Improving petrale sole (*Eopsetta jordani*) fishery management advice through a mechanistic understanding of oceanographic divers of recruitment and biophysical connectivity

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PICES Annual Meeting

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The whole is greater than the sum of its parts ~Aristotle

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Meeting NMFS core science needs

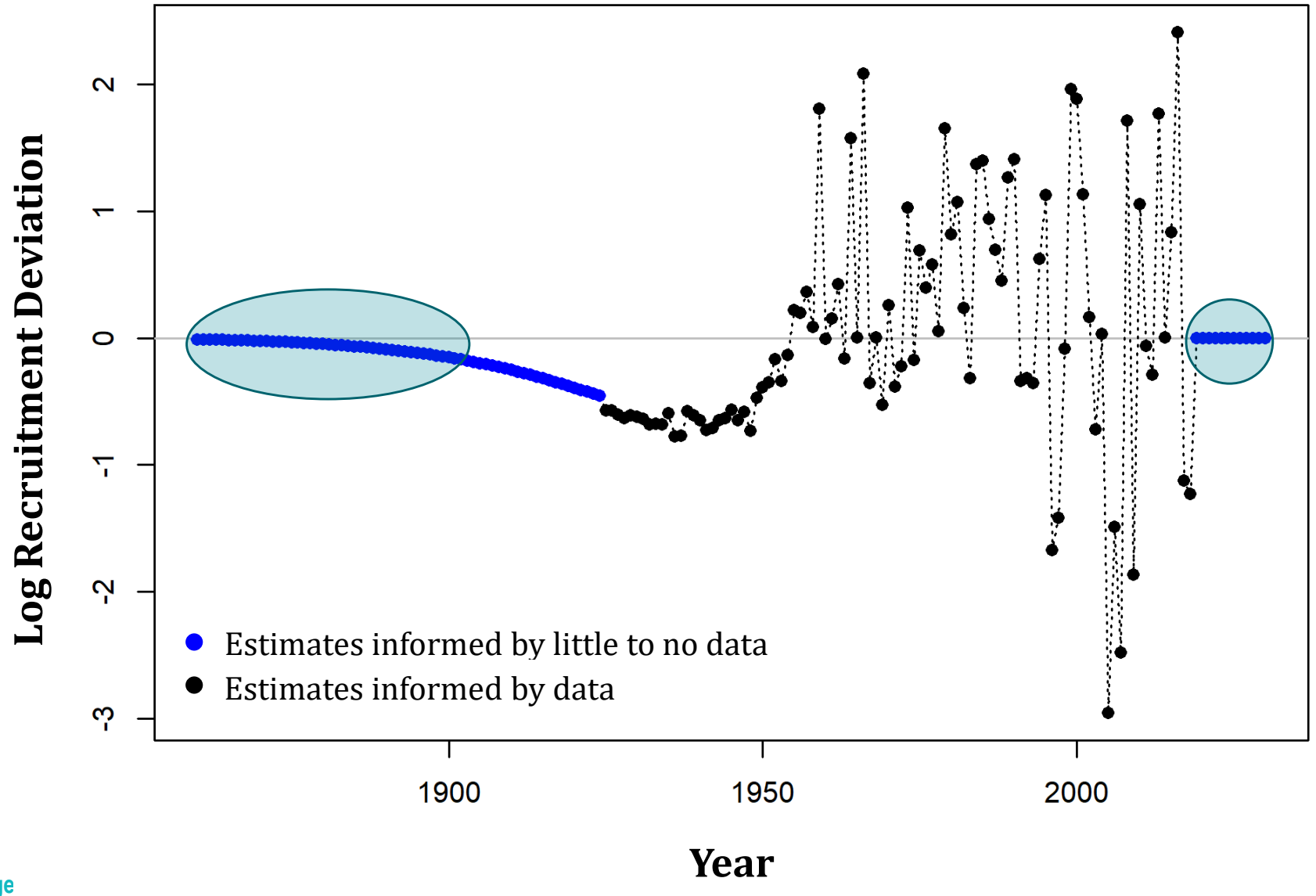
Core science needs

- Stock assessments are the scientific foundation of successful and sustainable fishery harvest management
- Measure the impact of fishing
- Predict future sustainable harvest levels
  - Using the long-term average number of age-x fish entering a population annually (recruitment)

How to improve estimates of recent recruitment not yet informed by data AND recruitment predictions in the absence of annual stock assessments?

- Use climate drivers to inform recruitment
- Commercially valuable, high attainment groundfish stocks

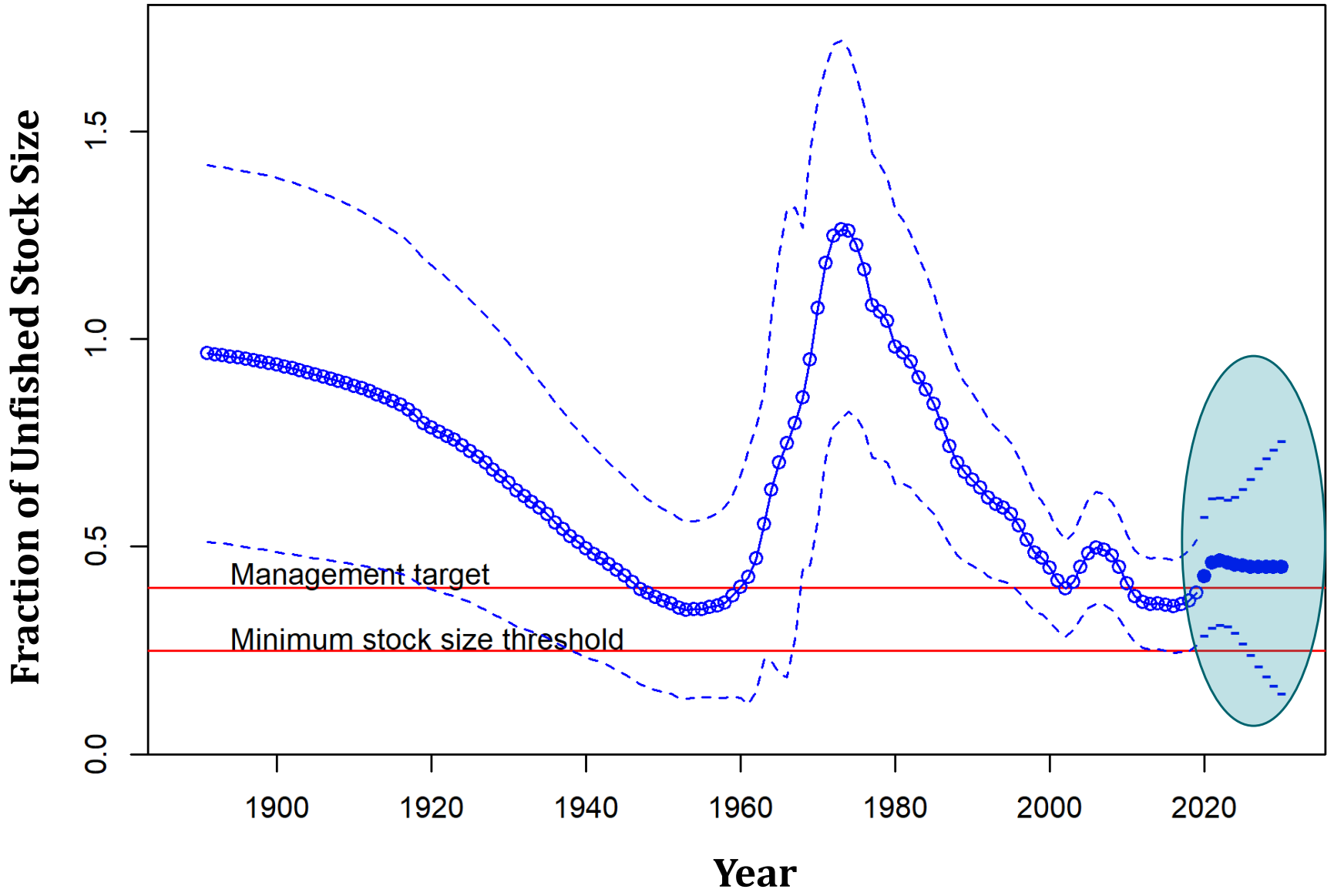
What is average recruitment?



Recruitment Deviation - model estimates of the annual recruitment variation as a random deviate from a stationary functional relationship between spawners and subsequent recruitment.

In this case, the Beverton-Holt stock-recruitment relationship.

How does average recruitment impact stock predictions?



