Session 2

SSC HCR workshop

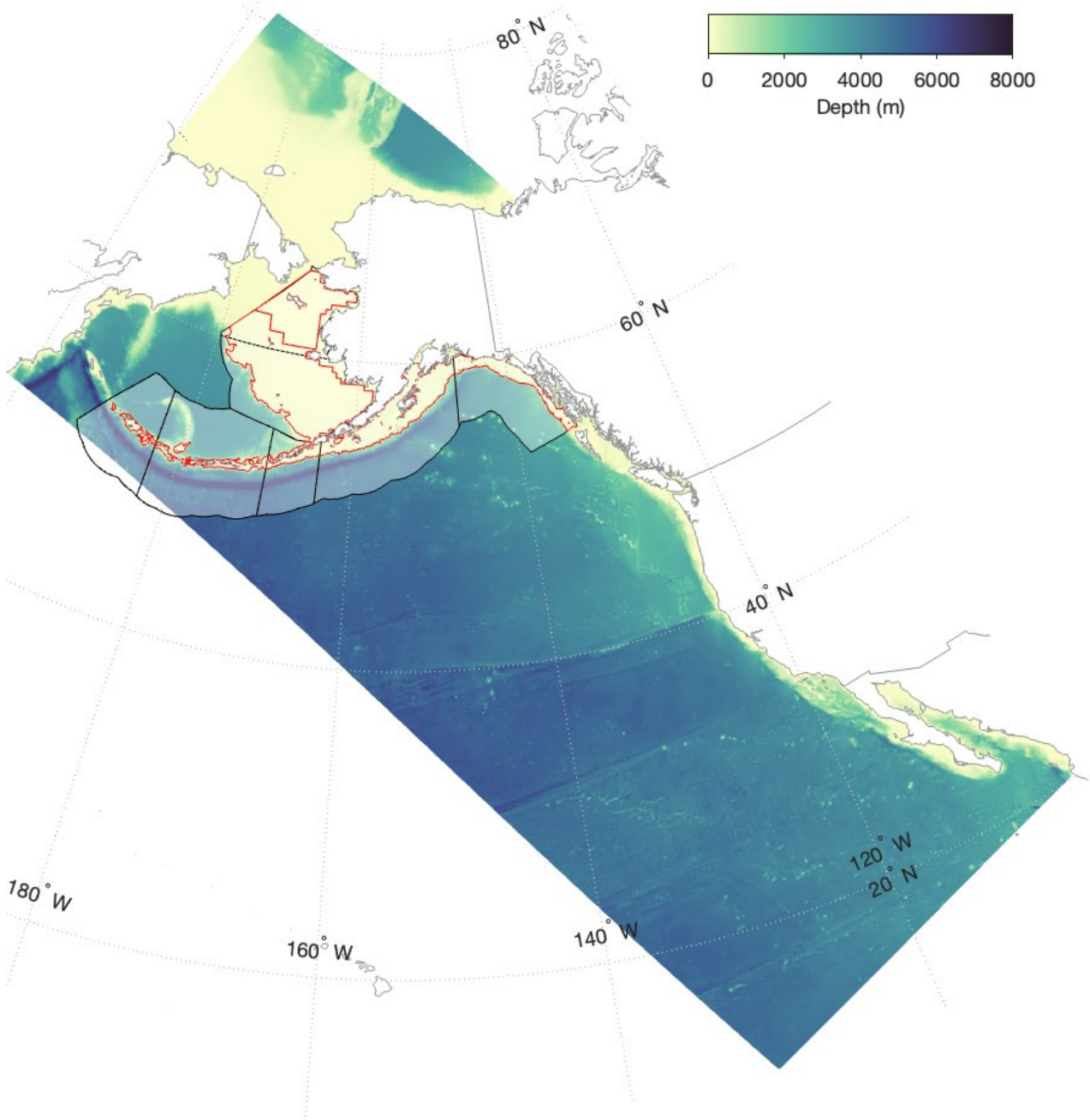
June 2025

Regional modeling (MOM6-NEP) in Alaska

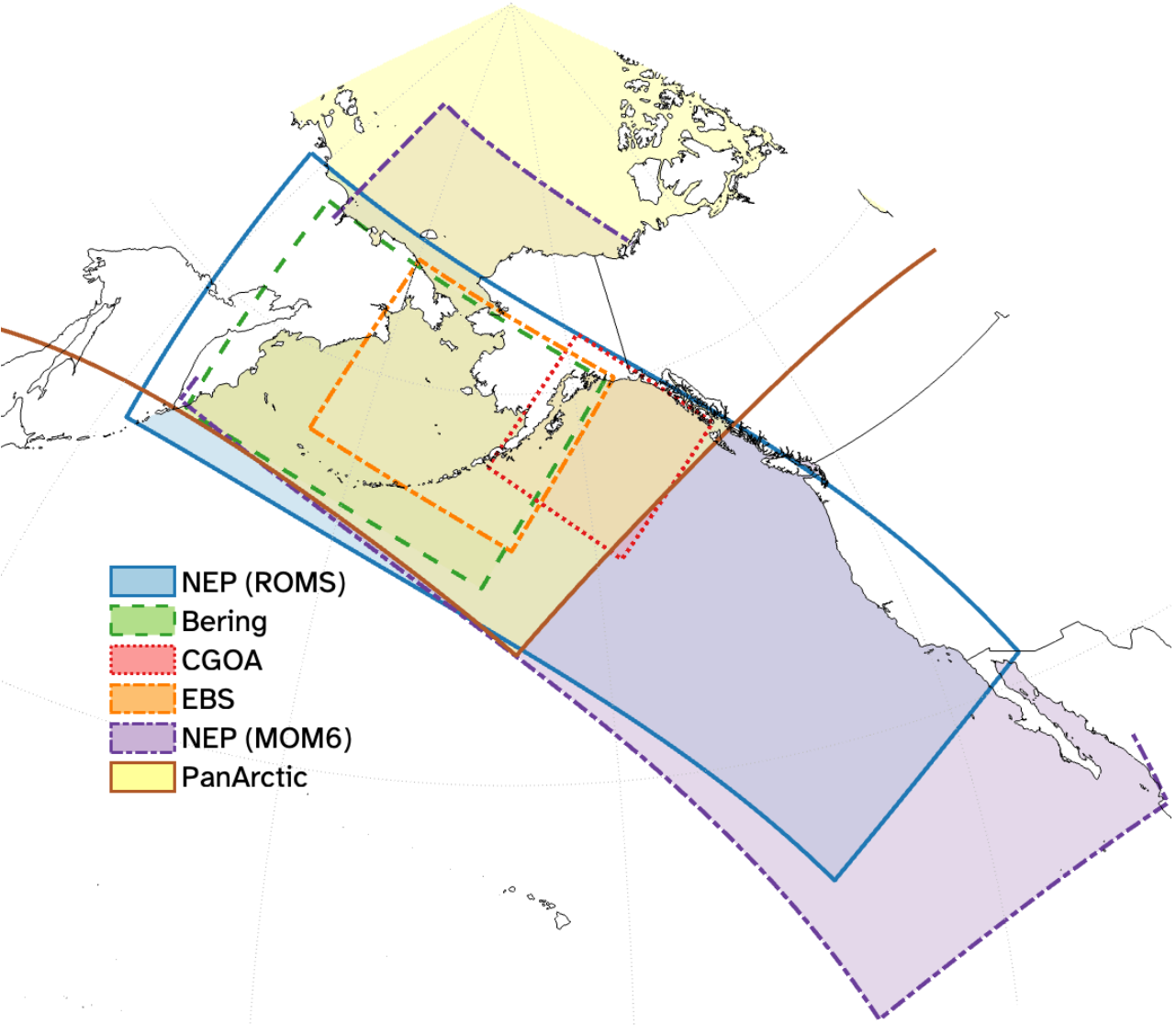
Kelly A. Kearney[1], Albert J. Hermann[2,3], Wei Cheng2, Liz Drenkard[4], (and the entire CEFI team!)

[1]NOAA Alaska Fisheries Science Center, [2]University of Washington, CICOES, [3]NOAA Pacific Marine Environmental Laboratory, [3]NOAA Geophysical Fluid Dynamics Laboratory

D6 SSC Workshop: Harvest Control Rules
June 4, 2025



The regional modeling landscape: ROMS to MOM6



ROMS-GOANPZ (GOACLIM):

- NEP10K
- CGOA3K

ROMS-Ice-BESTNPZ (ACLIM)

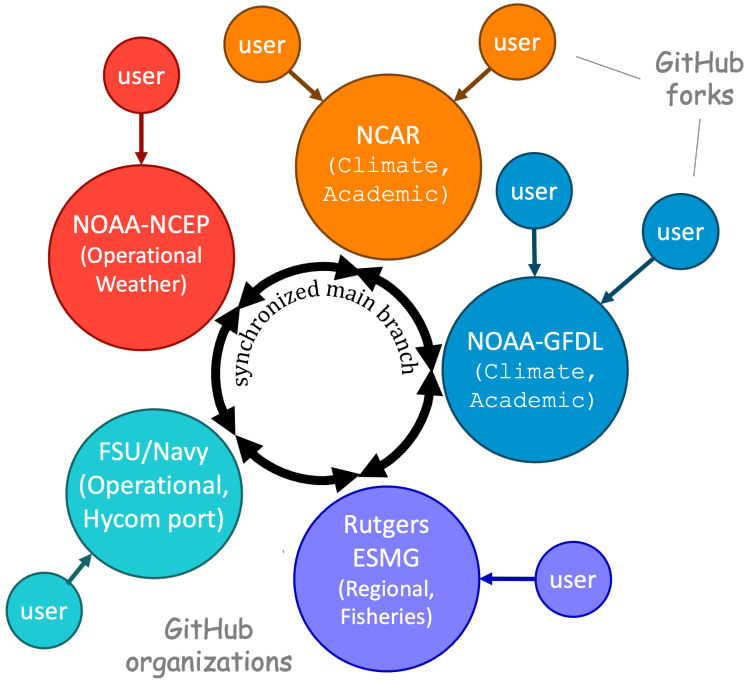
- Bering10K
- EBS3K*
- NEP10K*

MOM6-SIS2-COBALT (CEFI):

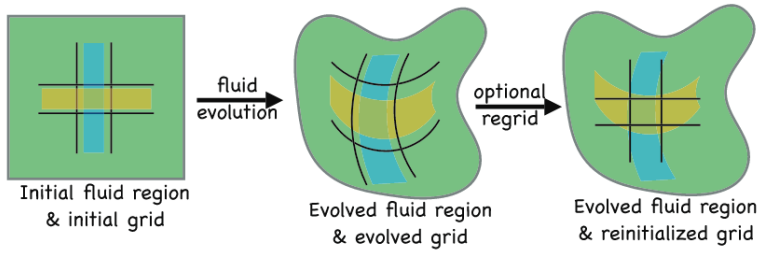
- NEP10K
- NEP5K
- Pan-Arctic

Why MOM6?

