PICES 2026 ANNUAL MEETING — NANAIMO, BC, CANADA

Decreased coastal productivity facilitates the northward, inshore expansion of juvenile Pacific hake

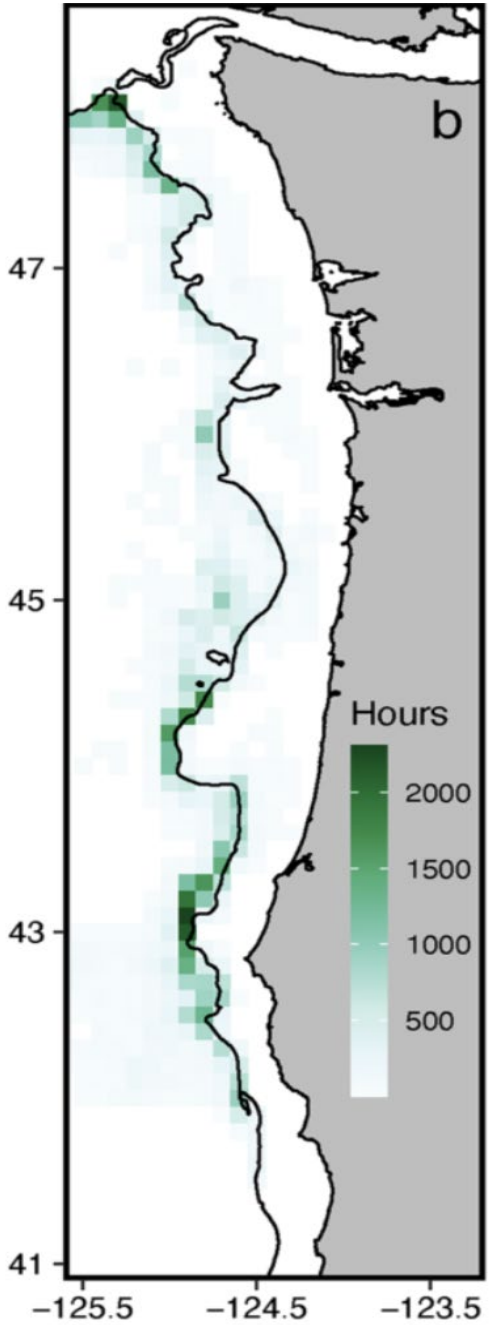
Brian K. Wells[1], David D. Huff[2], Jarrod A. Santora[1], Toby D. Auth[3], Mary E. Hunsicker[2], Tanya L. Rogers[1], Joseph J. Bizzarro[4], Aaron M. Berger[2], Keith M. Sakuma[1], Isaac D. Schroeder[1], Rebecca R. Miller[1], John C. Field[1]

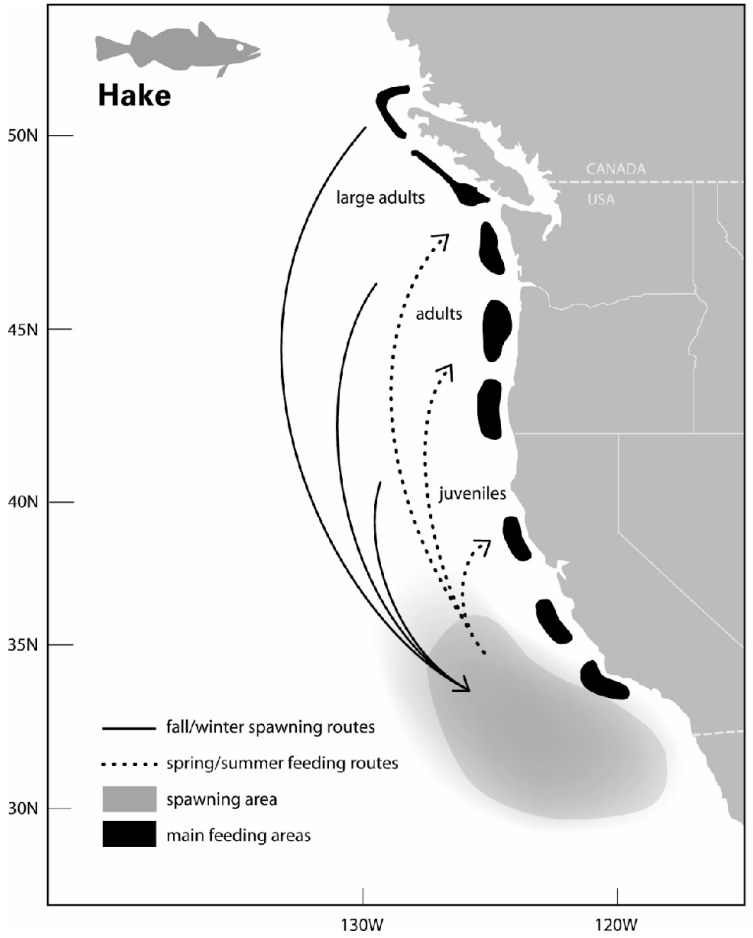
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[3]Pacific States Marine Fisheries Commission, Newport, OR
[4]University of California Santa Cruz, Department of Ecology & Evolutionary Biology

