Bridging the gap between mechanistic understanding and climate projections: an example based on the Bering Sea project

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Alaska Fisheries Science Center

Seattle, WA

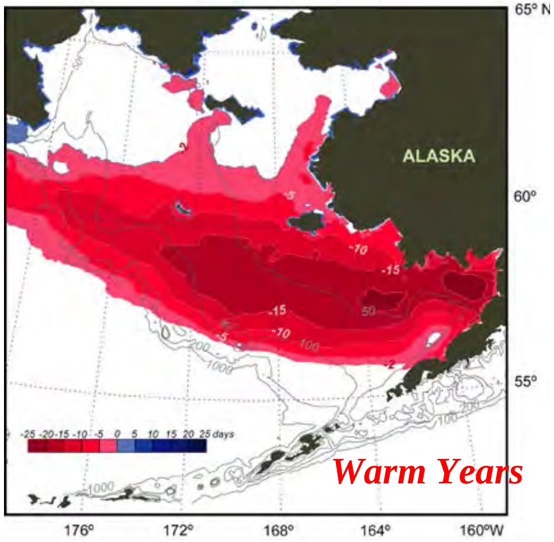
Anne Hollowed, Kirstin Holsman, Alan Haynie, Kerim Aydin, Steve Barbeaux, Wei Cheng, Janet Duffy-Anderson, Amanda Faig, Robert Foy, Al Hermann, Jim Ianelli, Stephen Kasperski, Jon Reum Phyllis Stabeno, Cody Szuwalski

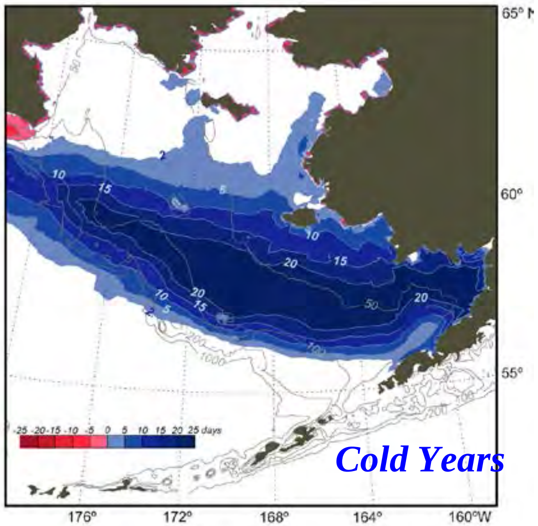
Case Study for the Bering Sea

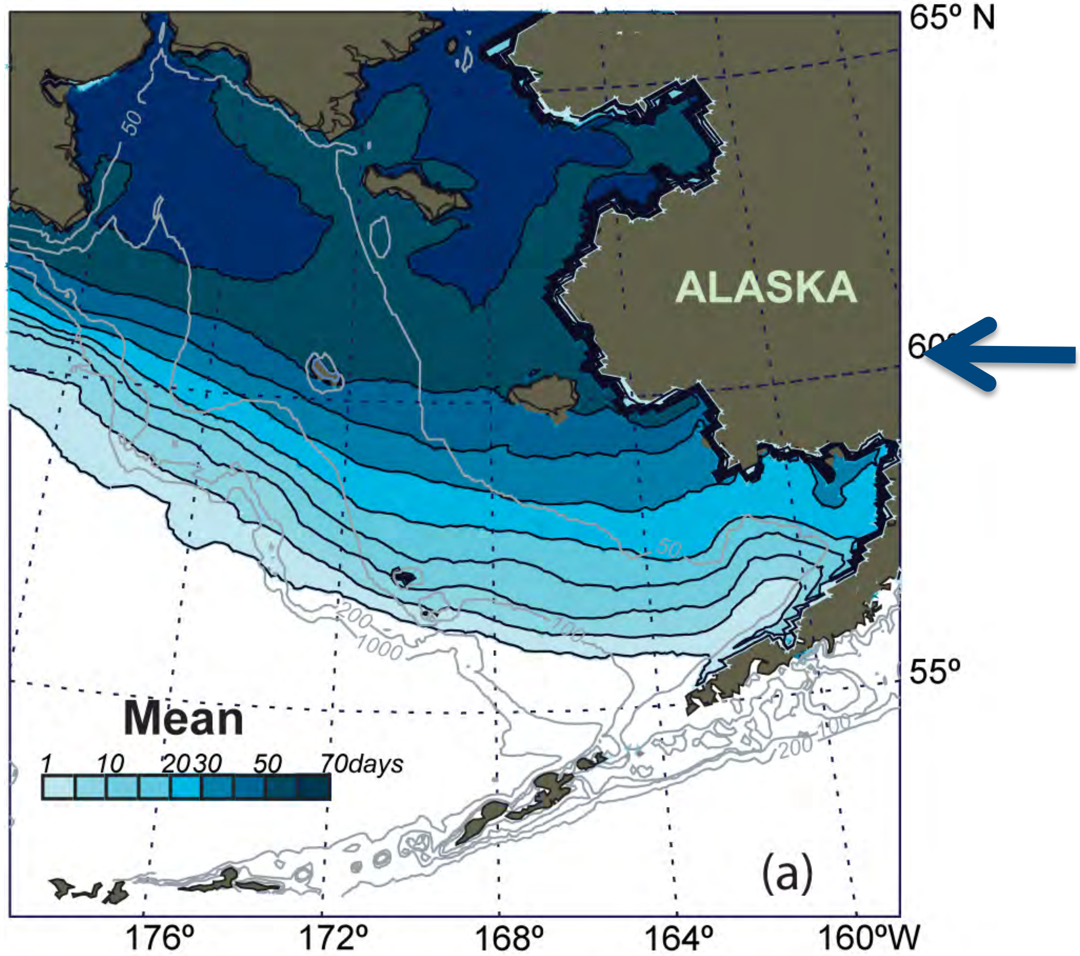
Interdisciplinary, Integrated, Over 90 PIs

