ACLIM

The Alaska Climate Change Integrated Modeling Project

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Andy Whitehouse, UW
Thomas Wilderbuer, NOAA
Trond Kristiansen, NOR
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Jim Thorson, NOAA
Ingrid Spies, NOAA
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Mark Holsman

The ACLIM team


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Stephen Kasperski


Jim Ianelli


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Andy Whitehouse


Jonathan Reum


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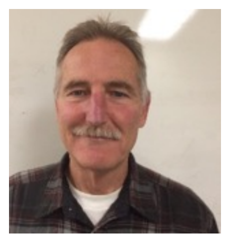
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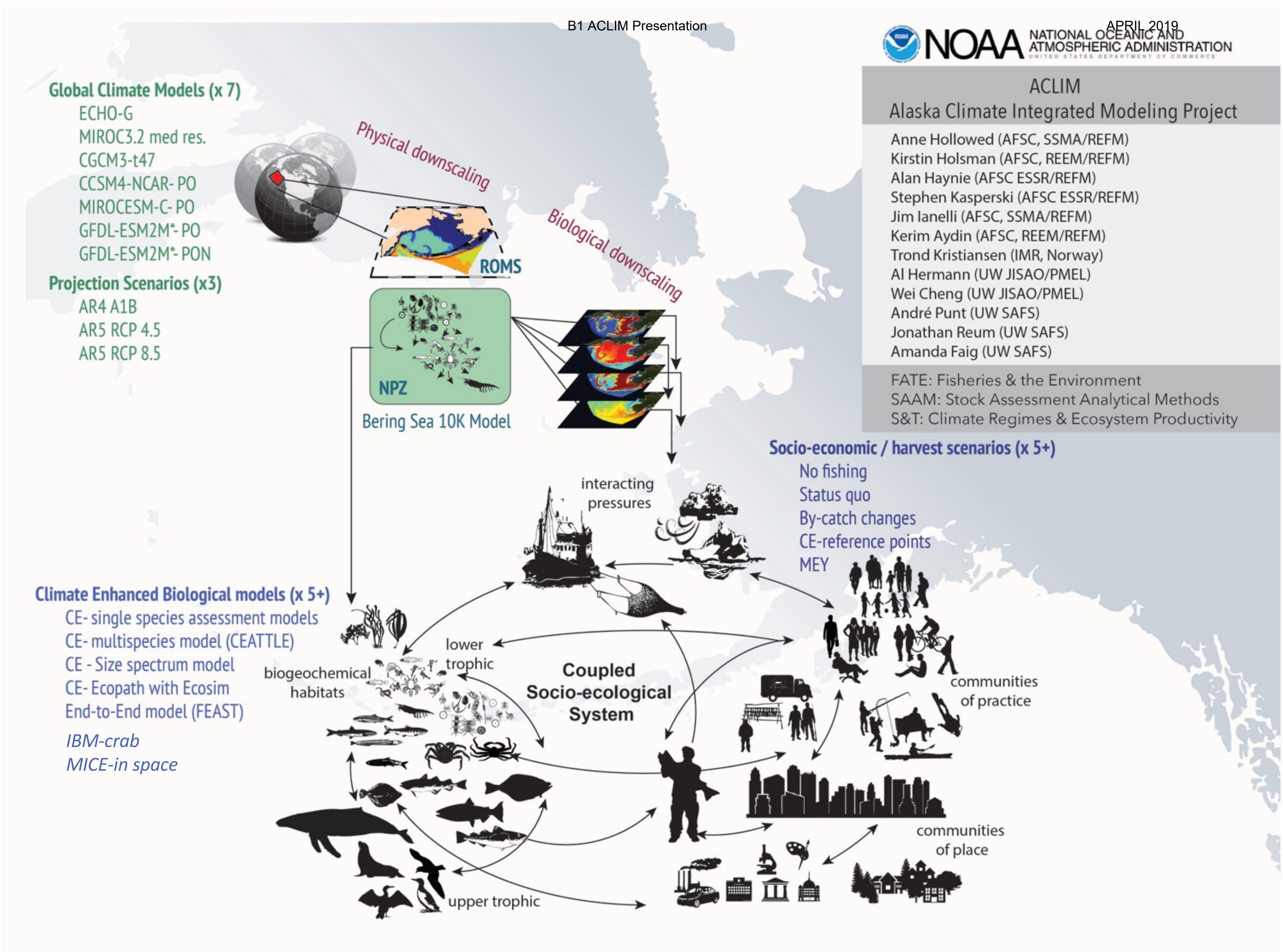
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project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CE- single species assessment models
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MICE-in space
lower
trophic
biogeochemical
habitats
Coupled
Socio-ecological
System
communities
of practice
communities
of place
upper trophic

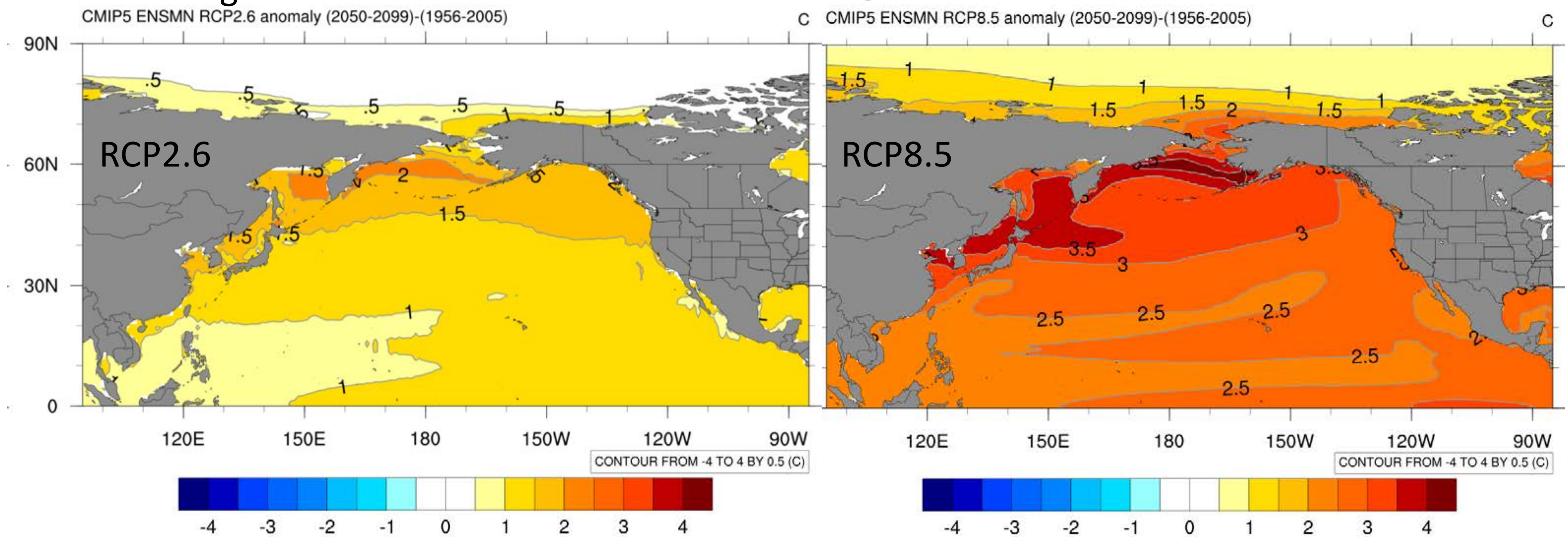
ACLIM

- MSE tool for testing climate-resilient polices for management
- ACLIM is a proof of concept, now endorsed by leadership
- Done in coordination with national international partners and is now spinning up in multiple regions (e.g., Future Seas, NCLIM, Nor BARENTS RISK)
- Approach is central to the FEP Climate Module, as are rapid assessments and EFH

CMIP5 ENSMN Annual SST anomaly (°C) (2050 to 2099) - (1956 to 2005)

CO2 mitigation scenario

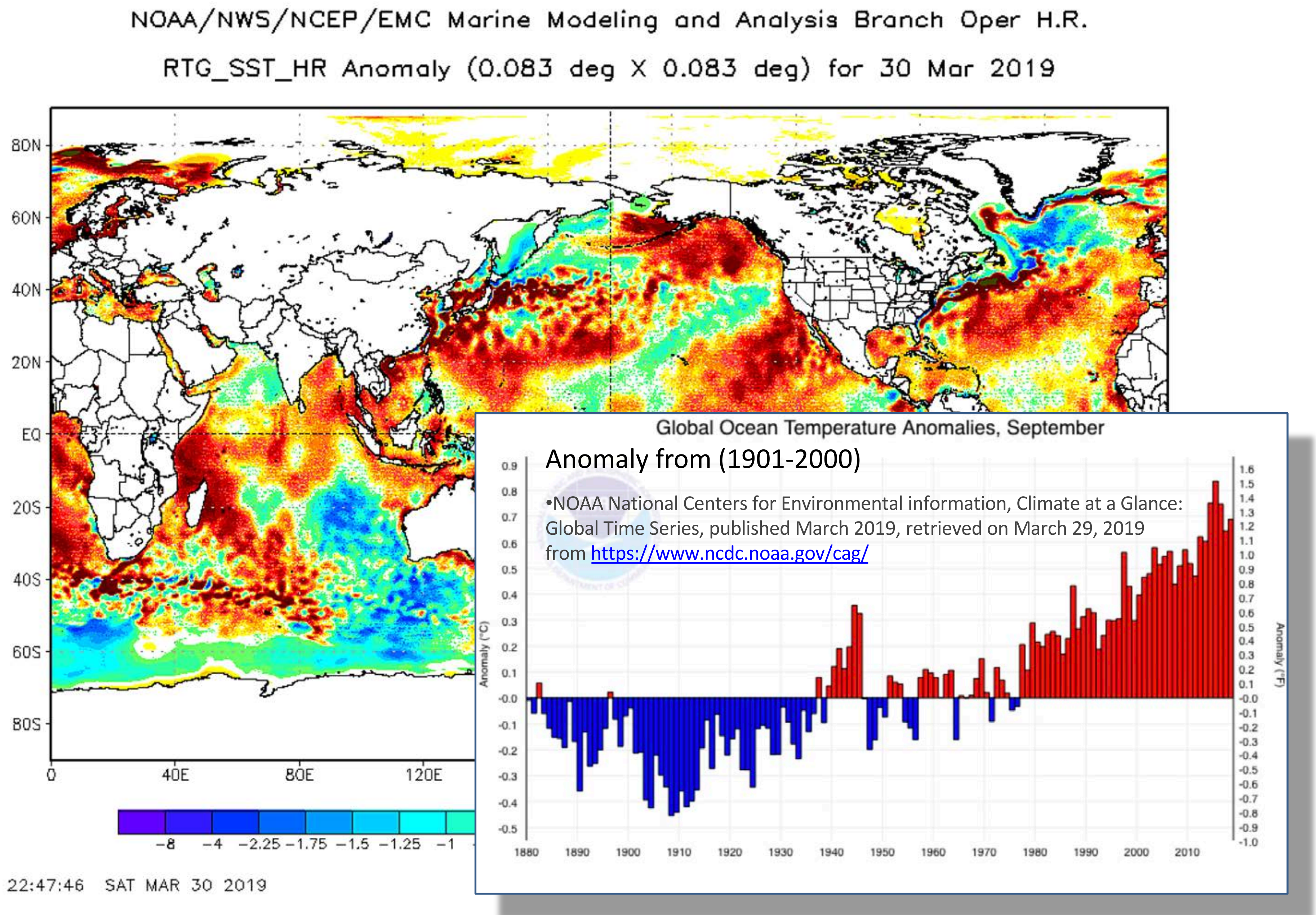
High baseline scenario ("Business as usual")



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.

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

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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

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

ELSEVIER

A hierarchical approach to defining marine heatwaves

CrossMark

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
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[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

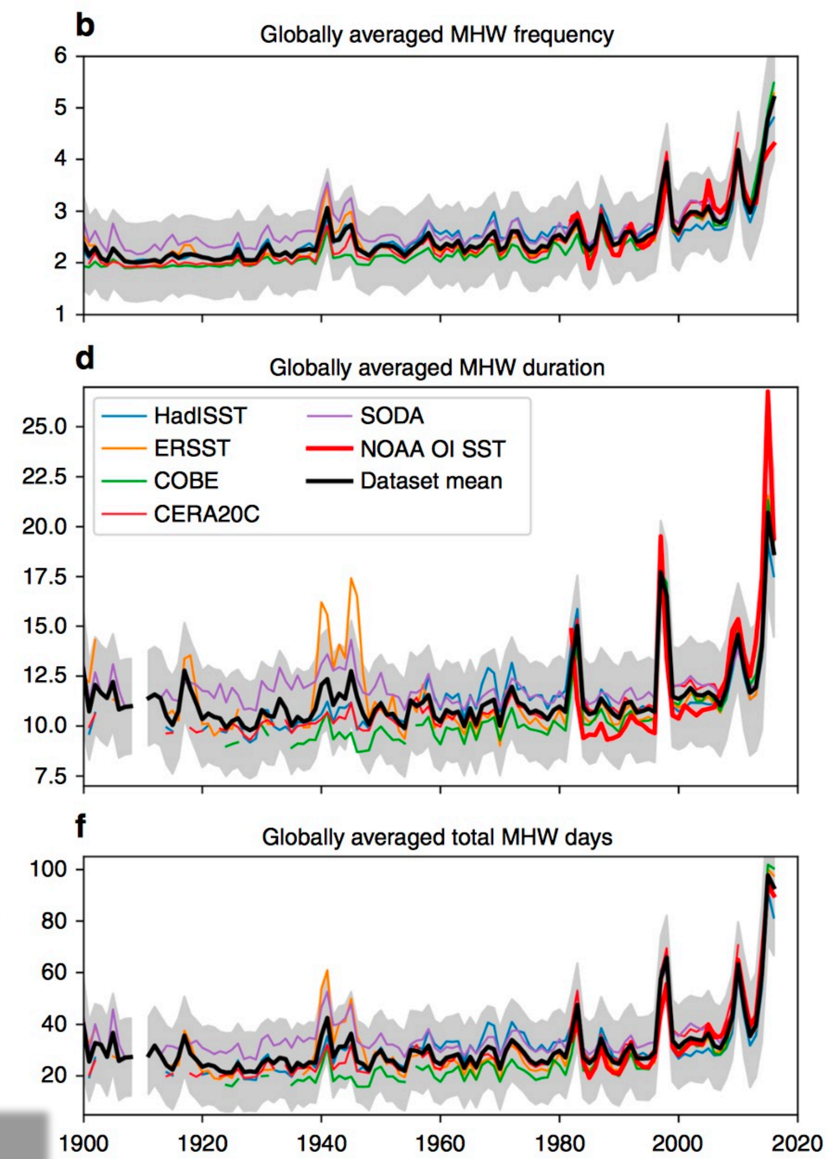
Climate Dynamics
https://doi.org/10.1007/s00382-019-04707-2

Check for updates

Mean warming not variability drives marine heatwave trends

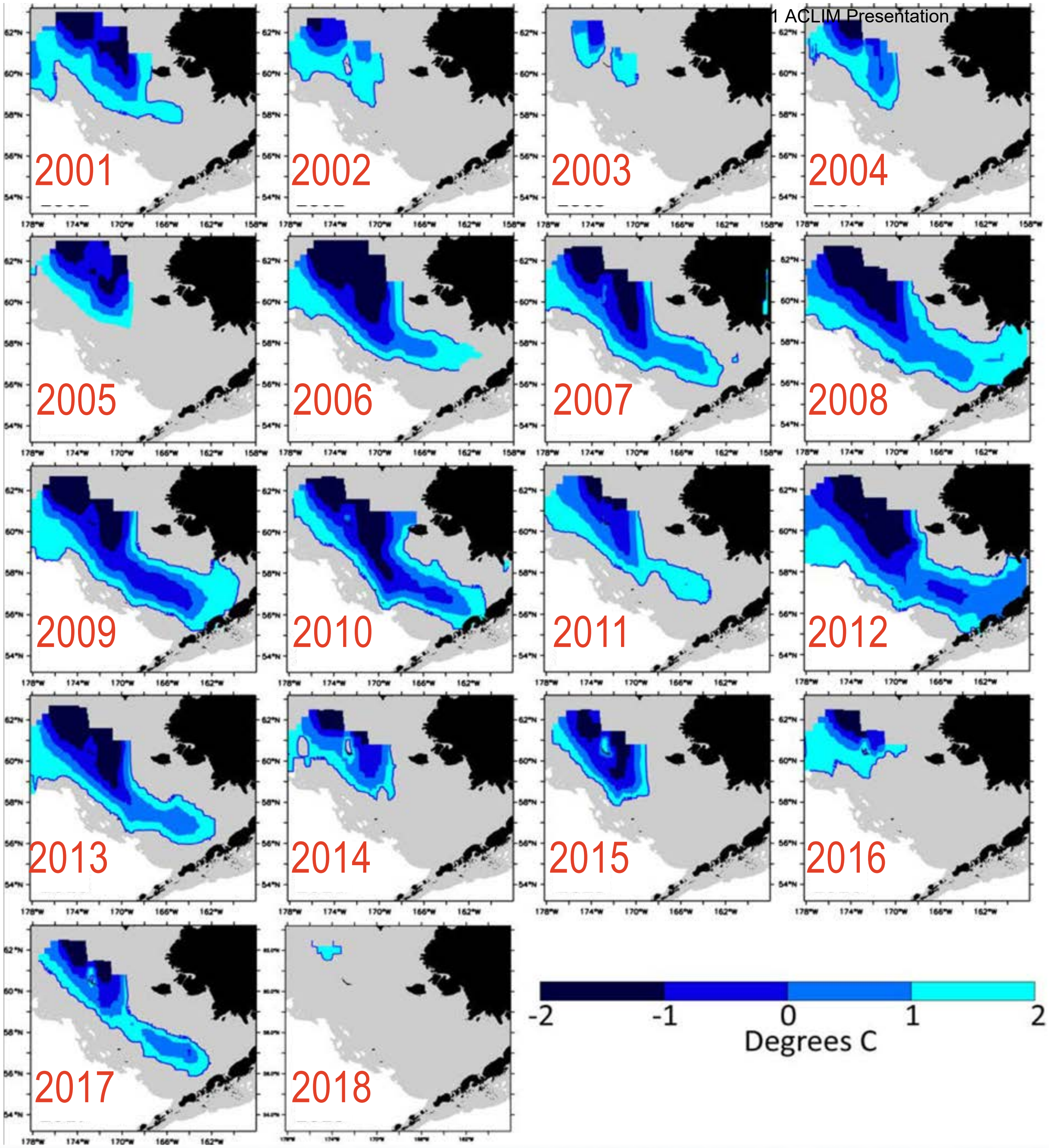
Eric C. J. Oliver[1]

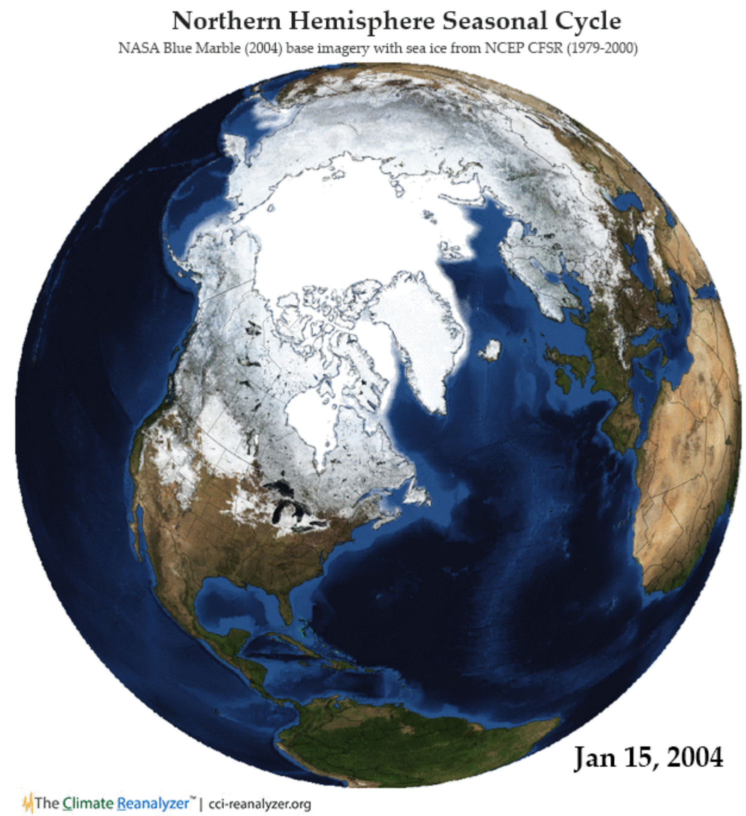
Received: 1 May 2018 / Accepted: 1 March 2019