System Setting

Adult Pacific Hake System Dynamics

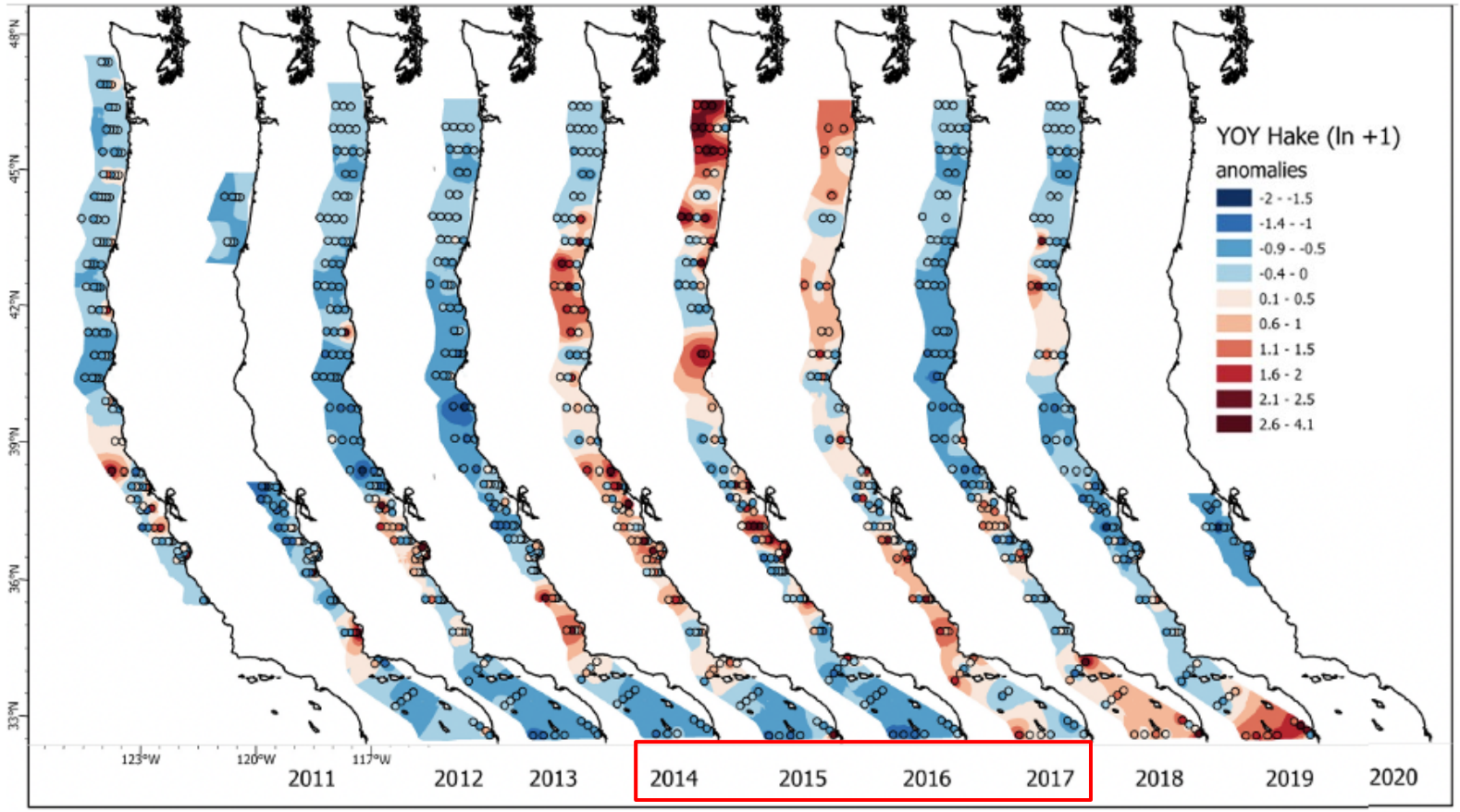
- **Ecological Dominance:** **Numerically dominant** pelagic fish species in the California Current
- **Commercial Importance:** **Largest commercial fishery** on US West Coast
- **Migratory Life Cycle:** **Adults spawn off Southern California**; feed along Pacific Northwest in summer.
- **Trophic Backup:** Serves as **secondary prey** for salmon, seabirds, and marine mammals.





