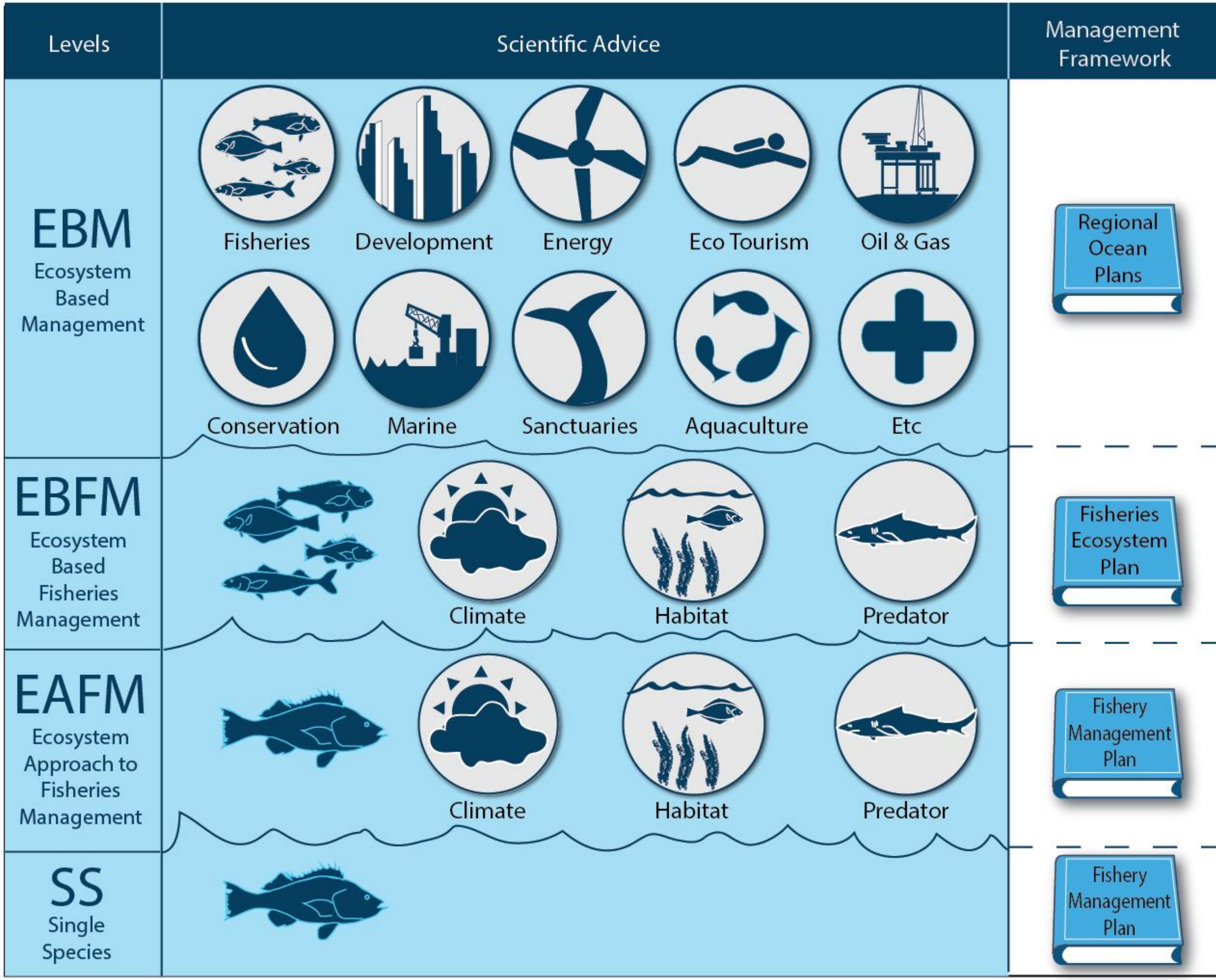
Ecosystem Risk Assessments (MRA) & Management Strategy Evaluations (MSE)

Kirstin Holsman
Kerim Aydin, Stephani Zador,
Ivonne Ortiz

kirstin.holsman@noaa.gov
Seattle, WA, USA

Photo: Mark Holsman

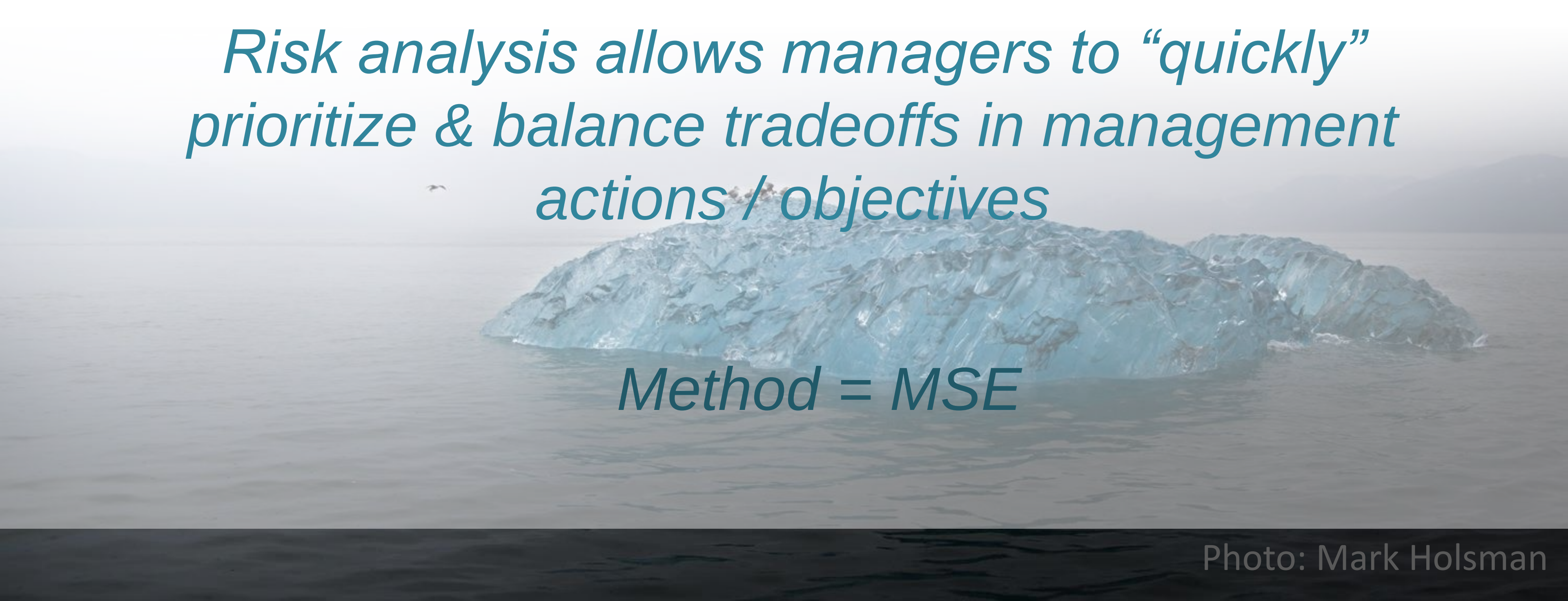


NOAA FISHERIES

Ecosystem Risk Assessment

"The goal of these risk analyses is to qualitatively or quantitatively determine the probability that an ecosystem indicator will reach or remain in an undesirable state (i.e., breach a reference limit)."

Levin et al. 2013 "*IEA: Guidance for implementation*"

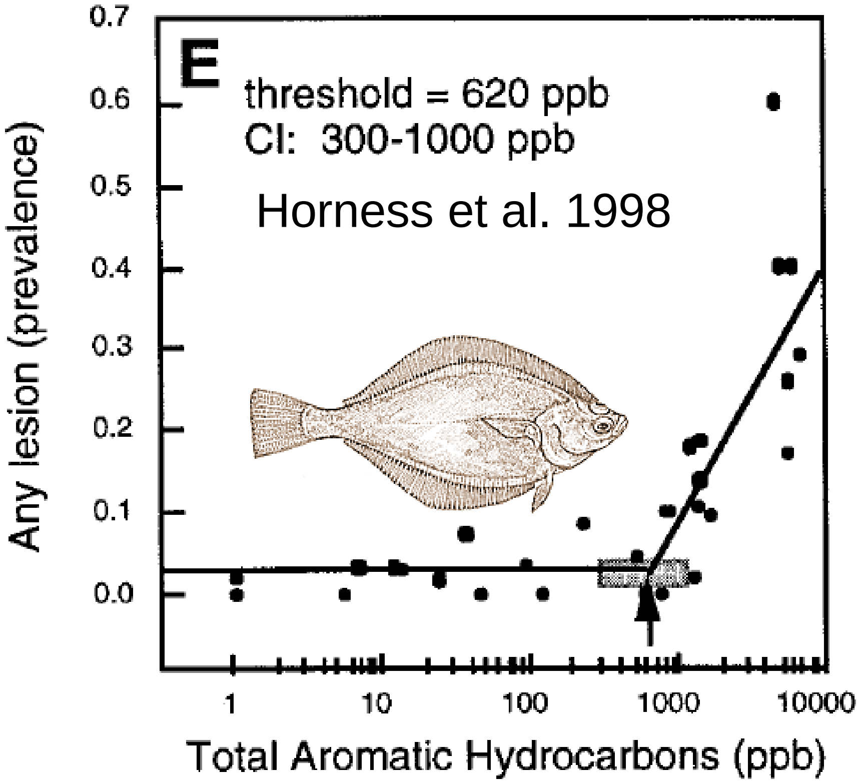


Risk analysis allows managers to "quickly" prioritize & balance tradeoffs in management actions / objectives

Method = MSE

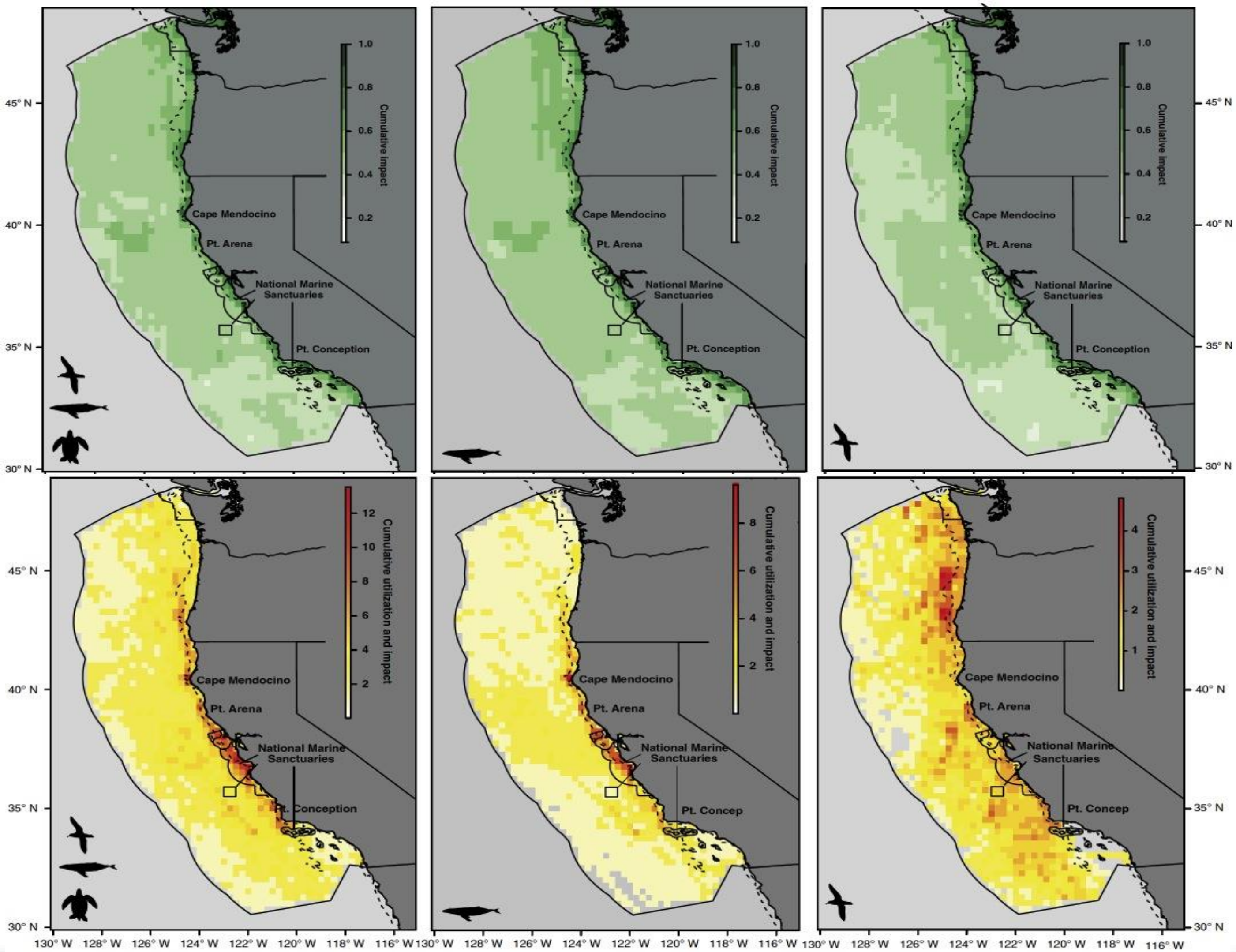
Photo: Mark Holsman

How has the concept of risk evolved over time?

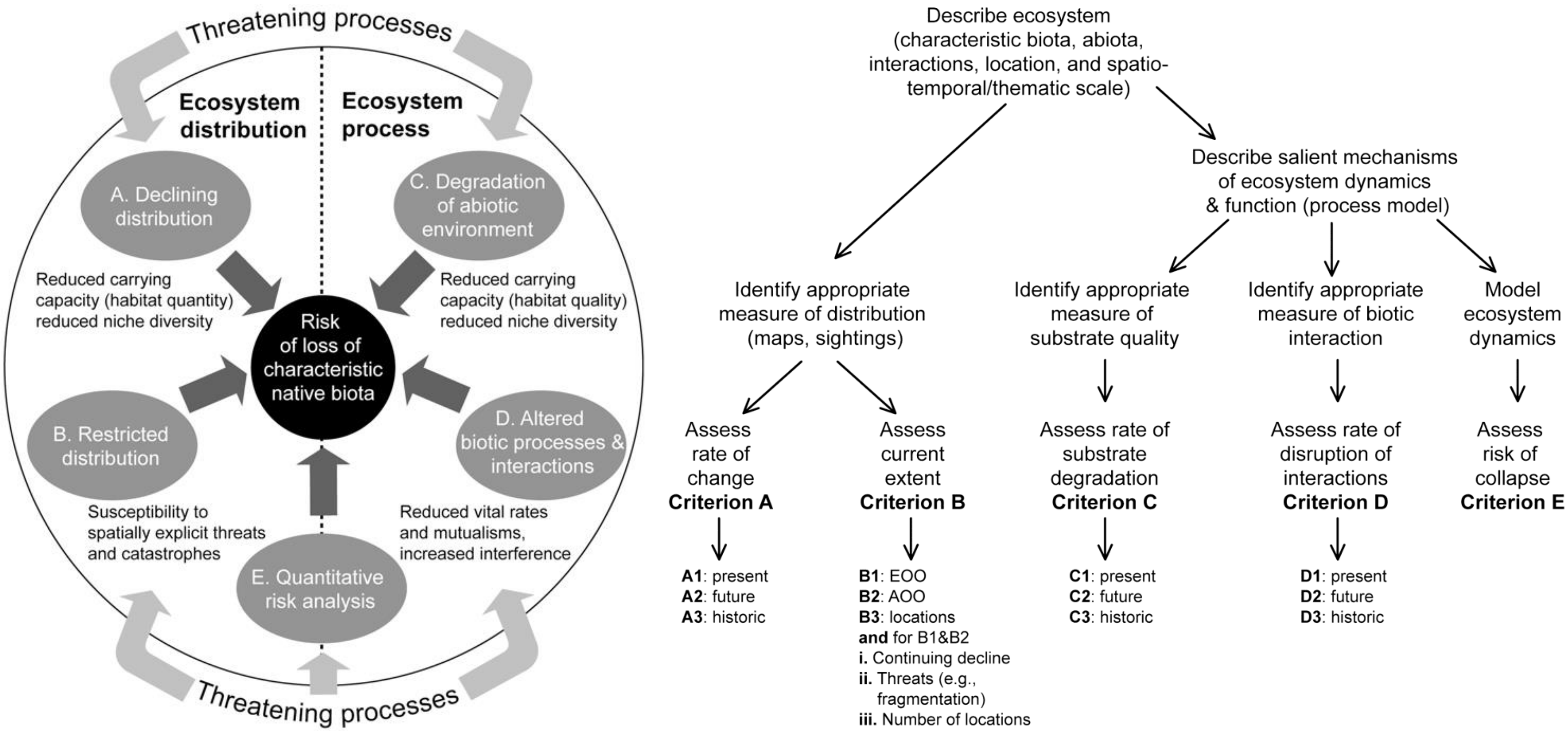


Multispecies & Cumulative Impacts

Maxwell et al
2013



IUCN Risk of Ecosystem Collapse



Keith et al 2013

Why conduct an ecosystem risk assessment?

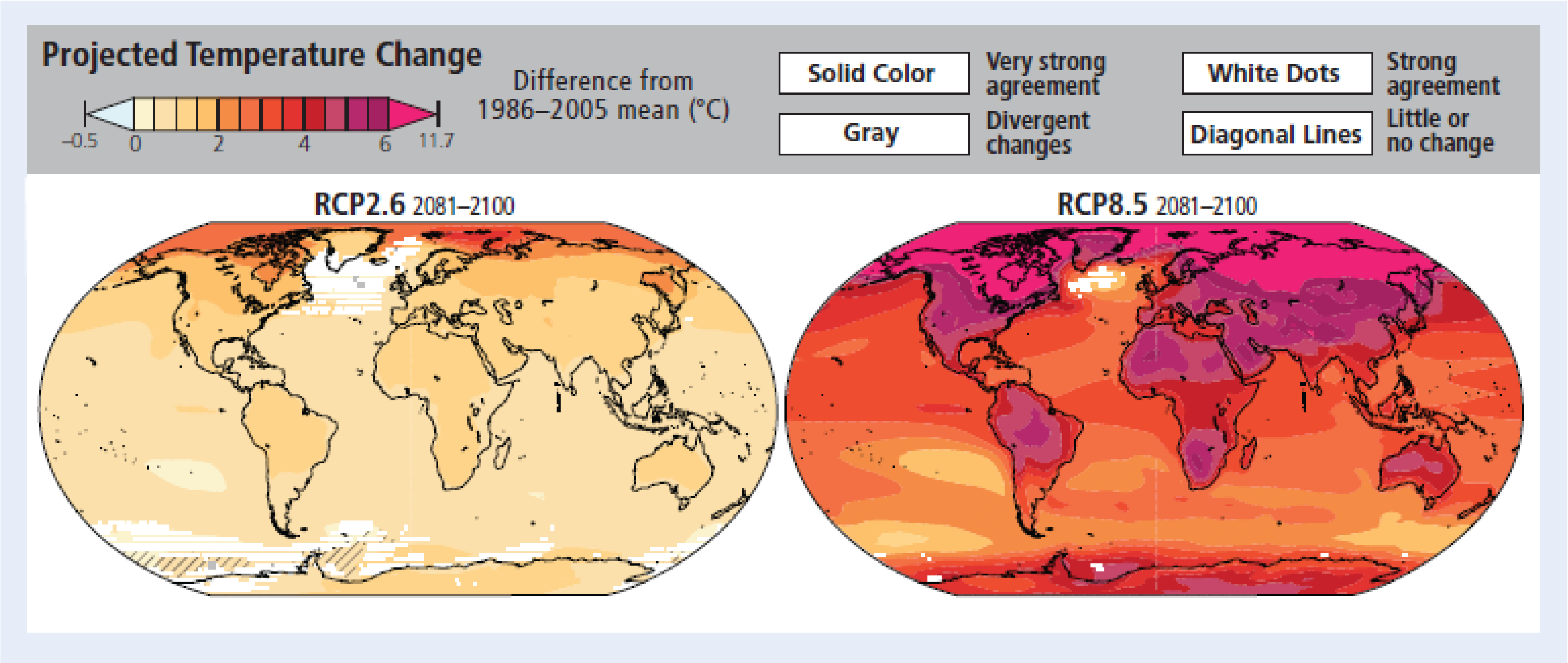
Photo: Mark Holsman

Why risk assessment?

identify pressures that pose the greatest risk to valued ecosystem components, quickly & efficiently

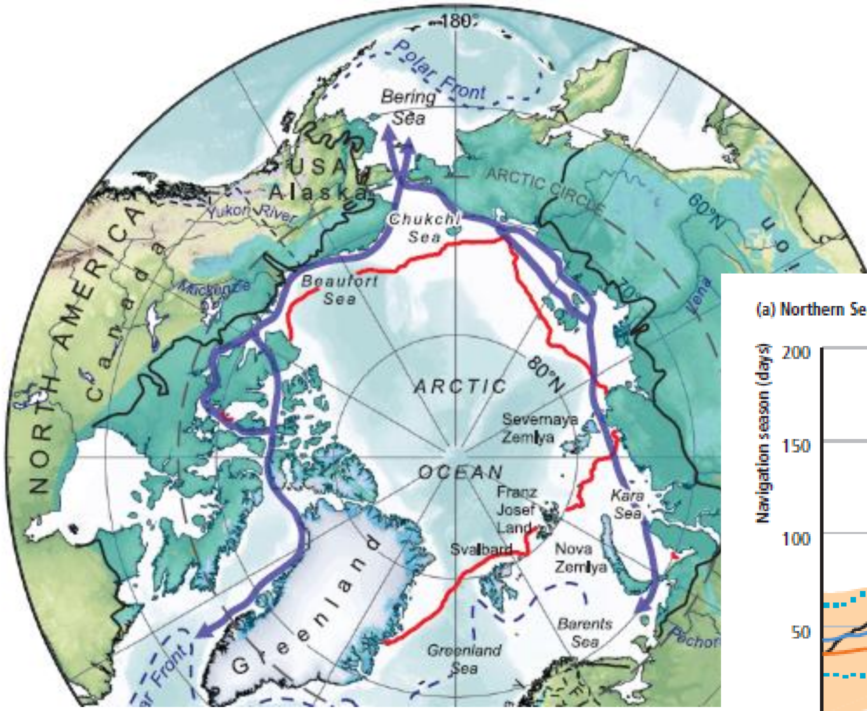
Projected Average Annual Surface Temperature (IPCC AR5 SPM, 2014)