Mean number of days of ice cover March –April

Stabeno et al. 2012, Deep-Sea Research II







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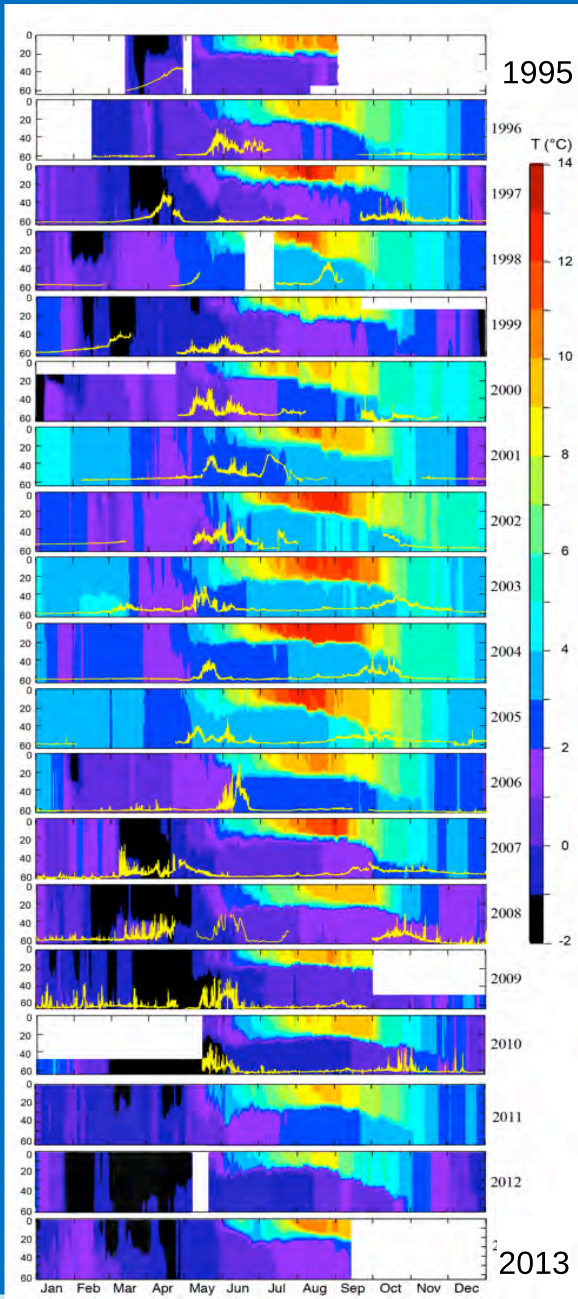
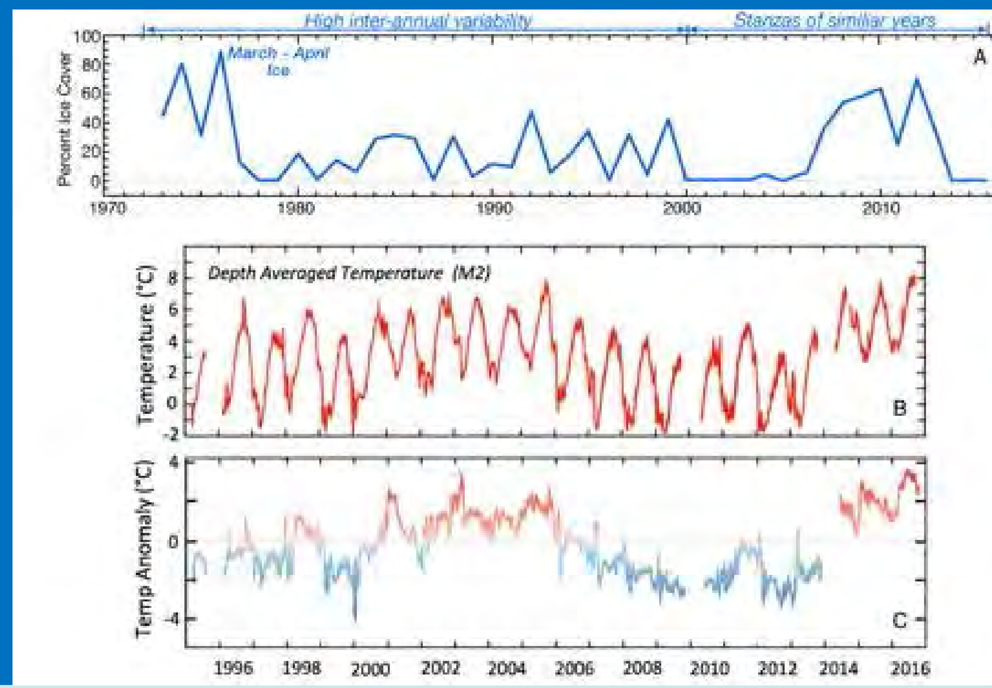


Temperature and Sea Ice at M2

Measurements on M2:
currents, temperature, salinity, O_2, fluorescence, pCO_2, nitrate, sound, zooplankton biovolume, and
summer met package



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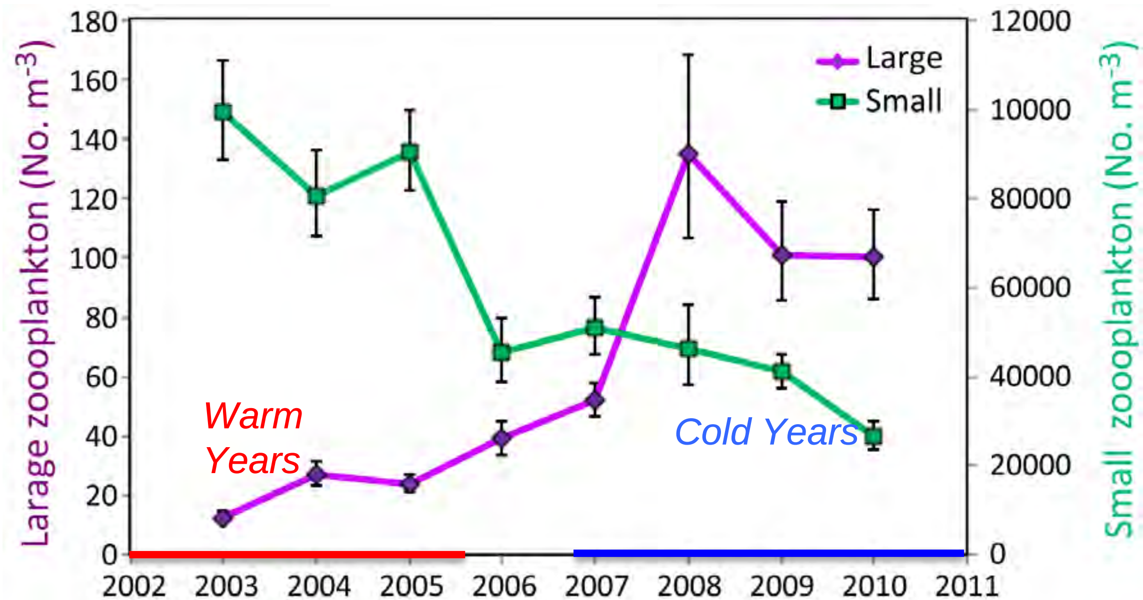
Stabeno et al., 2017

