Developing a workplan for the FEP Climate Change Module

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Alaska Fisheries Science Center
FEP Meeting, Seattle WA
May 7, 2019

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:
  - Taskforce
  - Products
  - 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.”

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)

"knowledge and culture construct societal limits to adaptation, but these <u>limits are mutable</u>"

- Adger et al. (2009).

- ✓ Risk inherently depends on values
- ✓ Include a "plurality of perspectives" *
- ✓ Consider interacting (non-linear) pressures

**Allison & Bassett. 2015. Climate change in the oceans: Human impacts and responses. Science 350 (6262), 778-782. [doi: 10.1126/science.aac8721]*

- ✓ 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

"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

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.

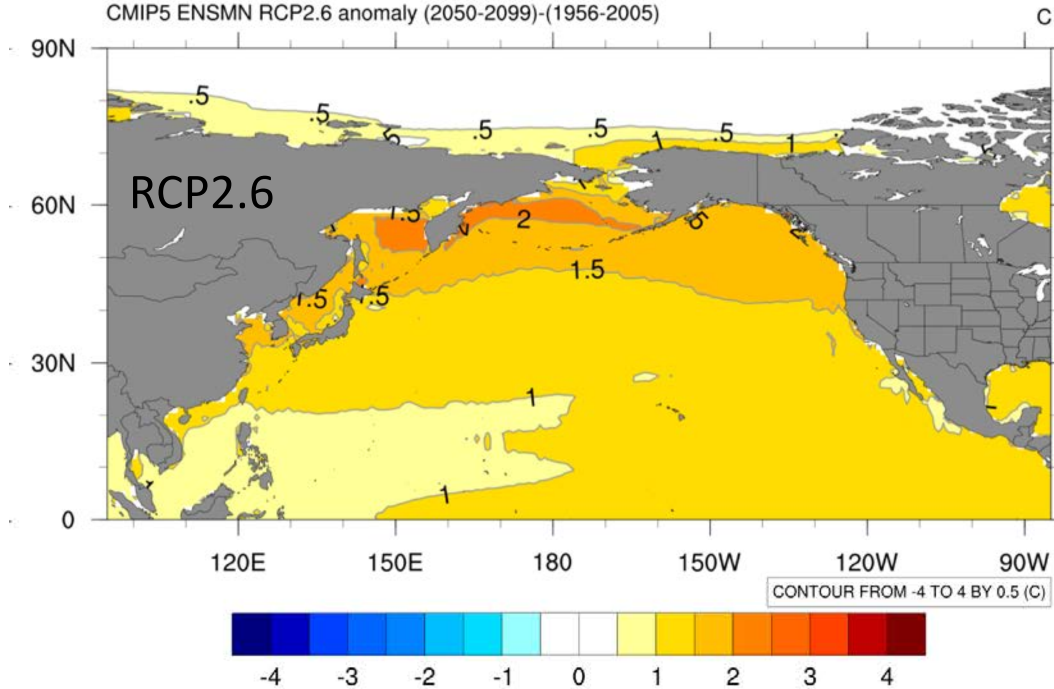
d) ***Project changes in species distributions and phenology*** which includes projected changes in habitat under future climate scenarios in order to estimate potential shifts in BSAI FMP species distributions and potential fishing grounds (*sensu Predicting changes in habitat for groundfishes under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

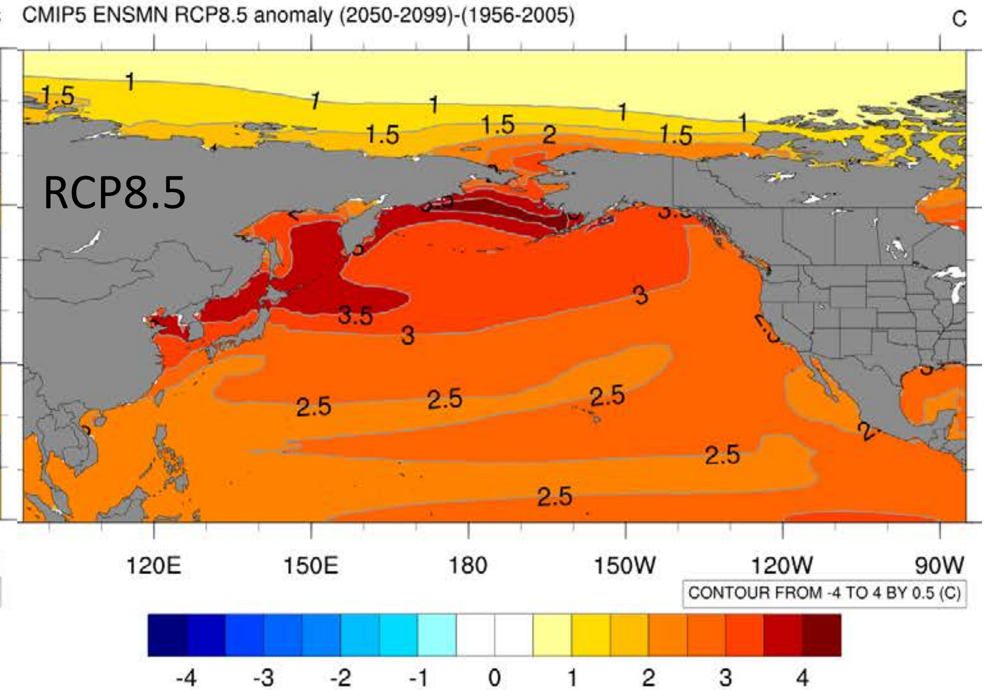
WHY?

CMIP5 ENSMN Annual SST anomaly (^{o}C)
(2050 to 2099) - (1956 to 2005)

CO2 mitigation scenario

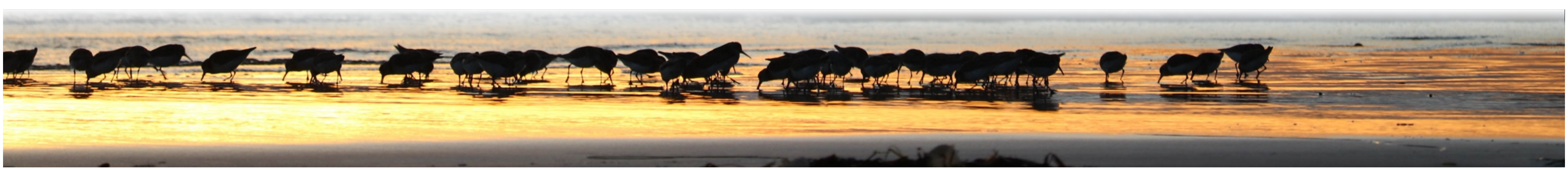


High baseline scenario ("Business as usual")



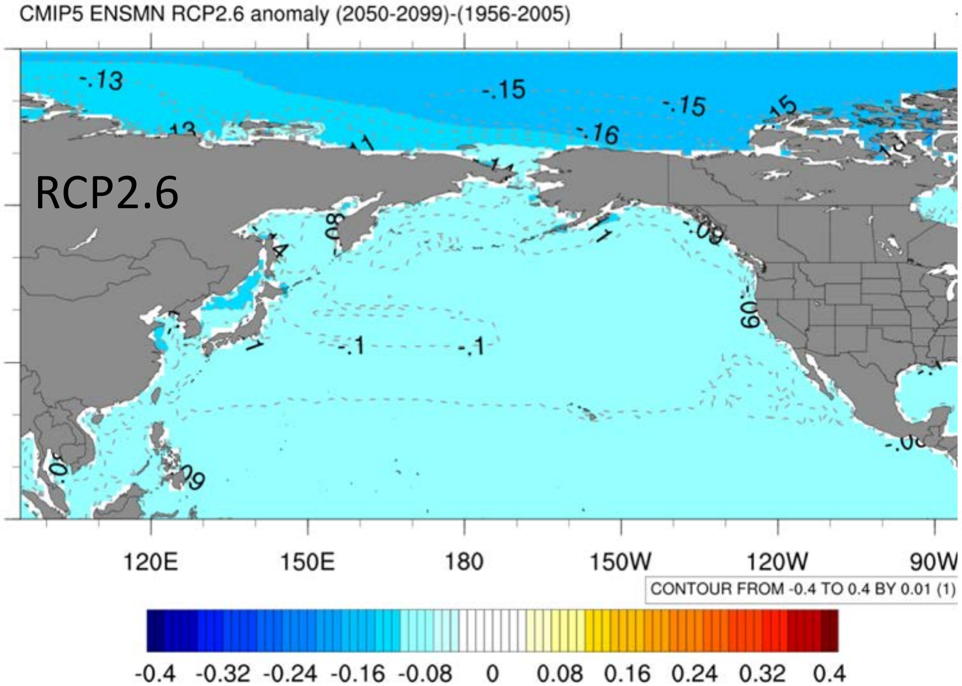
Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

Modified from Fig. 6.2 Holsman et al. 2018 [in] Barange et al. (Eds.)
2018. Impacts of climate change on fisheries and aquaculture. TP 627.

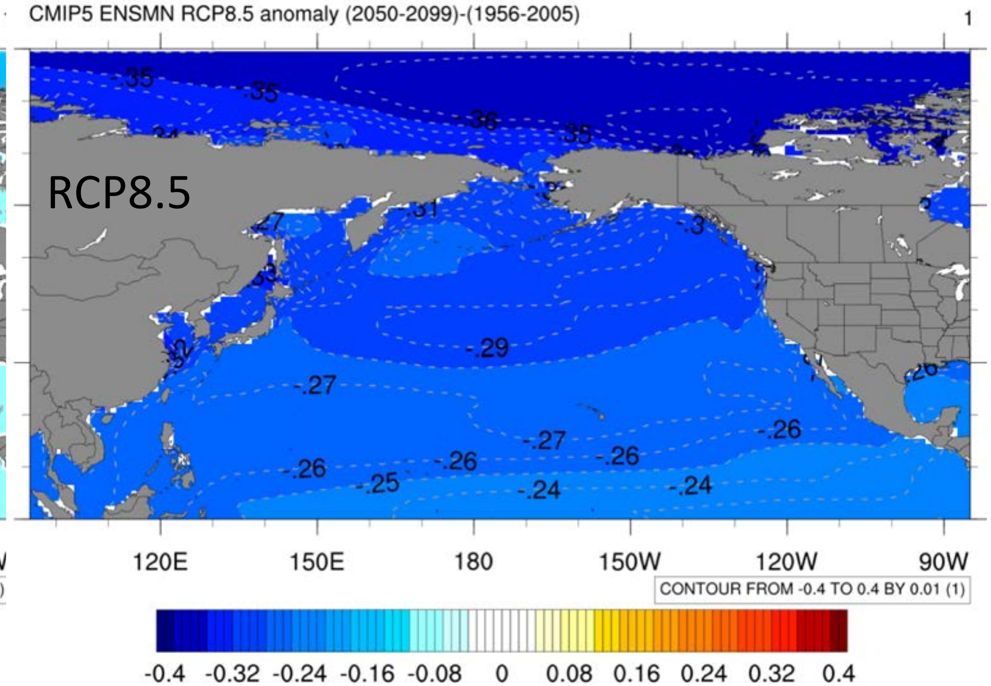


CMIP5 ENSMN Annual Ocean pH anomaly (2050 to 2099) - (1956 to 2005)

CO2 mitigation scenario

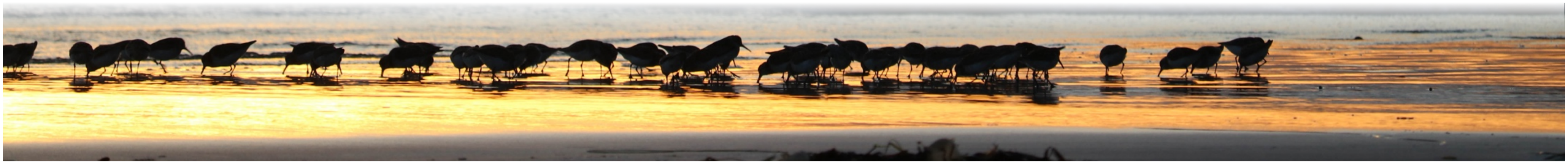


High baseline scenario ("Business as usual")



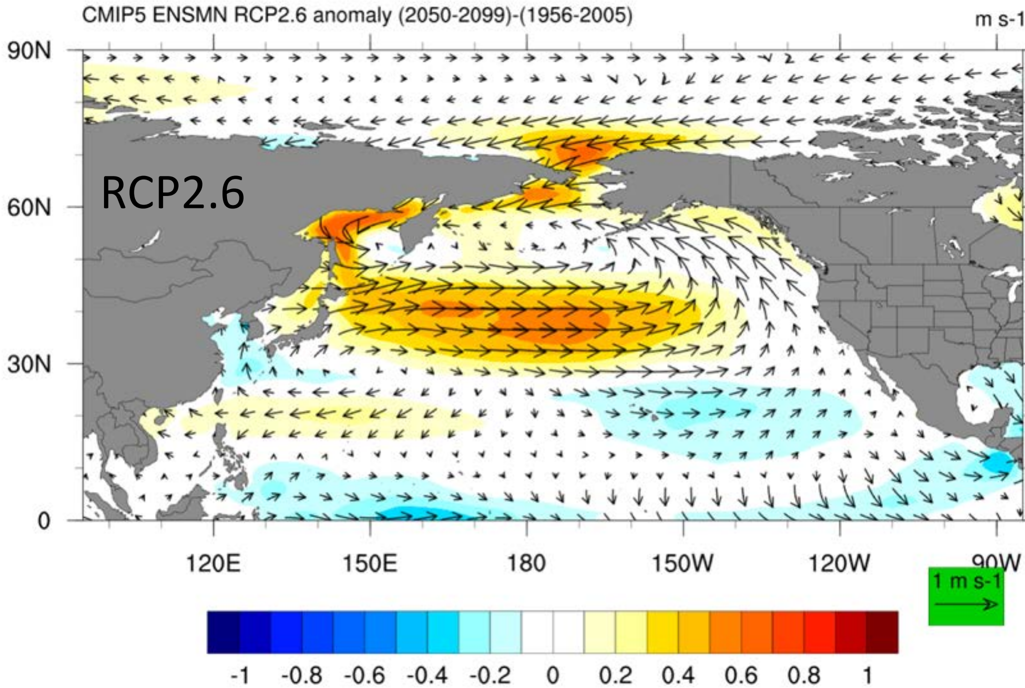
Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

Modified from Holsman et al. 2018 [in] Barange et al. (Eds.) 2018. Impacts of climate change on fisheries and aquaculture. TP 627.

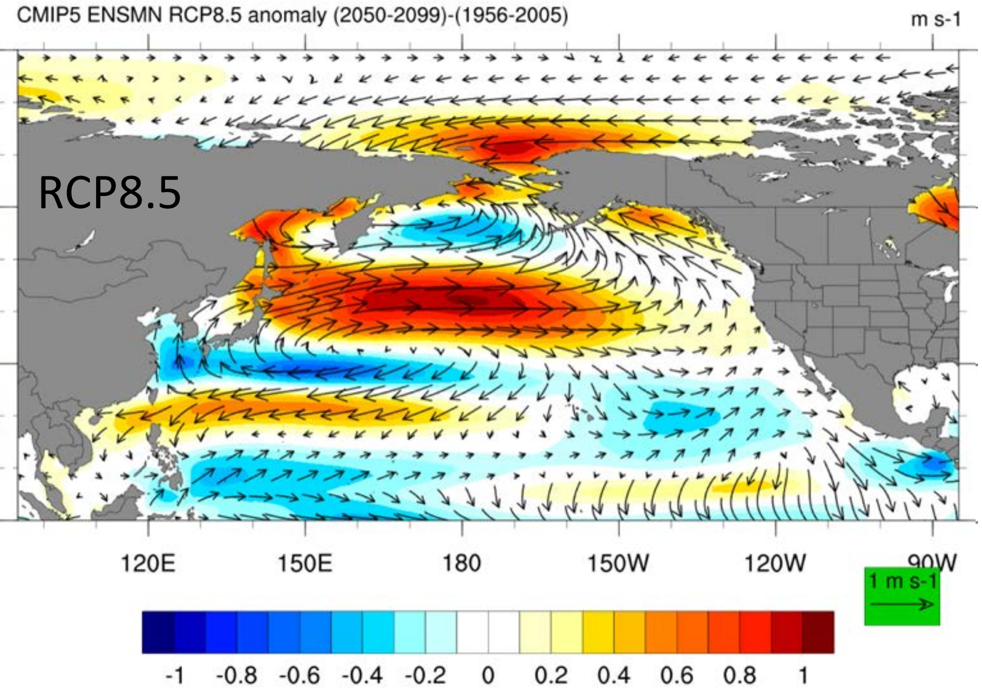


CMIP5 ENSMN JFM Wind Speed anomaly (m/s)
(2050 to 2099) - (1956 to 2005)