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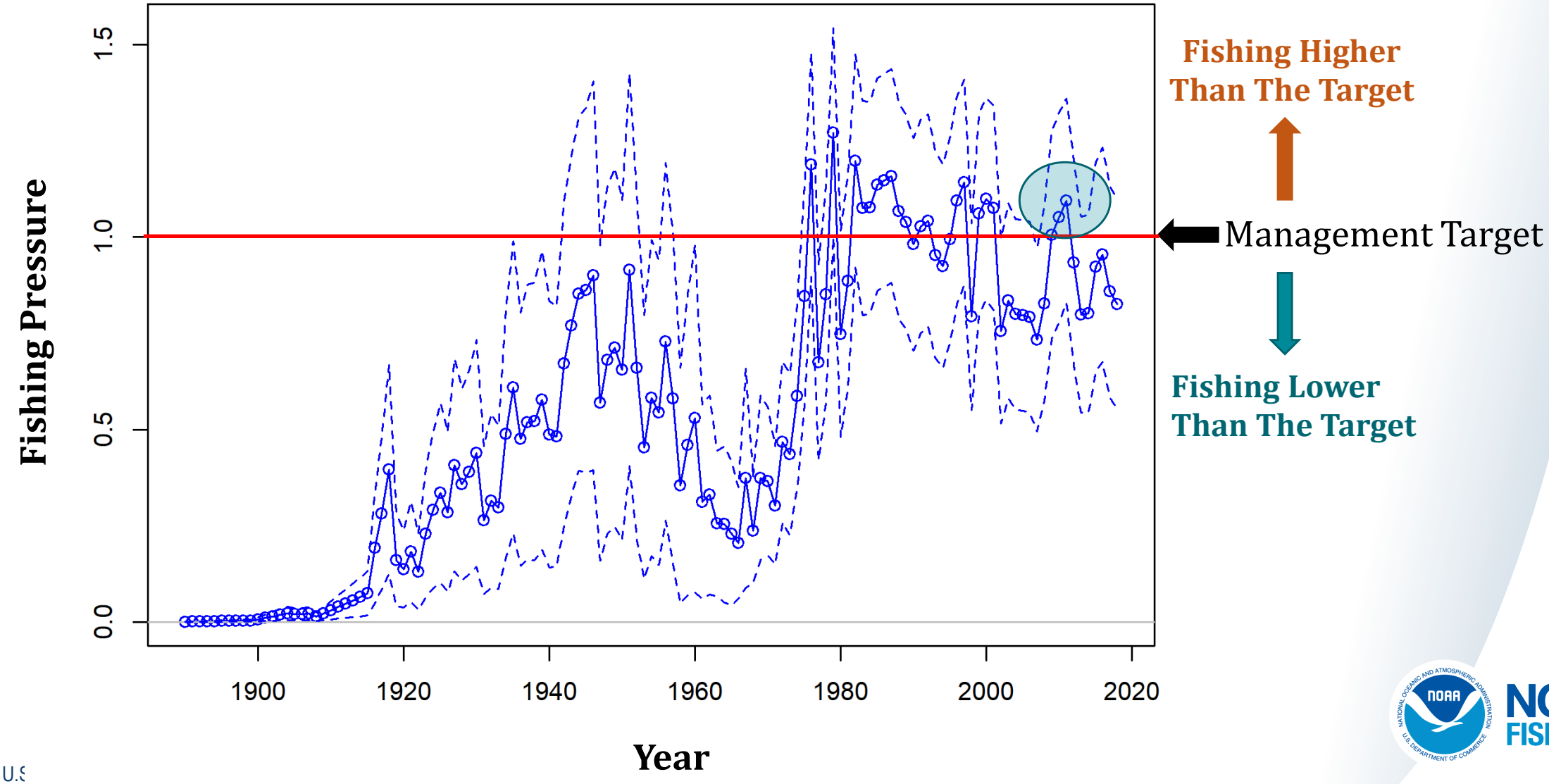
Problem: Recruitment is seldom average, leading to retrospectively fishing higher or lower than the target



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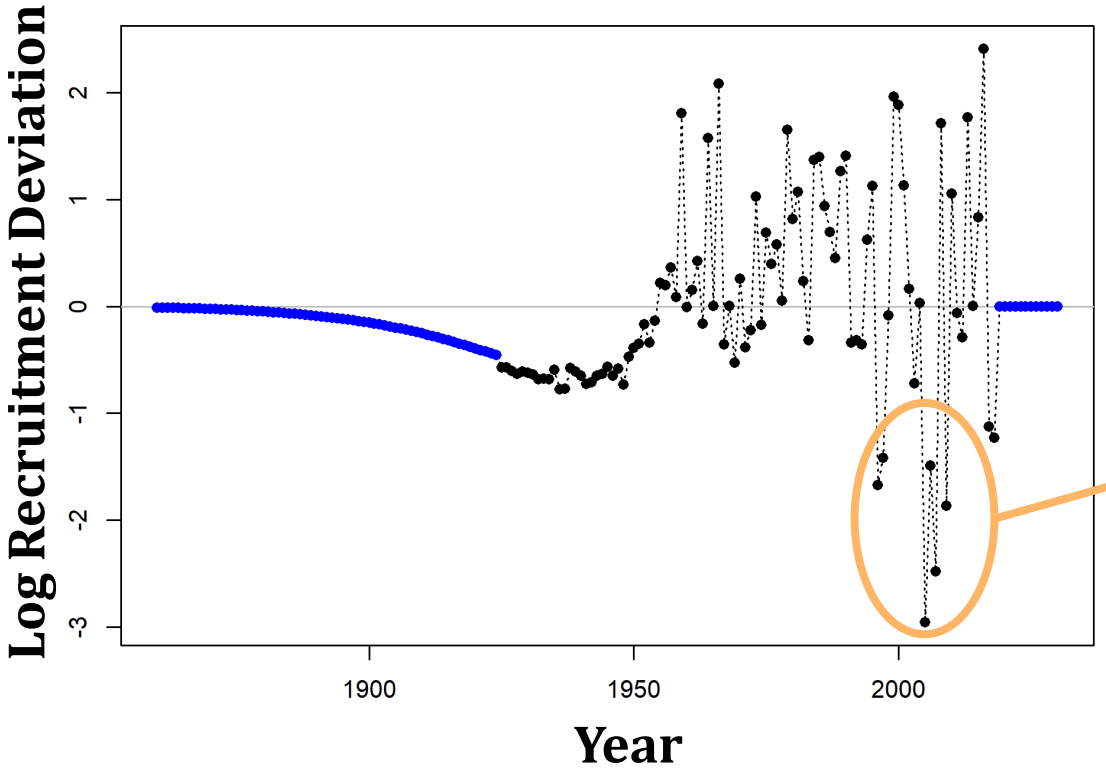

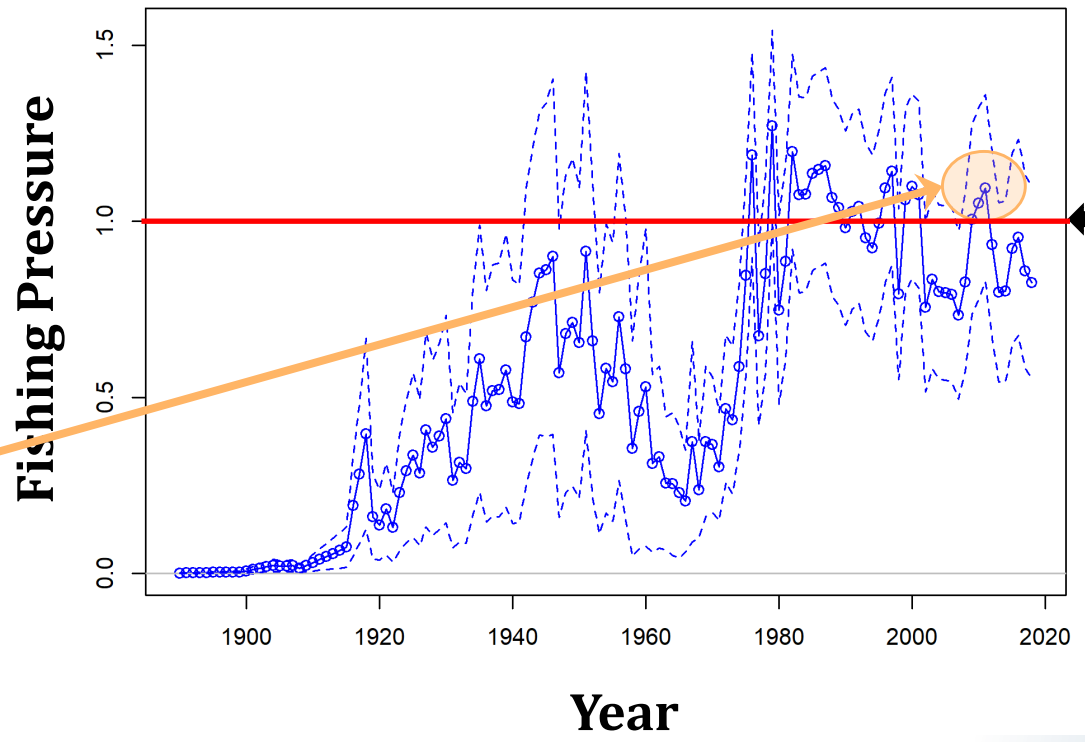

Fishing Higher Than The Target

Management Target

Fishing Lower Than The Target

Imperfect knowledge of poor/large recruitments contributes to subsequent higher/lower-than-target harvests