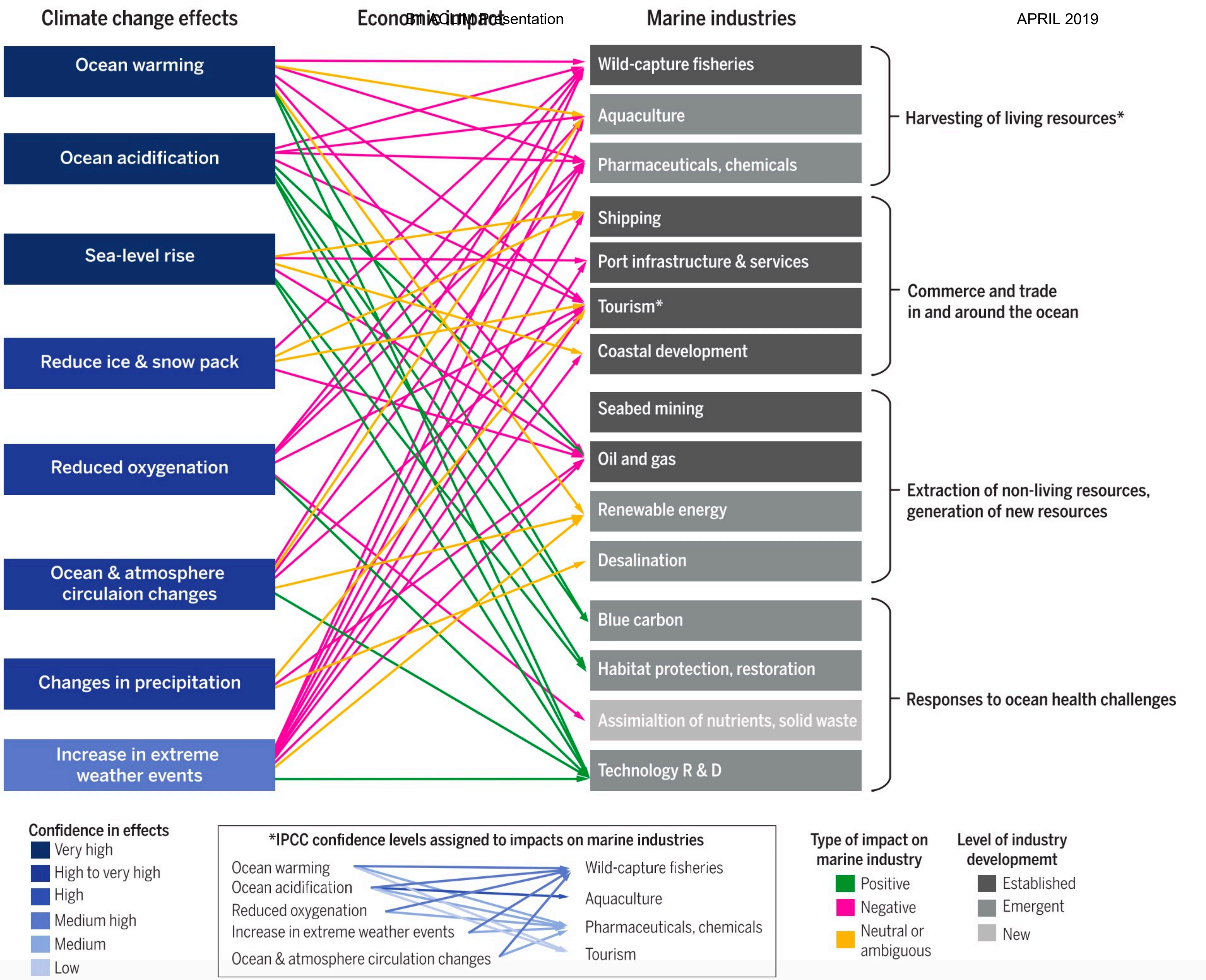
*"We find that **mean SST change was the dominant driver of increasing MHW** exposure over nearly two thirds of the ocean, and of changes in MHW intensity over approximately one third of the ocean. "*

Bering Sea "Cold Pool" 2001-2018

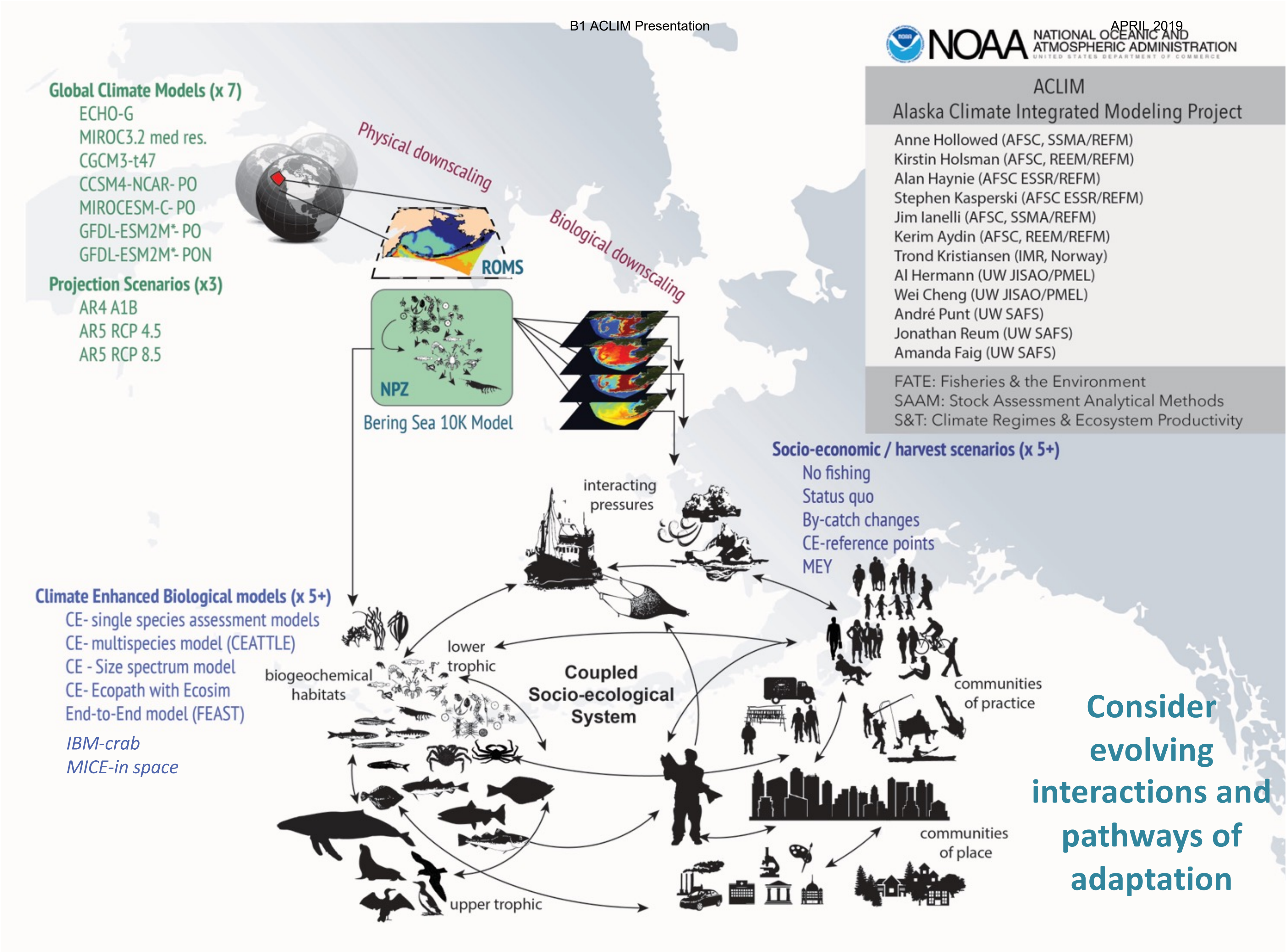




Graphic: J. Overland, P. Stabeno, M. Wang, C. Ladd, N. Bond, and S. Salo, PMEL/NOAA



Climate change in the oceans: Human impacts and responses E. Allison and H. R. Bassett (November 12, 2015) Science 350 (6262), 778-782.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lower trophic
Coupled Socio-ecological System
communities of practice
communities of place
upper trophic
Consider evolving interactions and pathways of adaptation

Promote and protect **adaptive capacity** in fish and fisheries

Improve management **foresight** in a changing climate *“knowledge and culture construct societal limits to adaptation, but these <u>limits are mutable.”</u>*

- Adger et al. (2009).

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

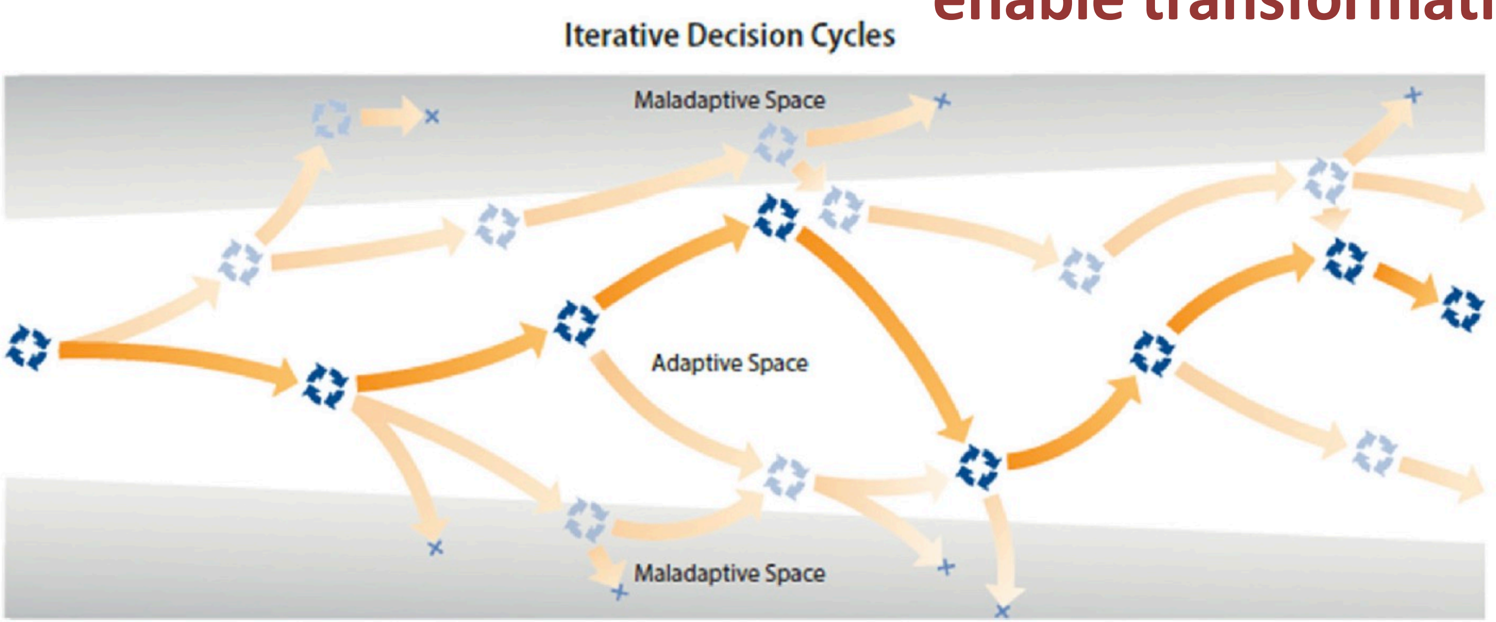
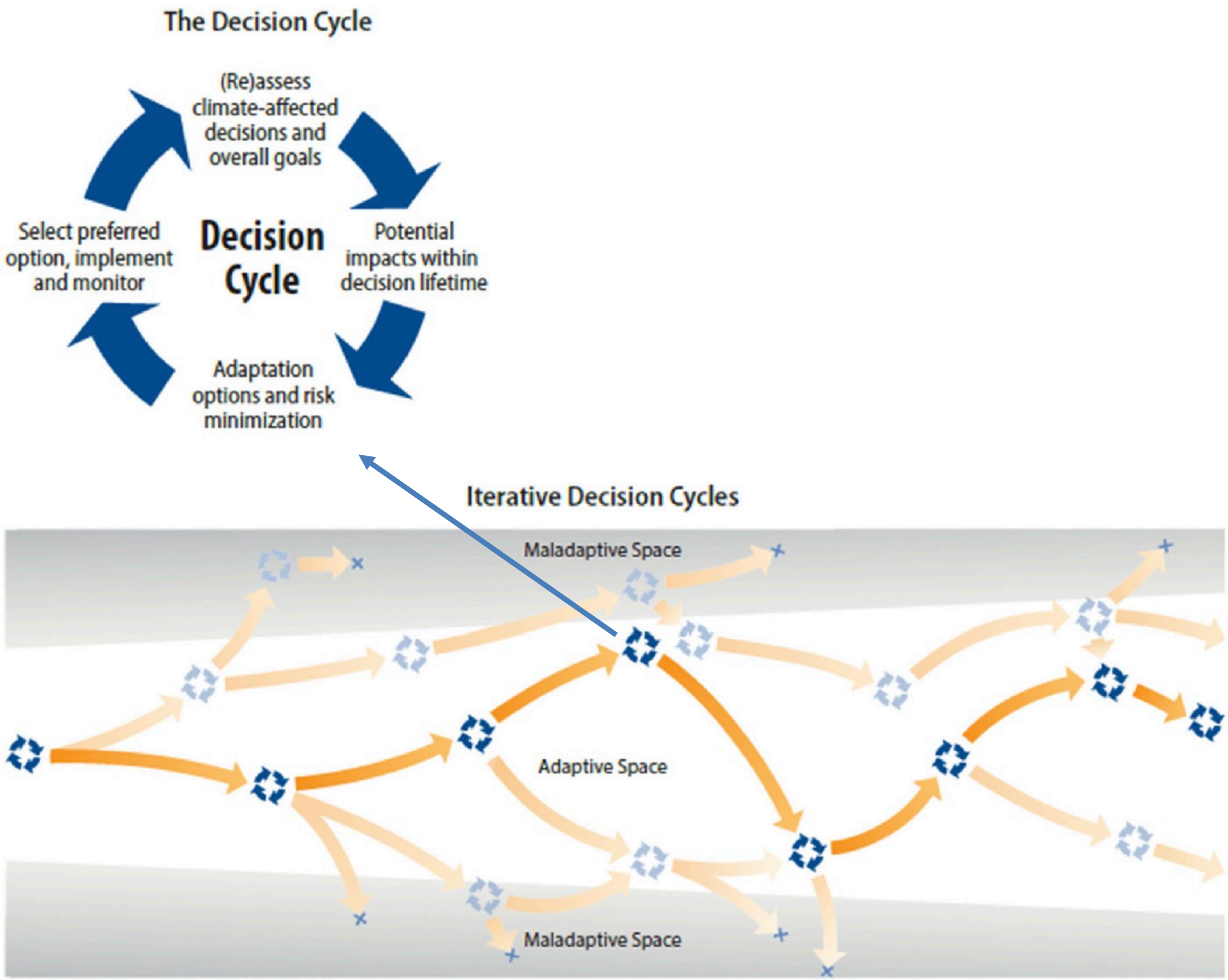


Fig. 1. The current 'classic' conceptualisation of adaptation pathways – as a series of adaptive learning decision cycles over time (top left, cf. Willows and Connell, 2003; Haasnoot et al., 2013) with their decision lifetimes (top right – the sum of lead and consequence times, cf. Stafford Smith et al., 2011), where some chains of decisions lead to maladaptive outcomes over time, but there may be other alternatives that are adaptive (bottom, cf. Reeder and Ranger, 2011; Haasnoot et al., 2013). From the perspective of the current decision point at the left, a currently satisfactory pathway can be plotted through the future (strongest colour), but this must be re-visited at each decision point (Figure developed by Andy Reisinger, pers. comm.).

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



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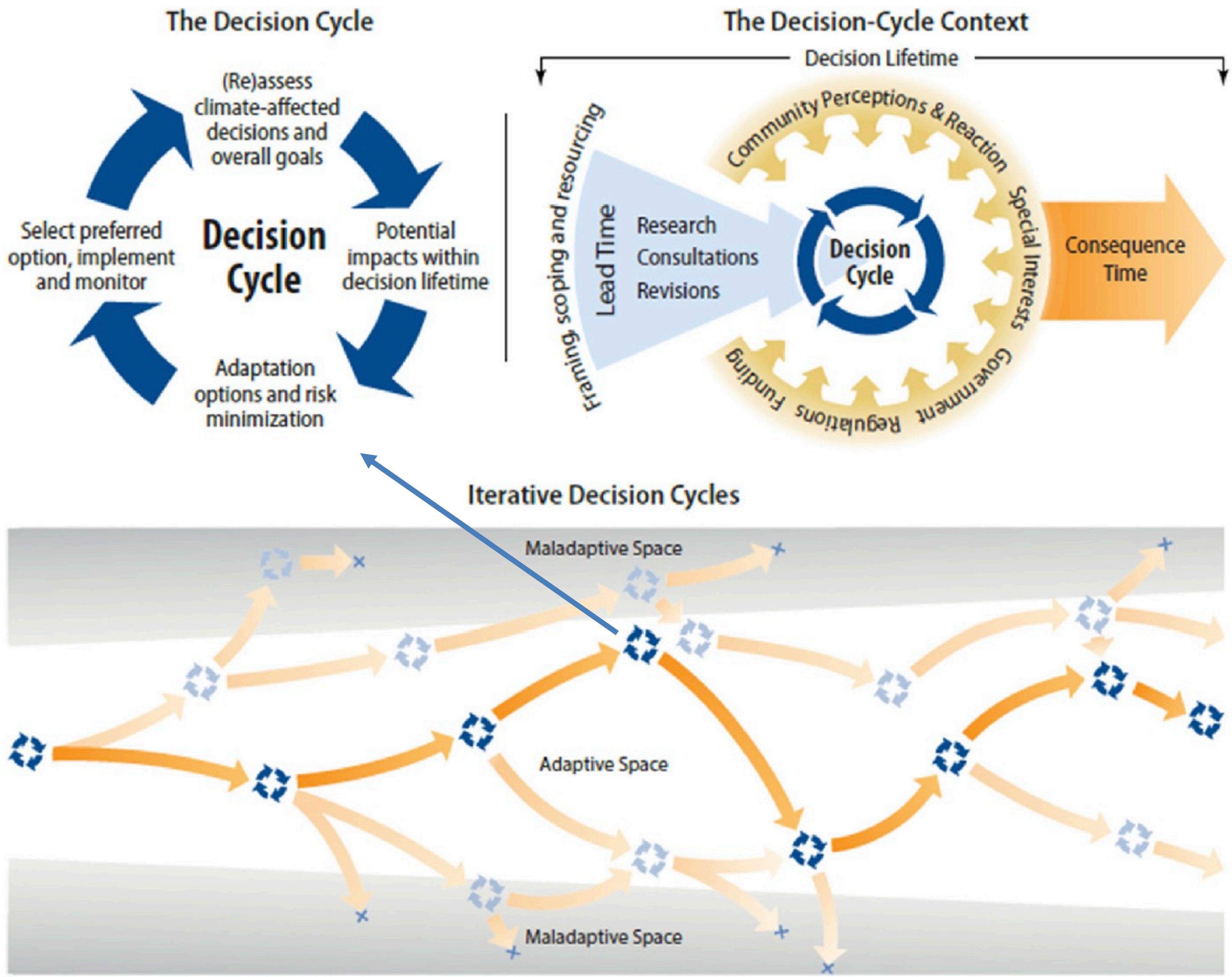

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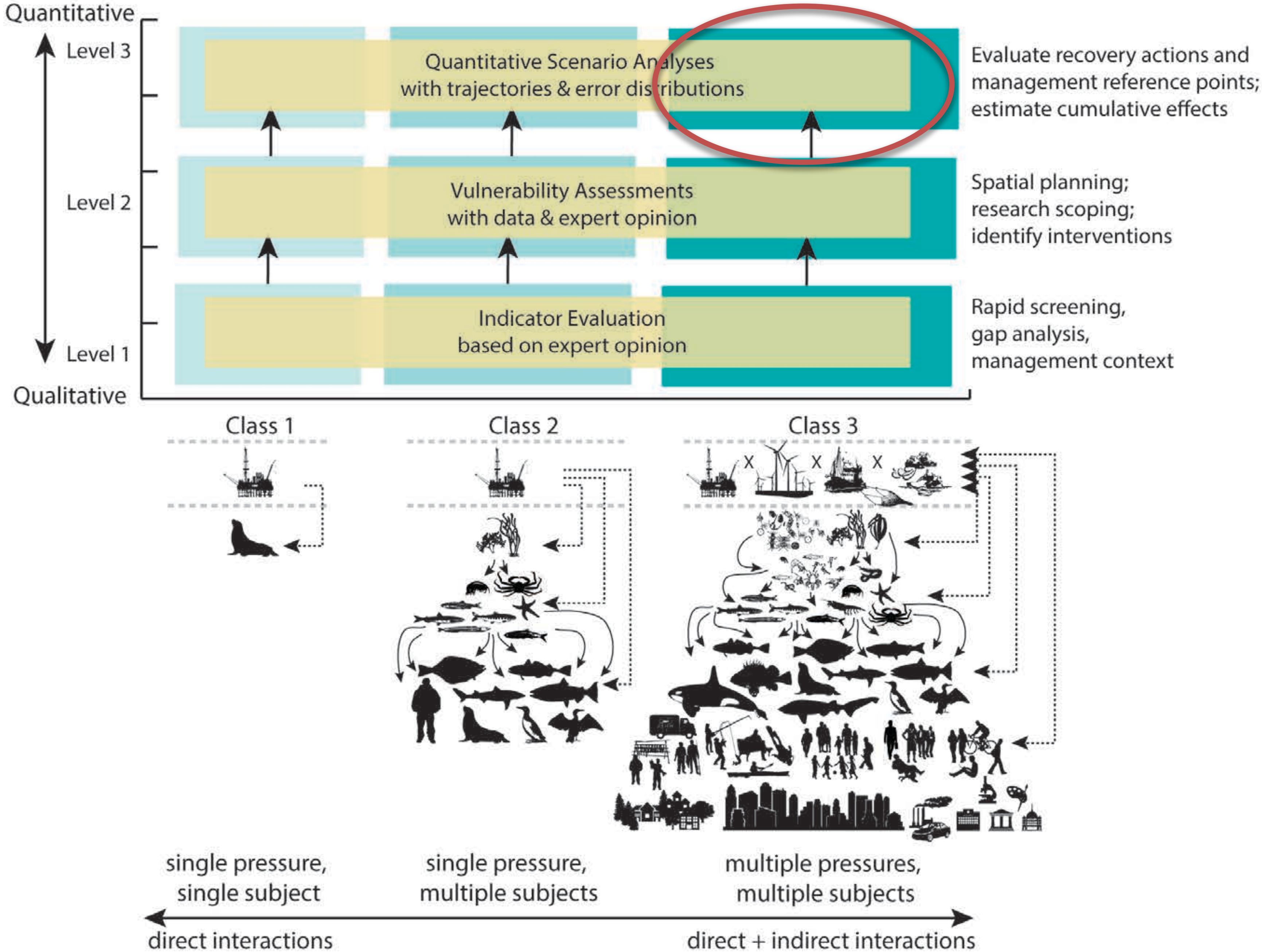
Project changes in ocean conditions & fish populations