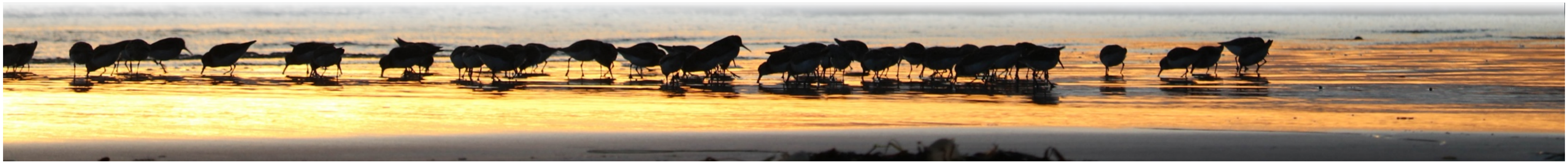
CO2 mitigation scenario



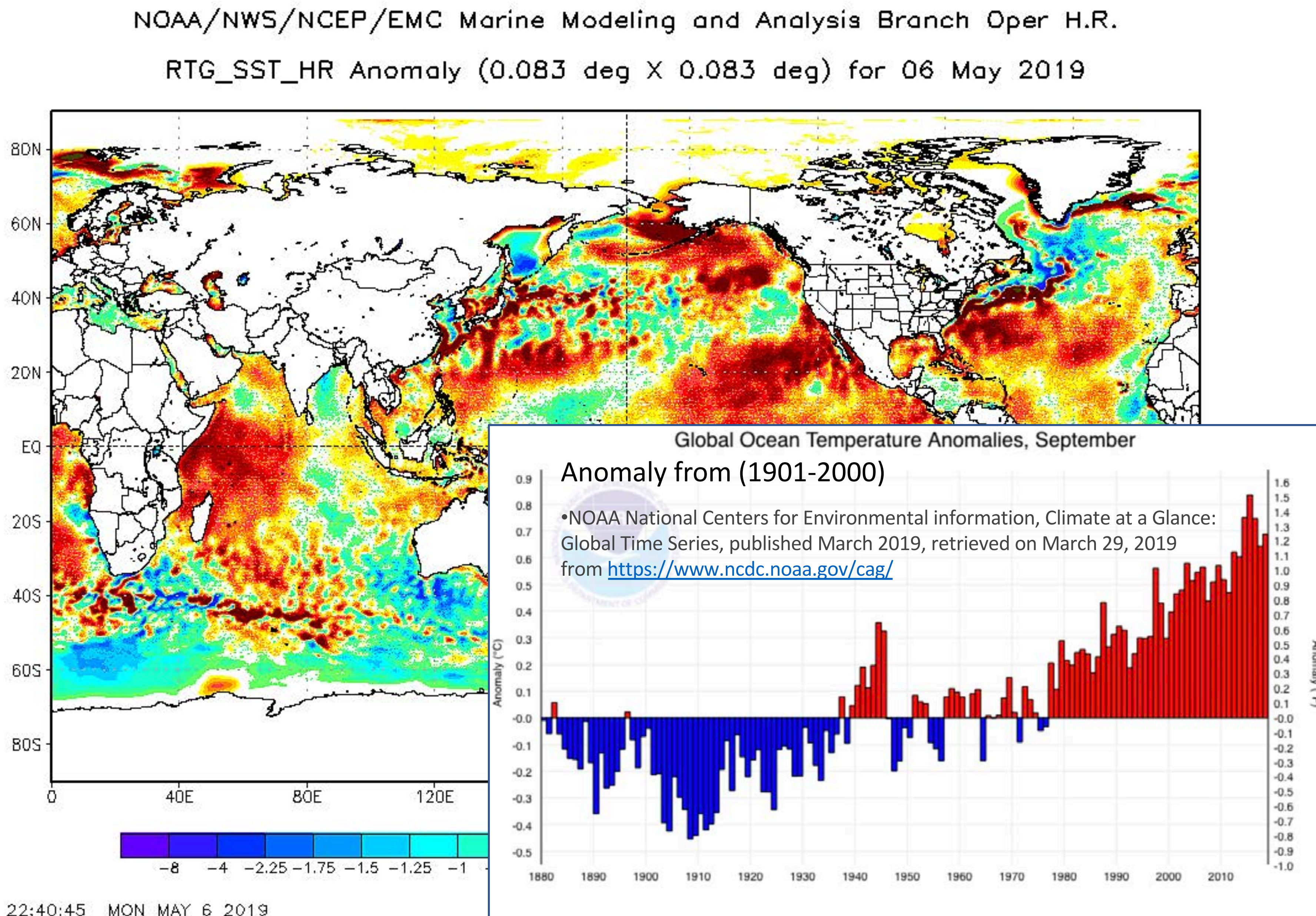
High baseline scenario ("Business as usual")



Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn



Anomaly from 1961-1990 climatology, 1 degree, weekly resolution



Anomaly from (1901-2000)

•NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published March 2019, retrieved on March 29, 2019 from https://www.ncdc.noaa.gov/cag/

http://polar.ncep.noaa.gov/sst/rtg_high_res 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]

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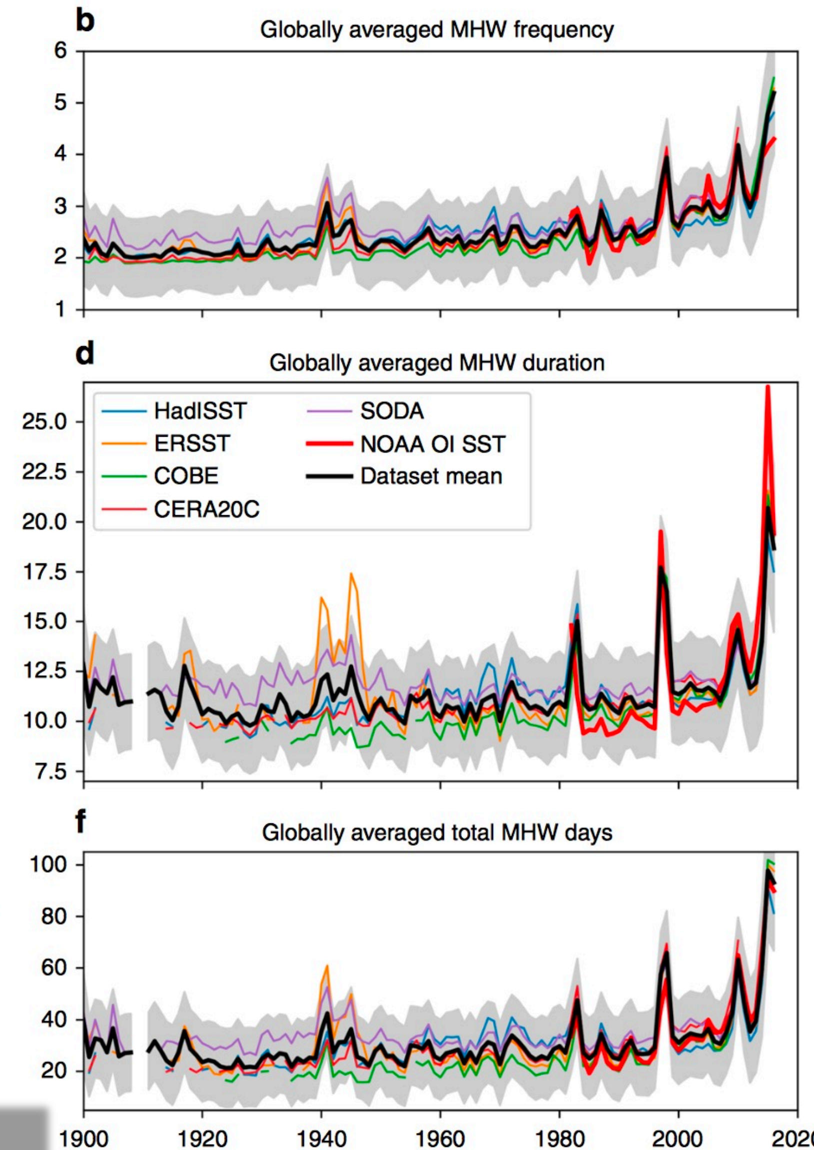
[b] ARC Centre of Excellence for Climate System Science, The University of New South Wales, Sydney, Australia
[c] Climate Change Research Centre, The University of New South Wales, Sydney, Australia
[d] Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB,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

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

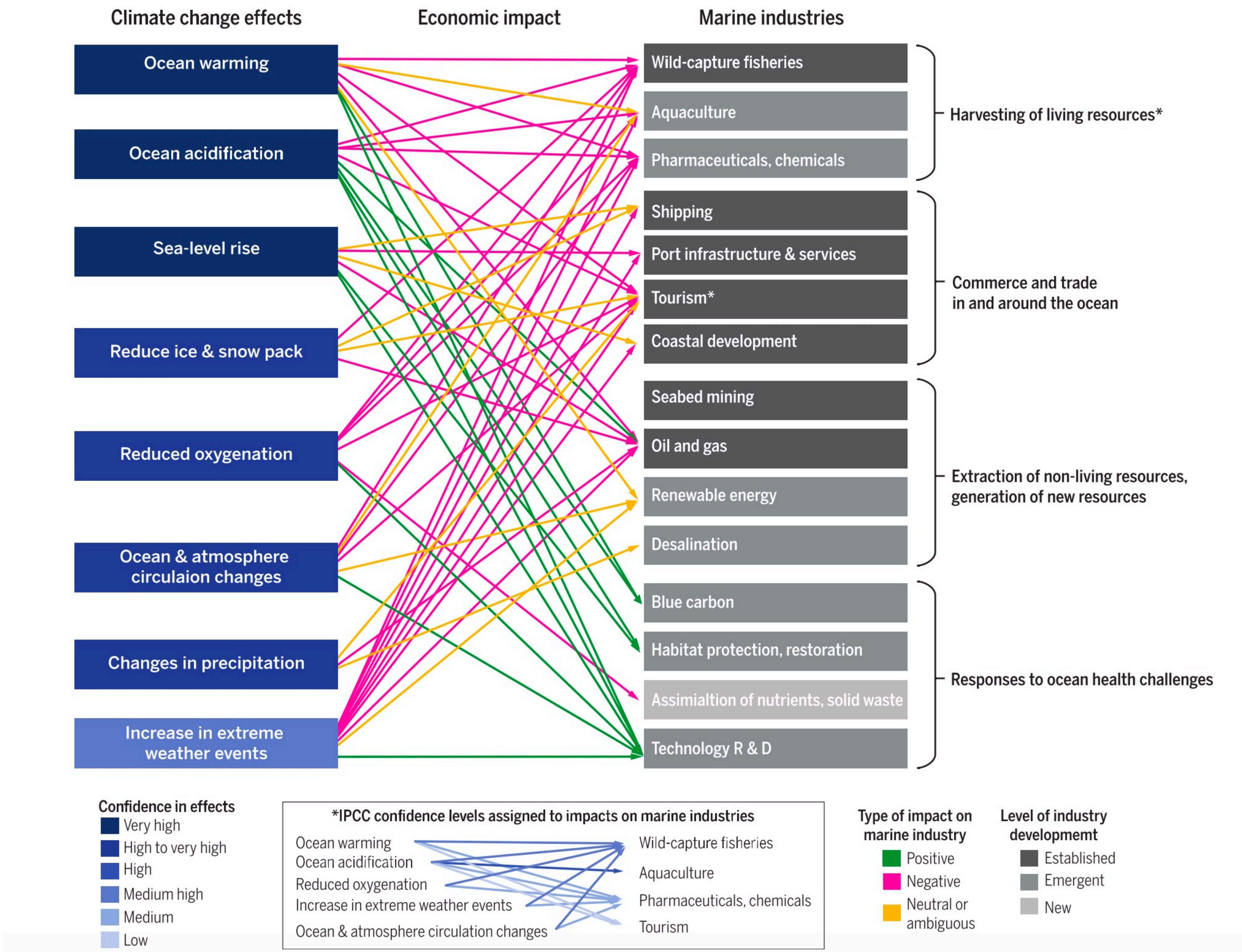
Mean warming not variability drives marine heatwave trends

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.

COMMENT

POLICY Rubric for prioritizing action on the Sustainability Development Goals p.320 | PHYSICS A fond history of the Cavendish, a lab with few rivals p.323 | FILM Biomechanics adviser to *Finding Dory* in conversation p.325 | REPRODUCIBILITY A call to shun predatory journals p.326

MICHAEL D. KOCK

Women from a traditional sea-harvesting community fishing in Mozambique.

Fall in fish catch threatens human health

Christopher Golden and colleagues calculate that declining numbers of marine fish will spell more malnutrition in many developing nations.

How will the 10 billion people expected to be living on Earth by 2050 obtain sufficient and nutritious food? This is one of the greatest challenges humanity faces. Global food systems must supply enough calories and protein for a growing human population and pro-

under five is attributable to undernutrition; nutritional deficiencies are responsible for 50% of years lived with disability in children aged four and under[1].

Fish are crucial sources of micronutrients, often in highly bioavailable forms. And fish populations are declining. Most

Waters'. This new view underlines the need for nutrition-sensitive fisheries policies.

NUTRITIONAL RISK

Presently, 17% of the global population is zinc deficient, with some subpopulations being particularly at risk[1]. Nearly one-fifth of preg-

PLOS | ONE

RESEARCH ARTICLE

Potential impacts of climate-related decline of seafood harvest on nutritional status of coastal First Nations in British Columbia, Canada

Lesya Marushka[1], Tiff-Annie Kenny[1], Malek Batal[2], William W. L. Cheung[3,4], Karen Fediuk[5], Christopher D. Golden[6,7], Anne K. Salomon[8], Tonio Sadik[9], Lauren V. Weatherdon[10], Hing Man Chan[1]*

1 Biology Department, University of Ottawa, Ottawa, Ontario, Canada, **2** Nutrition Department, Faculty of Medicine, Université de Montréal, Pavillon Liliane de Stewart, Montreal, Québec, Canada, **3** Changing Ocean Research Unit, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, British Columbia, Canada, **4** Nippon Foundation-UBC Nereus Program, Institute for the Oceans and Fisheries, University of British Columbia, Vancouver, British Columbia, Canada, **5** Dietitian and Nutrition Researcher, Victoria, British Columbia, Canada, **6** Department of Environmental Health, Harvard TH Chan School of Public Health, Boston, Massachusetts, United States of America, **7** Harvard University Center for the Environment, Cambridge, Massachusetts, United States of America, **8** School of Resource & Environmental Management, Simon Fraser University, Burnaby, British Columbia, Canada, **9** Assembly of First Nations, Ottawa, Ontario, Canada, **10** UN Environment World Conservation Monitoring Centre, Cambridge, United Kingdom

* laurie.chan@uottawa.ca

Check for updates

Citation: Marushka L, Kenny T-A, Batal M, Cheung WWL, Fediuk K, Golden CD, et al. (2019) Potential

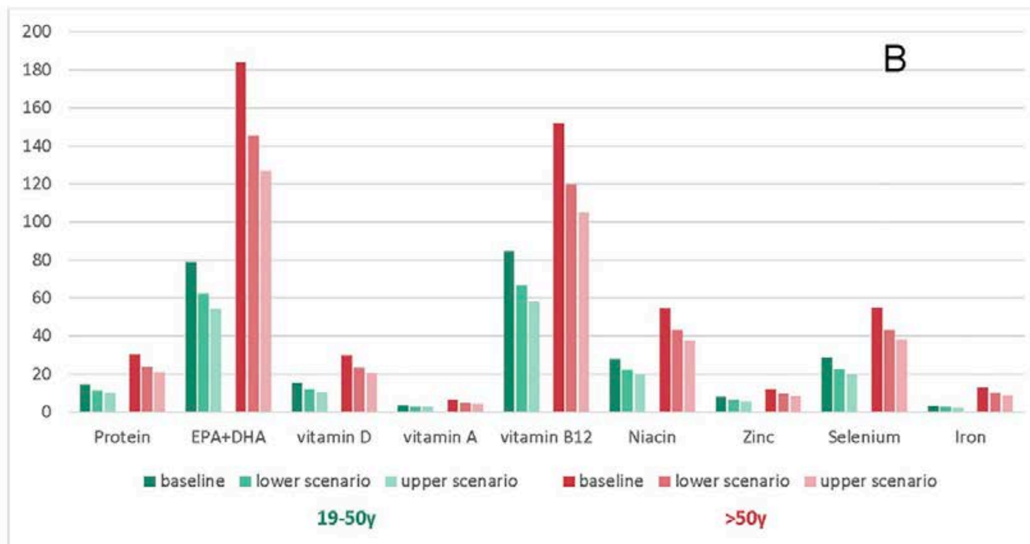
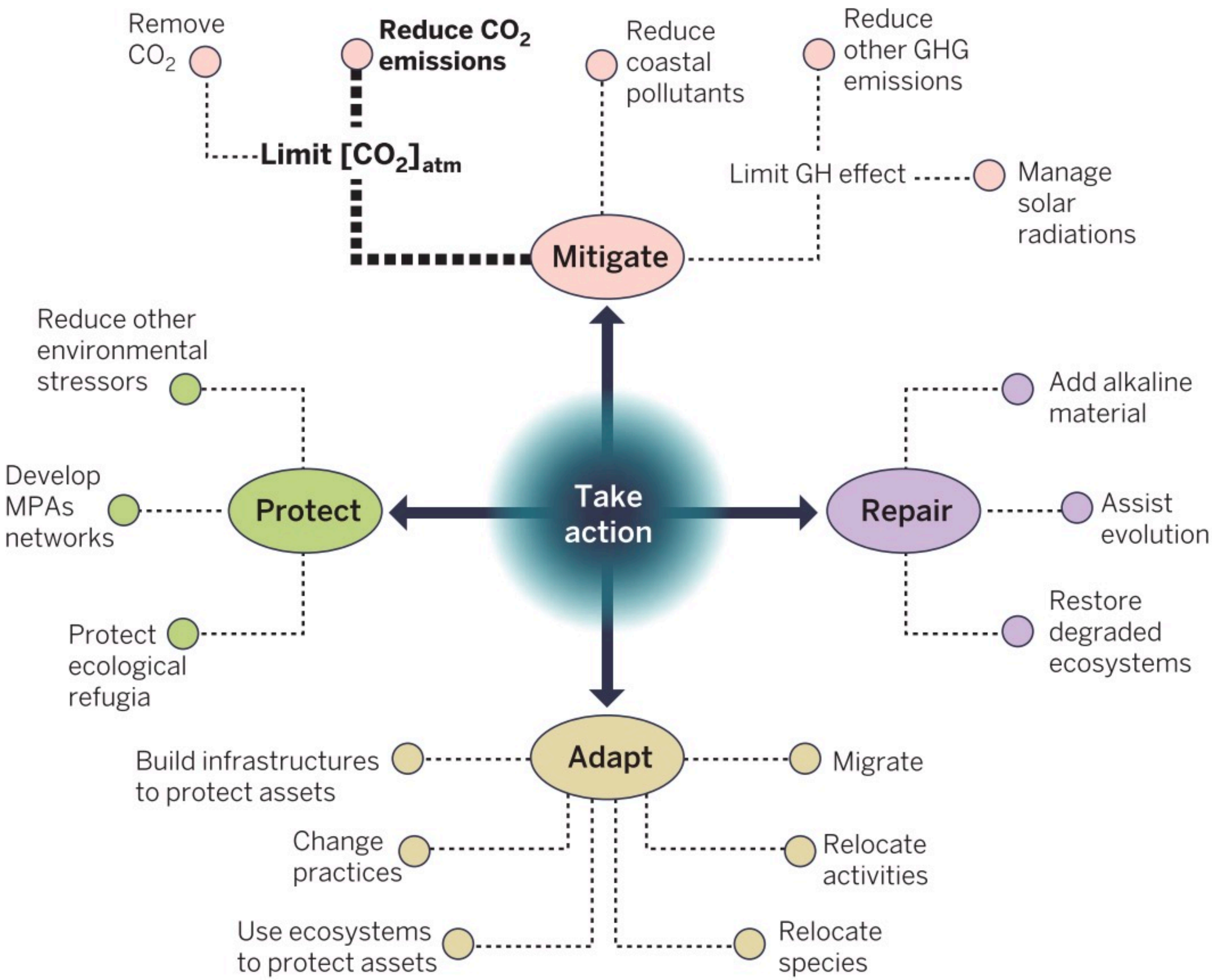


