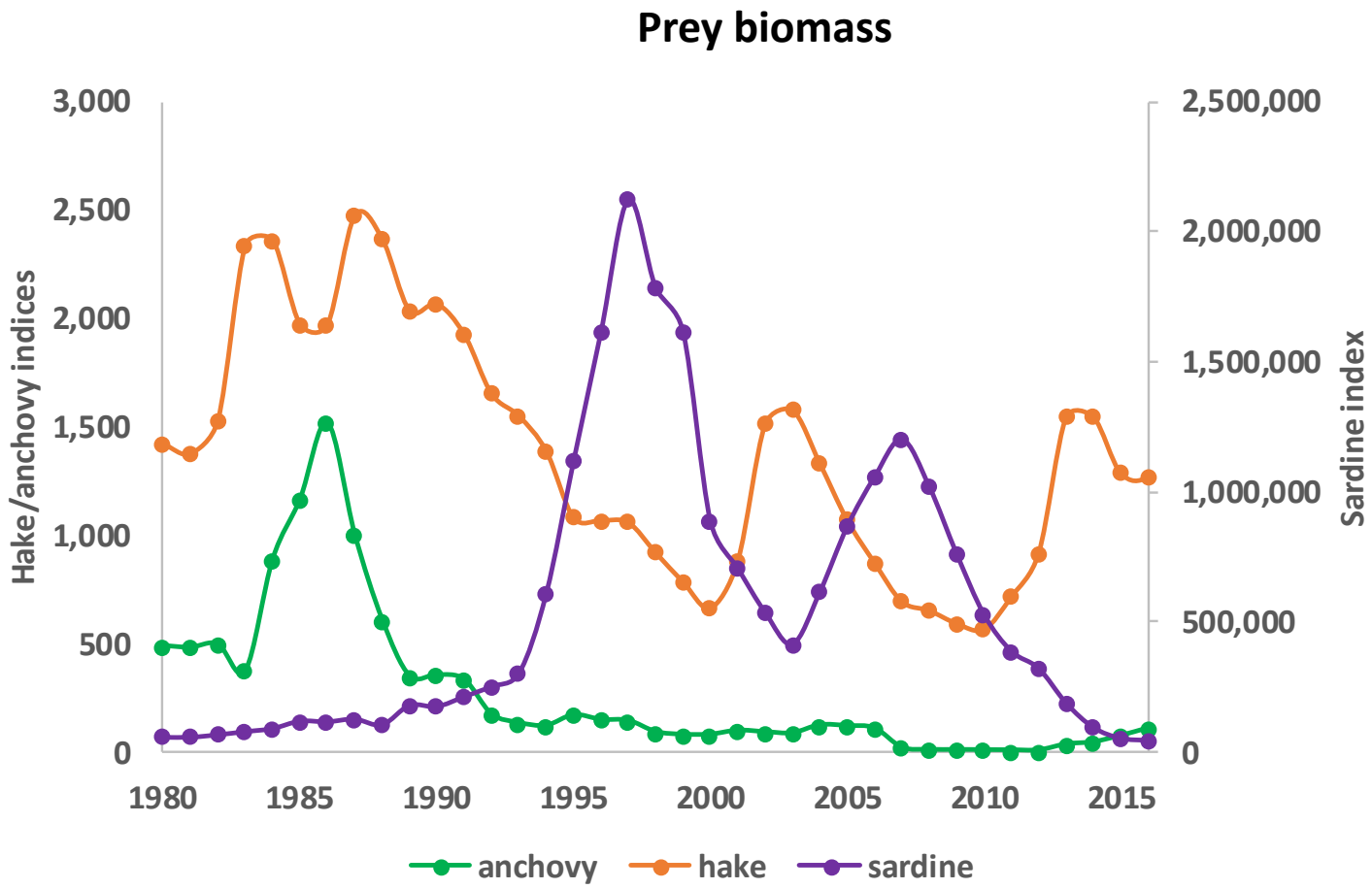
Biomass predictors - albacore

- Albacore could be more abundant in the CCS after a strong year-class
  - Included recruitment from stock assessment for 2 and 3 years prior as annual predictors



