Developing a workplan for the FEP Climate Change Module

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FEP Meeting, Seattle WA
May 7, 2019

Mark Holsman

Today

- Intro to module
- Brief background
- Module overview:
  - a) ***Synthesize current & projected climate change impacts***
  - b) ***Rapid Climate Vulnerability Assessments***,
  - c) ***Operationalized climate change management strategy evaluations (MSEs)***
  - d) ***Project changes in species distributions and phenology***
  - e) ***Performance, validation, and operationalized delivery of 9 month seasonal forecasts***
- Next Steps:
  - o Taskforce
  - o Products
  - o Tracking progress

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GOAL:

”**support climate change adaptation pathways and long-term resilience** for the coupled social-ecological system of the Eastern Bering Sea.”

- ✓ **synthesize current knowledge** regarding climate change effects on the EBS system,
- ✓ **identify potential climate-resilient management measures** that can improve adaptive capacity and avoid maladaptation
- ✓ **evaluate the risk, timescale, and probability of success of various climate-resilient management policies** under future scenarios of change.

Policy relevant not policy prescriptive

(climate-resilient management would go through the existing Council process)

✓ Risk inherently depends on values

✓ Include a “plurality of perspectives” *

✓ Consider interacting (non-linear) pressures

“Interconnections among risks can span sectors and regions with multiple climatic and non-climatic influences, including societal responses to climate change and other issues (Helbing 2013; Moser and Hart 2015; Oppenheimer 2013).”
- Mach et al. 2016

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“One ongoing challenge is developing and addressing research questions from a Traditional Knowledge lens rather than solely from a western researcher's perspective.”

Raymond-Yakoubian, J., & Daniel, R. (2018). Marine Policy, *97:*101–108.

WHO?

Taskforce comprised of diverse knowledge holders and experts

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WHAT:

a) ***Synthesize current and projected climate change impacts on the coupled social-ecological Bering Sea system*** through synthesis of diverse knowledge sources of understanding, context and impacts of change and evaluation of future impacts and risk.

b) ***Rapid Climate Vulnerability Assessments***, which use expert knowledge to identify vulnerable species and communities to climate change and prioritize research needs.

c) ***Operationalized climate change management strategy evaluations (MSEs)*** of various alternative harvest strategies for key species under the most recent Intergovernmental Panel on Climate Change projections of carbon mitigation scenarios (*sensu ACLIM: Alaska Climate Integrated Modeling Project*). Include synthesis of current understanding from cross regional and global coordination of ensemble modeling projects aimed at evaluating climate-resilient management tools.

d) ***Project changes in species distributions and phenology*** which includes projected changes in habitat under future climate scenarios in order to estimate potential shifts in BSAI FMP species distributions and potential fishing grounds (*sensu Predicting changes in habitat for groundfishes under future climate scenarios using spatial distribution modeling)*

e) ***Performance, validation, and operationalized delivery of 9 month seasonal forecasts*** of Bering Sea conditions and fish and fisheries specifically aimed at informing the annual groundfish assessment cycle (*sensu The Bering Seasons Project).*

WHY?

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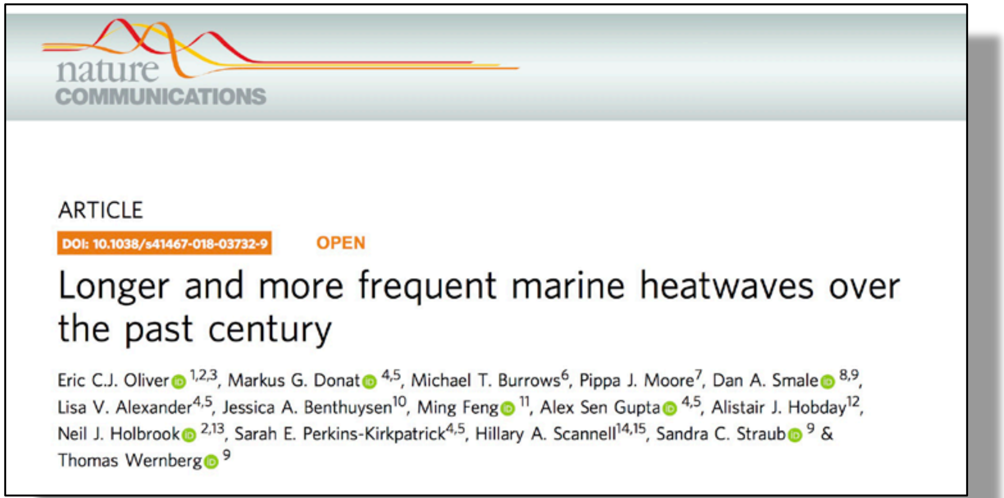
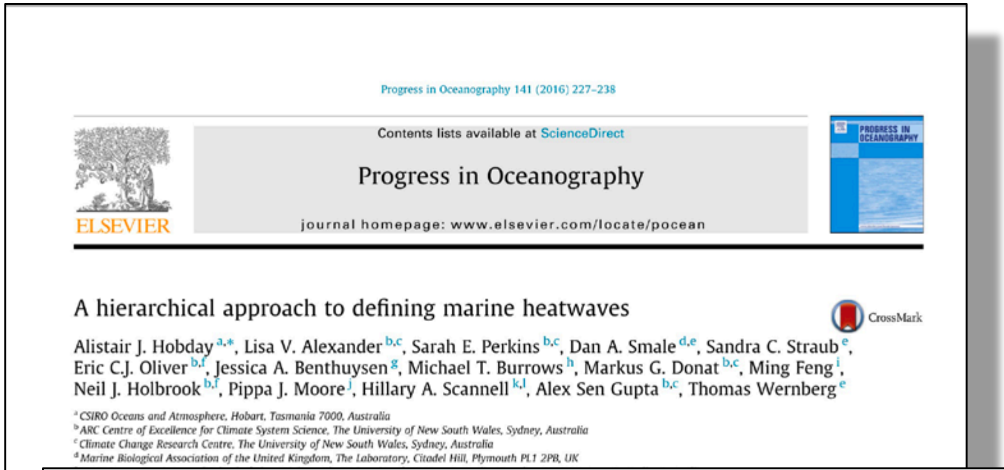

nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-03732-9 OPEN

Longer and more frequent marine heatwaves over the past century

Eric C.J. Oliver[1,2,3], Markus G. Donat[4,5], Michael T. Burrows[6], Pippa J. Moore[7], Dan A. Smale[8,9], Lisa V. Alexander[4,5], Jessica A. Benthuysen[10], Ming Feng[11], Alex Sen Gupta[4,5], Alistair J. Hobday[12], Neil J. Holbrook[2,13], Sarah E. Perkins-Kirkpatrick[4,5], Hillary A. Scannell[14,15], Sandra C. Straub[9] & Thomas Wernberg[9]


Progress in Oceanography 141 (2016) 227–238

Contents lists available at ScienceDirect

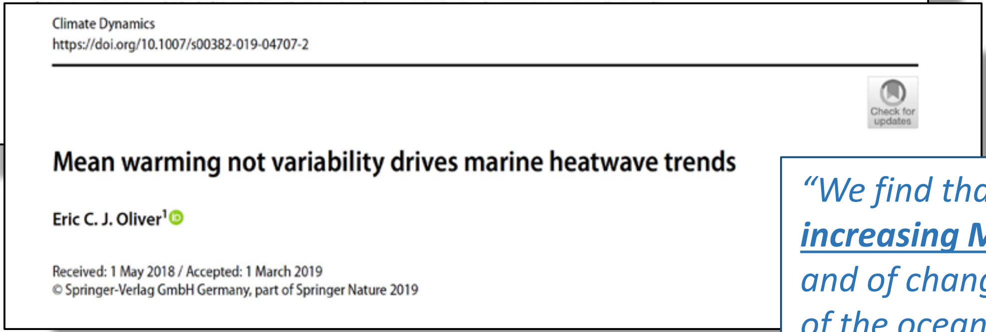
Progress in Oceanography

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

A hierarchical approach to defining marine heatwaves

Alistair J. Hobday[a,*], Lisa V. Alexander[b,c], Sarah E. Perkins[b,c], Dan A. Smale[d,e], Sandra C. Straub[e], Eric C.J. Oliver[b,f], Jessica A. Benthuysen[g], Michael T. Burrows[h], Markus G. Donat[b,c], Ming Feng[i], Neil J. Holbrook[b,f], Pippa J. Moore[j], Hillary A. Scannell[k,l], Alex Sen Gupta[b,c], Thomas Wernberg[e]

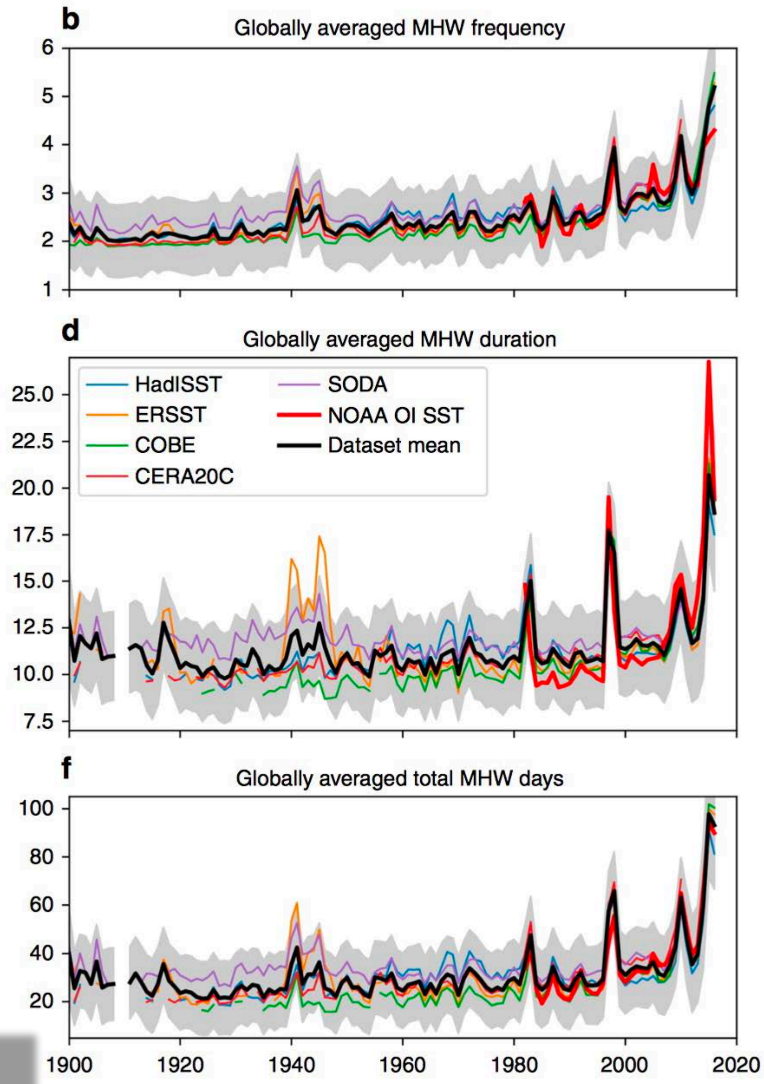
[a] CSIRO Oceans and Atmosphere, Hobart, Tasmania 7000, Australia
[b] ARC Centre of Excellence for Climate System Science, The University of New South Wales, Sydney, Australia
[c] Climate Change Research Centre, The University of New South Wales, Sydney, Australia
[d] Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK


Climate Dynamics
https://doi.org/10.1007/s00382-019-04707-2

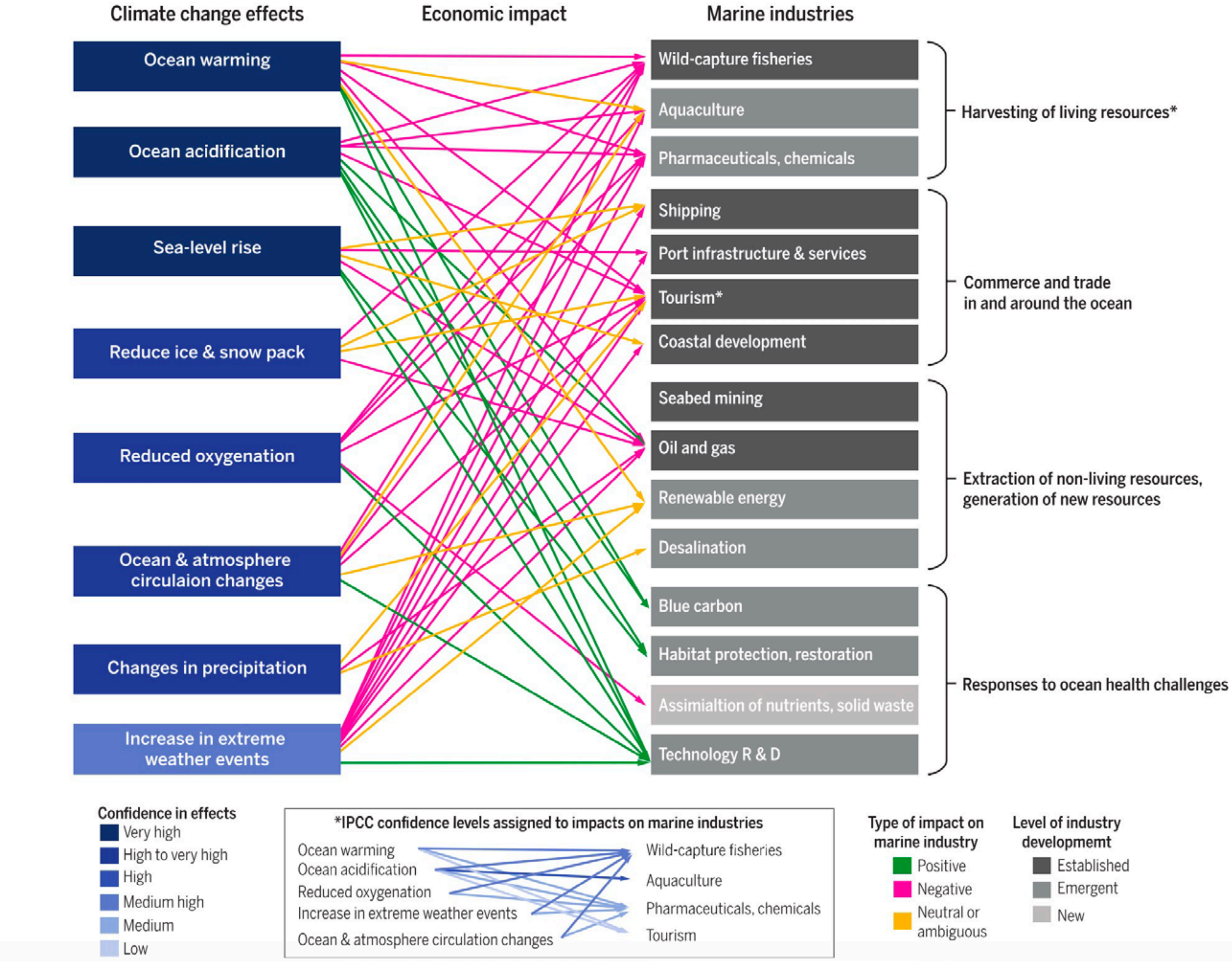
Mean warming not variability drives marine heatwave trends

Eric C. J. Oliver[1]

Received: 1 May 2018 / Accepted: 1 March 2019

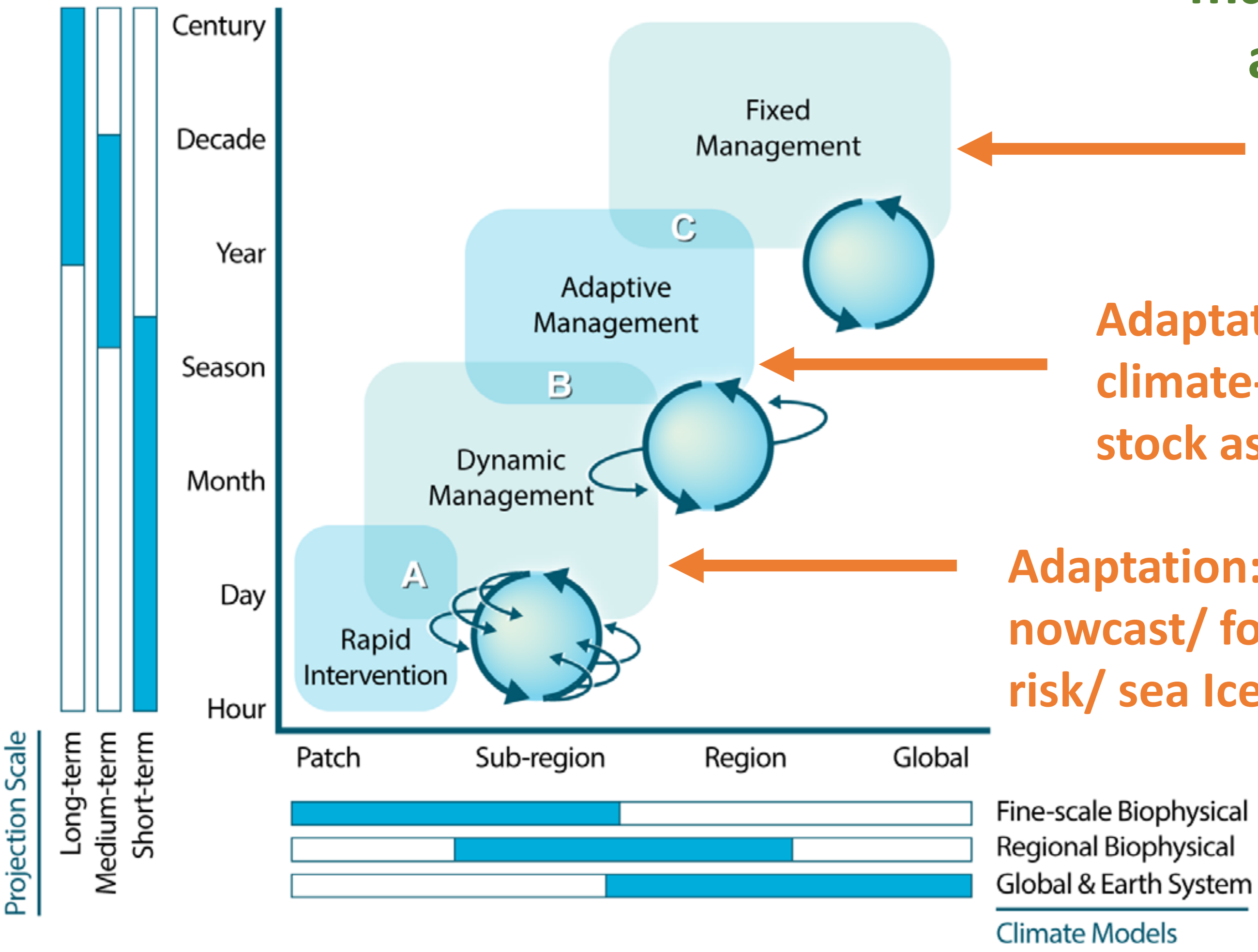


> *“We find that **mean SST change was the dominant driver of increasing MHW** exposure over nearly two thirds of the ocean, and of changes in MHW intensity over approximately one third of the ocean. “*



Climate change in the oceans: Human impacts and responses E. Allison and H. R. Bassett (November 12, 2015) Science 350 (6262), 778-782.

Consider nested scales of management & adaptation



Adaptation: increased flexibility

Adaptation: climate-enhanced stock assessments

Adaptation: nowcast/ forecast maps of risk/ sea Ice/spp distributions

Holsman, K. K., Hazen, E. L., Haynie, A., Gourguet, S., Hollowed, A., Bograd, S. J., … Aydin, K. (2019). Towards climate resiliency in fisheries management. ICES Journal of Marine Science. https://doi.org/10.1093/icesjms/fsz031

Test new & existing tools

Adaptation

- *incremental (normative) adaptation to preserve current livelihoods, health, and well being and meet future demands*
- *transformational adaptation, especially to address/prevent continued marginalization and promote diverse well being, values, and views*

Build capacity to revaluate & enable transformative actions

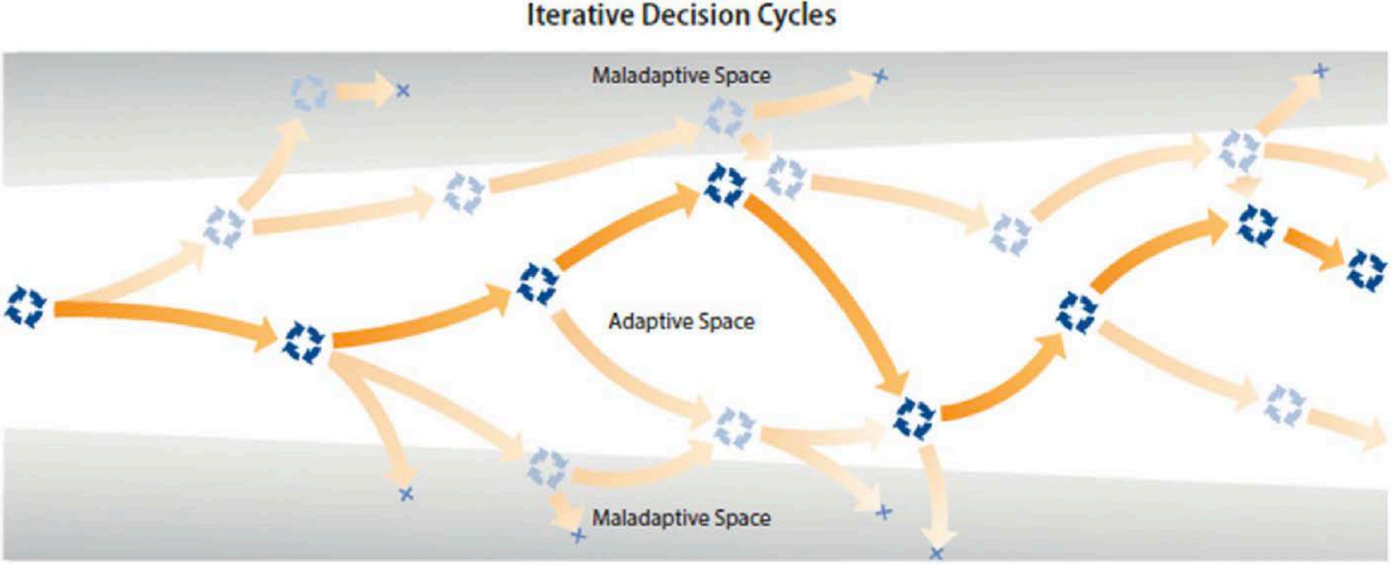


Fig. 1 from Wise et al. 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change 28: 325–336

HOW?