Nation-wide effort



Flexible vertical coordinates

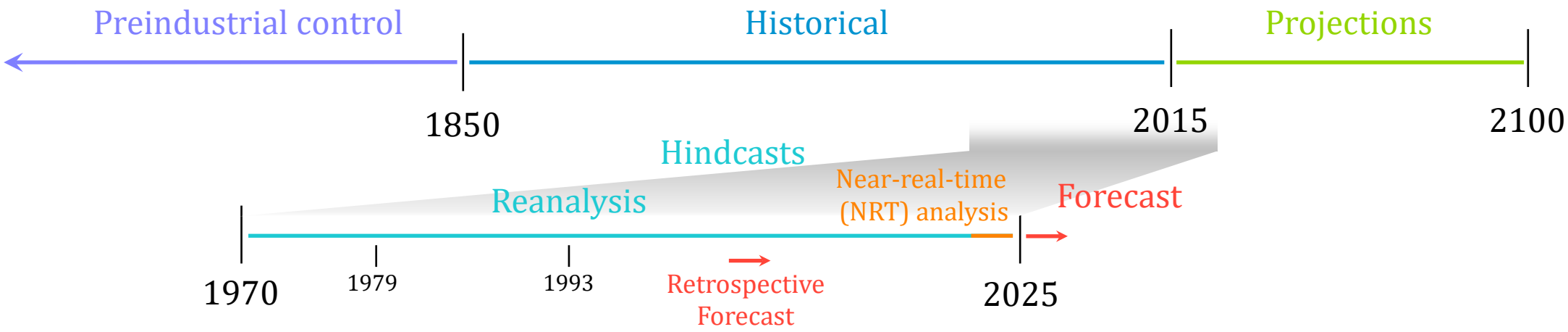


(i.e., better representation of shelf break)

Efficient time-stepping

Barotropic (2D linear momentum, integrated continuity)	$\frac{\partial \eta}{\partial t} + \nabla \cdot \left((D+\eta)\vec{u}_{BT}\right) = P - E$ $\frac{\partial \vec{u}_{BT}}{\partial t} = -g\nabla\eta - f\hat{z}\times\vec{u}_{BT} + \vec{F}_{BT}$	Δt = 20 s (CM4, ¼°)
Lagrangian dynamics (3D stacked shallow water equations)	$\frac{\partial \vec{u}_k}{\partial t} + (f + \nabla_s \times \vec{u}_k)\hat{z}\times\vec{u}_k = -\frac{\nabla_s p_k}{\rho} - \nabla_s\left(\phi_k + \frac{1}{2}\|\vec{u}_k\|^2\right) + \frac{\nabla\cdot\vec{\tilde{\tau}}_k}{\rho}$ $\frac{\partial h_k}{\partial t} + \nabla_s \cdot (\vec{u} h_k) = 0$	Δt = 900 s
Tracer advection, thermodynamics, and mixing	$\frac{\partial h_k}{\partial t} + \nabla_s \cdot (\vec{u} h_k) = 0$ $\frac{\partial}{\partial t}(h_k\theta_k) + \nabla_s \cdot (\vec{u} h_k \theta_k) = Q_k^g h_k + \Delta\left(\kappa \frac{\partial \theta}{\partial z}\right) + \nabla_s (h_k K \nabla_s \theta)$	Δt = 7200 s
Remapping and coordinate restoration	$h_k^{new} = \Delta_k z_{Coord}$ $\quad \sum h_k^{new} = \sum h_k^{old}$ $\vec{u}_k^{new} = \frac{1}{h_k}\int_{z_{k+\frac{1}{2}}}^{z_{k+\frac{1}{2}}+h_k} \vec{u}^{old}(z')dz'$ $\quad \theta_k^{new} = \frac{1}{h_k}\int_{z_{k+\frac{1}{2}}}^{z_{k+\frac{1}{2}}+h_k} \theta(z')dz'$	Δt = 7200 s

Simulation time scales



The original CEFI timeline

MOM6-NEP status:

Hindcast:
- 1993-2024 available, published, annual updates expected

Seasonal forecast:
- 1993-2020 retrospective forecasts complete, being assessed for regional skill
- 2025 forecasts and publication in progress

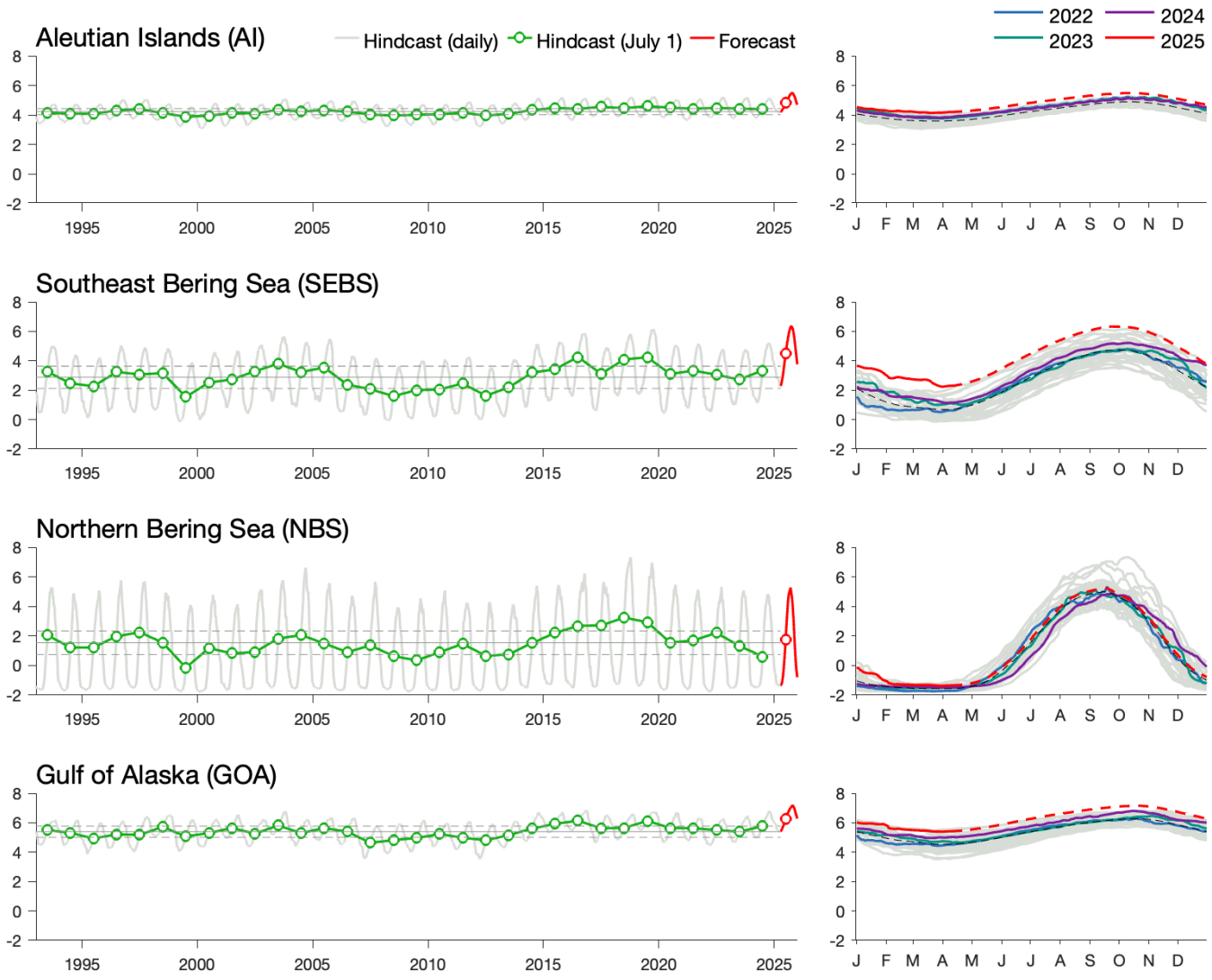
Decadal forecasts:
- Configuration in progress

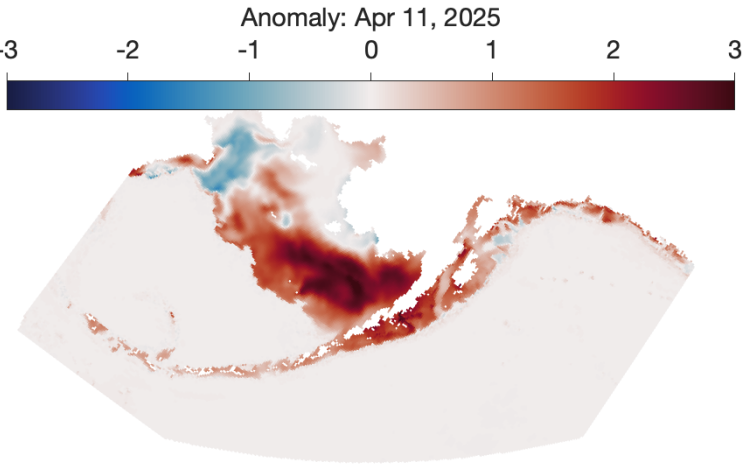
Projections:
- Configuration in progress

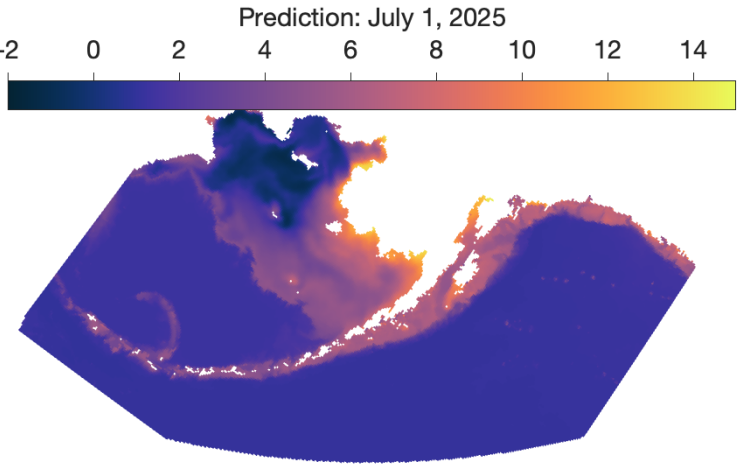
An ambitious timeline for deliverables

Year	East Coast	West Coast and Arctic	Great Lakes, Pacific Islands
FY23	Initial hindcast	Initial Configuration	
FY24	Hindcast update, retrospective seasonal predictions	Initial hindcast	Initial configuration
FY25	Hindcast update, retrospective decadal predictions, initial climate change projections	Hindcast update, retrospective seasonal predictions, initial climate change projections	Initial hindcast
FY26	Hindcast update, expanded projections, seasonal outlooks reliably delivered	Hindcast update, expanded projections, retrospective decadal predictions	Hindcast update, retrospective seasonal predictions, initial climate change projections
FY27	All products reliably delivered	Hindcast update, seasonal outlooks reliably delivered	Hindcast update, expanded projections, retrospective decadal predictions
FY28	All products reliably delivered	All products reliably delivered	Hindcast update, seasonal outlooks reliably delivered
FY29	All products reliably delivered	All products reliably delivered	All products reliably delivered