Agostini et al 2006, Dorn 1995, Wells et al. 2023, Vestfals et al. 2023

Coastal Distribution Shifts Across Productivity States



Observed Coastal Dynamics

- **Cool / Productive State:** YOY hake concentrate in Southern Bight
- **Warm / Low-Productivity State:** northward, inshore expansion into Central and Northern domains.
- **Ecosystem Implication:** Abundant juvenile hake presence in northern waters dominate forage assemblage.

Core Study Hypotheses (Conceptual Framework)

HYPOTHESIS 1 (H1): Southern Domain SSB Control (Density-Dependent)

Spawning Stock Biomass (SSB) dictates YOY juvenile hake abundance in southern spawning grounds

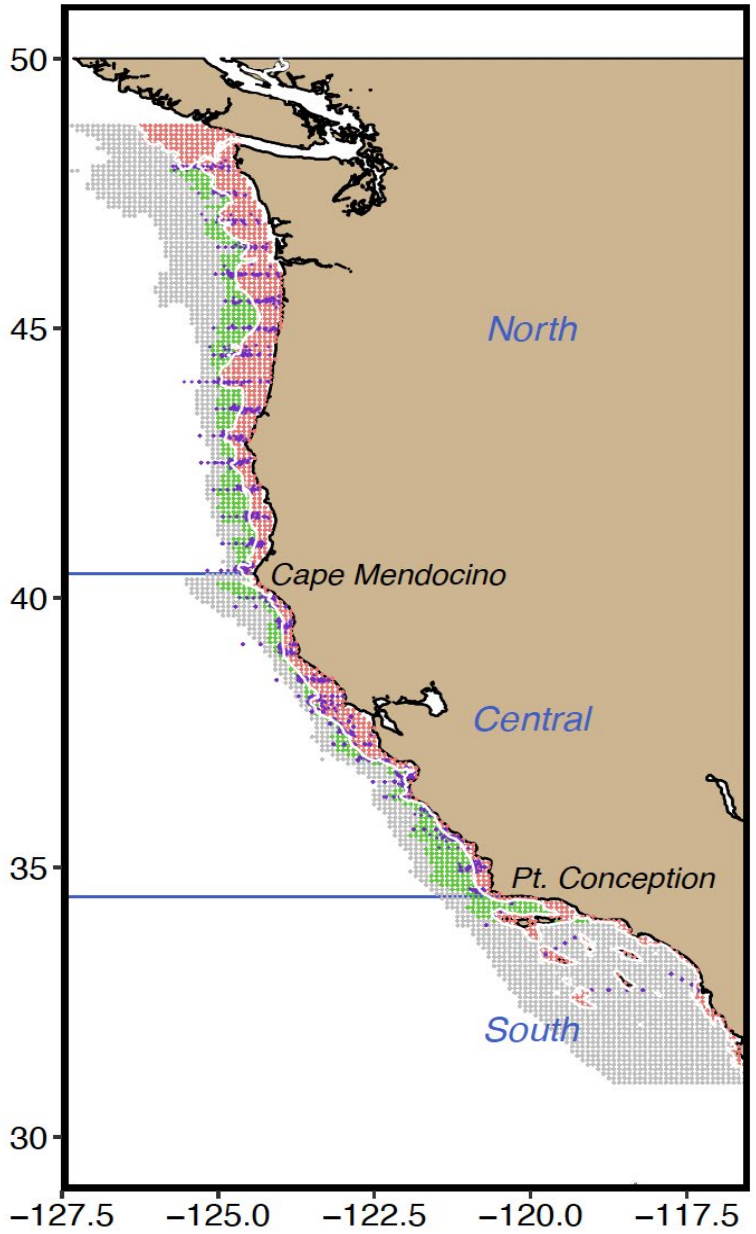
HYPOTHESIS 2 (H2): Central & Northern Environmental Control (Density-Independent)

YOY presence in Central and Northern bioregions is driven by density-independent ocean transport and thermal habitat compression, not SSB.