Physical, biological, & socioeconomic change; now - 2100

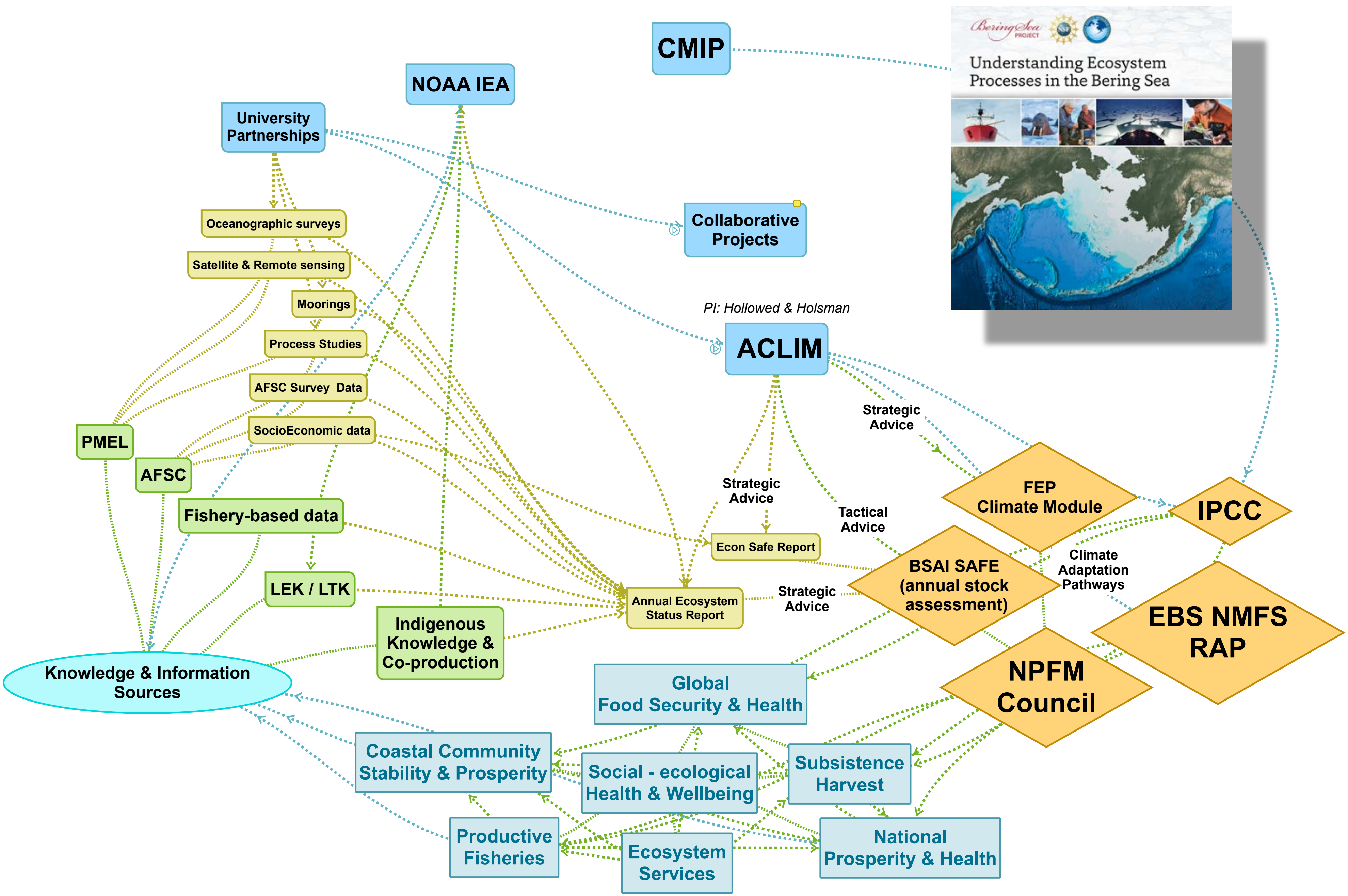
Evaluate how management can promote adaptation & minimize negative impacts

gradual change & sudden shocks; test existing & new tools; estimate risk

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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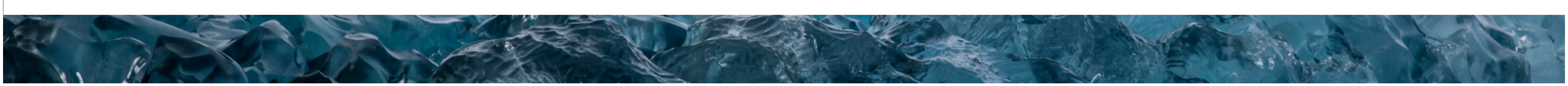
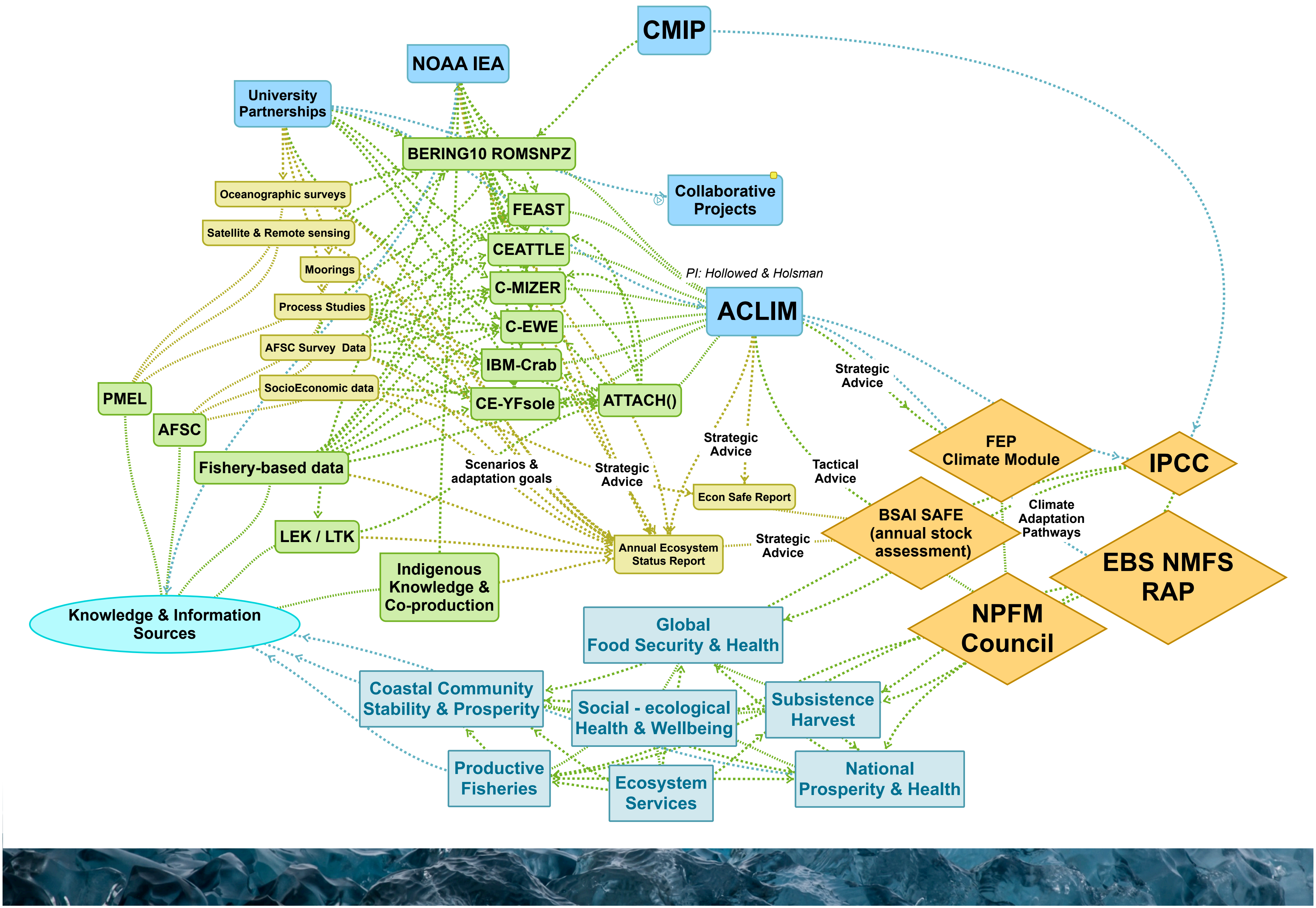
Bering Sea PROJECT
Understanding Ecosystem Processes in the Bering Sea
NOAA IEA
University Partnerships
Collaborative Projects
Oceanographic surveys
Satellite & Remote sensing
Moorings
Process Studies
AFSC Survey Data
SocioEconomic data
PMEL
AFSC
Fishery-based data
LEK / LTK
Indigenous Knowledge & Co-production
Knowledge & Information Sources
PI: Hollowed & Holsman
ACLIM
Strategic Advice
Strategic Advice
Tactical Advice
Strategic Advice
Econ Safe Report
Annual Ecosystem Status Report
FEP Climate Module
IPCC
BSAI SAFE (annual stock assessment)
Climate Adaptation Pathways
EBS NMFS RAP
NPFM Council
Global Food Security & Health
Coastal Community Stability & Prosperity
Social - ecological Health & Wellbeing
Subsistence Harvest
Productive Fisheries
Ecosystem Services
National Prosperity & Health

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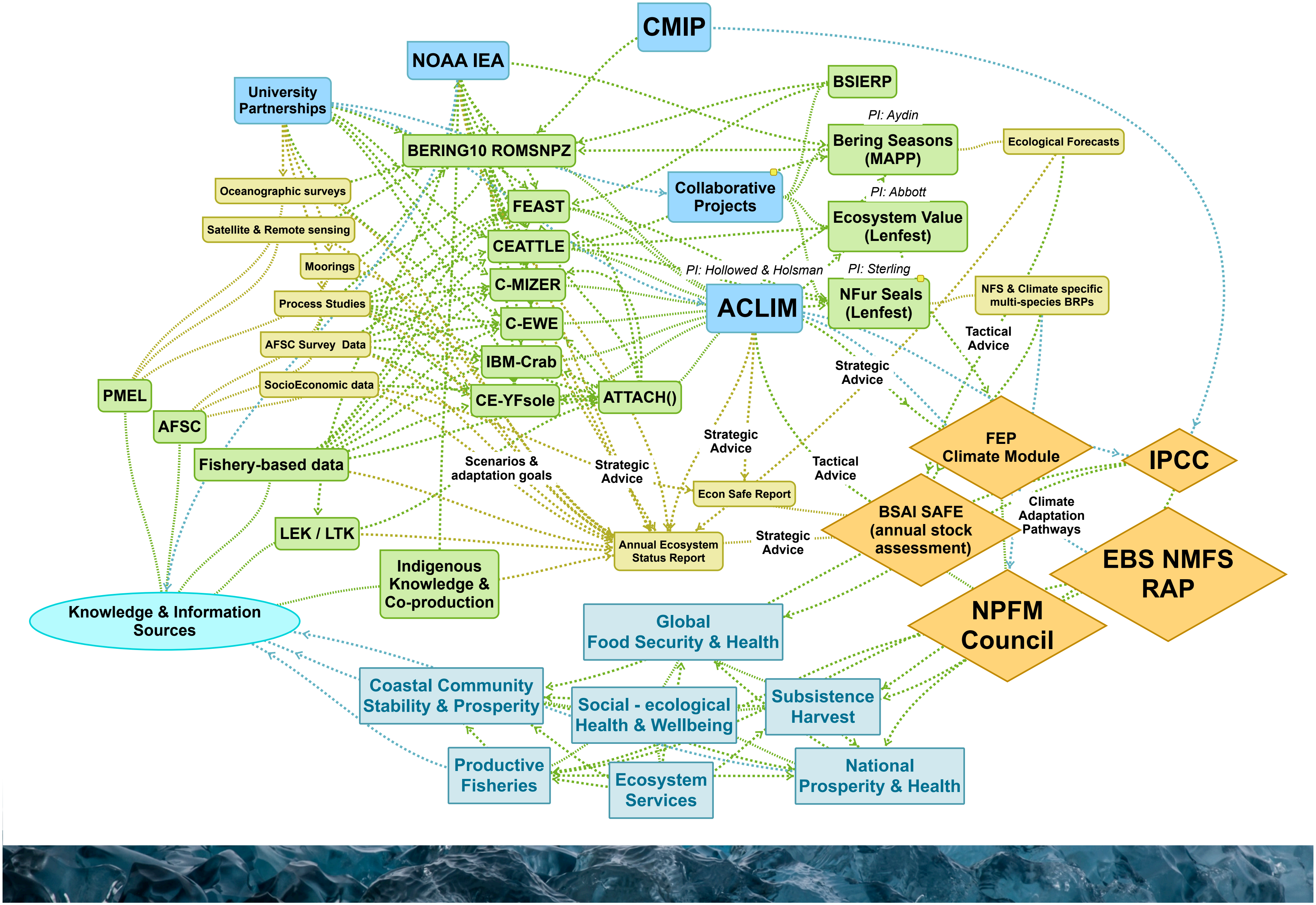
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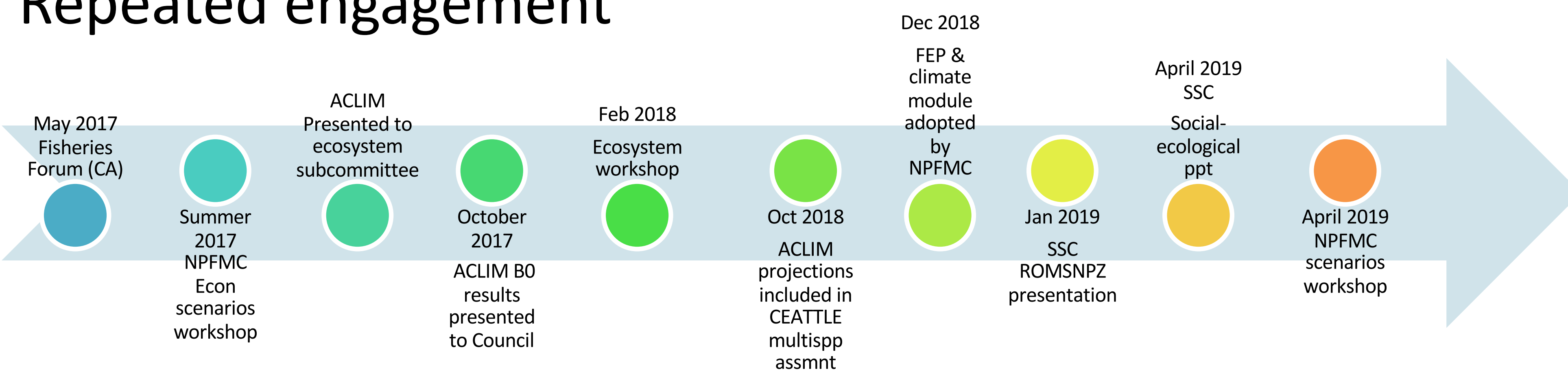
Challenges to evaluating adaptation options:

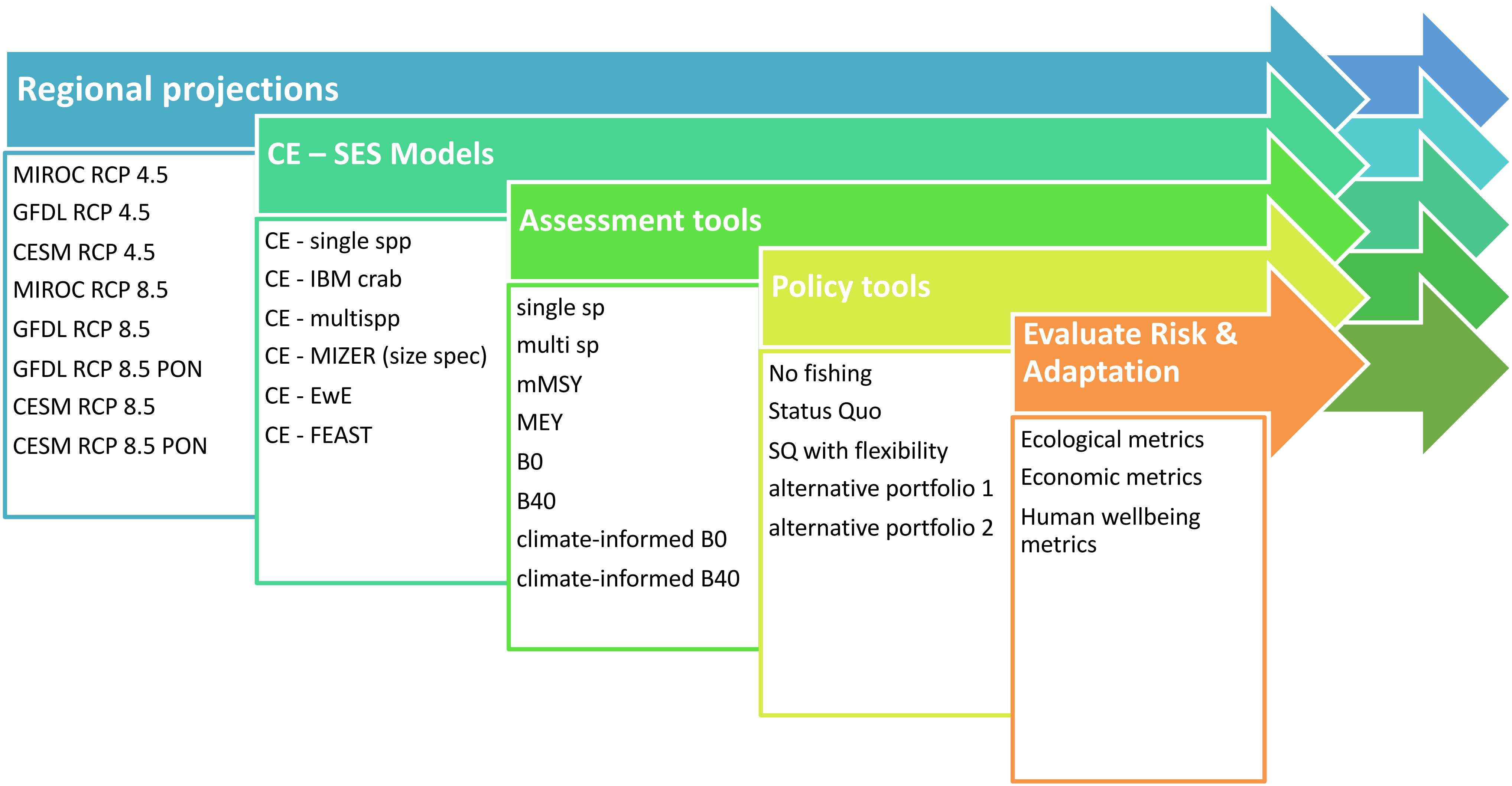
- **long time horizons** of adaptation outcomes;
- the **shifting baseline and uncertainty** around climate hazards;
- assessing **attribution** of any results;
- addressing the **additional climate risk** and counterfactual scenarios

"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



Craft, B., & Fisher, S. (2018). Measuring the adaptation goal in the global stocktake of the Paris Agreement. Climate Policy. https://doi.org/10.1080/14693062.2018.1485546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CE - FEAST
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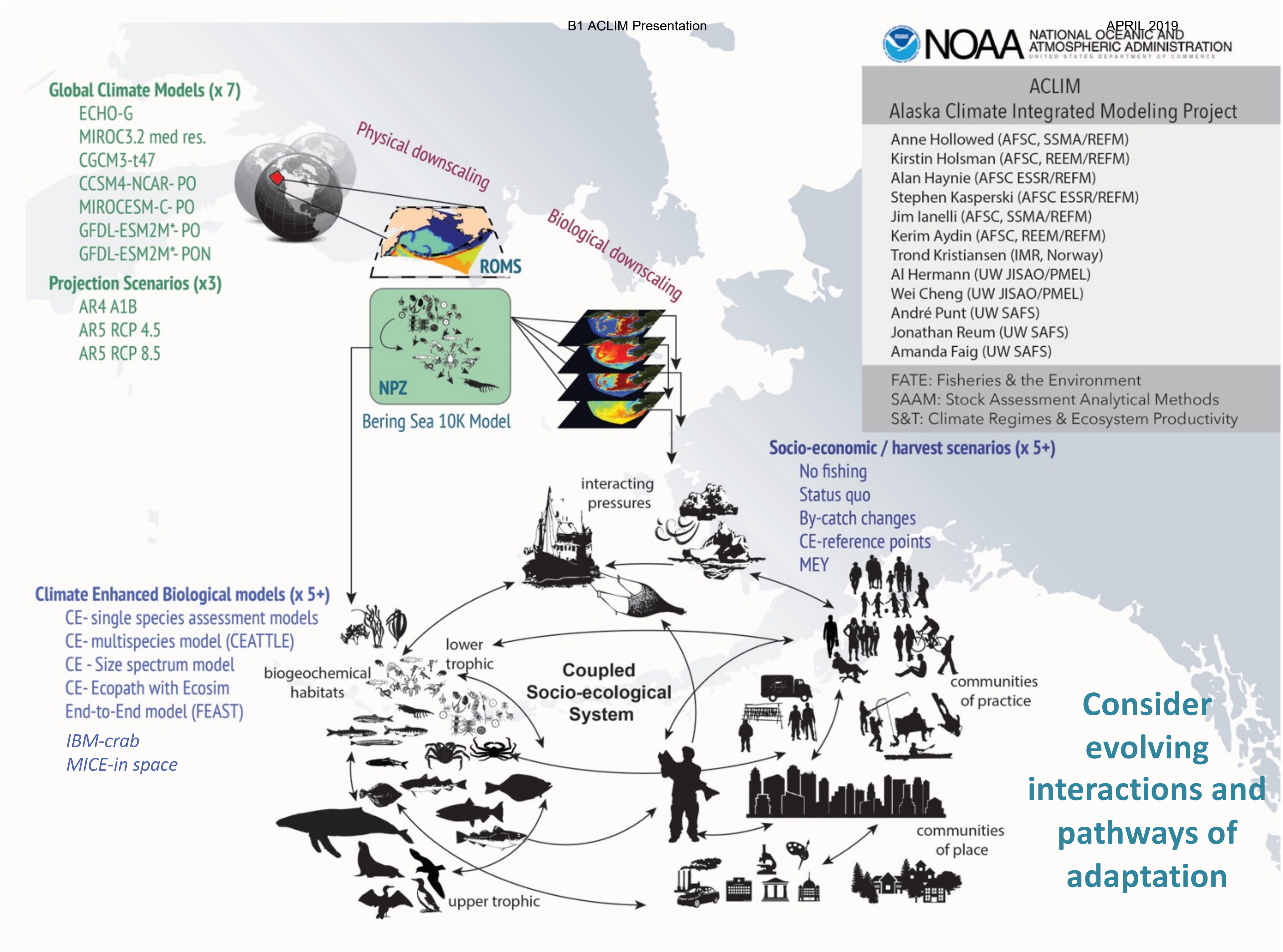
multi sp
mMSY
MEY
B0
B40
climate-informed B0
climate-informed B40
Policy tools
No fishing
Status Quo
SQ with flexibility
alternative portfolio 1
alternative portfolio 2
Evaluate Risk & Adaptation
Ecological metrics
Economic metrics
Human wellbeing metrics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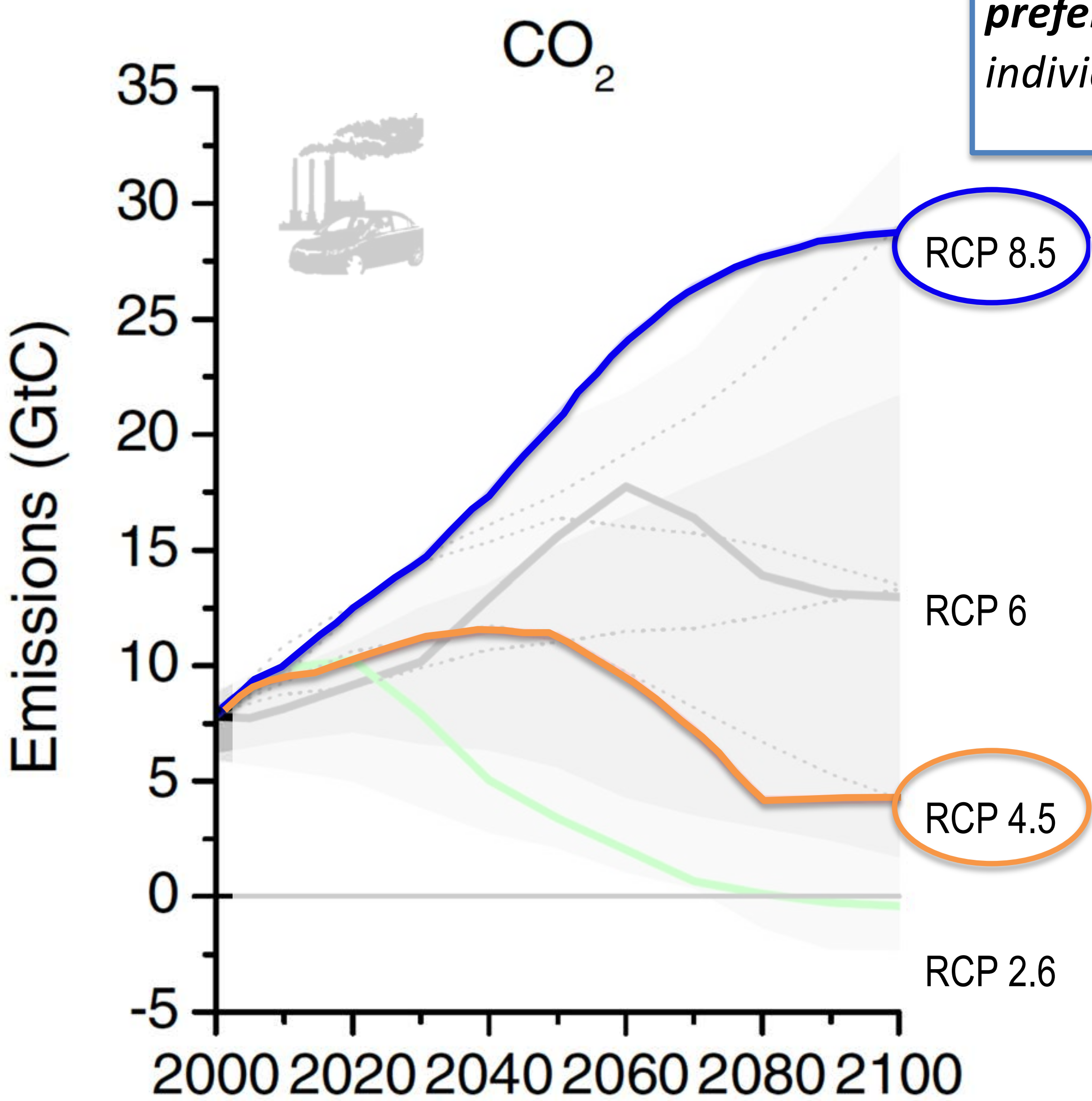
communities of practice
communities of place
upper trophic
Consider evolving interactions and pathways of adaptation