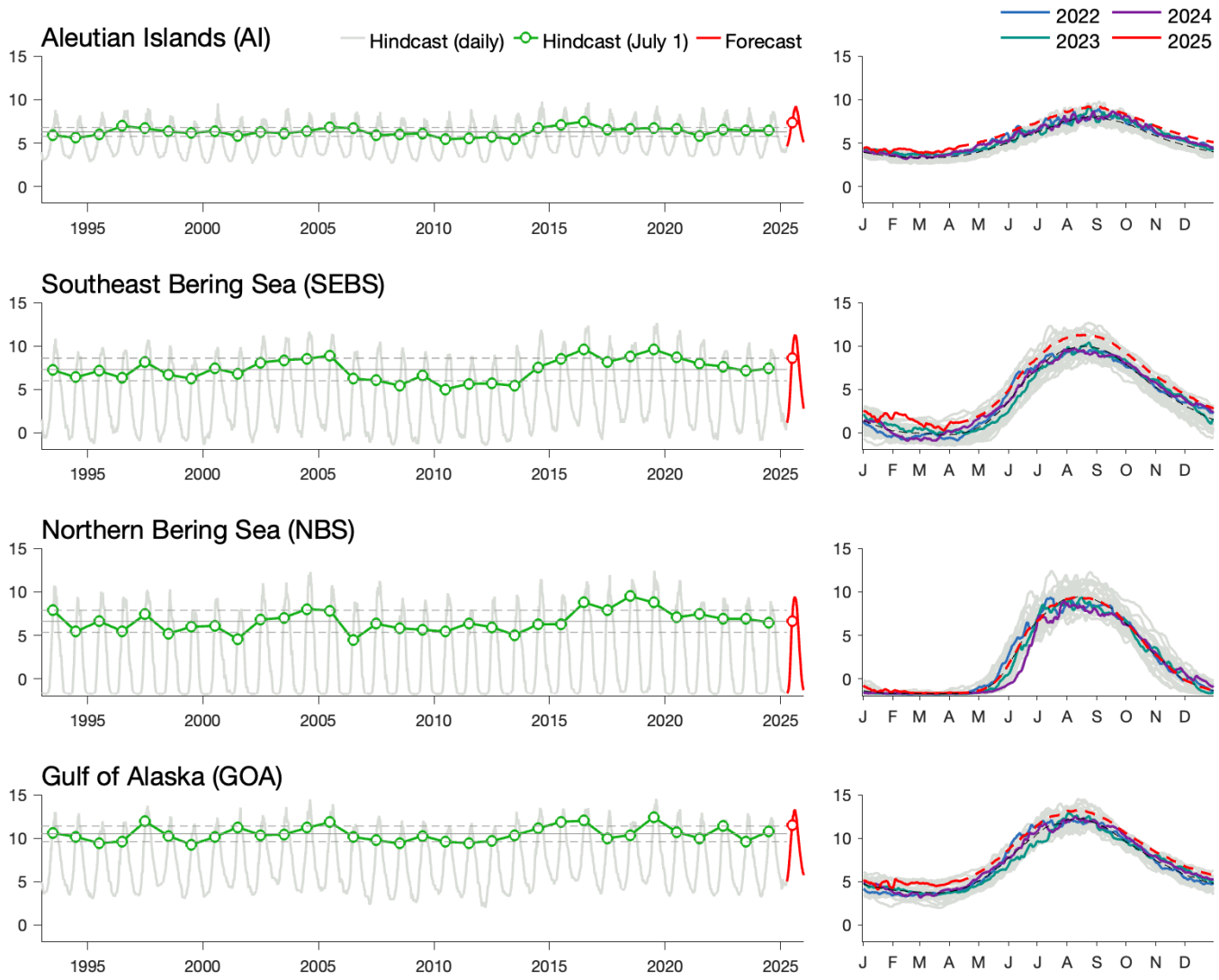
MOM6-NEP at the 2025 Alaska Spring PEEC

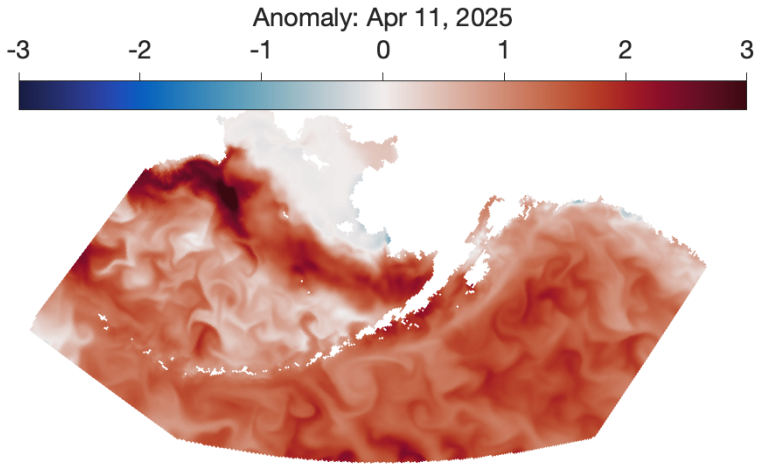


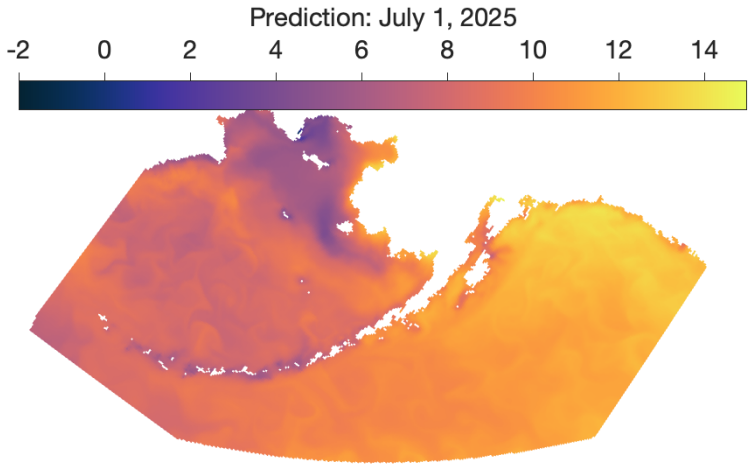




MOM6-NEP at the 2025 Alaska Spring PEEC





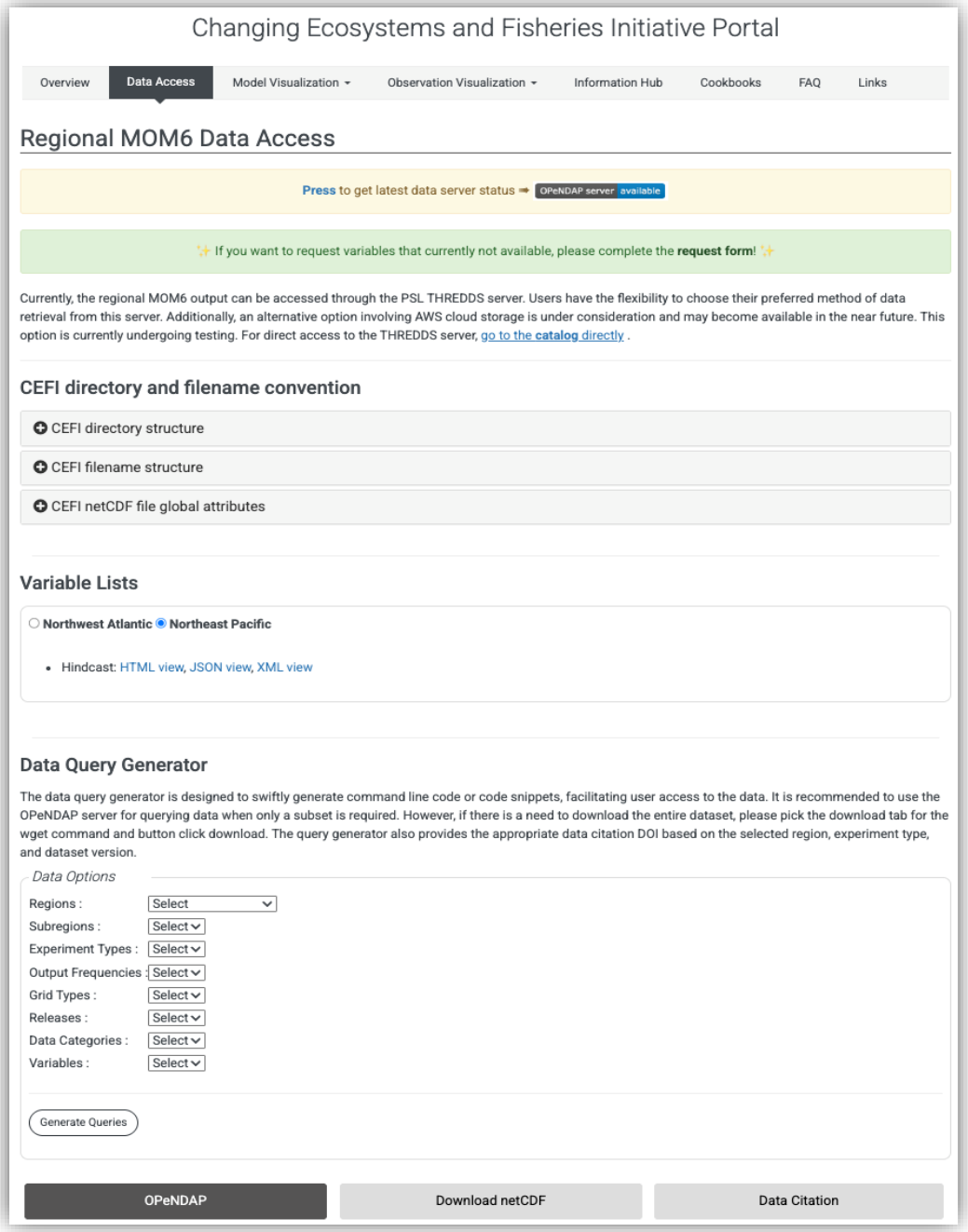


The CEFI Data portal

https://psl.noaa.gov/cefi_portal/

Other options:

- GFDL archive: contact your regional DST member (that's me!)
- Coming soon: ACE portal (for Alaska-specific derived products)