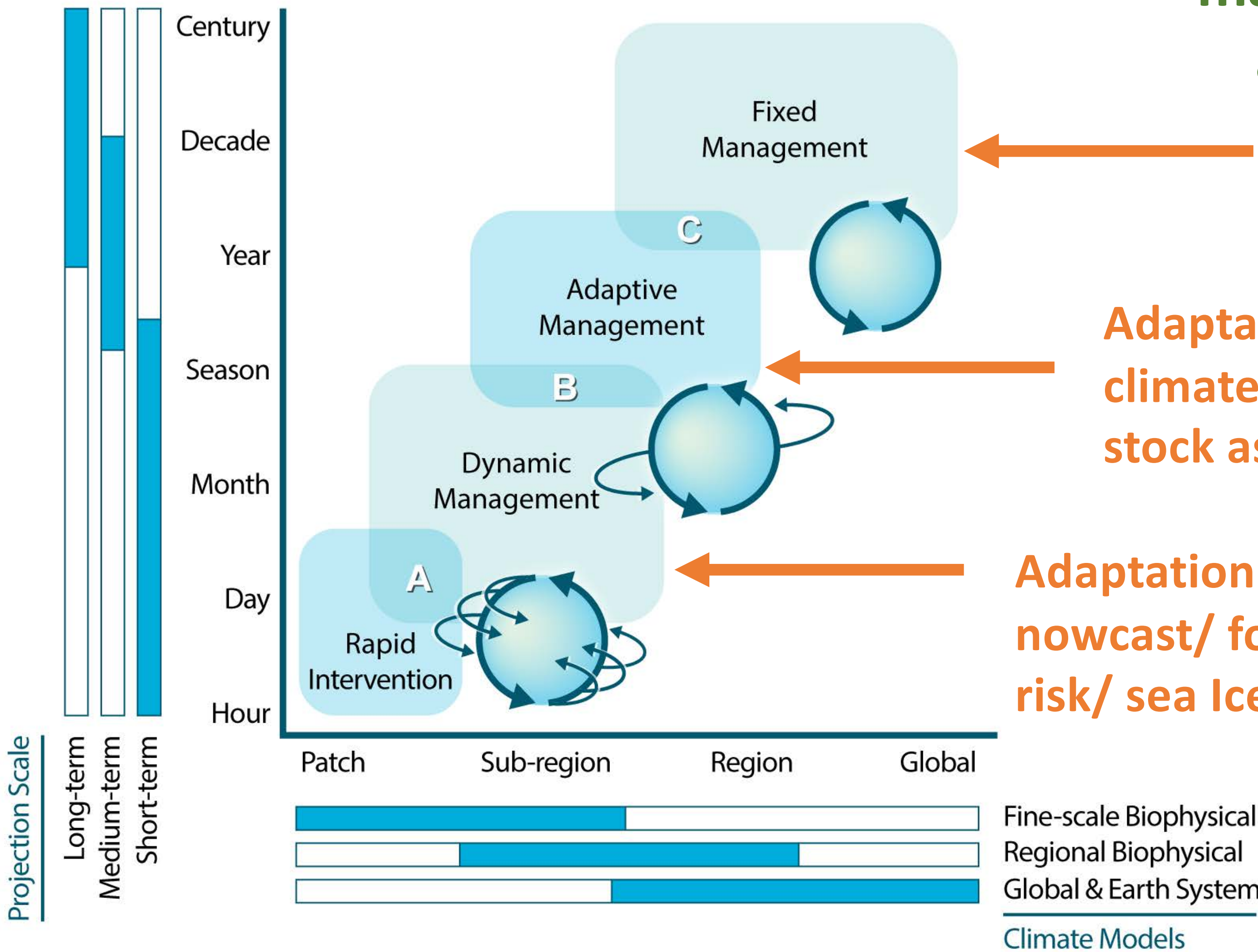
Fig 4. Baseline and projected percentage contributions to the DRI from total seafood in First Nations by (A) gender and (B) by age groups, under 'strong mitigation' (RCP 2.6) and 'business-as-usual' (RCP 8.5) climate change scenarios. DRI—dietary reference intakes using recommended dietary allowance (RDA) and recommended intake (RI) for EPA+DHA.

https://doi.org/10.1371/journal.pone.0211473.g004



Gattuso et al. (2015). Contrasting futures for ocean and society from different anthropogenic CO 2 emissions scenarios. Science, 349(6243), aac4722. https://doi.org/10.1126/science.aac4722

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

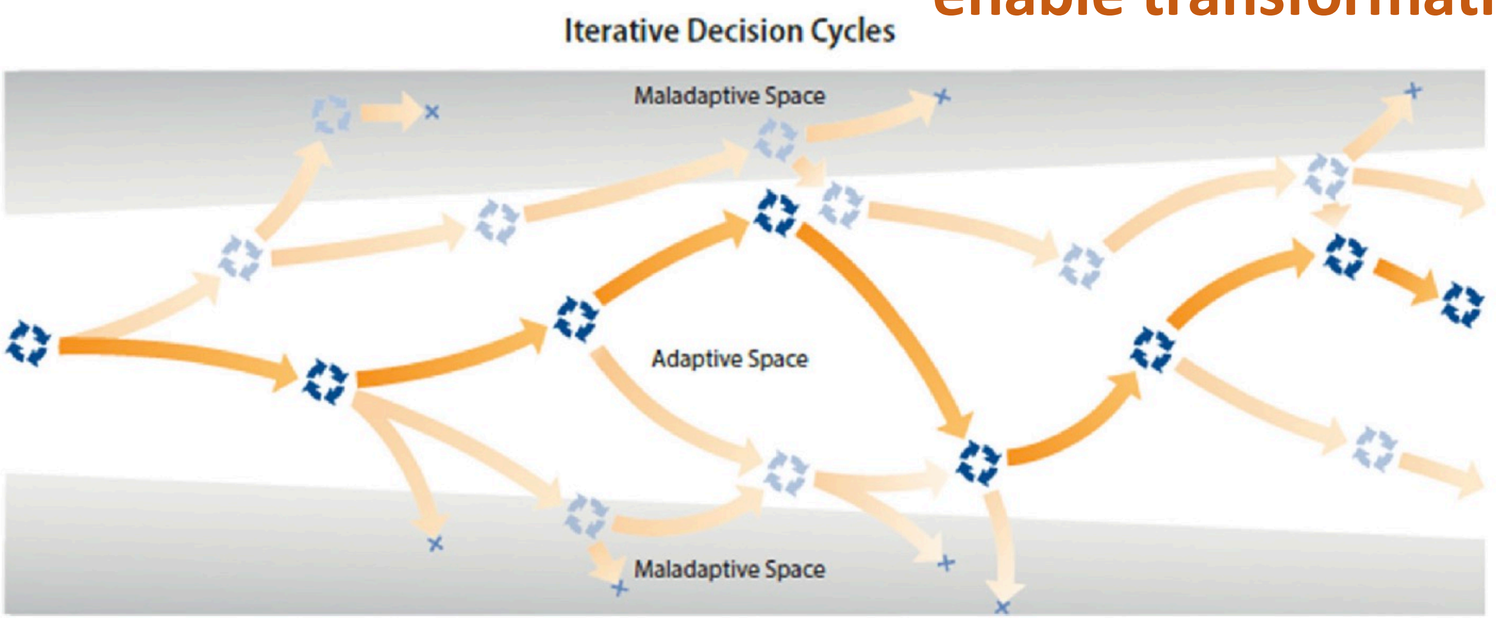


Fig. 1 from Wise et al. 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change 28: 325–336

‘Adaptation Pathways’

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

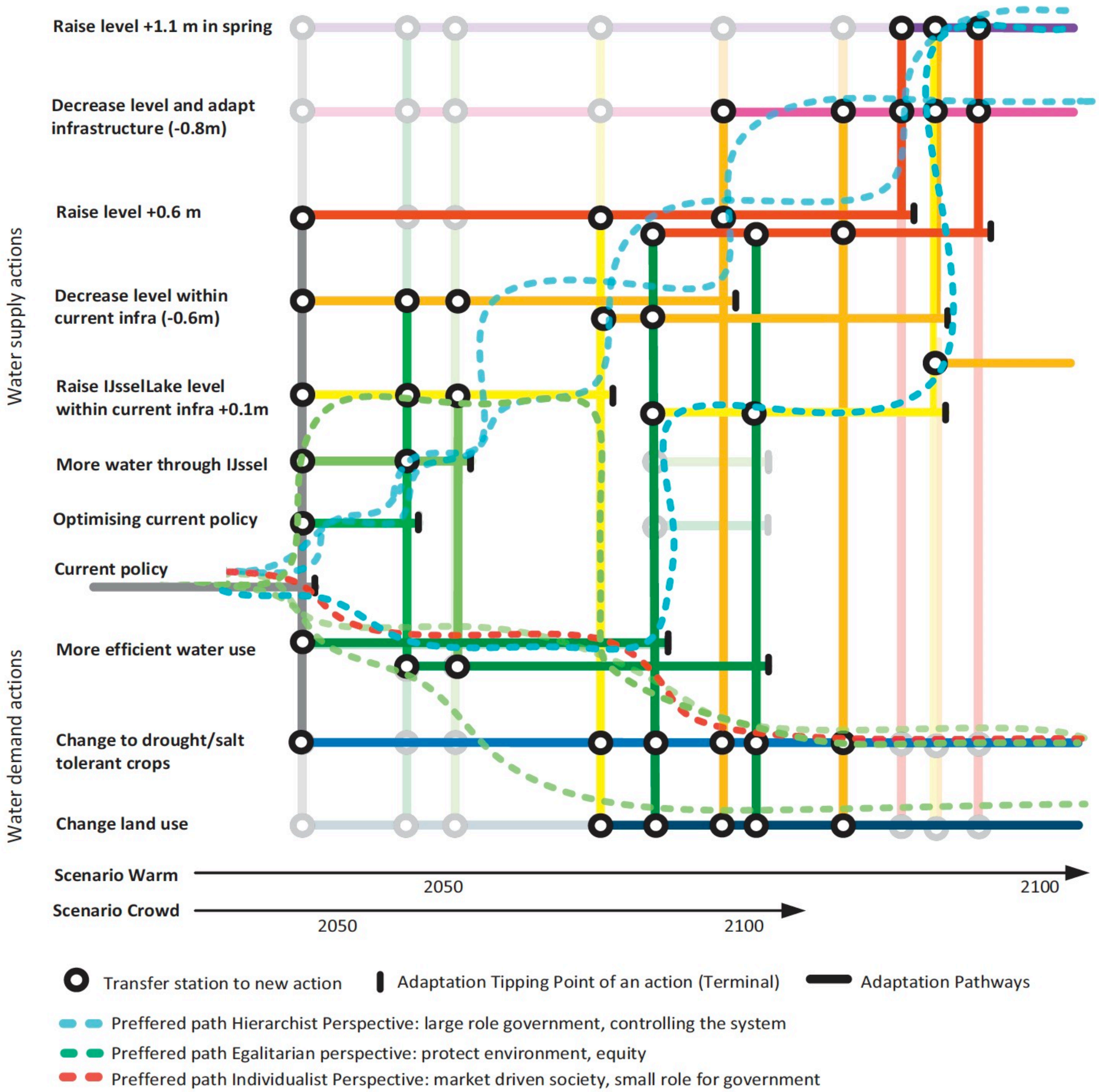


Fig. 7. Adaptation pathways map with preferred pathways for three different perspectives.

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

HOW?

‘Adaptive Policymaking’

Every 5 Yr

Annually

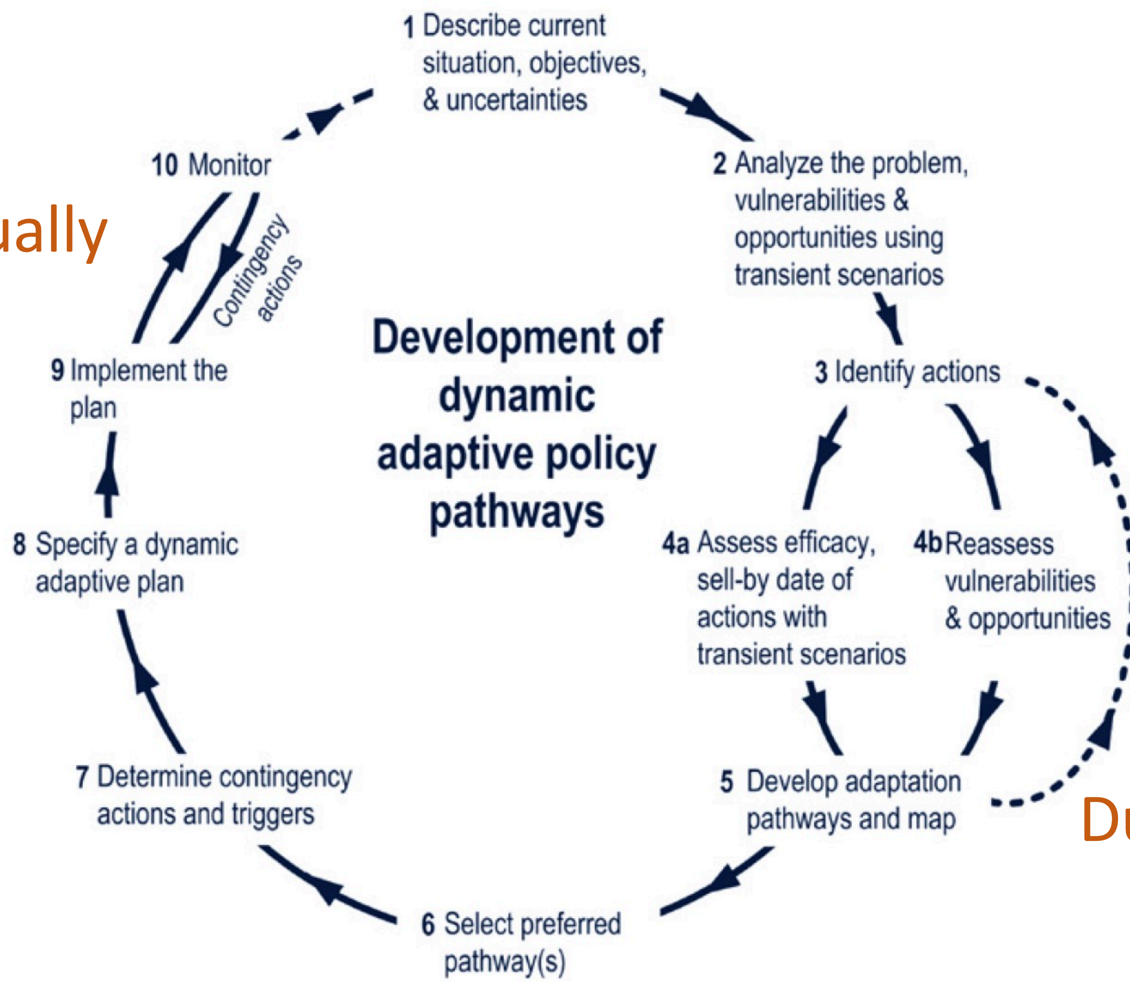


Fig. 4. The Dynamic Adaptive Policy Pathways approach.

Annually
During Module

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

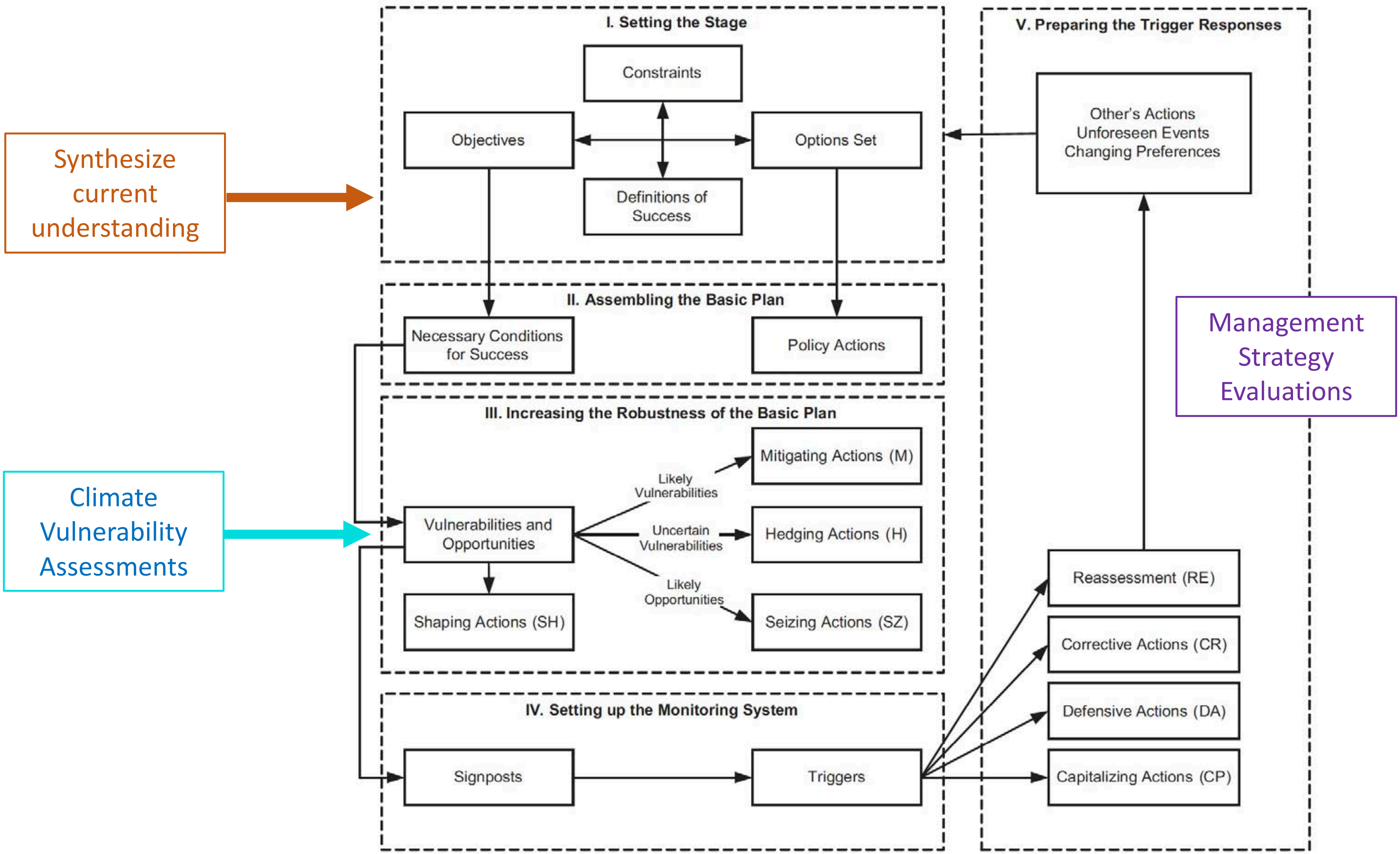


Fig. 3. The Adaptive Policymaking approach to designing a dynamic adaptive plan (Kwakkel et al., 2010a).