Change in abundance of large zooplankton

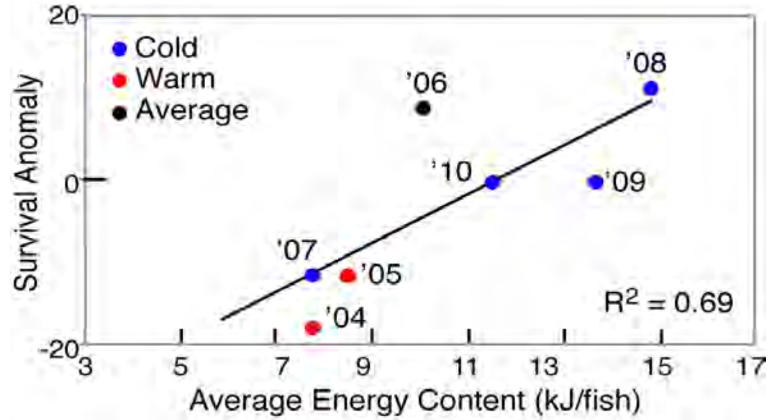


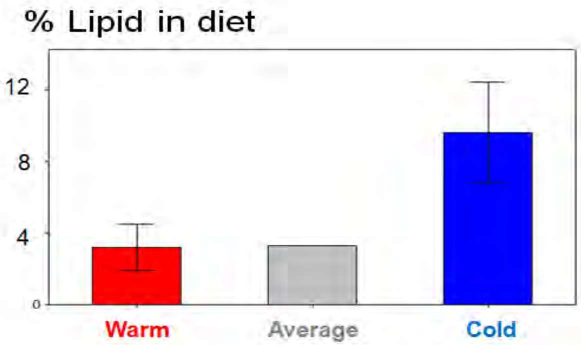
Cold years increased abundance of large zooplankton and successive warm years reduced numbers of zooplankton

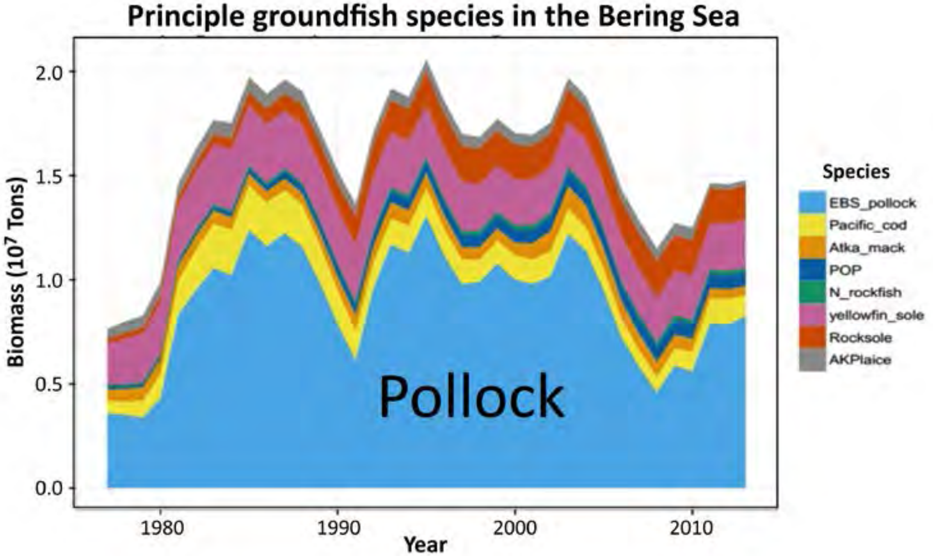
Eisner et al., 2014

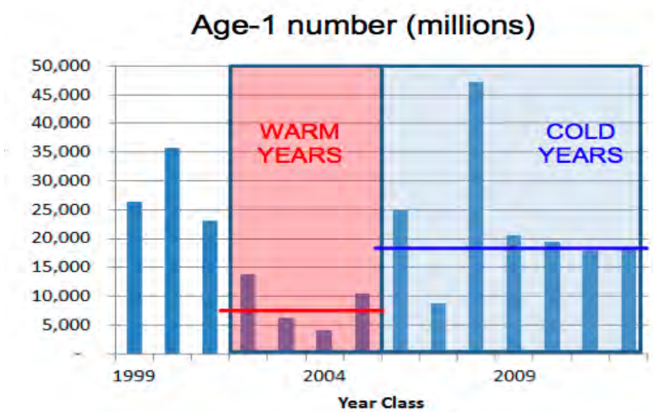
Change in survival of young-of-the-year pollock

As a consequence, age-0 pollock consume richer diets in cold years, better preparing them for their first winter and enhancing survivorship.