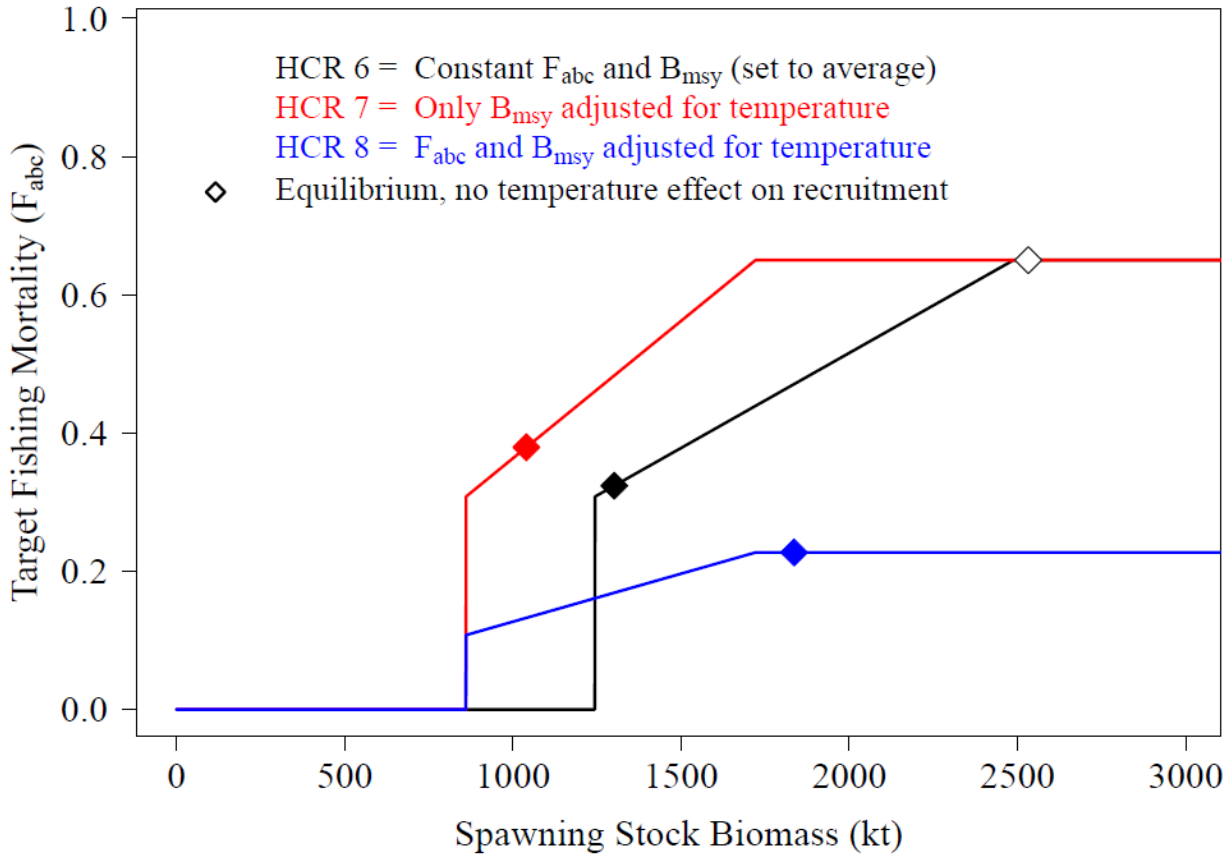
Temperature-dependent recruitment and dynamic harvest-control rules for Bering Sea walleye pollock

Outline

- Summer SST and pollock recruitment seem to be related, affecting productivity, fishing rate reference points, and harvest control rules.
- Ongoing work is evaluating dynamic harvest control rules for pollock.
- Many stocks nationwide show time-varying population productivity (50 of 85 stocks, Marshall et al., 2025, DOI: 10.1111/faf.12862). This suggests that the fishing rate reference points that underlie harvest control rules would change over time.
- We are attempting in incorporate a flavor of dynamic HCRs in the ACLIM simulations.

What happens if stock productivity changes and we do not recognize it?

Simulated control rules (with equilibrium values for pollock)



Imagine a case where the temperature was at the maximum observed value, but it was not fully recognized in the control rule

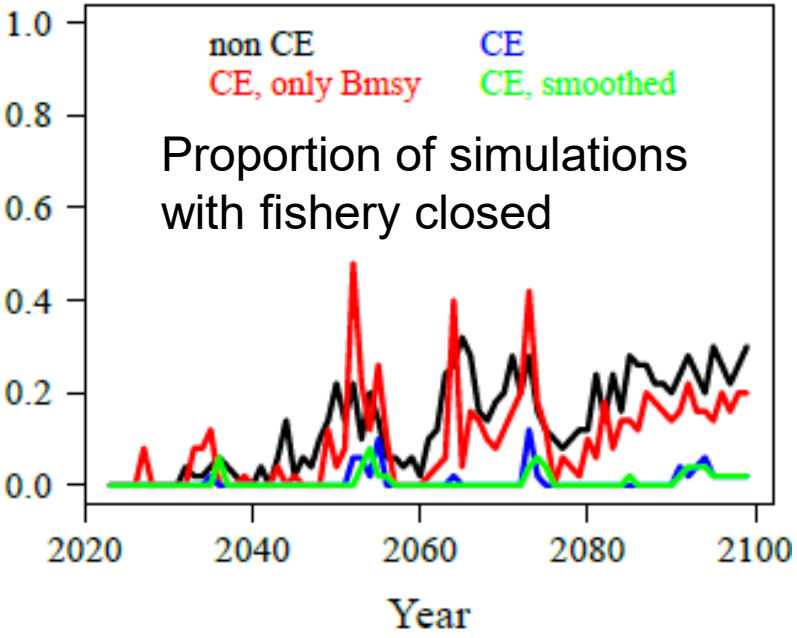
If there was an SST effect on recruitment but our control rule did not recognize it, we would expect lower SSB and higher fishing mortalities (relative to the climate-informed HCR)

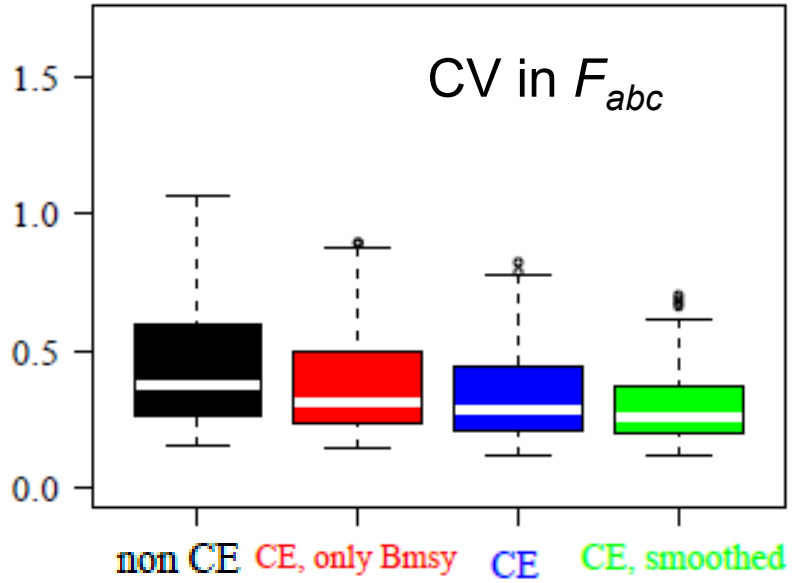
Population simulations (with recruitment variability)

Recruitment: 2023 – 2099 affected by temperatures from ROMS downscaled from global climate models

HCR	F_{abc}	B_{msy}
Non CE	Constant	Constant
CE, only Bmsy	Constant	adjusted for temperature
CE	adjusted for temperature	adjusted for temperature
CE, smoothed	adjusted for temperature & smoothed	adjusted for temperature & smoothed

Results (Fishery performance)

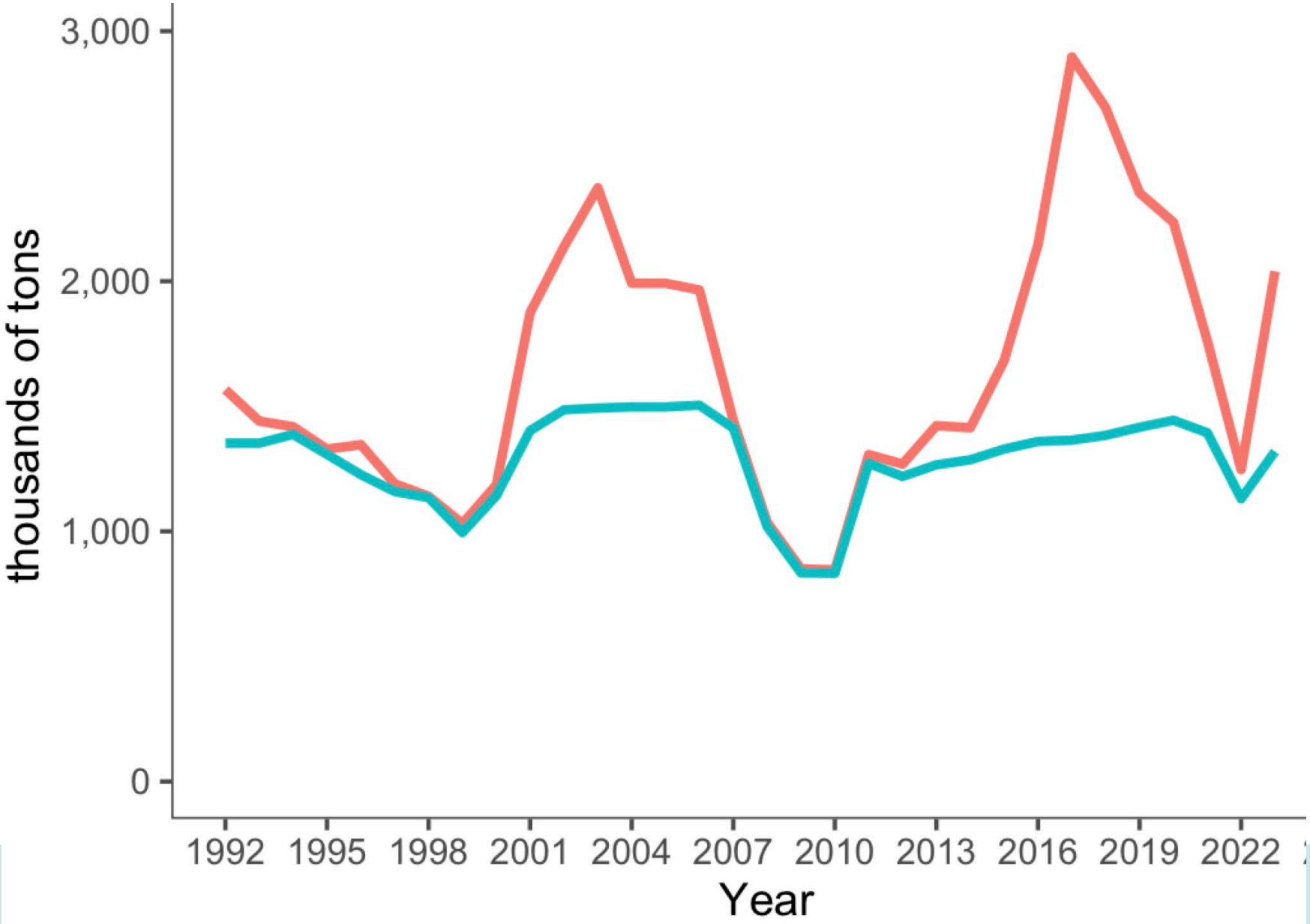




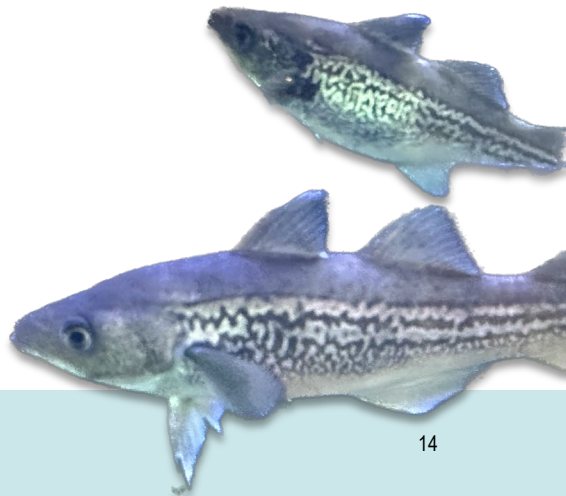
Conclusions

- For pollock, time-varying HCRs result in decreased fishery closures when productivity is reduced.
- In data-rich stocks, estimates of recruitment are not strongly dependent on the SR model formulation – this work is about getting the best estimates of future productivity under changing conditions.
- Our reference points are already time-varying, and reflect estimated changes in selectivity, growth, and maturity. Incorporation of variation in productivity is conceptually consistent.
- A challenges is to apply this approach to Tier 3 stocks. Some empirical operational procedures, based on R/S, could be useful.