(C)



http://www.ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

Arctic Sea Routes



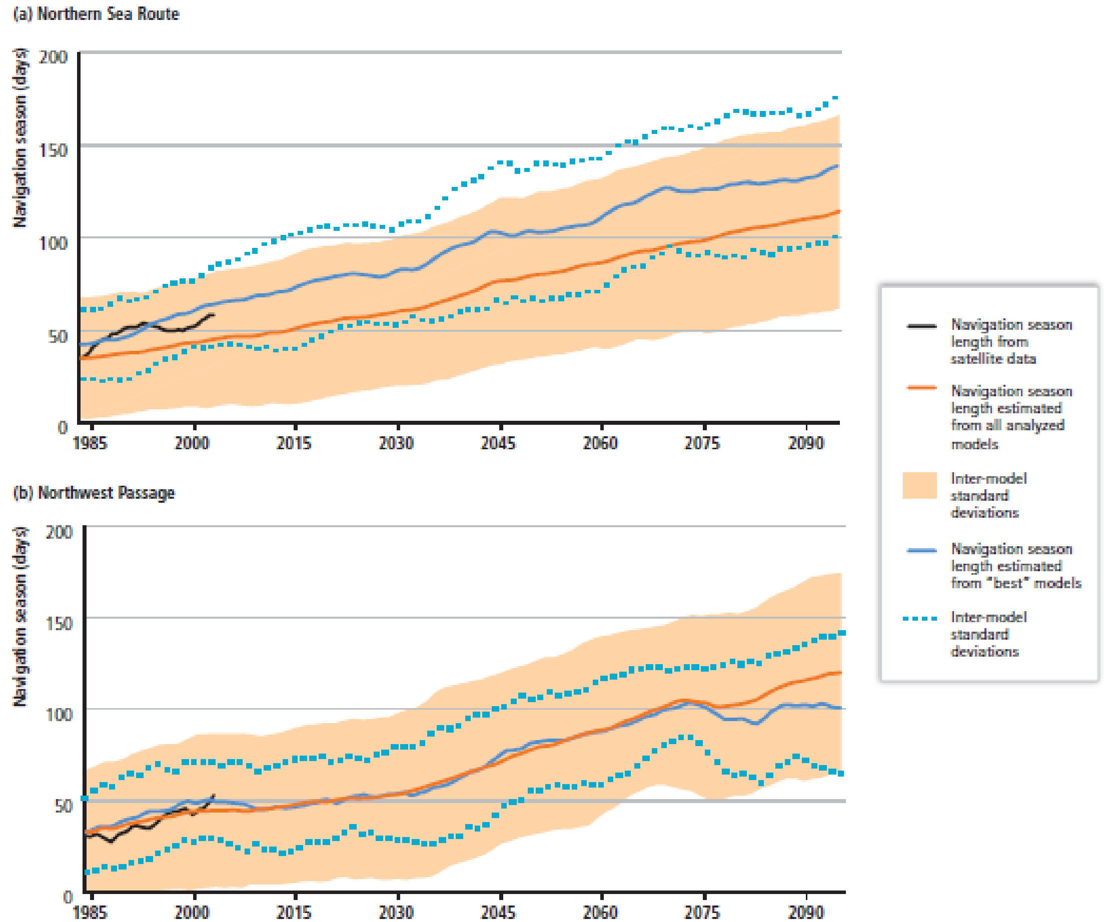


Figure 28-4 | Projected duration of the navigation period (days) over the Northwest Passage and Northern Sea Route (Khon et al., 2010).

What is an Ecosystem Risk Assessment?

Photo: Mark Holsman

Hobday et al. 2011

Scoping
Establish & document objectives & hazards

↓

Risk Assessment Level1
Qualitative assessment
Uncertainty analysis

Low Risk ← → Med/ High Risk

Level 1: Analysis for each pressure qualitatively scores each human activity or natural perturbation for its impact on the focal ecosystem components of the IEA. Those pressures receiving a high impact score move onto level 2 analyses.

Hobday et al. 2011

Scoping
Establish & document objectives & hazards

Risk Assessment Level1
Qualitative assessment
Uncertainty analysis

Low Risk | Med/ High Risk

Risk Assessment Level 2
Semi-quantitative assessment
Uncertainty analysis

Low Risk | Med/ High Risk

Level 2: Analysis considers the exposure of an ecosystem component to a pressure, and the sensitivity of the component to that pressure.

Hobday et al. 2011

Scoping
Establish & document objectives & hazards

Risk Assessment Level1
Qualitative assessment
Uncertainty analysis

Low Risk | Med/ High Risk

Risk Assessment Level 2
Semi-quantitative assessment
Uncertainty analysis

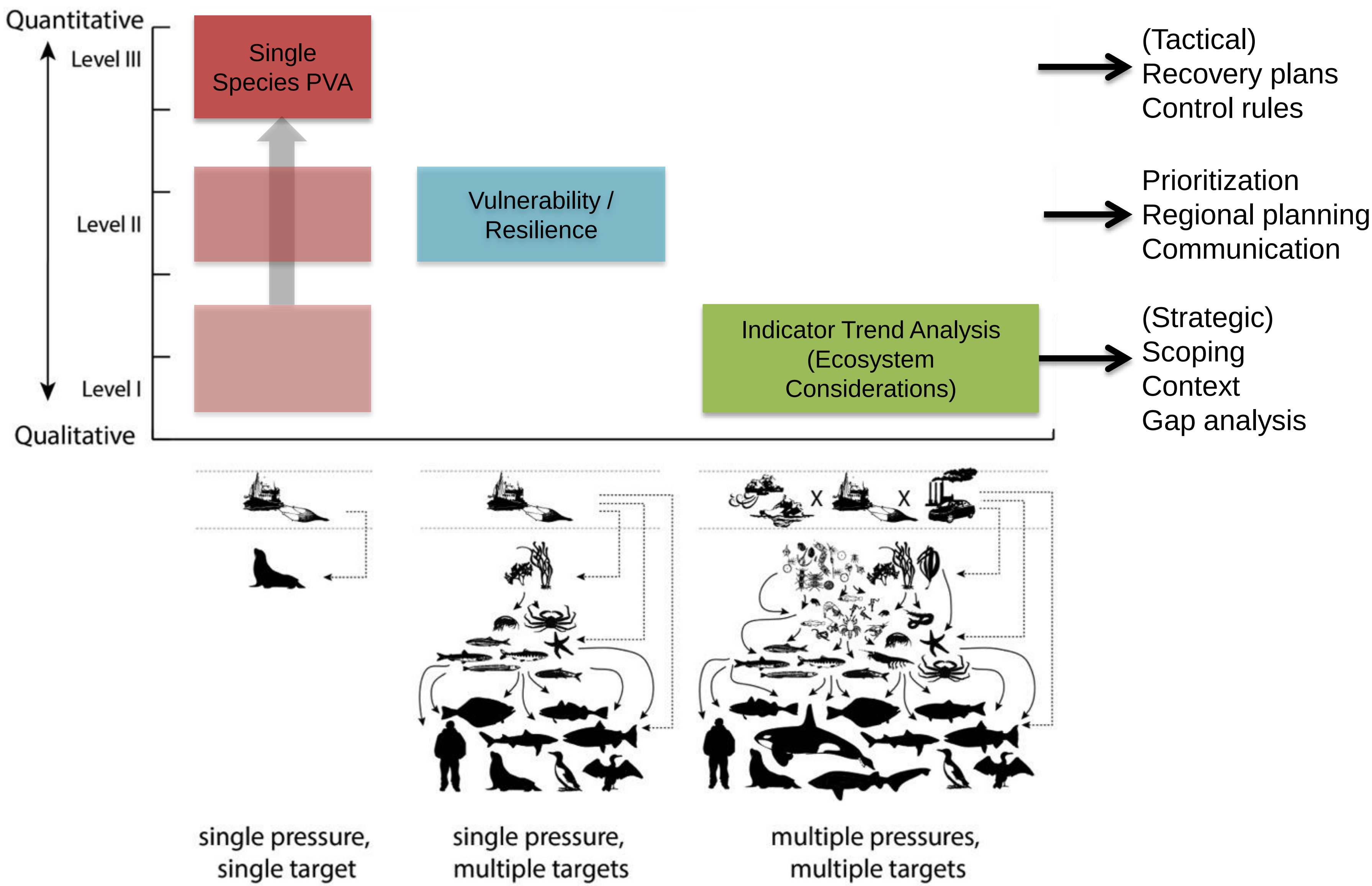
Low Risk | Med/ High Risk

Risk Assessment Level 3
Quantitative assessment
Uncertainty analysis

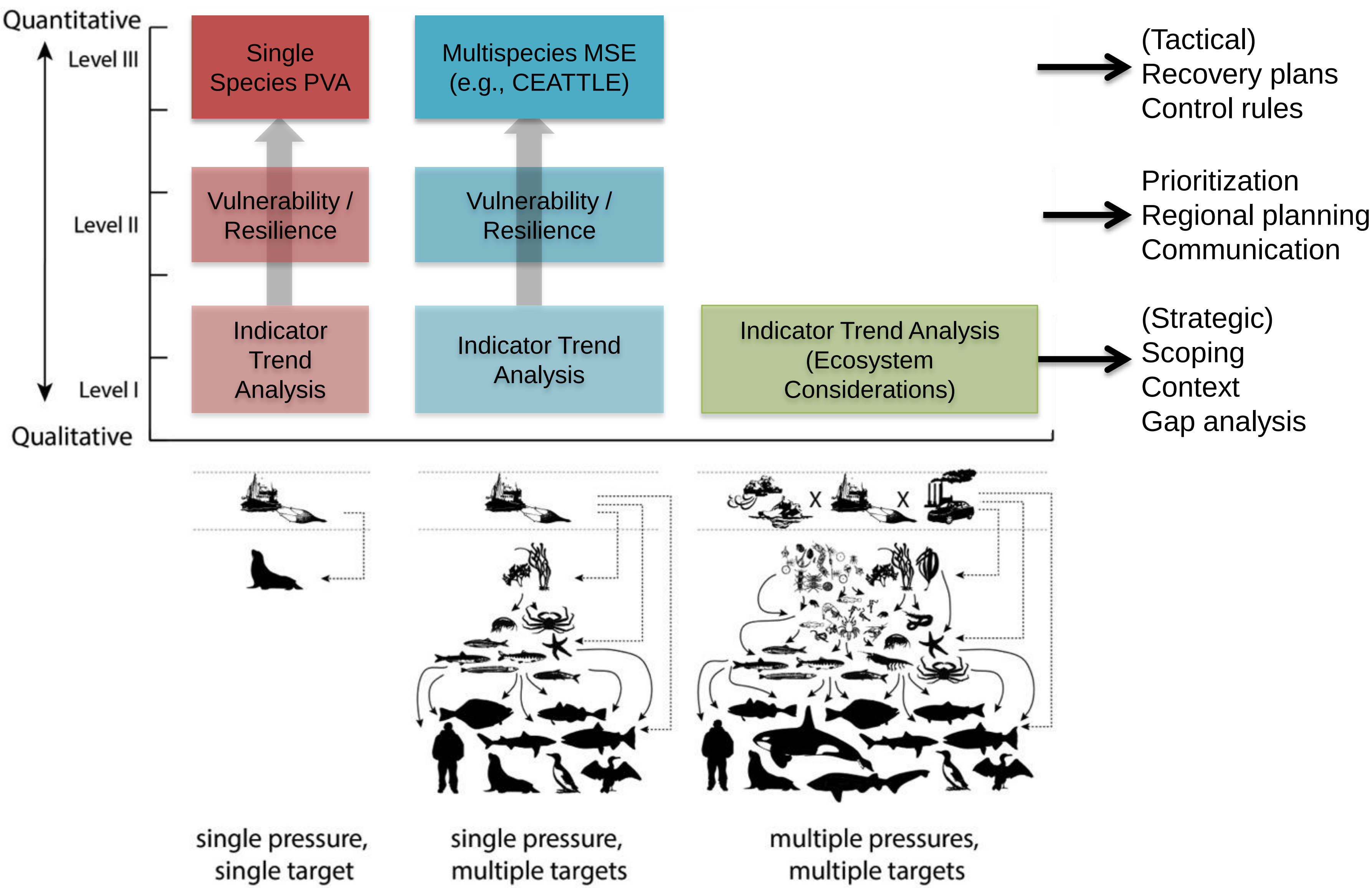
Low Risk | Med/ High Risk

Level 3: Analysis takes a quantitative approach such as is used in stock assessments & population viability analyses

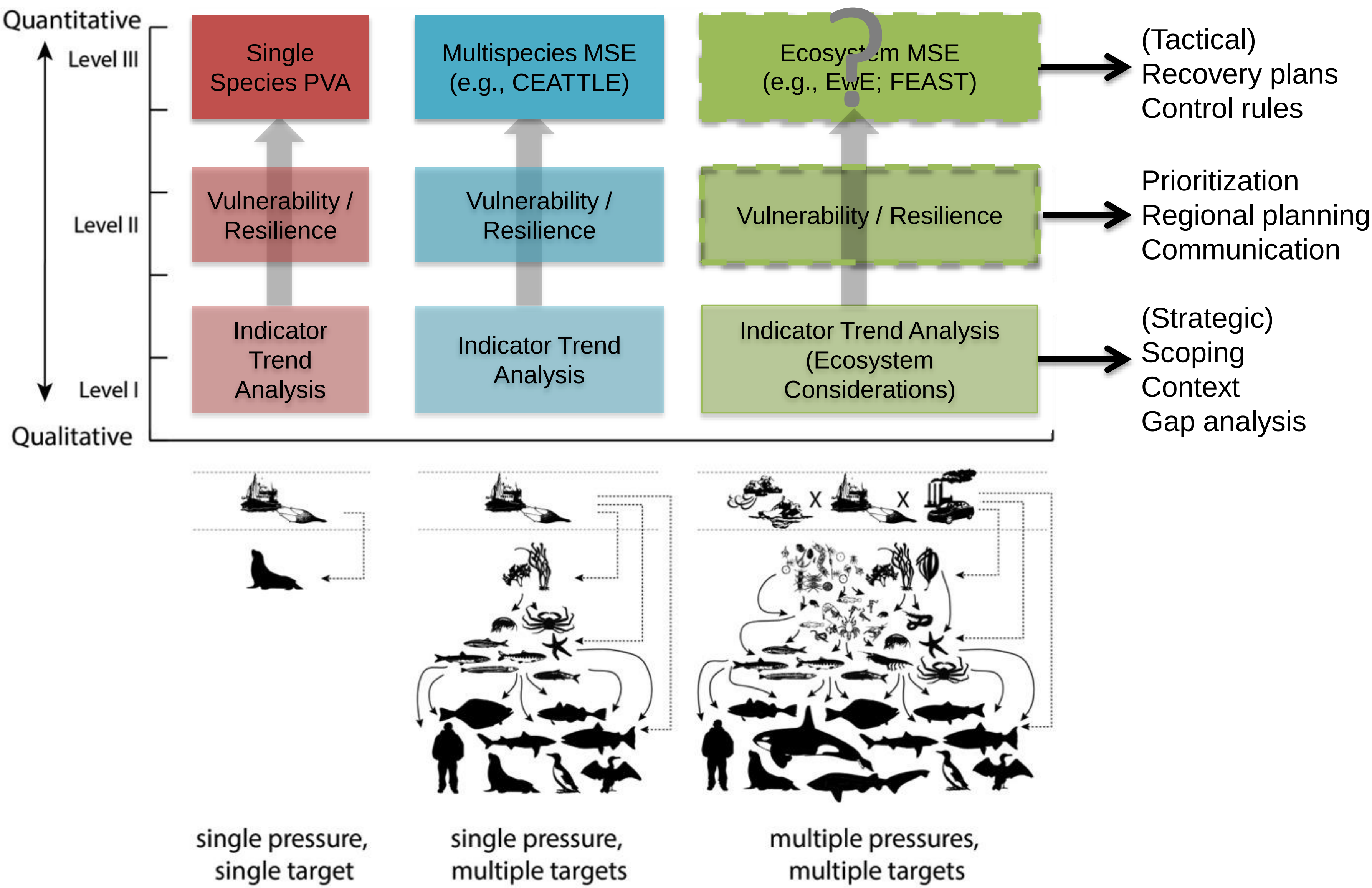
Ecosystem Risk Assessment



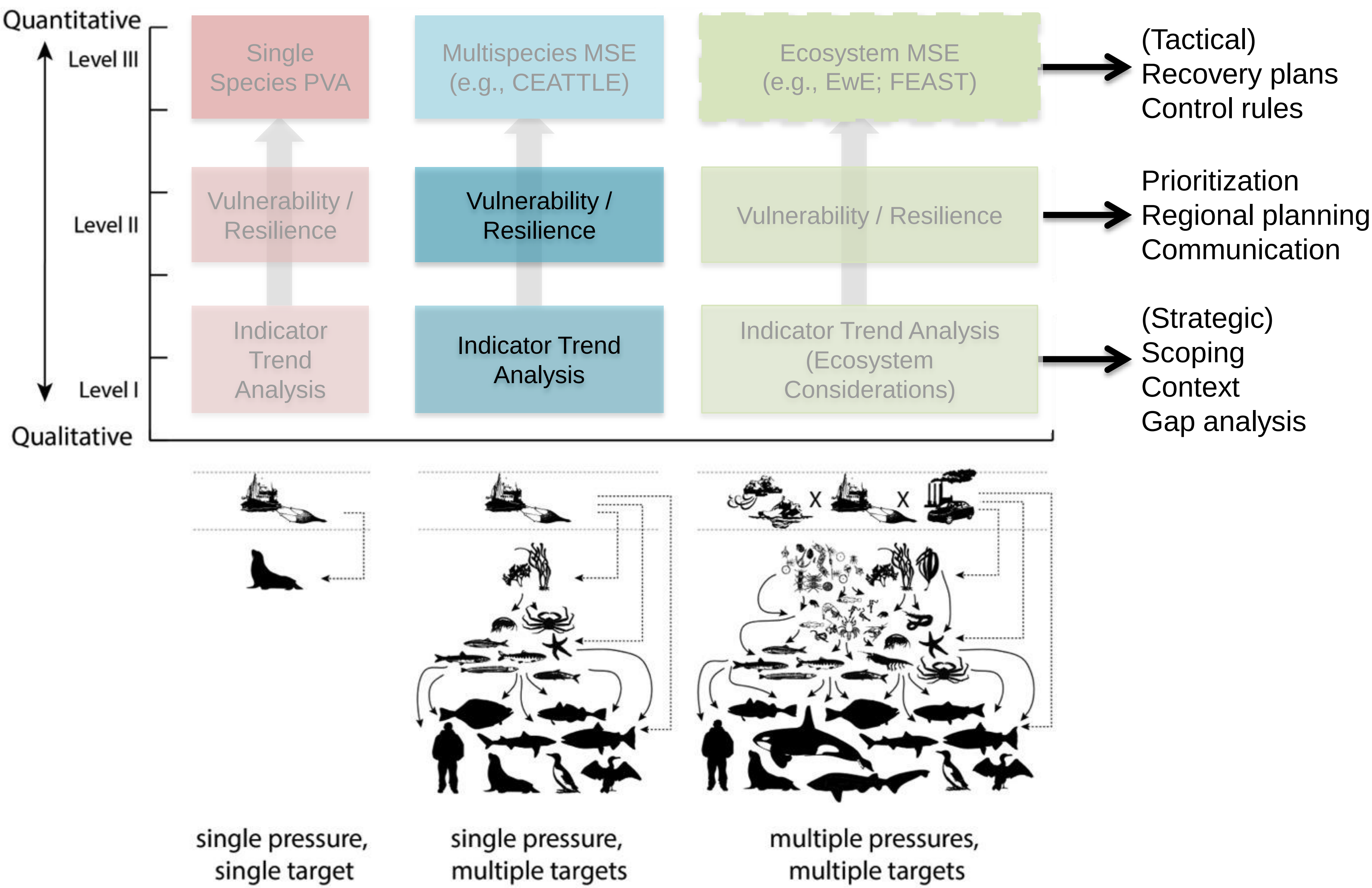
Ecosystem Risk Assessment



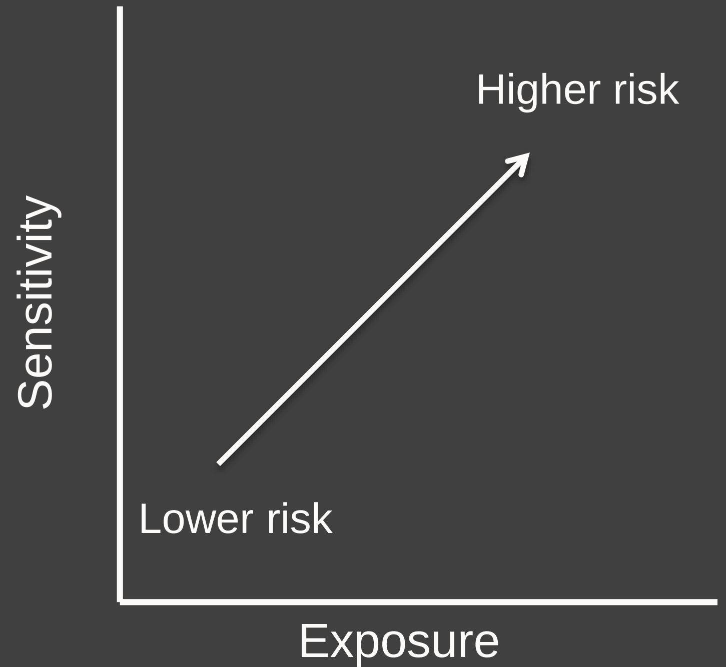
Ecosystem Risk Assessment



Ecosystem Risk Assessment



Ecosystem risk assessment framework



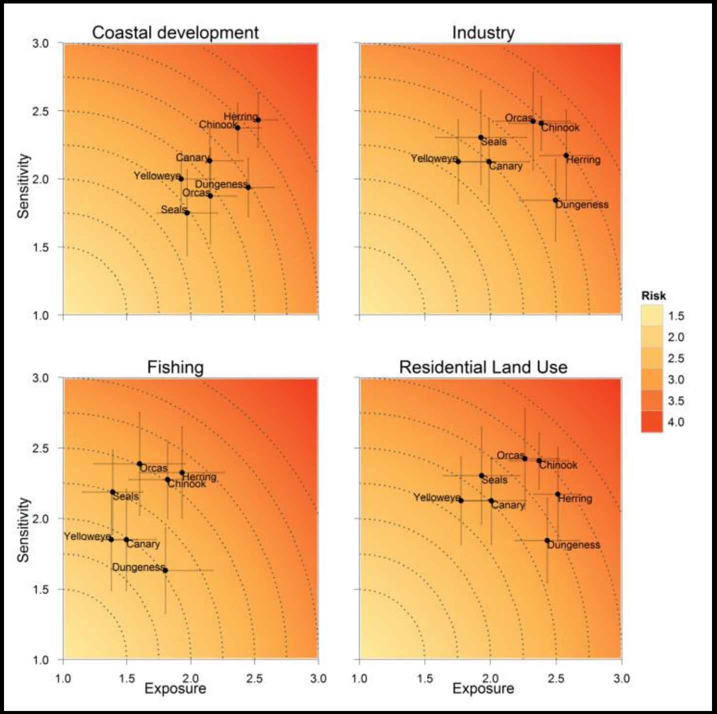
Focus on:

1. ecosystem indicators
2. multiple pressures

ECOSYSTEM RISK ASSESSMENT

viewed through the lens of Puget Sound

Premise: Risk to habitats → risk to the ecosystem



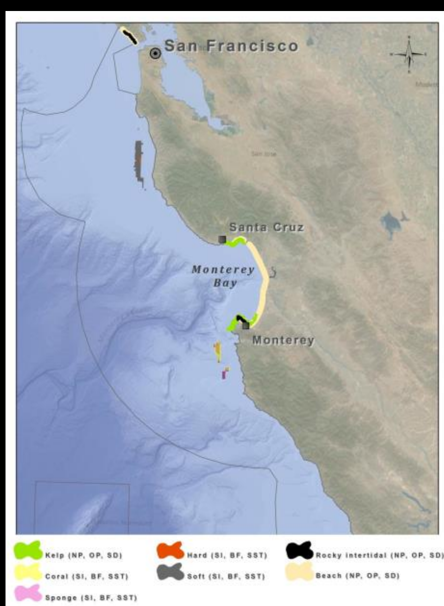
Samhouri and Levin 2012

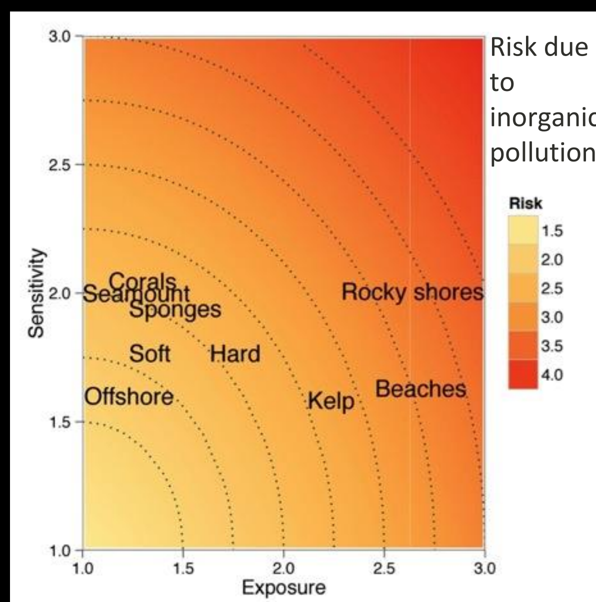
HABITAT RISK ASSESSMENT

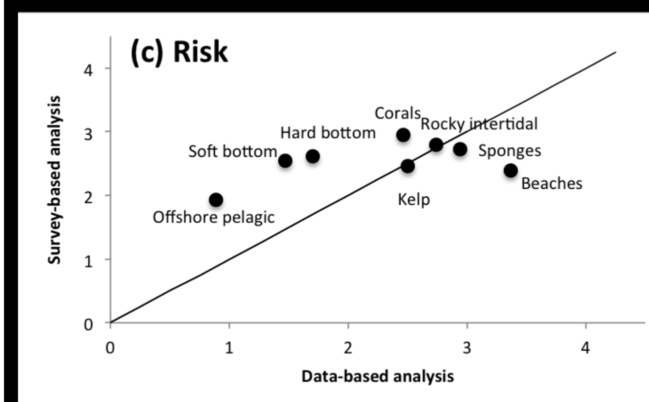
Monterey bay national marine sanctuary

Premise: Risk to habitats → risk to the ecosystem

*Includes a spatially explicit analysis of exposure + relies on a combo of data and expert-opinion