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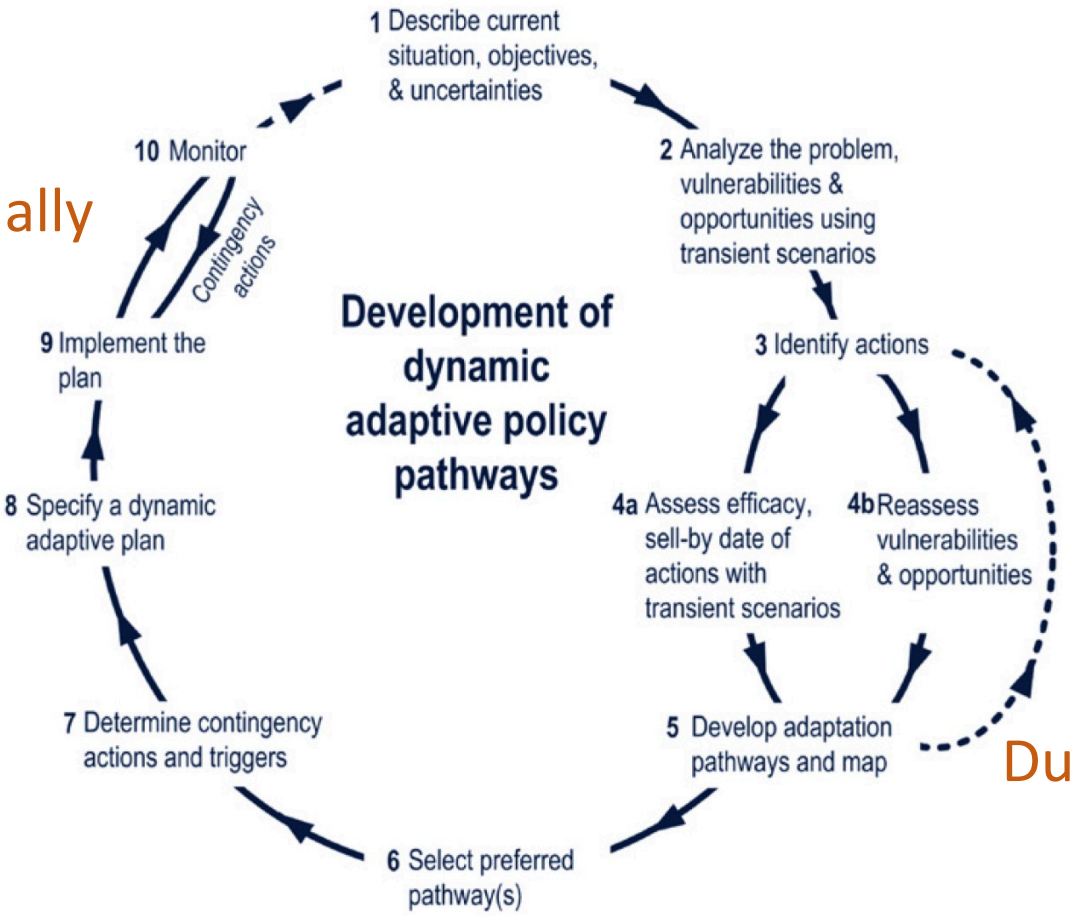
‘Adaptive Policymaking’

Every 5 Yr

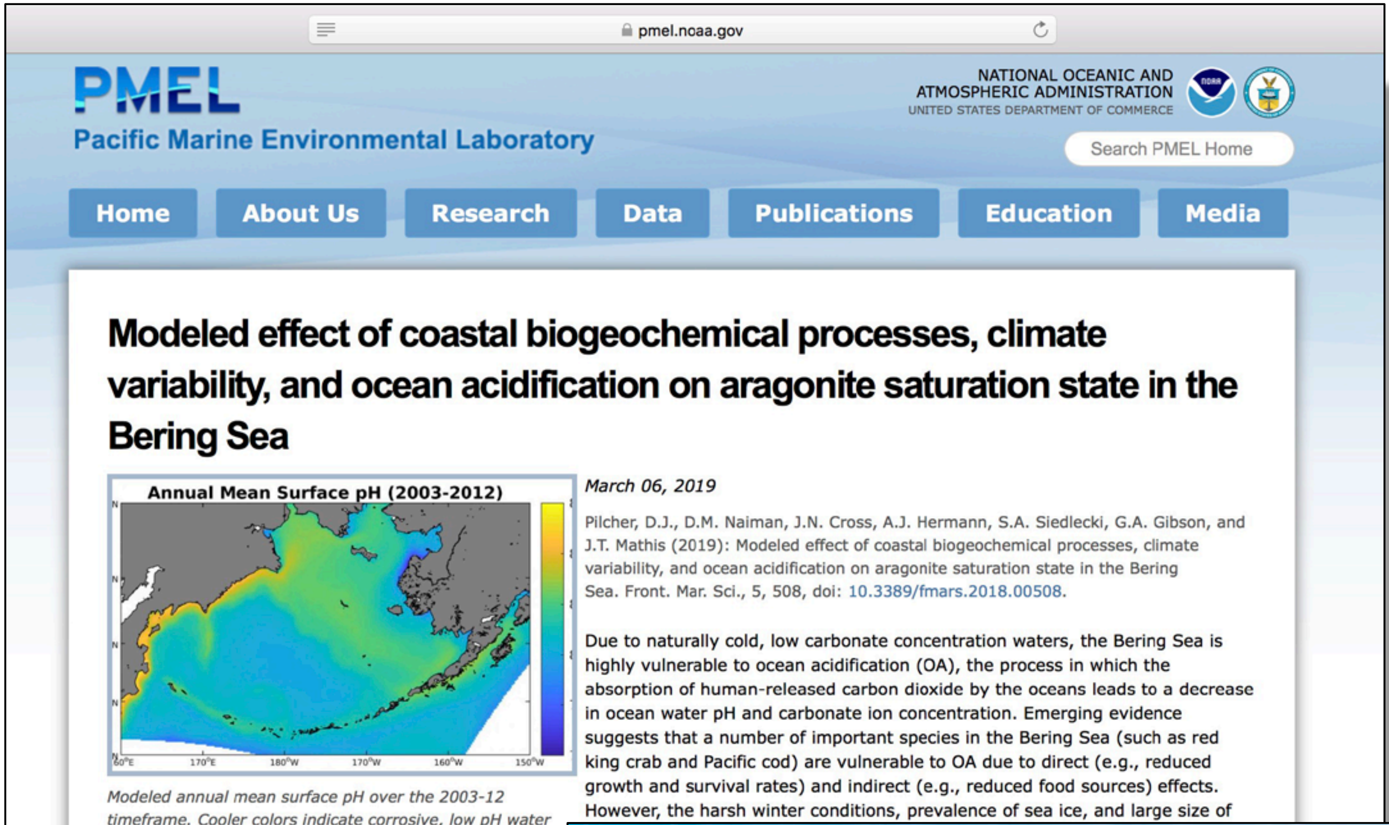


Annually

Annually
During Module

Fig. 4. The Dynamic Adaptive Policy Pathways approach.

M. Haasnoot et al. / Global Environmental Change 23 (2013) 488 485–498



Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea

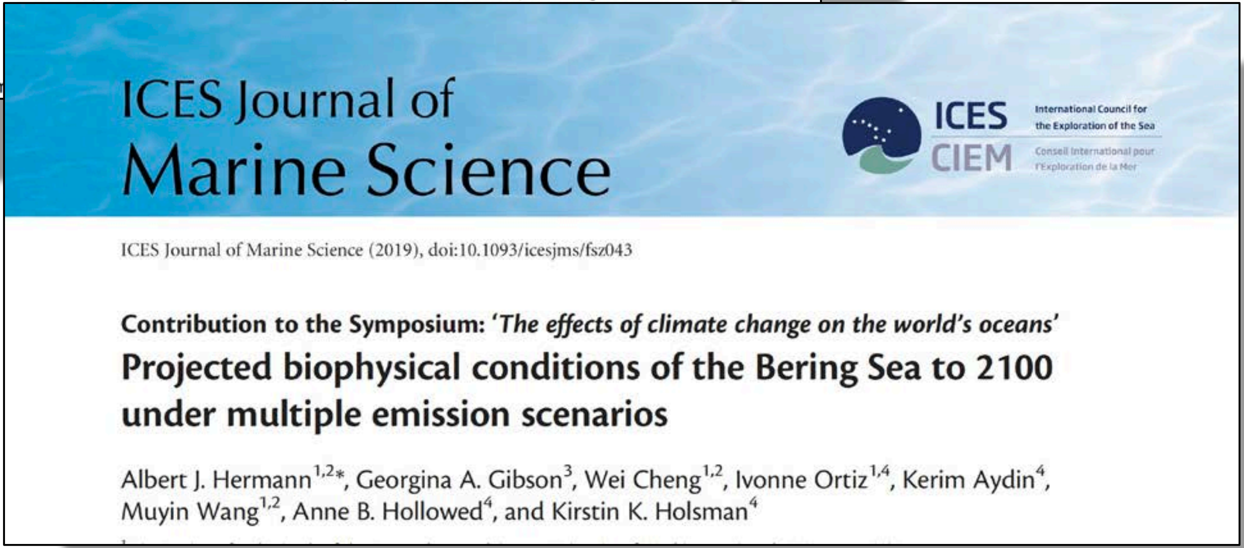
March 06, 2019

Pilcher, D.J., D.M. Naiman, J.N. Cross, A.J. Hermann, S.A. Siedlecki, G.A. Gibson, and J.T. Mathis (2019): Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea. Front. Mar. Sci., 5, 508, doi: 10.3389/fmars.2018.00508.