HYPOTHESIS 3 (H3): The Recruitment Trade-off (Advective Loss)

High YOY trawl catches in northern/central regions reflect advective loss into suboptimal juvenile habitats, resulting in reduced subsequent recruitment to the Age-1 adult stock.

Long-Term Midwater Trawl Survey Design



Survey Methodology (2001–2024)

- **Sampling Protocol:**
  - Cobb trawl, 30 m headrope depth at night targeting 20–80 mm SL young-of-year (YOY) juvenile hake.
  - Age 1 samples are from a biennial acoustic survey.
- **Spatial Coverage:** Extends from Southern California to Washington/BC border across 24 consecutive years.
- **Oceanographic Context:** Paired with GLORYS12V1 ocean reanalysis for physical transport (**Undercurrent, flow, Ekman velocities u/v, MLD, HCl).**

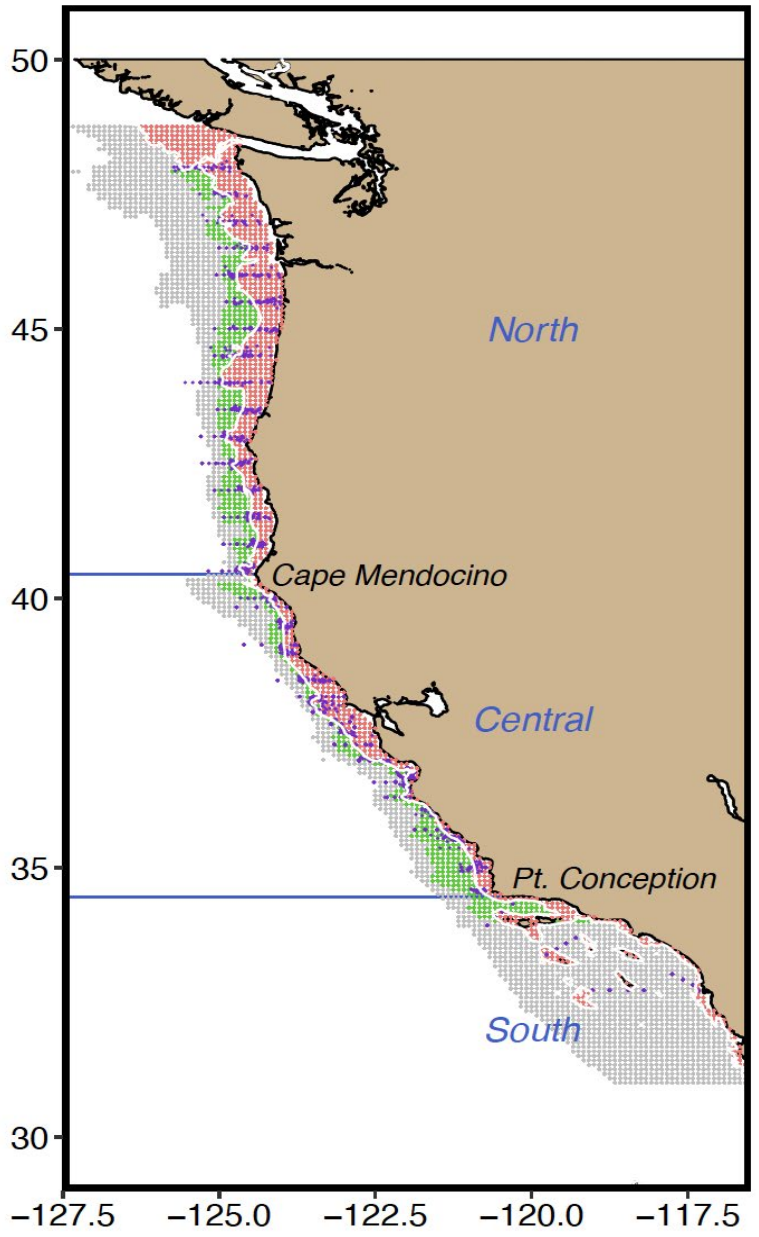
Bioregional Modeling Framework

RESOLVING HYPOTHESES
YOY and Age-1 analyses

- Regional YOY trawl observations evaluated against environmental drivers.
- Age-1 observations evaluated against YOY abundance and environment.

