NOAA FISHERIES
Northwest Fisheries Science Center

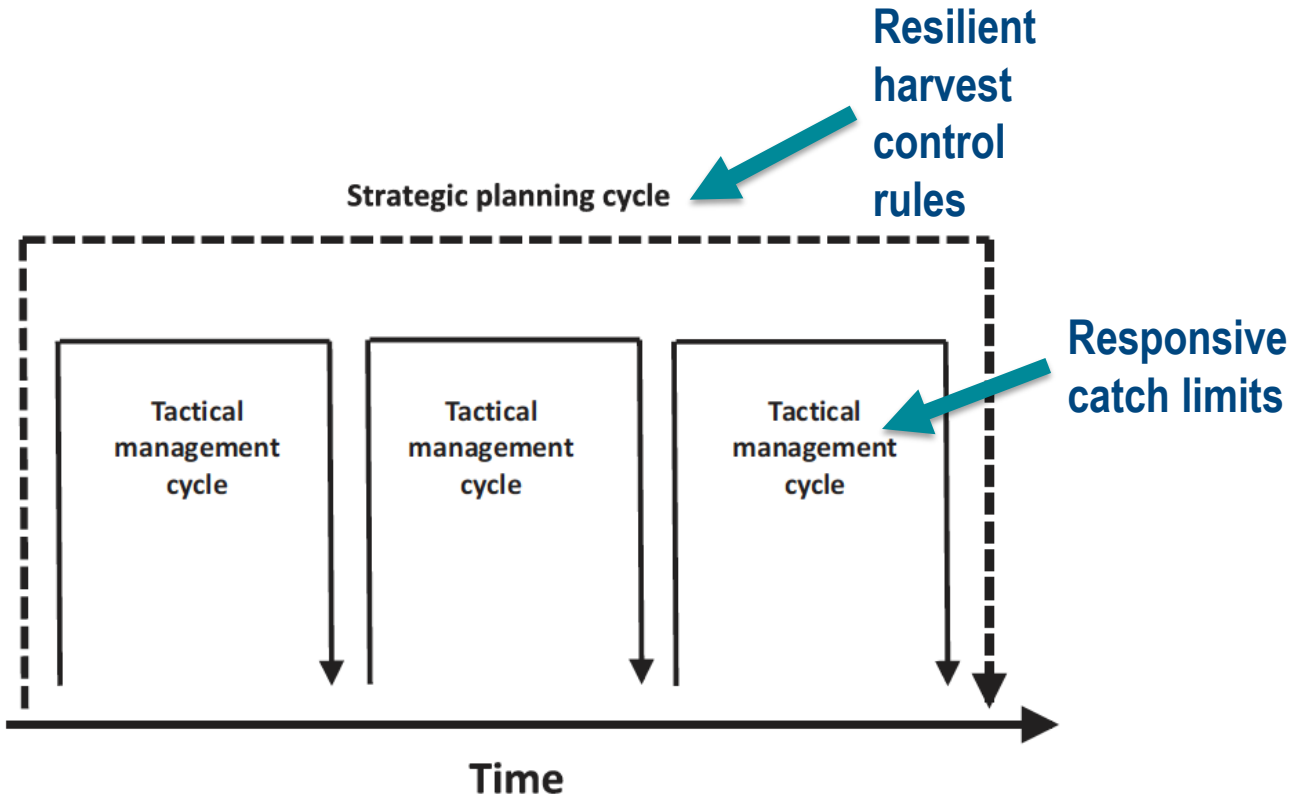
A multi-model approach to better understanding the robustness of management of Pacific hake to environmental variability

Kristin Marshall[1], Nis Jacobsen[1,2], Isaac Kaplan[1], Kirstin Holsman[3], and Grant Adams[4],

[1]Northwest Fisheries Science Center, [2]National Research Council
[3]Alaska Fisheries Science Center, [4]University of Washington

What is climate-robust fisheries management?