Due to naturally cold, low carbonate concentration waters, the Bering Sea is highly vulnerable to ocean acidification (OA), the process in which the absorption of human-released carbon dioxide by the oceans leads to a decrease in ocean water pH and carbonate ion concentration. Emerging evidence suggests that a number of important species in the Bering Sea (such as red king crab and Pacific cod) are vulnerable to OA due to direct (e.g., reduced growth and survival rates) and indirect (e.g., reduced food sources) effects. However, the harsh winter conditions, prevalence of sea ice, and large size of

Modeled annual mean surface pH over the 2003-12 timeframe. Cooler colors indicate corrosive, low pH water while warmer colors indicate relatively buffered, high pH water

In this paper, the authors developed a computational m



ICES Journal of Marine Science

ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz043

Contribution to the Symposium: '*The effects of climate change on the world's oceans*'

Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios

Albert J. Hermann[1,2]*, Georgina A. Gibson[3], Wei Cheng[1,2], Ivonne Ortiz[1,4], Kerim Aydin[4], Muyin Wang[1,2], Anne B. Hollowed[4], and Kirstin K. Holsman[4]

OBSERVATIONS

ROMSNPZ (downscaled)

GLOBAL MODEL

2003

2009

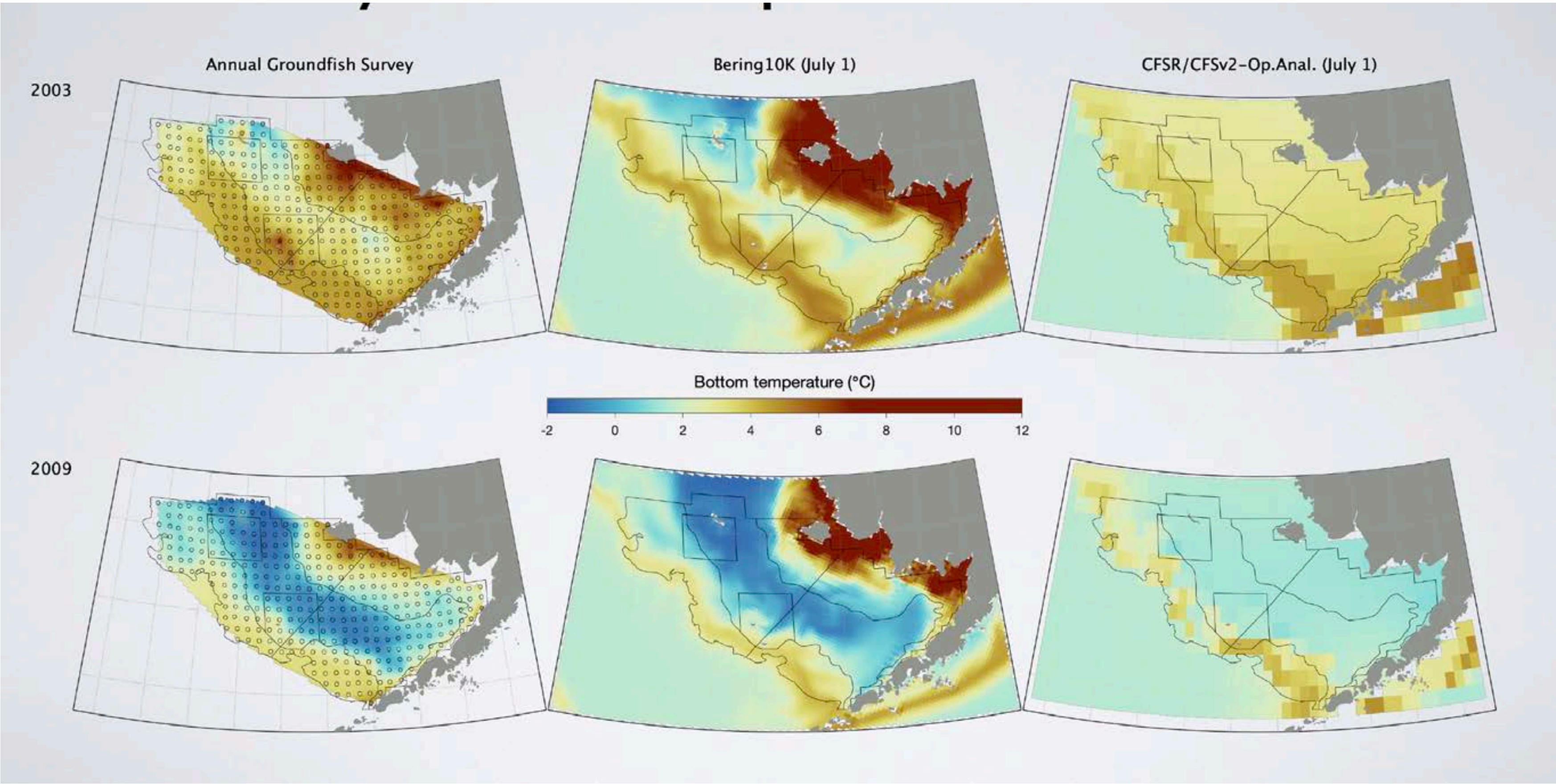
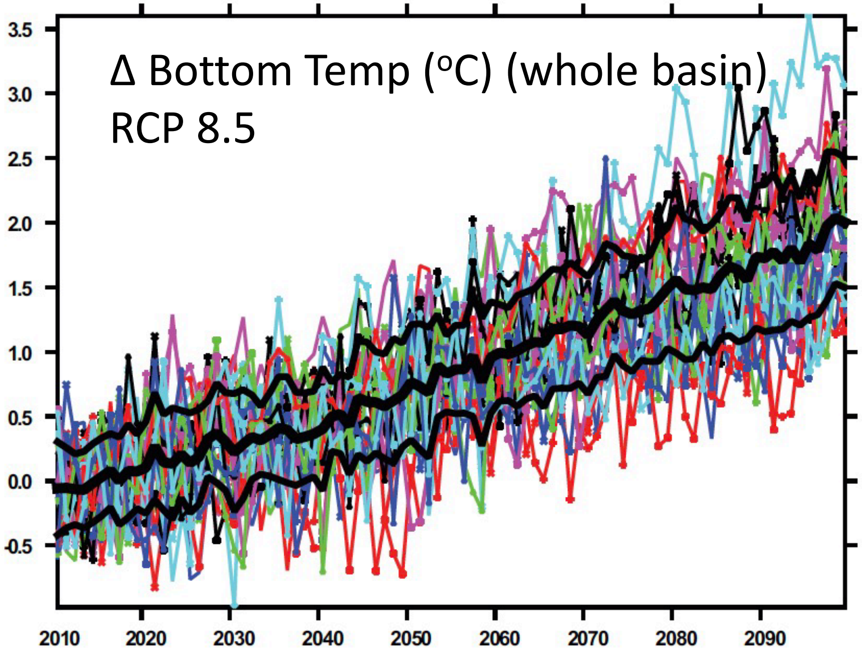
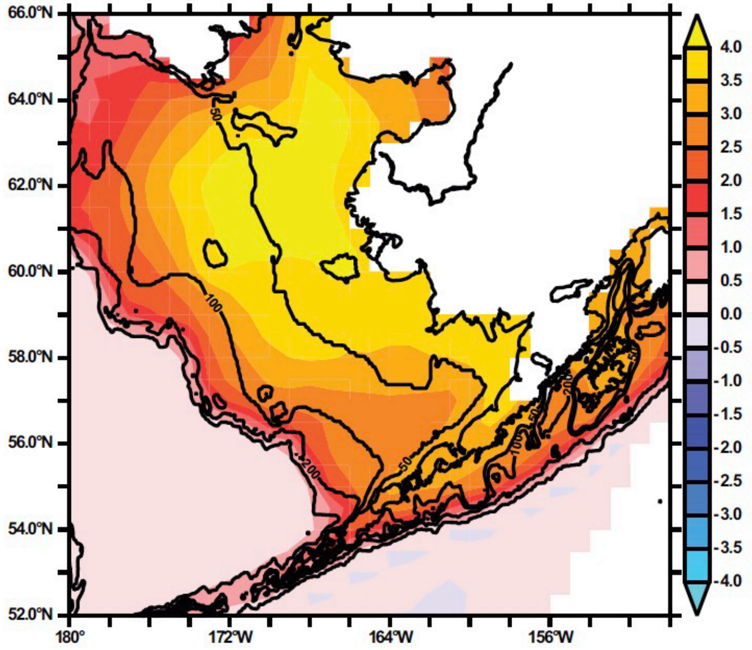


Image: Kelly Kearney

Increased warming (2090-2099)-(2010-2019)



Δ Bottom Temp (°C) (whole basin)
RCP 8.5



(2019) Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz1,K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES. doi: 10.1093/ices/fsz043

HOW?

b) Climate Vulnerability Assessments

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Methodology – Framework

Species Vulnerability

Exposure

Sensitivity

- Sea surface temperature
- Bottom temperature
- Air temperature
- Salinity
- Ocean acidification (pH)
- Precipitation
- Currents
- Sea surface height
- Large zooplankton biomass
- Phytoplankton biomass and bloom timing
- Mixed layer depth

- Habitat Specificity
- Prey Specificity
- Sensitivity to Ocean Acidification
- Sensitivity to Temperature
- Stock Size/Status
- Other Stressors
- Adult Mobility
- Spawning Cycle
- Complexity in Reproductive Strategy
- Early Life History Survival and Settlement Requirements
- Population Growth Rate
- Dispersal of Early Life Stages