SPATIAL DISAGGREGATION
3 Bioregions

- Domain division at major biogeographic capes
- **Inshore** vs **Offshore**.
- Accounts for spatial heterogeneity in physical transport and spawning proximity.



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STATISTICAL FORMULATION
GAMs with REML Penalty

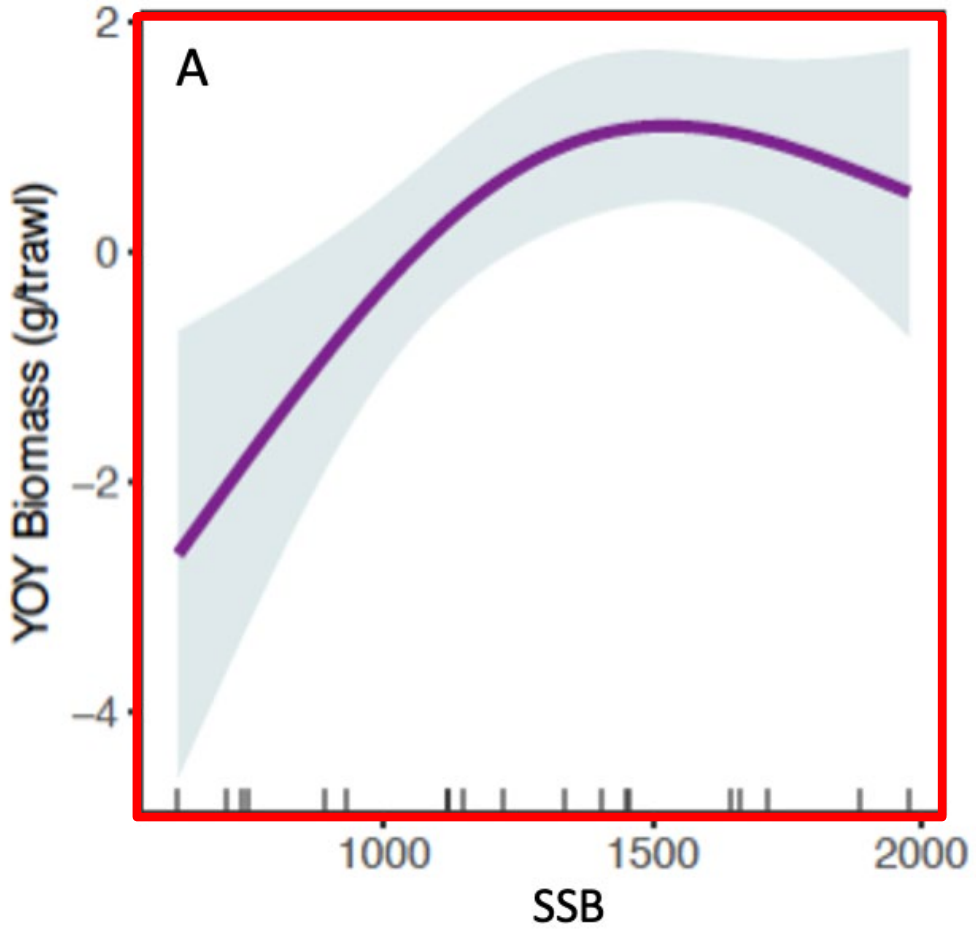
• GAMs with Tweedie distribution.

• Restricted Maximum Likelihood (REML) smoothing parameter estimation.

• Spline basis dimension constrained (k = 3) to prevent over-fitting.

• **Cross-validated Root Mean Square Error used for out-of-sample model evaluation**.