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

Marine Policy 97 (2018) 101–108

Contents lists available at ScienceDirect

Marine Policy

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

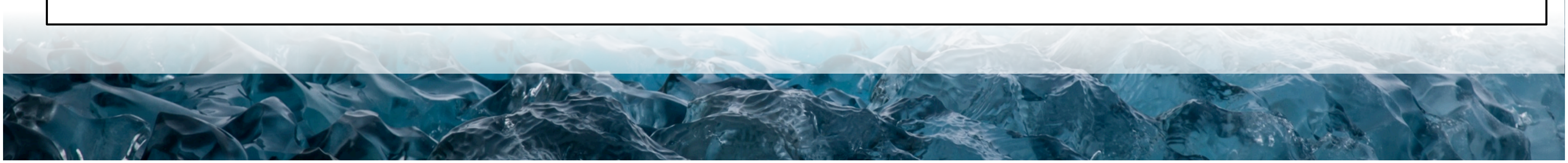
An Indigenous approach to ocean planning and policy in the Bering Strait region of Alaska

Julie Raymond-Yakoubian[a,*], Raychelle Daniel[b]

[a] Kawerak Incorporated, PO Box 948 Nome, AK 99762, United States
[b] The Pew Charitable Trusts, 901 E Street NW, Washington DC 20004, United States

Table 1
Ocean values from the Bering Strait region and example applications to the governance and decision-making component of ocean planning.

Ocean Values	Example	Application to ocean planning
Ecosystem	Knowledge of food web connections	Along with science, provides the knowledge base to better understand impacts
Health and well-being	Time on the water observing and hunting marine mammals	Informing vessel traffic routing measures
Economic	Walrus ivory carving	Provides means and ability to actively participate in walrus management
Cultural	Knowledge of ocean currents	Ability to effectively plan for and respond to maritime disasters



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UNITED STATES DEPARTMENT OF COMMERCE

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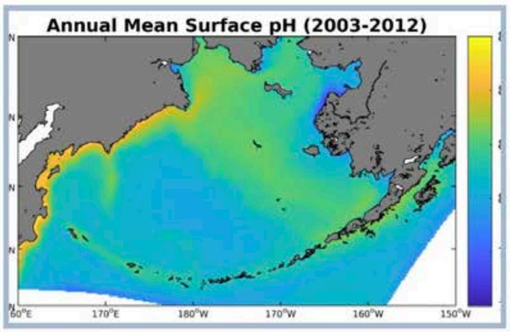
Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea



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

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

In this paper, the authors developed a computational m

ICES Journal of Marine Science

ICES CIEM — International Council for the Exploration of the Sea — Conseil International pour l'Exploration de la Mer

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

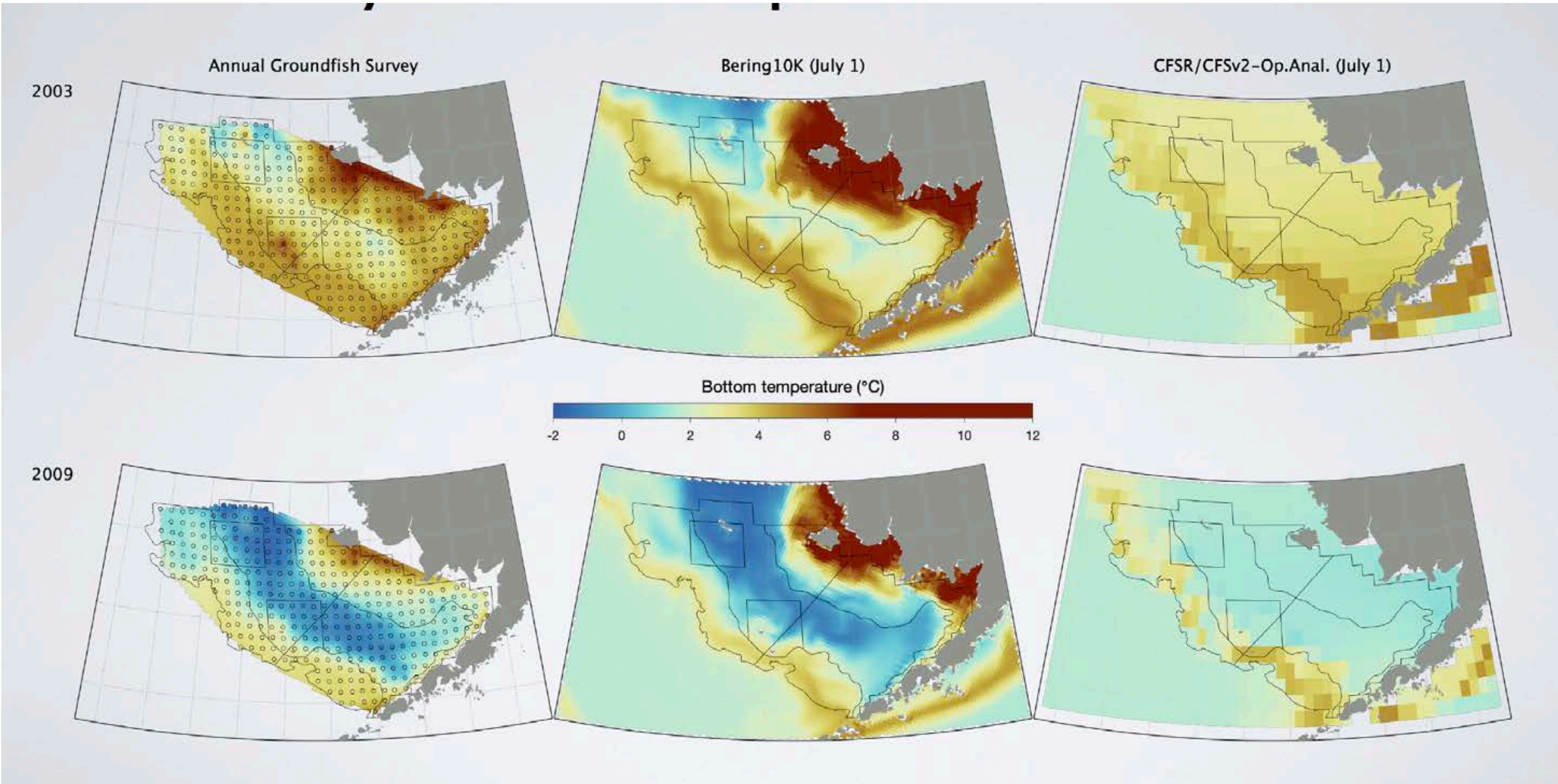
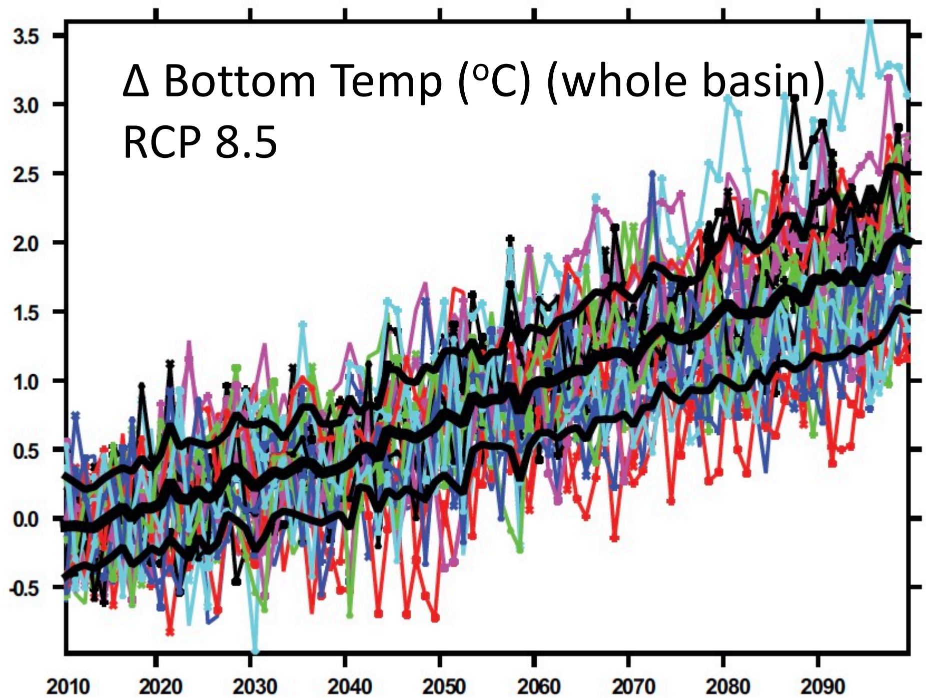
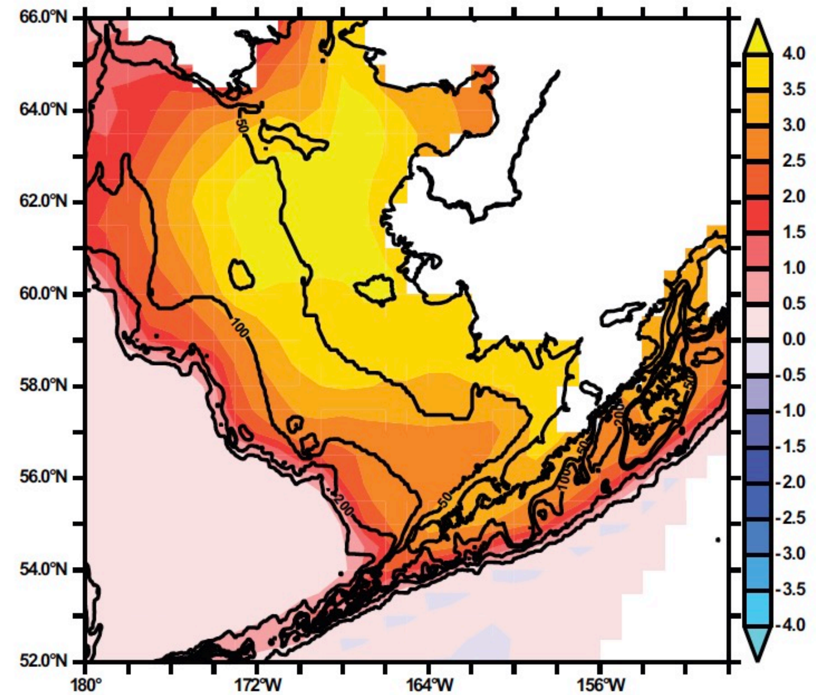


Image: Kelly Kearney

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





(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

Declines in large zooplankton
(2090-2099)-(2010-2019)

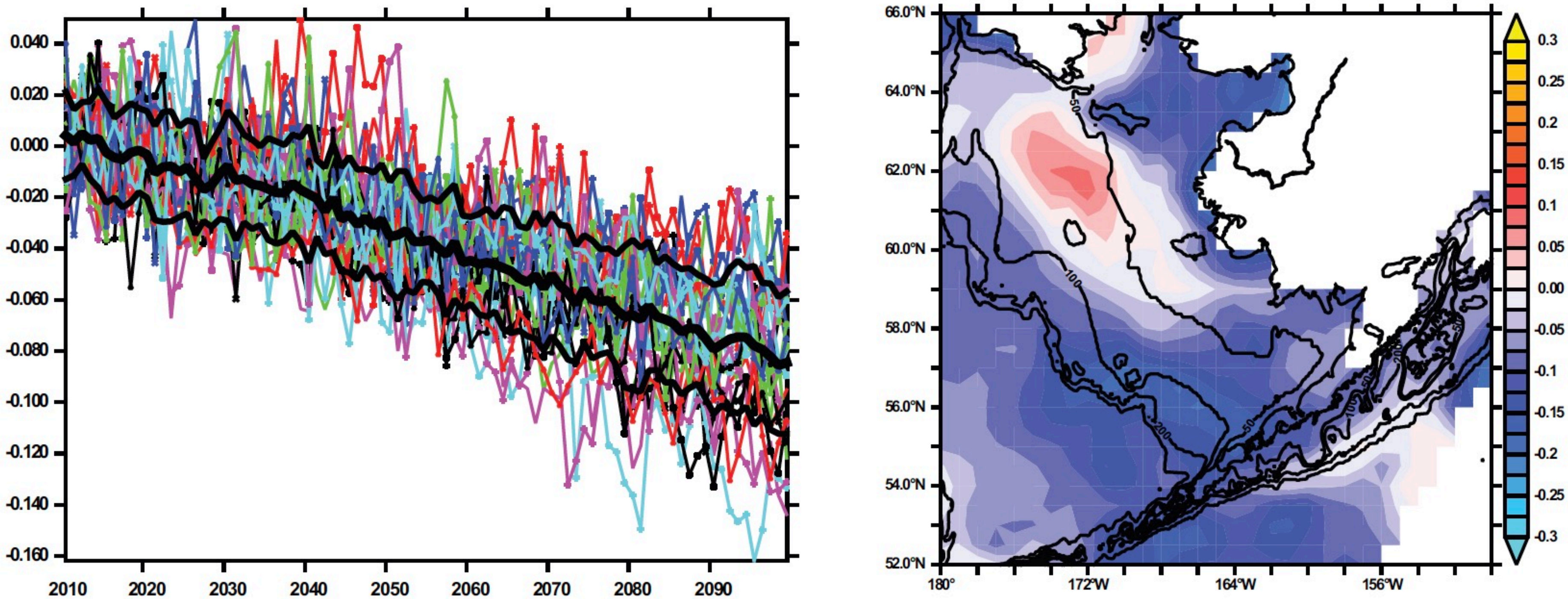
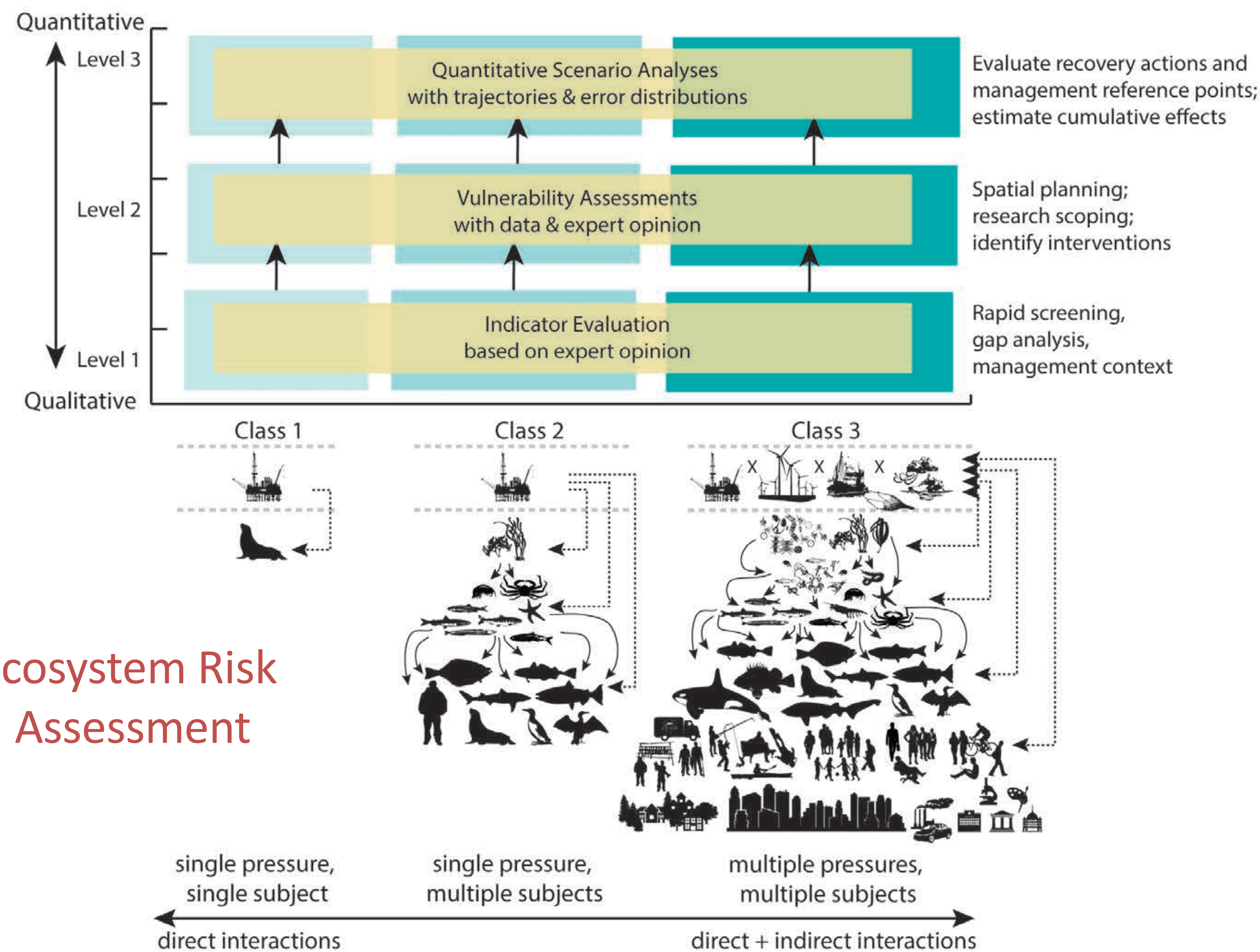


Figure 13. Ensemble results as in Figure 12, for $\log_{10}$ (large crustacean zooplankton).