Resilient **OR** Responsive

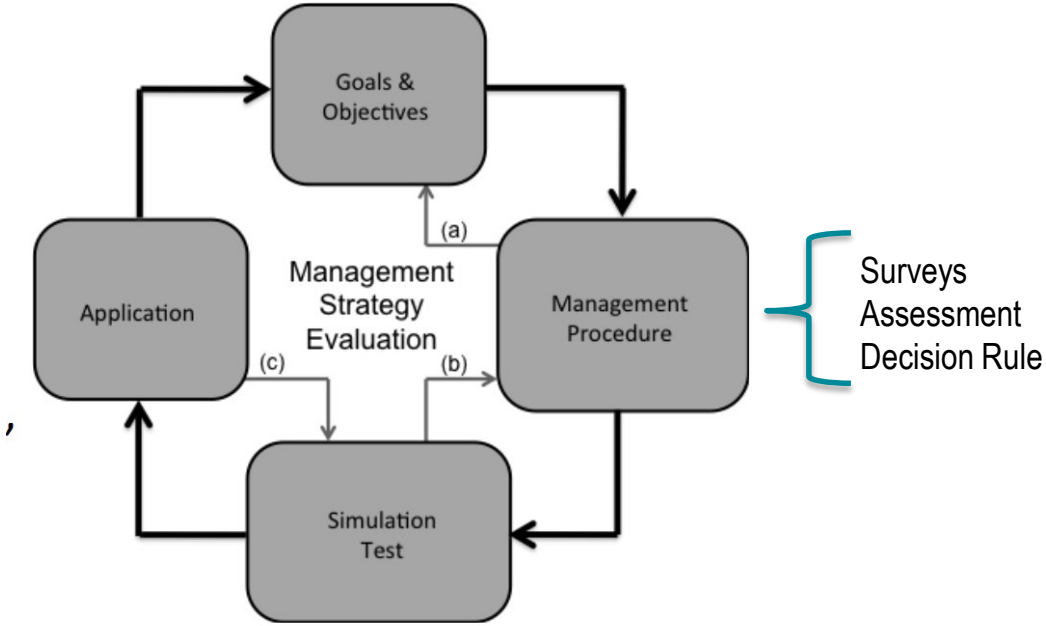


Benson et al. 2018 Fish and Fisheries

How do we know if we've achieved climate-robust management?

- Specify goals, objectives AND measure performance
- Test robustness to a wide range of uncertainties

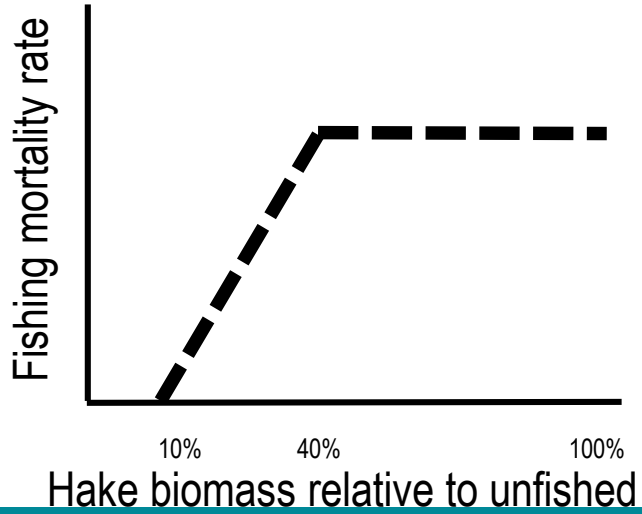
MSE as a collaborative, iterative process