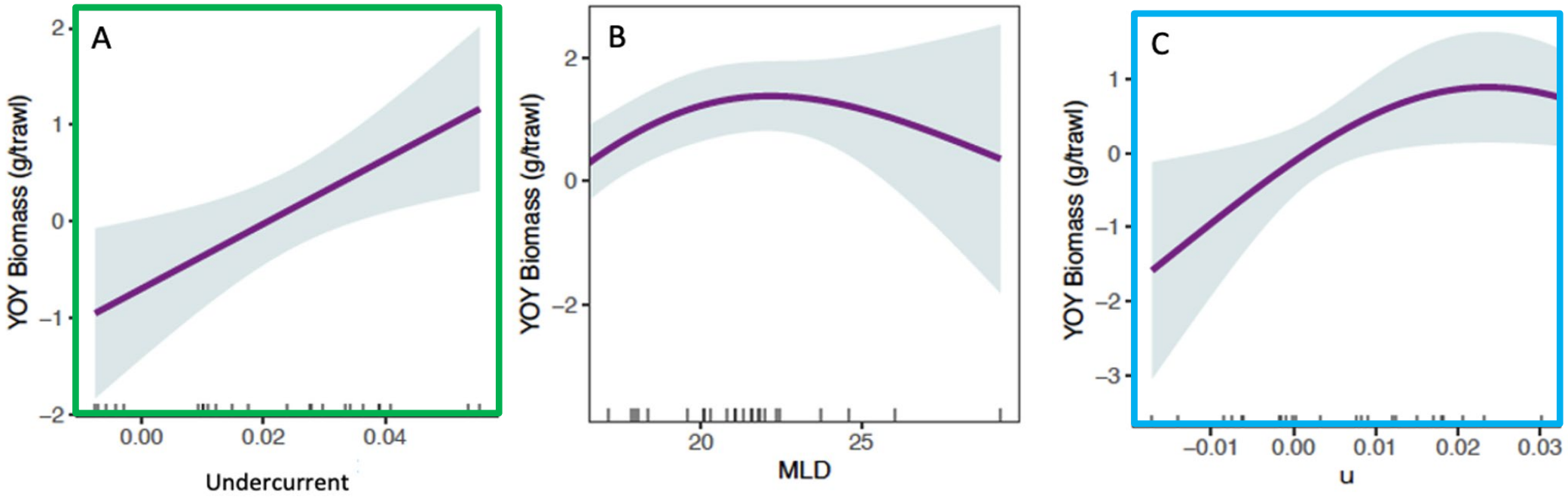
Southern Bioregion: Density-Dependent SSB Dominance (H1 Confirmed)



Southern Driver Mechanics

- **Spawning Stock Biomass (SSB)** is the primary significant driver of YOY hake biomass in the South.
- **Non-linear Response:** potentially reflecting stock density dependence.
- **Secondary Transport Effect:** Offshore northward velocity (**v**) exerts a secondary influence on local retention vs export.

Central Bioregion: Density-Independent Transport Control (H2 Confirmed)