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Petrale Sole

Widely distributed NE Pacific

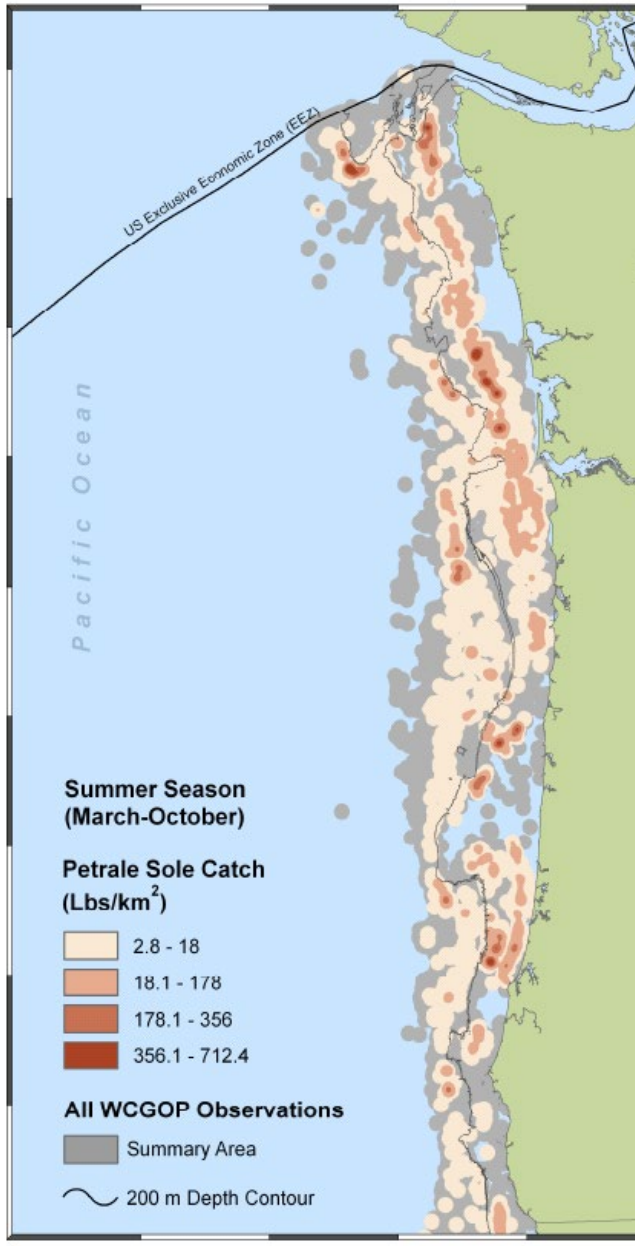
Seasonal onshore-offshore migration

Discrete winter spawning grounds

High site fidelity

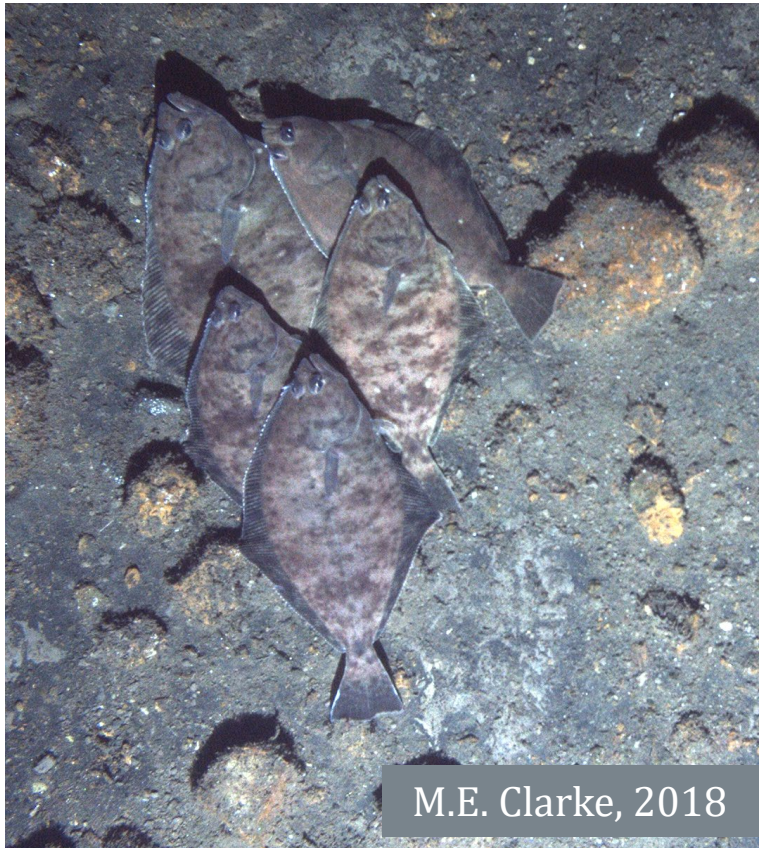
Where are successful pelagic life stages transported after spawning?

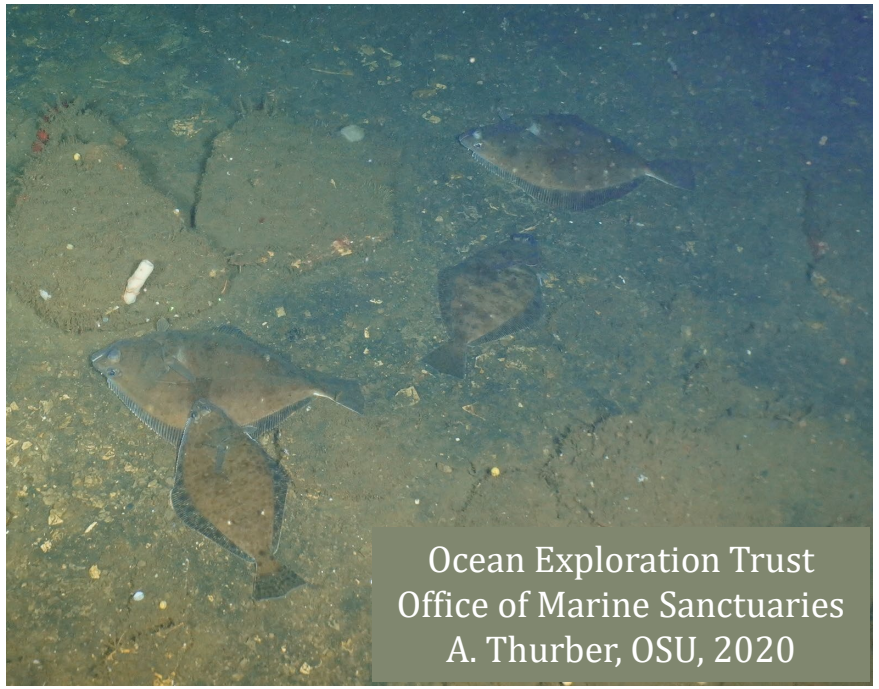
How do individual spawning grounds contribute to the stock?

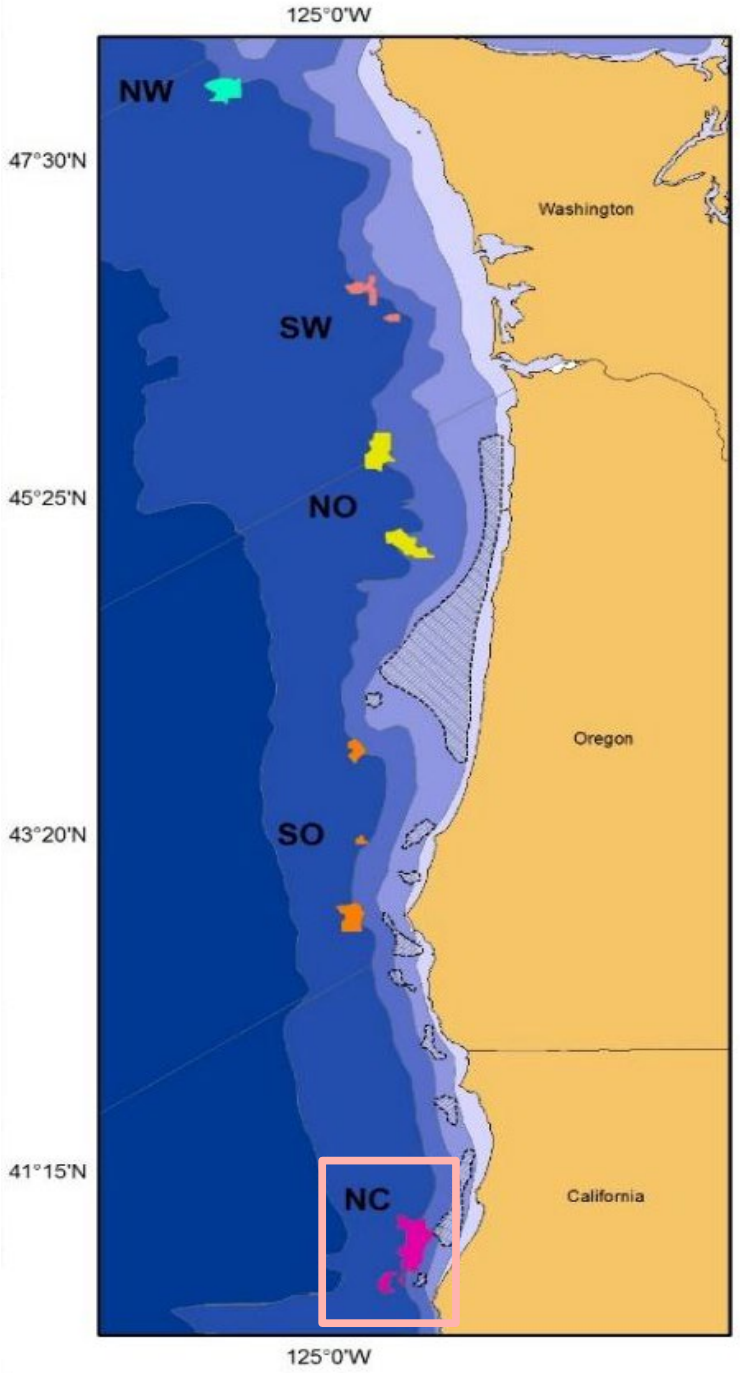



Daniel W. Gotshall

Petrale sole spawning grounds







Powell et al. 2022 Front. Mar. Sci.

Why focus on petrale sole?

Economically important flatfish species

History of stock decline and recovery

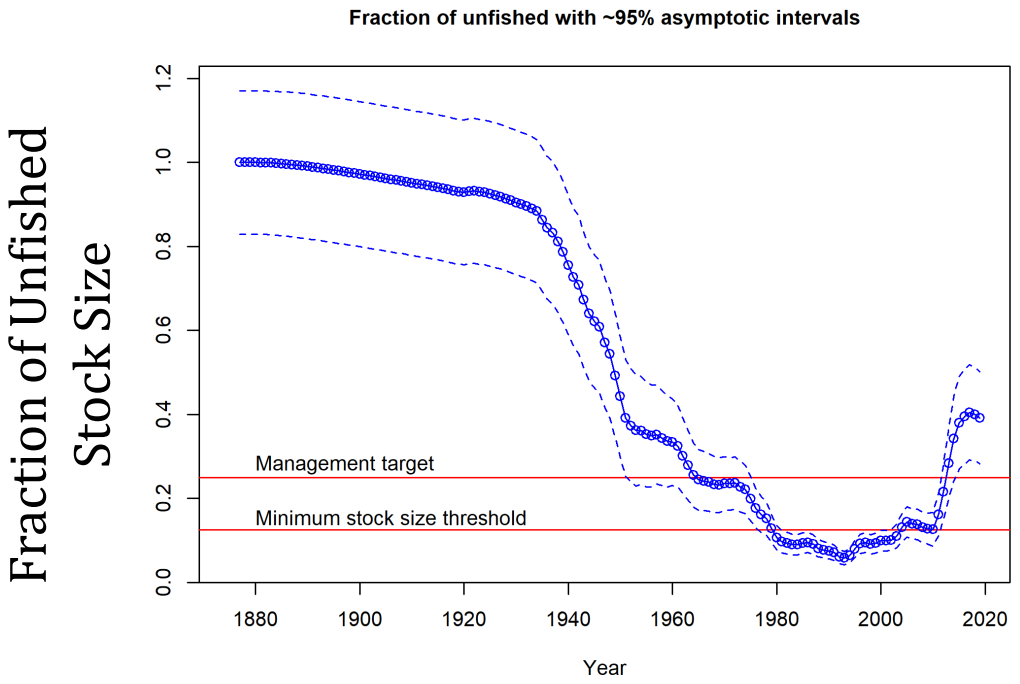
Research investments during past ~5 years