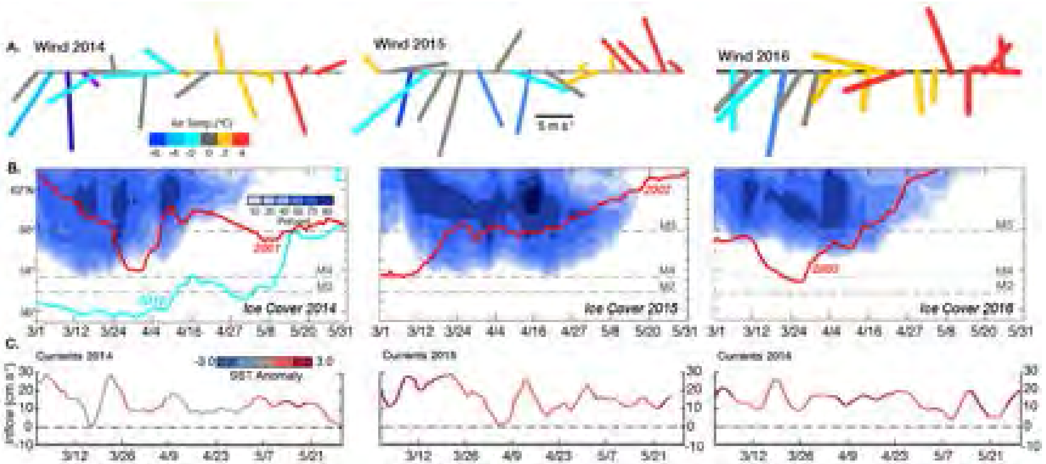


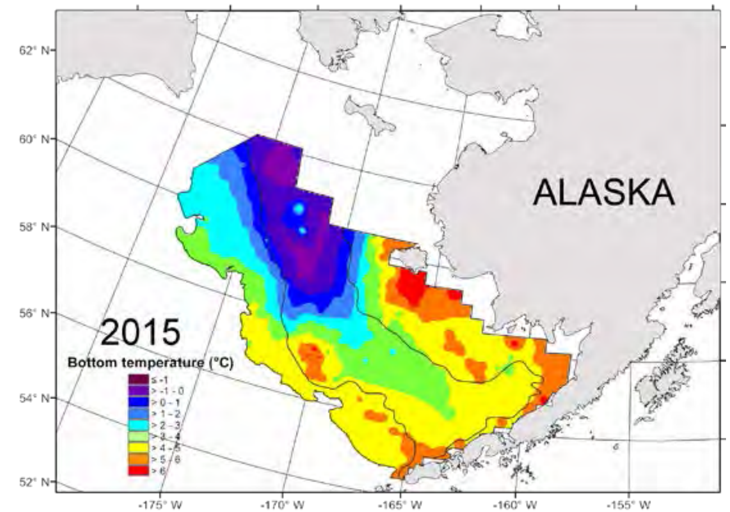


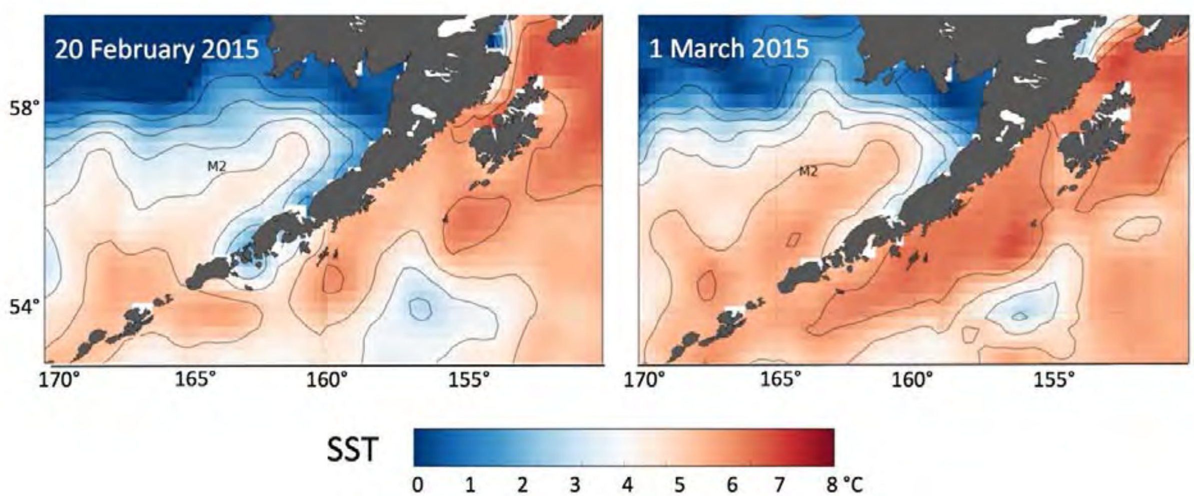


Heintz et al. 2013, DSR II

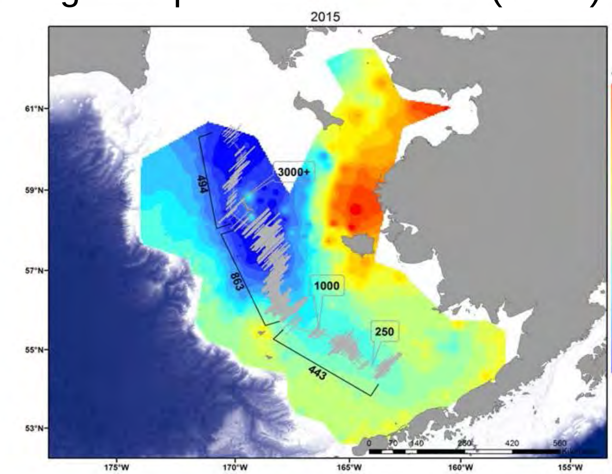
Unexpected finding: Young pollock survival better than expected during 2014-2016 warm phase (Recruitment Processes Alliance)







Age – 0 pollock distribution (silver)



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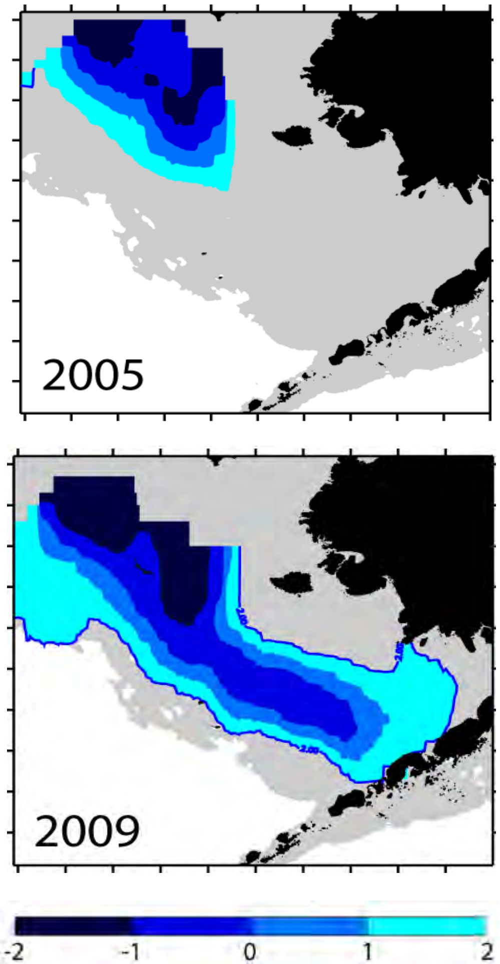
https://www.afsc.noaa.gov/News/BeringSea_warming.htm

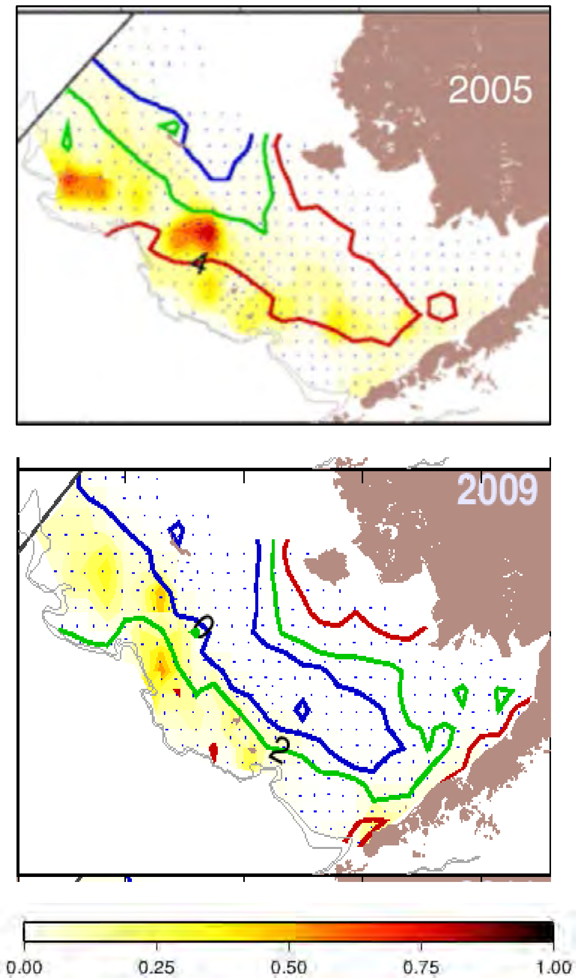
Cold pool and its influence on juvenile and adult pollock