Biomass predictors - prey

- Small pelagic spp. biomass fluctuates strongly, could impact migration, occupied habitat
  - Spawning stock biomass from stock assessment for hake and sardine
  - CalcCOFI larval abundance index for anchovy
  - None available for saury and clubhook squid



SDM Results

- Saury SDM weak, not considered further
- Surface temperature, chlorophyll, and bulk buoyancy frequency the most influential
- Biomass important to sardine, not to other species

	Albacore	Anchovy	Hake	Sardine	Clubhook
Variable Name					
Sea surface temperature	11.70	6.98	4.92	14.04	10.46
Sea surface temperature st.dev.	5.06	6.97	6.53	6.73	6.56
Sea surface height	6.00	6.23	10.53	6.19	5.92
Sea surface height st.dev.	4.62	3.59	7.46	3.45	5.56
Surface eastward current velocity	3.85	3.31	5.60	4.09	2.28
Surface eastward wind stress	4.86	4.03	3.42	6.31	7.60
Surface northward current velocity	4.17	6.66	3.16	4.95	3.24
Surface northward wind stress	4.78	15.82	3.70	5.1	9.4
Wind stress curl	4.81	2.72	4.31	5.86	7.29
Eddy kinetic energy (log)	3.73	7.27	4.37	5.37	3.64
Isothermal layer depth	6.34	9.52	9.03	3.41	10.65
Bulk buoyancy frequency	17.57	5.74	10.03	8.27	8.34
Surface chlorophyll (4th root)	10.90	12.51	17.89	10.41	6.58
Moon phase	4.83	5.01	6.86	4.78	11.44
Albacore recruits 2 years ago	3.83	---	---	---	---
Albacore recruits 3 years ago	2.93	---	---	---	---
Anchovy SSB index	---	3.64	---	---	---
Hake SSB index	---	---	2.2	---	---
Sardine SSB index	---	---	---	11.03	---
SDM AUC or R2	**R2 = 0.31**	**AUC = 0.82**	**AUC = 0.79**	**AUC = 0.78**	**AUC = 0.71**

Top 3

Top 5

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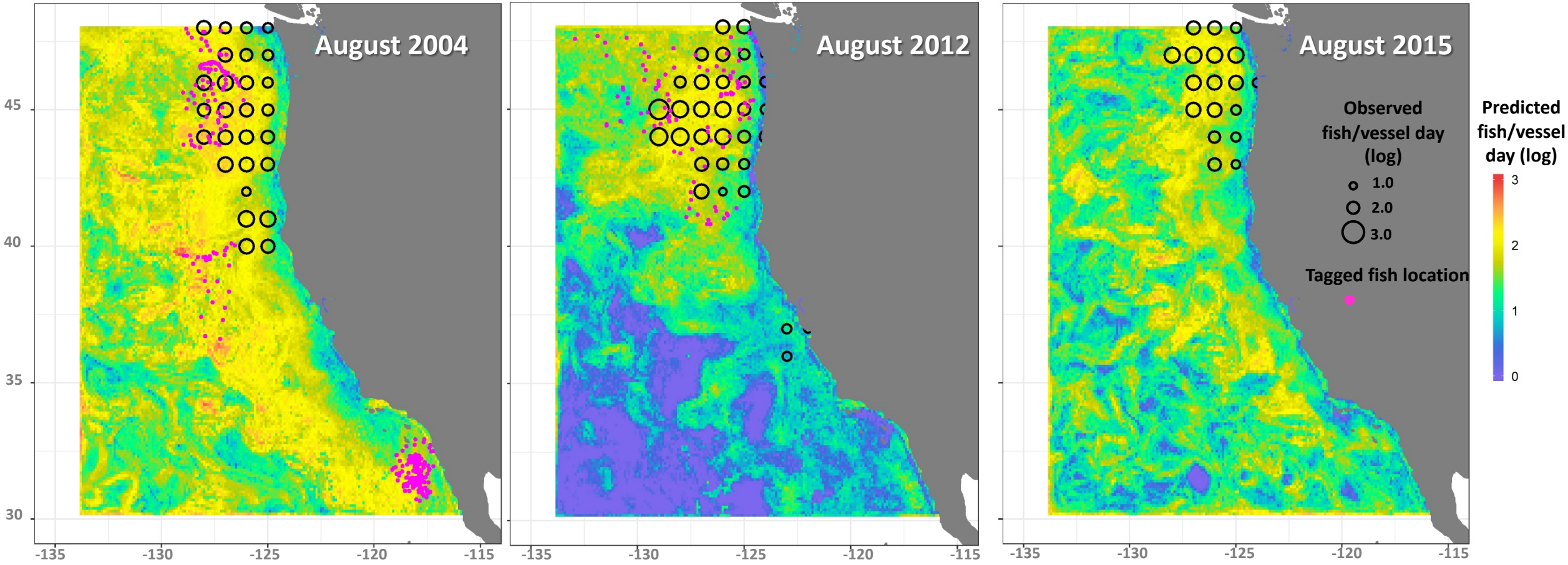
Top 3