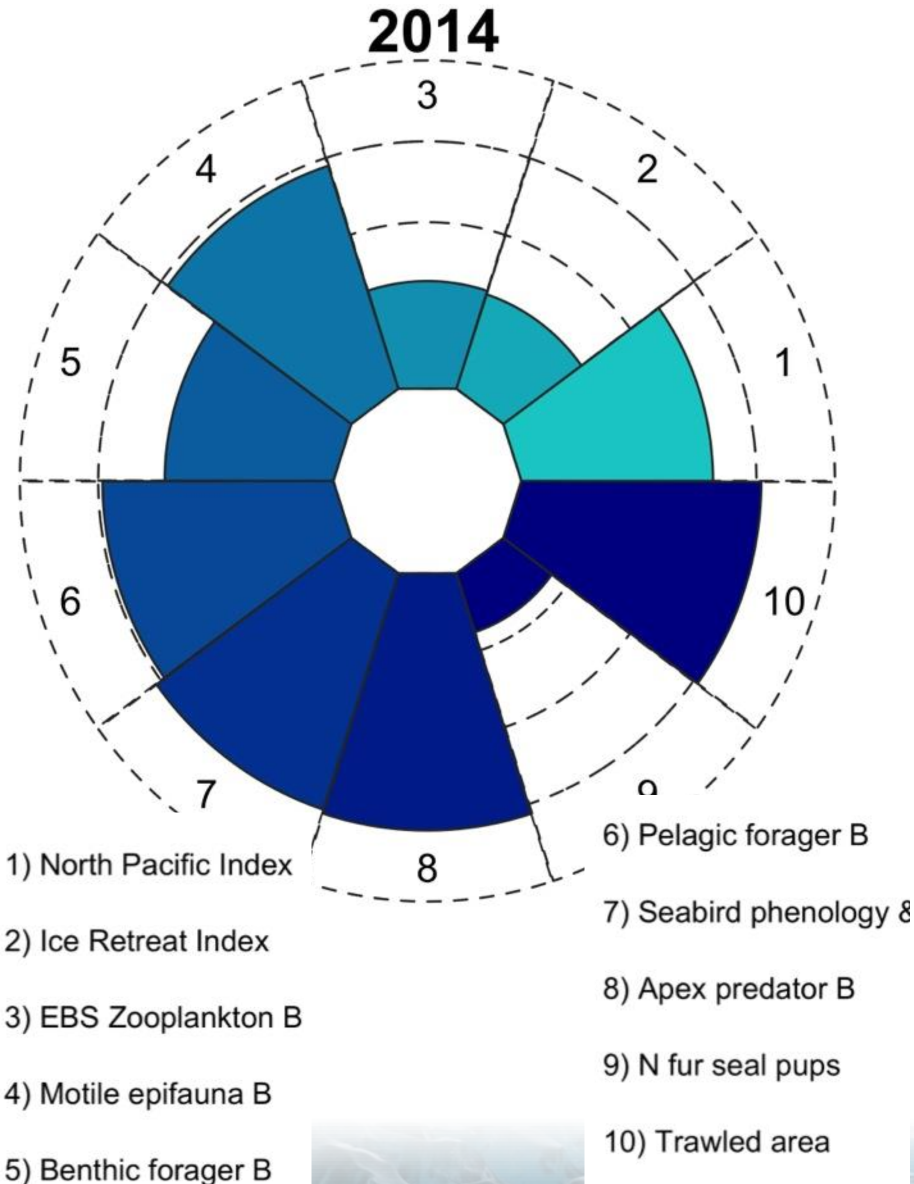




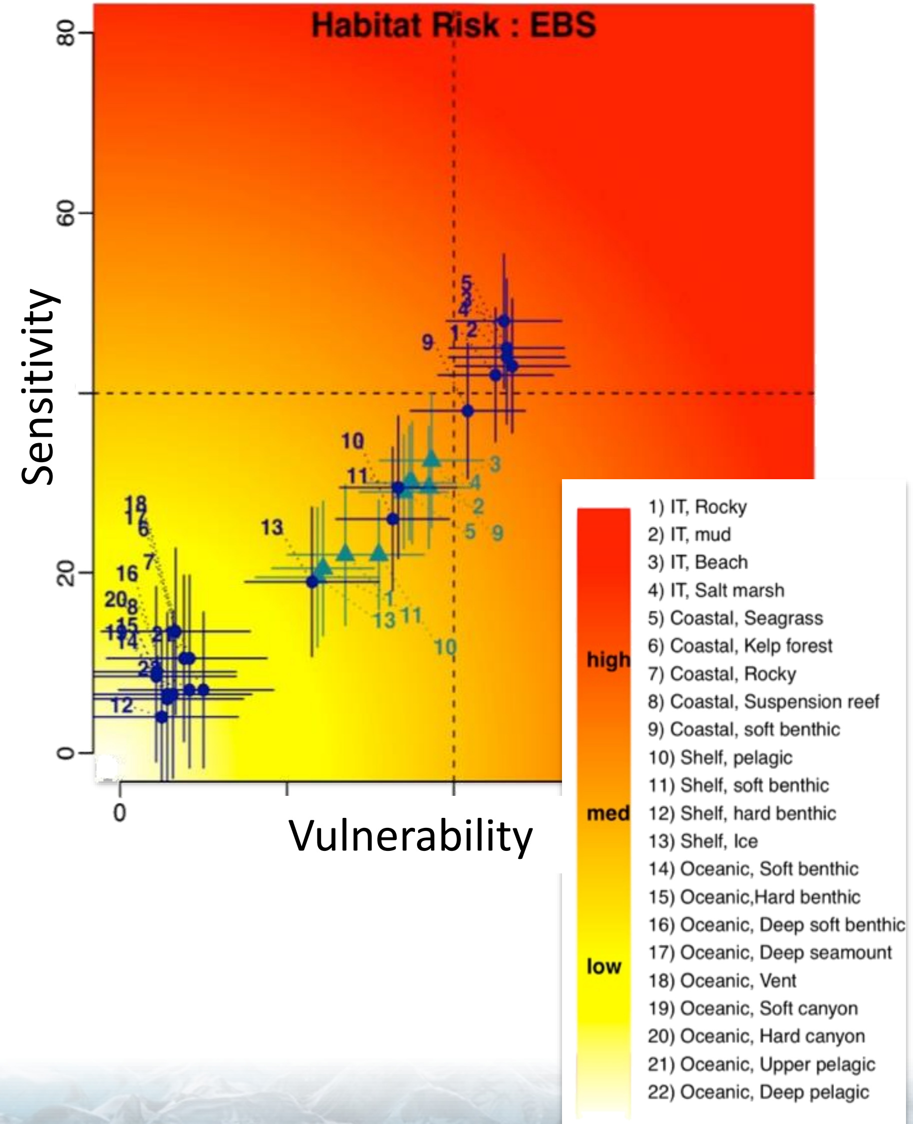


Samhouri et al. 2012

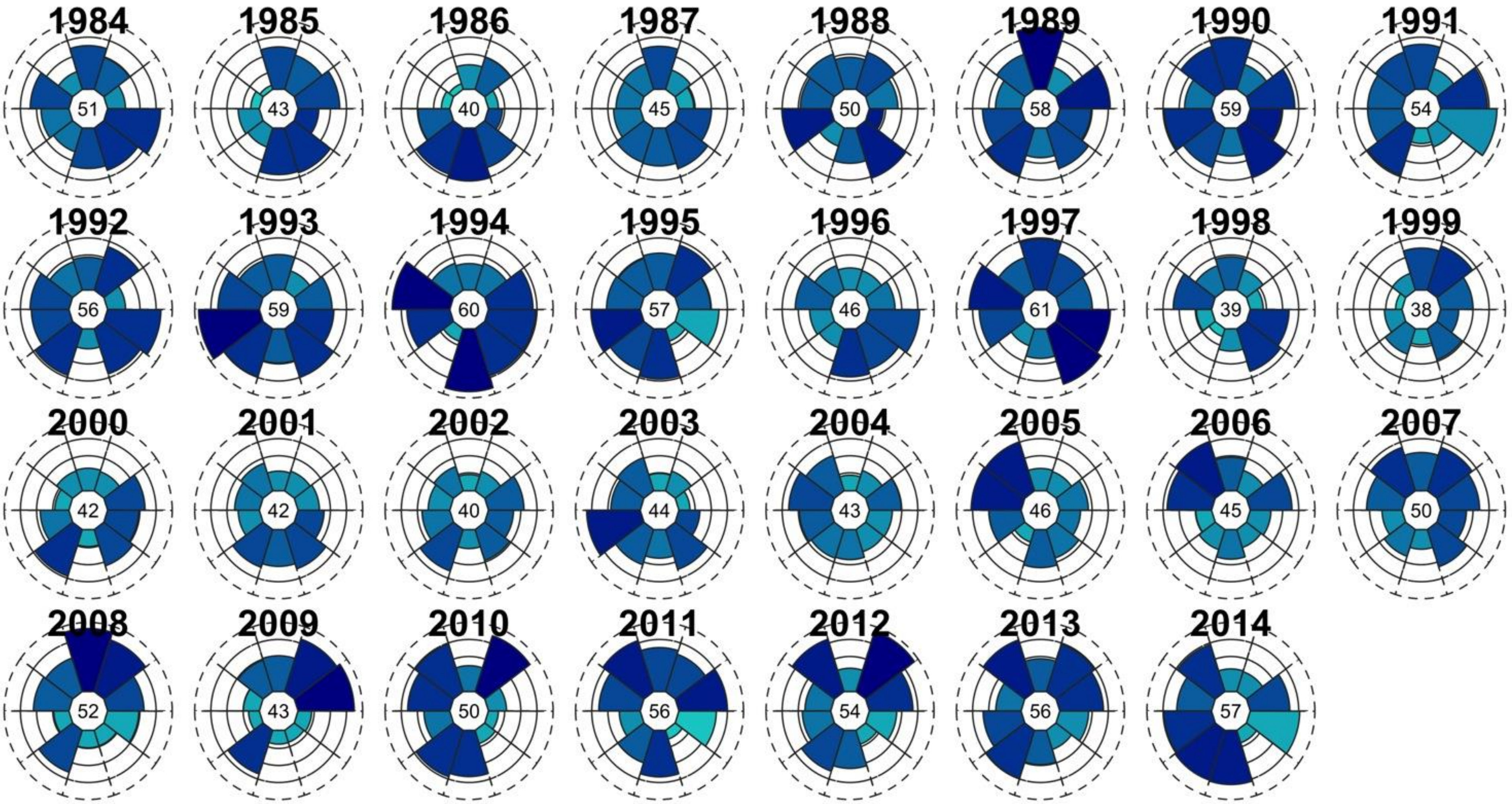
Ecosystem Index



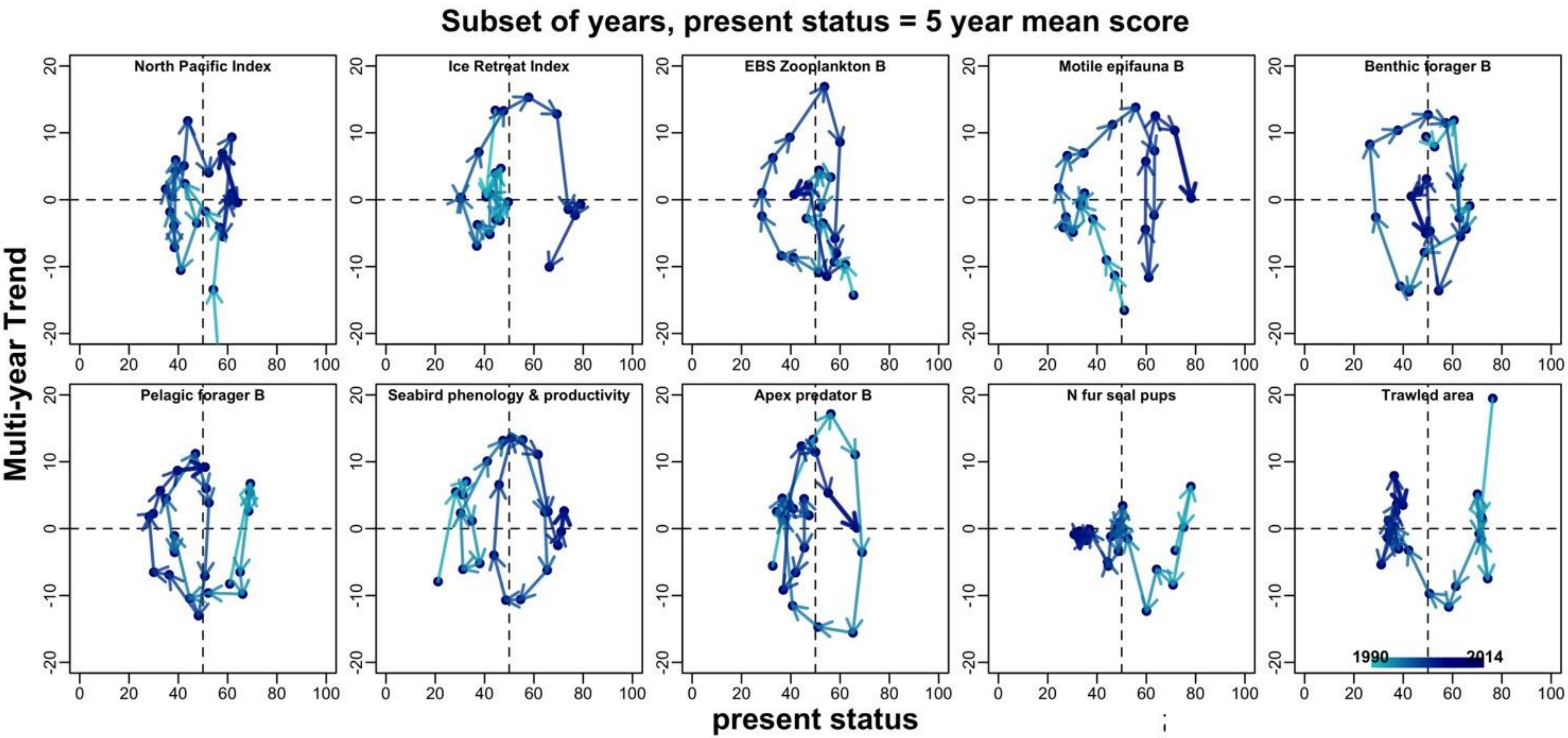
Habitat Risk

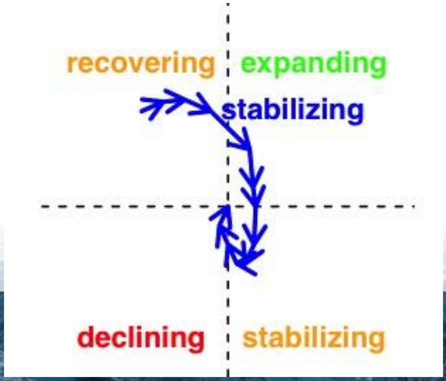


Ecosystem Reference Point (ERP): OHIAK

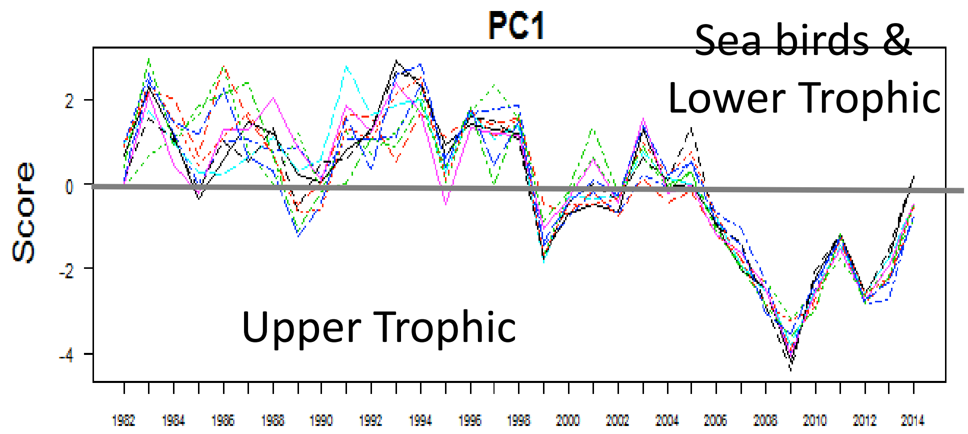


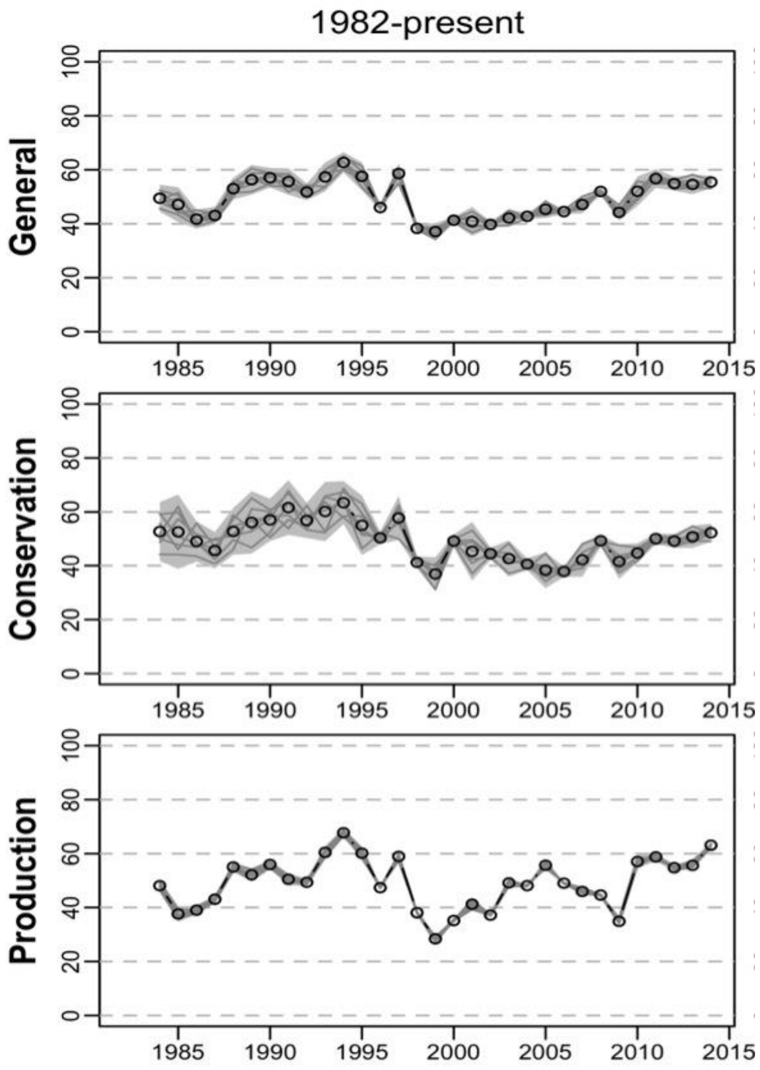
Ecosystem Reference Point (ERP): OHIAK





Index comparison





Risk Assessment

Abstract—Assessing the vulnerability of stocks to fishing practices in U.S. federal waters was recently highlighted by the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration, as an importan
consider when 1) identif
that should be managed ar
under a fishery managem
grouping data-poor stocl
evant management comp
3) developing precautiona
control rules. To assist the regional fishery management councils in determining vulnerability, NMFS elected to use a modified version of a productivity and susceptibility analysis (PSA) because it can be based on qualitative data, has a history of use in other fisheries, and is recommended by several organizations as a reasonable approach for evaluating risk. A number of productivity and susceptibility attributes for a stock are used in a PSA and from these attributes, index scores and mea-

Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing

Put targets (e.g., species / habitats) with varying data quality and sensitivities on an "even" playing field.

Donald Kobayashi[6]

William Overholtz[3]

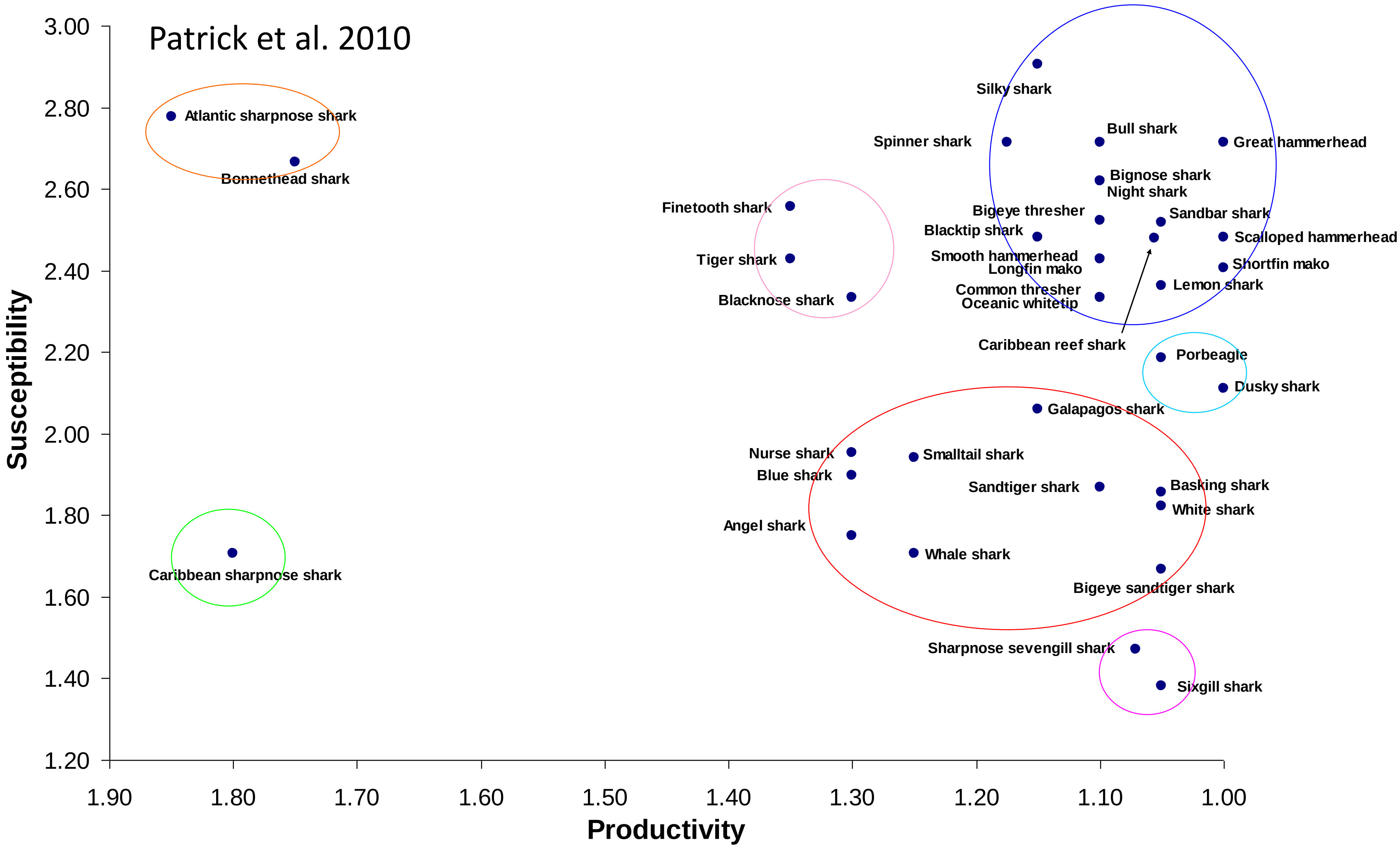
Email address for contact author: Wesley.Patrick@noaa.gov

[1] Office of Sustainable Fisheries
National Marine Fisheries Service
National Oceanographic and Atmospheric Administration
1315 East-West Highway
Silver Spring, Maryland 20910

[2] Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanographic and Atmospheric Administration
7600 Sand Point Way

[6] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanographic and Atmospheric Administration
2570 Dole Street
Honolulu, Hawaii 96822

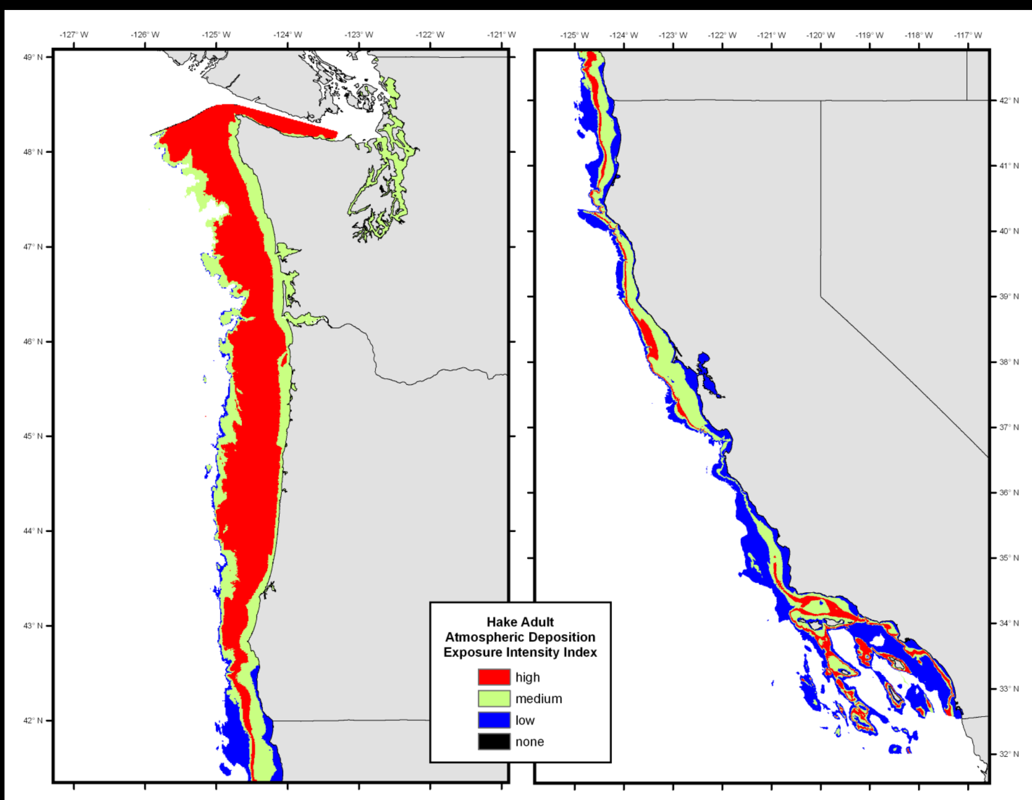
[7] Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanographic and Atmospheric Administration
2030 South Marine Science Drive

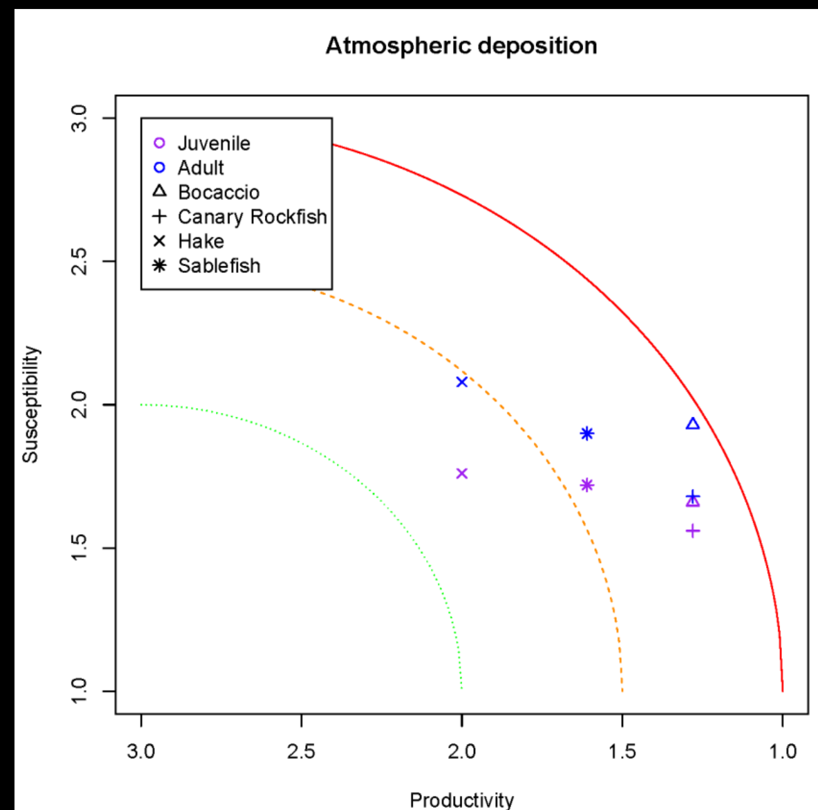


Patrick et al. 2010
Susceptibility
Productivity
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
Atlantic sharpnose shark
Bonnethead shark
Caribbean sharpnose shark
Finetooth shark
Tiger shark
Blacknose shark
Silky shark
Spinner shark
Bull shark
Great hammerhead
Bignose shark
Night shark
Bigeye thresher
Sandbar shark
Blacktip shark
Scalloped hammerhead
Smooth hammerhead
Longfin mako
Shortfin mako
Lemon shark
Common thresher
Oceanic whitetip
Caribbean reef shark
Porbeagle
Dusky shark
Galapagos shark
Nurse shark
Smalltail shark
Blue shark
Sandtiger shark
Basking shark
White shark
Angel shark
Whale shark
Bigeye sandtiger shark
Sharpnose sevengill shark
Sixgill shark

GROUNDFISH RISK ASSESSMENT

Premise: risk to groundfish → risk to groundfish
Includes a spatially explicit analysis of susceptibility

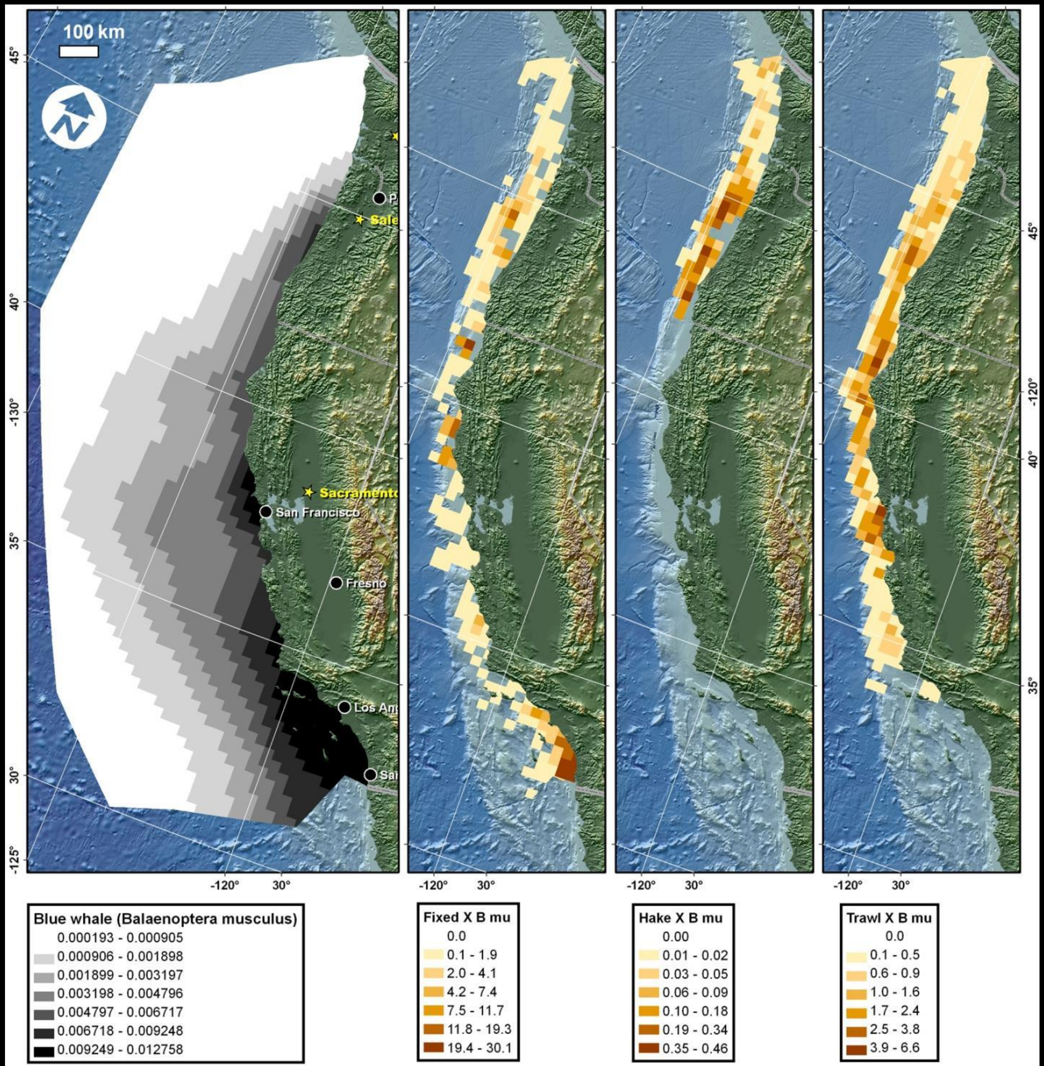




Andrews et al. 2011, Hamel et al. 2012

MARINE MAMMALS RISK ASSESSMENT

Premise:
increased overlap of marine mammals with fisheries → increased risk to marine mammals

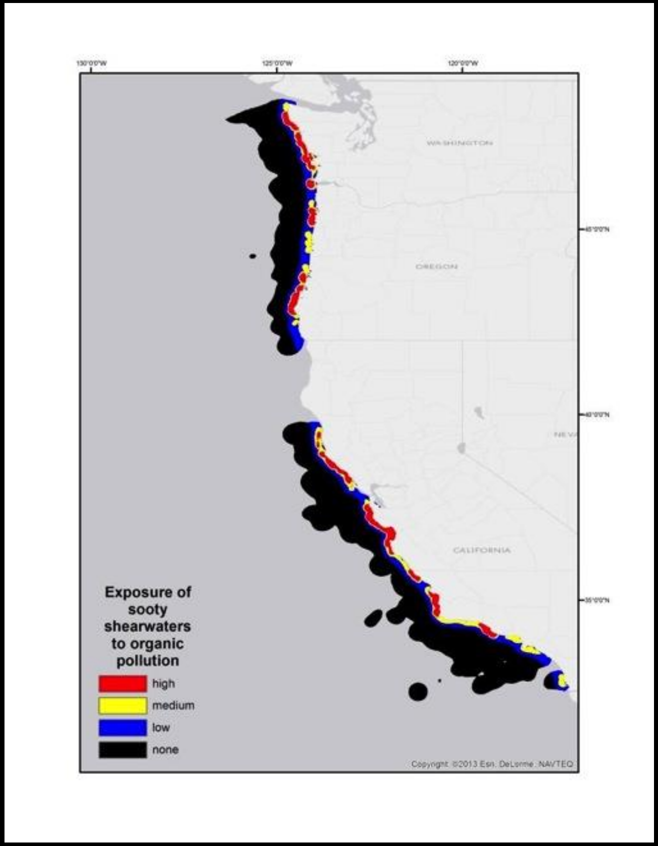


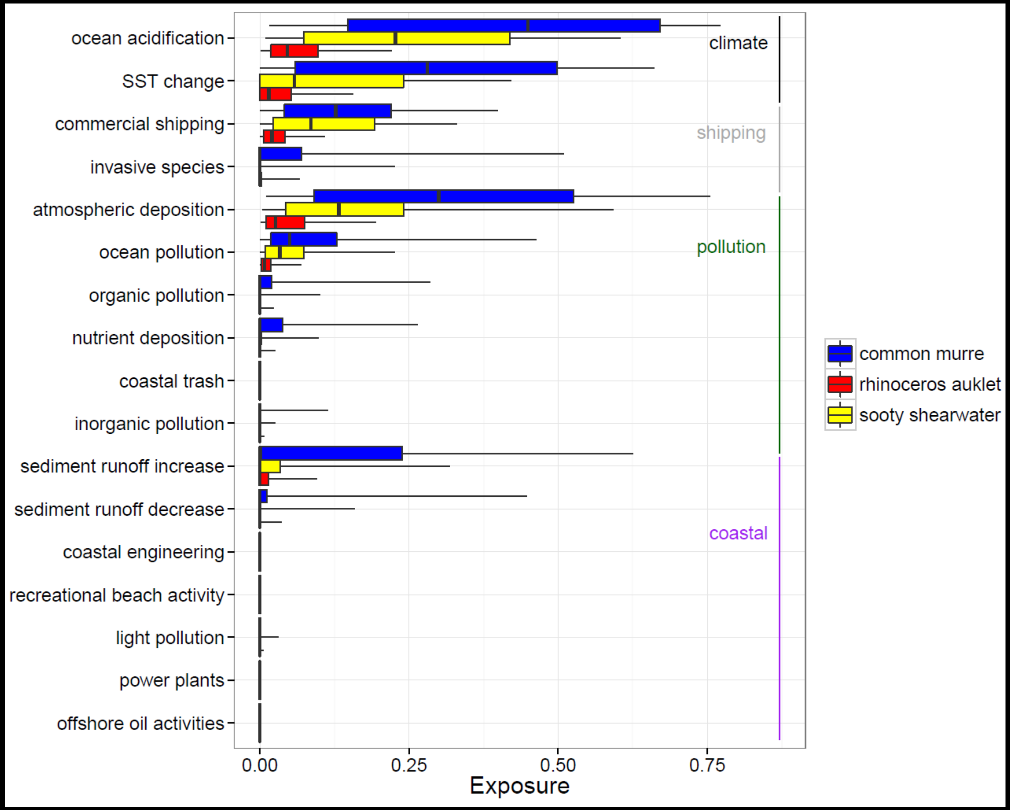
Feist et al. 2012



SEABIRD RISK ASSESSMENT

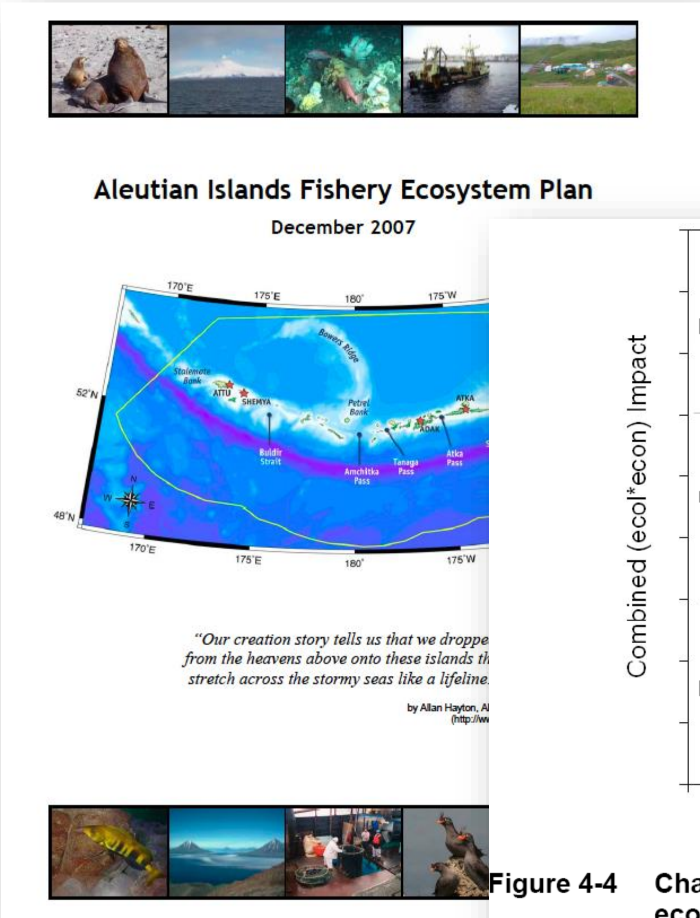
Premise: increased overlap of seabirds with human pressures → increased risk to seabirds