Warm (2005)

Cold (2009)



Bottom Temperature (°C)



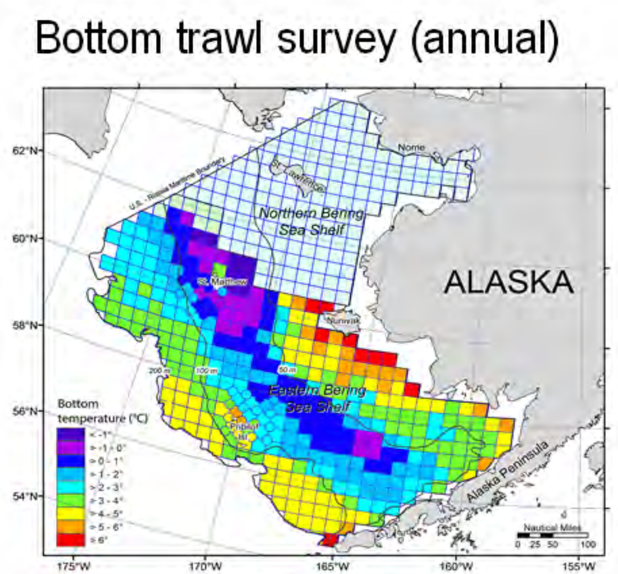
Relative Abundance of pollock

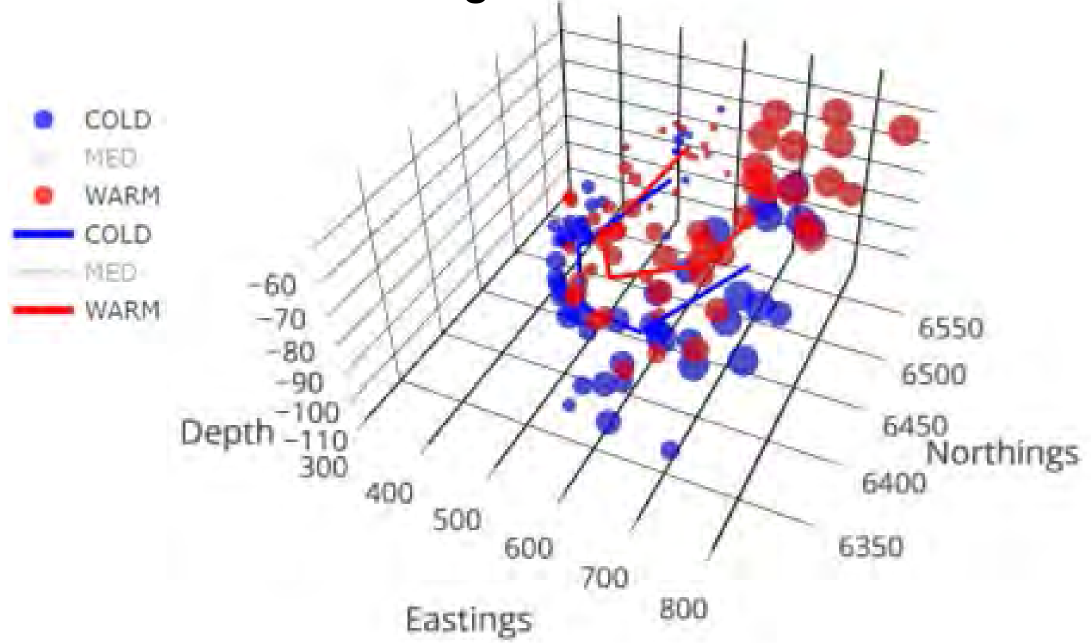
Differences in the extent of the cold pool and relative abundance of pollock in warm and cold years.

Kotwicki et al. 2013, Deep-Sea Research II

Juvenile and adult spatial shifts

Pollock distributed differently by size and in warm and cold years Barbeaux and Hollowed (In Press) Fish. Oceanogr.





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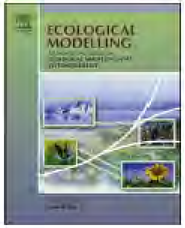
journal homepage: www.elsevier.com/locate/ecolmodel



Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay

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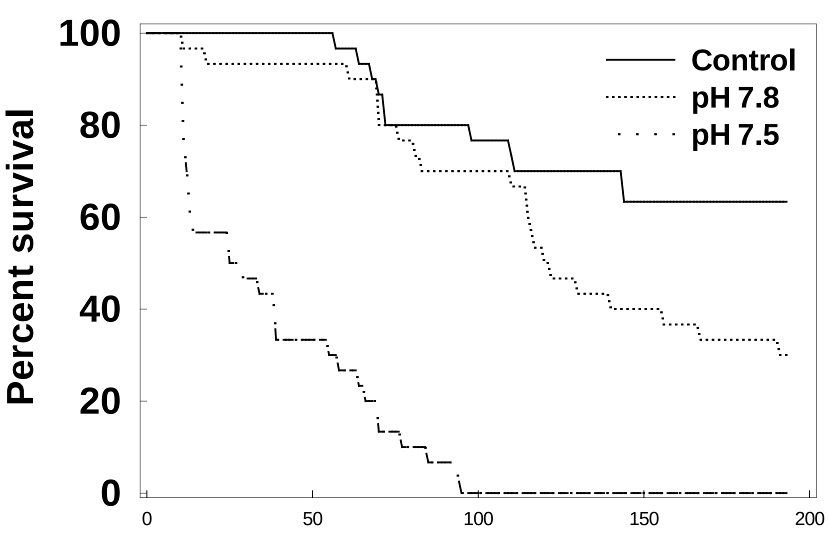
[b] Alaska Fisheries Science Center, 7600 Sand Way Point Way, NE, Seattle, WA 98115, United States
[c] Alaska Fisheries Science Center, Kodiak Laboratory, 301 Research Ct, Kodiak, AK 99615, United States