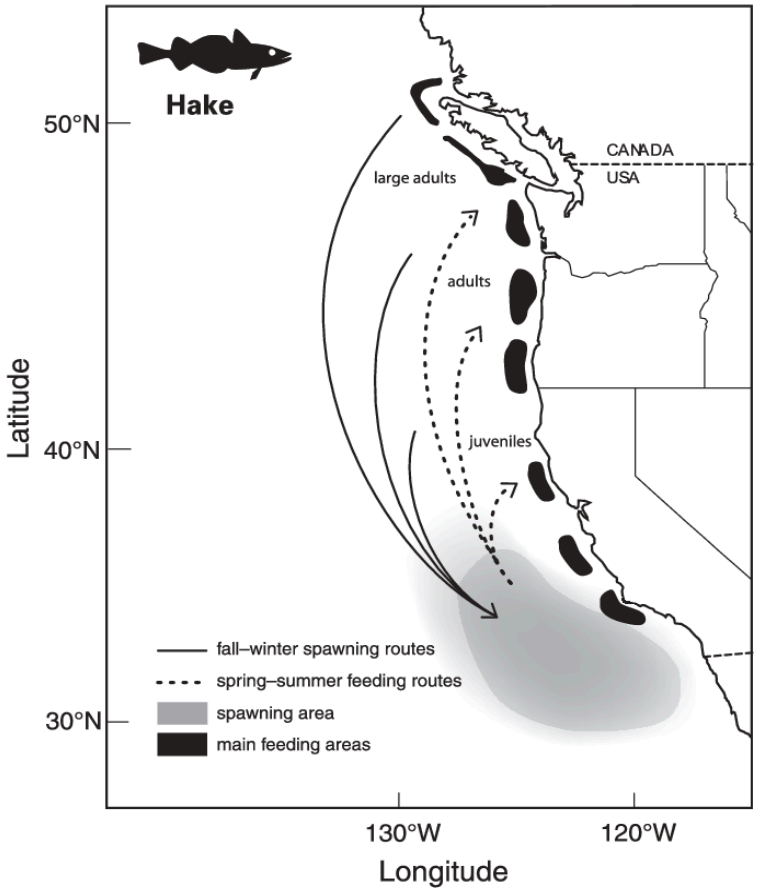
Pacific Hake Fishery and Management

West Coast US Groundfish Landings

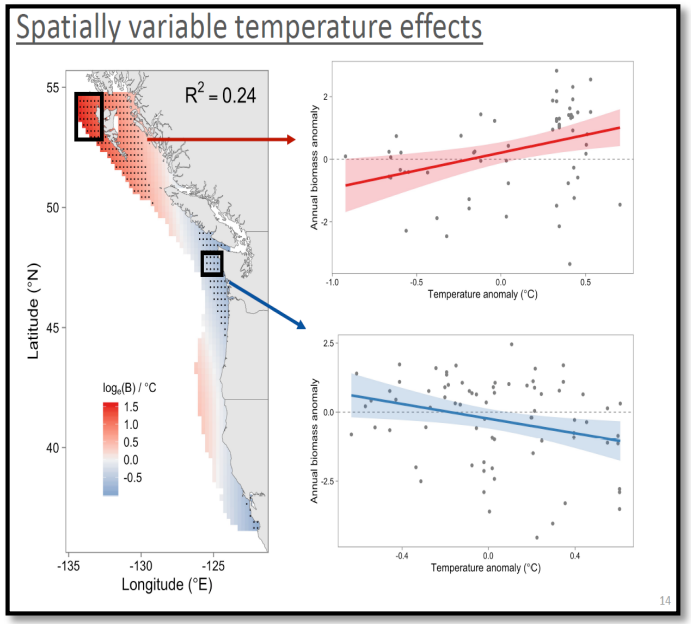
- International Pacific Whiting Treaty (2003)
- 74/26 percent of annual quota allocated to US/CA
- Harvest Control Rule F-SPR 40:10



More fish, younger fish, in US than Canada



Agostini et al. 2006



Malick et al. in review

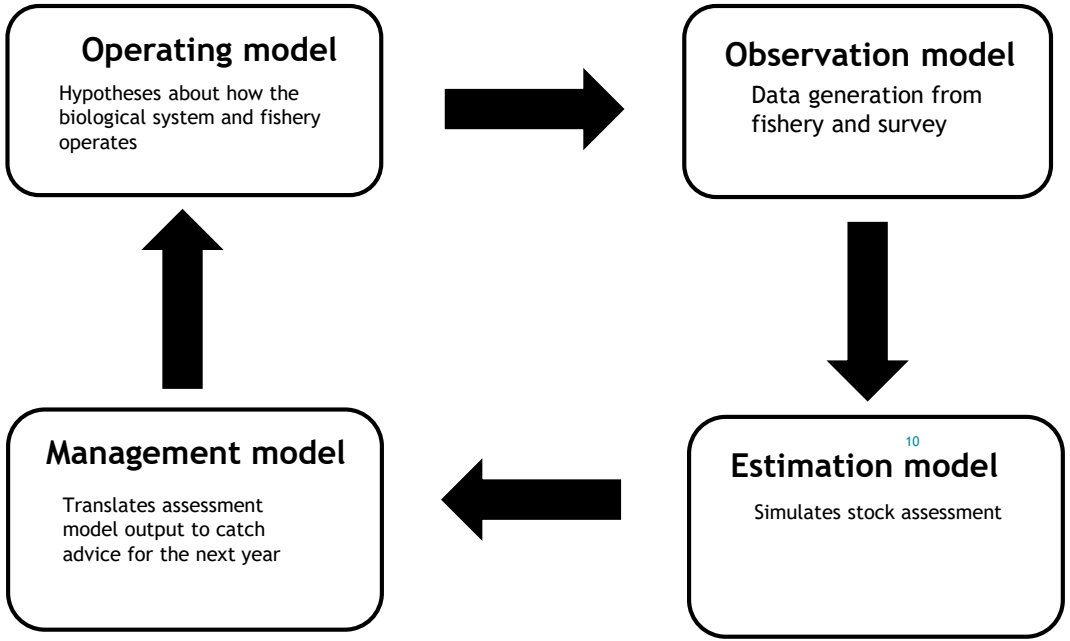
Co-created (managers, industry, and scientists) goals for this iteration of the Hake MSE:

- Evaluate the performance of current hake management procedures under alternative hypotheses about current and future environmental conditions
- Better understand the effects of hake distribution and movement on both countries' ability to catch fish
- Better understand how fishing in each country affects the availability of fish to the other country in future years

Tools for evaluating climate-robust management for hake

	Operating Model			Estimation Model	Management model
	Spatially explicit	Environ. drivers	Trophic dynamics		
Prev. Hake MSE model				X	X

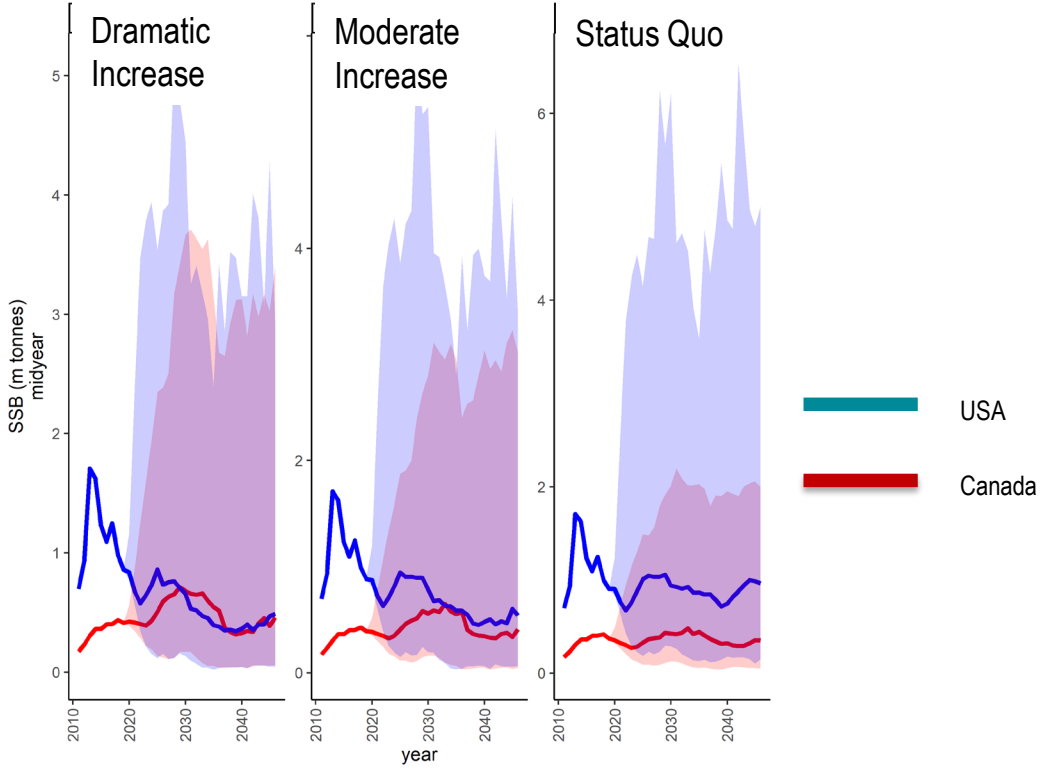
Generalized closed-loop simulation model for MSE