Good et al. in review

AK IEA Risk Assessment



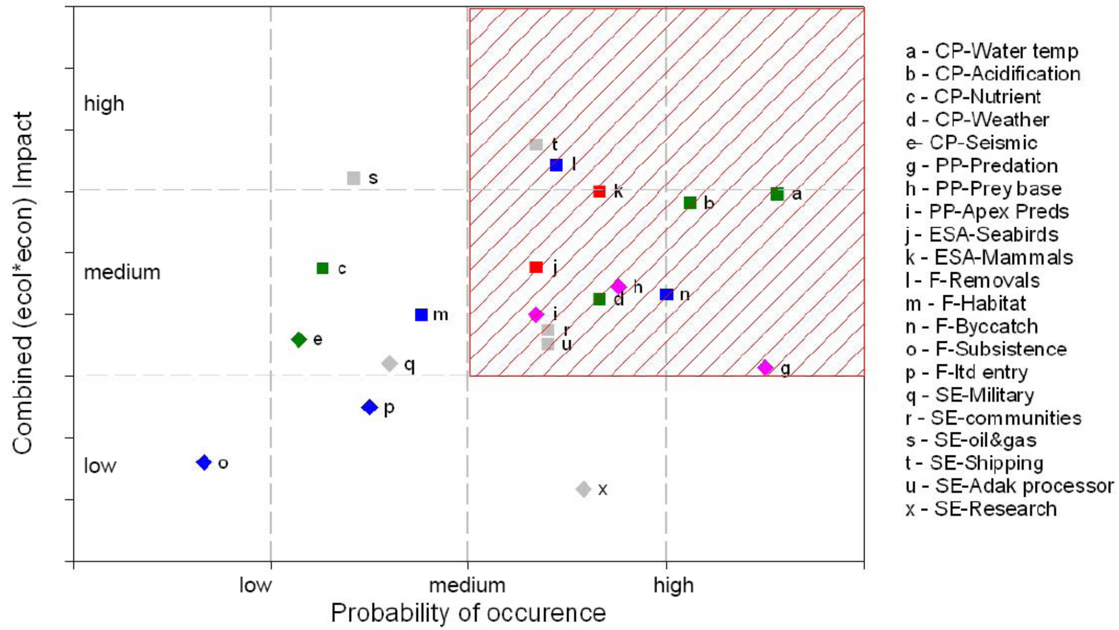
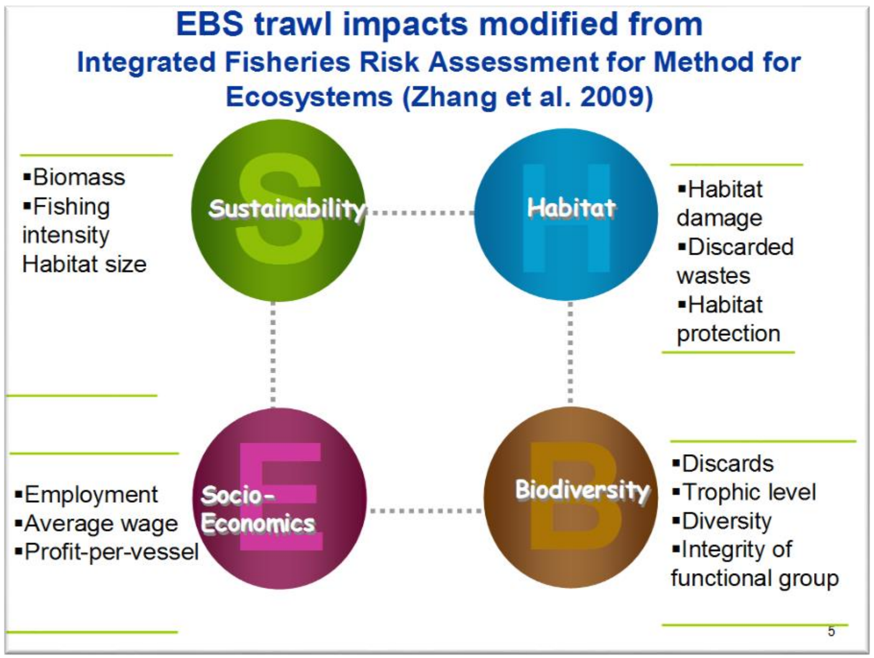
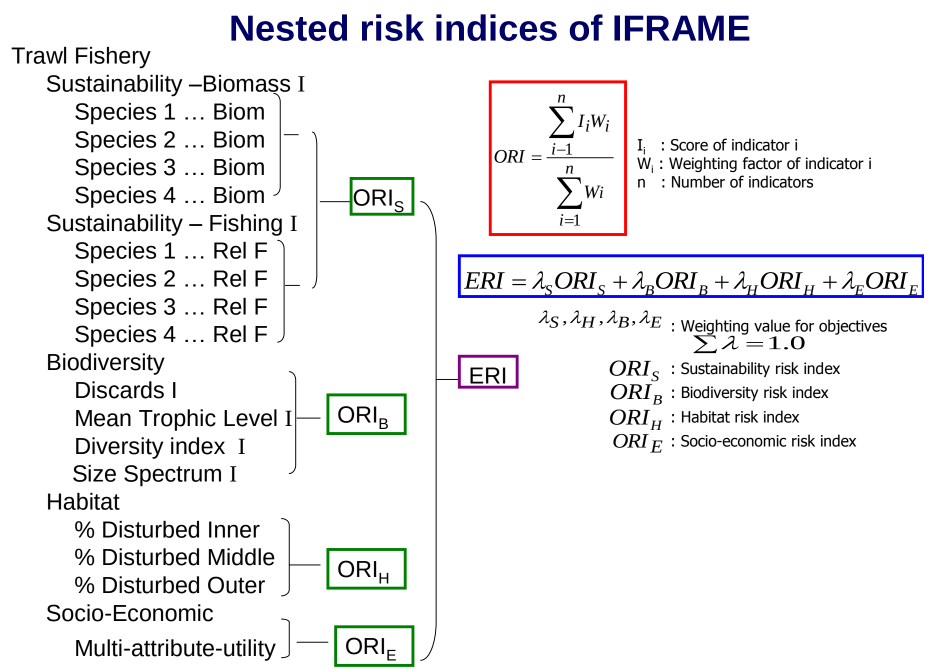


Figure 4-4 **Characterization of interactions in terms of probability of occurrence and a combined ecological multiplied by economic impact. Shaded area in upper right quadrant highlights those interactions with a medium to high probability of occurring and likely impact.**