(in press) 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



Ecosystem Risk Assessment

Holsman et. al 2017. An ecosystem-based approach to marine risk assessment. Ecosystem Health and Sustainability 3(1):e01256. *10.1002/ehs2.1256*

Methodology – Framework

Species Vulnerability

Exposure

- 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

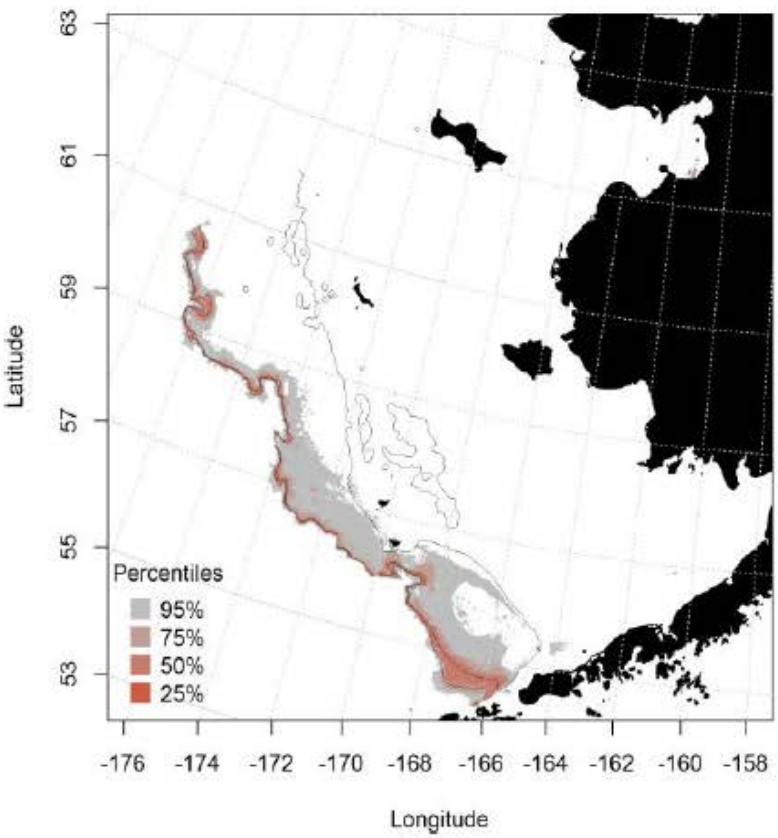
Sensitivity

- 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

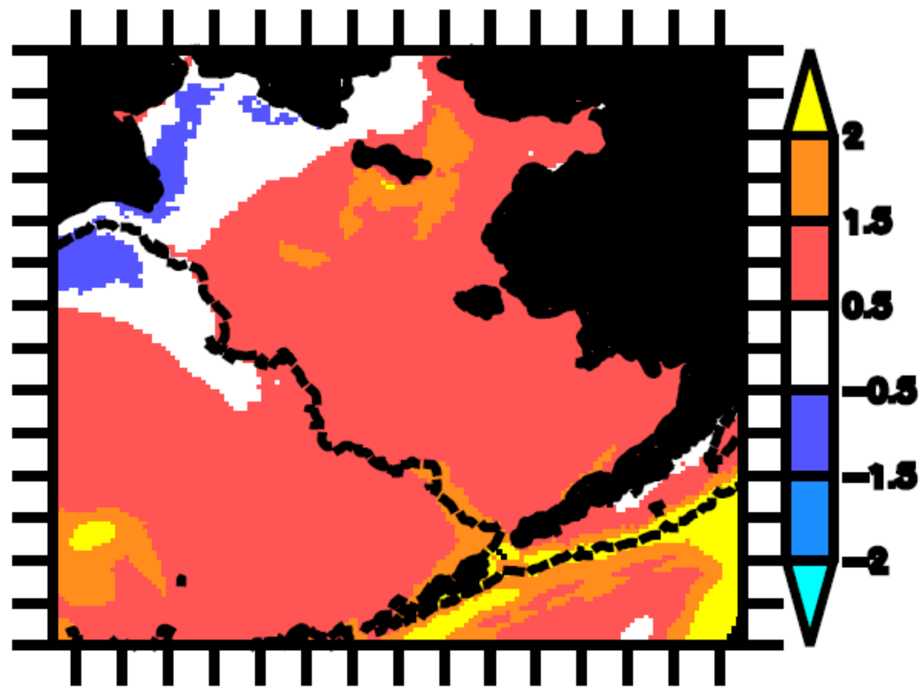
Slide credit: P. Spencer

Exposure scoring, general methodology

Compare maps of exposure factors to maps of stock distributions and qualitatively estimate their overlap. Example for Pacific ocean perch shown below



Z-score for annual bottom temperature



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

Potential next step – linking to social-economic variables

For northeast US study, information on the species composition of different fishing ports was combined with species vulnerability to estimate vulnerability of fishing communities (Colburn et al 2016)

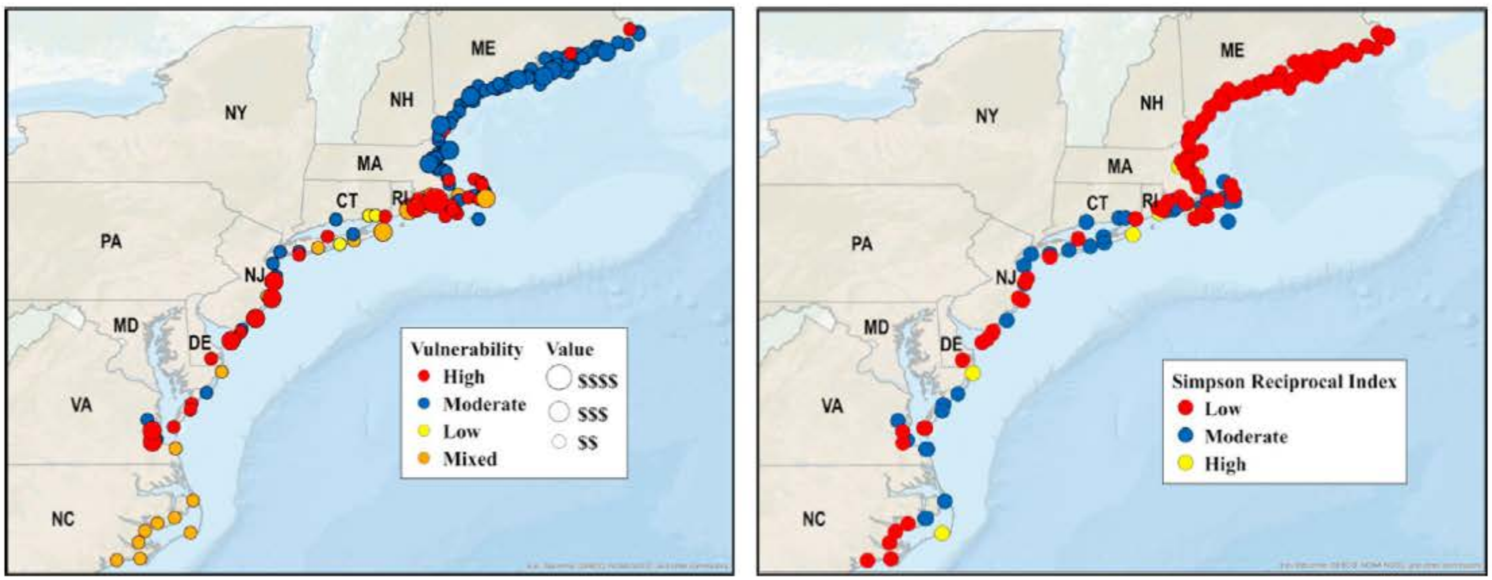
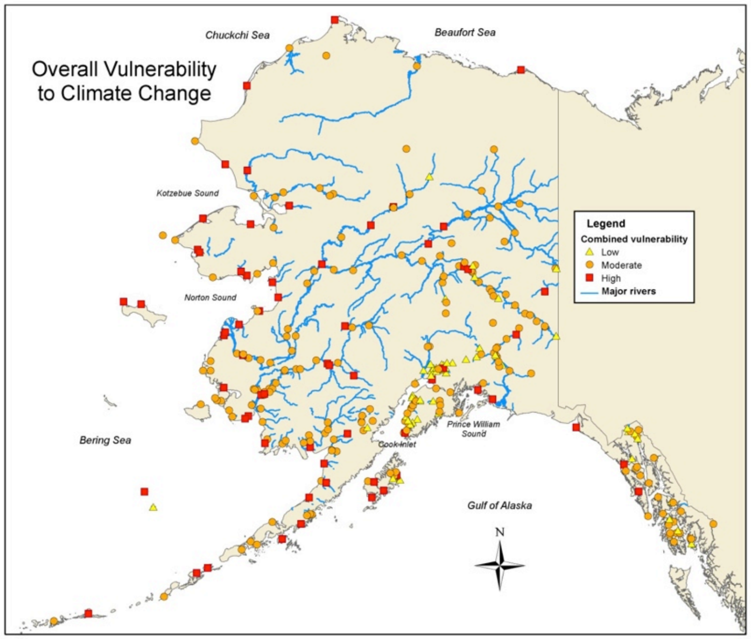


Fig. 6. New England and Mid-Atlantic Fishing communities' climate vulnerability classification based on categories of dependence on vulnerable species (left), and catch diversity scores (Simpson's Reciprocal Index (right)). Only communities with total landings value of 100 thousand dollars or more were mapped.

OA Risk Assessment



Himes-Cornell and Kaspersky 2014

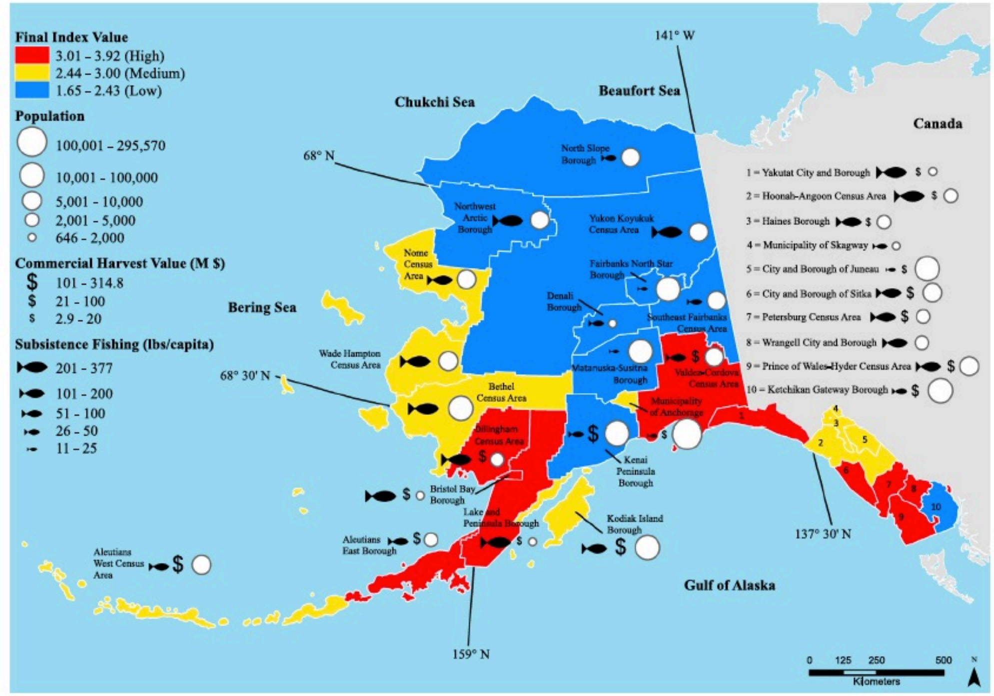


Fig. 11. Individual components of the final ocean acidification risk index for each census area.

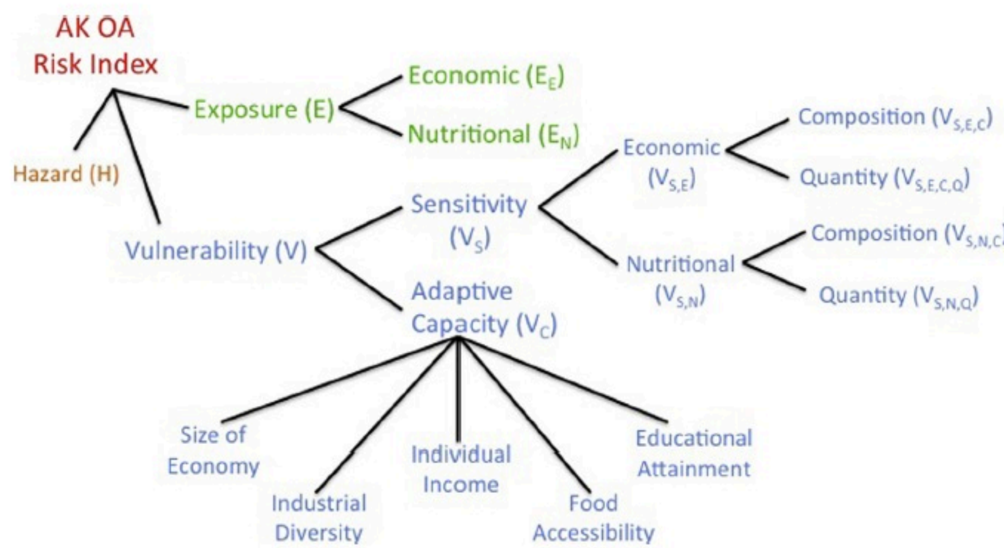


Fig. 3. Components of the risk index. Each branch is evenly weighted relative to others at the same level.

Vulnerability of Arctic marine mammals to vessel traffic in the increasingly ice-free Northwest Passage and Northern Sea Route

Donna D. W. Hauser[a,1,2], Kristin L. Laidre[a], and Harry L. Stern[a]

[a]Polar Science Center, Applied Physics Laboratory, University of Washington, Seattle, WA 98105

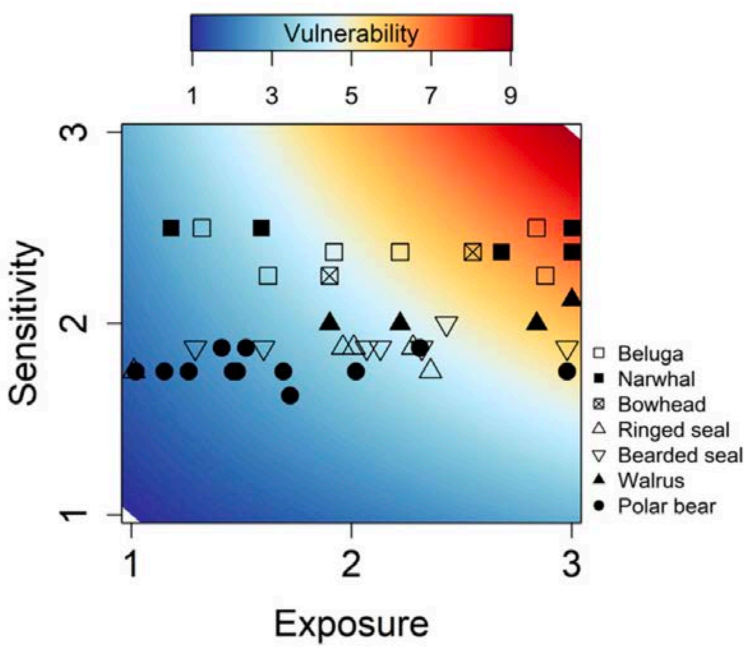


Fig. 2. Vulnerability plot expressing sensitivity and exposure scores across Arctic marine mammal subpopulations exposed to the Northwest Passage or Northern Sea Route. Vulnerability is the product of exposure and sensitivity.

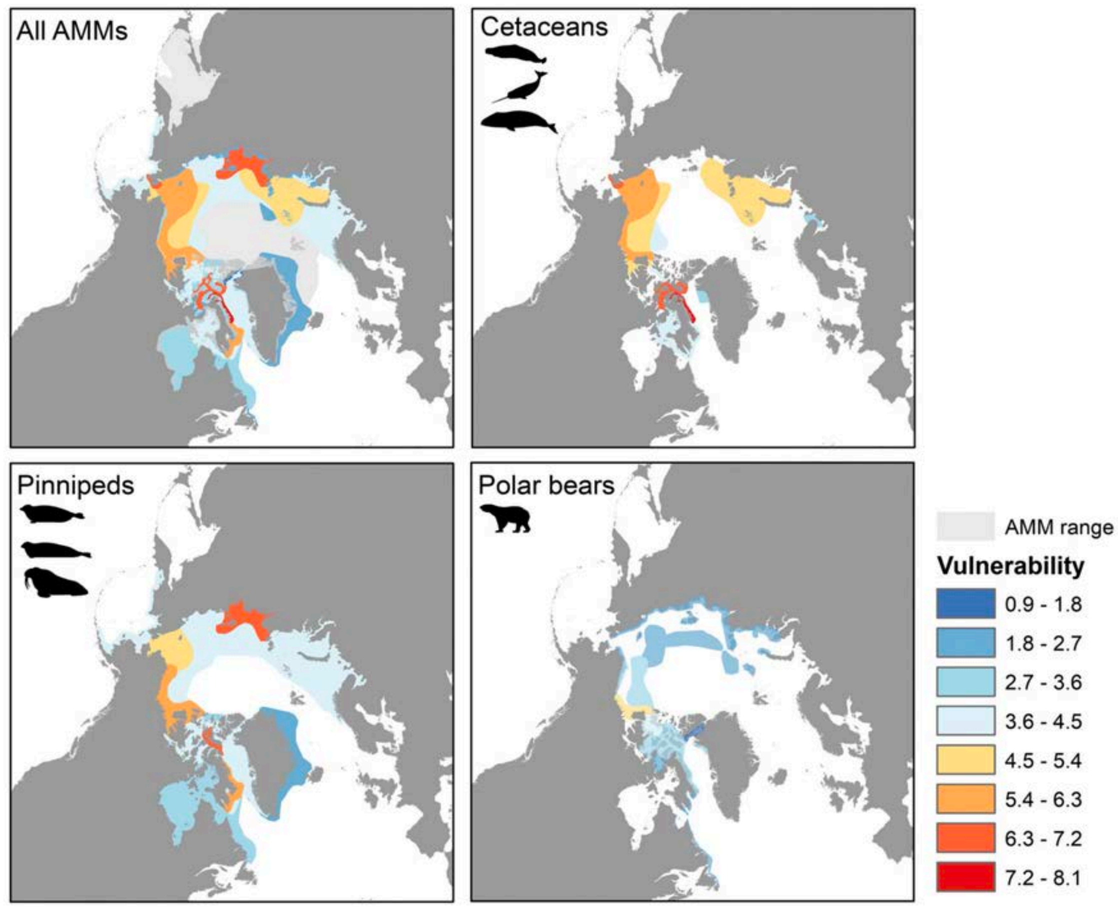


Fig. 4. Maximum vulnerability scores for all AMM species (*Top Left*) and taxonomic groups exposed to the Arctic sea routes. Vulnerability color shading corresponds to the vulnerability plot in Fig. 2. The combined ranges of all other AMM subpopulations that did not overlap the Arctic sea routes are shown in gray in the *Top Left*, including portions of polar bear subpopulations that range onto land during the open-water period.

Marine Policy 51 (2015) 119–127

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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

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Table 2

Categories of regulatory implementation. Although mandatory measures are not necessarily dependent on having voluntary measures in place (and domestic measures are not required prior to international measures), in practice the development of regulations typically starts with voluntary and domestic measures and moves on from there.