“***plausible descriptions** of how the future may evolve with respect to a range of variables…they are not meant to be policy prescriptive, (i.e. **no likelihood or preference is attached** to any of the individual scenarios of the set)”*

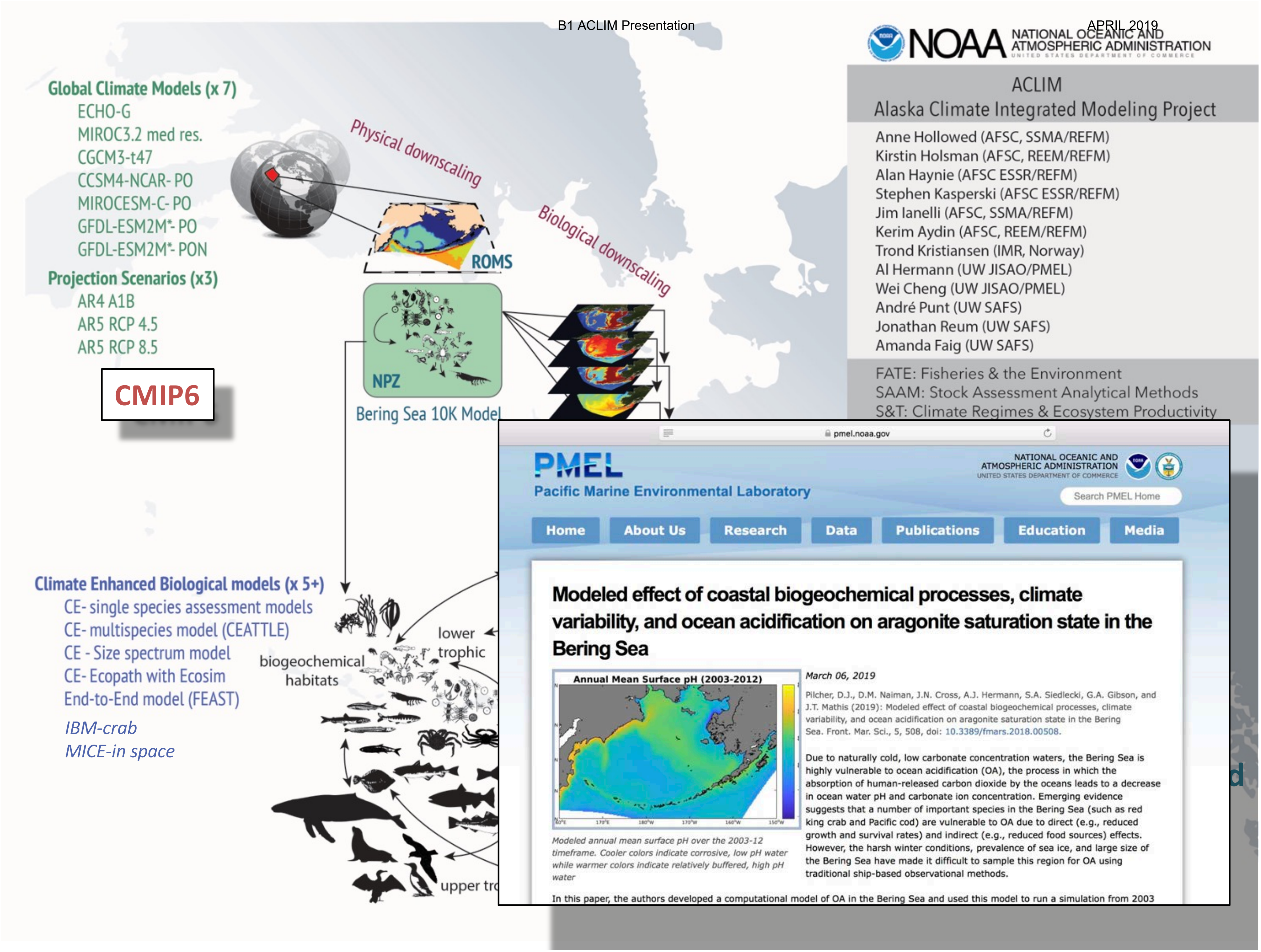
van Vuuren et al. 2011

Carbon Emission Scenarios



High-Baseline
“Business as usual”

Medium-low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IBM-crab
MICE-in space
biogeochemical habitats
lower trophic
upper tr
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Pacific Marine Environmental Laboratory
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE
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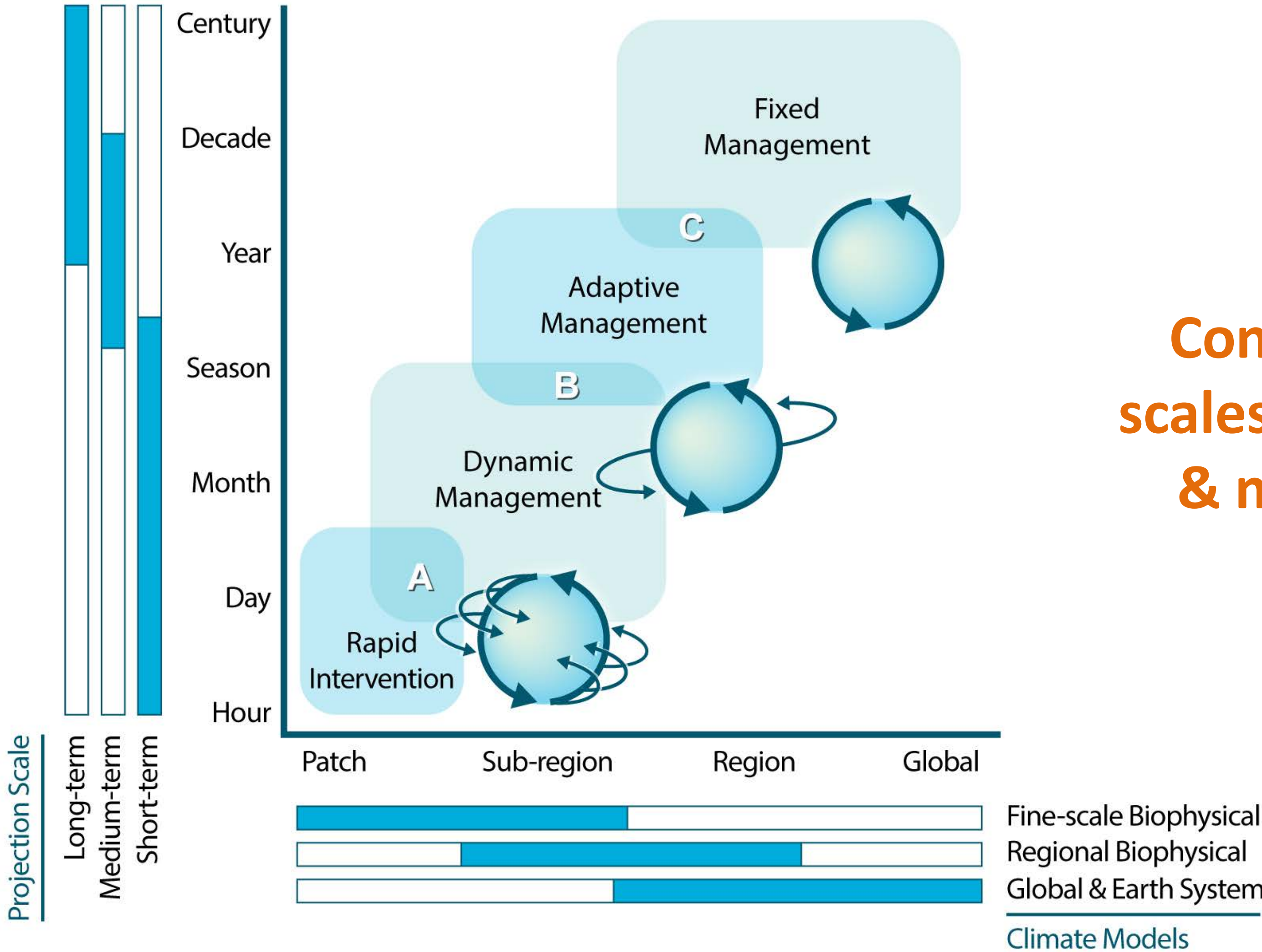
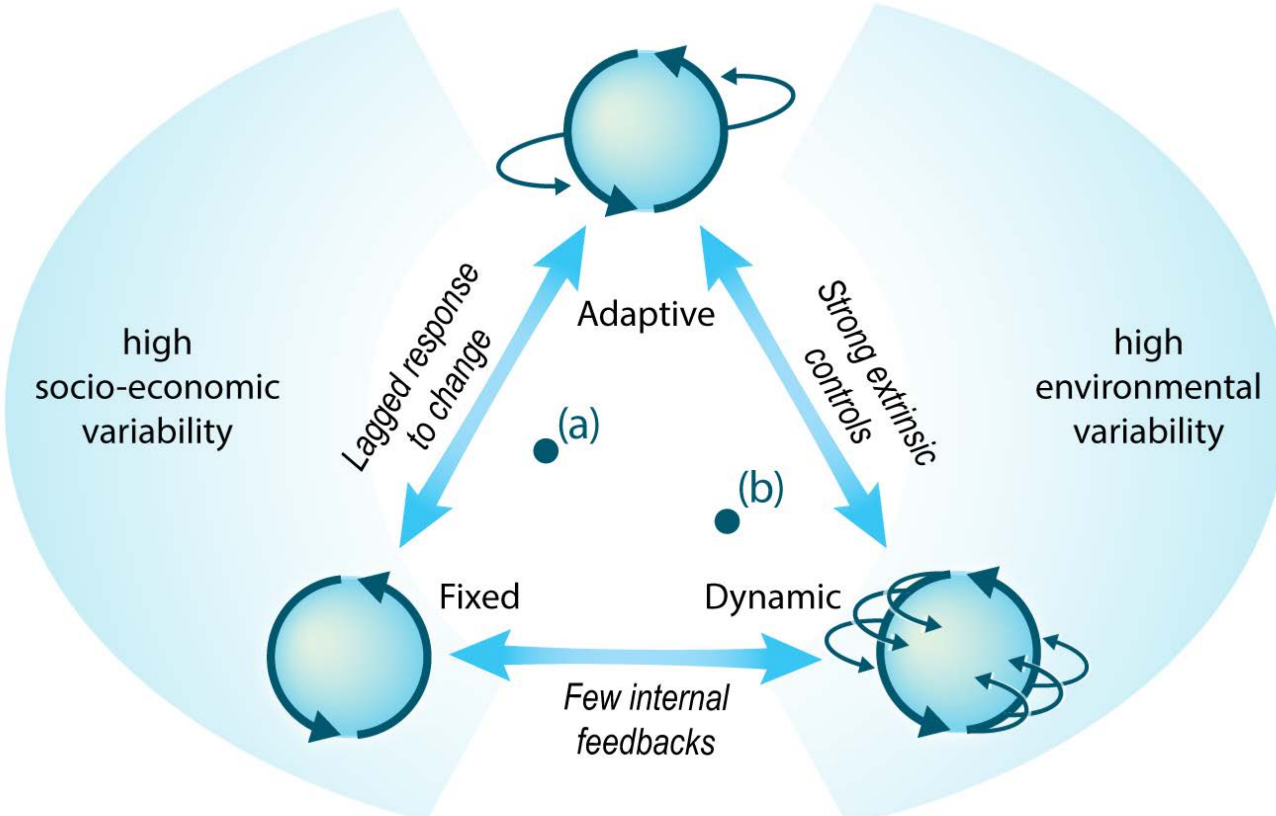
Modeled effect of coastal biogeochemical processes, climate variability, and ocean acidification on aragonite saturation state in the Bering Sea
Annual Mean Surface pH (2003-2012)
March 06, 2019
Pilcher, D.J., D.M. Naiman, J.N. Cross, A.J. Hermann, S.A. Siedlecki, G.A. Gibson, and J.T. Mathis (2019): 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 the Bering Sea have made it difficult to sample this region for OA using traditional ship-based observational methods.
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 model of OA in the Bering Sea and used this model to run a simulation from 2003



Consider nested scales of adaptation & management

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

Climate resilient management = portfolio of multiscale approaches



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

RESULTS: *physics & lower trophic*

OBSERVATIONS ROMSNPZ (downscaled) GLOBAL MODEL

2003

2009

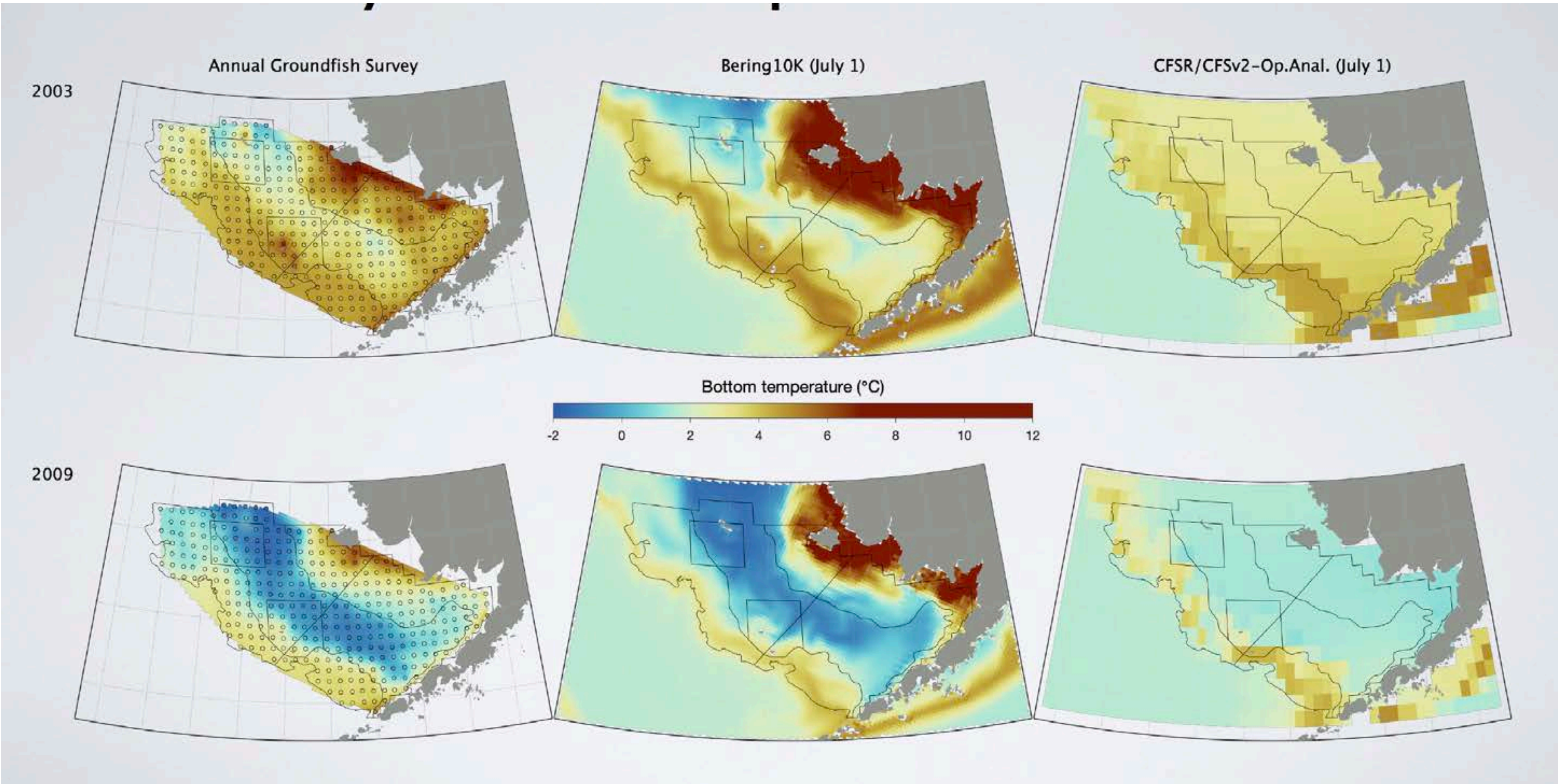
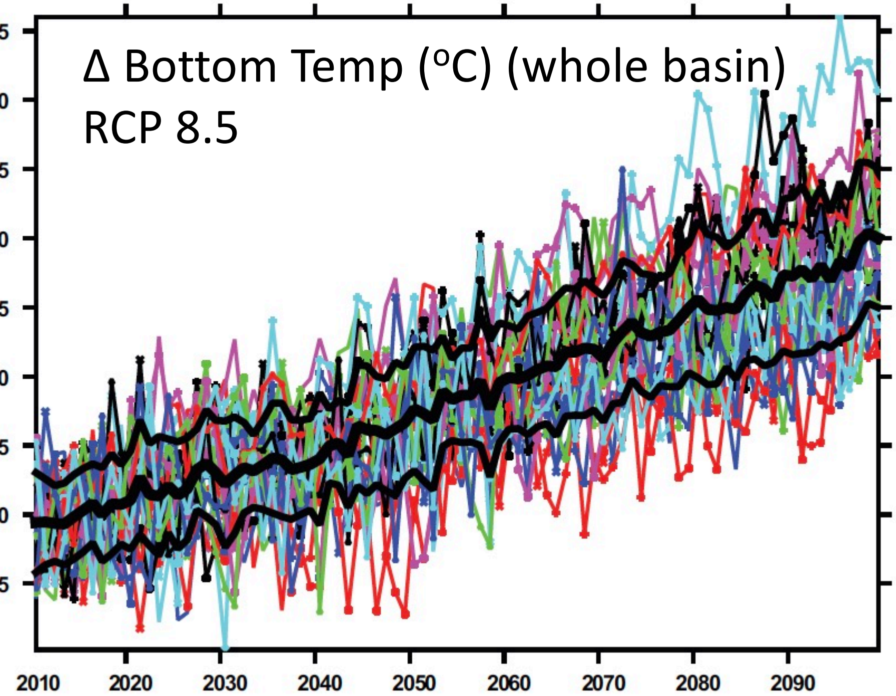