http://www.fakr.noaa.gov/npfmc/conservation-issues/aifep.html

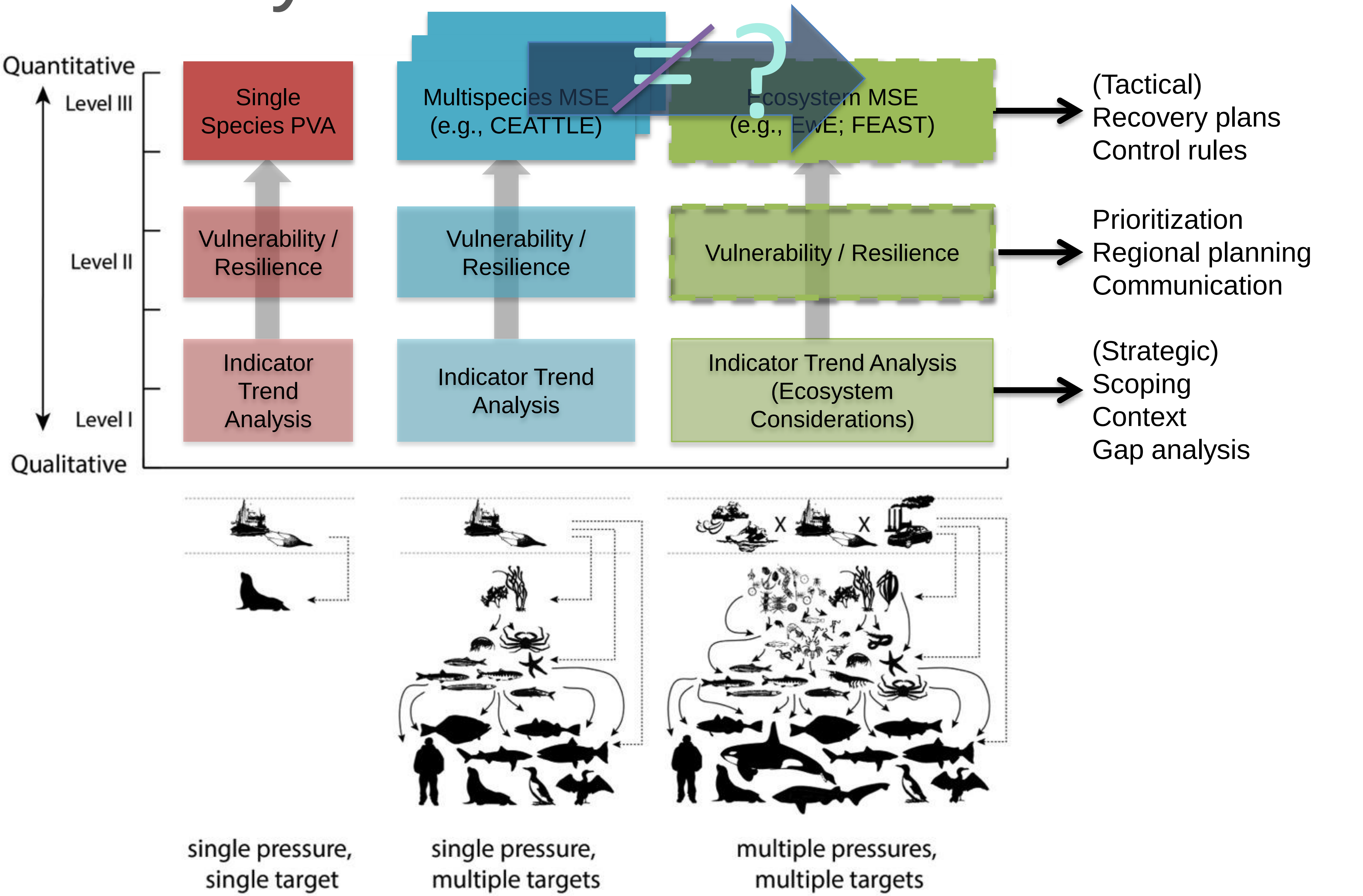
IFRAME



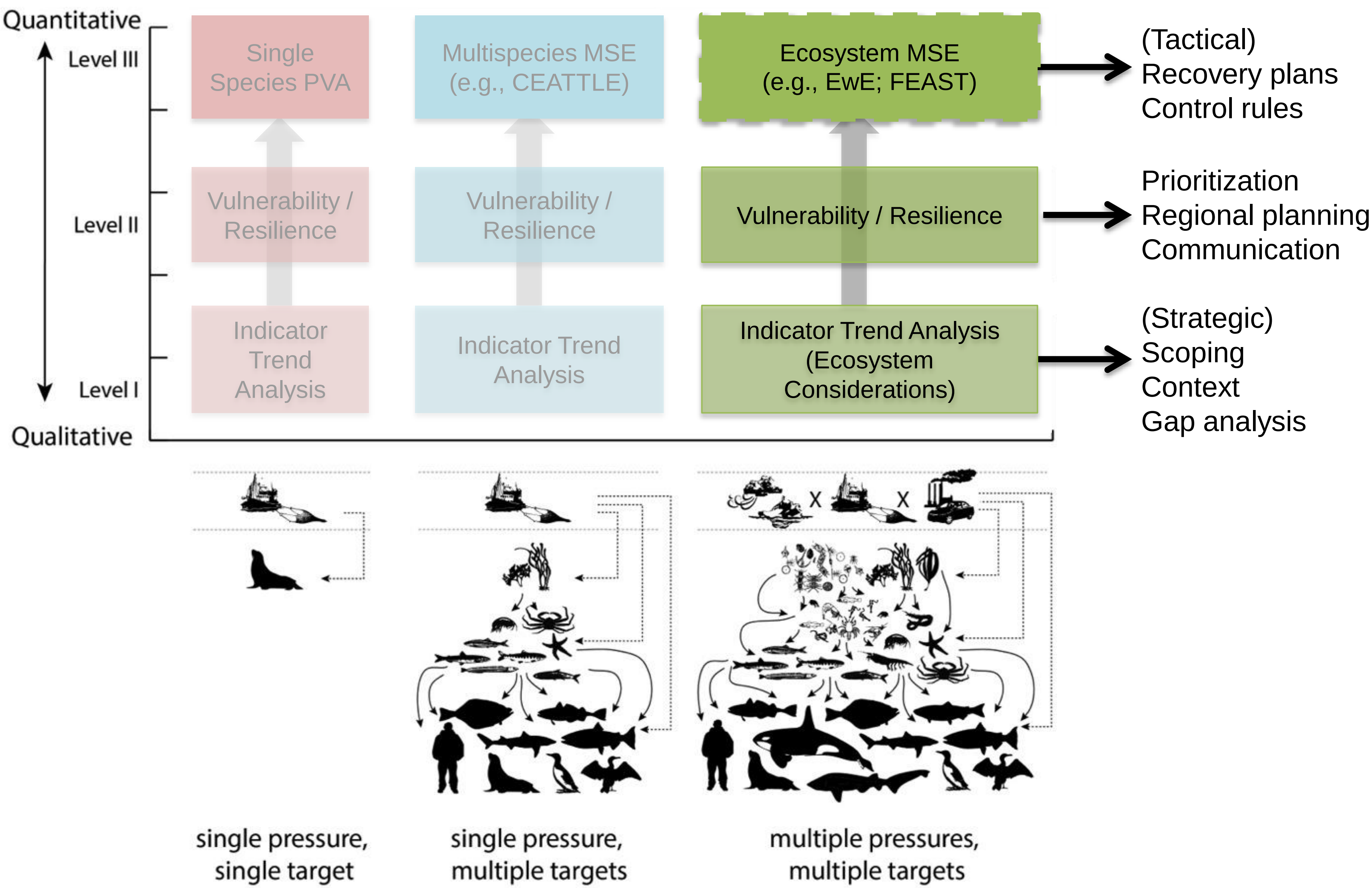


http://www.fakr.noaa.gov/npfmc/conservation-issues/aifep.html

Ecosystem Risk Assessment

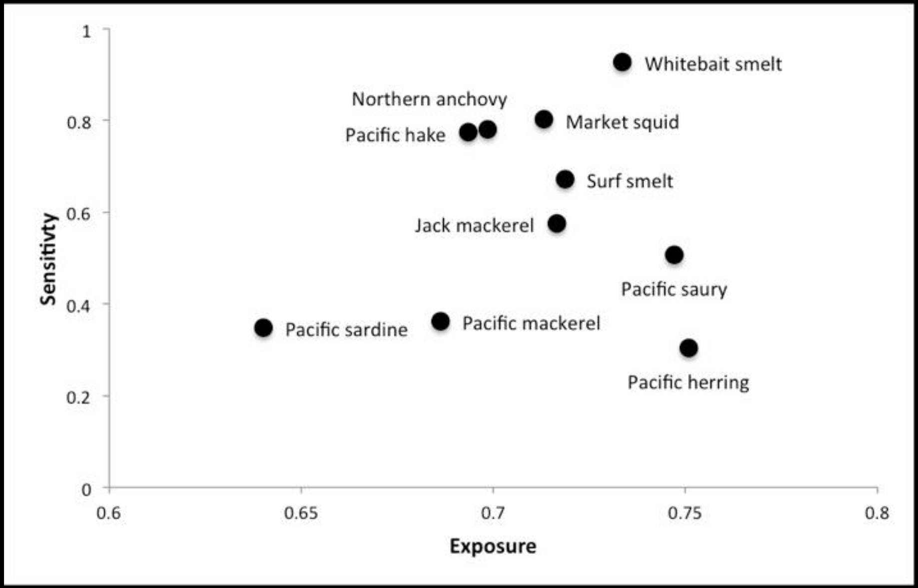


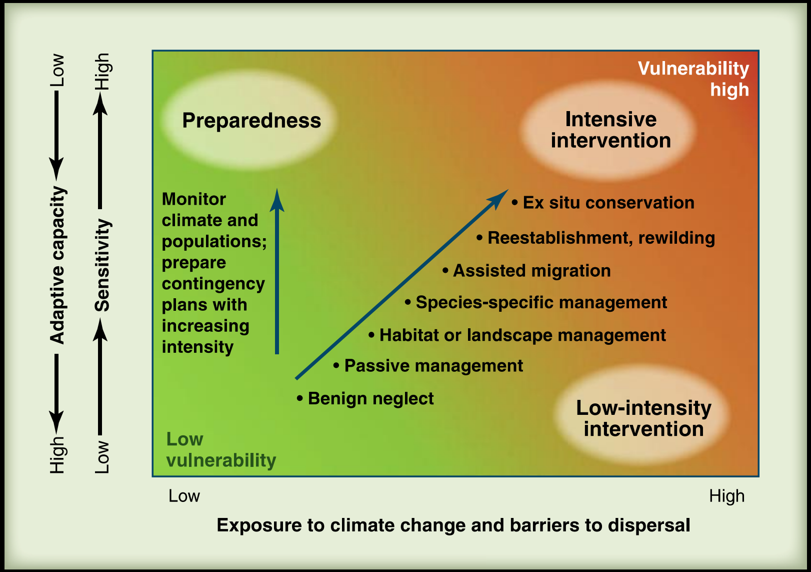
Ecosystem Risk Assessment



VULNERABILITY OF FORAGE FISH TO CLIMATE CHANGE

Dawson et al. 2011

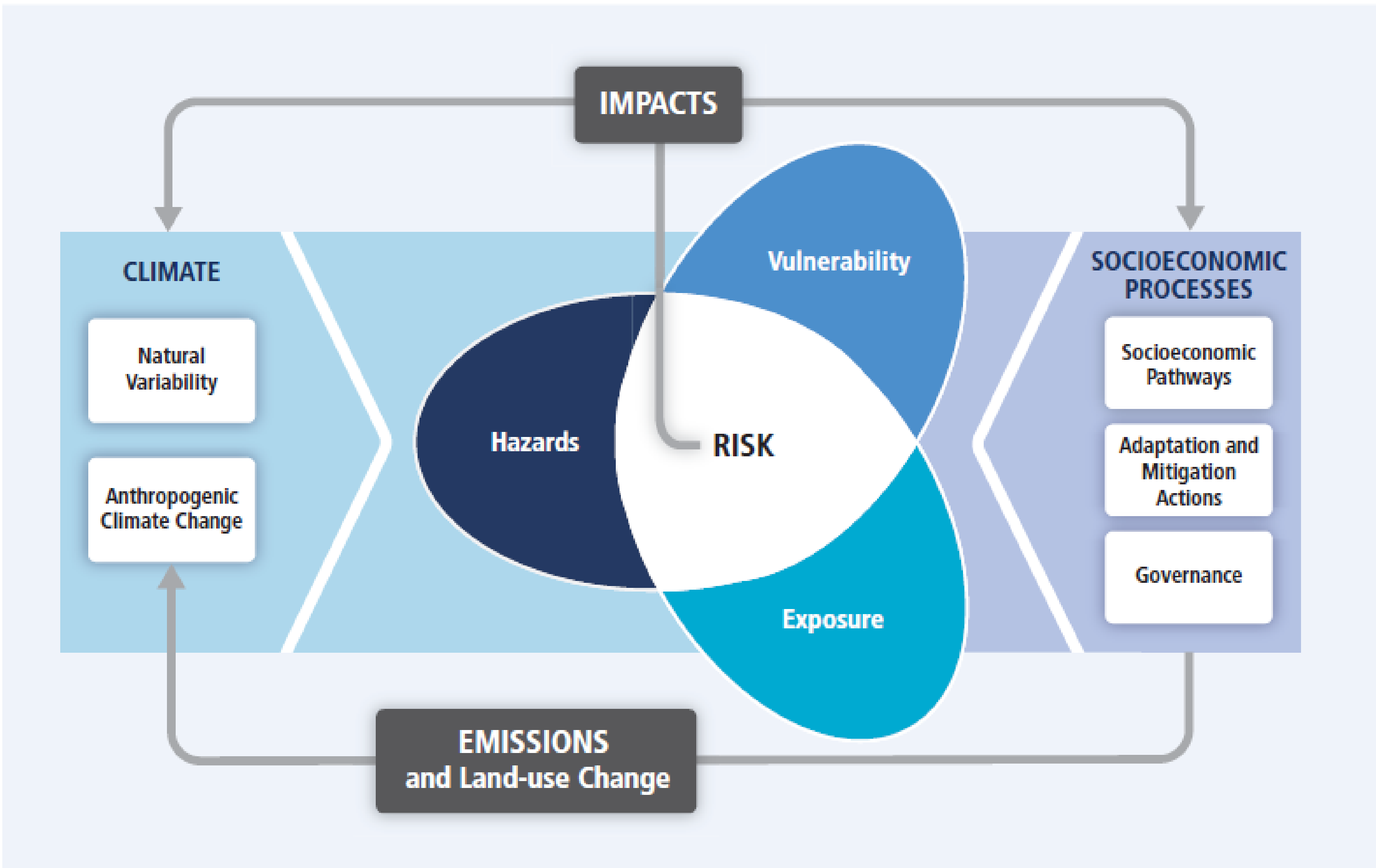




Samhouri et al. in review

For a similar approach, see Gaichas et al. 2014…

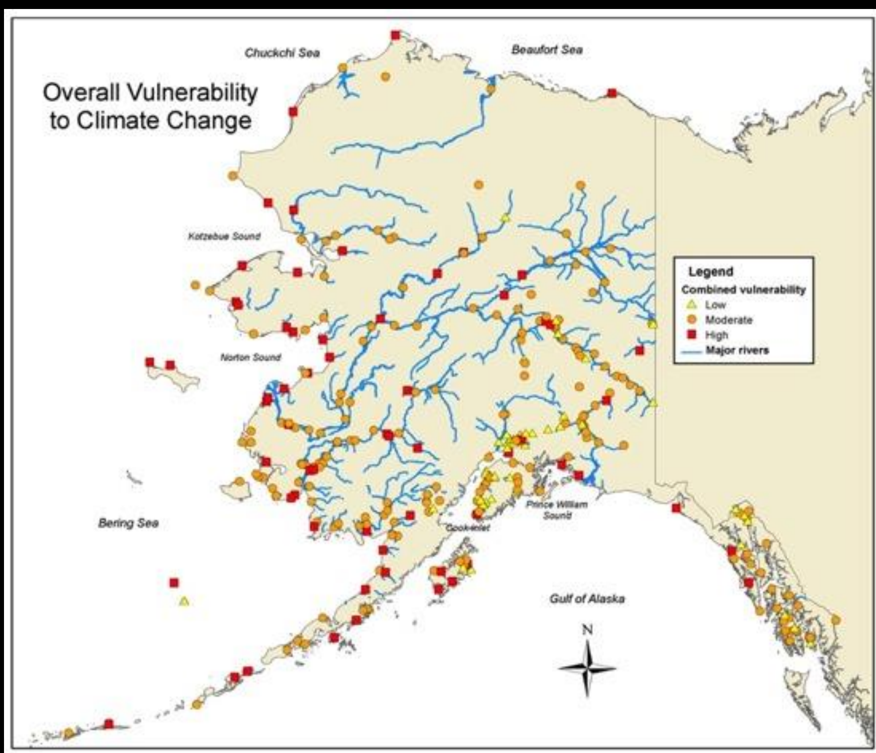
Climate Change Assessment
(IPCC - WGII Summary for Policy Makers)



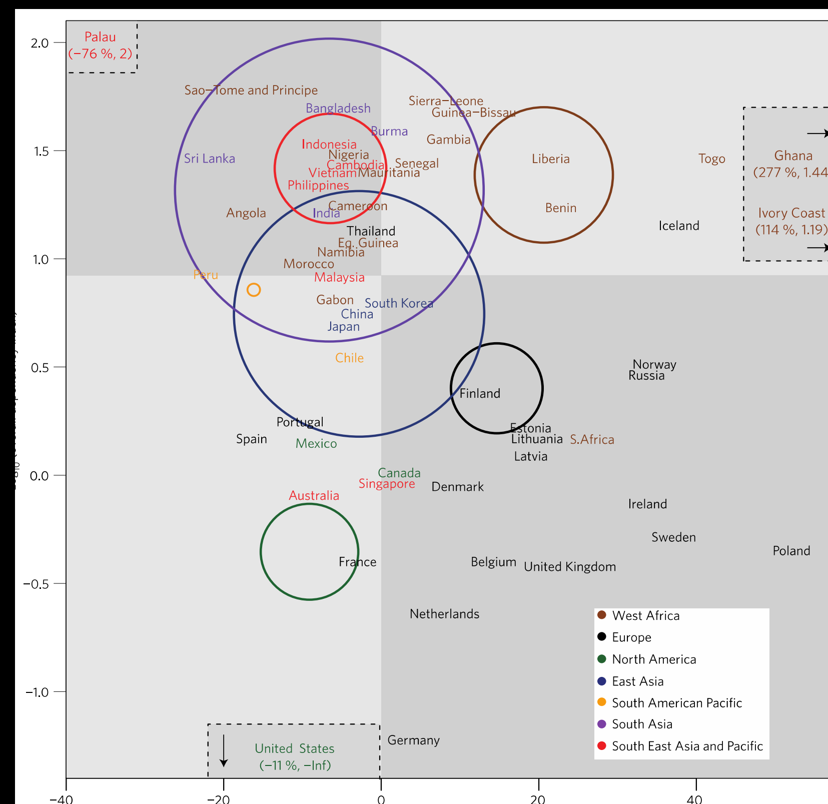
http://www.ipcc-wg2.gov/AR5/images/uploads/WG2AR5_SPM_FINAL.pdf

VULNERABILITY OF PEOPLE TO CLIMATE CHANGE

Premise: increased exposure of marine resources to expected climatic change, and reduced resilience in human communities → increased vulnerability



Himes-Cornell and Kaspersky in review



Barange et al. 2014

Risk Assessment

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

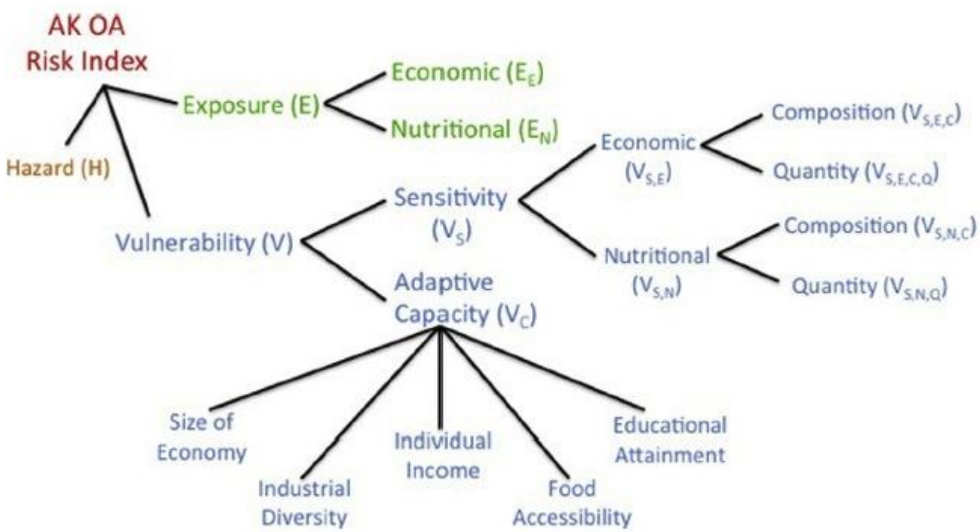


Fig. 3. Components of the risk index. Each branch is evenly weighted relative to others at the same level.

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

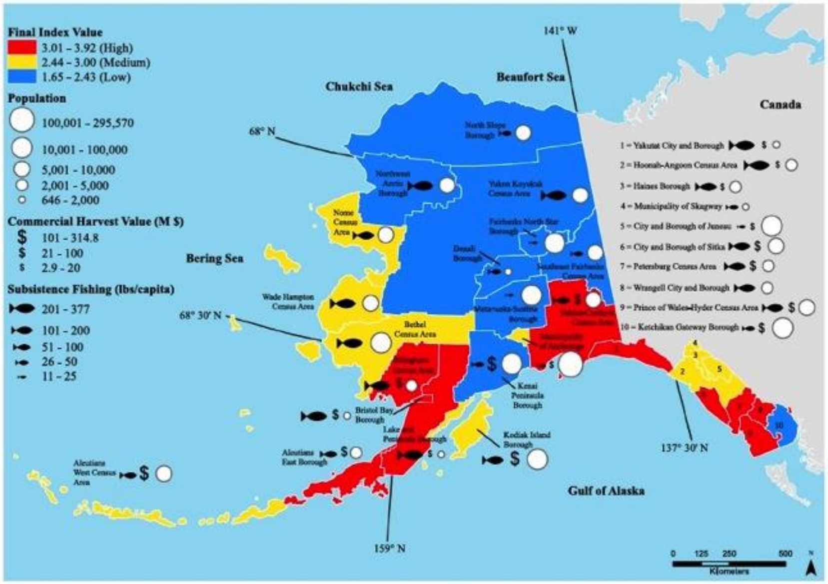


Fig. 11. Individual components of the final ocean acidification risk index for each census area.

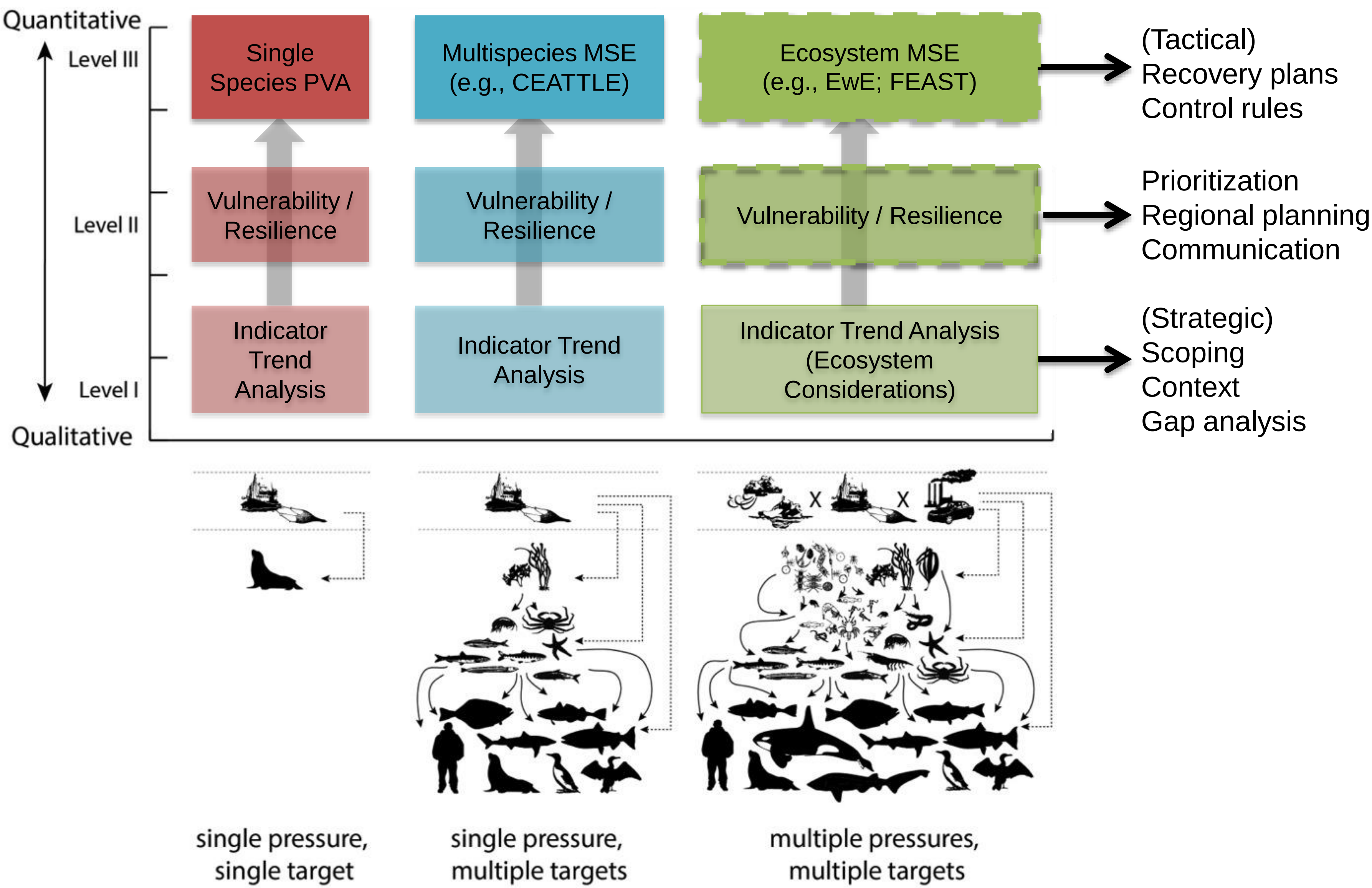
Elements of Risk Assessment

Decision to be made

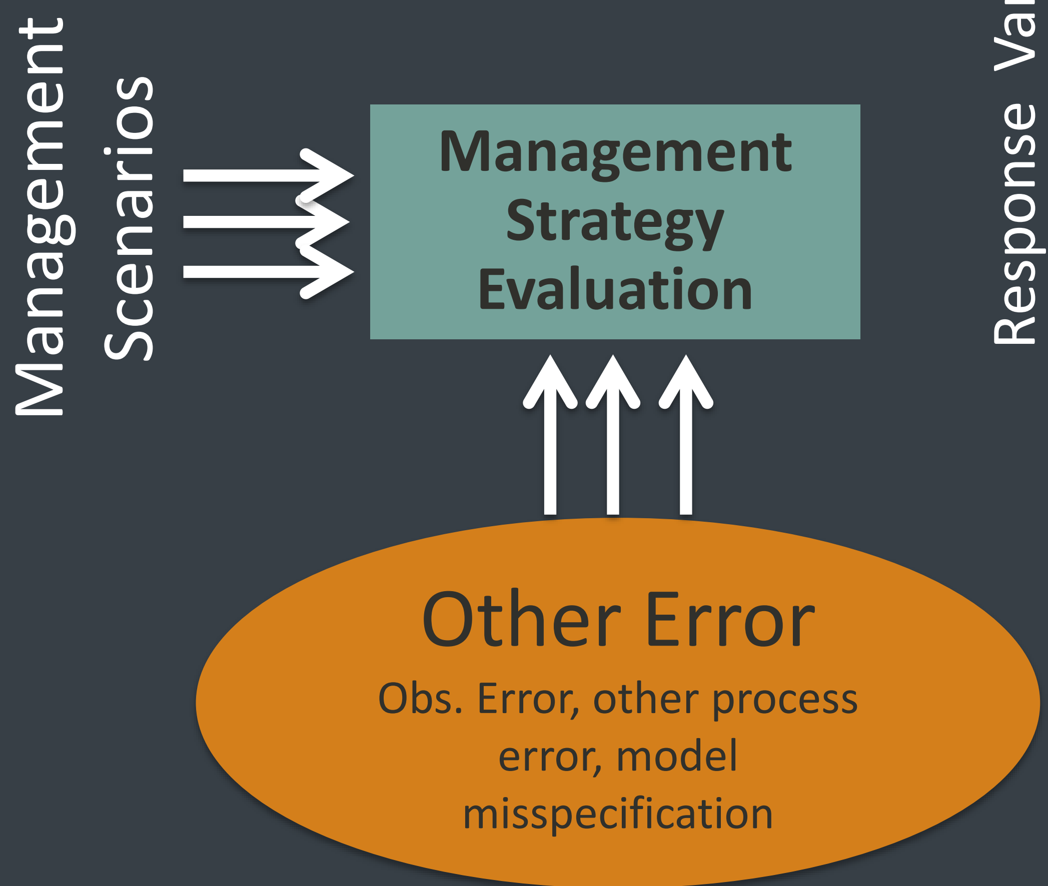
Uncertainty around outcomes

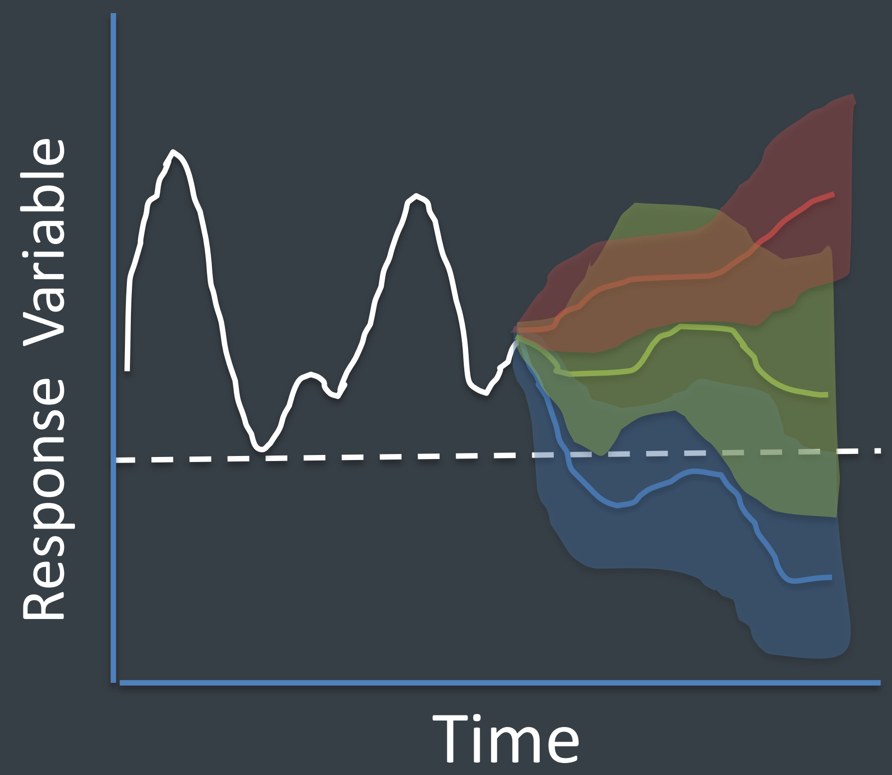
Risk assessment = "Technical support for decision making under uncertainty"