Top 5

SDM Results: Albacore

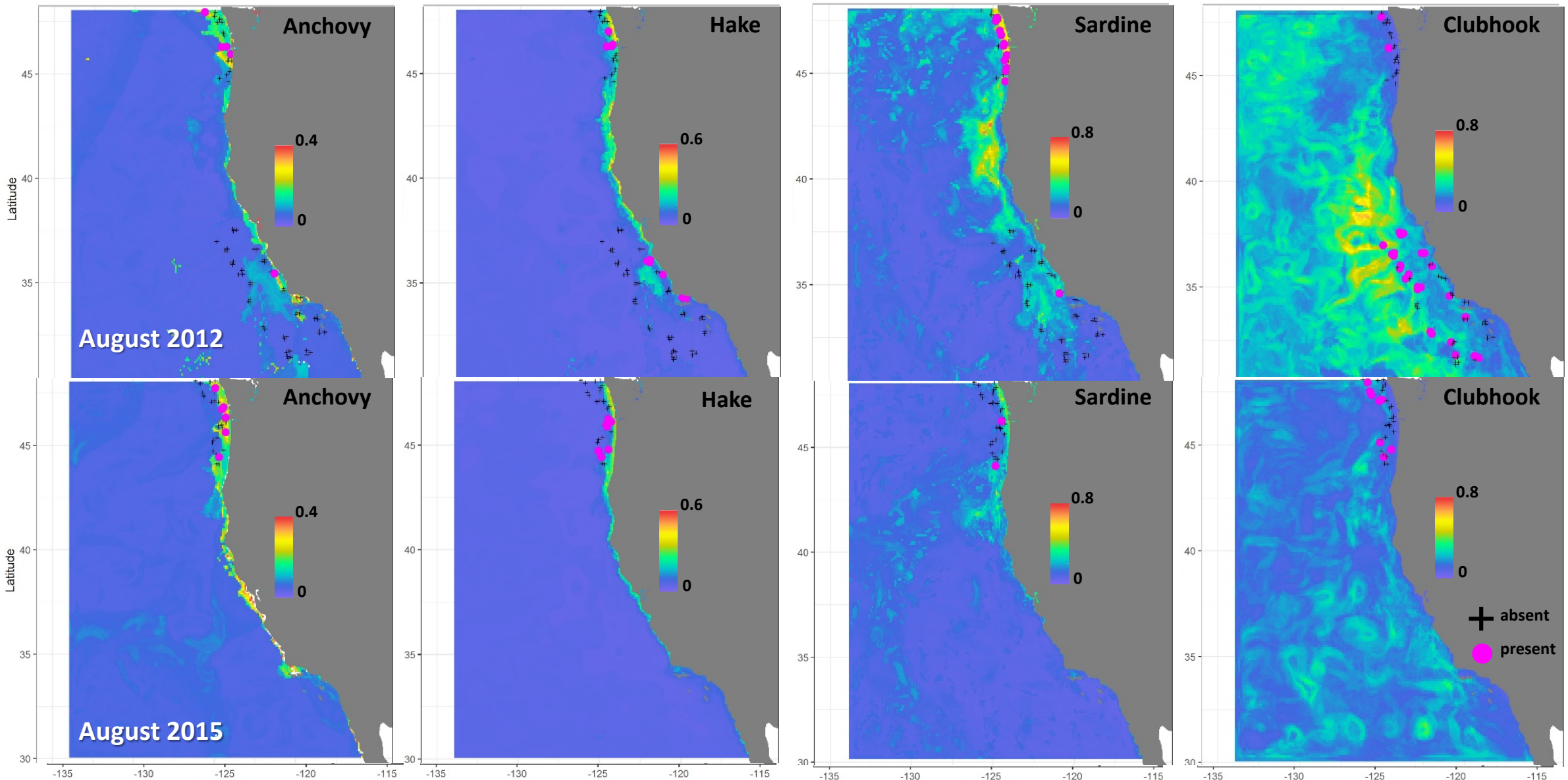
- Example results from August show interannual variability in southward habitat extent for albacore
- Habitat off Oregon and Washington more consistent than off California