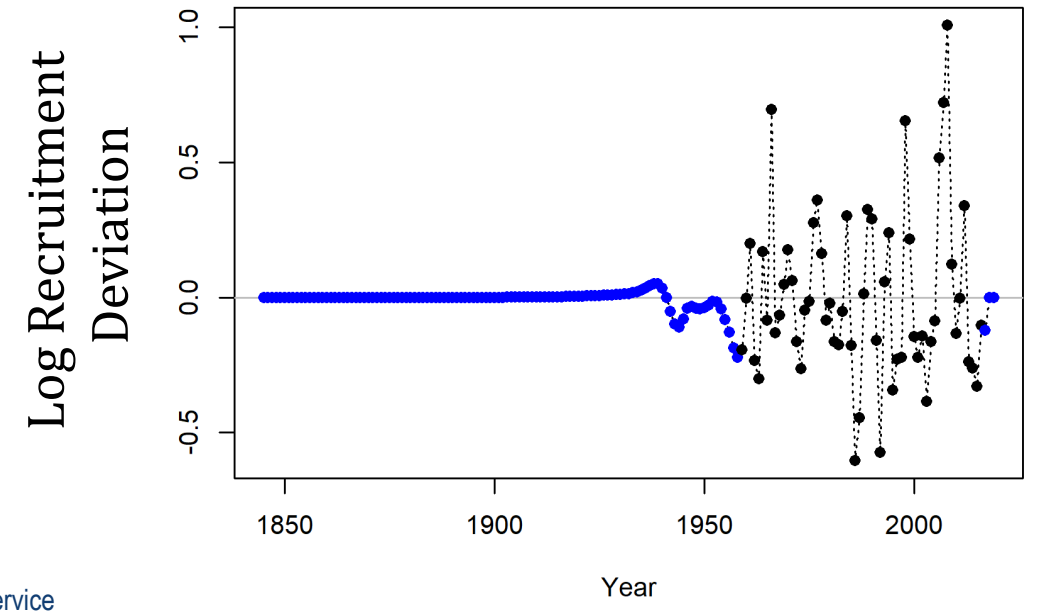
- Climate drivers of recruitment
- ROMs coupled IBM aids in understanding climate-recruitment mechanisms

Assessments with climate drivers could be extended to…

- Inform recruitment in absence of survey data
- Use short-term oceanographic forecasts to inform future recruitment

Interaction between spatial fishery and stock dynamics may impact stock trends





What mechanisms drive recruitment variability in time and space?

Conceptual life-history model coupled with hypothesis testing

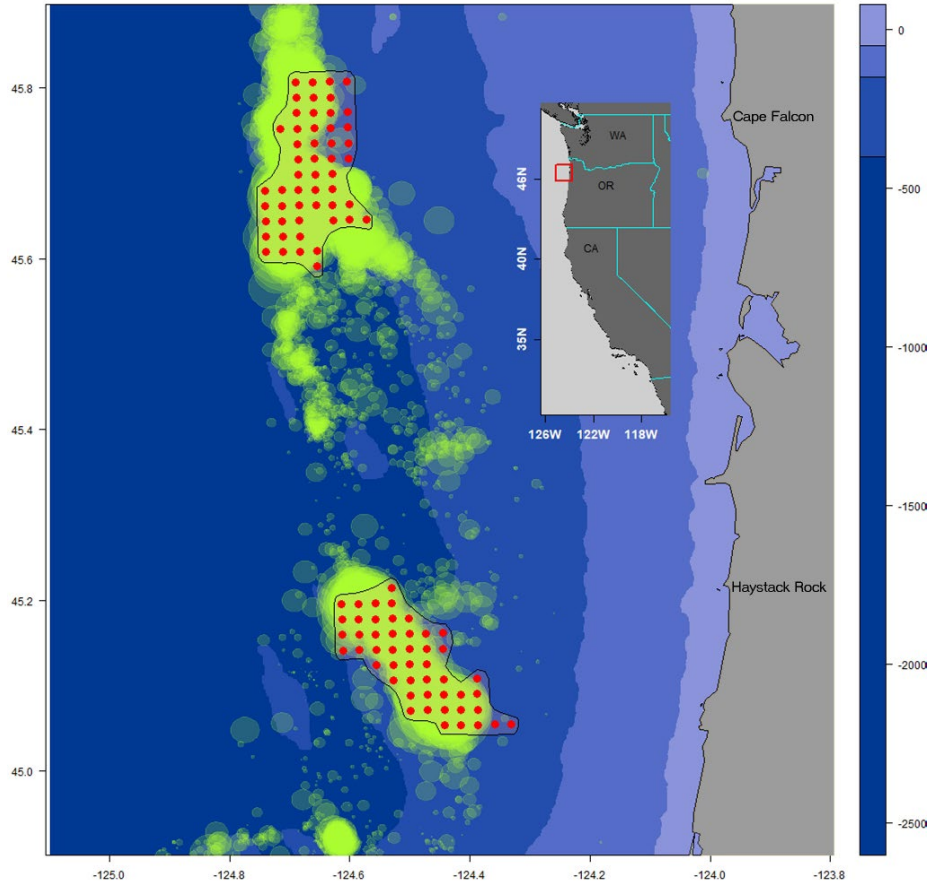
Stage- and spatio-temporally specific.

Physical oceanographic variables that influence survival. (C. Edwards, UCSC ROMS)

Biophysical ROMs driven IBM

(E. Curchitser, Rutgers ROMS)

Spatio-temporal modeling of fishery trawl log-book data to identify spawning grounds and the proportion of the spawning stock on each spawning ground over time.



Petrale sole conceptual life history model

Spawner preconditioning to benthic juveniles

Lat:	39-48.5 °N
Years:	1981-2010

Life stage	Year	Stage duration	Stage depth	Ho Number	Hypothesis	ROMS covariates (40°N–48°N)
Preconditioning	Year 0, May–October		Bottom depths of 50–200 m	1	Higher bottom water temperatures increases food demand resulting in lower egg production, egg quality, or probability of spawning and lowers recruitment (likely a bell-shaped relationship)	Mean **bottom water temperature** (°C, 4 days)
Spawning	Year 1, November–March		Bottom depths of 250–500 m	2	Bottom water temperature acts as a spawning cue with fish less likely to spawn at high temperature resulting in lower recruitment	Mean **bottom water temperature** (°C, 4 days)
			Bottom depths of 250–500 m	3	Water column temperature acts as a spawning cue with fish less likely to spawn at high temperature resulting in lower recruitment	Mean **water column temperature** (°C, 4 days)

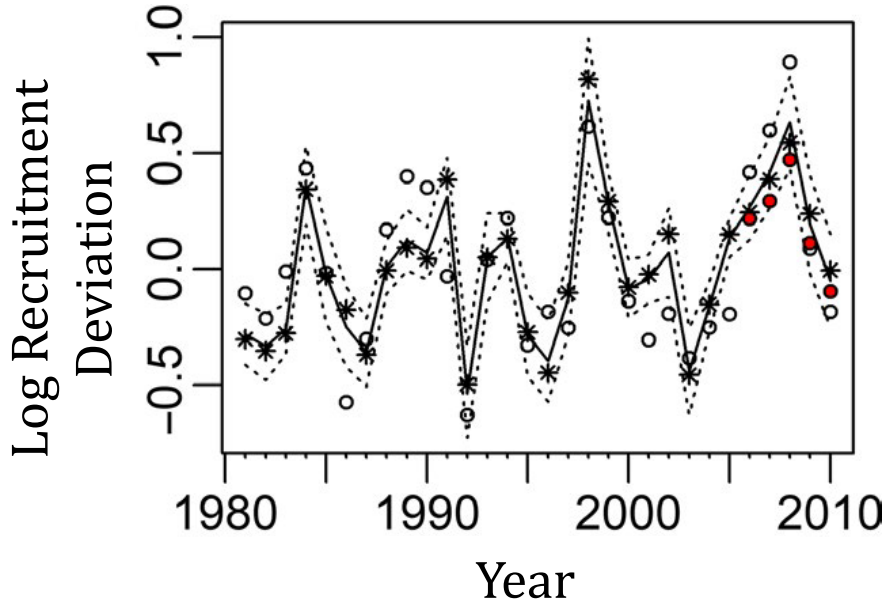
Fit GLMs, model selection (AICc), model testing and validation