Image: Kelly Kearney

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



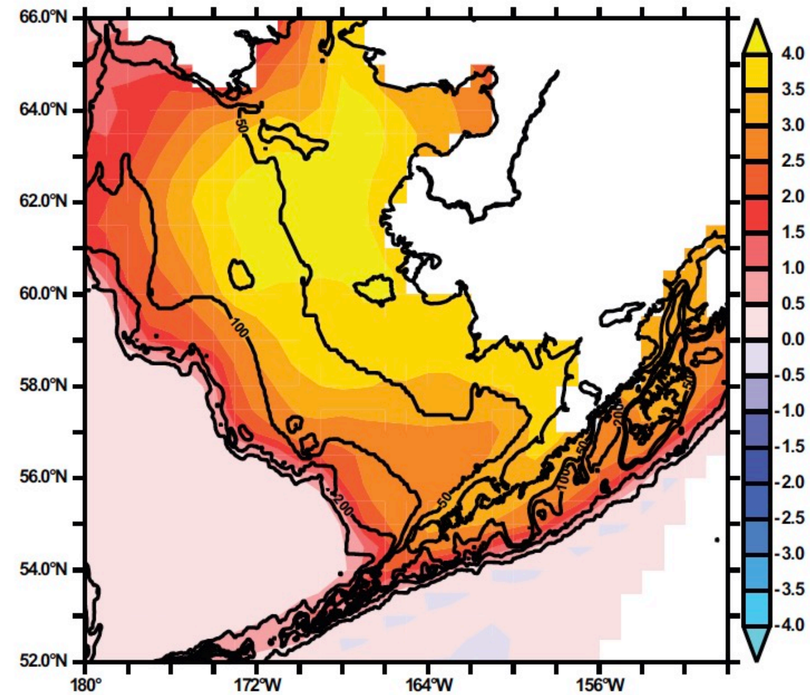


Figure 12: Ensemble results for sea bottom temperature (sbt), obtained by projecting atmospheric forcing (from 28 different CMIP5 models under emission scenario RCP8.5) onto the multivariate modes. Left: yearly areal average for each CMIP5 realization, relative to the 2010-2019 mean. Dark black lines show ensemble mean; light black lines indicate +/- Sd for that year. Right: ensemble mean change based on the 28 CMIP5 models. (modified from Hermann et al. in press)

(in press) Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz, 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)

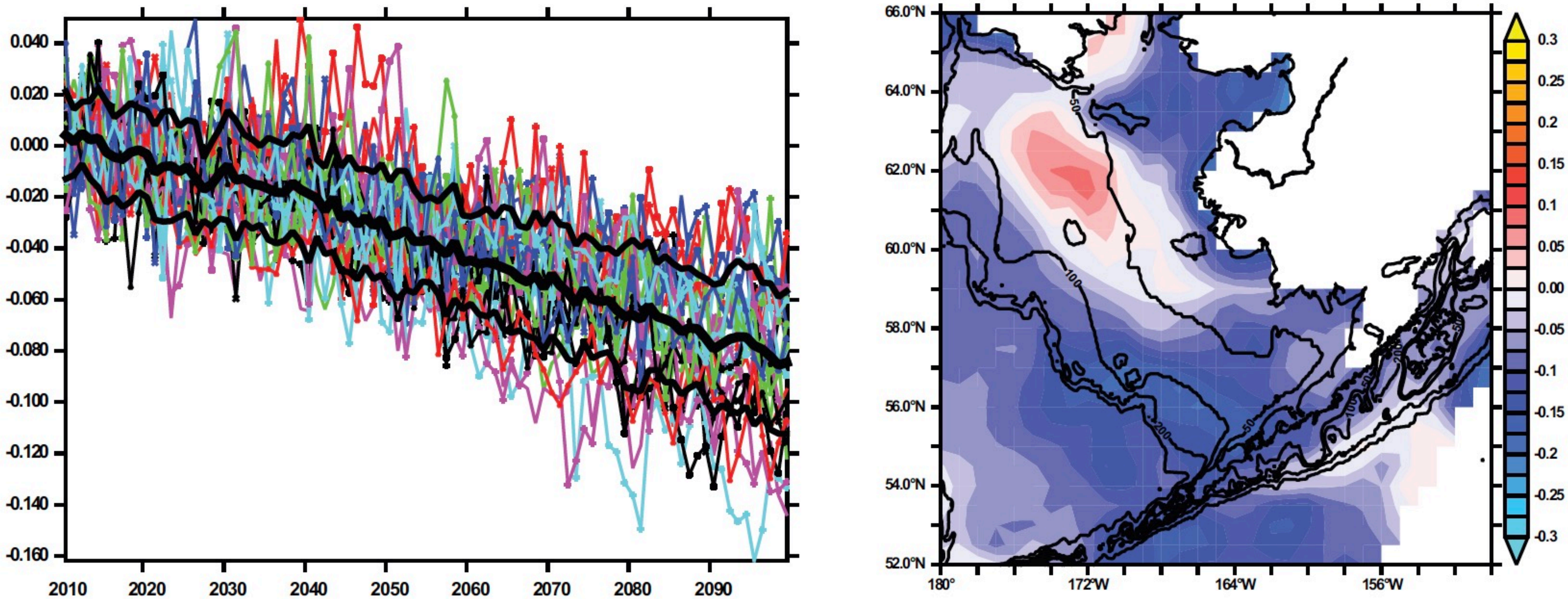


Figure 13. Ensemble results as in Figure 12, for $\log_{10}$ (large crustacean zooplankton).

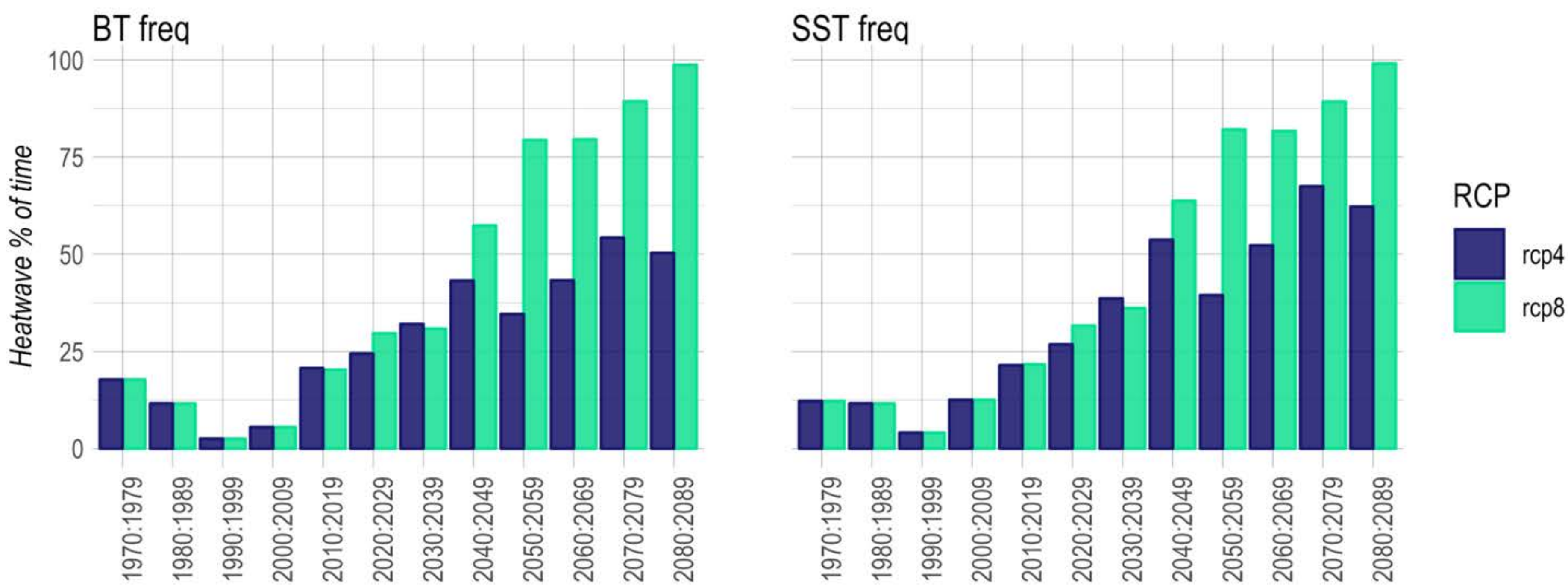
(in press) Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz,K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES. doi: 10.1093/ices/fsz043

Marine heatwaves will likely increase in frequency and duration

Heatwaves
Now ~ 21% of the time
2050 ~ 30-77% of the time
2100 ~ 60-90% of the time

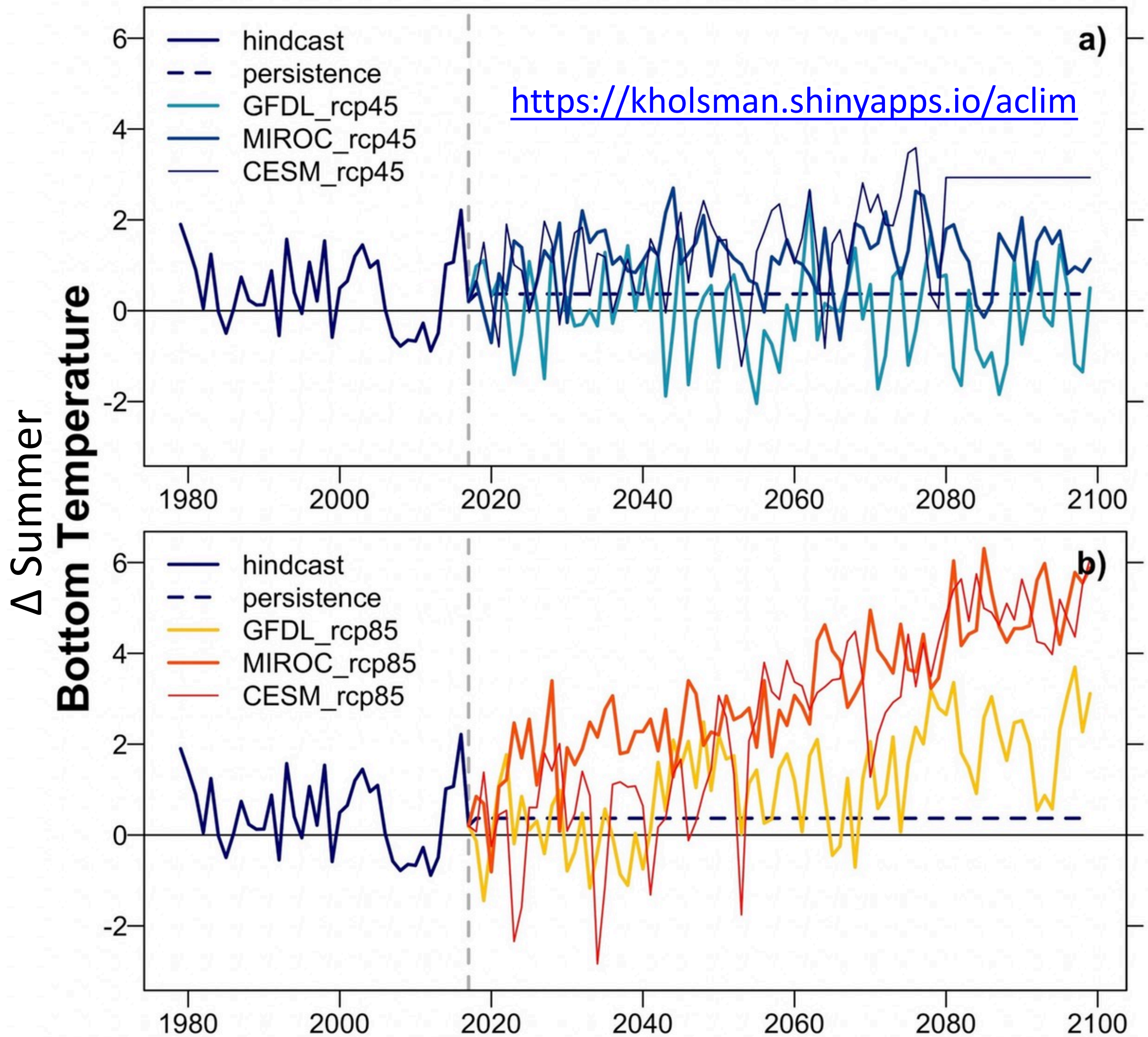
Duration

Marine heatwave analysis based on downscaled ROMSNPZ hindcast + projections, and 1970-2000 climatology.



ROMSNPZ: K. Kearney, A. Hermann, W. Cheng, K. Aydin, 2018
Heatwave analysis: K. Holsman, 2018, based on Hobday et al. (2016)
Data source: NOAA PMEL, AFSC REEM Program, IEA, MAPP Bering Seasons,ACLIM

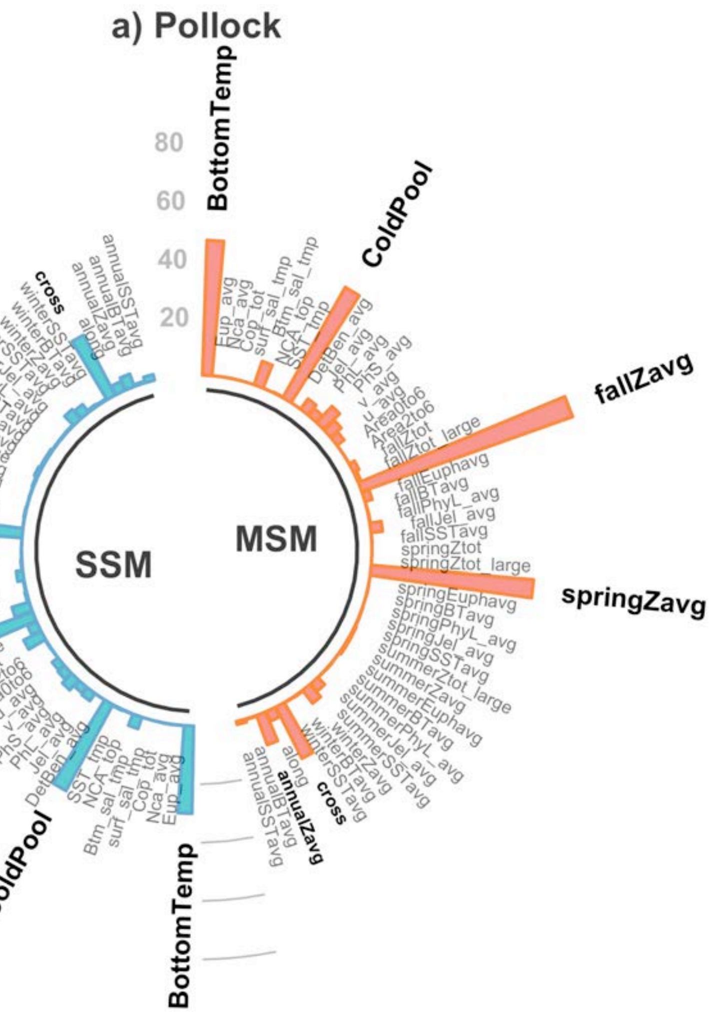
RESULTS: *upper trophic & fisheries*

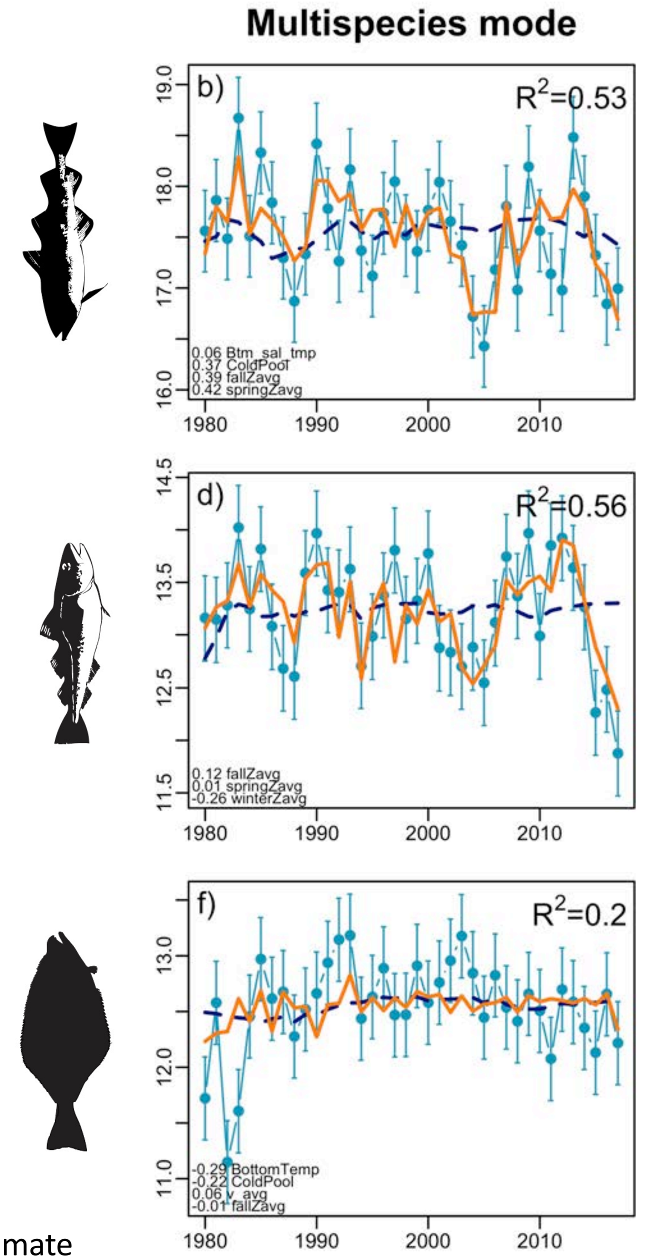


(in prep) Holsman et al. Evidence for trophic amplification and attenuation of potential climate change impacts on groundfish productivity in the Bering Sea, AK. Climate change.

(in press) Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz ,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

CEATTLE Recruitment

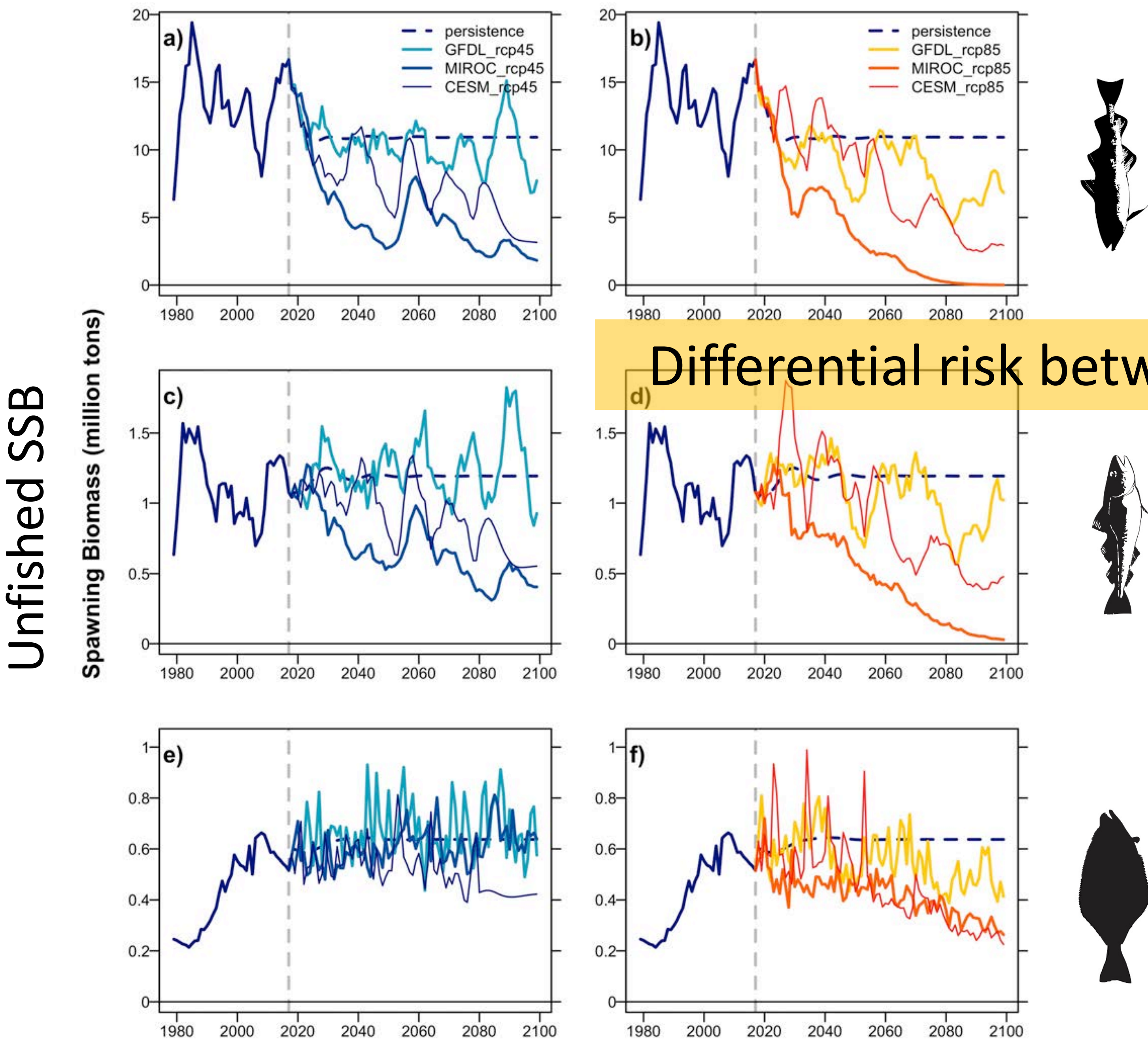




(in prep) Holsman et al. Evidence for trophic amplification and attenuation of potential climate change impacts on groundfish productivity in the Bering Sea, AK. Climate change.