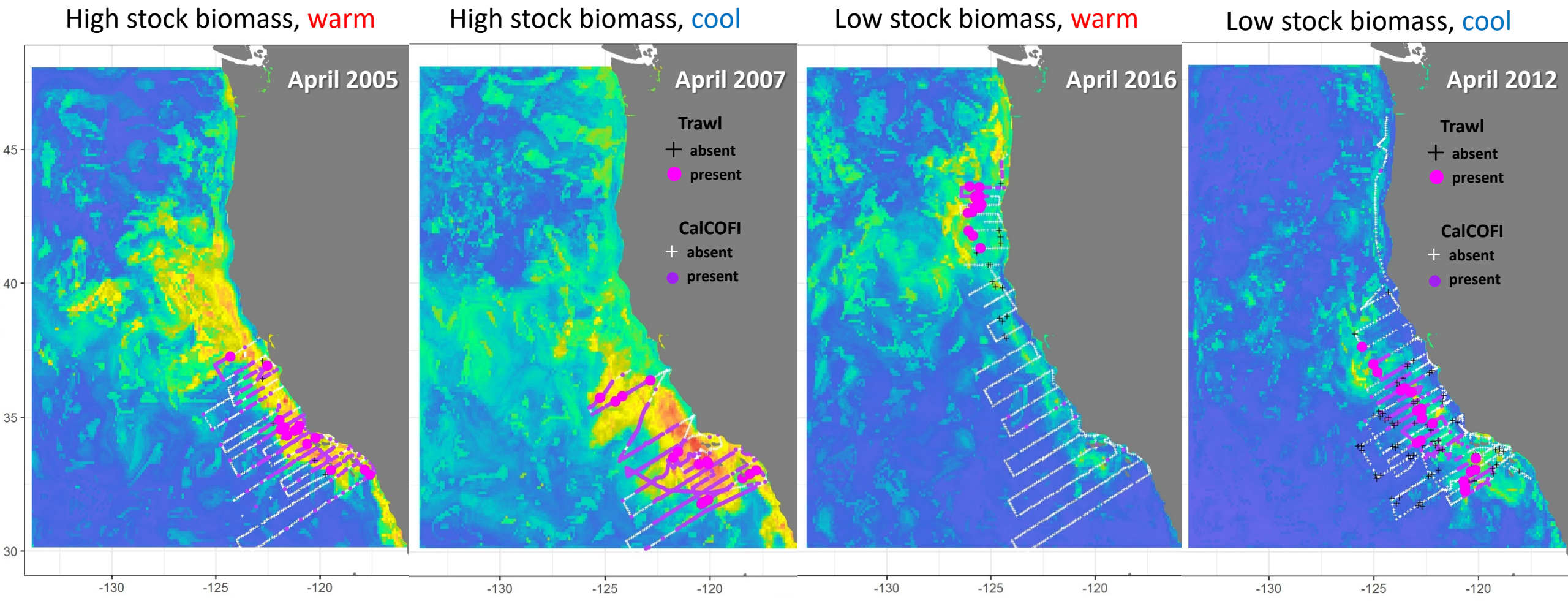
Muhling et al. submitted

SDM Results: Prey species

- Anchovy and hake habitat inshore, sardine and clubhook squid more offshore
- Less sardine and clubhook squid habitat in southern CCS during blob