Climate change inspired movement scenarios

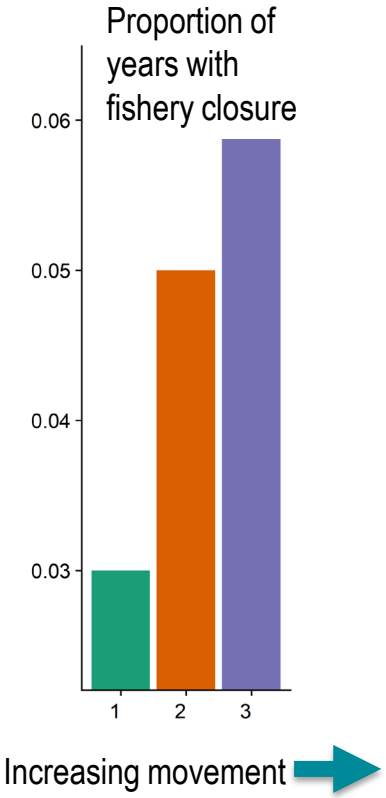
- Linearly increase the maximum movement rate over time
- Linearly decrease the proportion of fish returning to US to spawn
- Compare 3 scenarios – no change to movement, moderate increase in movement, and dramatic increase in movement

Spawning biomass distribution in the future



Jacobsen et al. in prep

Coastwide performance metrics



1) No climate change effect

2) Moderate increase in movement

3) Dramatic increase in movement

Jacobsen et al. in prep

Conclusions thus far

- Current management procedure shows sensitivity to dramatic changes in movement rate (relatively robust to small changes)

- If model-assumed movement rates occurred, status quo management would lead to lower total catch, higher variation in catch, and lower spawning biomass

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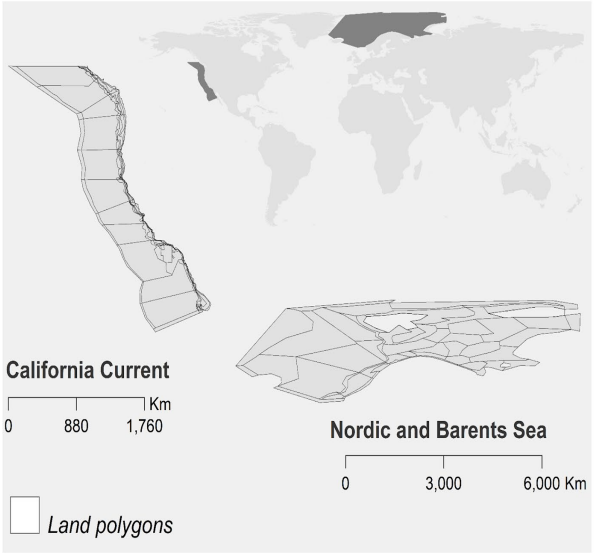
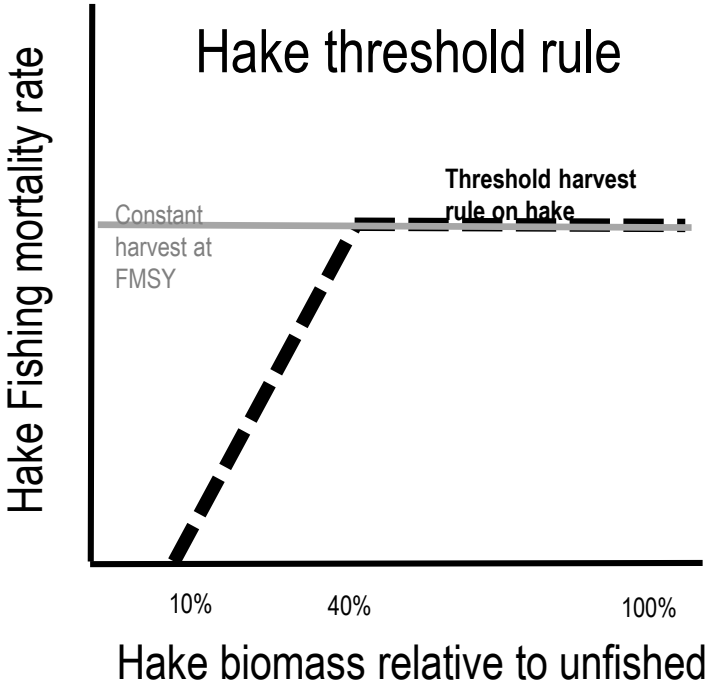
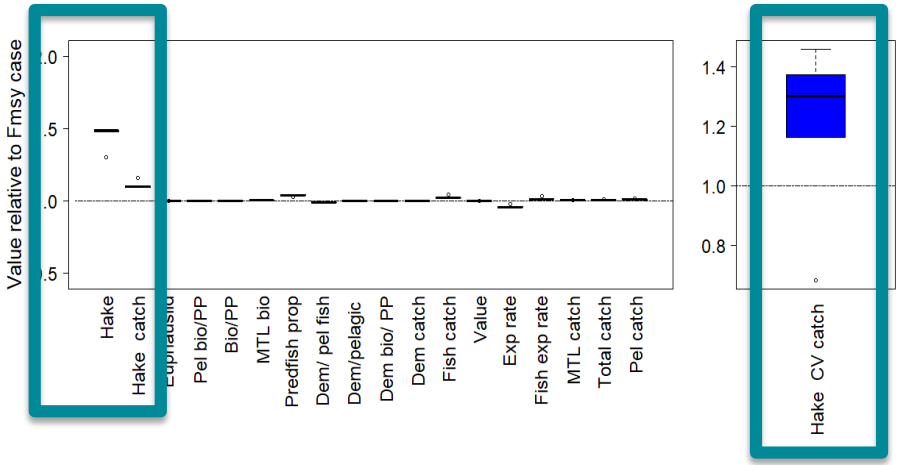
Prev. Hake MSE model				X	X
Current Hake MSE model	X	X		X	X