Extensions to Snow Crab

R. Foy Kodiak

The ACLIM team


Anne Hollowed

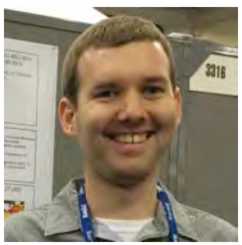

Kirstin Holsman


Alan Haynie


Albert Hermann


Wei Cheng


Andre Punt


Darren Pilcher


Kerim Aydin


Jim Ianelli


Ingrid Spies

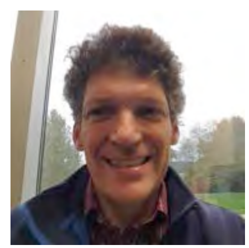

Stephen Kasperski


Cody Szuwalski


Amanda Faig


Jonathan Reum

Michael Dalton


Paul Spencer

Tom Wilderbuer

William Stockhausen

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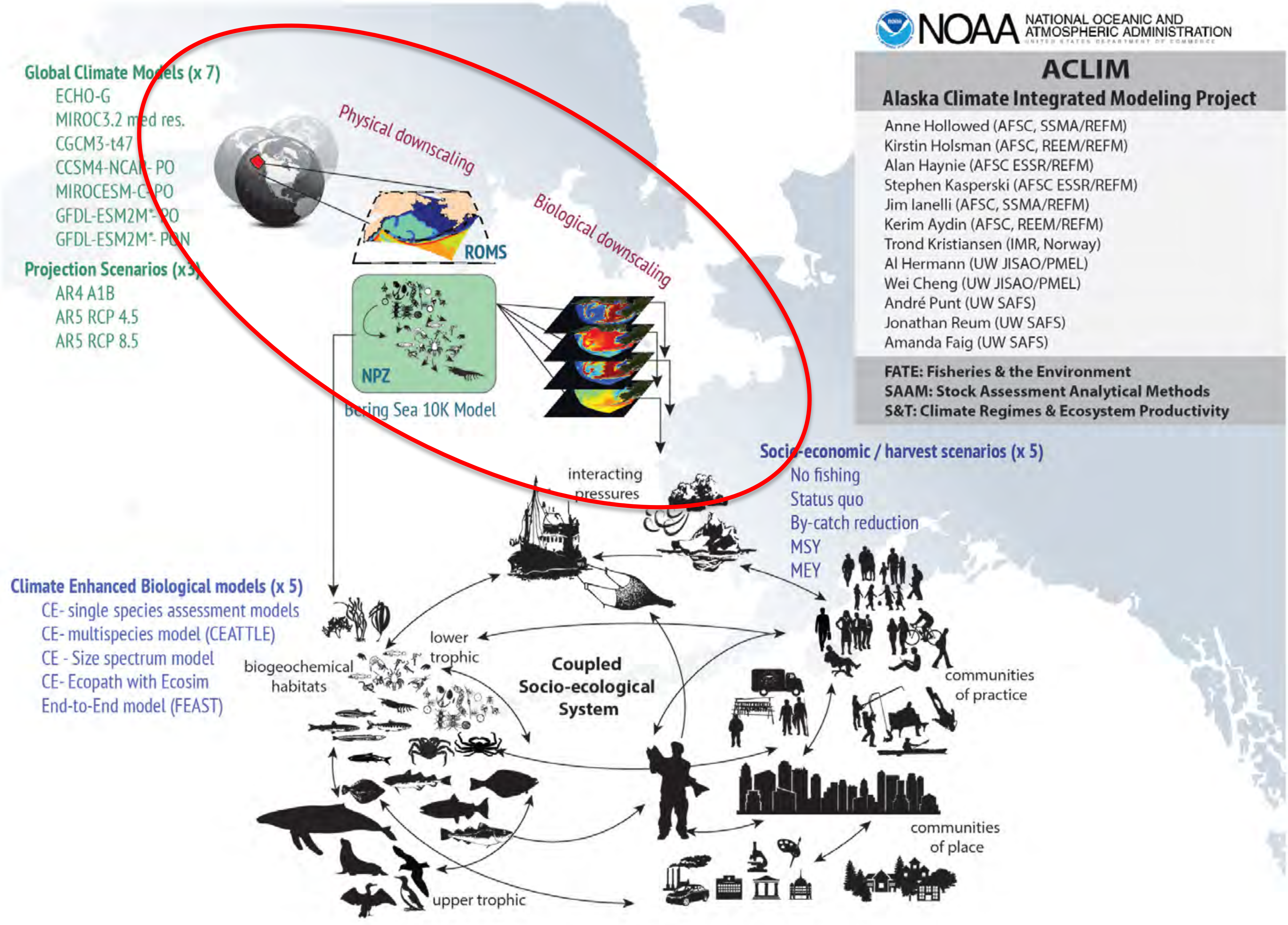
FUNDED BY FATE, SAAM, NPCREP, RTAP

Mapping the uncertainty landscape

Type	Scenario	Parameter	Model
Global Model	RCP 4.5, 8.5		GFDL-CM, CCSM, MIROC
Regional ocean model	RCP 4.5, 8.5	Retrospective performance	Bering-10K with NPZ with and without nutrients as boundary condition
Biological model	Variety of functional linkages to environmental change.	CESM & CEMSM includes MCMC resampling of parameter uncertainty; Ecosystem models explore parameter sensitivity	CESM, Spatial CESM, CEMSM, spatial CEMSM, ECOSIM, Size Spectral, FEAST
Socio-economic model	Identify range of possible management or industry responses		