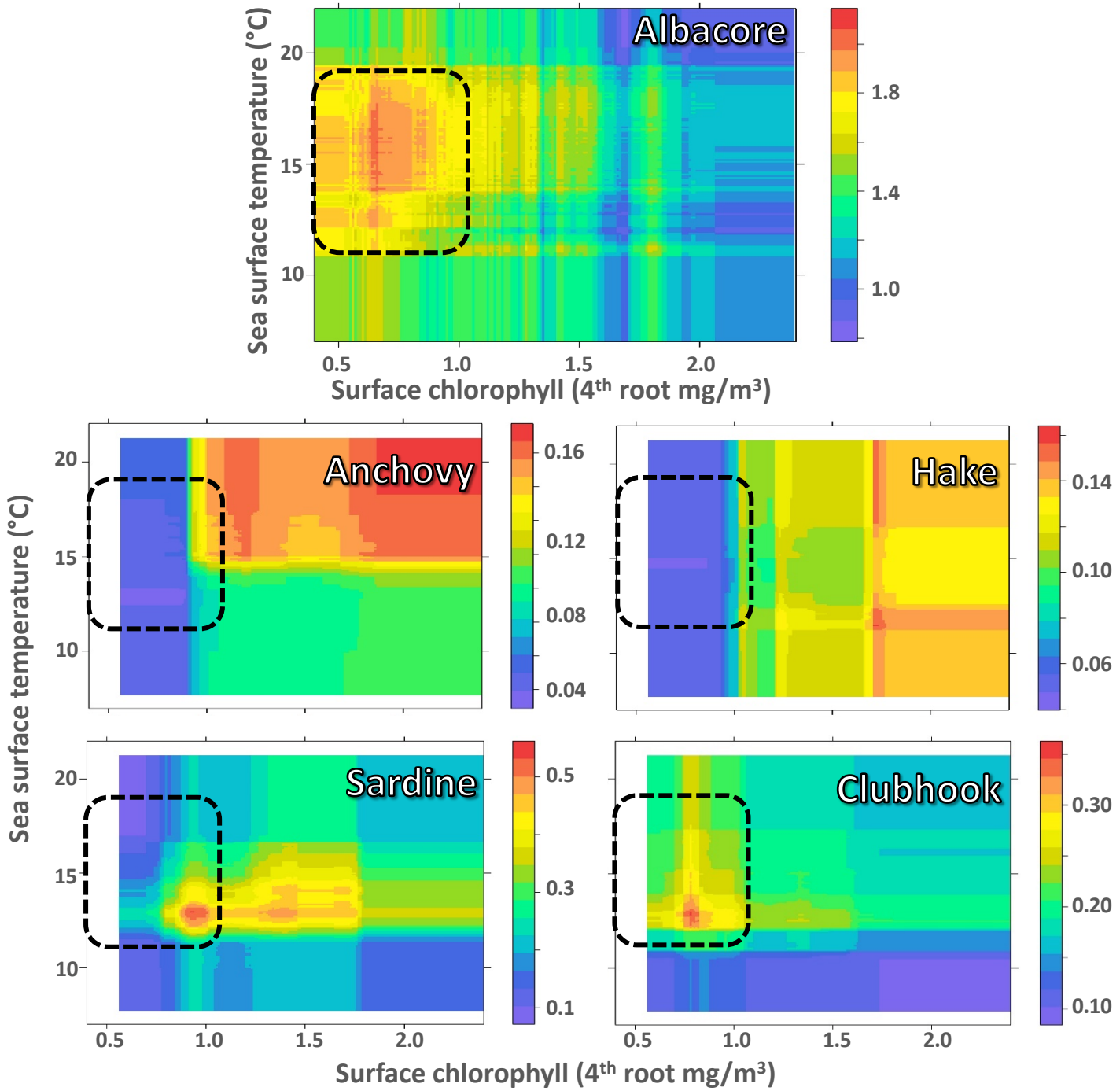


Example: Impact of sardine stock size and temperature on distribution and spawning