RCP 4.5

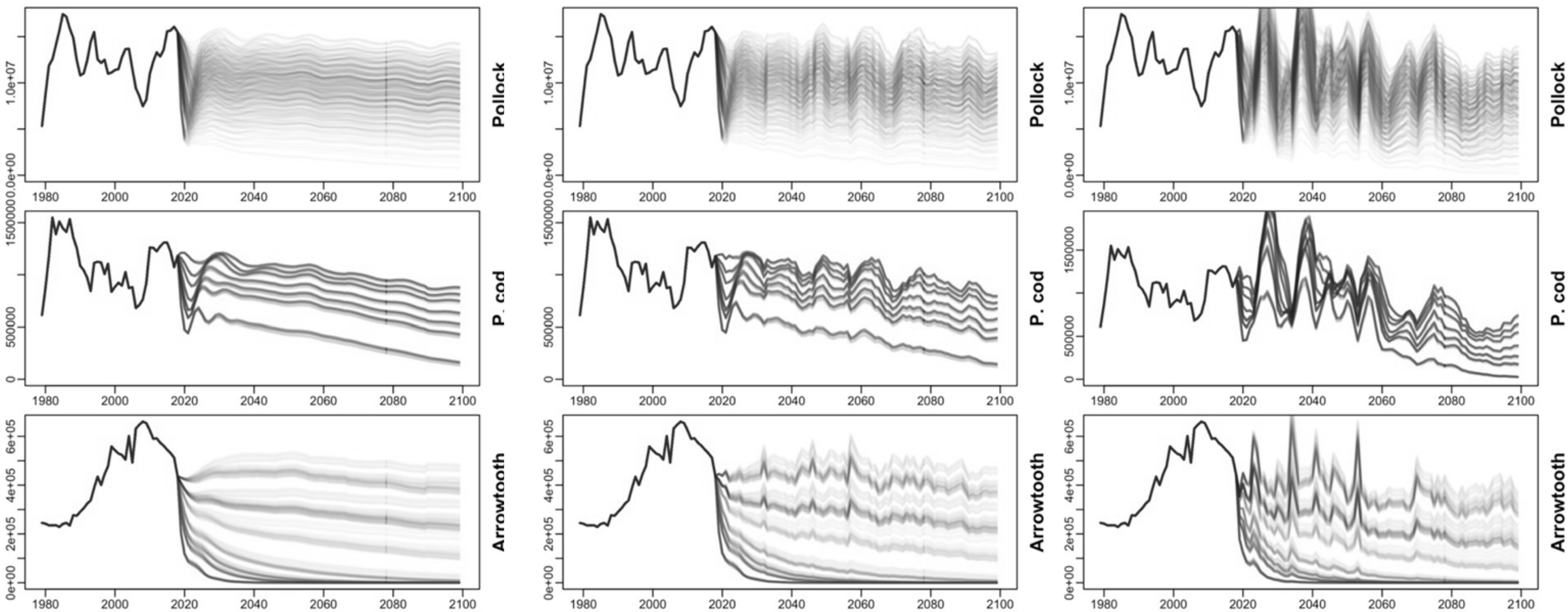
RCP 8.5



Differential risk between RCPs

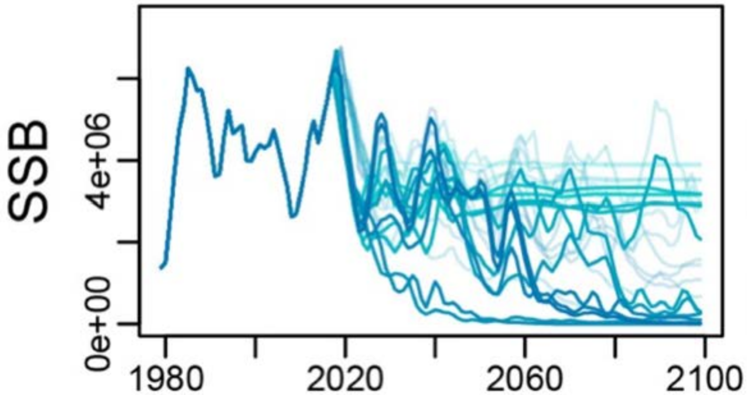
(in prep) Holsman et al. Evidence for trophic amplification and attenuation of potential climate change impacts on groundfish productivity in the Bering Sea, AK. Climate change.

Global CESM RCP 8.5 (20 yr smooth) | Global CESM RCP 8.5 (annual) | Downscaled CESM RCP 8.5

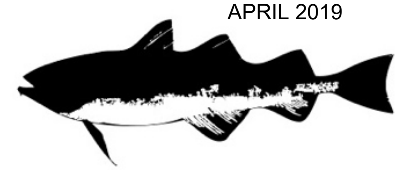


Downscaling is key for understanding variability

Holsman, KK et al. in prep. Comparative global and downscaled projections yield divergent estimates of fishery volatility under climate change.

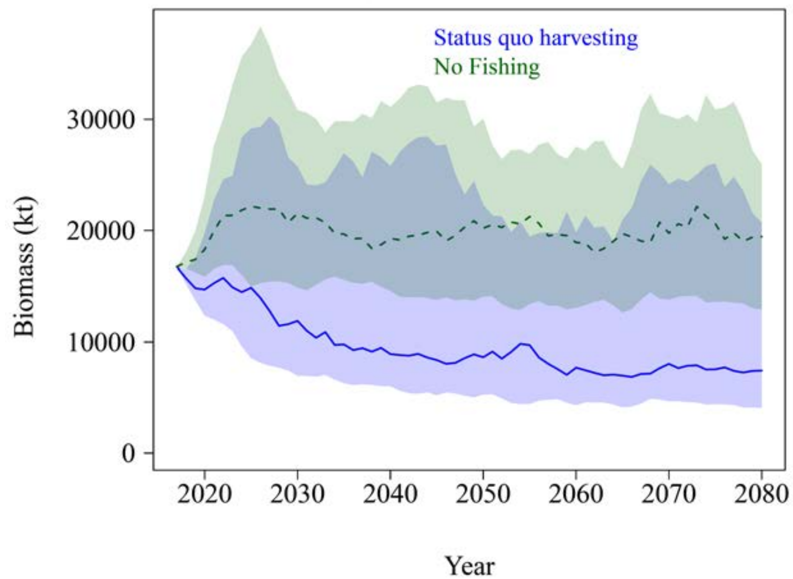


CEATTLE
model



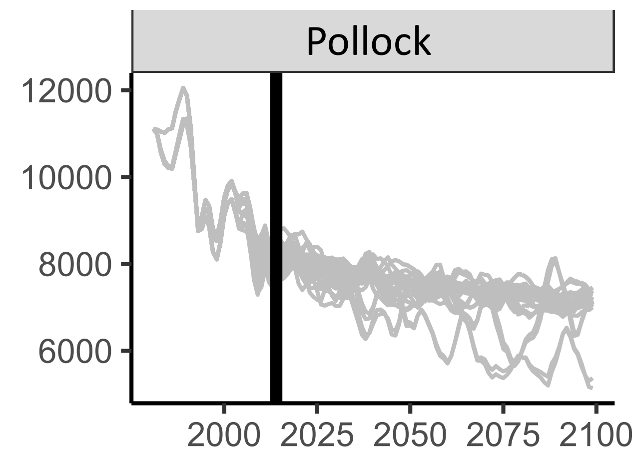
Pollock spawning biomass

Ecologically-enhanced
single spp



Spencer et al. in prep

Bering Sea
Size-spectrum model



Reum et al. 2019

Synergies despite structural differences

Future populations driven by Climate change scenarios

More research on interactions & processes would reduce uncertainty

Changing fishing approaches changes populations

“Random noise”

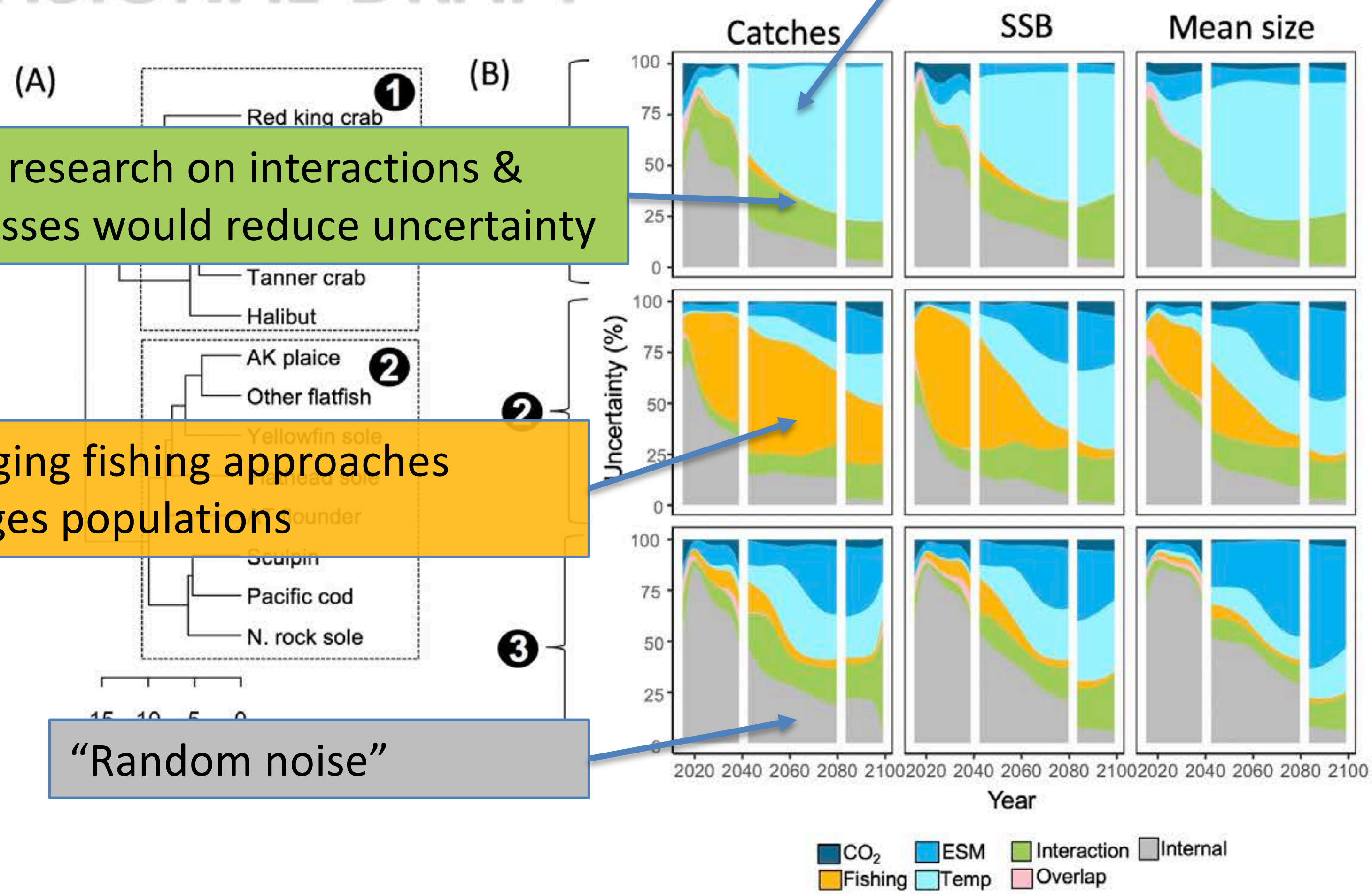


Fig. SXXX. (A) Dendrogram of species similarity (Euclidean distance) based on relative importance of different uncertainty sources to catches, SSB, and mean weight ensemble projections. Three clusters were identified (labeled 1-3). (B) Area plots indicate the proportion of uncertainty associated with each source averaged across species within the three clusters.

Reum JCP, et al. (In Prep) Ensemble projections of future climate change impacts on the Eastern Bering Sea food web using a multispecies size spectrum model. *Intended for* Frontiers in Marine Science

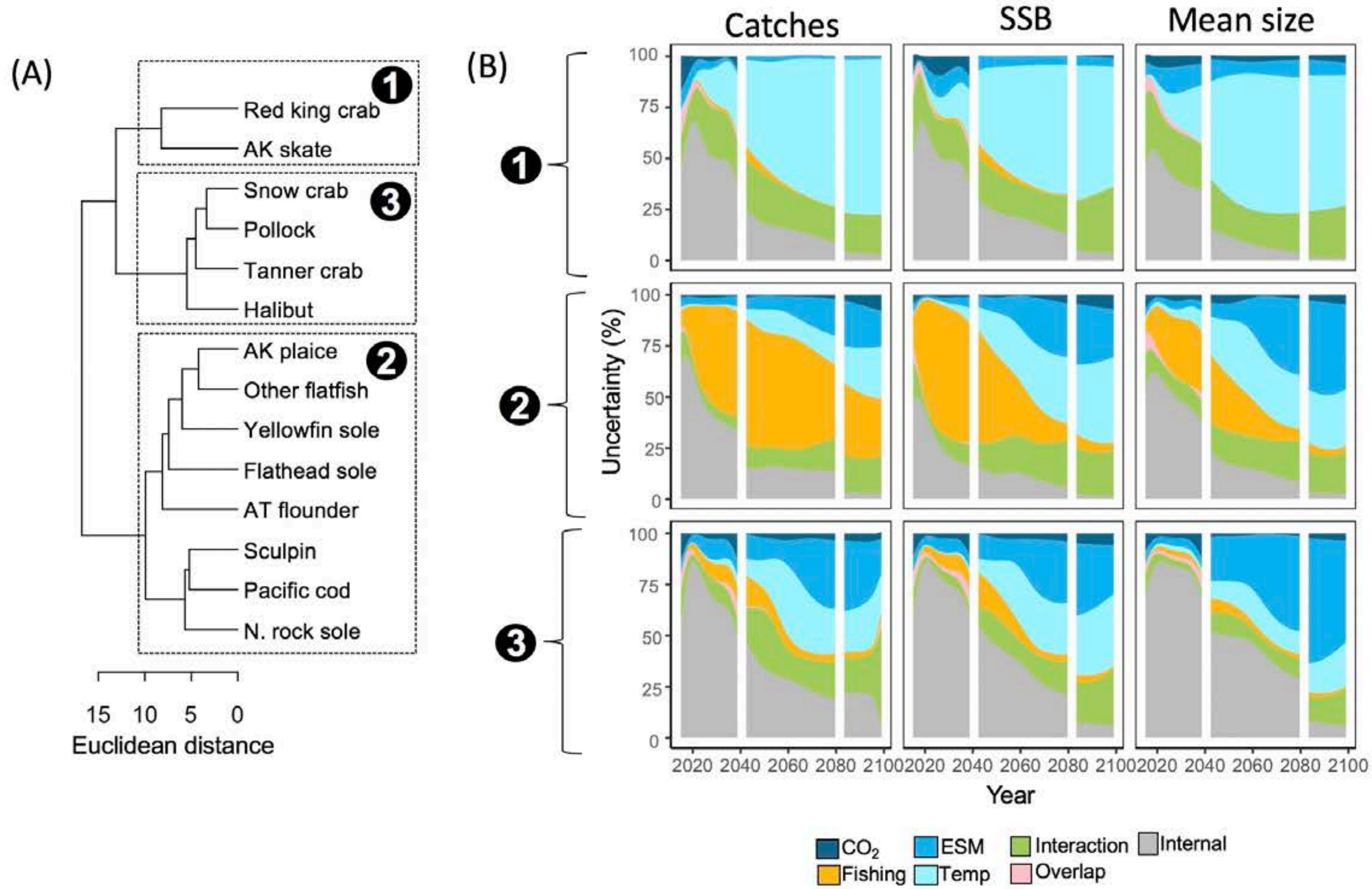


Fig. SXXX. (A) Dendrogram of species similarity (Euclidean distance) based on relative importance of different uncertainty sources to catches, SSB, and mean weight ensemble projections. Three clusters were identified (labeled 1-3). (B) Area plots indicate the proportion of uncertainty associated with each source averaged across species within the three clusters.

Reum JCP, et al. (In Prep) Ensemble projections of future climate change impacts on the Eastern Bering Sea food web using a multispecies size spectrum model. *Intended for* Frontiers in Marine Science

Downscaling is needed

Projections based on global climate models may underestimate future variance

Account for trophic interactions

Accounting for predation changed the direction of projections from increases (single-sp model) to declines (multi-sp)

Mitigation is lower risk

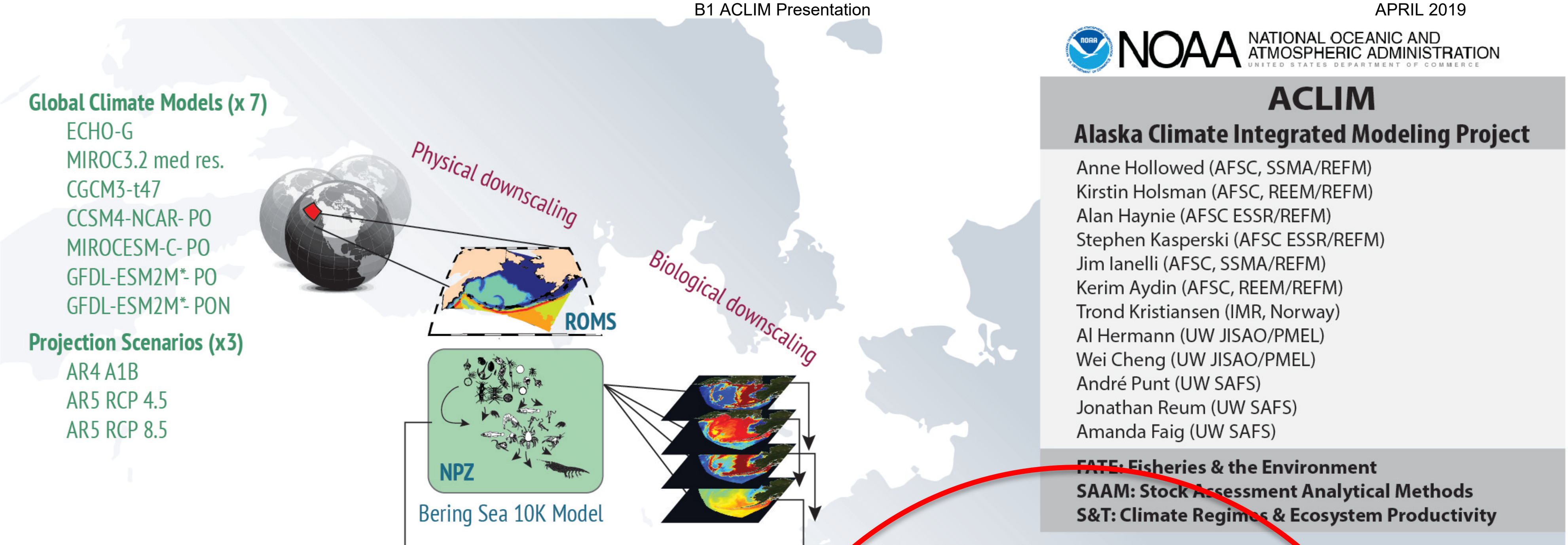
Most pollock and cod scenarios crashed under business as usual (RCP8.5) by 2100; carbon mitigation (RCP 4.5) may lessen or prevent declines

Adaptation through fisheries management

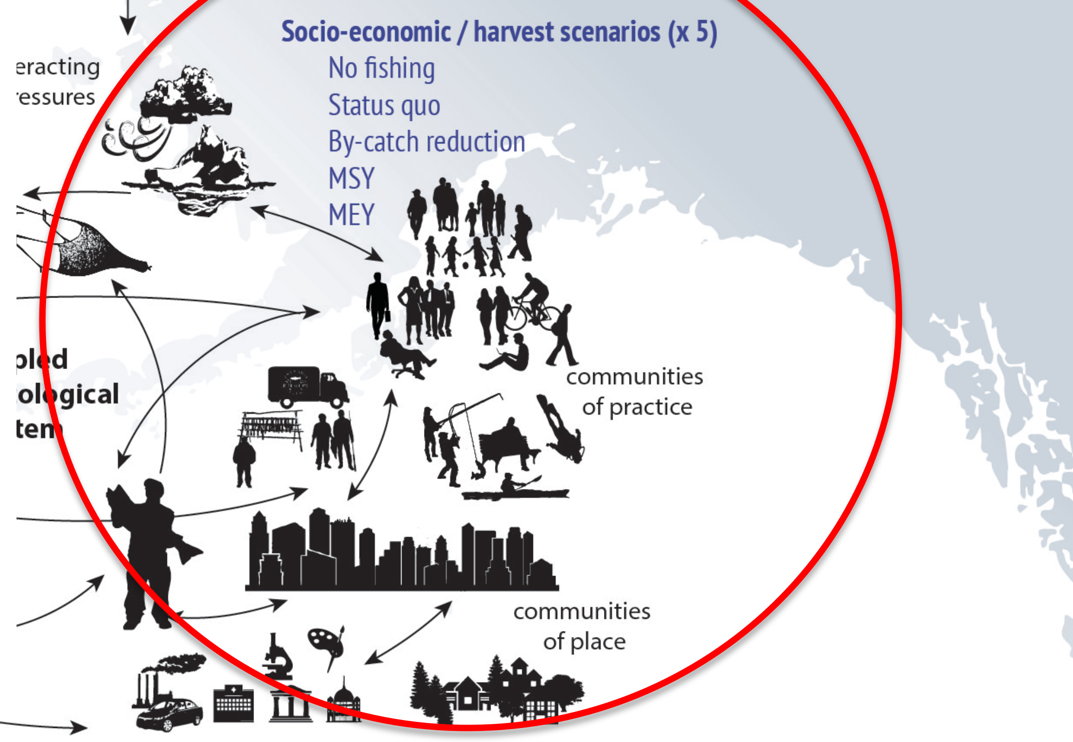
Changing harvest rates through management can help lessen climate impacts, to a point. Considering regional management policies is important.