EBS pollock history: ABCs and TACs

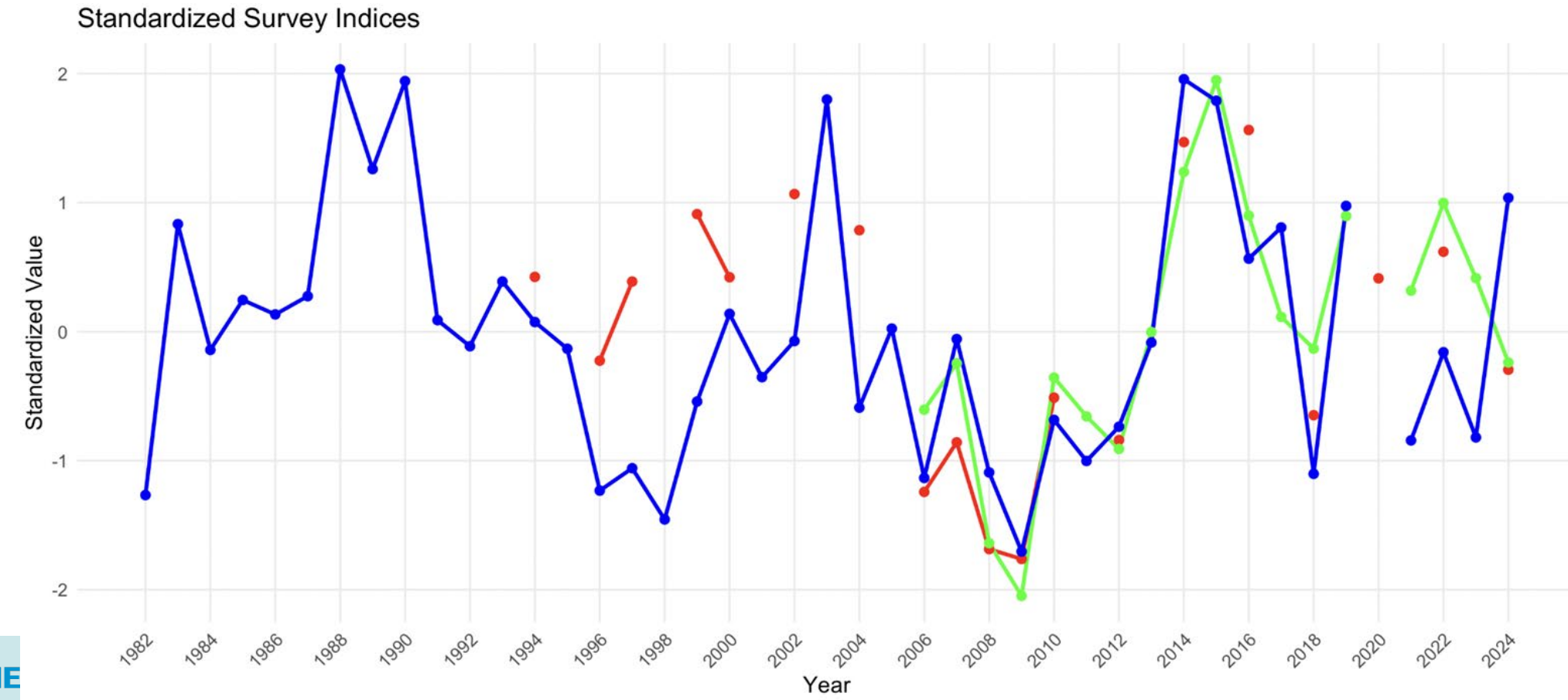


	Mean (t)	CV
ABC	1,727,839	32%
TAC	1,291,989	15%



Productivity estimates for EBS Pollock

- Effective **surveys**



Do proxies capture dynamic ecosystem changes?

I.e., for B_{MSY} and F_{MSY}

Are there other "ecosystem function" metrics that we're missing?

- E.g., economics
- Forage
- Predation

The effects of implementing a 'dynamic B_0' harvest control rule in Australia's Southern and Eastern Scalefish and Shark Fishery

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[a] CSIRO Oceans and Atmosphere, Castray Esplanade, Hobart, TAS, Australia
[b] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA
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ARTICLE INFO

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Keywords:
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Environmental drivers
Management
Reference points
SESSF
Stationarity

ABSTRACT

The harvest control rules for many fish and invertebrate stocks, managed using stock assessments based on fitting population dynamics models to monitoring data, rely on biological reference points. These reference points are often related to unfished conditions ('B_0') and are calculated assuming that biological parameters and their associated functional forms (e.g., unfished recruitment ('R_0'), natural mortality, growth) are stationary. However, there is increasing evidence that the assumption of stationarity is untenable in the face of environmental change. In principle, non-stationarity can be addressed by defining stock status (i.e., spawning biomass relative to unfished spawning biomass) using 'dynamic B_0' (the spawning biomass that would be expected in the absence of fishing). We show how catch limits (Recommended Biological Catches) for stocks in Australia's Southern and Eastern Scalefish and Shark Fishery would have differed had management been based on dynamic B_0. We also explore the performance of static and dynamic B_0-based harvest control rules using simulations where various biological parameters (R_0, B_0, L_∞, κ, natural mortality, and stock-recruitment steepness) exhibit trends over time. The results confirm previous work that the implications of adopting a dynamic B_0 approach would differ among species, with quite major changes in stock status and catch limits for some species and negligible changes for

Matching management to productivity

- Keys
  - Climate-resilience requires data-based management
  - HCR considerations and simulation-based climate modeling can identify management levers

EBS Pollock

- Fishery production

- Higher biomass means better value across fishery domain

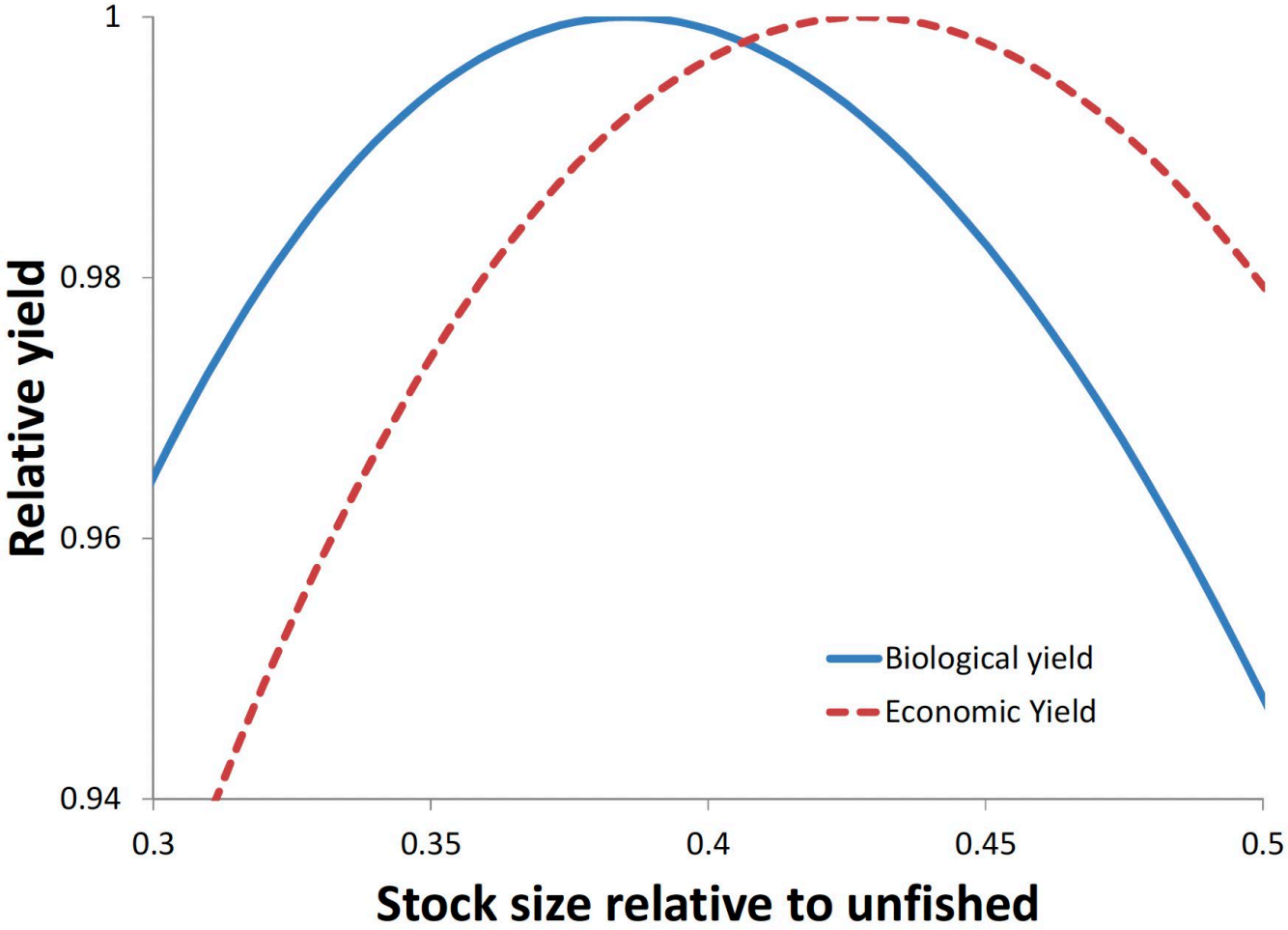
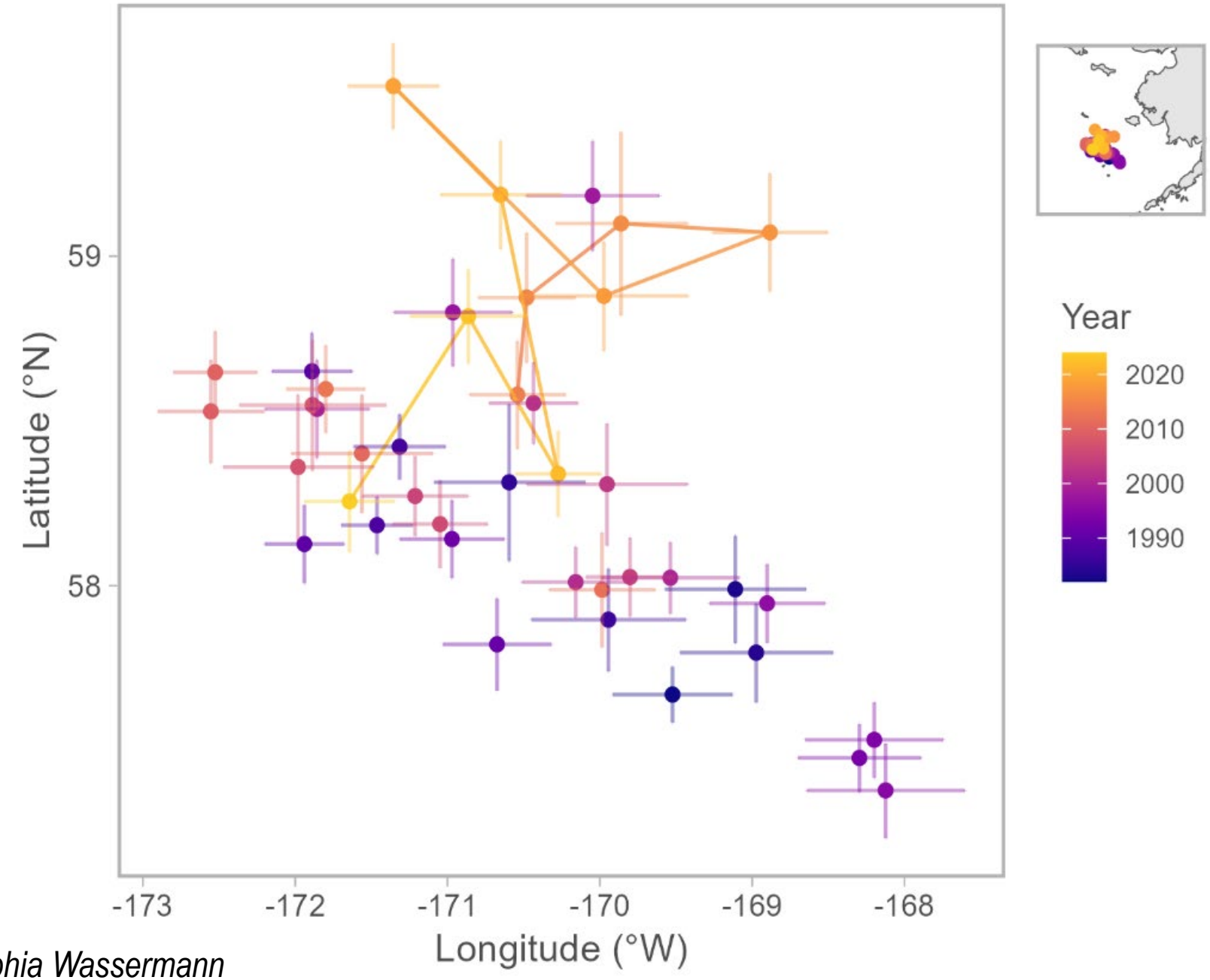