Category of implementation	*To whom the measures apply*	*Effectiveness at reducing risk*
Voluntary	All vessels, but with no enforcement power	Depends on compliance, but there is likely to be pressure to comply Can be enhanced if insurers and others regard such measures as appropriate standards of care Can be enhanced by monitoring and communication
Mandatory (domestic)	Vessels addressed by the regulations that are either (a) registered in the country issuing the regulations, or (b) traveling to or from a port in that country	Depends on the proportion of vessels in the area that are subject to the regulations Other vessels may comply voluntarily or be required to do so by insurers Can be enhanced by monitoring and enforcement
Mandatory (international)	All vessels addressed by the regulations	Compliance can be enhanced by monitoring and enforcement

HOW?

c) Operationalized climate change management strategy evaluations (MSEs)

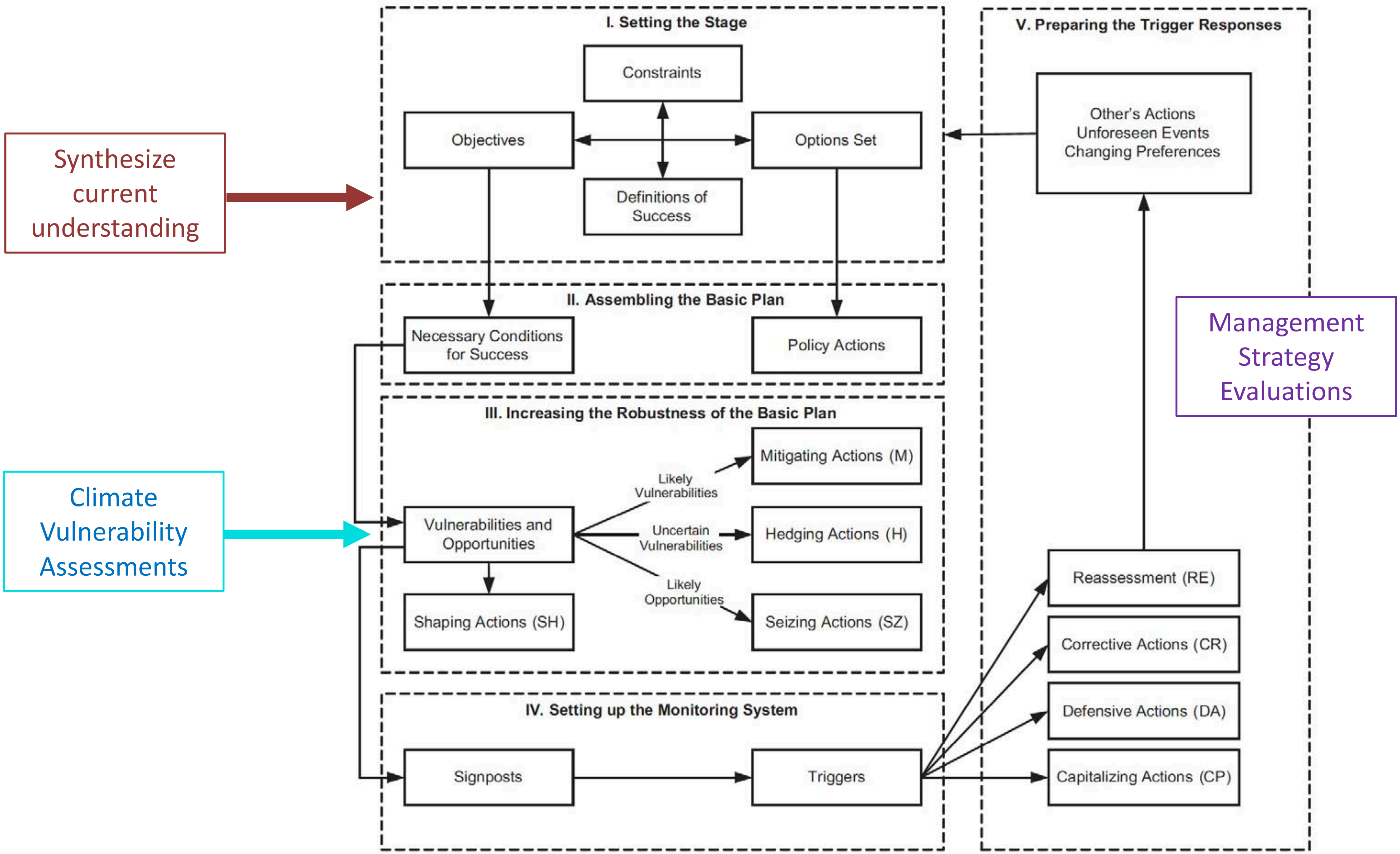
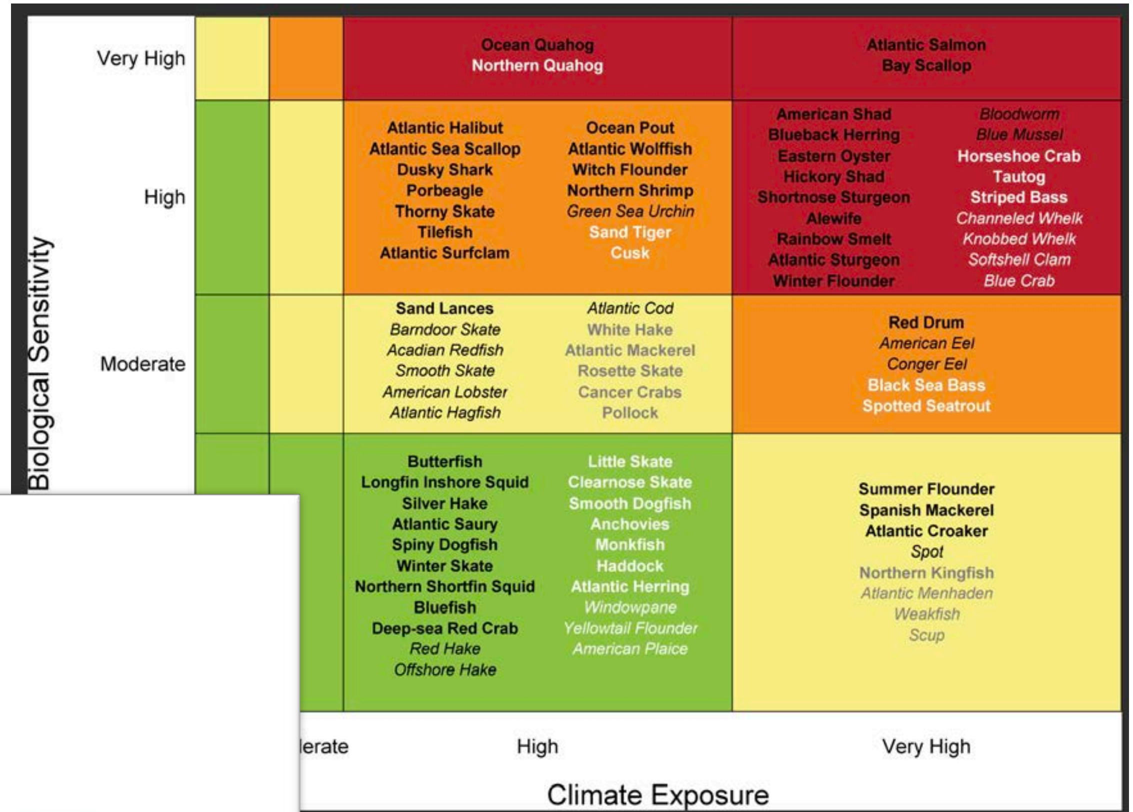
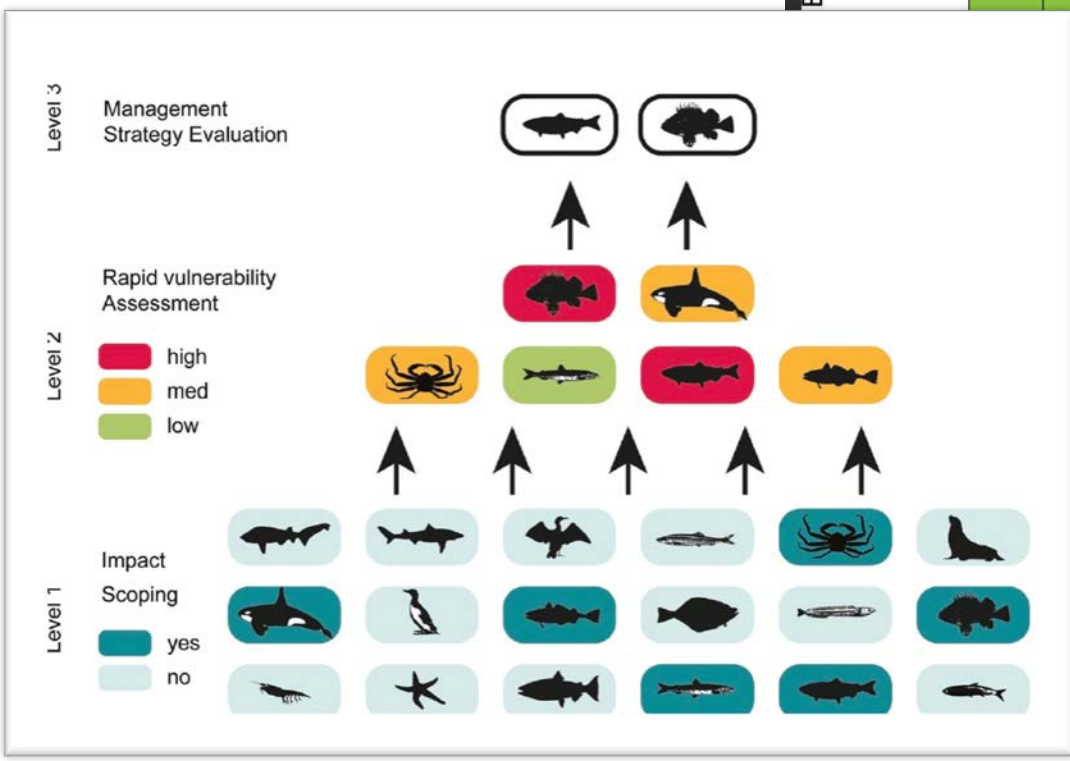


Fig. 3. The Adaptive Policymaking approach to designing a dynamic adaptive plan (Kwakkel et al., 2010a).

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

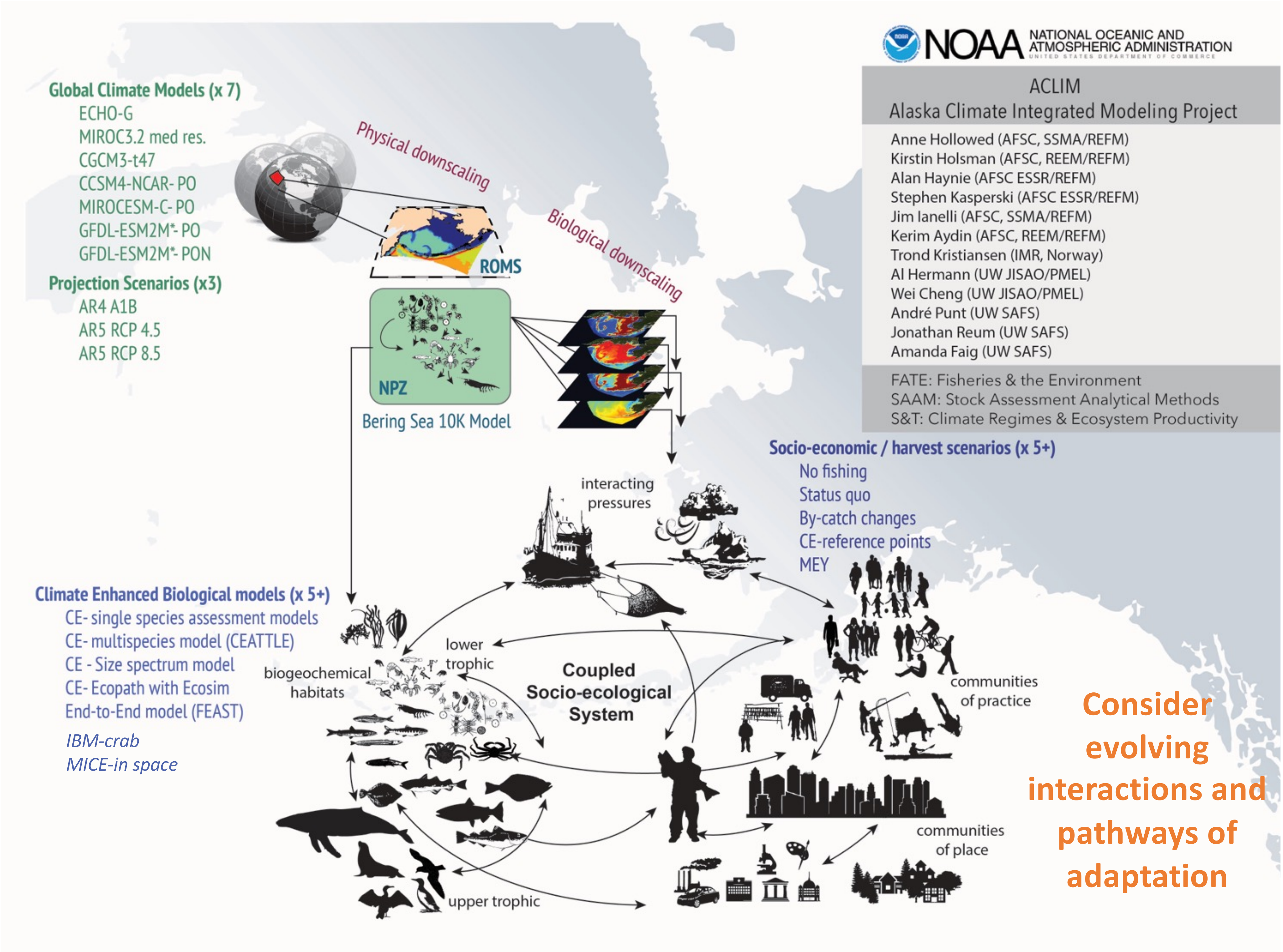
Examples:





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
Physical downscaling
ROMS
Biological downscaling
NPZ
Bering Sea 10K Model
Socio-economic / harvest scenarios (x 5+)
No fishing
Status quo
By-catch changes
CE-reference points
MEY
interacting pressures
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
lower trophic
biogeochemical habitats
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic
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

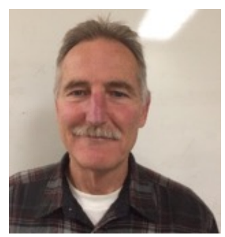

Kelly Kearney

Buck Stockhausen


Paul Spencer


Michael Dalton


Darren Pilcher


Tom Wilderbuer


Cody Szuwalski

Jim Thorson

Ingrid Spies

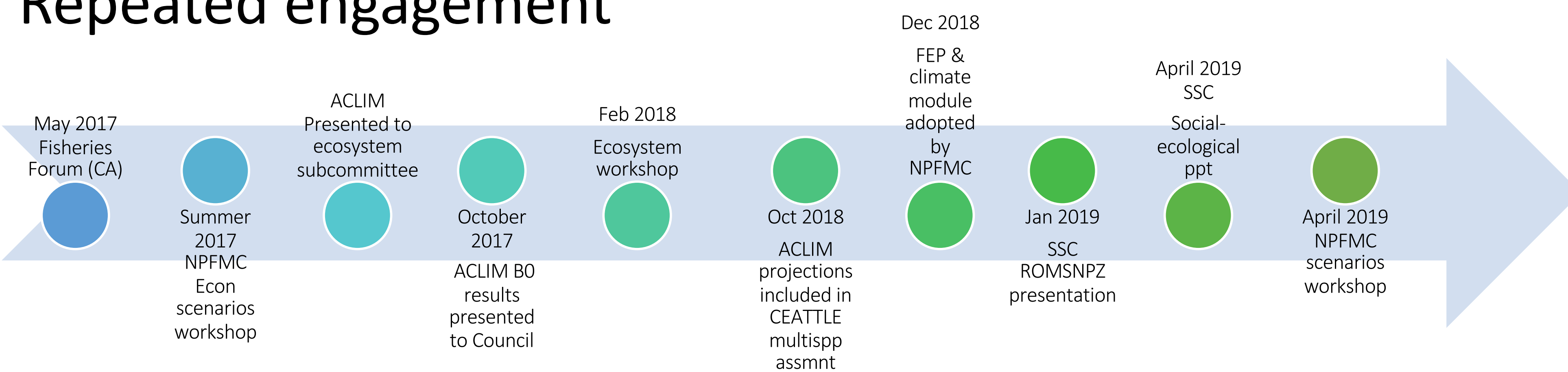
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project

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



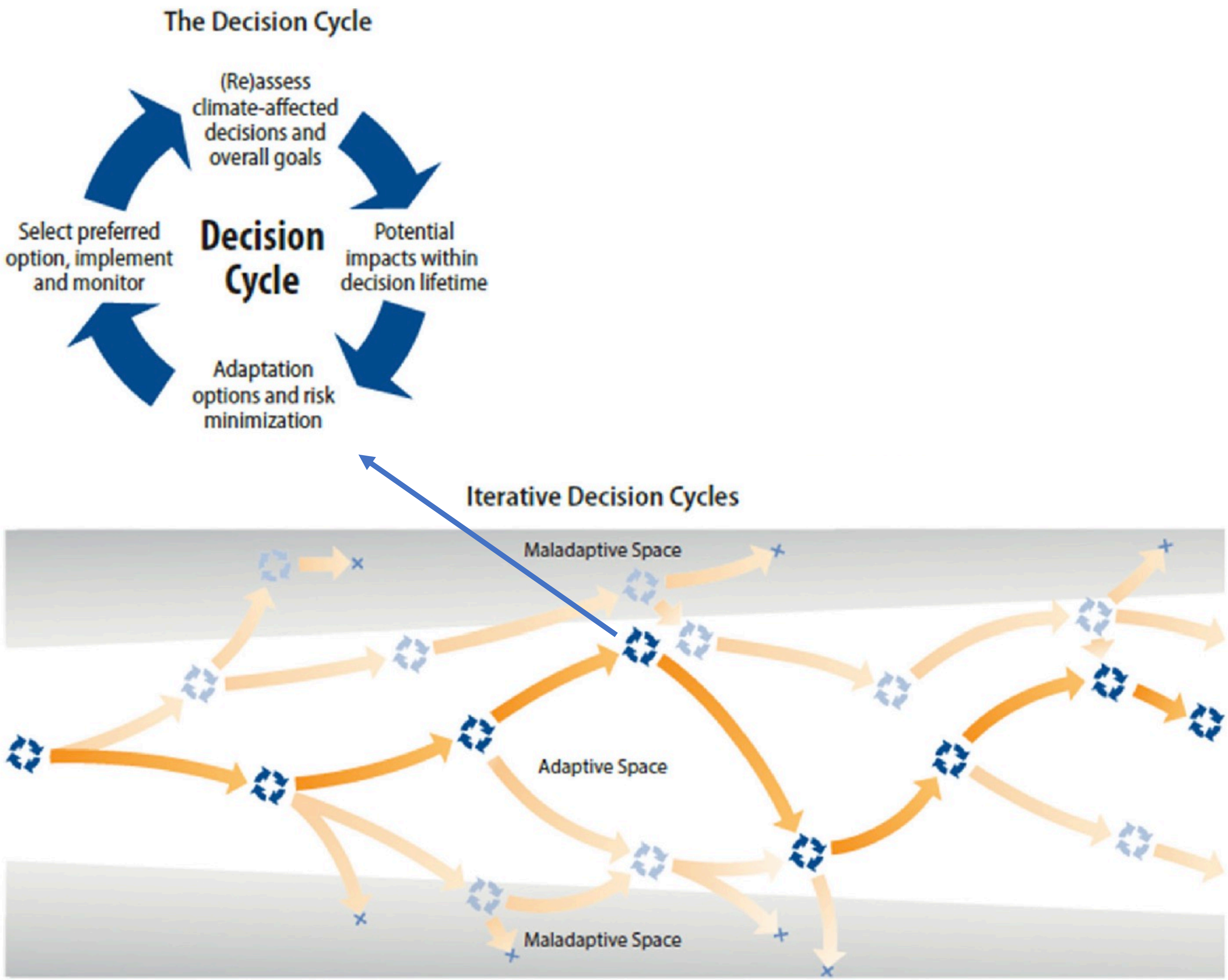


Fig. 1 from Wise et al. 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change 28: 325–336