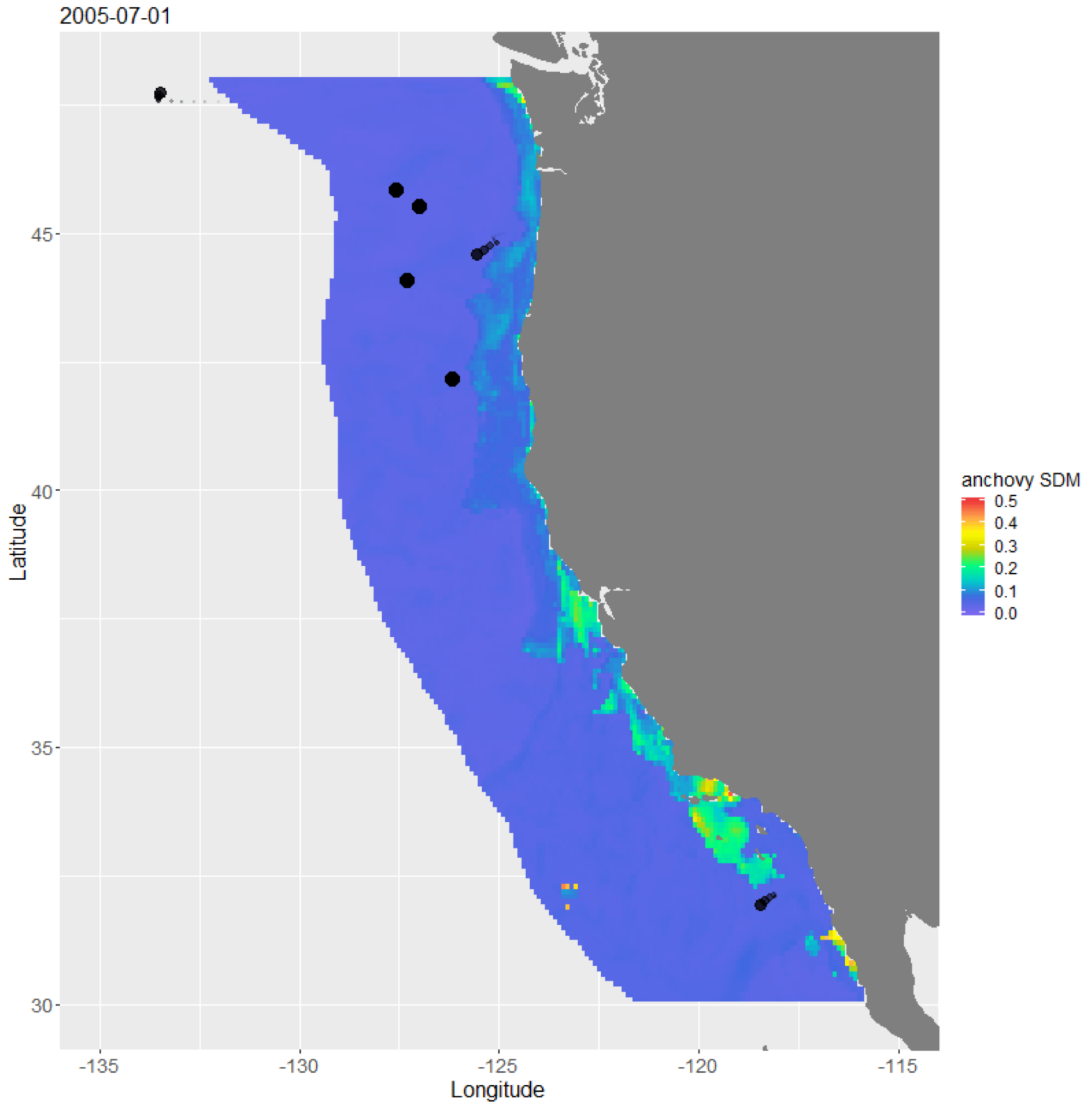
Habitat overlap: albacore vs. prey

- Albacore CPUE highest in low chlorophyll, moderate temperatures
- Overlaps with sardine and club hook squid, but not anchovy or hake
- But diet studies show anchovies can be large proportion of albacore diet