CESM – Climate enhanced Single species model; CEMSM – Climate enhanced multi-species model; FEAST – Forage Euphausiid Abundance in Space and Time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UNITED STATES DEPARTMENT OF COMMERCE
ACLIM
Alaska Climate Integrated Modeling Project
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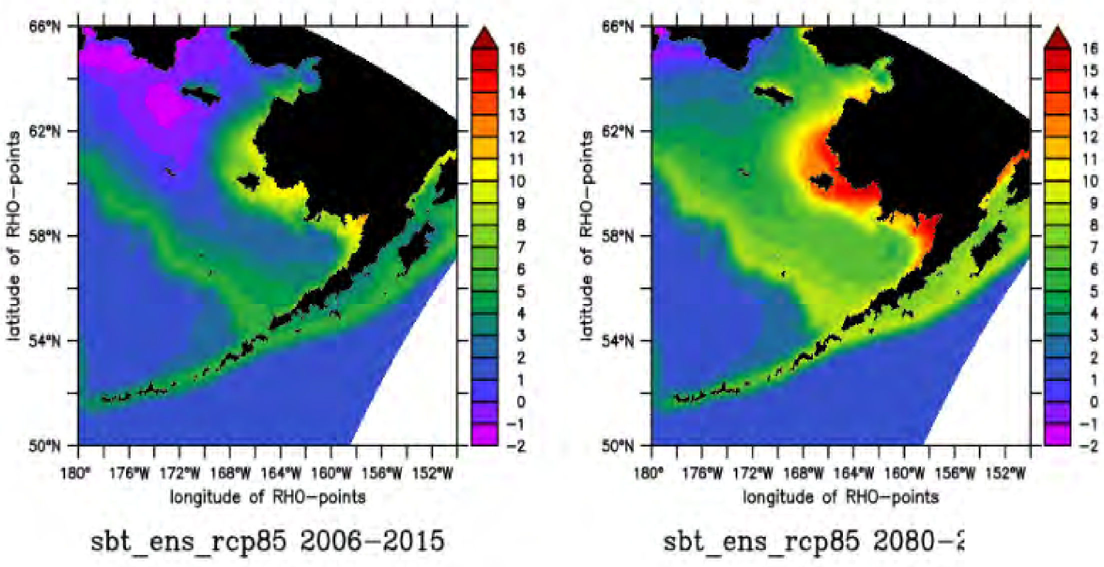
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity
Global Climate Models (x 7)
ECHO-G
MIROC3.2 med res.
CGCM3-t47
CCSM4-NCAR- PO
MIROCESM-C- PO
GFDL-ESM2M*- PO
GFDL-ESM2M*- PON
Projection Scenarios (x3)
AR4 A1B
AR5 RCP 4.5
AR5 RCP 8.5
Physical downscaling
ROMS
Biological downscaling
NPZ
Bering Sea 10K Model
interacting pressures
Socio-economic / harvest scenarios (x 5)
No fishing
Status quo
By-catch reduction
MSY
MEY
Climate Enhanced Biological models (x 5)
CE- single species assessment models
CE- multispecies model (CEATTLE)
CE - Size spectrum model
CE- Ecopath with Ecosim
End-to-End model (FEAST)
biogeochemical habitats
lower trophic
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