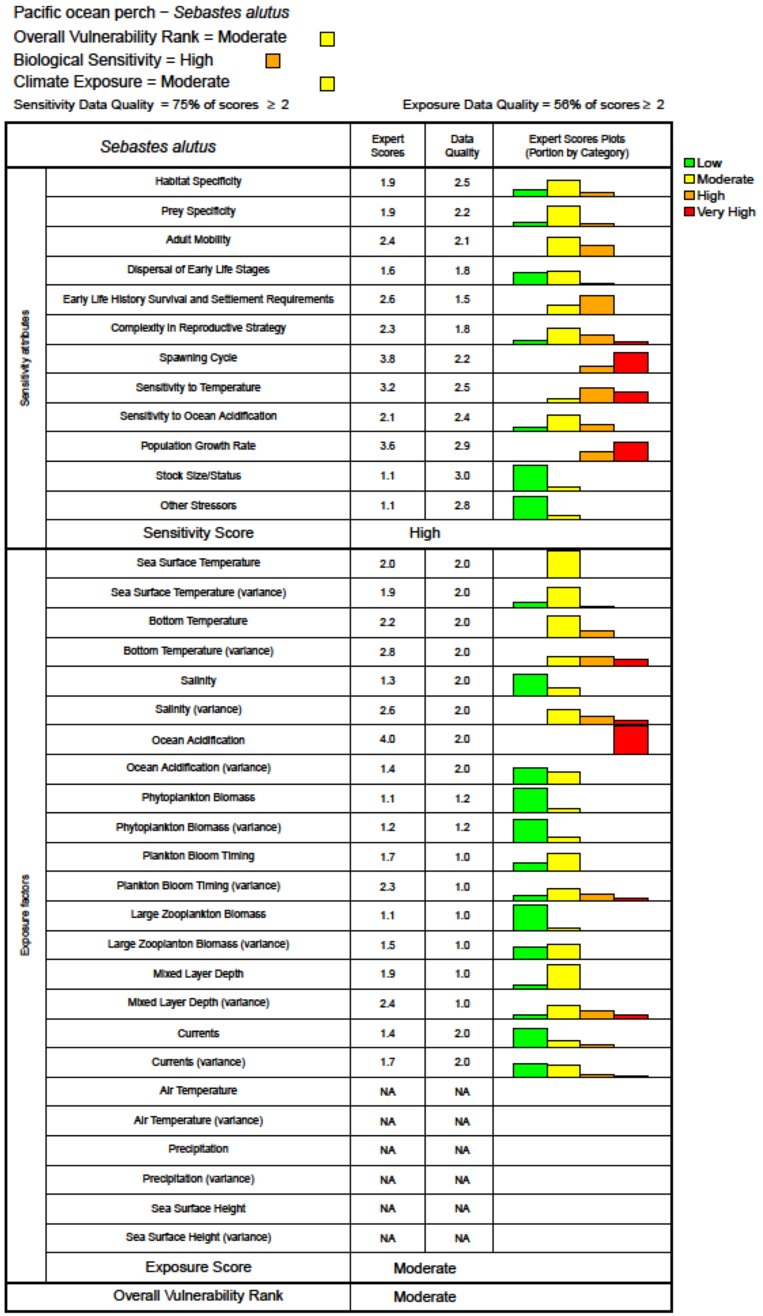
Slide credit: P. Spencer

Example of Species Specific Results (from EBS)

Pacific ocean perch

Bootstrap outcomes:

<1	Very High
10	High
89	Moderate
<1	Low



Pacific ocean perch – *Sebastes alutus*

Overall Vulnerability Rank = Moderate 🟨

Biological Sensitivity = High 🟧

Climate Exposure = Moderate 🟨

Sensitivity Data Quality = 75% of scores ≥ 2

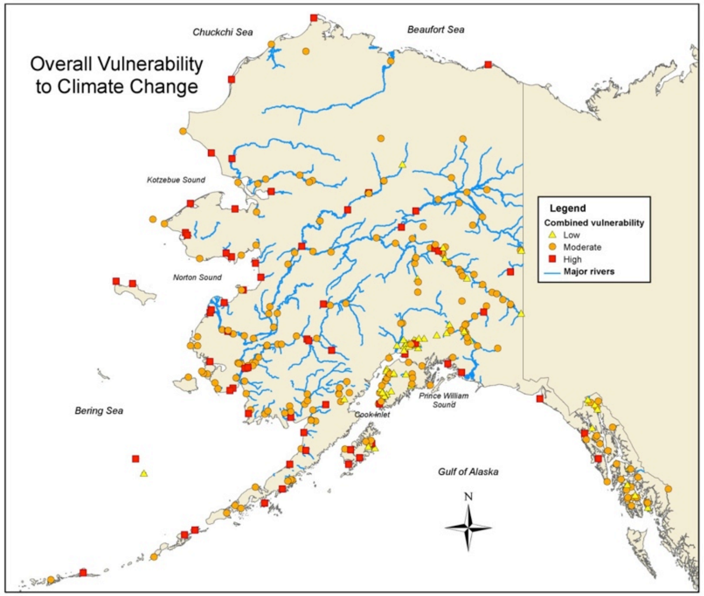
Exposure Data Quality = 56% of scores ≥ 2

	Sebastes alutus	Expert Scores	Data Quality	Expert Scores Plots (Portion by Category)
Sensitivity attributes	Habitat Specificity	1.9	2.5	
	Prey Specificity	1.9	2.2	
	Adult Mobility	2.4	2.1	
	Dispersal of Early Life Stages	1.6	1.8	
	Early Life History Survival and Settlement Requirements	2.6	1.5	
	Complexity in Reproductive Strategy	2.3	1.8	
	Spawning Cycle	3.8	2.2	
	Sensitivity to Temperature	3.2	2.5	
	Sensitivity to Ocean Acidification	2.1	2.4	
	Population Growth Rate	3.6	2.9	
	Stock Size/Status	1.1	3.0	
	Other Stressors	1.1	2.8	
	Sensitivity Score	High		
Exposure factors	Sea Surface Temperature	2.0	2.0	
	Sea Surface Temperature (variance)	1.9	2.0	
	Bottom Temperature	2.2	2.0	
	Bottom Temperature (variance)	2.8	2.0	
	Salinity	1.3	2.0	
	Salinity (variance)	2.6	2.0	
	Ocean Acidification	4.0	2.0	
	Ocean Acidification (variance)	1.4	2.0	
	Phytoplankton Biomass	1.1	1.2	
	Phytoplankton Biomass (variance)	1.2	1.2	
	Plankton Bloom Timing	1.7	1.0	
	Plankton Bloom Timing (variance)	2.3	1.0	
	Large Zooplankton Biomass	1.1	1.0	
	Large Zooplanton Biomass (variance)	1.5	1.0	
	Mixed Layer Depth	1.9	1.0	
	Mixed Layer Depth (variance)	2.4	1.0	
	Currents	1.4	2.0	
	Currents (variance)	1.7	2.0	
	Air Temperature	NA	NA	
	Air Temperature (variance)	NA	NA	
	Precipitation	NA	NA	
	Precipitation (variance)	NA	NA	
	Sea Surface Height	NA	NA	
	Sea Surface Height (variance)	NA	NA	
	Exposure Score	Moderate		
Overall Vulnerability Rank		Moderate		

🟩 Low
🟨 Moderate
🟧 High
🟥 Very High

Slide credit: P. Spencer

OA Risk Assessment



Himes-Cornell and Kaspersky 2014

J.T. Mathis et al. / Progress in Oceanography xxx (2014) xxx–xxx

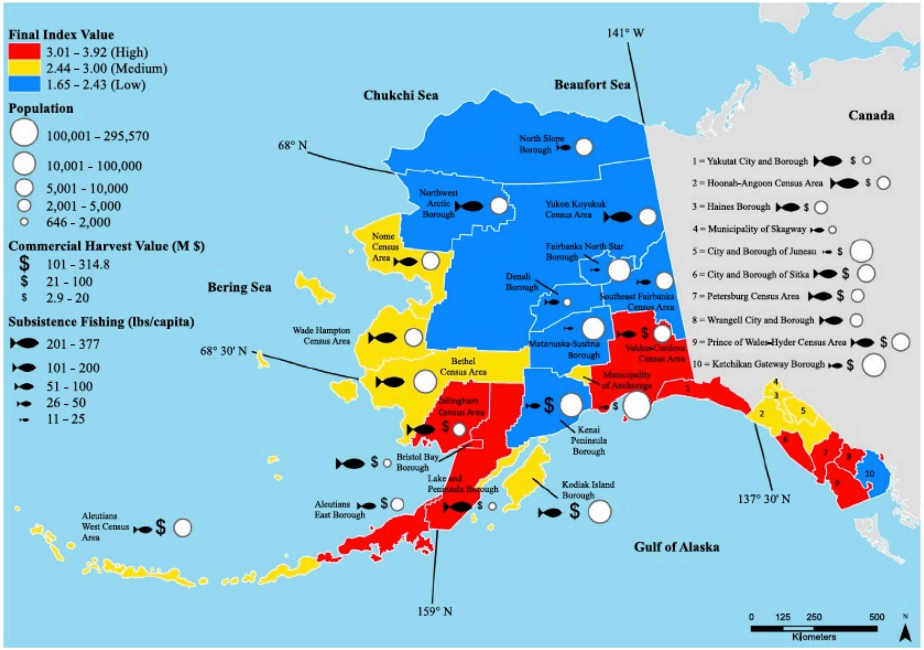


Fig. 11. Individual components of the final ocean acidification risk index for each census area.

J.T. Mathis et al. / Progress in Oceanography xxx (2014) xxx–xxx

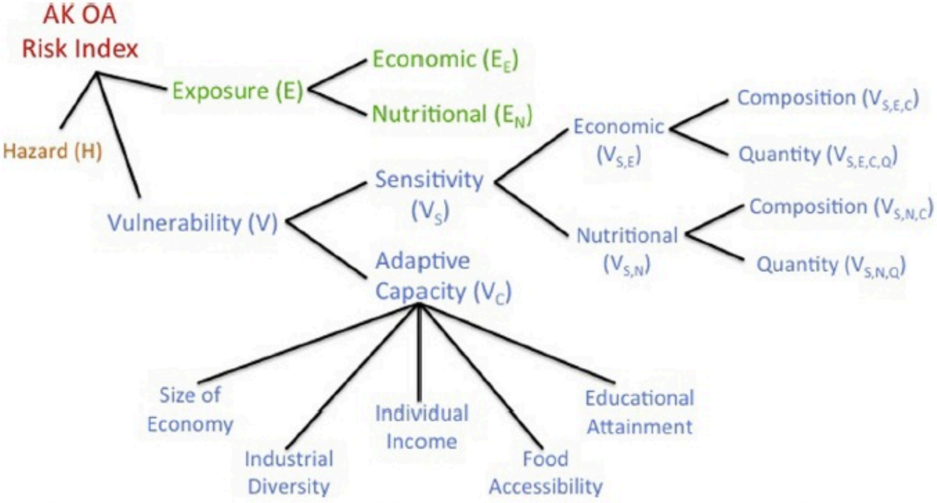


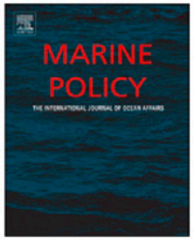
Fig. 3. Components of the risk index. Each branch is evenly weighted relative to others at the same level.

Marine Policy 51 (2015) 119–127

Contents lists available at ScienceDirect

Marine Policy

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



Vessels, risks, and rules: Planning for safe shipping in Bering Strait

Henry P. Huntington [a,*], Raychelle Daniel [b], Andrew Hartsig [c], Kevin Harun [d], Marilyn Heiman [b], Rosa Meehan [e], George Noongwook [f], Leslie Pearson [g], Melissa Prior-Parks [b], Martin Robards [h], George Stetson [i]

Table 1
Comparison of environmental and cultural risks (columns) and regulatory measures (rows). The first four risks are environmental ones and also cultural risks for those who depend on the environment for food and well-being. Note that most or all regulatory measures can be implemented by voluntary, domestic, or international action. Which vessels would be covered by each type of action, and how much of the risk would be reduced, depends on the details of the shipping activities in question.