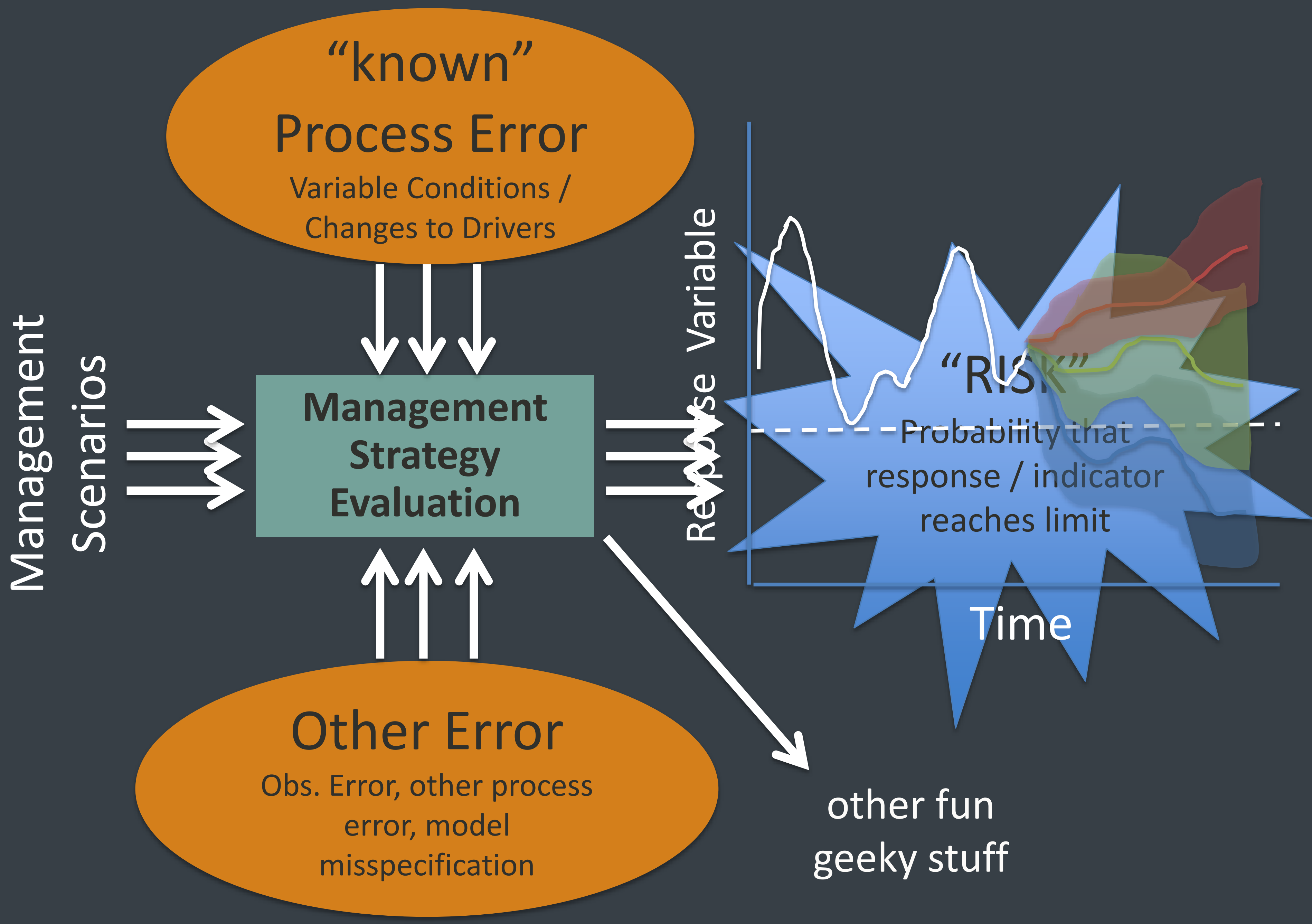
Ecosystem Risk Assessment



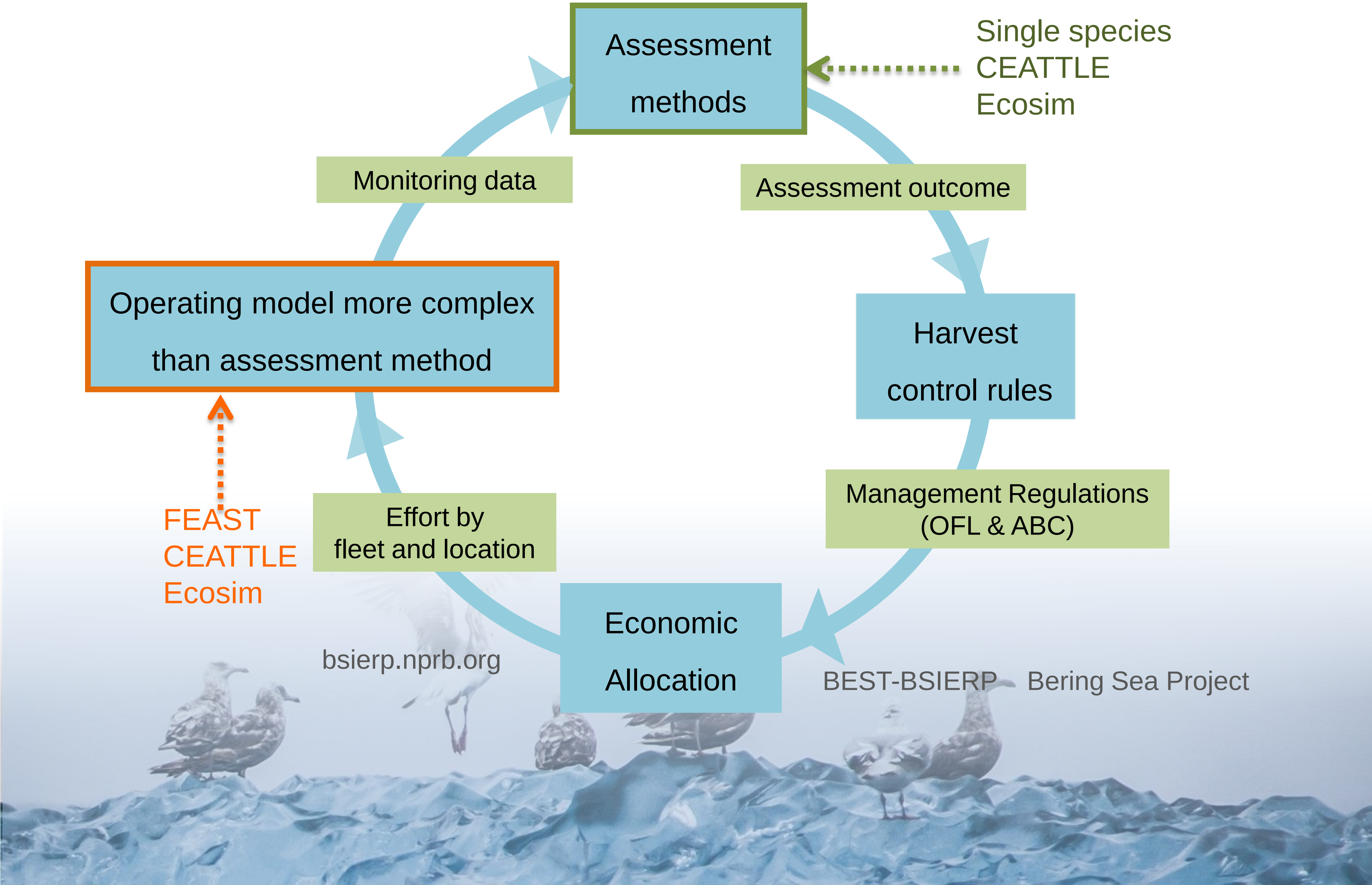
Risk Assessment



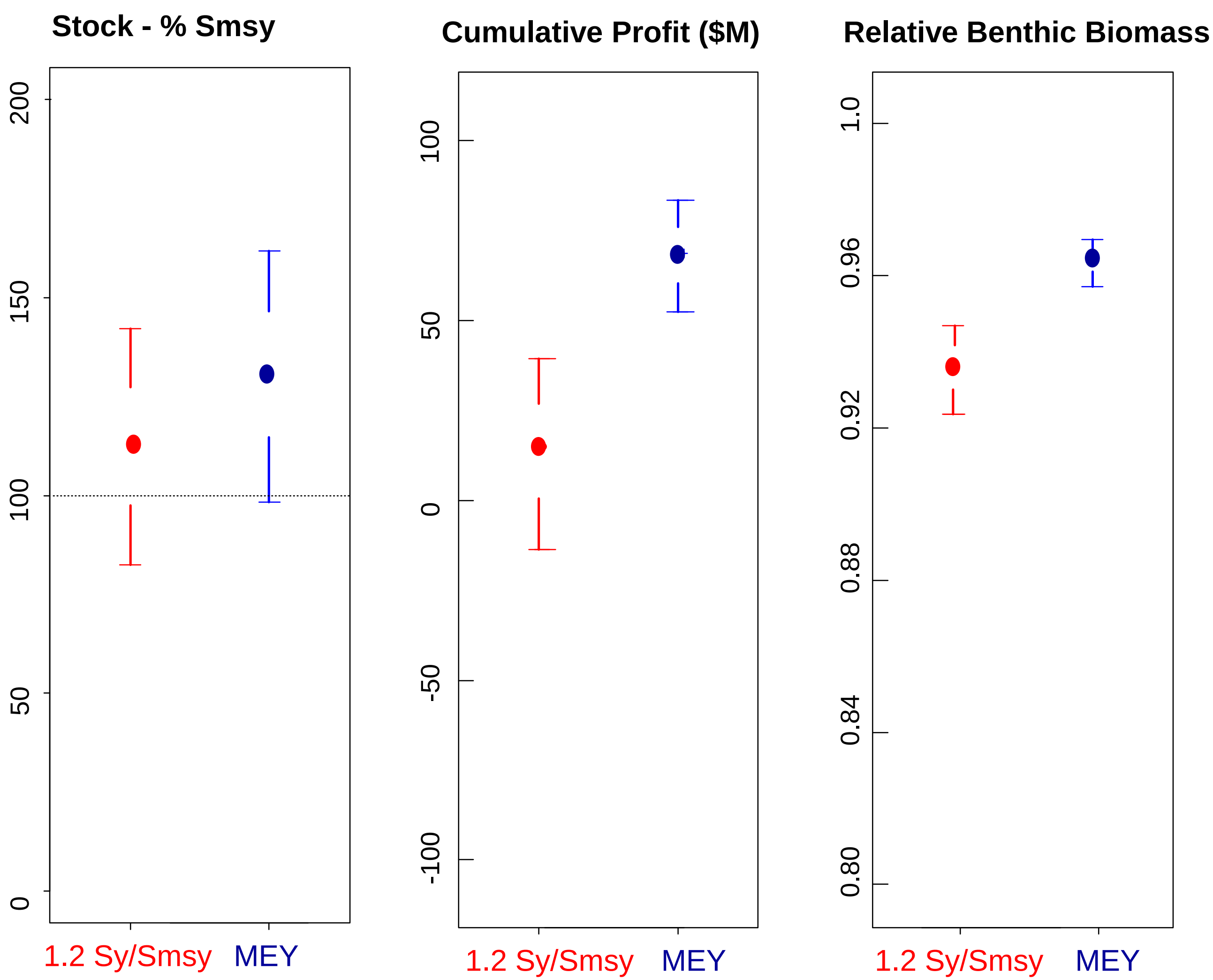



"known"
Process Error
Variable Conditions / Changes to Drivers
Management Scenarios
Management Strategy Evaluation
Response Variable
"RISK"
Probability that response / indicator reaches limit
Time
Other Error
Obs. Error, other process error, model misspecification
other fun geeky stuff

MSE : “manage” simulated ecosystems & summarize performance (relative to management objectives)



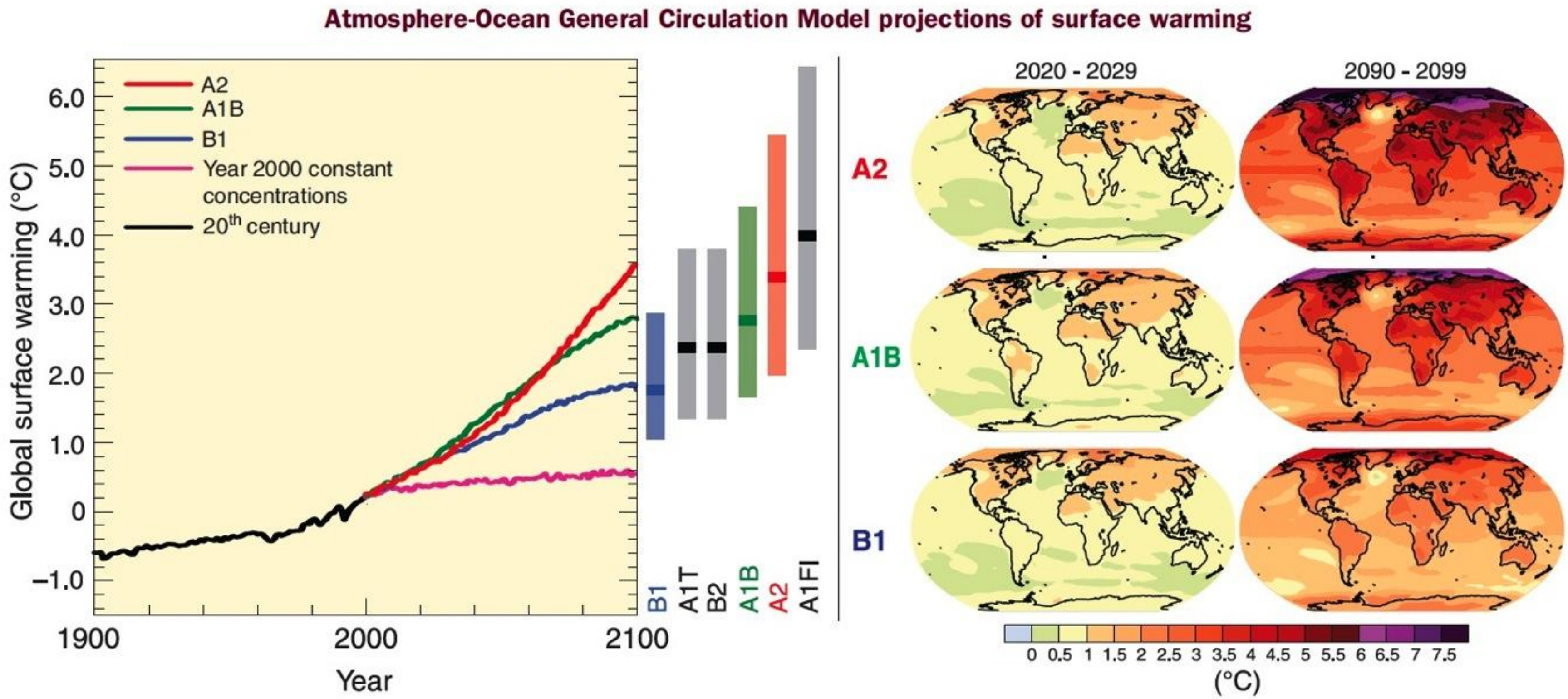
Performance metrics for ecosystem MSEs



a climate change example

Photo: Mark Holsman

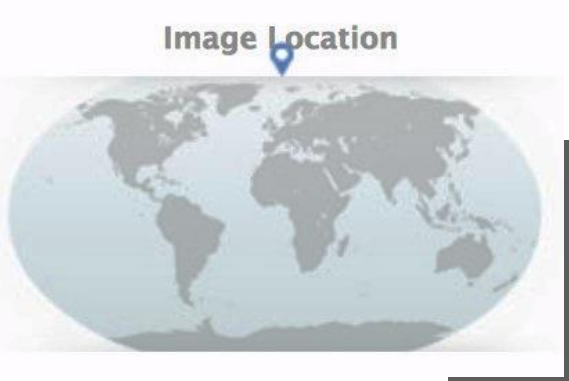
IPCC projected changes in temperature



Graphic: IPCC AR4

3-7 ^{o}C of warming in Arctic

Arctic Sea Ice: September 1984



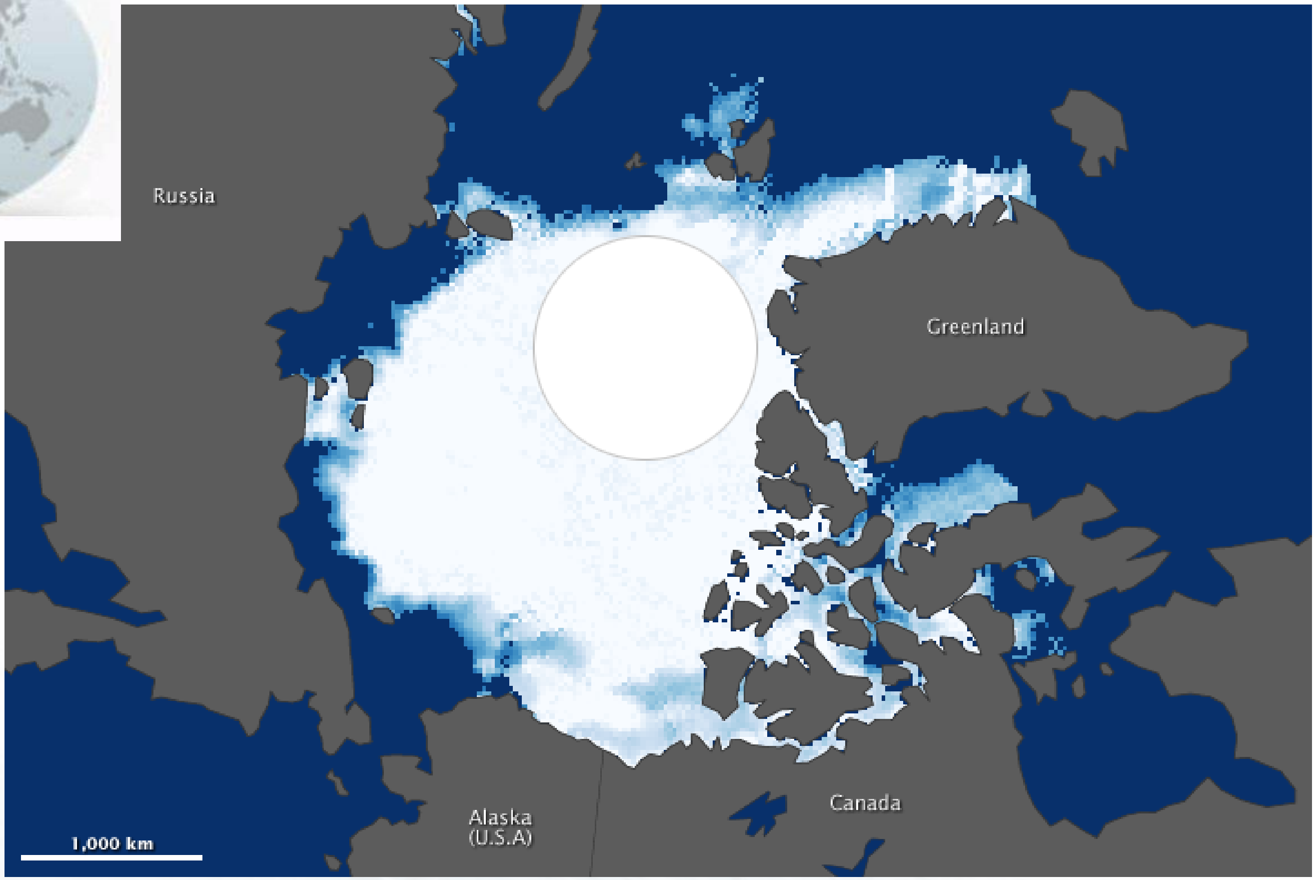
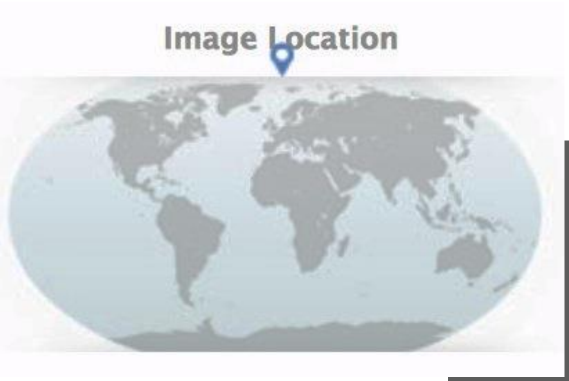


Image: NASA Earth Observatory image by Jesse Allen
Data: National Snow and Ice Data Center