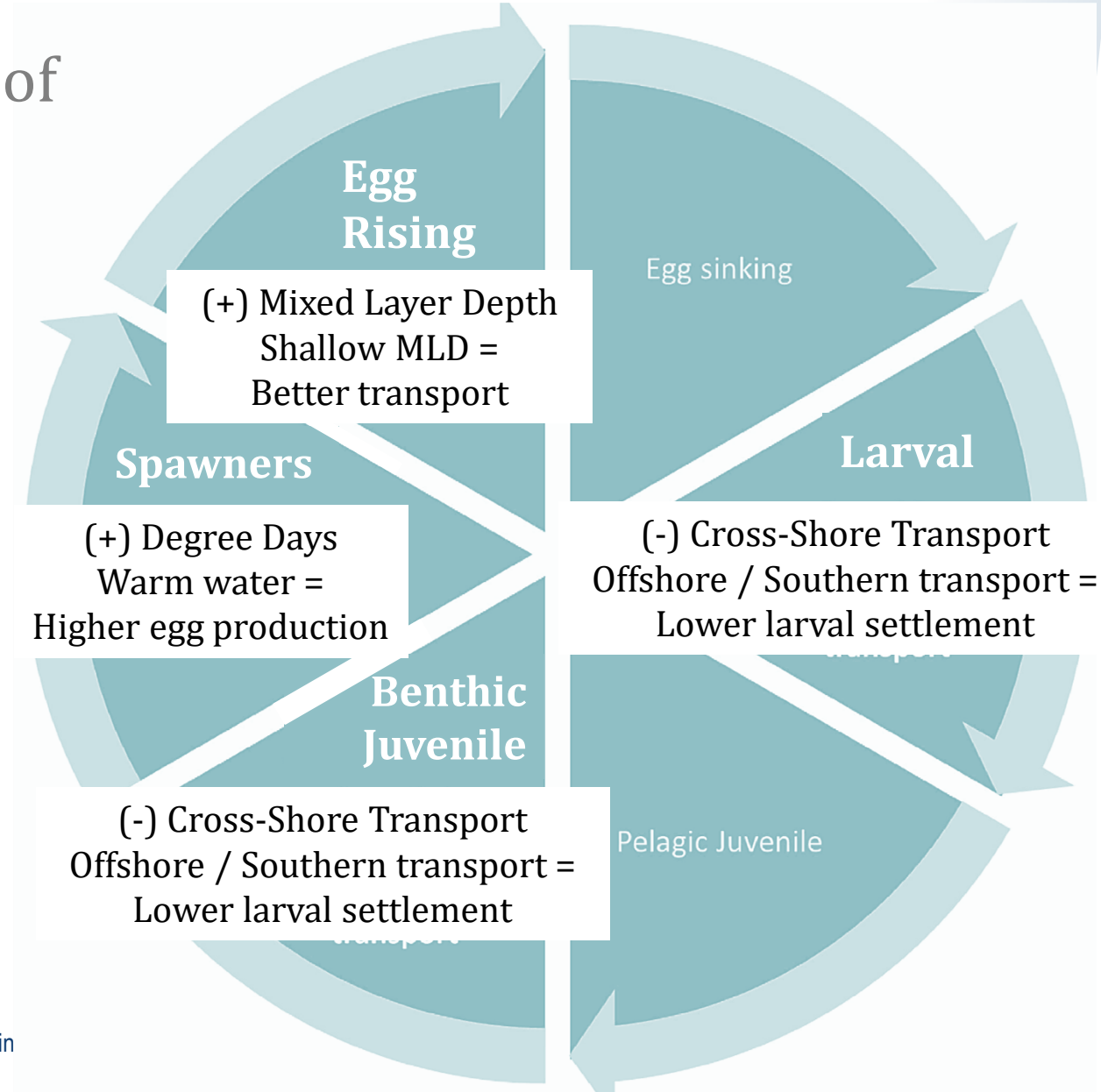
Haltuch et al. 2020 Fish. Ocean.

Mechanistic drivers of petrale sole recruitment

Four ROMS covariates explain 73% of recruitment variability (C. Edwards, UCSC)

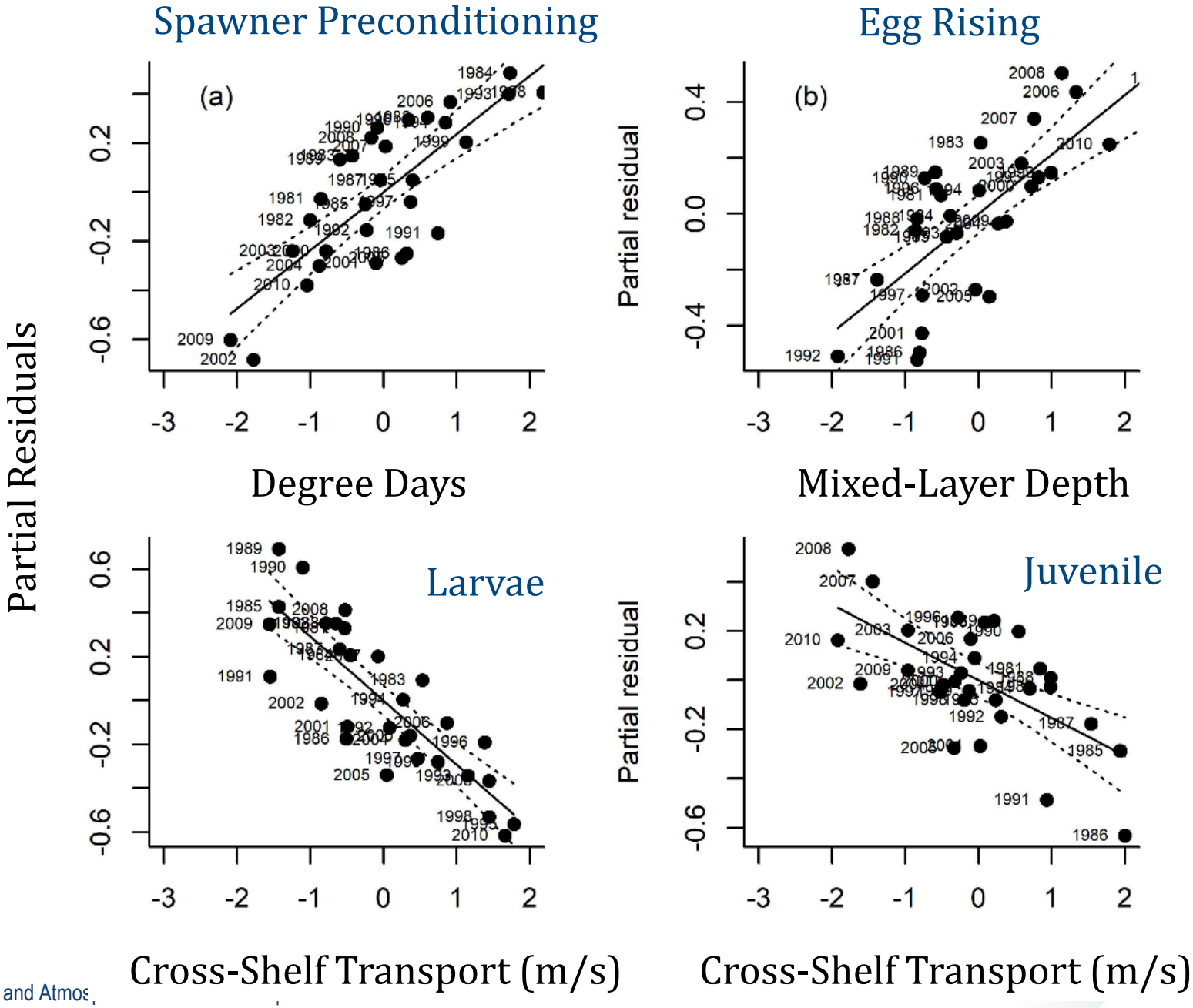
Present in trawl survey ~2+





Haltuch et al. 2020 Fish. Ocean.