Risk/Regulatory measure	Ship strikes	Noise	Discharges and contamination	Accidental oil spills	Vessel collisions	Disturbance to hunting	Damage to cultural heritage
Shipping lanes	X	X		X	X	X	
Areas-to-be-avoided	X	X		X	X	X	X
Speed limits	X			X	X	X	
Communications	X				X	X	X
Reporting systems					X	X	
Emission controls		X	X			X	
Salvage and oil spill prevention and preparedness			X	X			
Rescue tug capability			X	X			
Voyage and contingency planning	X			X	X	X	X
Charting				X			X

HOW?

c) Operationalized climate change management strategy evaluations (MSEs)

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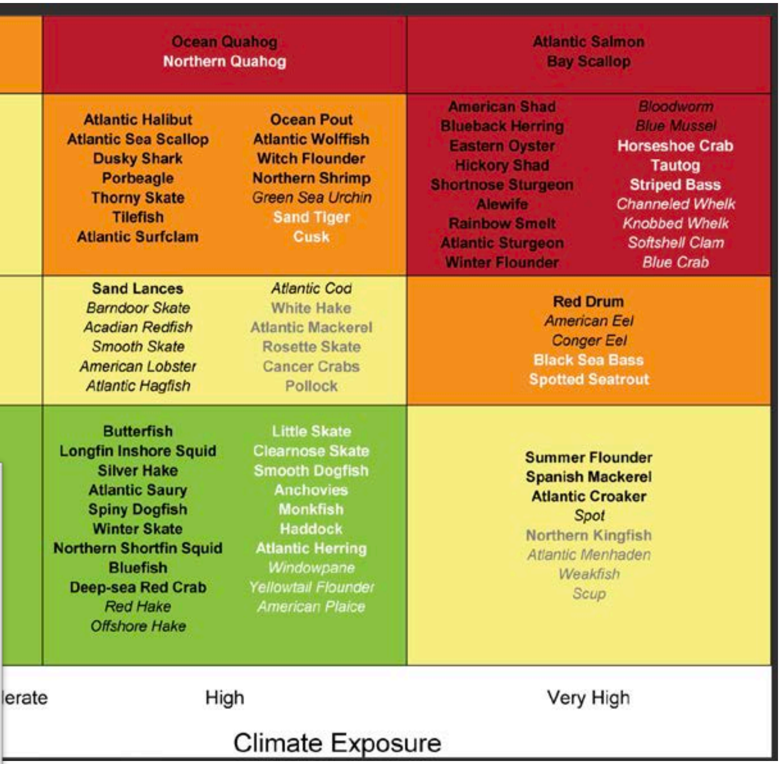
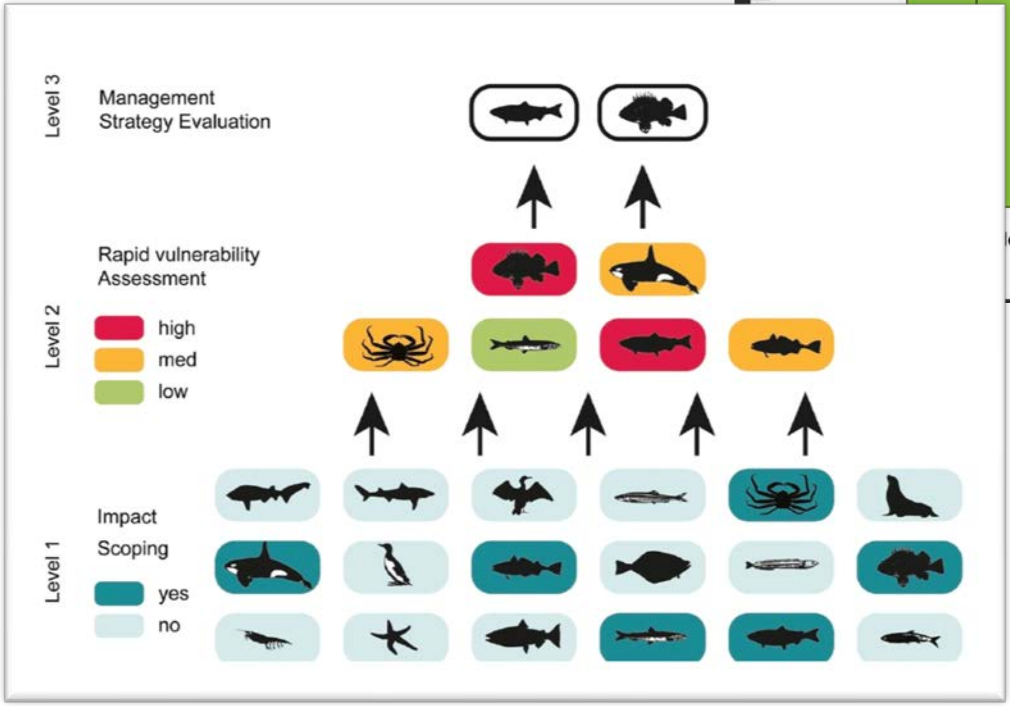
Examples:



Hare et al. (2016) A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf. PLOS ONE 11(2): e0146756. https://doi.org/10.1371/journal.pone.0146756



Holsman et al. 2017

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

ACLIM
Alaska Climate Integrated Modeling Project

Anne Hollowed (AFSC, SSMA/REFM)
Kirstin Holsman (AFSC, REEM/REFM)
Alan Haynie (AFSC ESSR/REFM)
Stephen Kasperski (AFSC ESSR/REFM)
Jim Ianelli (AFSC, SSMA/REFM)
Kerim Aydin (AFSC, REEM/REFM)
Trond Kristiansen (IMR, Norway)
Al Hermann (UW JISAO/PMEL)
Wei Cheng (UW JISAO/PMEL)
André Punt (UW SAFS)
Jonathan Reum (UW SAFS)
Amanda Faig (UW SAFS)

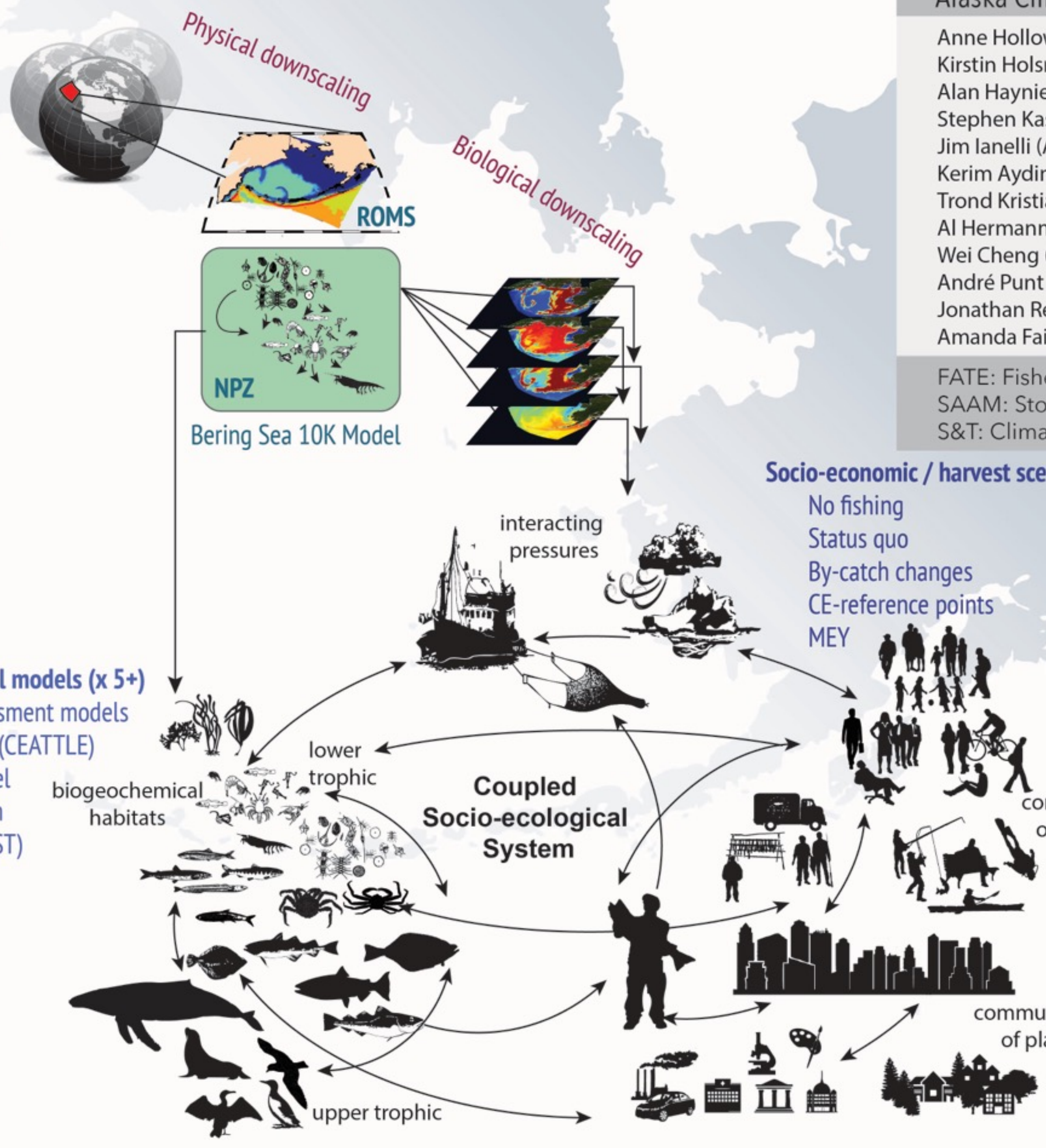
FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity

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



Socio-economic / harvest scenarios (x 5+)

- No fishing
- Status quo
- By-catch changes
- CE-reference points
- 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)
- *IBM-crab*
- *MICE-in space*