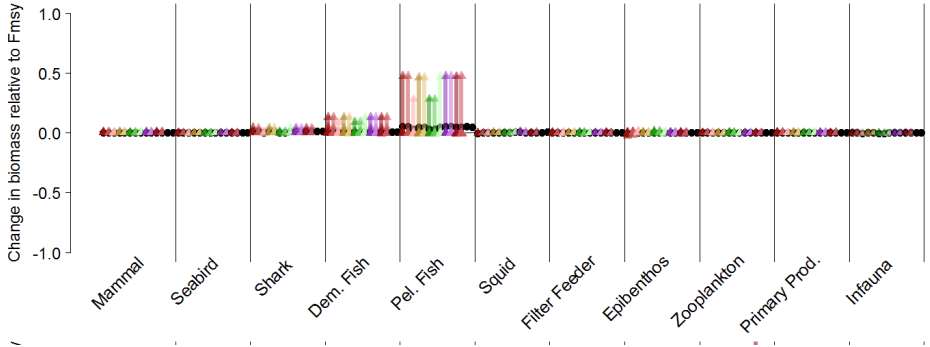
Ecosystem-Based Harvest Control Rules for Norwegian and US Ecosystems



Kaplan et al. in review







Kaplan et al. in review

Tools for evaluating climate-robust management for hake

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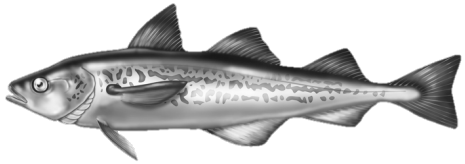
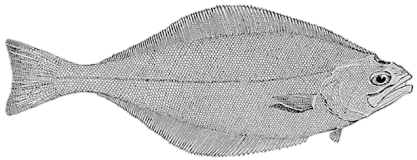
Previous MSE model				X	X
Current Hake MSE model	X	X		X	X
Atlantis ecosystem model	X	X	X	In progress	X