Petrale sole recruitment relationships

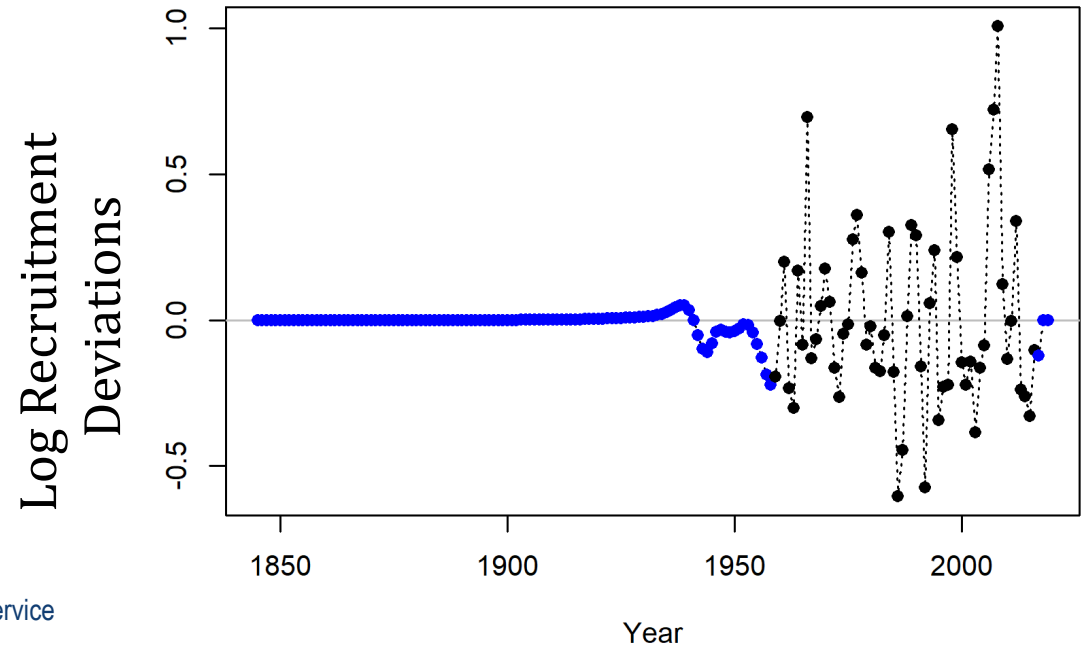


Next generation **tactical** models: research to application

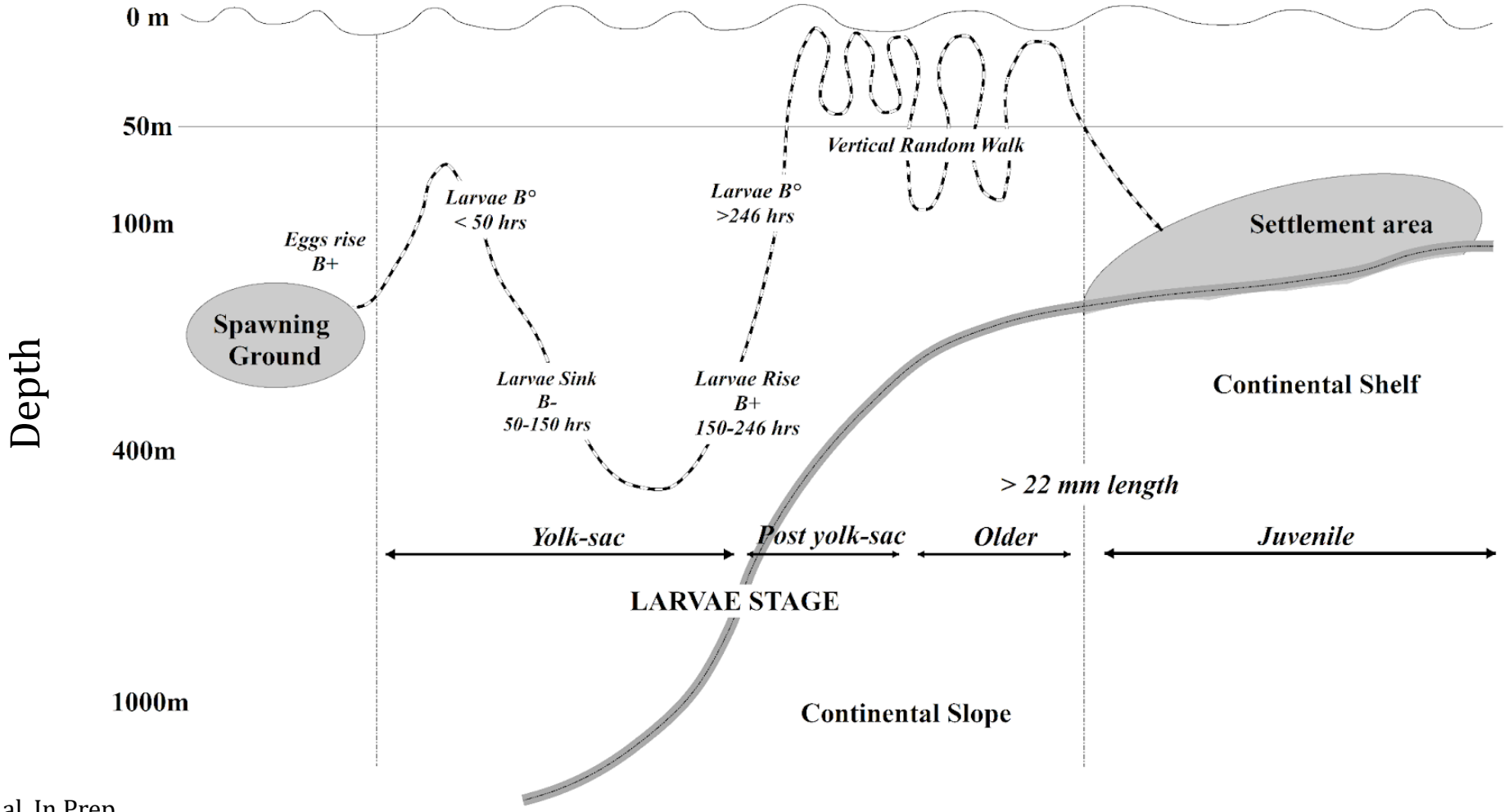
ROMs model outputs are not always available on operational timelines.

Currently completing reanalysis of relationships with updated data for use in 2023 stock assessment.

GLM predictions as age-0 survey index



Biophysical ROMs driven IBM
connectivity and settlement success



Santa Cruz et al. In Prep.

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IBM

IBM of larval drift forced by ROMS

Years 1988-2008

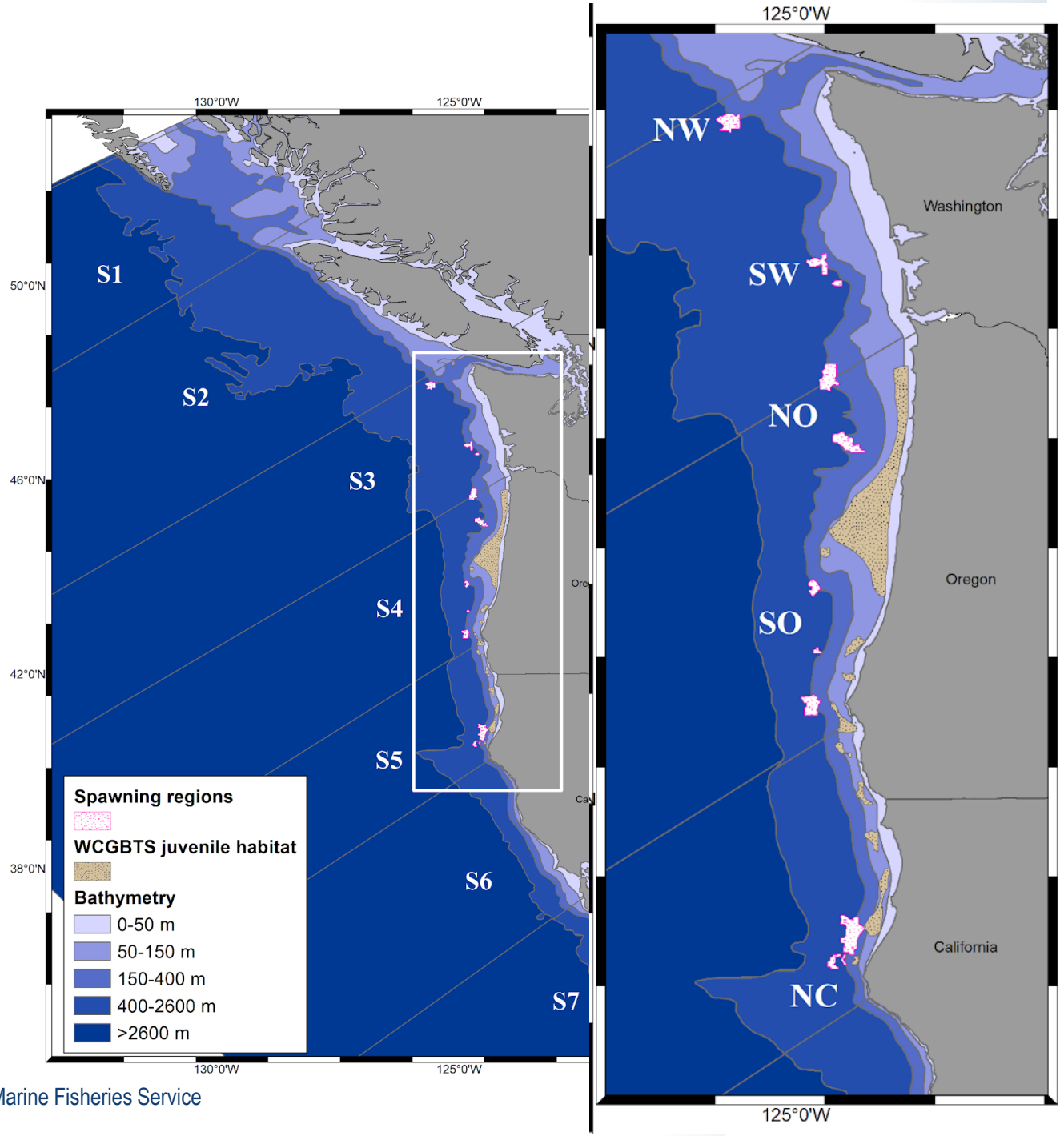
Larval release locations based on spawning aggregation fishery

Annual larval release density varies based on stock size estimated in assessment

Settlement areas based on ~~age 2 survey~~ samples or bathymetry.

Results summarized by spawning region and settlement sectors.

Santa Cruz et al. In Prep.



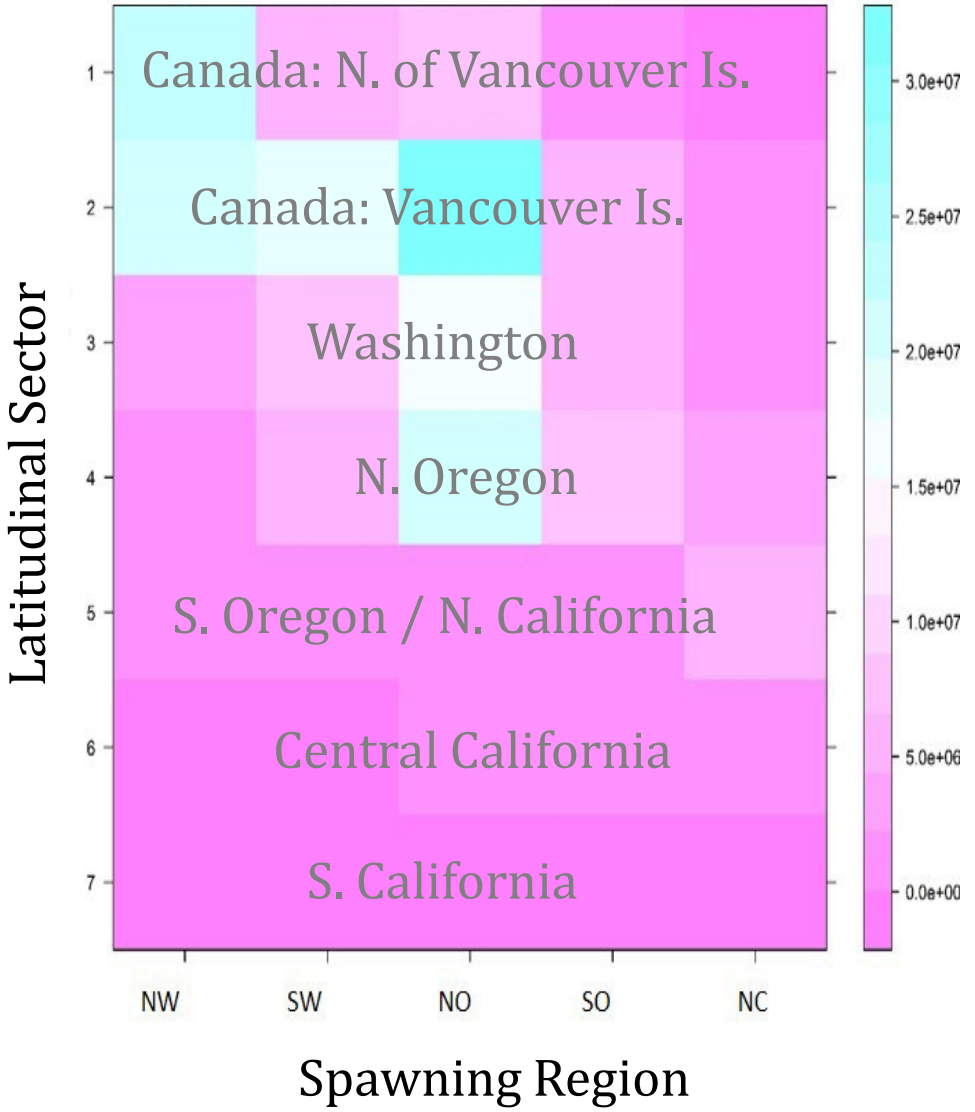
Average Connectivity Anomalies

Blue – Juveniles from other regions

Pink – Areas of retention

Canadian shelf contributes most to successful settlement of juveniles

Northern Oregon is a region of local retention



more successful settlement

less successful settlement

Santa Cruz et al. In Prep.