Consider evolving interactions and pathways of adaptation

The ACLIM team

Anne Hollowed

Kirstin Holsman

Alan Haynie

Kerim Aydin

Albert Hermann

Wei Cheng

Stephen Kasperski

Jim Ianelli

Andre Punt

Andy Whitehouse

Jonathan Reum

Amanda Faig

Kelly Kearney

Buck Stockhausen

Paul Spencer

Michael Dalton

Darren Pilcher

Tom Wilderbuer

Cody Szuwalski

Jim Thorson

Ingrid Spies

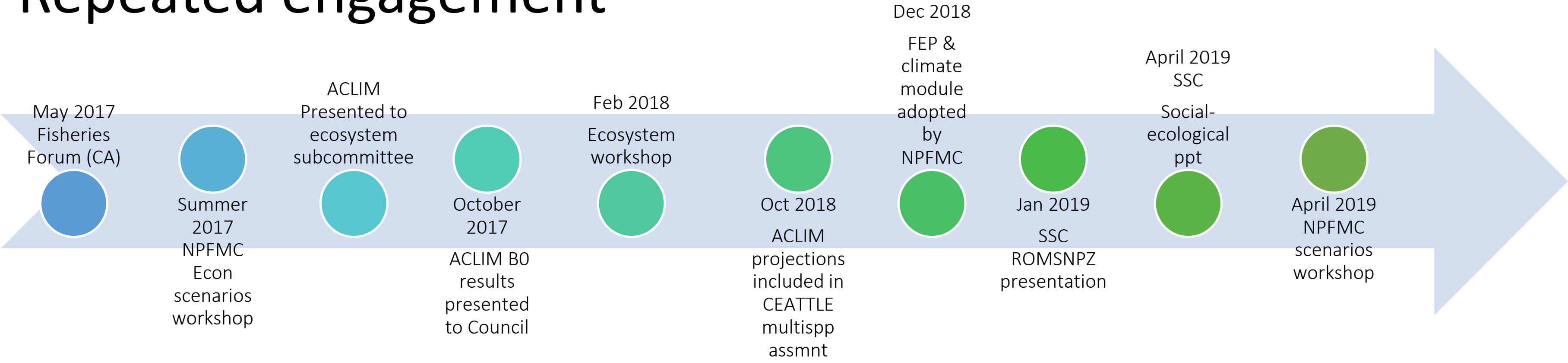
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project

Challenges to evaluating adaptation options:

- **long time horizons** of adaptation outcomes;
- the **shifting baseline and uncertainty** around climate hazards;
- assessing **attribution** of any results;
- addressing the **additional climate risk** and counterfactual scenarios

"an ***approach built on mixed methods, participation and learning helps alleviate some of the uncertainties*** around interpreting results on adaptation." Craft & Fisher 2018, Fisher 2015

Repeated engagement



May 2017
Fisheries Forum (CA)

Summer 2017
NPFMC Econ scenarios workshop

ACLIM Presented to ecosystem subcommittee

October 2017
ACLIM B0 results presented to Council

Feb 2018
Ecosystem workshop

Oct 2018
ACLIM projections included in CEATTLE multispp assmnt

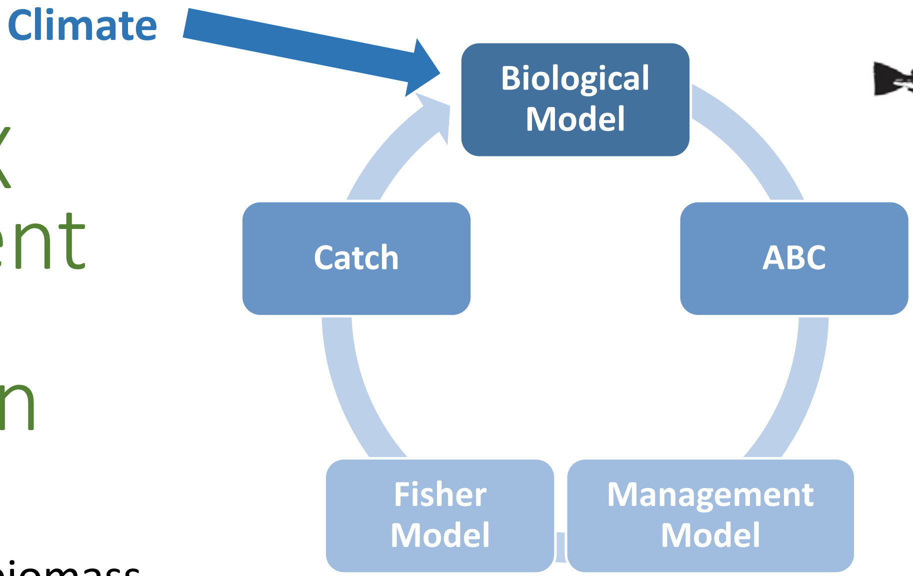
Dec 2018
FEP & climate module adopted by NPFMC