Figure 1.36. Population-level estimated yield curves normalized for biomass (solid line) and economic yield (dashed line). The economic curve uses age-specific with relationship between relative effort (distance) required for capture with a 60-40 weighting and an example age-specific value for ex-vessel landings (slope parameter equal to 0.1).

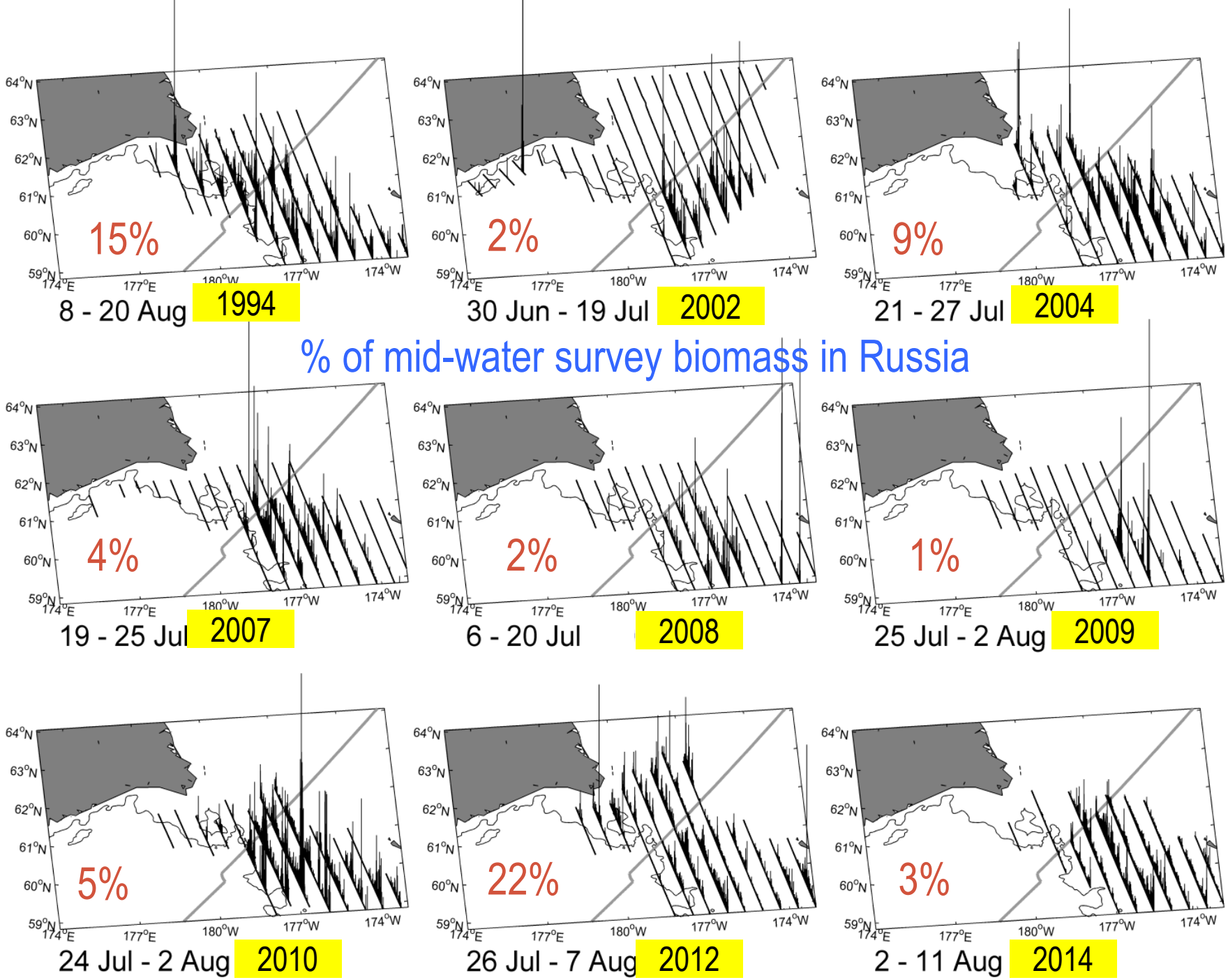
EBS pollock

- Fishery ”domain” shifting



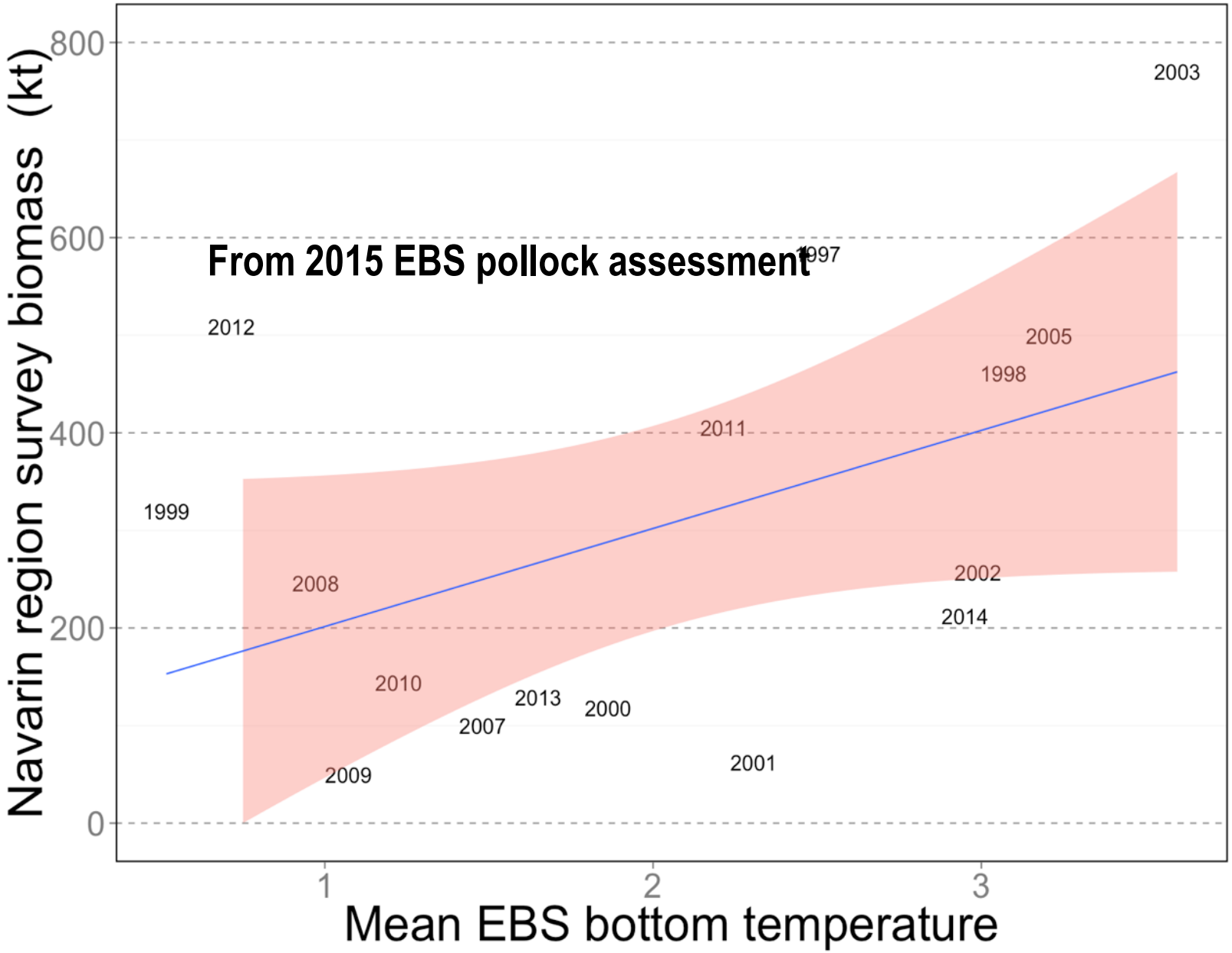
Thanks to Sophia Wassermann

EBS pollock

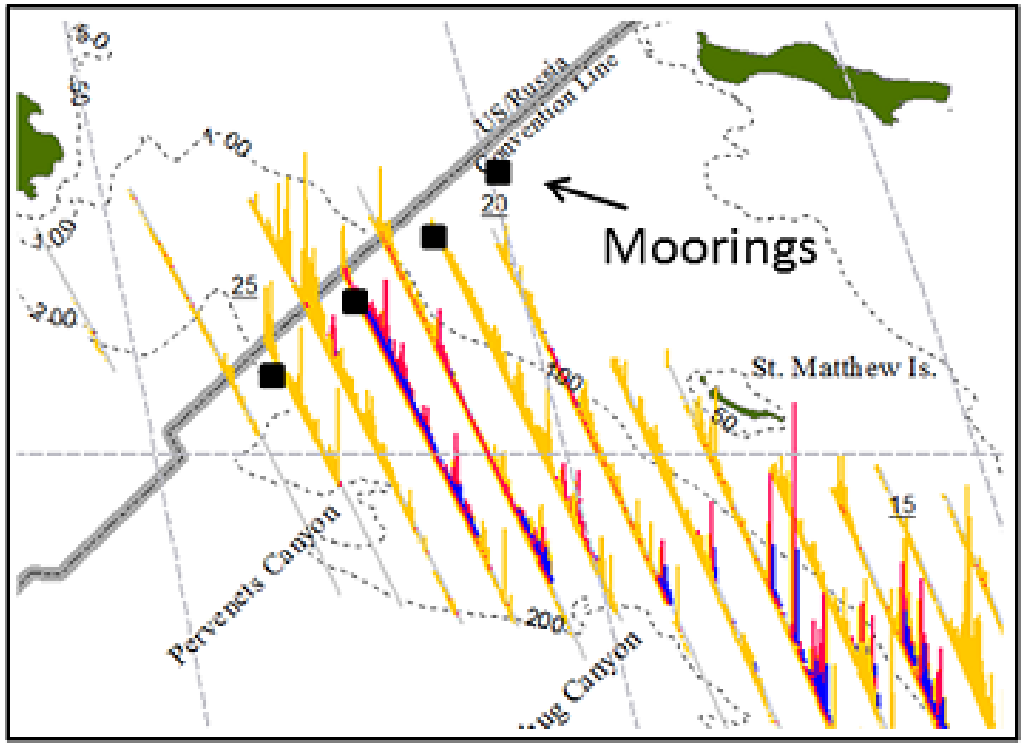


NOAA FISHERIES

Pollock movement?



Monitoring movements of Bering Sea pollock

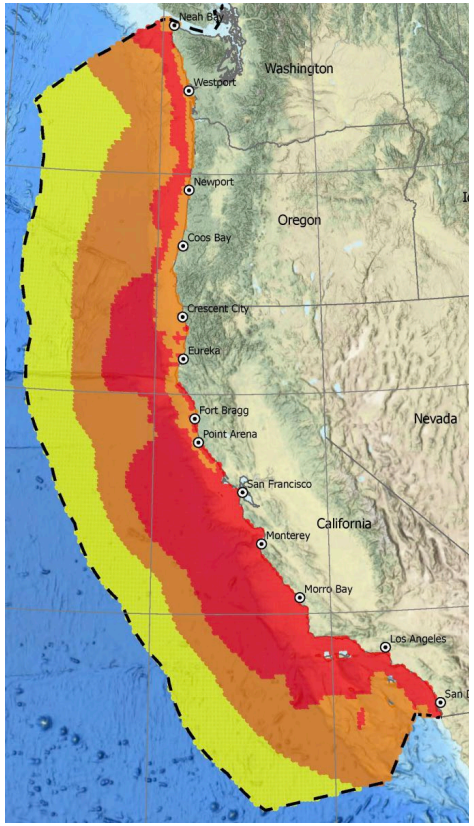


- ✓12 month deployments
  - summer 2019 – 2020
  - summer 2021 – 2022
- ✓Also physical oceanographic data collections

EBS pollock

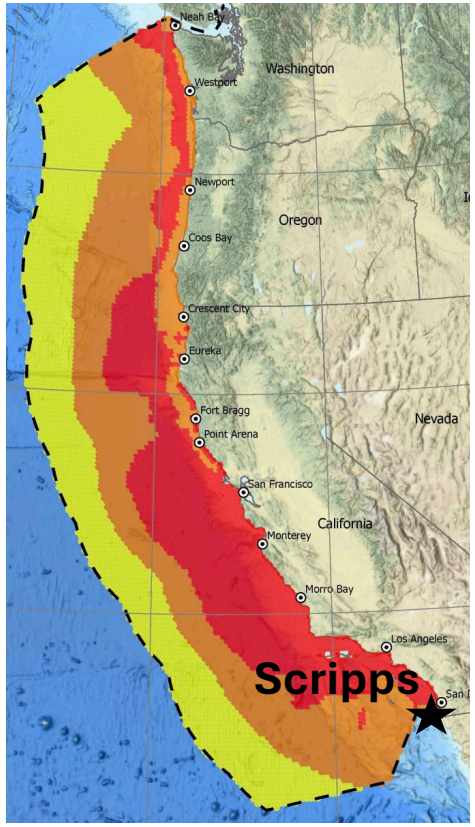
- Changes in distribution combined with fishing effort will impact fishery productivity