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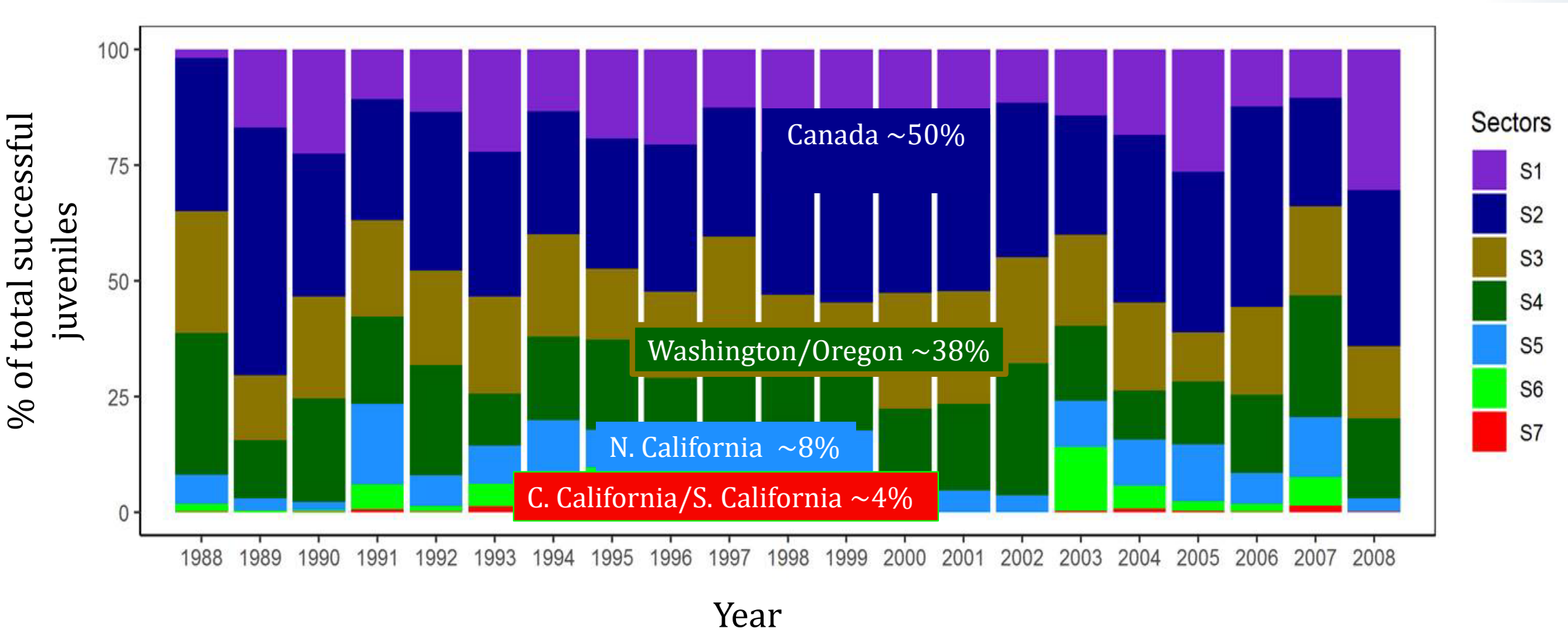
Percentage of successful juveniles by latitudinal sector



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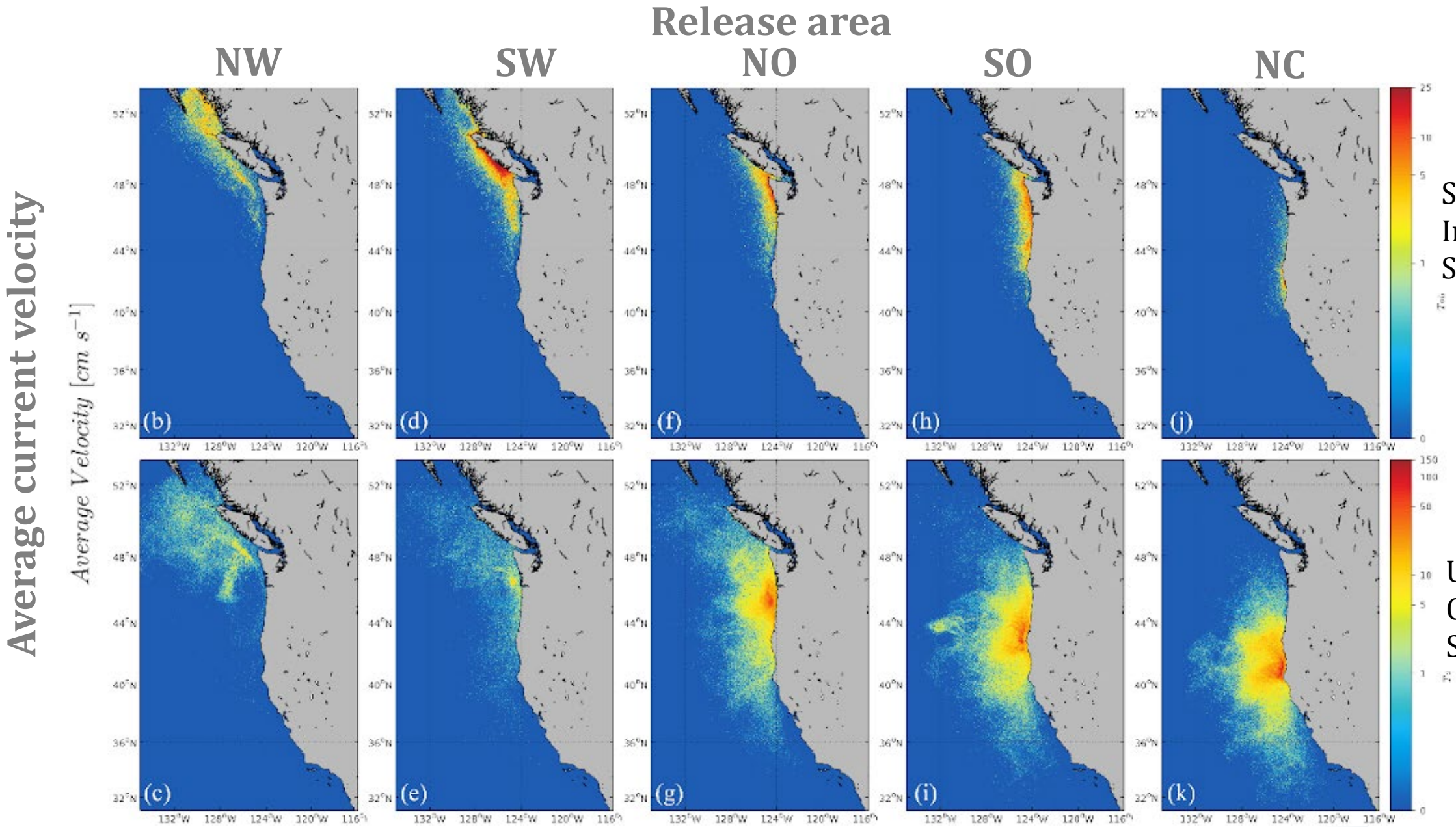
Transport Trajectories



Successful Inshore Settlement

Unsuccessful Offshore Settlement

Santa Cruz et al. In Prep.

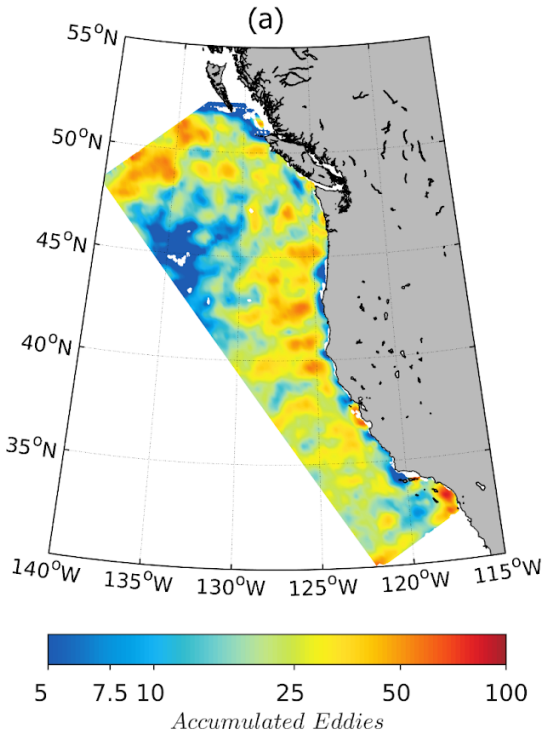
Physical mechanisms for horizontal transport