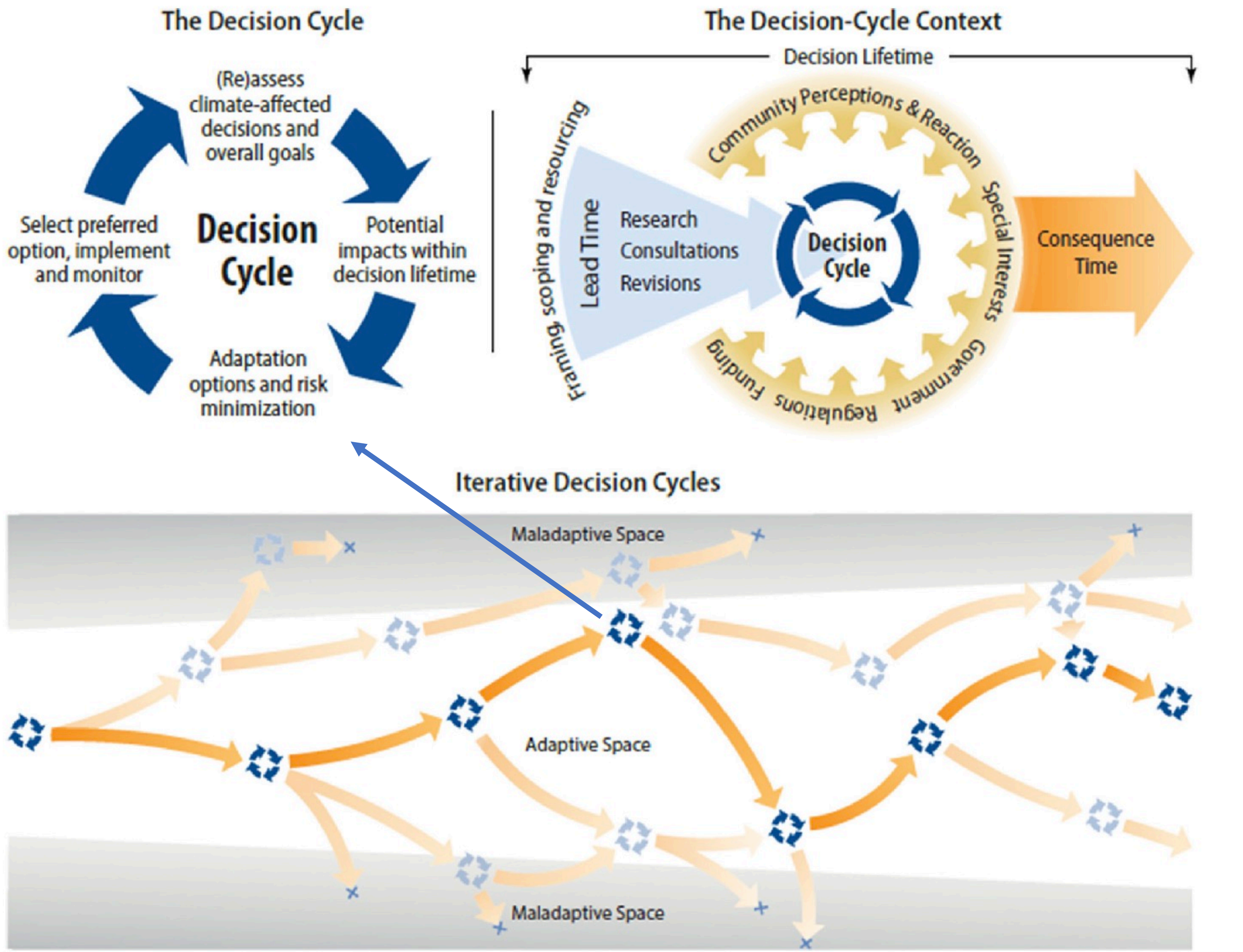
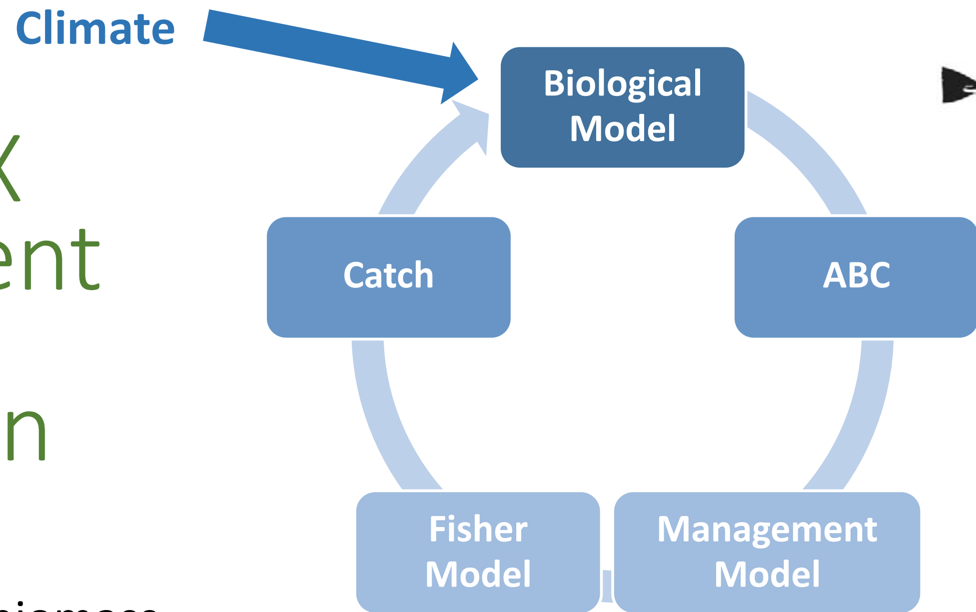
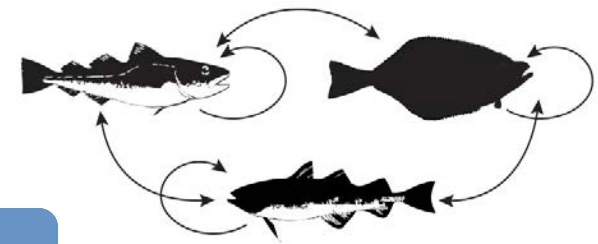


Fig. 1 from Wise et al. 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change 28: 325–336

Climate X management dynamic interaction

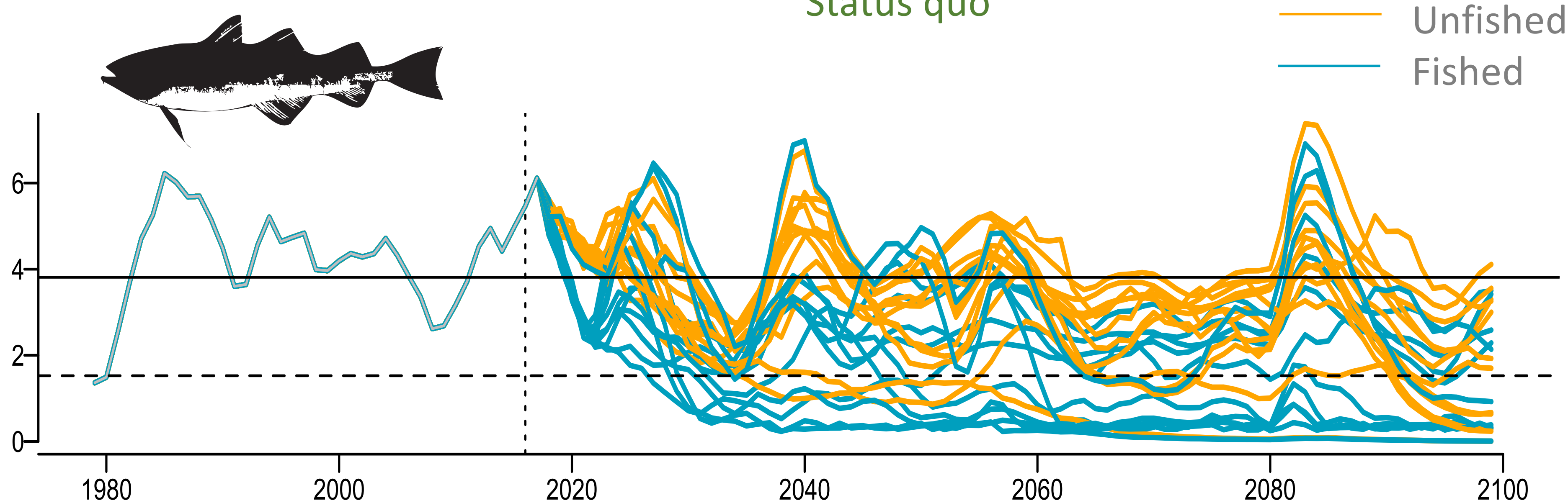




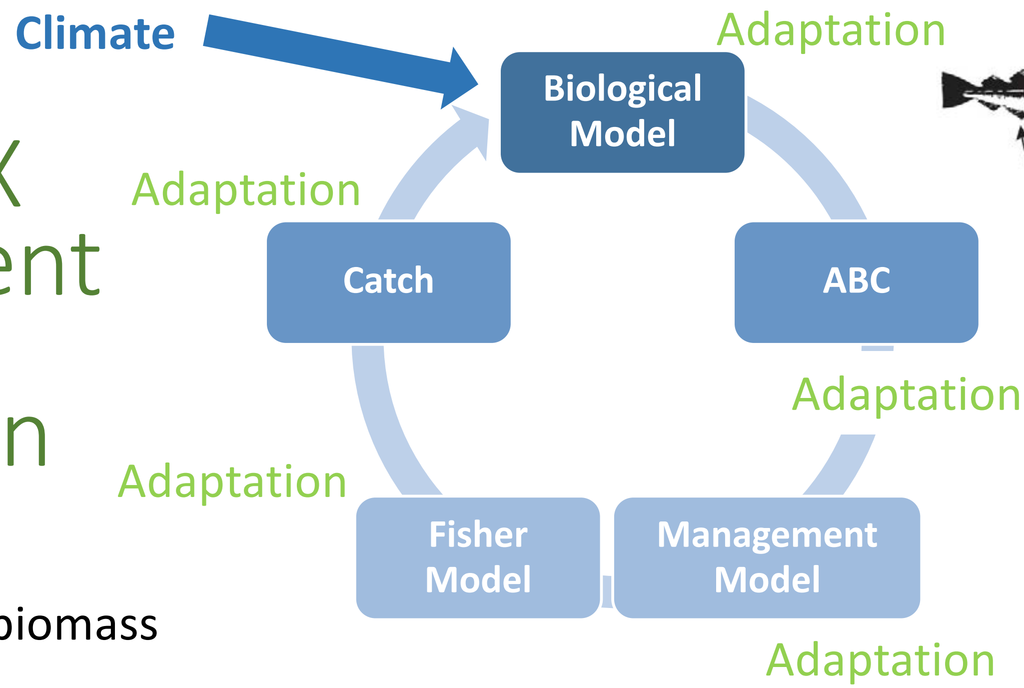
CEATTLE model
Holsman et al. 2016

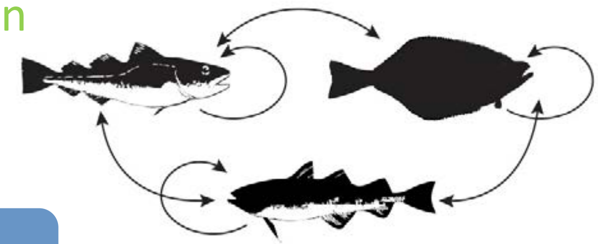
Pollock Spawning biomass

Status quo



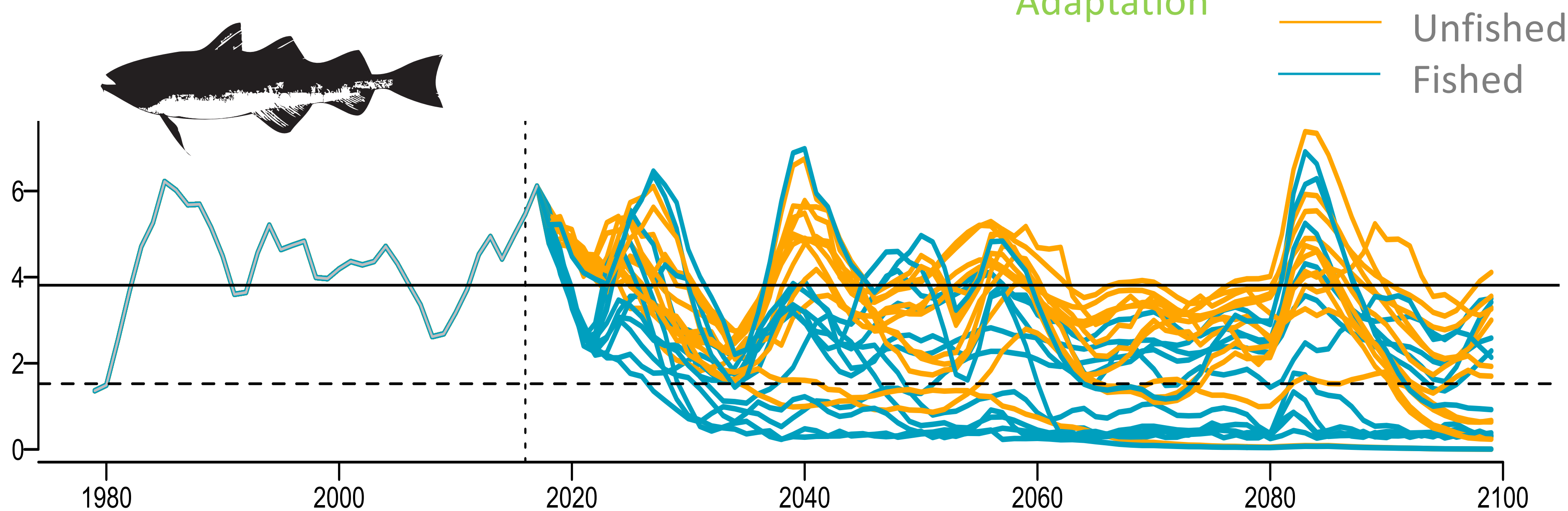
Climate X management dynamic interaction