- Innovative survey and monitoring systems needed to track appropriately
- As with temperature-driven productivity estimates, fishery stability key

Pacific sardine harvest control rule

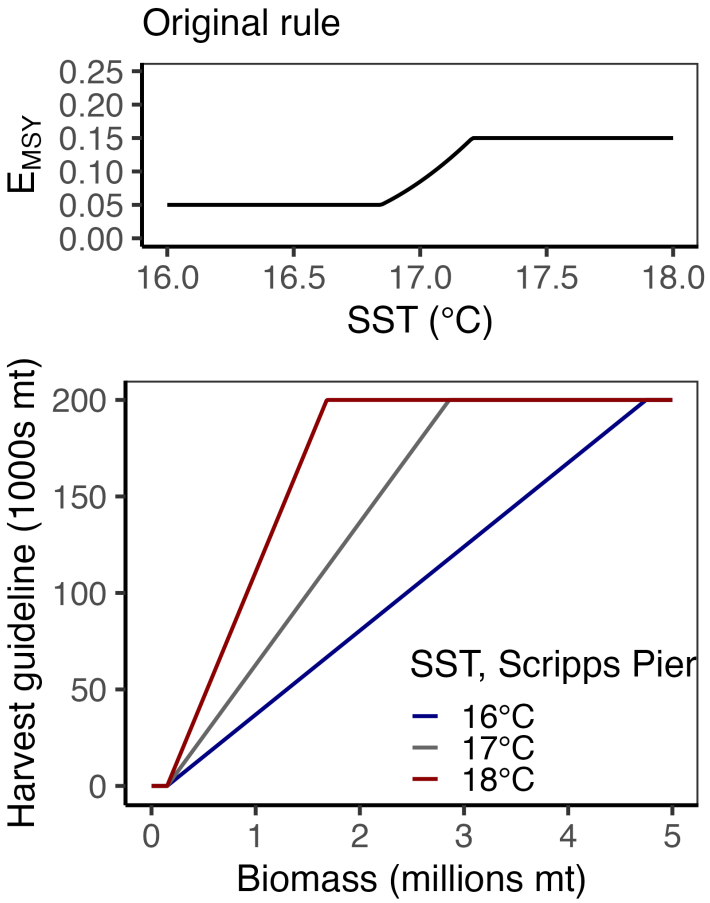


- Only climate-linked HCR in the US
- An alluring option for climate adaptiveness
- Depends on predictable / stationary environmental relationships
- Requires consistent updates with new data and regimes
- Risks overfishing if assumed relationship breaks down

Pacific sardine harvest control rule



1998: Rule established



Cutoff: 150,000 mt

Max catch: 200,000 mt

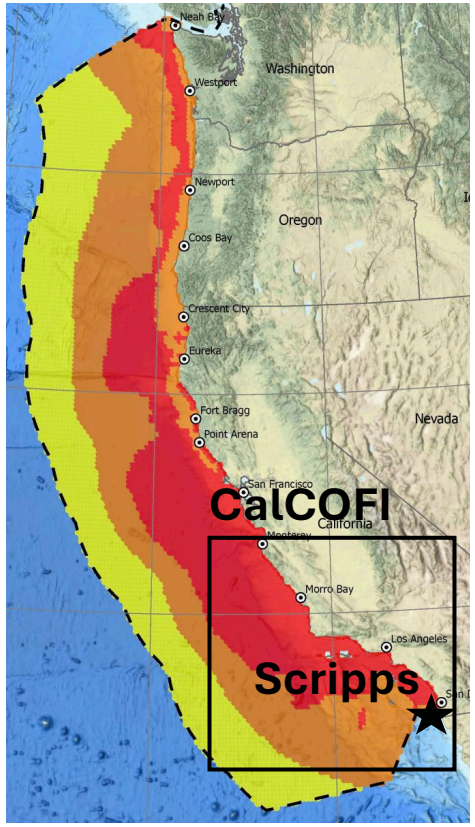
Distribution: 87% USA

SST source: Scripps pier

E_{MSY} range: 5 - 15%

Jacobson & MacCall (1995)

Pacific sardine harvest control rule



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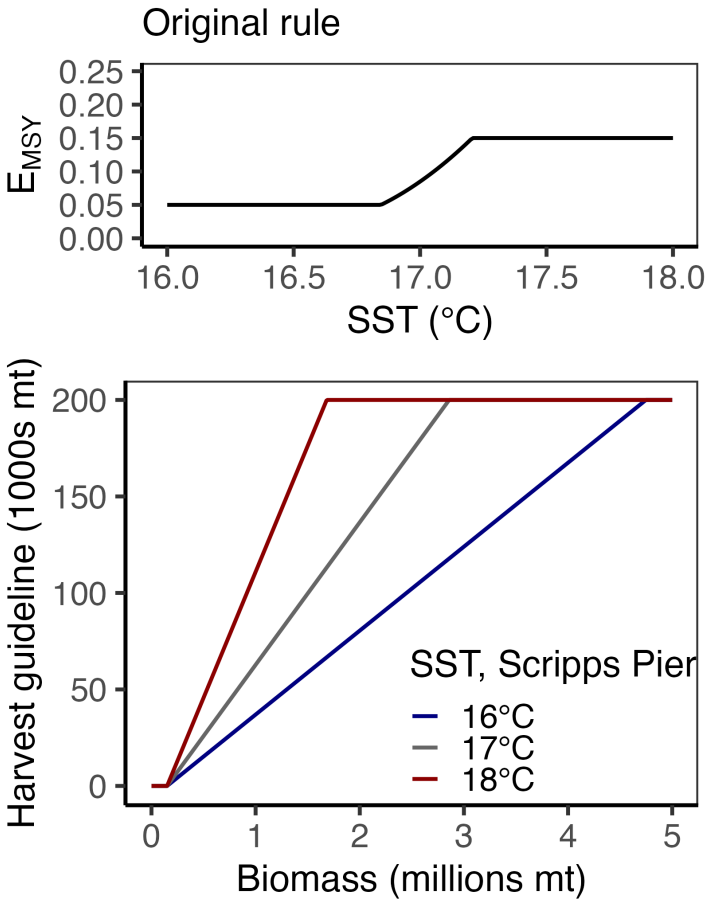