Jan 2019
SSC ROMSNPZ presentation

April 2019 SSC
Social-ecological ppt

April 2019
NPFMC scenarios workshop

Climate X management dynamic interaction



Climate

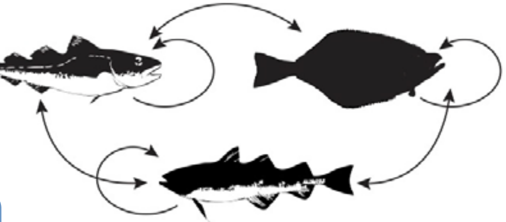
Biological Model

ABC

Management Model

Fisher Model

Catch

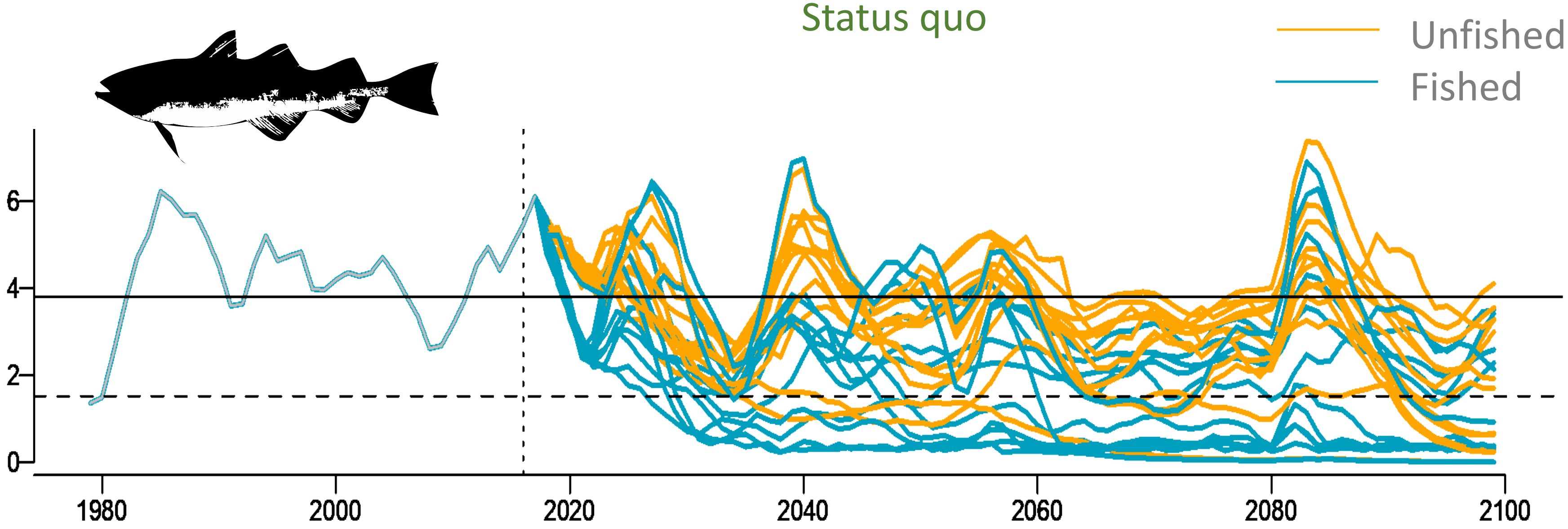


CEATTLE model

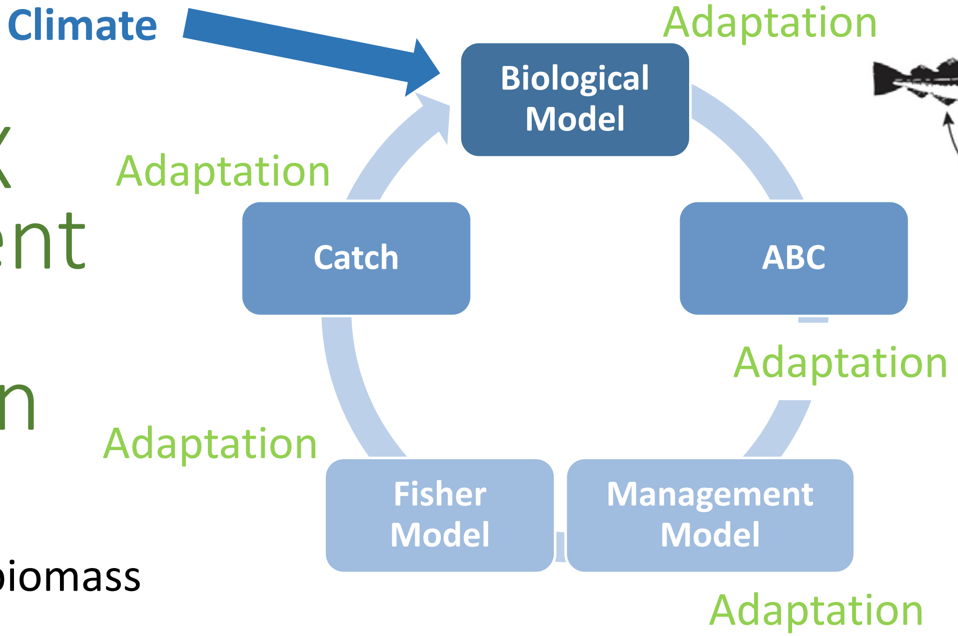
Holsman et al. 2016

Pollock Spawning biomass

Status quo



Climate X management dynamic interaction



Climate

Adaptation

Biological Model

Adaptation

Catch

ABC

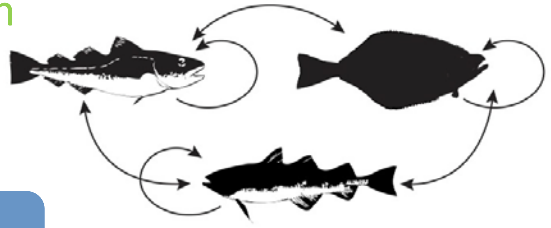
Adaptation

Adaptation

Fisher Model

Management Model

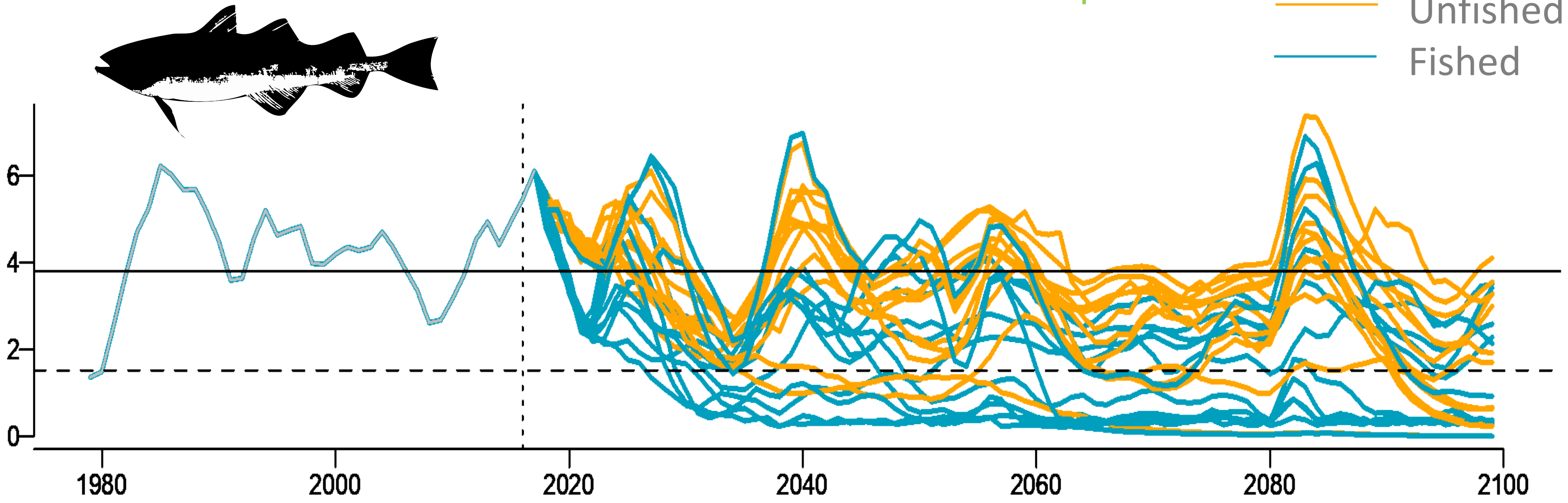
Adaptation

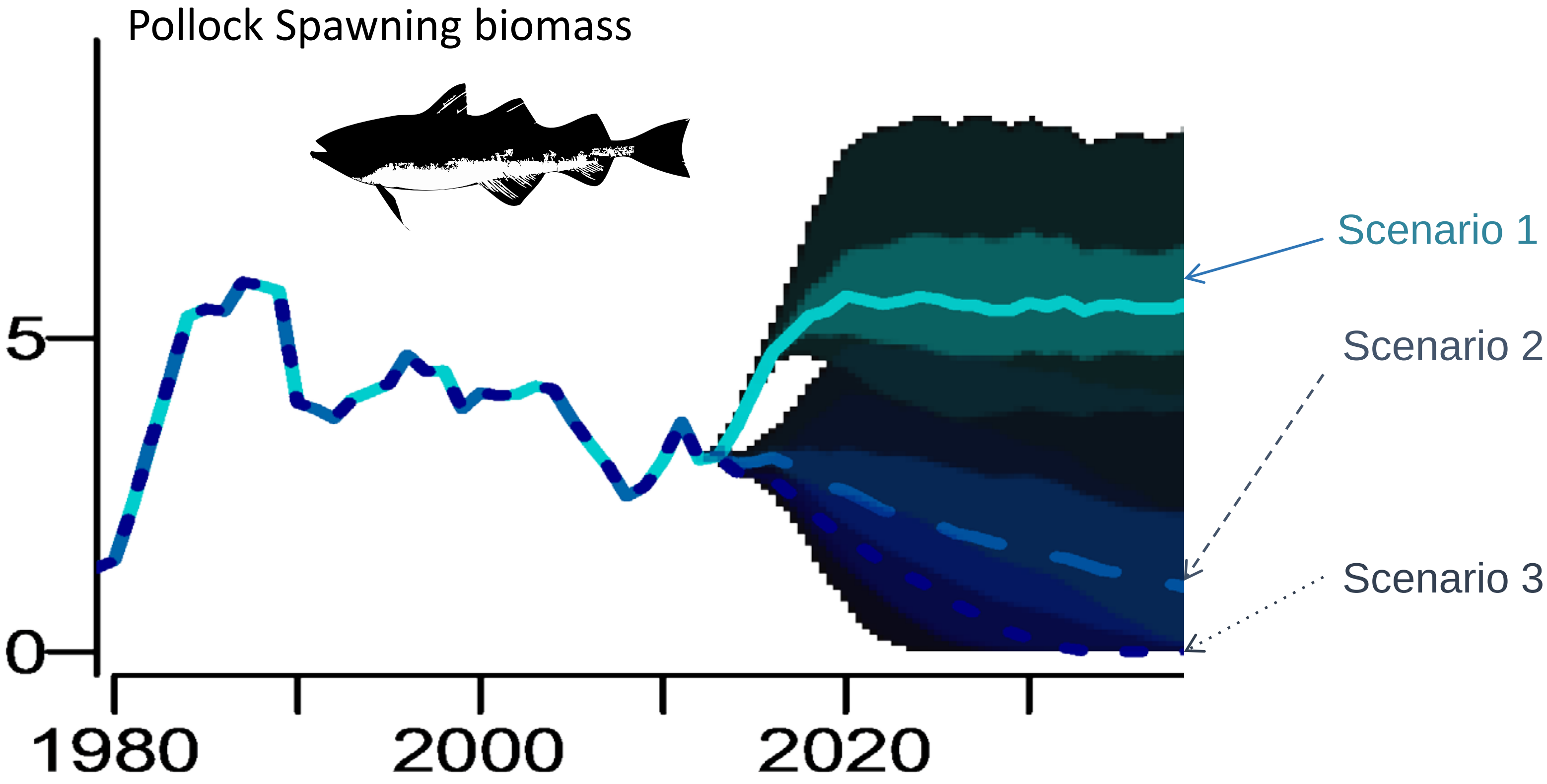


CEATTLE model

Holsman et al. 2016

Pollock Spawning biomass





Ianelli, J KK Holsman, AE Punt, K Aydin (2016). Multi-model inference for incorporating trophic and climate uncertainty into stock assessment estimates of fishery biological reference points. Deep Sea Res II. 134: 379-389 DOI: 10.1016/j.dsr2.2015.04.002

HOW?

d) Project changes in species distributions and phenology

Mark Holsman

Future Essential Fish Habitat

(Chris Rooper, Ivonne Ortiz, Ned Laman, Al Hermann, *in prep*)

Used Slope, SE Bering Sea shelf and Northern Bering Sea data to build EFH models 1982-2017 except when noted

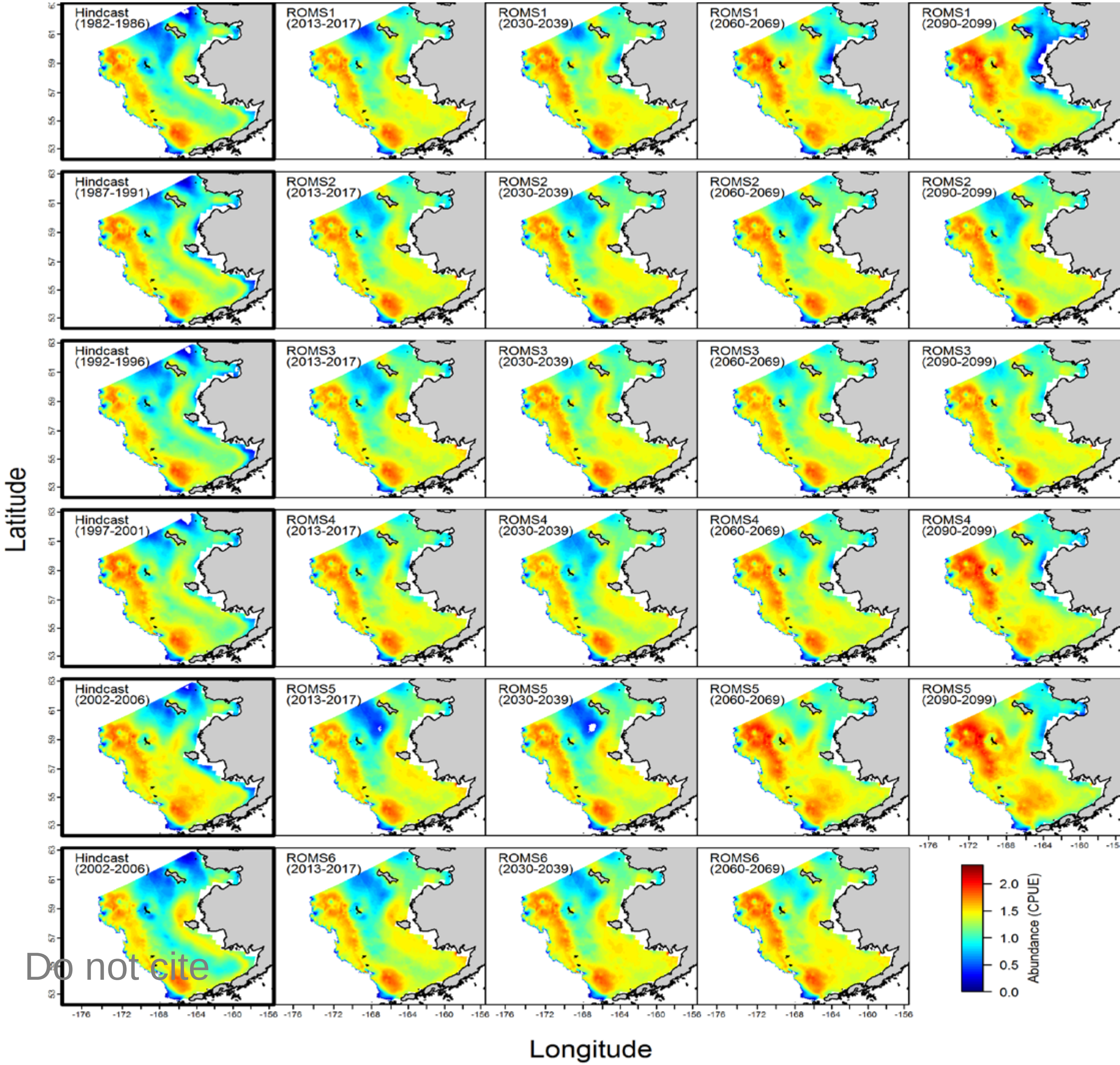
1) AK plaice
2) Arrowtooth flounder (1993-)
3) flathead sole
4) Northern rock sole (2001-)
5) Pacific cod
6) Walleye pollock
7) Red king crab (1996-)
8) Snow crab
9) Tanner crab
10) Yellowfin sole

Variables used: depth, slope, maximum tidal current, sediment grain size, mean bottom ocean current, bottom temperature

Slide credit: I. Ortiz

P.Cod

(Chris Rooper, Ivonne Ortiz, Ned Laman, Al Hermann, *in prep*)



Slide credit: I. Ortiz

Today

- Intro to module
- Brief background
- Module overview:
  - ***a) Synthesize current & projected climate change impacts***
  - ***b) Rapid Climate Vulnerability Assessments***,
  - ***c) Operationalized climate change management strategy evaluations (MSEs)***
  - ***d) Project changes in species distributions and phenology***
  - ***e) Performance, validation, and operationalized delivery of 9 month seasonal forecasts***
- Next Steps:
  - o Taskforce
  - o Products
  - o Tracking progress

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