Holsman et al. in prep

BEYOND 'STATUS QUO': *SocioEcon*

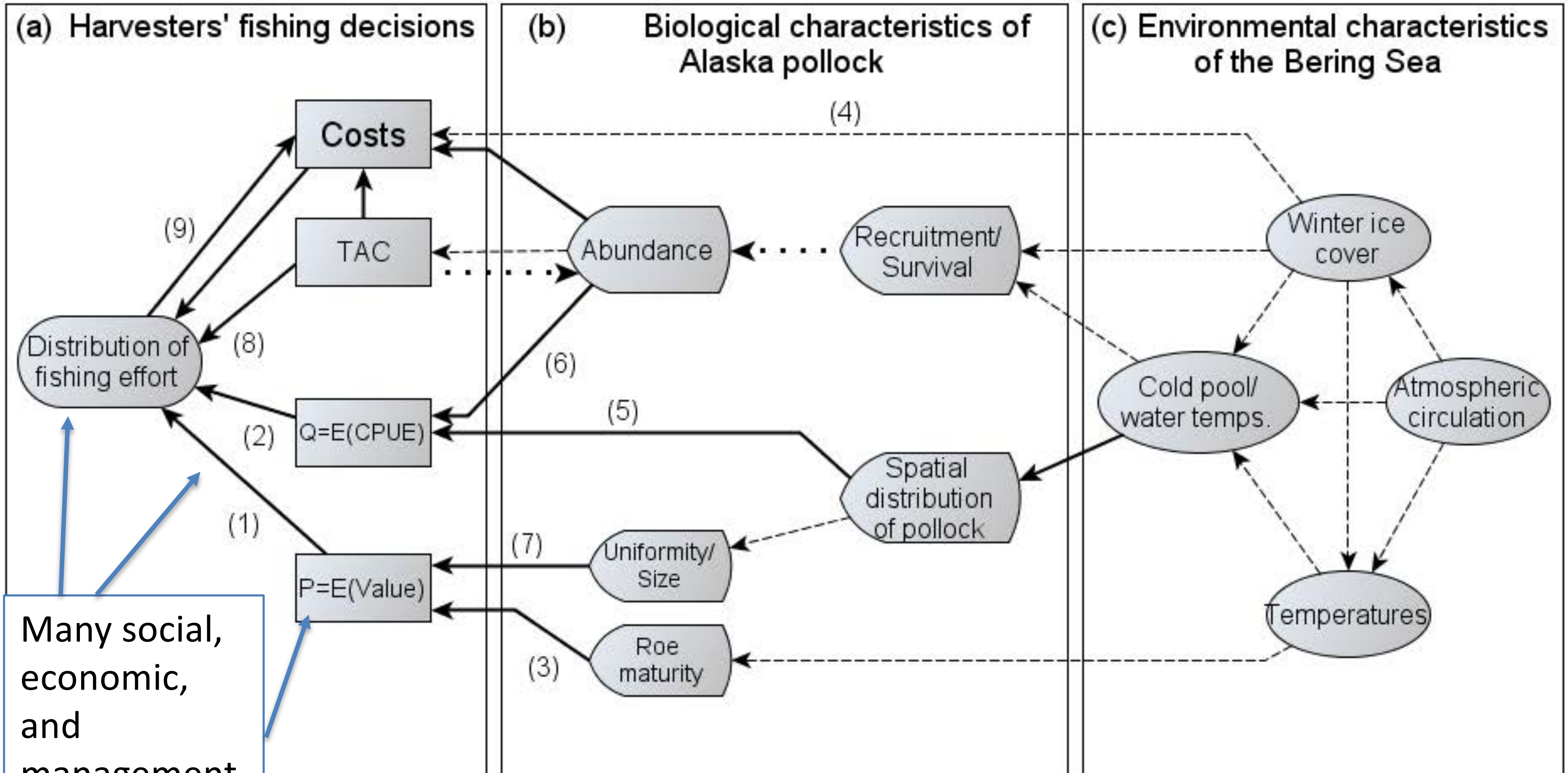


How can we make these complex dynamics realistic but as simple as possible?



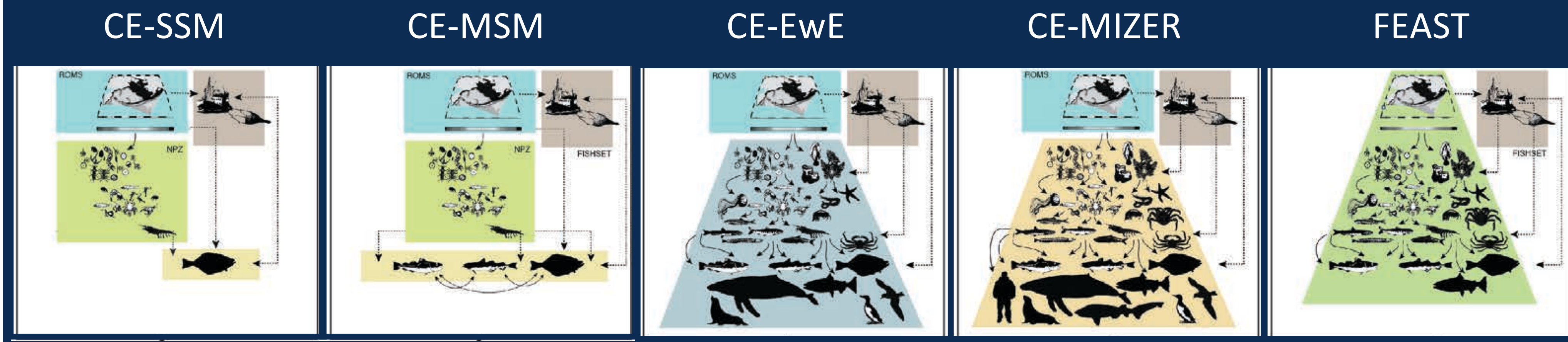
"Downscaled" Bering Sea Socioeconomic Scenarios

- Markets – project prices and costs
- Translate key economic changes to fisher behavior through different models
- Evaluate management tools
- Estimate impacts on fishers & communities.



Many social, economic, and management factors.

Haynie and Pfeiffer 2013 *CJFAS*



Fast
Statistical
Implicit ecosystem “noise”

Slow, high resolution
Mechanistic
Explicit ecosystem interactions

- Effort response to abundance
- Spatial models of fleets responding to shifts in fish distributions.
- Maximum economic yield (MEY)
- Community impact analyses

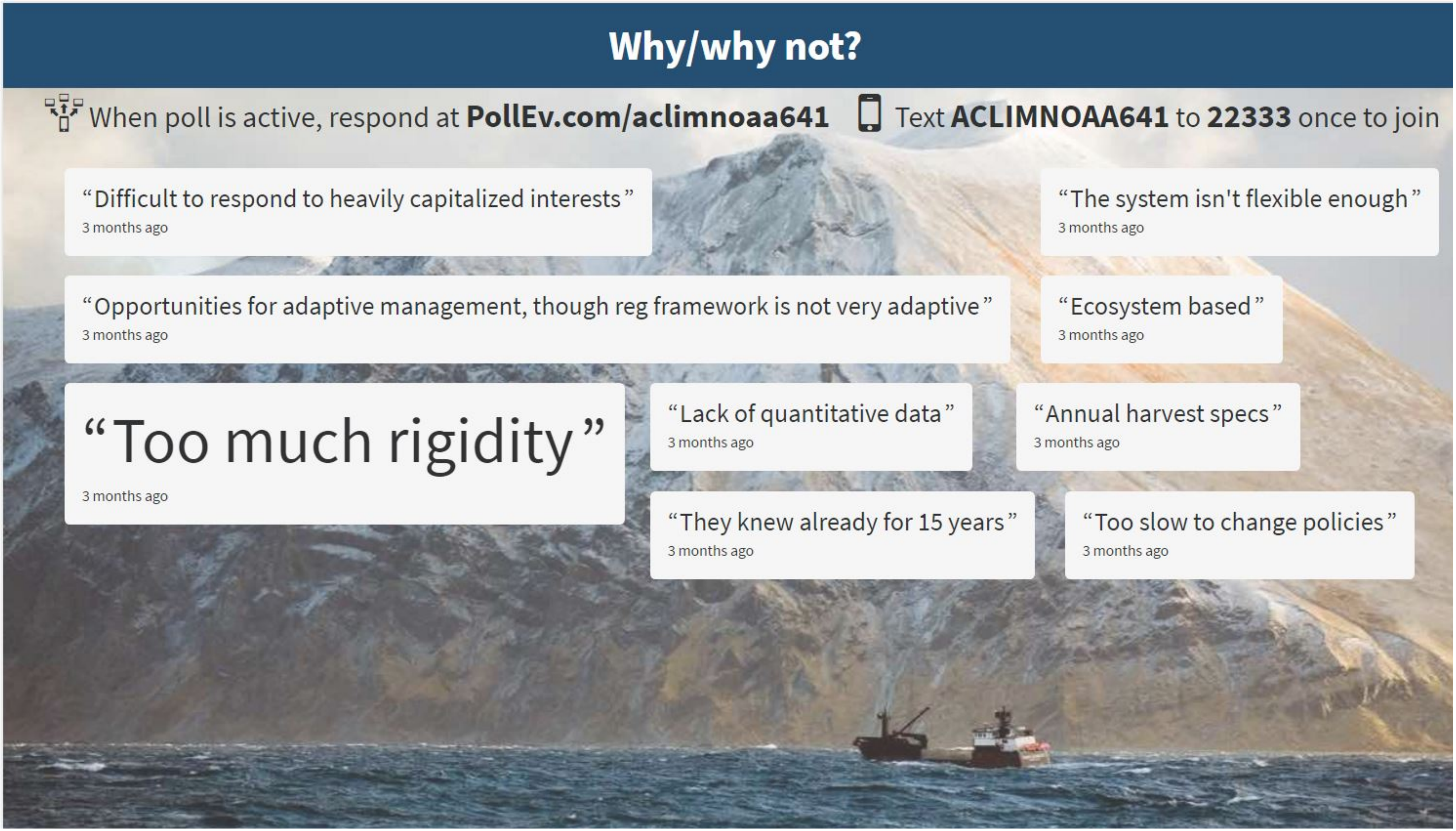
ACLIM utilizes economic models of different complexity

Multiple ACLIM workshops with North Pacific Fishery Management Council and Other Alaska Stakeholders 2016-2018+

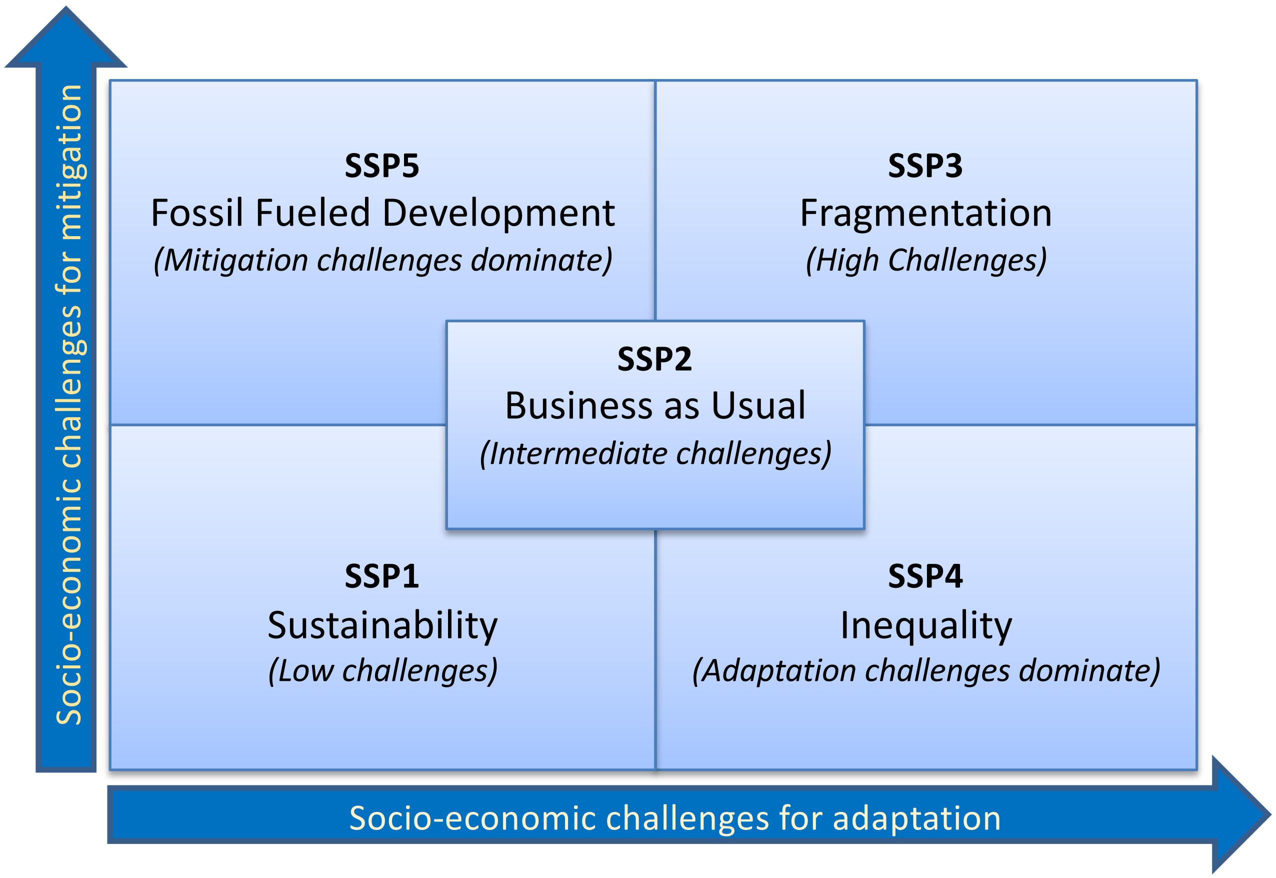
- ACLIM Presentations of results & progress
- Interactive workshops
- Repeated discussions: impacts & priority issues

Photo: Alan Haynie

"Do you think our current management process is well suited to handle climate change?”



IPCC Socio-Economic Pathways (SSPs)



There is large uncertainty about economic trends…

O'Neill et al *Global Environmental Change* 2015

Ocean System Pathways (OSPs)

Global Environmental Change 45 (2017) 203–216

Contents lists available at ScienceDirect

Global Environmental Change

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

ELSEVIER

From shared socio-economic pathways (SSPs) to oceanic system pathways (OSPs): Building policy-relevant scenarios for global oceanic ecosystems and fisheries

CrossMark

O. Maury[a,b,*], L. Campling[c], H. Arrizabalaga[d], O. Aumont[e], L. Bopp[f,g], G. Merino[d], D. Squires[h], W. Cheung[i], M. Goujon[j], C. Guivarch[k], S. Lefort[f], F. Marsac[a,b], P. Monteagudo[l], R. Murtugudde[m], H. Österblom[n], J.F. Pulvenis[o], Y. Ye[p], B.J. van Ruijven[q]

[a] IRD – UMR 248 MARBEC, Av Jean Monnet CS 30171, 34203 SETE cedex, France

- Alcamo, J., 2008. The SAS approach: combining qualitative and quantitative knowledge in environmental scenarios environmental futures – the practice of environmental scenario analysis.

scenarios provide contrasting futures of how the social-ecological system could evolve

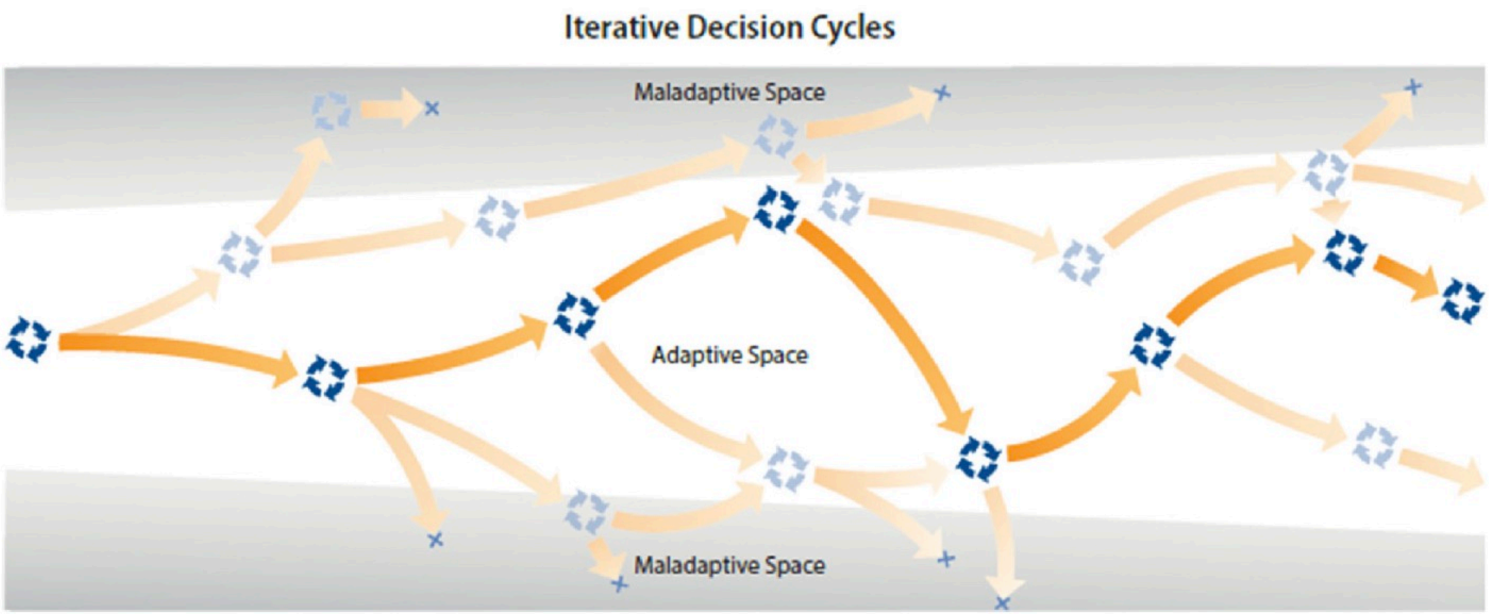


Fig. 1. The current 'classic' conceptualisation of adaptation pathways – as a series of adaptive learning decision cycles over time (top left, cf. Willows and Connell, 2003; Haasnoot et al., 2013) with their decision lifetimes (top right – the sum of lead and consequence times, cf. Stafford Smith et al., 2011), where some chains of decisions lead to maladaptive outcomes over time, but there may be other alternatives that are adaptive (bottom, cf. Reeder and Ranger, 2011; Haasnoot et al., 2013). From the perspective of the current decision point at the left, a currently satisfactory pathway can be plotted through the future (strongest colour), but this must be re-visited at each decision point (Figure developed by Andy Reisinger, pers. comm.).

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

Fishery Mechanisms	Why this might increase	Why this might decrease
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		

Fishery Mechanisms	Why this might increase	Why this might decrease
Fish prices	Driven by consumer demand, income and/or scarcity	Driven by fishing & 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	Mar	
Fishing and processing costs	Incr tax. incr	
Priority on conservation values or other uses of resources	Change in demand or strength of conservation measures	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

Can we simplify this further?

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

Can we simplify this further?

Price & cost change storylines

1. Increase in value and quota share of **pollock & cod** relative to others in the management system
2. Increase in relative value and quota share of lower-value species – primarily "**flatfish**"