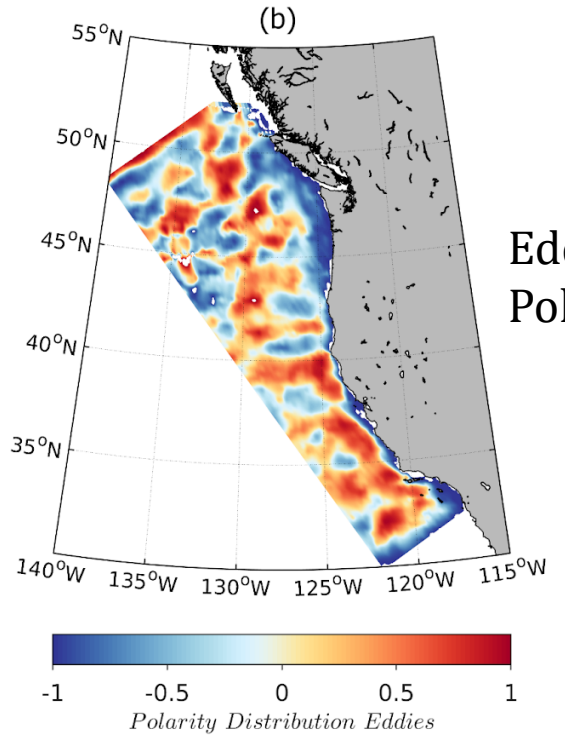
1988-2008

Eddies as drivers of onshore and offshore advection

Consider a northern cyclonic eddy index for stock assessment

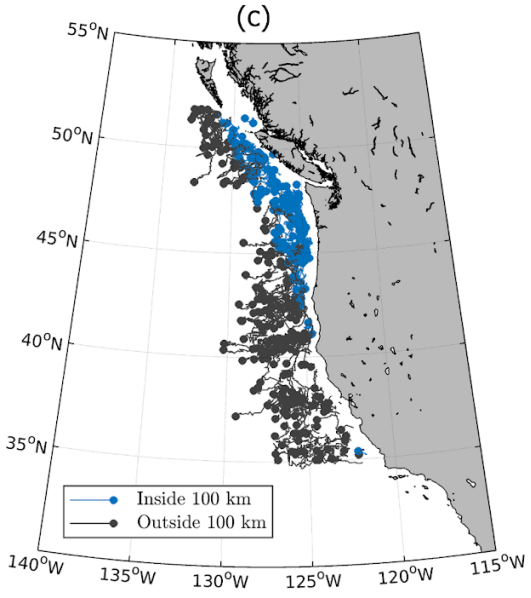
Accumulated Eddies

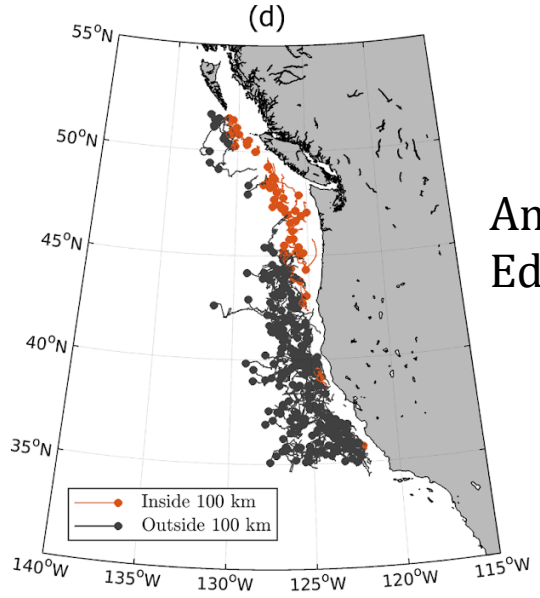




Eddy Polarity

Cyclonic Eddies





Anticyclonic Eddies

Santa Cruz et al. In Prep.

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Petrale sole research summary

What are climate drivers of recruitments?

Spawner Preconditioning
(+) Degree Days
Warm water = Higher egg production

→

Eggs Rising
(+) Mixed Layer Depth
Shallow MLD = Better transport

→

Larvae and Benthic Juveniles
(-) Cross-shore Transport
Offshore / Southern transport = Lower larval settlement

What spawning grounds are most important for recruitment success?

Washington and N. Oregon

Where do successful recruits settle?

Cyclonic eddy transport northerly and onshore to Canada, Washington, and N. Oregon is important for recruits originating in Washington and N. Oregon

Cyclonic eddy retention is important for recruits originating in S. Oregon and California

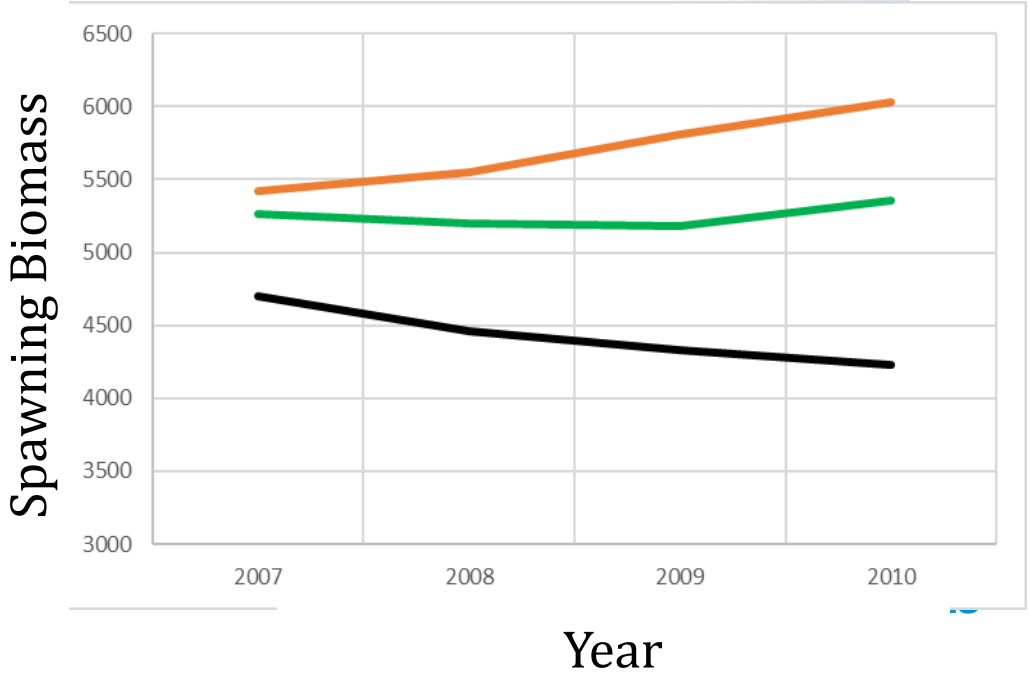
Next generation **tactical** models: research to application

Goal: To show that climate-based recruitment indices have the potential to provide fishery managers with improved leading recruitment predictions.

Retrospective stock assessment model runs to evaluate potential prediction skill

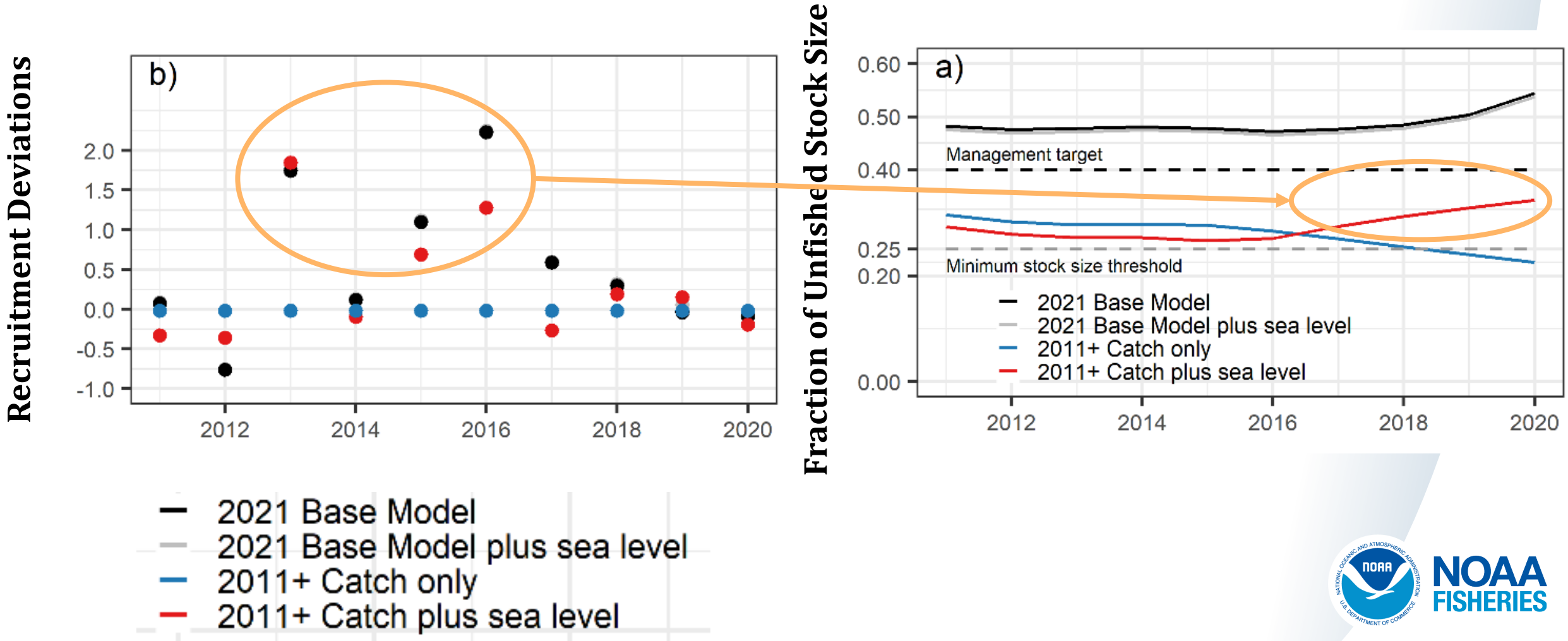
Evaluate how the climate index can inform age-0 recruitment in the absence of survey and fishery data by:

1. Removing all fishery and survey data except catch (orange line)
2. Removing all fishery and survey data except catch and ROMs age-0 recruitment (green line)
3. Comparing hindcast predictions to the assessment, the 'true' state given all available data (black line)



Next generation **tactical** models: research to application

Sablefish Example



Next generation **tactical** models: research to application

Climate index of recruitment shows promise as an improvement over average recruitment assumptions and is a step towards climate resilient fisheries.

- Single species climate enhanced models
- Need operational ROMs model products

Co-developed a mechanism to incorporate climate data (+ catches) into tactical forecasts for the Pacific Fishery Management Council.

Transboundary stock dynamics suggest a need for stronger collaboration between US and Canadian scientists and managers.

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Summing up next generation **strategic** models: research to application

Laying the groundwork for understanding long-term climate impacts on stock productivity

Identify Climate Resilient Harvest Control Rules / Management Approaches using Management Strategy Evaluation

Inform ecosystem models (Atlantis)

Inform species distribution modeling and subsequent socio-economic impacts on fishers and communities

Ecosystem considerations in stock assessment