CEATTLE Multi-species model



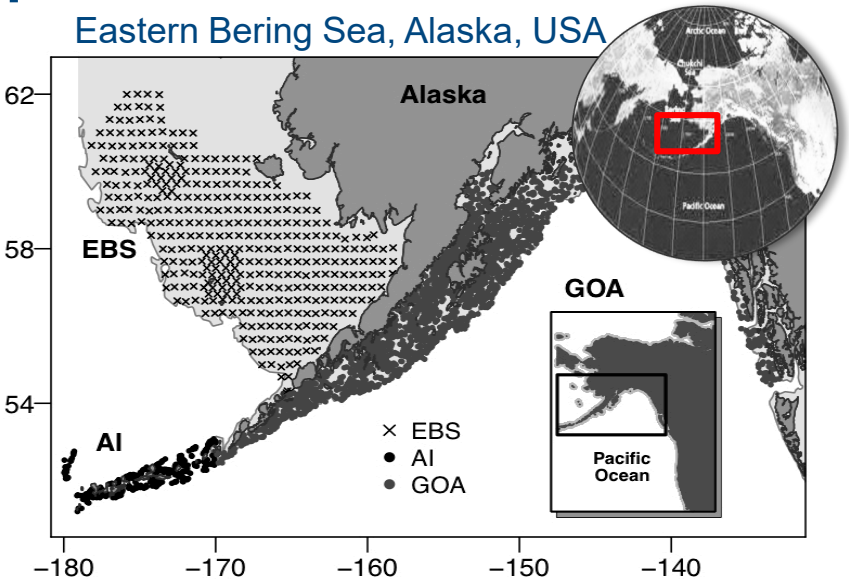
Walleye pollock
(*Gadus chalcogrammus*)



Arrowtooth flounder
(*Atheresthes stomias*)

Pacific cod
(*Gadus macrocephalus*)

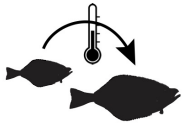
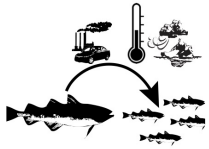
Eastern Bering Sea, Alaska, USA



W@Age~*f*(Temperature)
Pred/prey~*f*(Temperature)

Climate-Enhanced, Age-based model with Temperature-specific Trophic Linkages and Energetics Holsman et al.

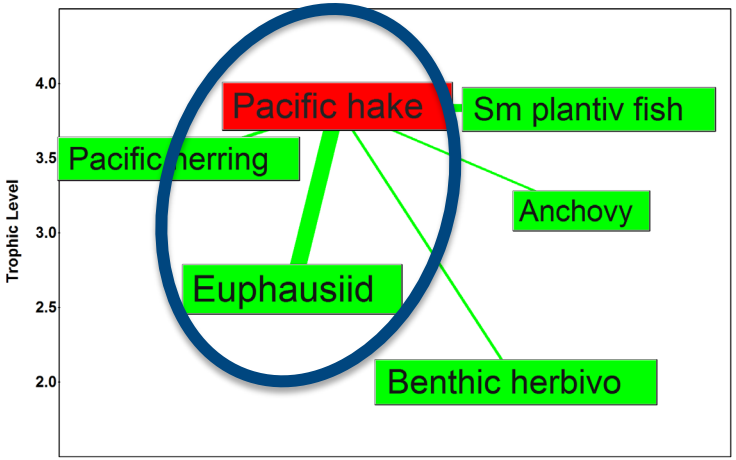
CEATTLE-EBS: Options

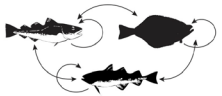
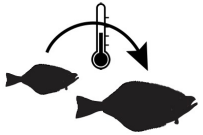
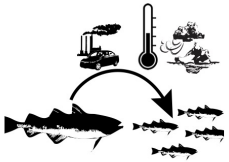
Mortality	Weight @ Age	Rec	HCRs
			
• Empirical diets • Bioenergetics	• Empirical • VonB with Temp	• Climate-S/R • S/R • mean R	• Climate ABC • MMSY • MEY • SPR • Aggregate MSY

https://github.com/grantdadams/Rceattle

Holsman et al.

Potential for CEATTLE-Hake as operating model



Mortality	Weight @ Age	Rec
		
• Empirical diets • Bioenergetics	VonB with Temp	• Climate-S/R • S/R

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Previous MSE model				X	X
Current Hake MSE model	X	X		X	X
Atlantis ecosystem model	X	X	X	In progress	X
CEATTLE-Hake		X	X	X	X

Is current management strategy for Pacific hake climate-ready?

- Testing robustness of current management to dramatic changes in environment is a first step
- Single-species spatial model suggests some resilience
- Testing robustness to a wider range of uncertainties is underway

Thank you!

kristin.marshall@noaa.gov