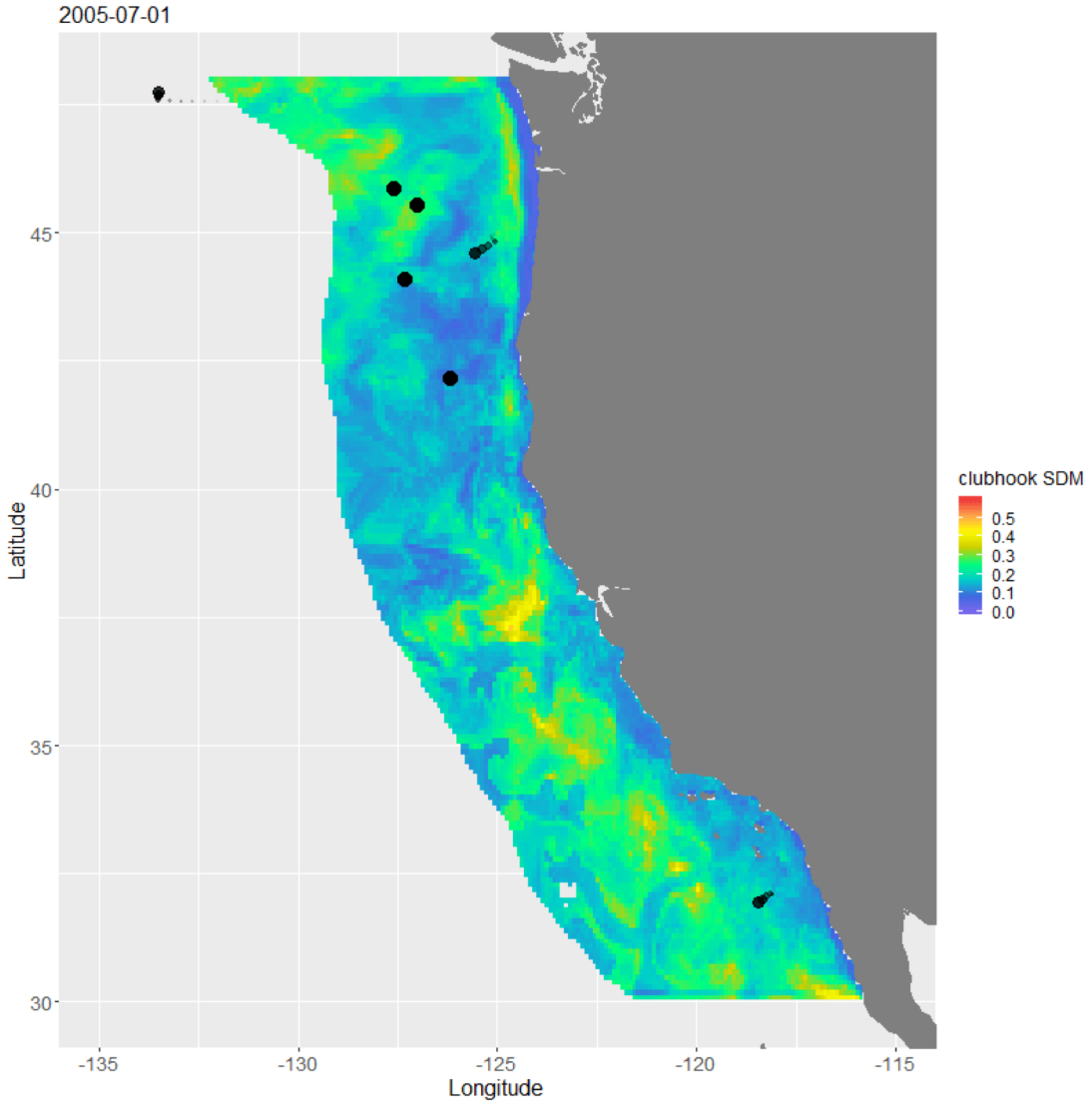


Dynamic predator/prey interactions

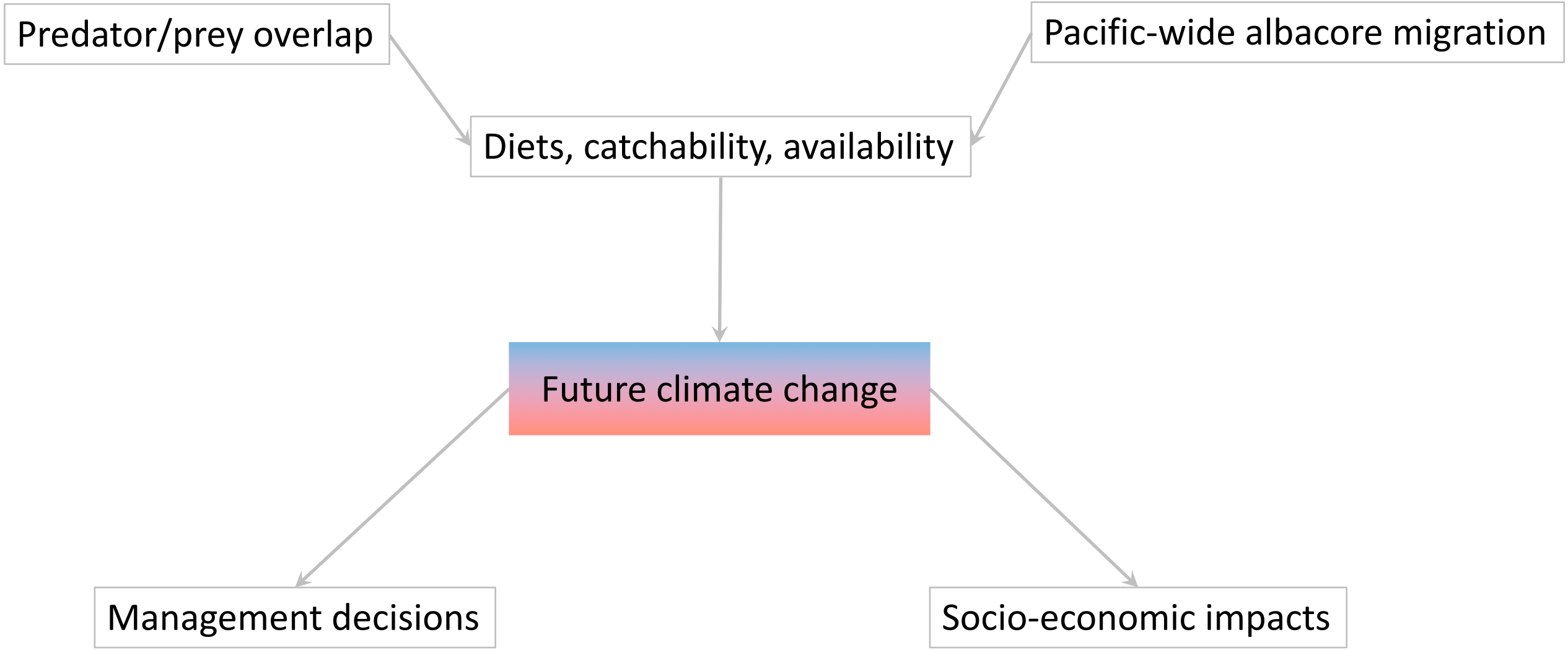
Tagged albacore and anchovy habitat July 2005



Tagged albacore and clubhook squid habitat July 2005



Next steps


Predator/prey overlap
Pacific-wide albacore migration
Diets, catchability, availability
Future climate change
Management decisions
Socio-economic impacts

Thank you!

- Yuhong Gu, Arjun Joshi (Ocean Associates, NOAA SWFSC)
- Andrew Thompson, Juan Zwolinski, Ed Weber, Steve Teo, Gerard DiNardo, Keith Sakuma, Elliott Hazen, Bev Macewicz, Roy Mendelssohn (SWFSC)
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