Environmental scenarios used to project future change

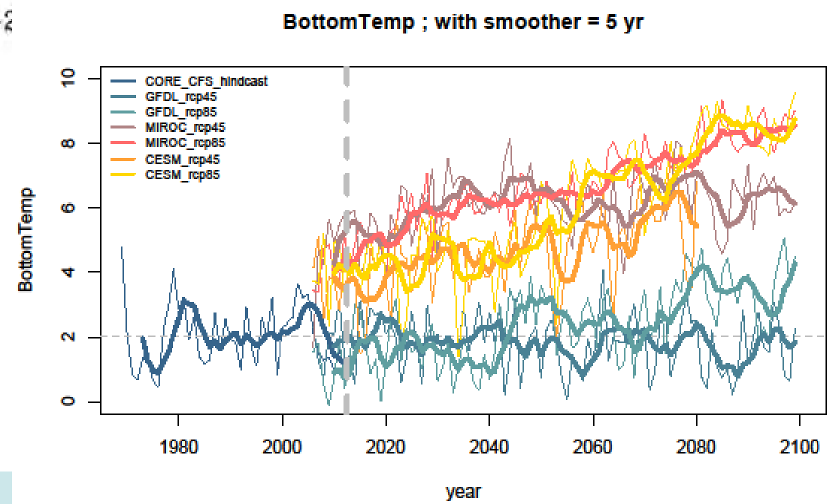
2006-2015

2080-2089



20 + environmental variables stored at daily time step

Bottom Temperature ºC Ensemble RCP 8.5



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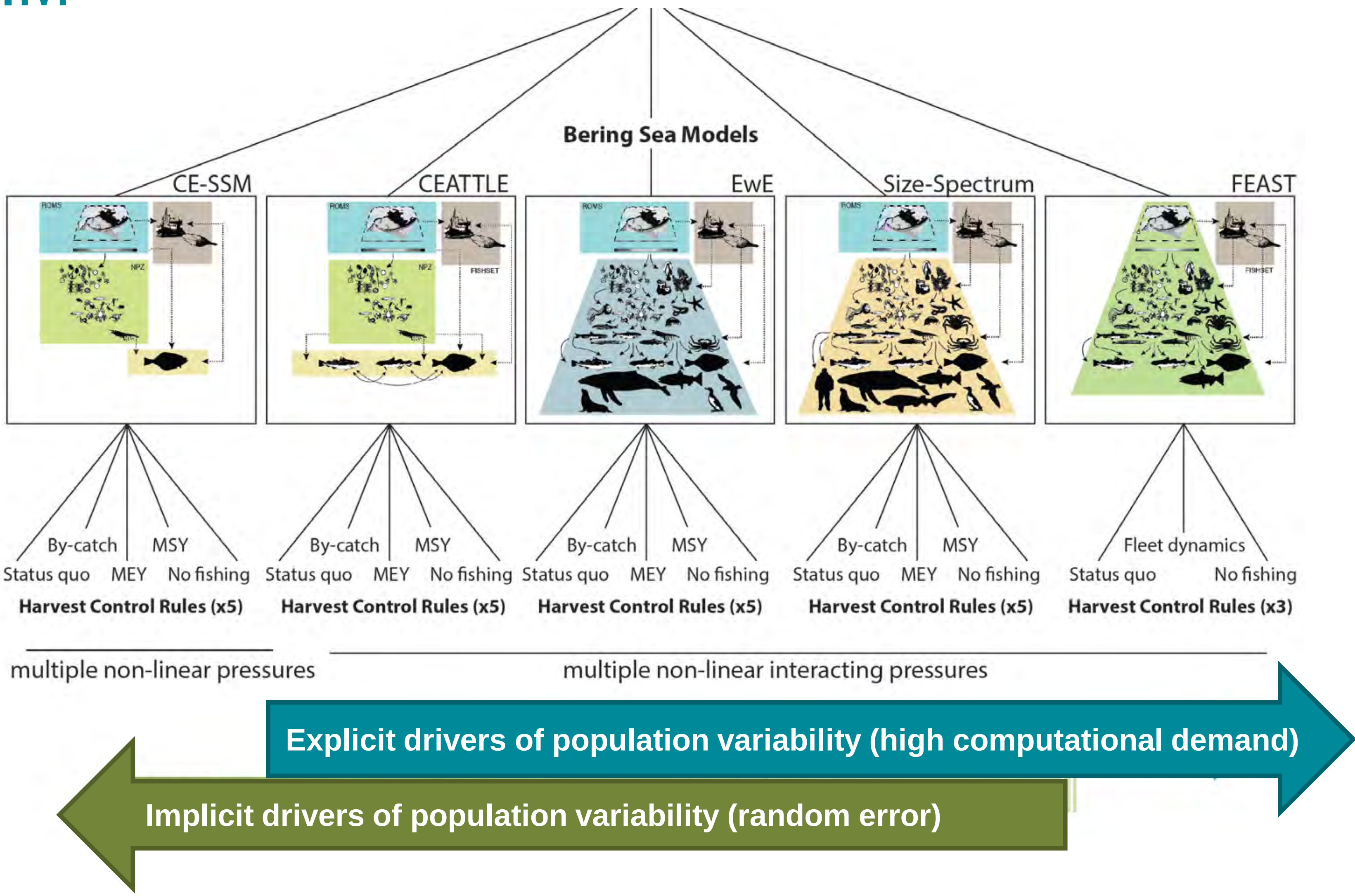
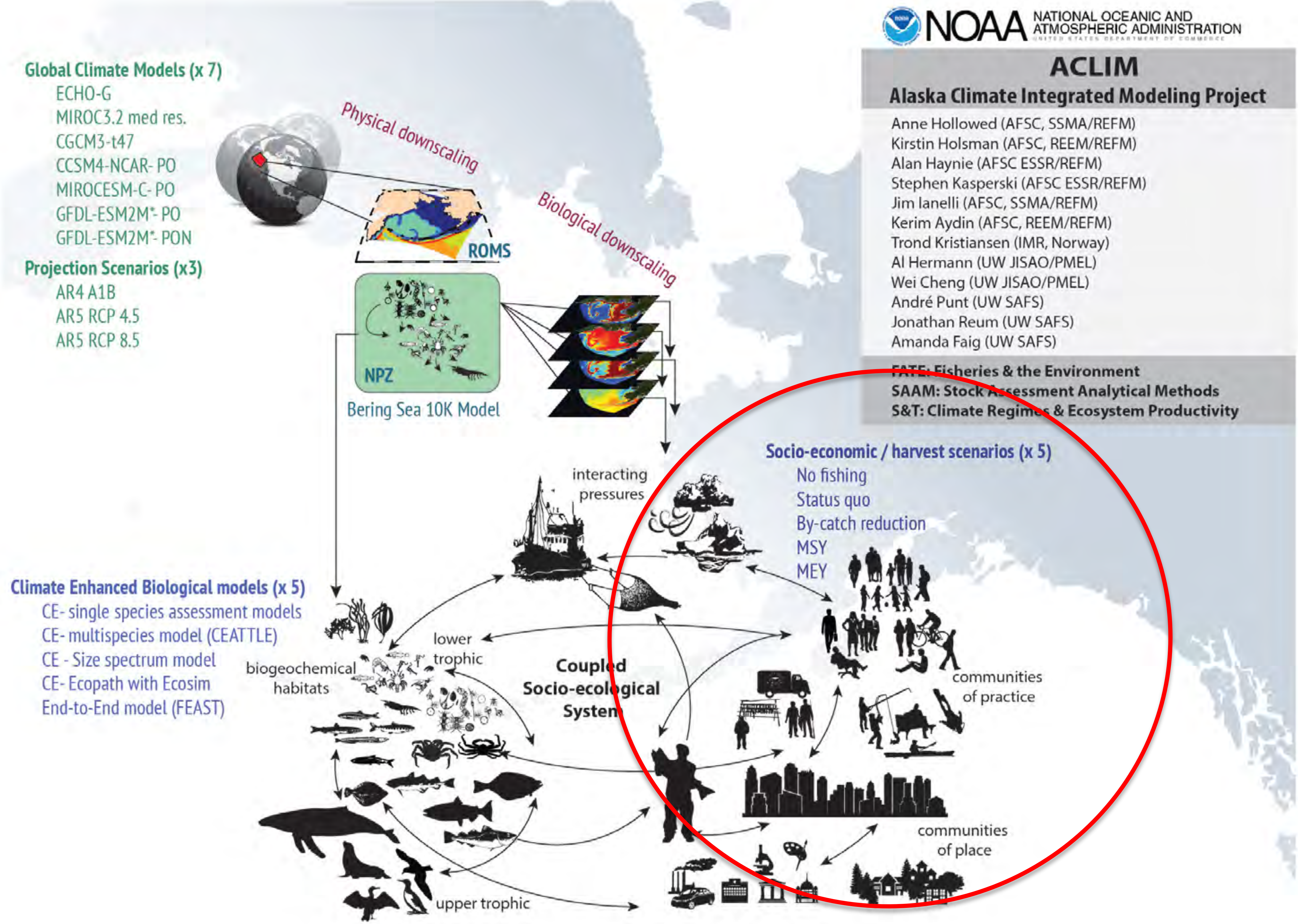

Bering Sea Models
CE-SSM
CEATTLE
EwE
Size-Spectrum
FEAST
By-catch
MSY
Status quo
MEY
No fishing
Harvest Control Rules (x5)
Fleet dynamics
Harvest Control Rules (x3)
multiple non-linear pressures
multiple non-linear interacting pressures
Explicit drivers of population variability (high computational demand)
Implicit drivers of population variability (random error)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biogeochemical habitats
lower trophic
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic

Fishery Mechanisms	Why this might increase	Why this might decrease
Fish prices	Driven by consumer demand, income and/or scarcity	Driven by fishing and aquaculture demand or smaller populations of valuable species
Change in relative price of premium fish	Concentrated wealth interacting with scarcity (e.g., high prices for halibut)	Increased value of protein for humans or input to aquaculture
Number of species fished	Markets may develop	Environmental change may lead to the decline of some species
Fishing and processing costs	Increased fuel costs or carbon tax. Land or labor costs may increase.	Improved or more selective fishing or processing technology
Priority on conservation values or other uses of resources	Change in demand or strength of conservation measures	Change in weak stock policies; change in the Endangered Species Act
Increase in protection for fishing communities	Additional concern about preserving the distribution of fishing opportunities	Less interest or ability by inhabitants to live in remote, resource-based areas; more large fishing vessels.
Revenue volatility	If species are unable to adapt to changing climate; global economic factors	Better management or long-term investment strategies; global economic factors

Type of Change
Fish prices
Change in relative price of premium fish
Number of species fished
Fishing and processing costs
Priority on conservation values or other uses of resources
Increase in protection for fishing communities
Revenue volatility

Can we simplify this further?

- Net Trip Revenue
- Skill in selective harvesting
- Flexibility of fishing opportunities
- Revenue volatility

Management Tools & MSEs

- Revised harvest control rules
- New technology
- Catch shares
- Dynamic area closures
- Bycatch changes
- Price changes
- Others tools to be invented in the future

Conclusions

- Regional climate change projections have are being used to inform management.
- Scenarios rely on data rich history of bio-physical process studies.
- Surprises happened, necessitating continued monitoring.
- ACLIM attempting to address the uncertainty landscape using a multi-model approach.

Next Steps

- October Council Meeting / Workshop
- Continued model integration
- January Science Workshop

Acknowledgements

BEST–BSIERP Bering Sea Project

bsierp.nprb.org

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and all of the Bering Sea Project PIs

Especially

Modeling Component Group:
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