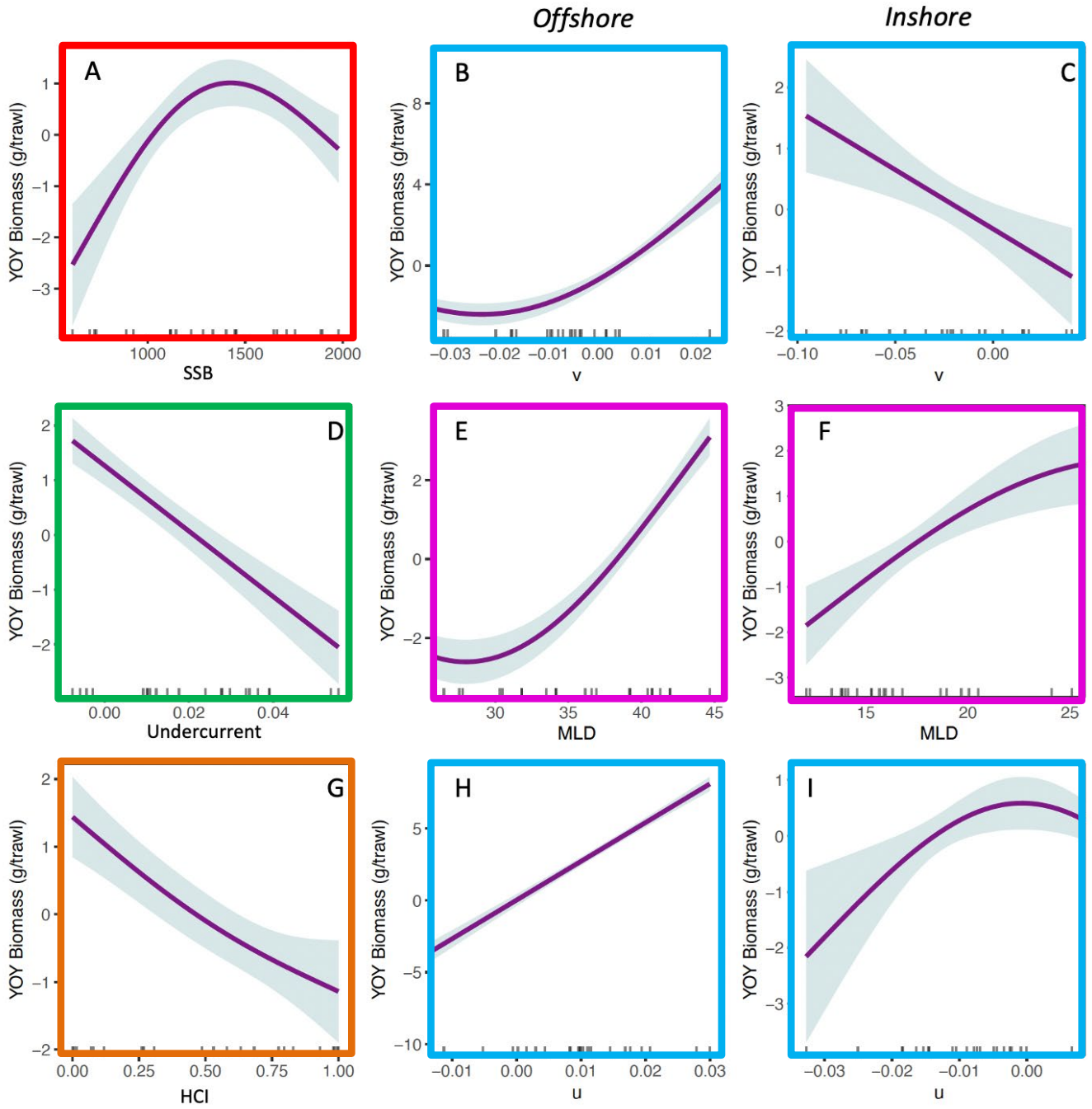
Key Findings for Central Bioregion:

- **California Undercurrent:** Poleward subsurface flow transports YOY juveniles and, likely, adults northward.
- **Onshore Transport**: Positive eastward surface current velocity transports juveniles toward coastal shelf habitats.

Northern Bioregion (H2 Confirmed)

Northern Model Takeaways

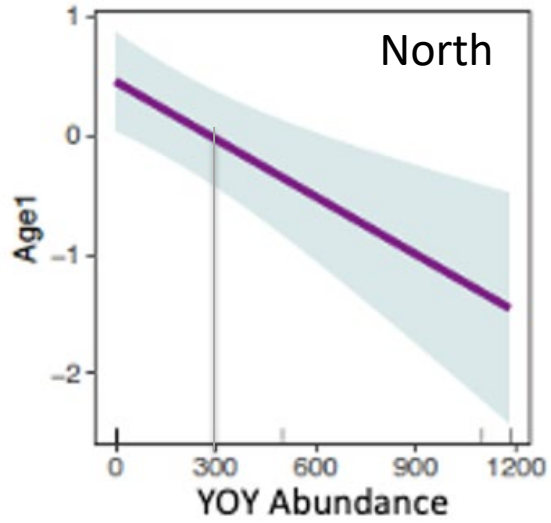
- Surface Currents: **Eastward u and v** influence nearshore placement.
- Resulting deeper **MLD**
- **Habitat Compression**: Compressed cool habitat may hold juveniles inshore
- **Undercurrent Transport**: velocity strongly impacts northward advective loss.
- **Density dependence** indicates a northern spawning contingent and/or cannibalism.