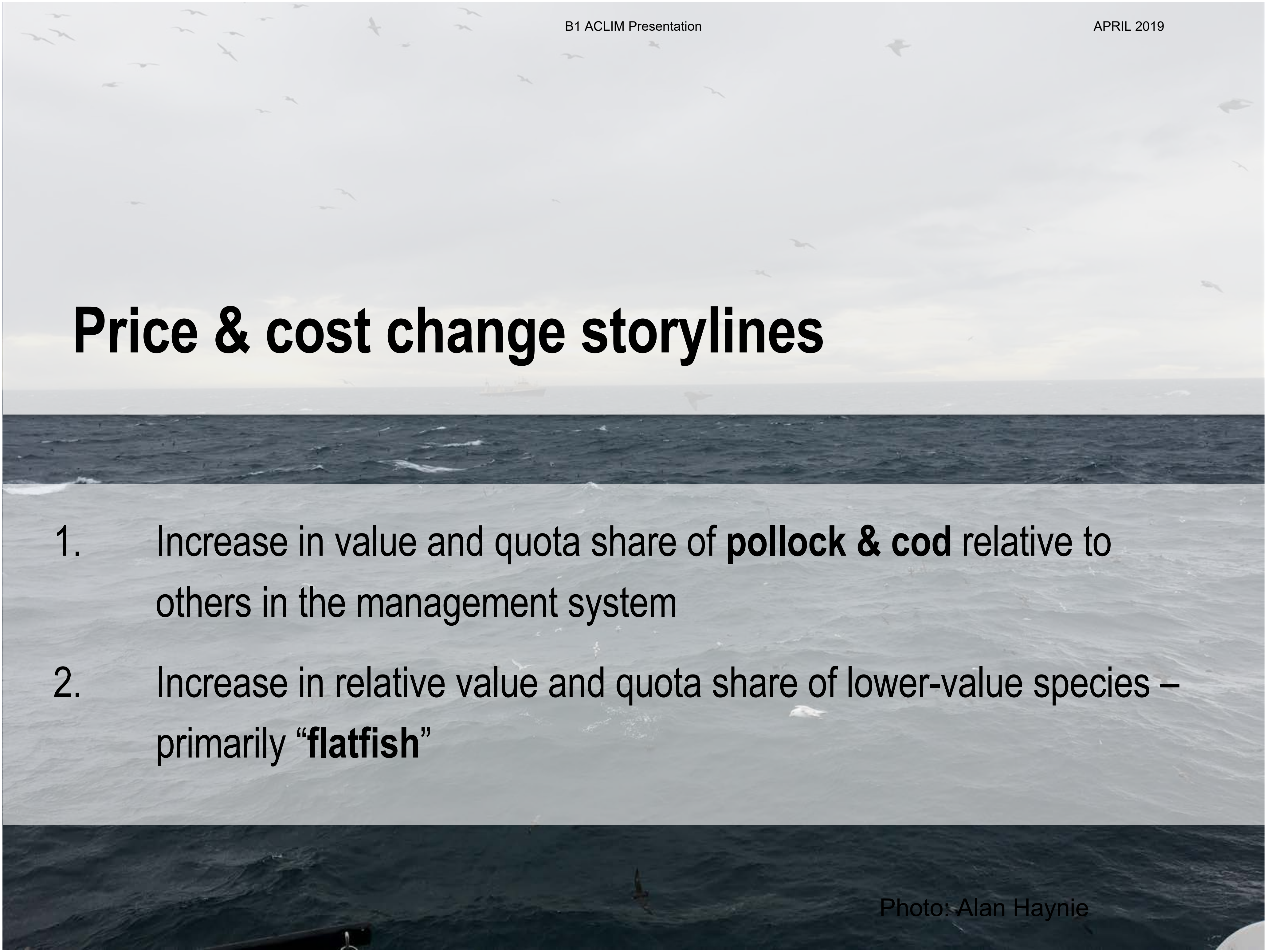


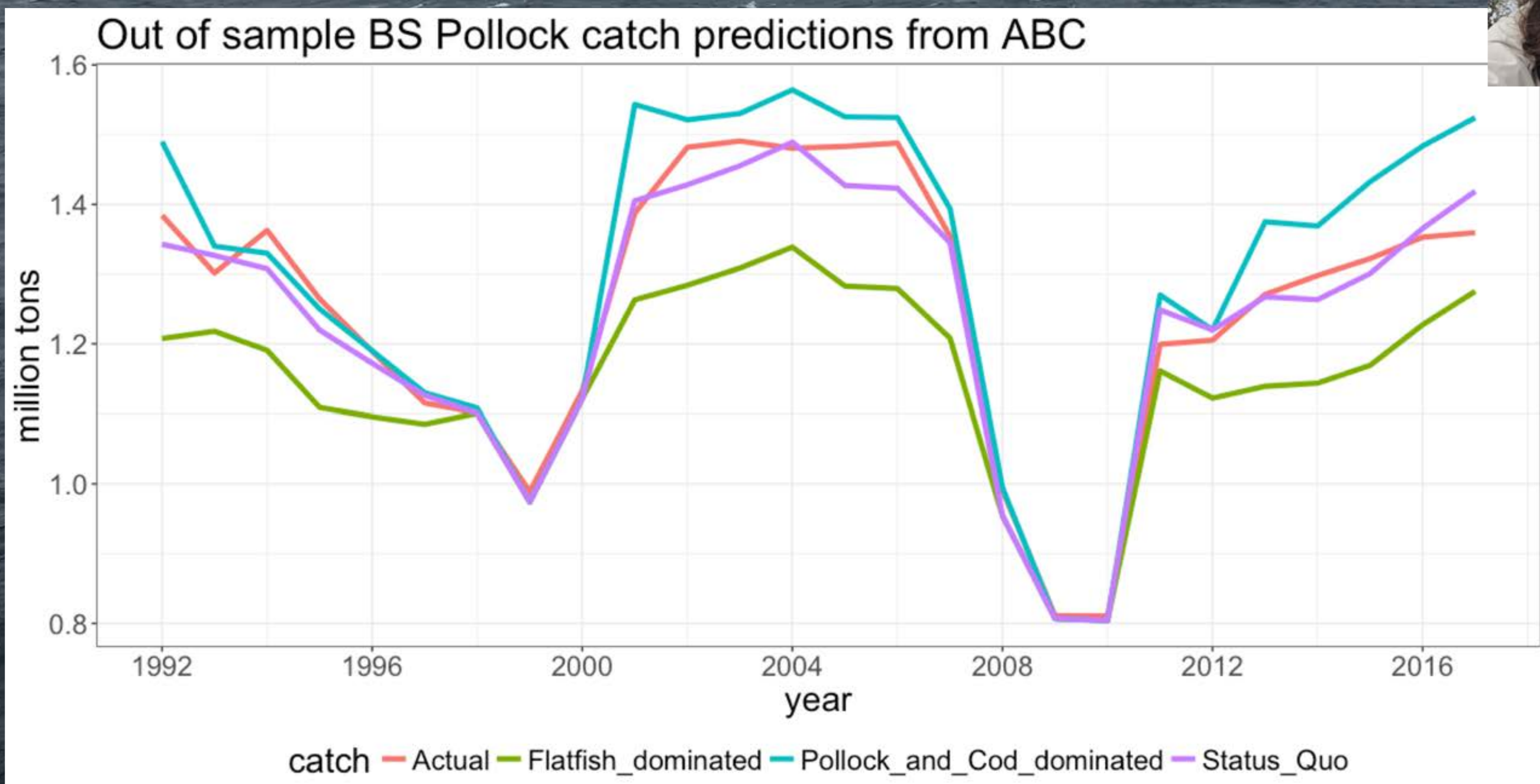
Photo: Alan Haynie

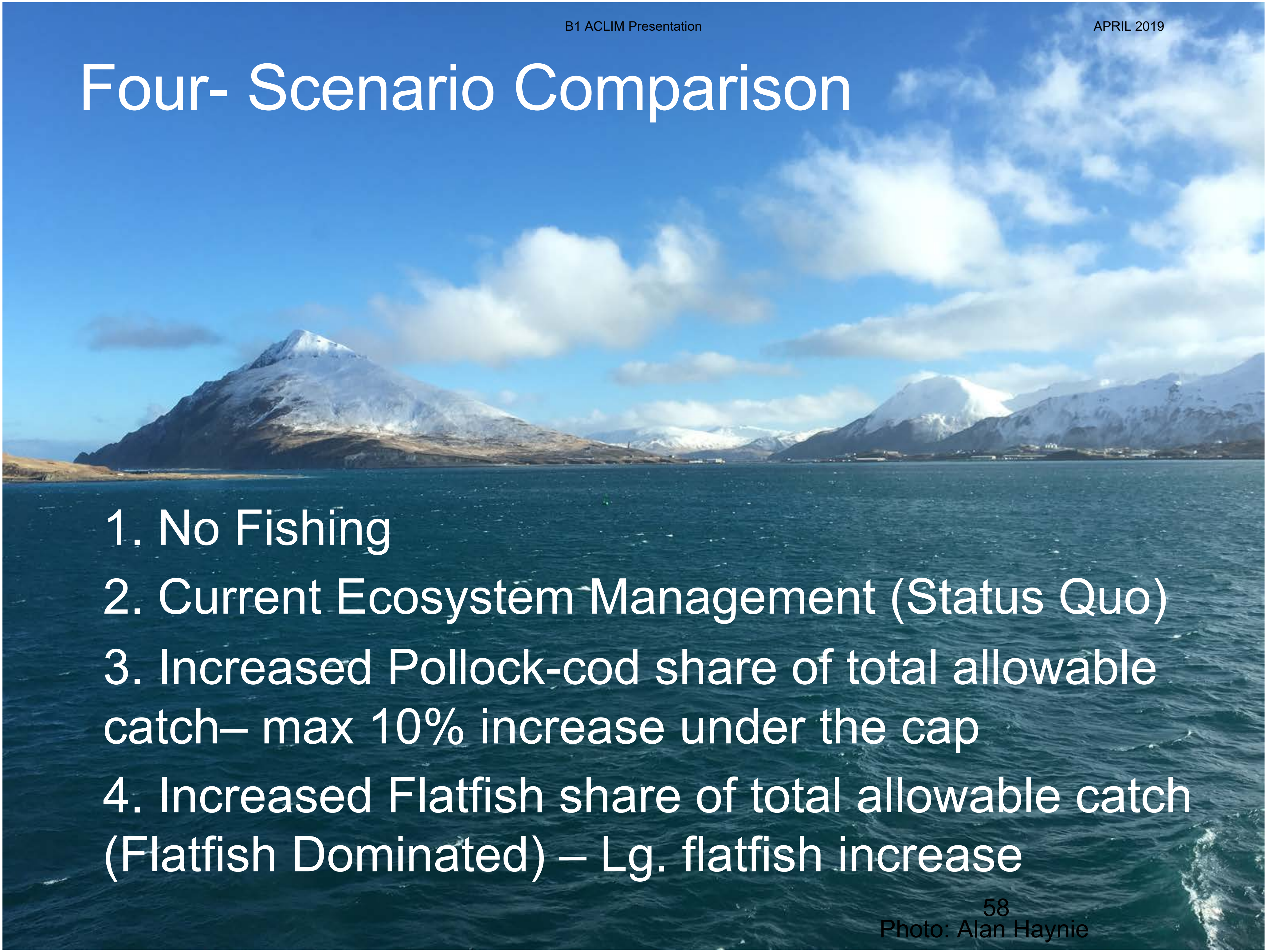
Bycatch and Protected Species Scenarios

- **Pollock constrained by challenges**
  - Chinook limits value/catch of pollock
  - Fur seals limit fishing near the Pribilof islands
- **Flatfish, Arrowtooth, and Atka constrained**
  - Increased SSL restrictions in the Aleutians
  - Reduced Flatfish TACs because of halibut

ABC To TAC And Commercial Harvest (ATTACH)

- Predicts TAC and harvest under current & alternative policies.
- Accurately captures management & fishing behaviors in the BSAI
- Allows ACLIM (& other) evaluate alternative policies performance



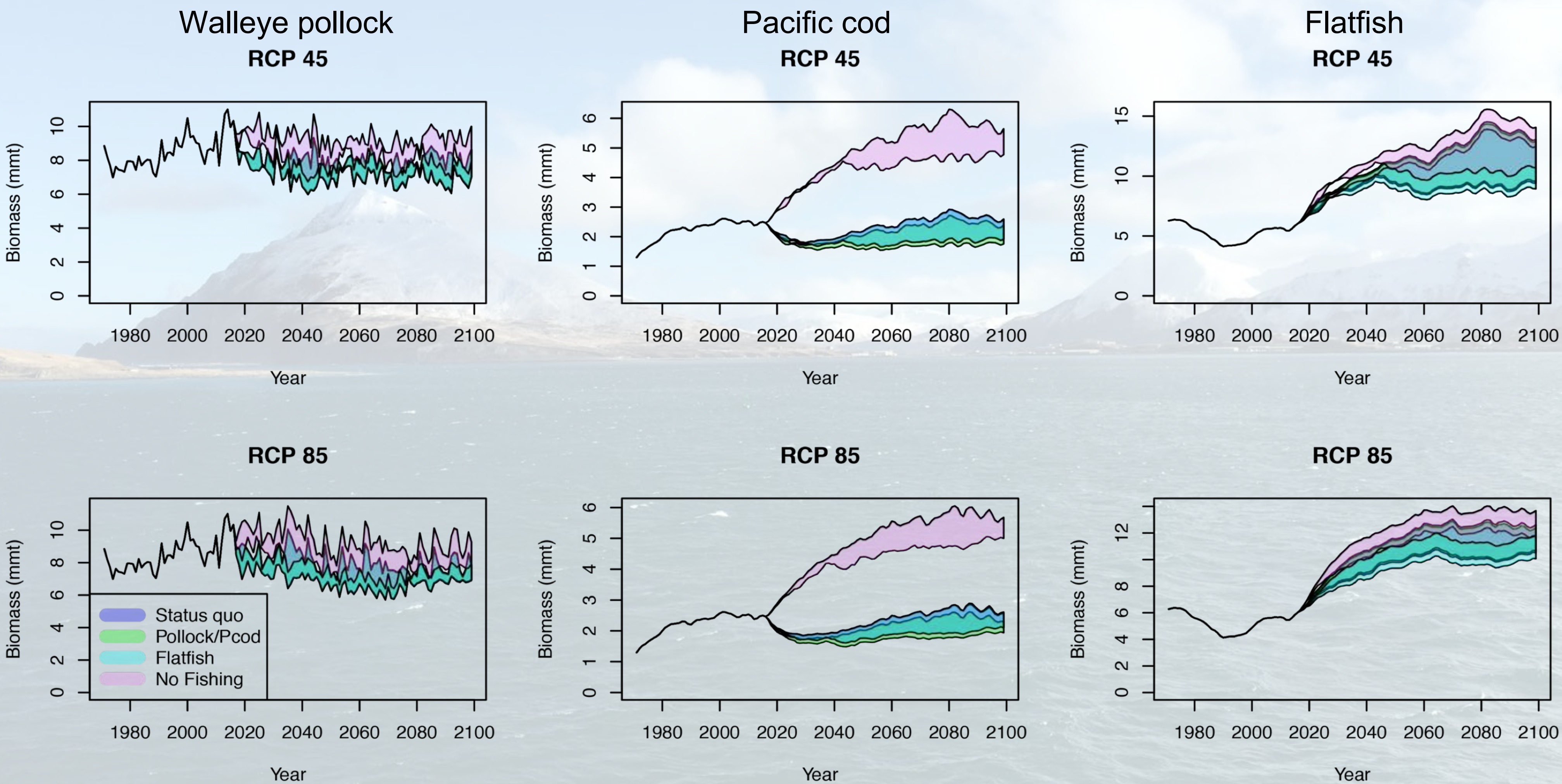


Four- Scenario Comparison

1. No Fishing
2. Current Ecosystem Management (Status Quo)
3. Increased Pollock-cod share of total allowable catch– max 10% increase under the cap
4. Increased Flatfish share of total allowable catch (Flatfish Dominated) – Lg. flatfish increase

Photo: Alan Haynie

Preliminary Results for Ecopath with Ecosim (EwE) Foodweb Model



From Whitehouse and Aydin. in prep (do not cite or copy)

Management Strategy Evaluations (MSEs)

- New technology
- Catch shares: differing impacts on risks
  (Kasperski & Holland 2013, Anderson et al 2017 etc.)
- Dynamic area closures
- Bycatch reduction incentives
- Revised harvest control rules
- Others (to be explored in the future)

Take-home Messages

- The Bering Sea is likely to change
- ACLIM tools are best available, but will continue to evolve & improve
- Continued excellent and responsive management will be essential.

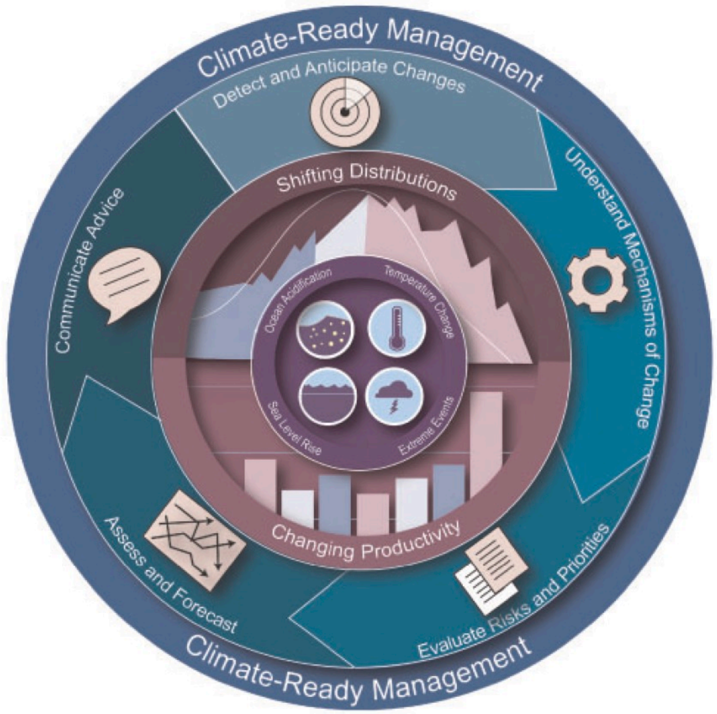
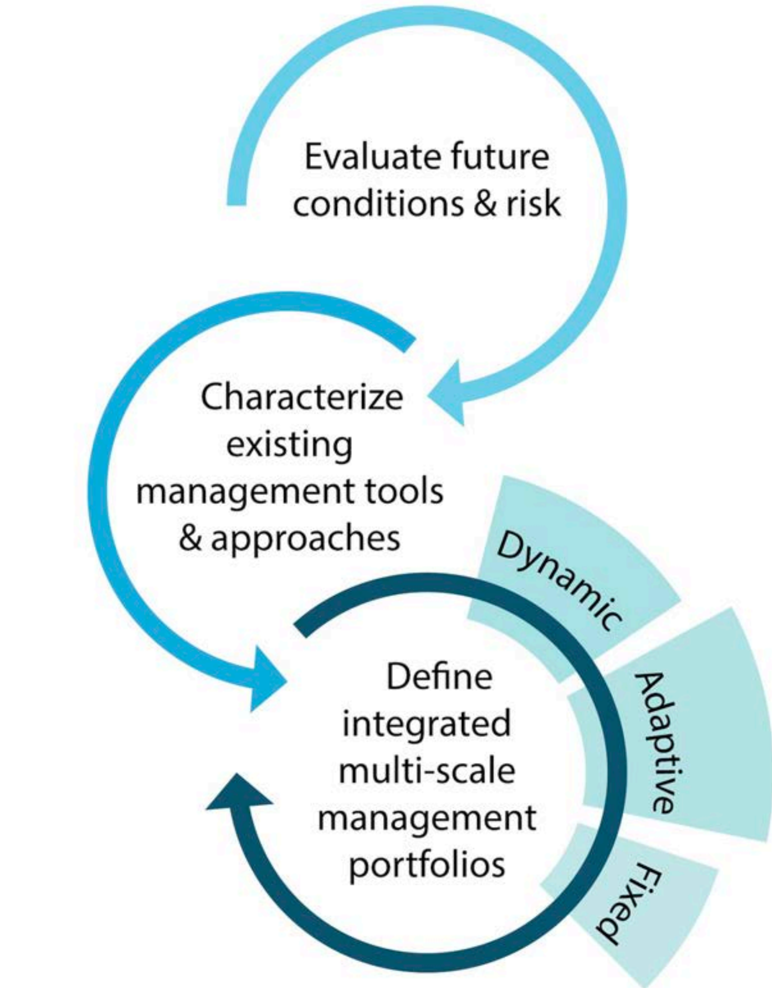


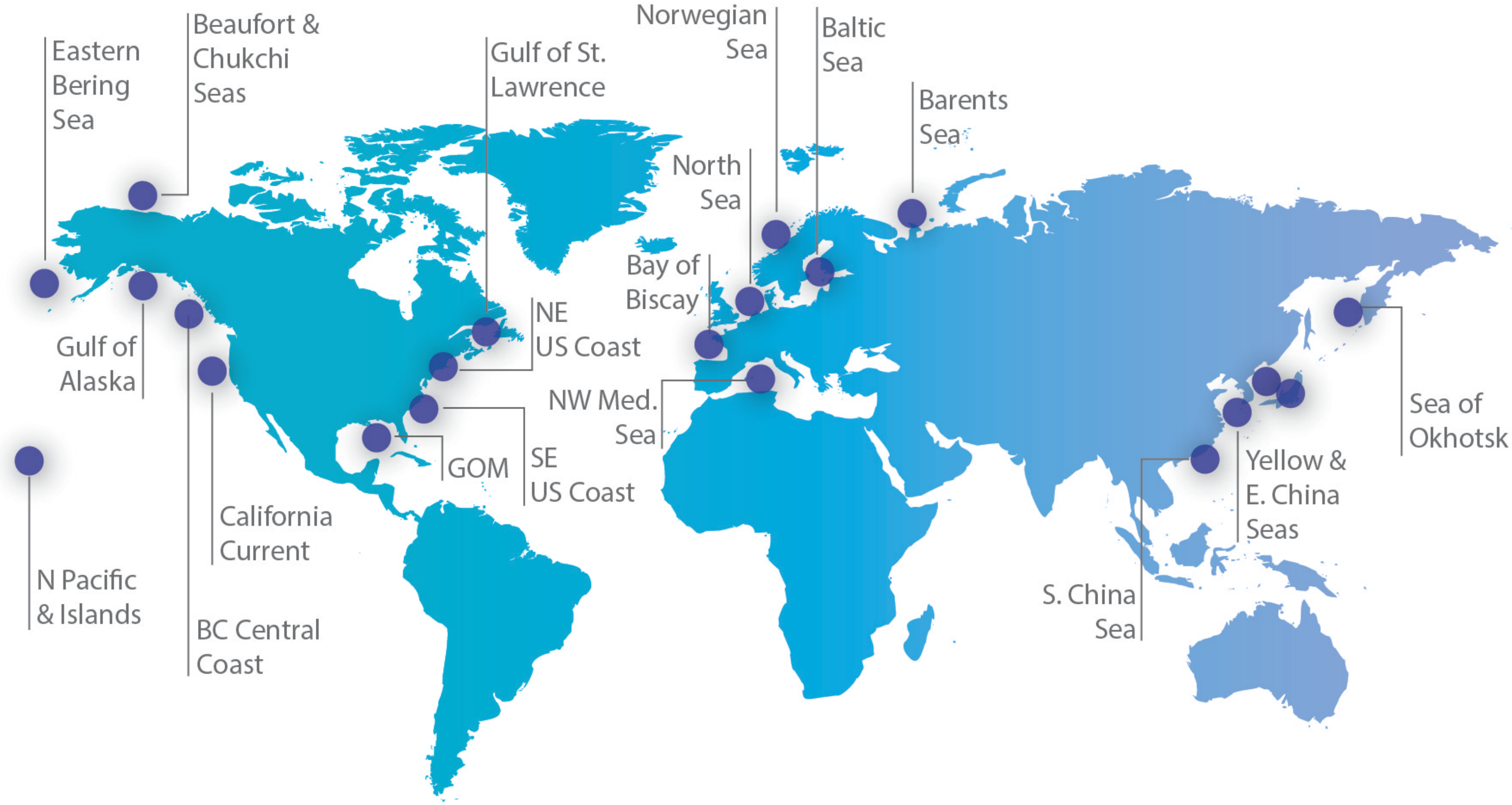
Figure 1. Climate-ready fisheries management process. Changing climate conditions are represented at the centre of the diagram as ocean acidification, temperature change, sea level rise, and extreme events. These cause changes in the biotic community, such as shifting distributions and changing productivity, as indicated in the next ring out from the centre. To enable managers to account for these changes and move toward climate-ready fisheries management (outermost ring), scientists and managers need to be able to detect changes, understand mechanisms of those changes, evaluate risks and priorities, conduct assessments and develop forecasts, and communicate results and advice to managers and stakeholders.

Karp et al. in press. Accounting for Shifting Distributions and Changing Productivity in the Development of Scientific Advice for Fishery Management. ICES JMS doi: 10.1093/icesjms/fsz048



Holsman, KK, EL Hazen, A Haynie, S Gourguet, A Hollowed, S Bograd, JF Samhouri, K Aydin, Toward climate-resiliency in fisheries management. ICES. 10.1093/icesjms/fsz031

SICCME/S-CCME
Regional Modeling Nodes



ICES-PICES Strategic Initiative on
Climate Change Effects on Marine Ecosystems

ACLIM Scenarios Workshop

Wed. April 3, 5:30 - 7:00 pm

Aleutian Room , Anchorage Hilton

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

Thanks!

NPRB & BSIERP Team
ACLIM Team
AFSC
SICCME/SCC-ME

Funding:
Fisheries & the Environment (FATE)
Stock Assessment Analytical Methods (SAAM)
Climate Regimes & Ecosystem Productivity (CREP)
Economics and Human Dimensions Program
NOAA Integrated Ecosystem Assessment Program (IEA)
NOAA Research Transition Acceleration Program (RTAP)

2019 ACLIM papers

- (*2019*) Holsman, KK, EL Hazen, A Haynie, S Gourguet, A Hollowed, S Bograd, JF Samhouri, K Aydin, Toward climate-resiliency in fisheries management. ICES. 10.1093/icesjms/fsz031
- *(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
- (*2019*) Reum, J., JL Blanchard, KK Holsman, K Aydin, AE Punt. Species-specific ontogenetic diet shifts attenuate trophic cascades and lengthen food chains in exploited ecosystems. Okios DOI: 10.1111/oik.05630
- *(2019)* Reum, J., K. Holsman, KK, Aydin, J. Blanchard, S. Jennings. Energetically relevant predator to prey body mass ratios and their relationship with predator body size. Ecology and Evolution (9):201–211 DOI: 10.1002/ece3.4715
- Reum, J., J. Blanchard, K. Holsman, K. Aydin, A. Hollowed, A. Hermann, W. Chang, A. Faig, A. Haynie, A. Kasperski, A. Punt, in prep. Ensemble projections of future climate change impacts on the Eastern Bering Sea food web using a multispecies size spectrum model. Frontiers in Marine Science