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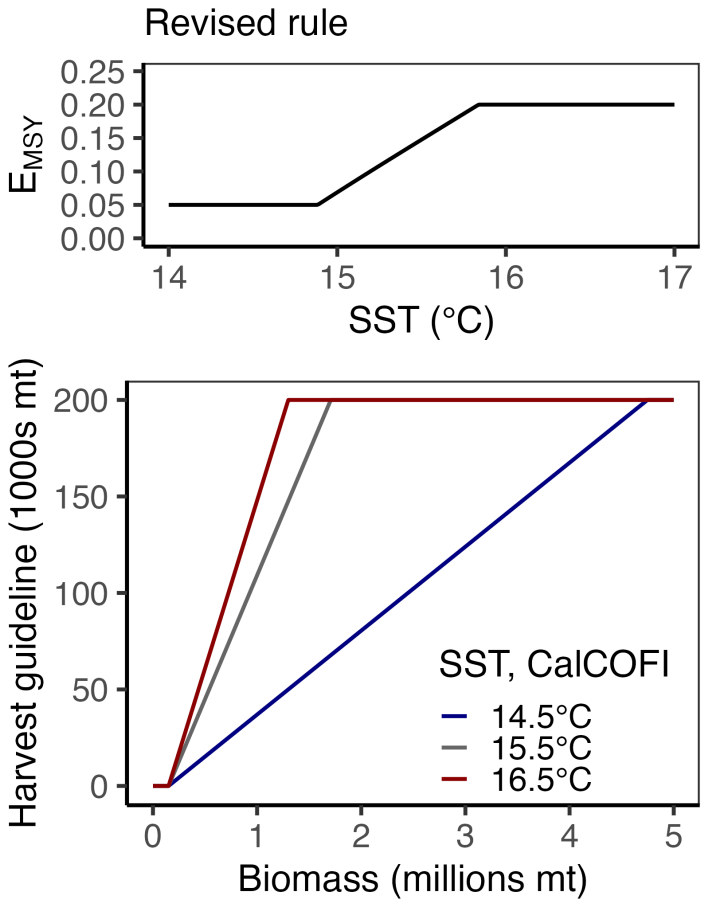
2014: Rule revised

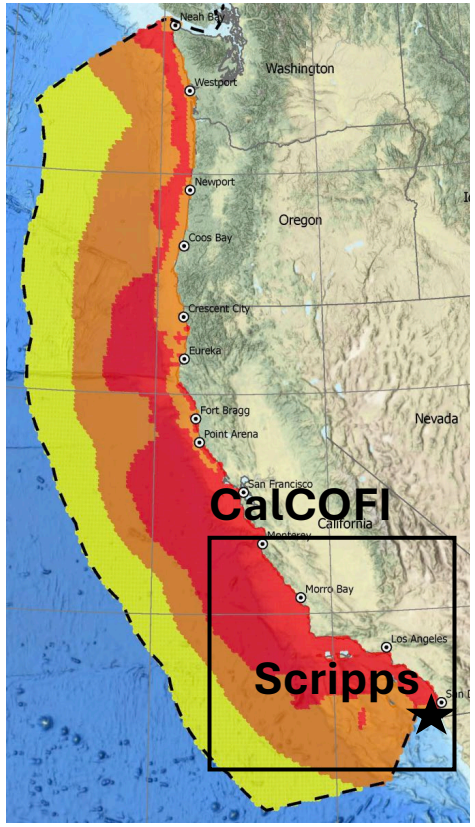


SST source: CalCOFI

E_{MSY} range: 5 - 20%

Hurtado-Ferro & Punt (2013)

Pacific sardine harvest control rule



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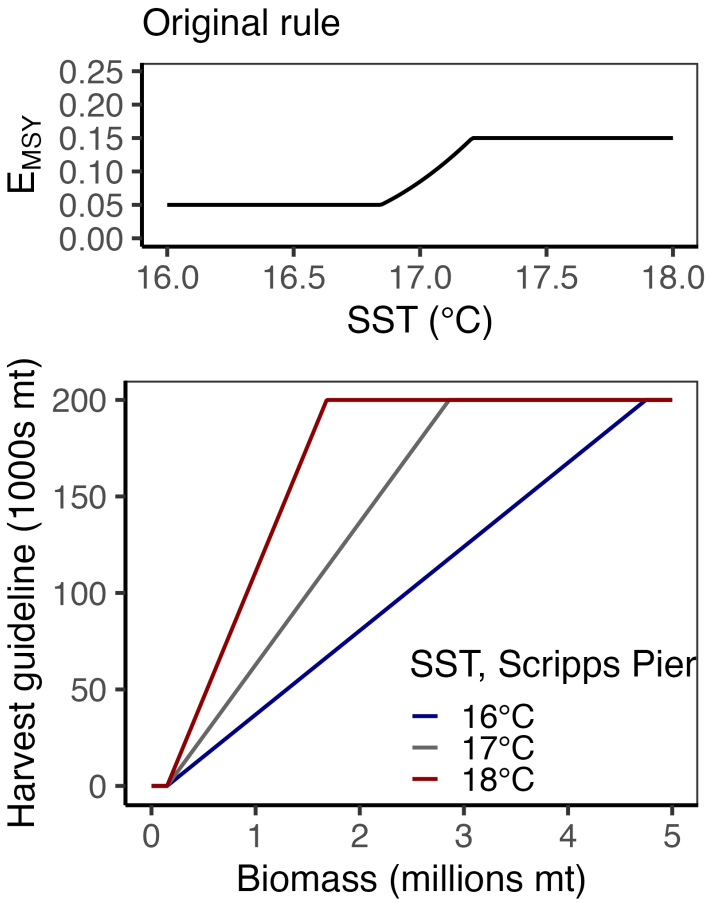

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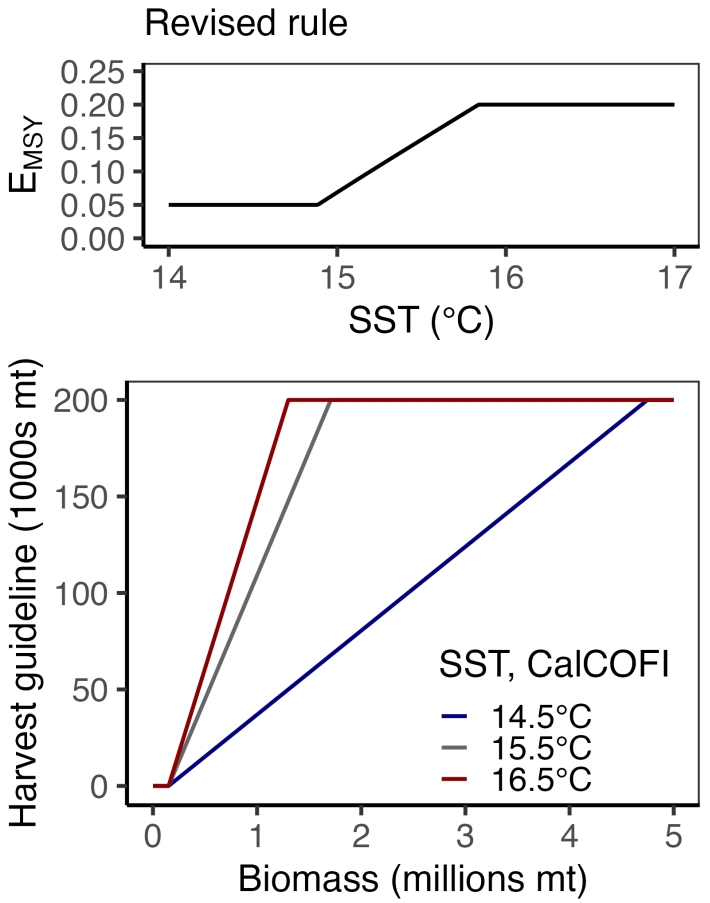


SST source: CalCOFI

E_{MSY} range: 5 - 20%

Hurtado-Ferro & Punt (2013)

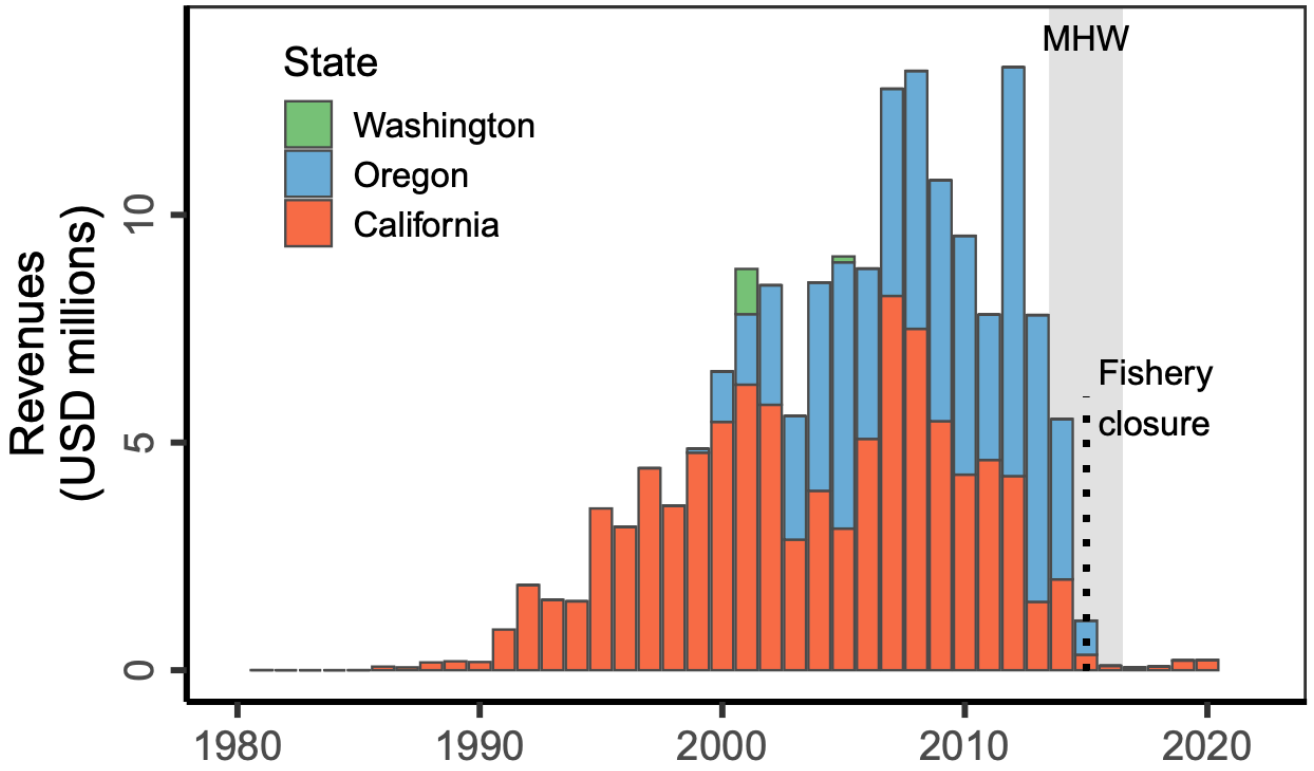
2025:
Revise again?

With new data (2005-2023), SST still matters, but the correlation has decreased

Akselrud et al. (2025)

Pacific sardine harvest control rule

Collapsed during heatwave,
despite benefits of warm water



"Many reviewed studies have found that modifying management strategies to include environmental factors does not improve the ability to achieve management goals much, if at all, and only if the manner in which these factors drive the system is well known."

Punt et al. (2014) *ICES JMS*

"The regime-based HCR slightly decreases yield and increases the probability of overfishing in non-regime-based systems."

Szuwalski & Punt (2013) *Fish & Fisheries*