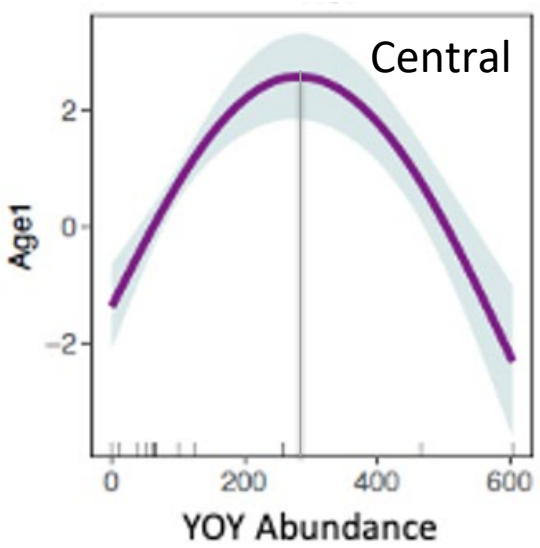


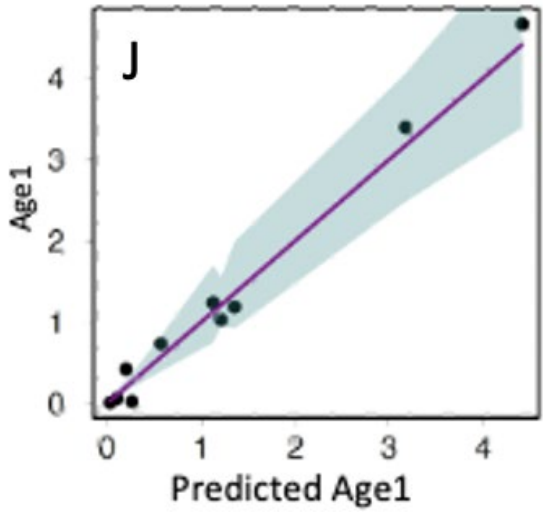
Summary Table: Bioregional GAM Model Comparisons

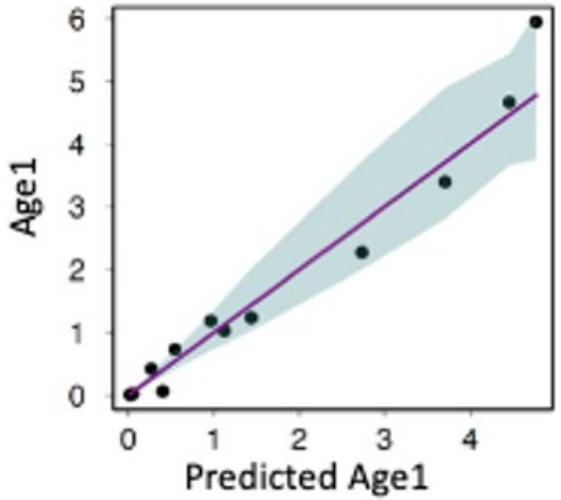
Bioregion	Primary Driver(s)
South	Spawning Stock Biomass
Central	Undercurrent, onshore current
North	HCI, Undercurrent, surface currents

Northern/Central YOY Trawl Catch Signals Recruitment Loss (H3 Confirmed)









Recruitment Loss Mechanics

- **Northern Signal:** **Linear negative** relationship
- **Central Signal:** **Parabolic**
- **Survey Interpretation:** Northern trawl surveys index advective loss rather than cohort strength. Dead end

BUT….

Trophic Dynamics: Diverse Forage vs. Hake-Dominated Forage Assemblage

Productive Upwelling State:
Diverse Lipid-Rich Forage Base



High Upwelling & Primary Production

Low-Productivity Warm State:
YOY Hake Acts as Primary Forage Buffer



Thermal Compression & Low Coastal Productivity

Conclusions: Re-evaluating Hypotheses & Summary

Re-evaluation of Study Hypotheses

- **H1 CONFIRMED (South):** **Spawning Stock Biomass (SSB)** modulates YOY biomass in southern spawning grounds via density dependence.

- **H2 CONFIRMED (Central/North):** **Density-independent ocean transport** (CUC, u/v currents) and thermal habitat compression (HCI) influence northern presence.

- **H3 CONFIRMED (Recruitment Loss):** High northern YOY catches signal **advective displacement** into suboptimal habitats, resulting in reduced Age-1 recruitment.

CONCLUDING STATEMENT

Decreased coastal productivity facilitates the northward, inshore expansion of YOY Pacific hake—subsidizing marine predator diets during lean upwelling years while marking an advective recruitment loss for the adult stock.