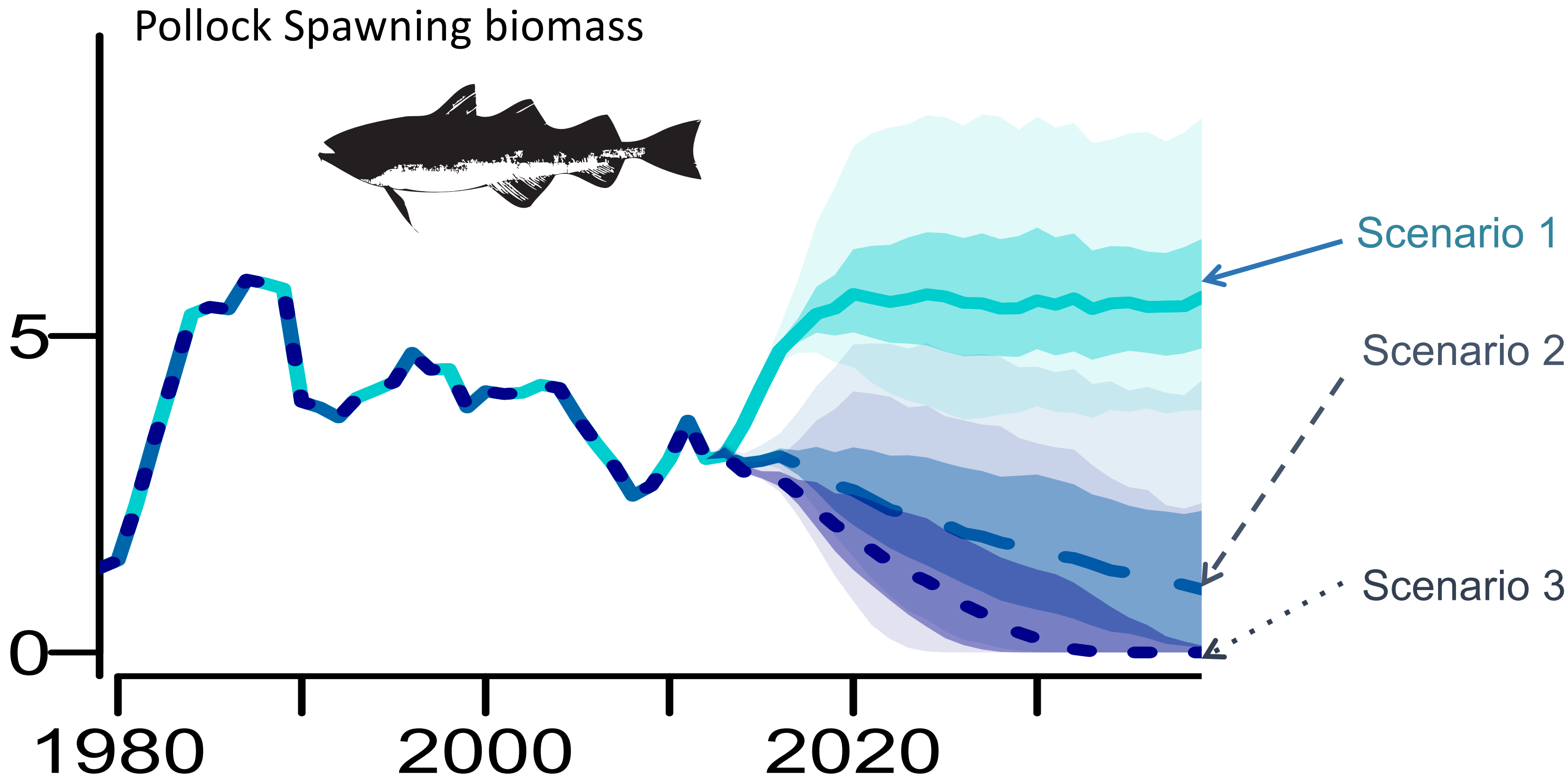




CEATTLE model
Holsman et al. 2016

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

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

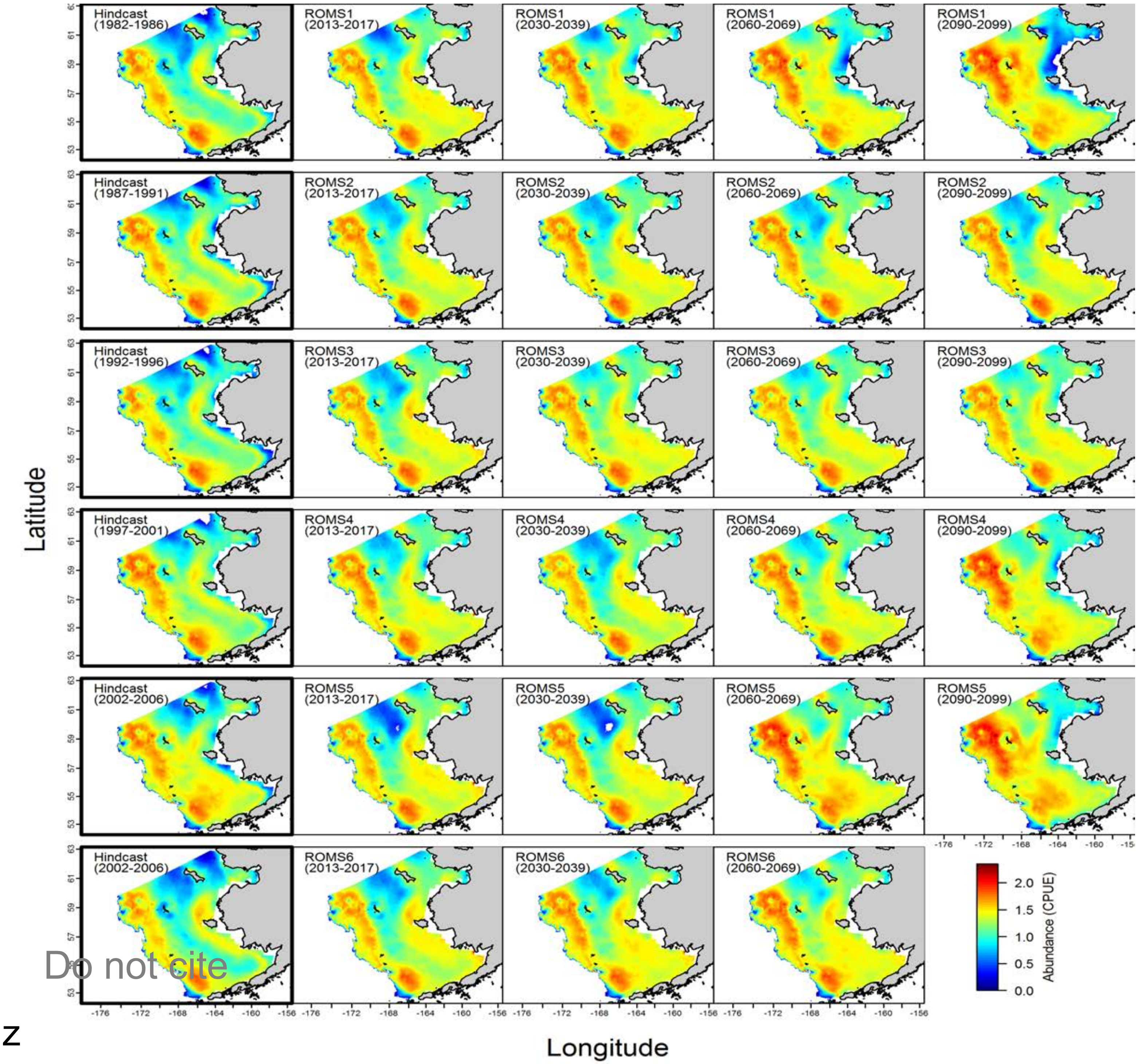
1) AK plaice
2) Arrowtooth flounder (1993-)
3) flathead sole
4) Northern rock sole (2001-)
5) Pacific cod
6) Walleye pollock
7) Red king crab (1996-)
8) Snow crab
9) Tanner crab
10) Yellowfin sole

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:
  - Taskforce
  - Products
  - Tracking progress

kirstin.holsman@noaa.gov

Potential Products:

- Topical expert briefings *sensu* SEARCH
- Annual updates during October meeting on module developments
- Management Scenario Evaluations (MSEs) annually? Bi-annually?
    - Tactical relevant results and findings → ESR / ESP
- Synthesis report to Council every 5 years
- Others…

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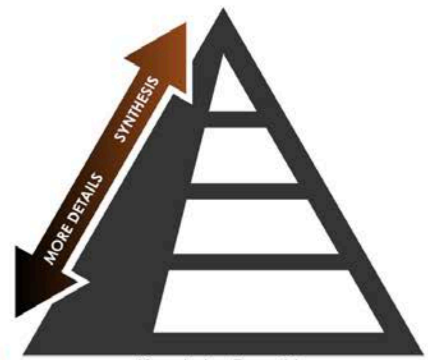
For further information on a topic or to suggest edits or updates, contact the experts listed for each question.

To suggest additional questions to be addressed on *Arctic Answers* or to volunteer to author a brief, contact Brendan Kelly (bpkelly@alaska.edu). When a proposed question is accepted for inclusion as an *Arctic Answer*, the author will receive a manuscript number and further instructions. Each brief will be reviewed for scientific accuracy and accessibility to readers with broad backgrounds.



Knowledge Pyramid

Sea Ice Questions	Expert Contacts	Science Brief
What do we know about the future of Arctic sea-ice loss?	Marika Holland & Walt Meier	Download Brief (PDF - 750 KB)
How is diminishing Arctic sea ice influencing lower latitude weather patterns?	Jennifer Francis & Stephen Vavrus	Download Brief (PDF - 393 KB)
Arctic Meltdown and Unruly Tropical Storms: Are They Connected?	Jennifer Francis	Download Brief (PDF - 218 KB)
How is diminishing Arctic sea ice influencing coastal communities?	Henry Huntington & Matthew Druckenmiller	Download Brief (PDF - 2.9 MB)
How is diminishing sea ice influencing marine ecosystems?	Brendan Kelly	Download Brief (PDF - 1.9 MB)
How will the diminishing sea ice affect commercial fishing in	George Hunt, Lisa Eisner, Neysa	Download Brief

Arctic Answers
Science briefs from the Study of Environmental Arctic Change
https://www.searcharcticscience.org/arctic-answers

How is diminishing Arctic sea ice influencing coastal communities?

THE ISSUE. Loss of sea ice, thawing permafrost, reduced snow cover, and rising sea level are reducing hunting and fishing opportunities and degrading infrastructure for rural Arctic communities. Most Alaska Native communities are affected by erosion and flooding, with 31 communities imminently threatened and 12 planning to relocate. Local responses to these stresses are hampered by the nation's highest prices for food and fuel and widespread poverty across rural Alaska.

WHY IT MATTERS. Climate change amplifies challenges confronting Arctic communities, where 60-80% of households depend on wild game and fish for food, harvesting several hundred pounds per person annually. Already faced with economic, social, and cultural changes, traditional ways of life in rural Alaska are further threatened by climate change impacts on diminishing food security, deteriorating water and sewage systems, increasing risk of accidents, and greater expenditures to construct and maintain infrastructure. Government agencies and other institutions need to promote policies that reduce stresses on Arctic communities and foster responses consistent with local economies and cultures.

STATE OF KNOWLEDGE. Arctic communities and scientists have worked together to document local observations of climate change; the associated impacts on hunting, fishing, safety, and food security; and the potential impacts of projected changes into the future. More recently, researchers have been assessing the efficacy of local responses. For example, subsistence whalers on St. Lawrence Island in the Bering Sea have initiated a fall harvest to help make up for spring whaling seasons made shorter by changing ice conditions. At Kivalina—a village that is also facing relocation due to erosion—changing spring ice conditions have prevented the harvest of bowhead whales for over 20 years. In other cases, changes can amplify one another. Limited time off from jobs means that whalers from Nuiqsut now have much shorter time available for whaling in fall. In Alaska's Arctic region, 78% of Native Iñupiat households combine jobs and subsistence to meet their economic, cultural, and nutritional needs. The benefits of employment are lessened, however, by the reduction in time devoted to harvesting wild foods. Less time to hunt means less chance to wait out fall storms or to adapt to other changes in weather or animal migration patterns. Those migration patterns may be further altered as diminishing sea ice opens opportunities for industrial activities (for example, shipping and offshore petroleum development). The cumulative effects of stresses and changes are broadly recognized but difficult to measure.

Map of the 11 Alaska traditional whaling communities, with the 2015 and 1981-2010 median September ice extents shown.

WHERE THE SCIENCE IS HEADED. More work is needed to understand how local responses can be effective (such as the St. Lawrence Island fall whaling season) as well as how how they fall short of what is needed (such as Kivalina's inability to hunt in spring). In addition, future research must address ways that policies exacerbate or mitigate such impacts, for example by imposing additional constraints on what communities can do, or by supporting flexibility and local initiative to solve problems. Actions made without adequate knowledge of local conditions, no matter how well intentioned, may undermine local well-being by promoting ineffective responses or fostering dependence on outside intervention rather than on local talent, capacity, and creativity. Ultimately, communities need support to identify local solutions.


Iñupiat hunters establish a whaling camp on coastal sea ice near Utqiaġvik (formerly Barrow), Alaska, where thinning ice and warming temperatures in Spring are reducing hunting opportunities and increasing risks to personal safety. (Courtesy: M. Druckenmiller)

FURTHER READING

Chapin, F.S., III, S.F. Trainor, P. Cochran, H. Huntington, C. Markon, M. McCammon, A.D. McGuire, and M. Serreze, 2014. Ch. 22: Alaska. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 514-536. doi:10.7930/J00Z7150. [Available online at: http://nca2014.globalchange.gov/report/regions/alaska]

Goldsmith, S., 2008. Understanding Alaska's Remote Rural Economy, UA Research Summary No. 10, Institute of Social and Economic Research, University of Alaska Anchorage. [Available online at: http://www.iser.uaa.alaska.edu/Publications/researchsumm/UA_RS10.pdf]

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https://www.searcharcticscience.org/arctic-answers

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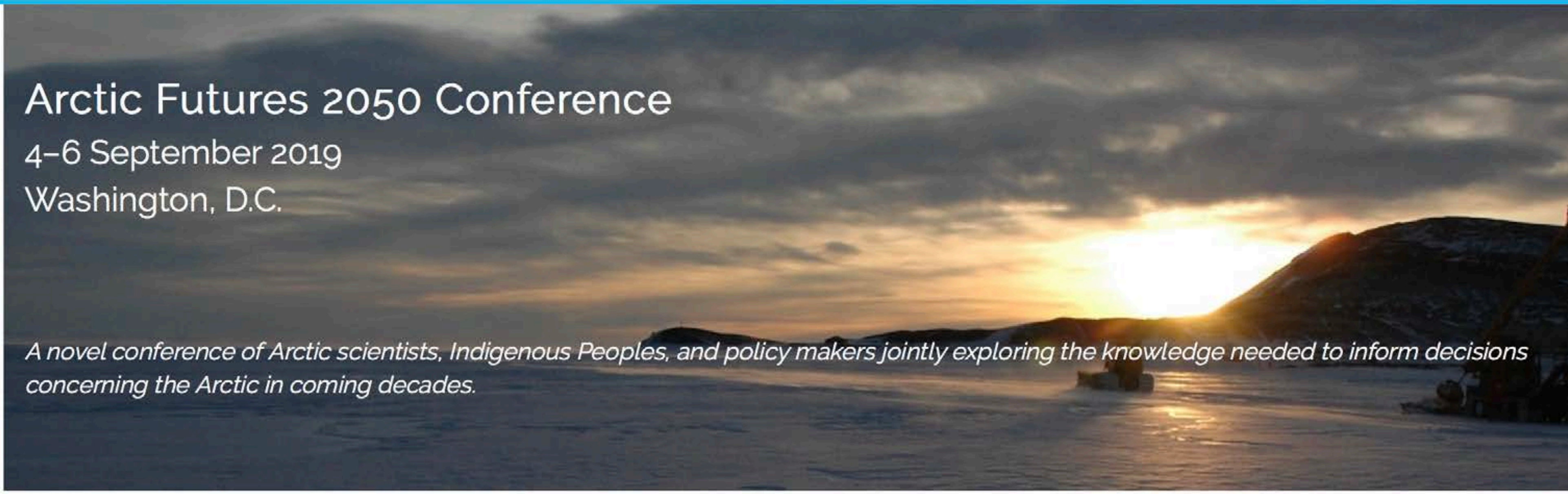
druckenmiller@nsidc.org

SEARCH is supported by the National Science Foundation. SEARCH Science Brief AA-002.

ARCTIC FUTURES 2050

HOME SCENARIOS WORKSHOP ARCTIC FUTURES 2050 CONFERENCE BACK TO SEARCH



Conference Menu About Registration Program Travel Awards Posters Logistics Background

Announcements

General Travel Award Announced – The conference Organizing Committee announces a travel award program for potential attendees regardless of background, nationality, or career stage. Applications are due 20 May 2019. For more information, go here.

Travel Awards Announced – Early-Career & Indigenous Knowledge Holder Travel Awards - We are pleased to announce travel award opportunities for early-career researchers and Indigenous knowledge holders! Applications are due 20 May 2019. More information is available through the "Travel Awards" link above or go here.

Important Dates

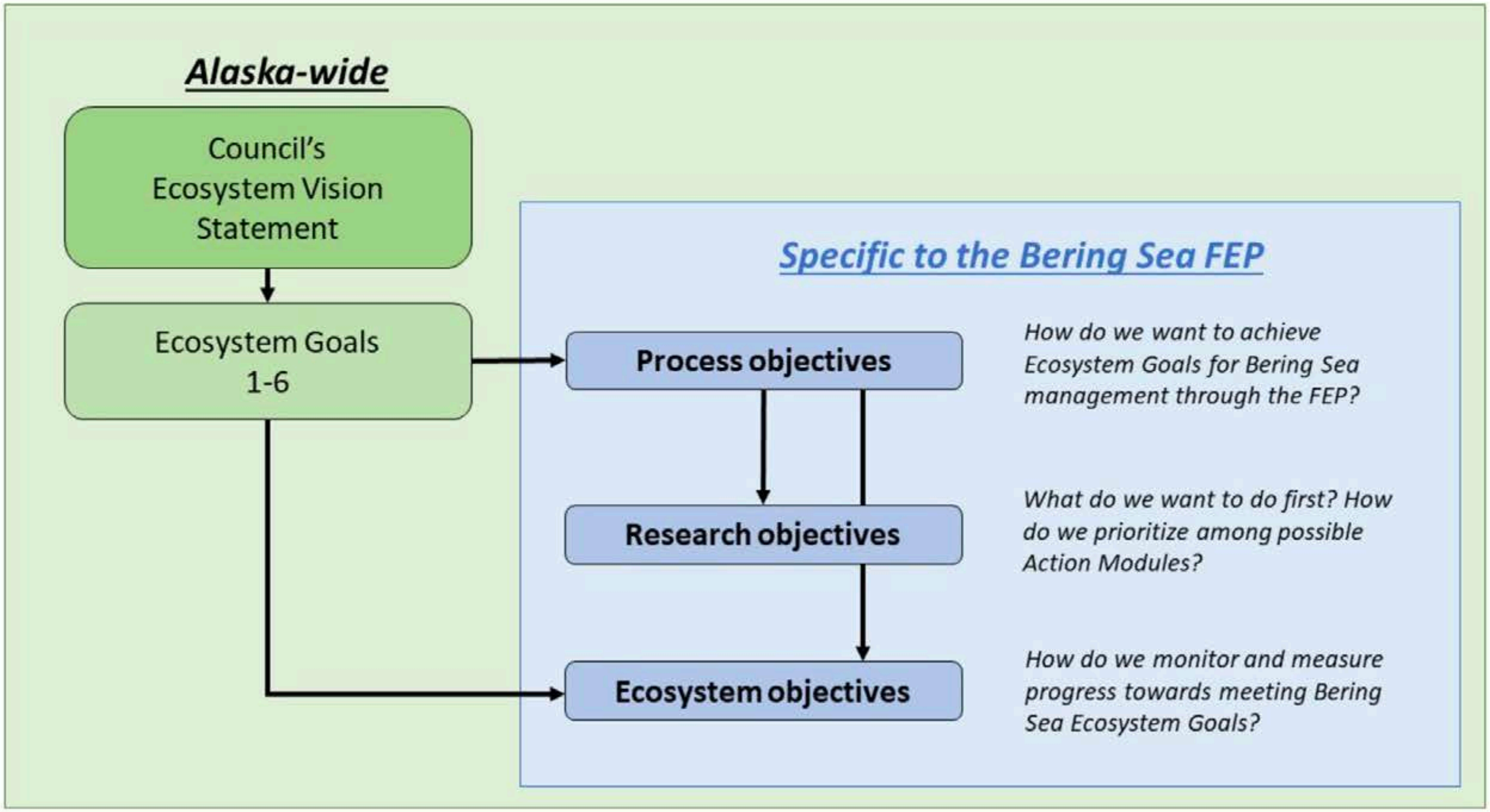
15 March: Call for Poster Abstracts
1 April: Registration Opens
1 April: Travel Award Program Announced
20 May: Poster Abstracts Due
20 May: Travel Award Applications Due
17 June: Poster Decisions and Travel Award Winners Announced
10 July: Early-bird Registration Rates End

- The Conference Organizing committee has extended the original May 1st deadline for Poster abstracts and Travel Award applications.

HOW?

Tracking progress

Objectives



Alaska-wide
Council's Ecosystem Vision Statement
Ecosystem Goals 1-6
Specific to the Bering Sea FEP
Process objectives
Research objectives
Ecosystem objectives
How do we want to achieve Ecosystem Goals for Bering Sea management through the FEP?
What do we want to do first? How do we prioritize among possible Action Modules?
How do we monitor and measure progress towards meeting Bering Sea Ecosystem Goals?

Ecosystem Goal	Ecosystem Objectives	Module evaluations	Metrics & indicators
Ecosystem Goal 1: Maintain, rebuild, and restore fish stocks at levels sufficient to protect, maintain, and restore food web structure and function	*1. Maintain target biomass levels for target species, consistent with optimum yield, using available tools.*	MSE: test climate informed biological reference points; test spatial and temporal regulations to address shifting distributions	long-term B/B0 ; total yield; volatility in B or C; access to subsistence resources; catch-->wellbeing analyses
	2. Maintain healthy populations and function of non-target and forage species.	Identify species at Risk/exposure to Climate change for non-target species (maybe based around long-term projections, scenarios, and recent extreme events)	Rapid vulnerability and Risk synthesis (IK/TK based and expert opinion); LK observations of change; long-term shifts in monitoring timeseries; ID uncertainty/gaps
	3. Adjust fishing-related mortality from the system to be commensurate with total productivity and continue to limit optimum yield to 2 million metric tons for the BSAI groundfish fisheries.	MSE: test climate informed multispecies reference points; test spatial and temporal regulations to address shifting distributions	Aggregate yield; long-term B/B0 ; total yield; volatility in B or C; access to subsistence resources; catch-->wellbeing analyses
Ecosystem Goal 2: Protect, restore, and maintain the ecological processes, trophic levels, diversity, and overall productive capacity of the system	*4. Maintain key predator/prey relationships.*	MSE & spatial analyses: evaluate changes to species overlap; project food-webs	Risk of collapse; changes in overlap; changes in diet & food web interactions
	5. Conserve structure and function of ecosystem components.	MSE and spatial analyses: project scenario changes in Fishing X Climate change scenarios through coupled social-ecological system	Benthic/pelagic productivity ratios; length of food-chain; access to key subsistence resources; economic and social indicators

LINK TO EXCEL SPREADSHEET