kirstin.holsman@noaa.gov

Arctic Sea Ice: September 2012



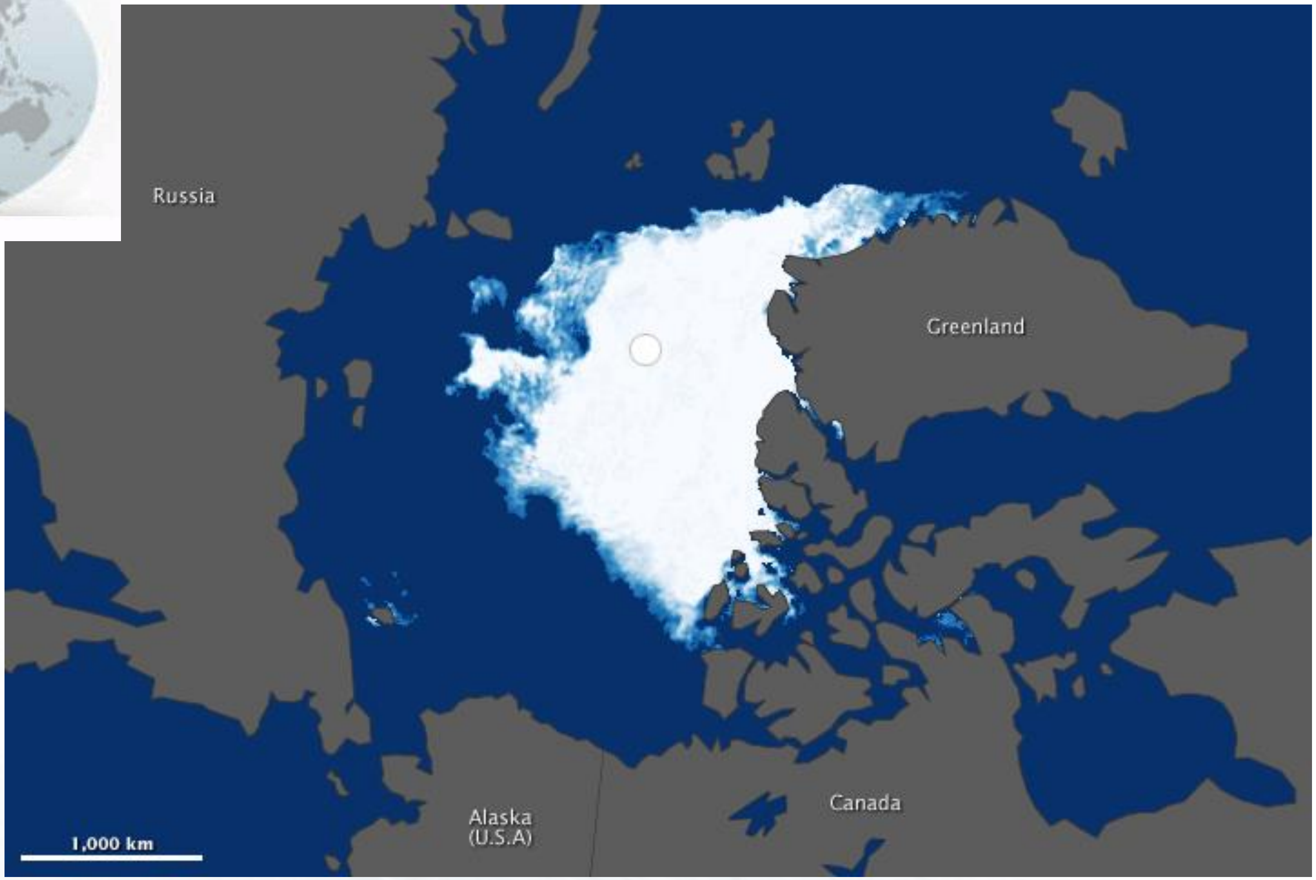
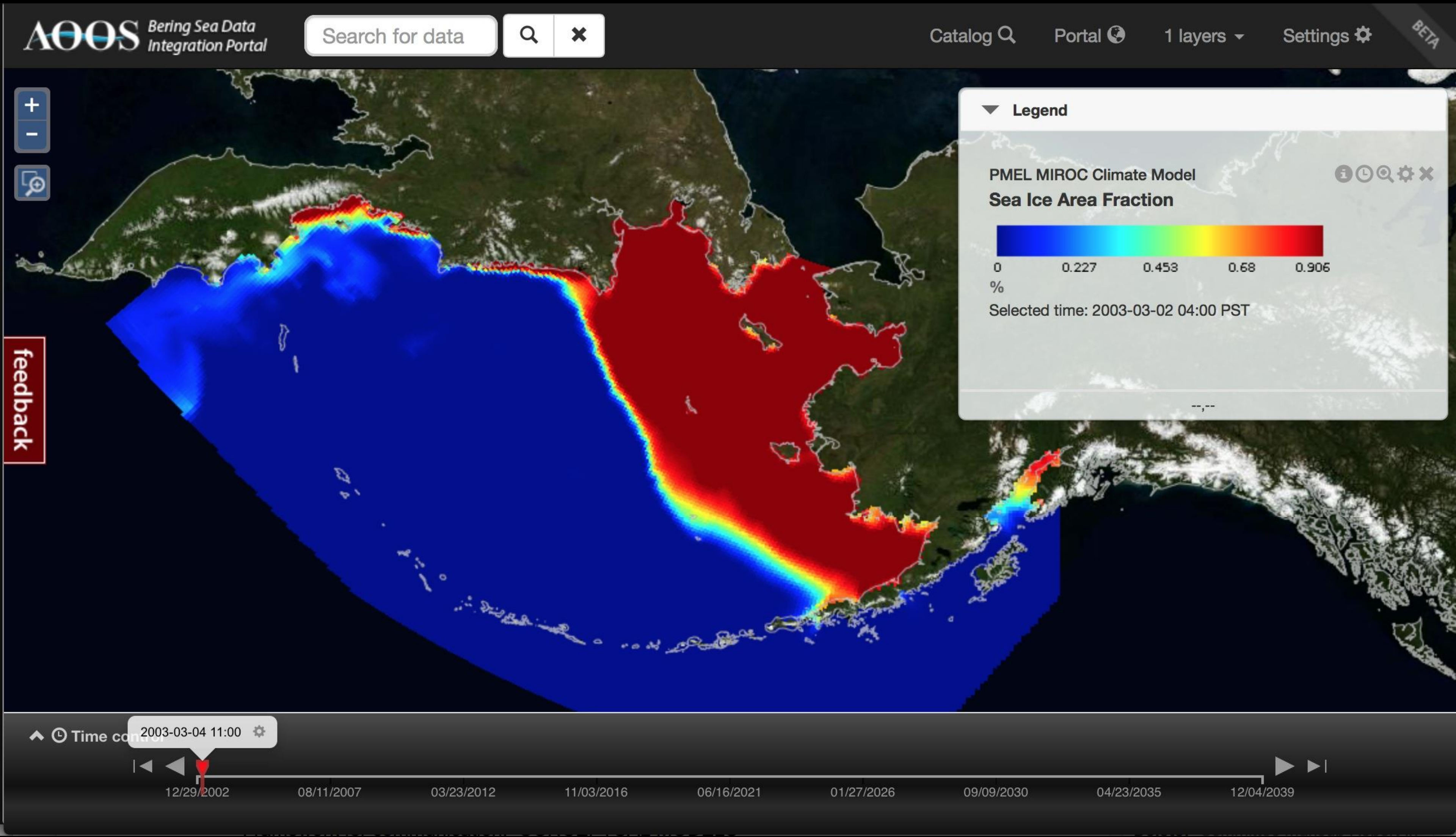
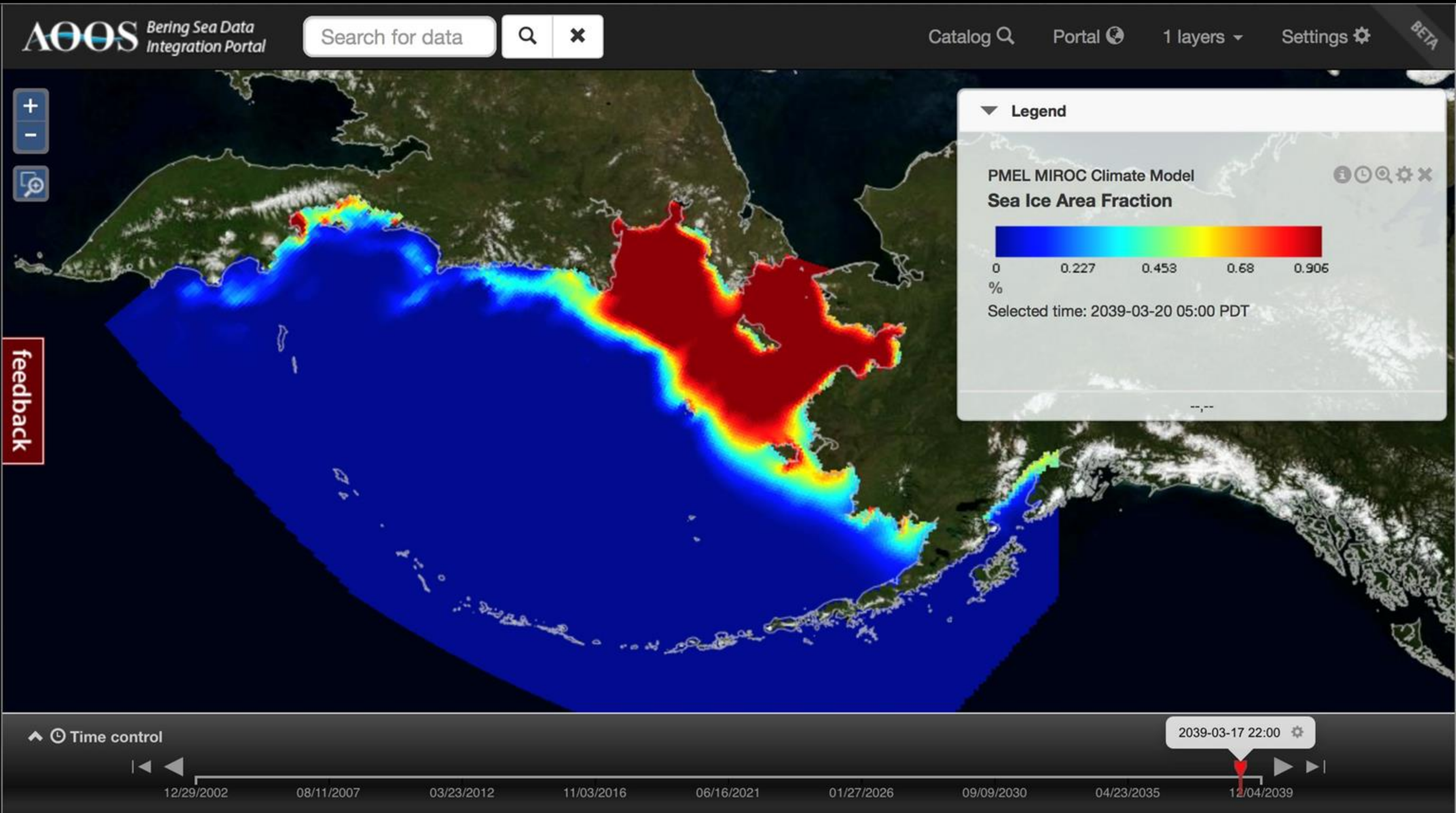


Image: NASA Earth Observatory image by Jesse Allen
Data: National Snow and Ice Data Center

kirstin.holsman@noaa.gov



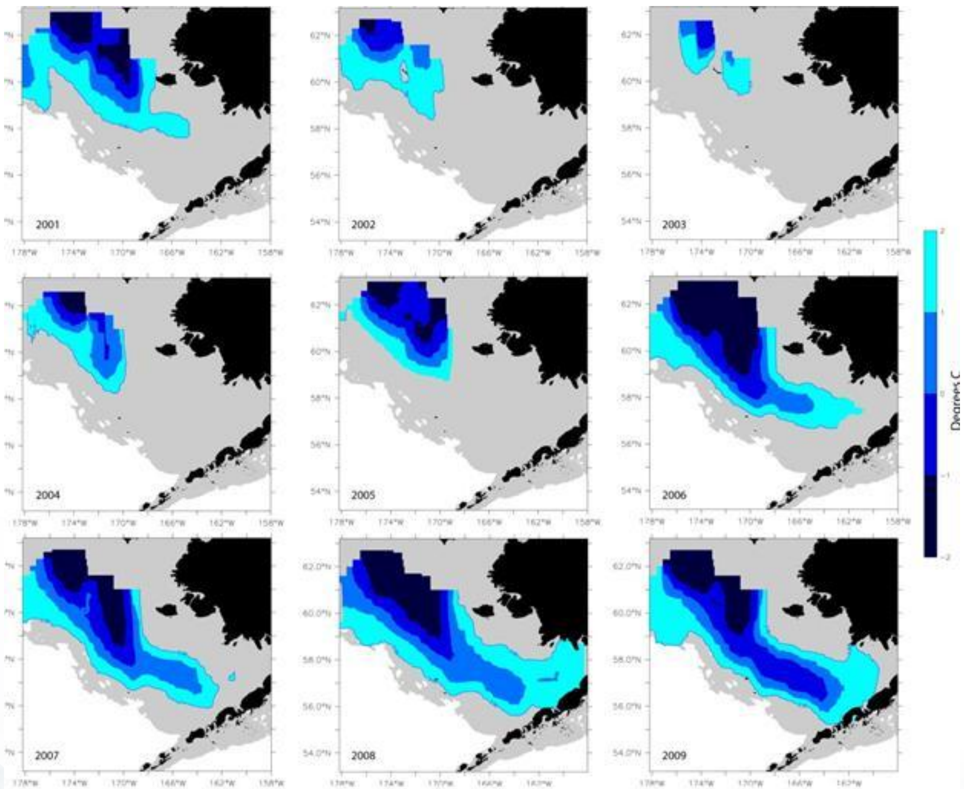
http://portal.aoos.org/bering-sea.php



http://portal.aoos.org/bering-sea.php

Bering Sea & Climate

Bering Sea “Cold Pool” 2001-2009



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

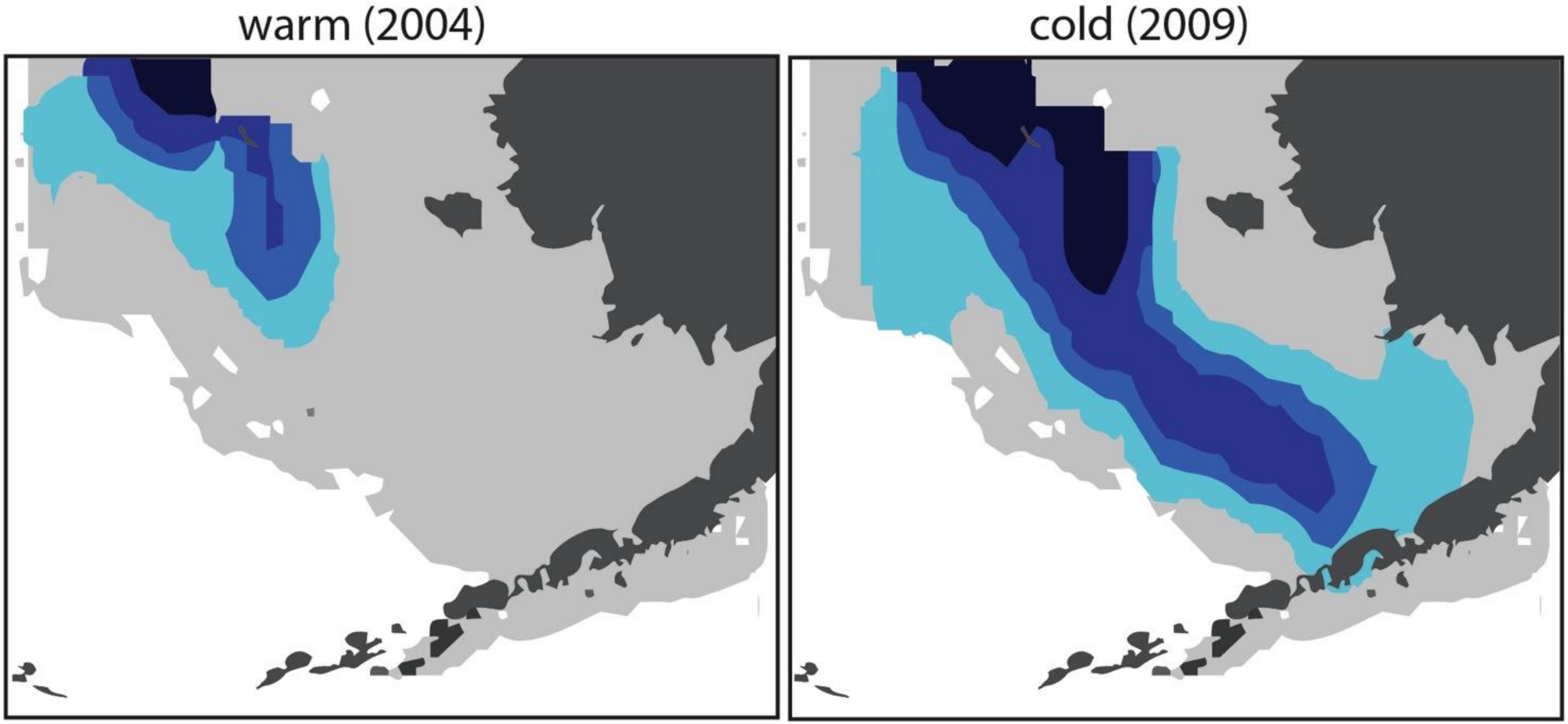
kirstin.holsman@noaa.gov

What is the future of Alaska fisheries ?

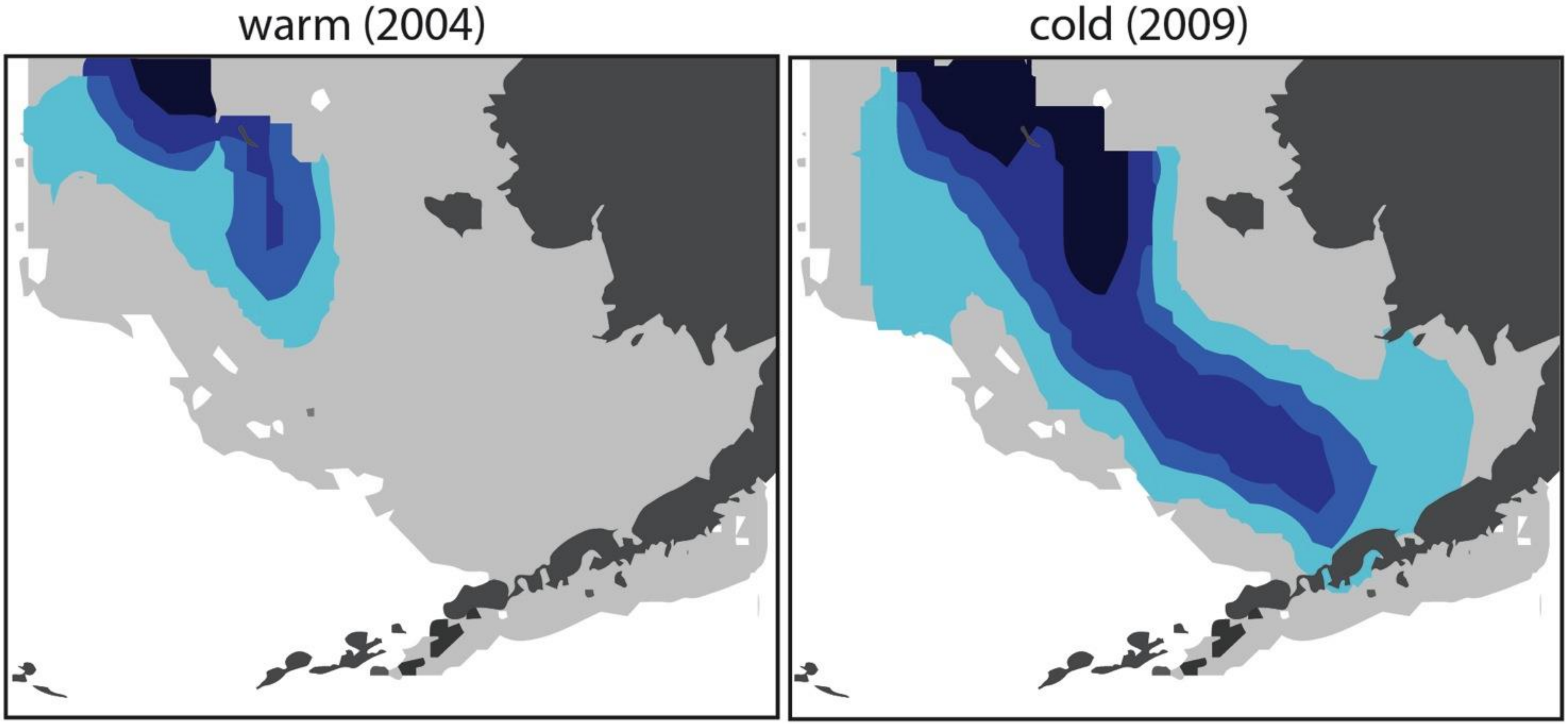
Will our current management work?

Photo: Mark Holsman

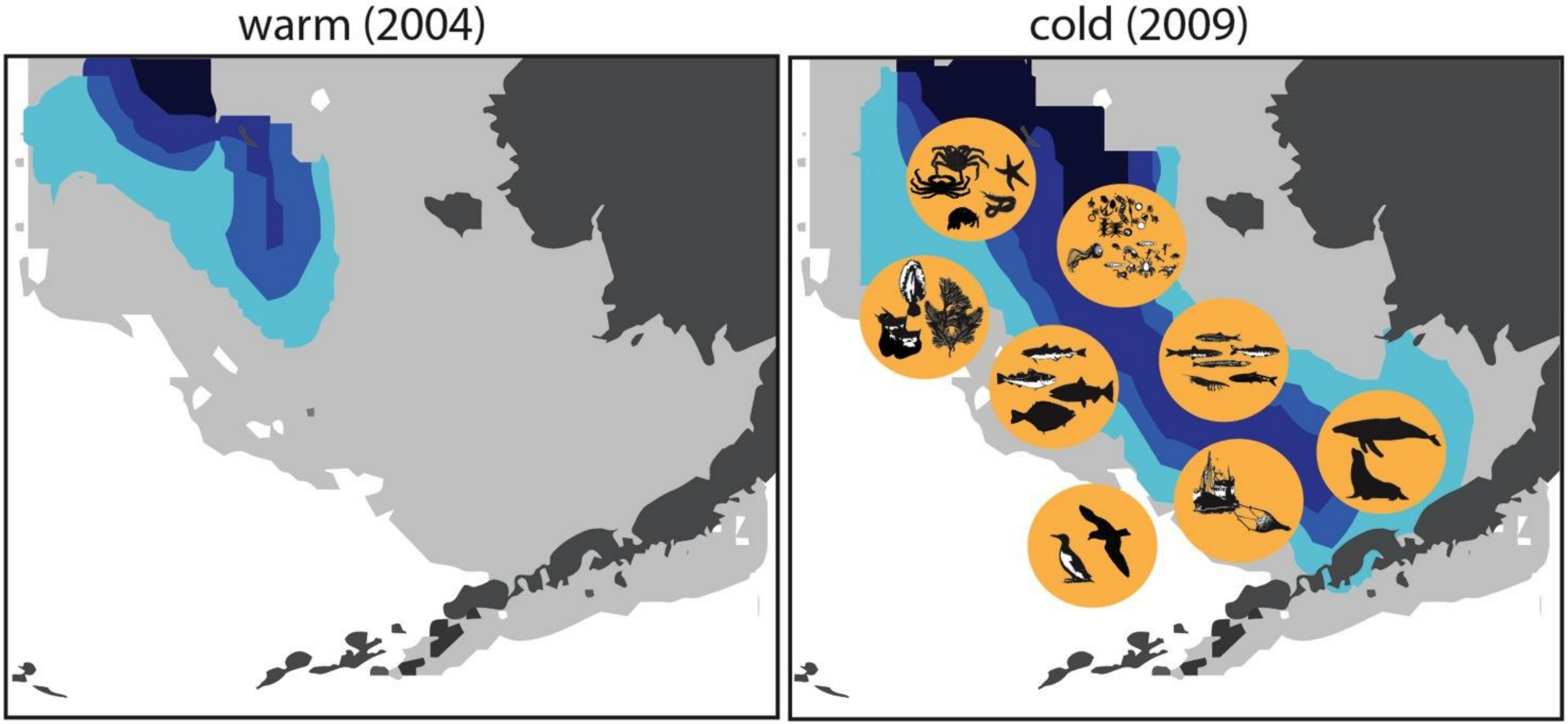
Bering Sea Models



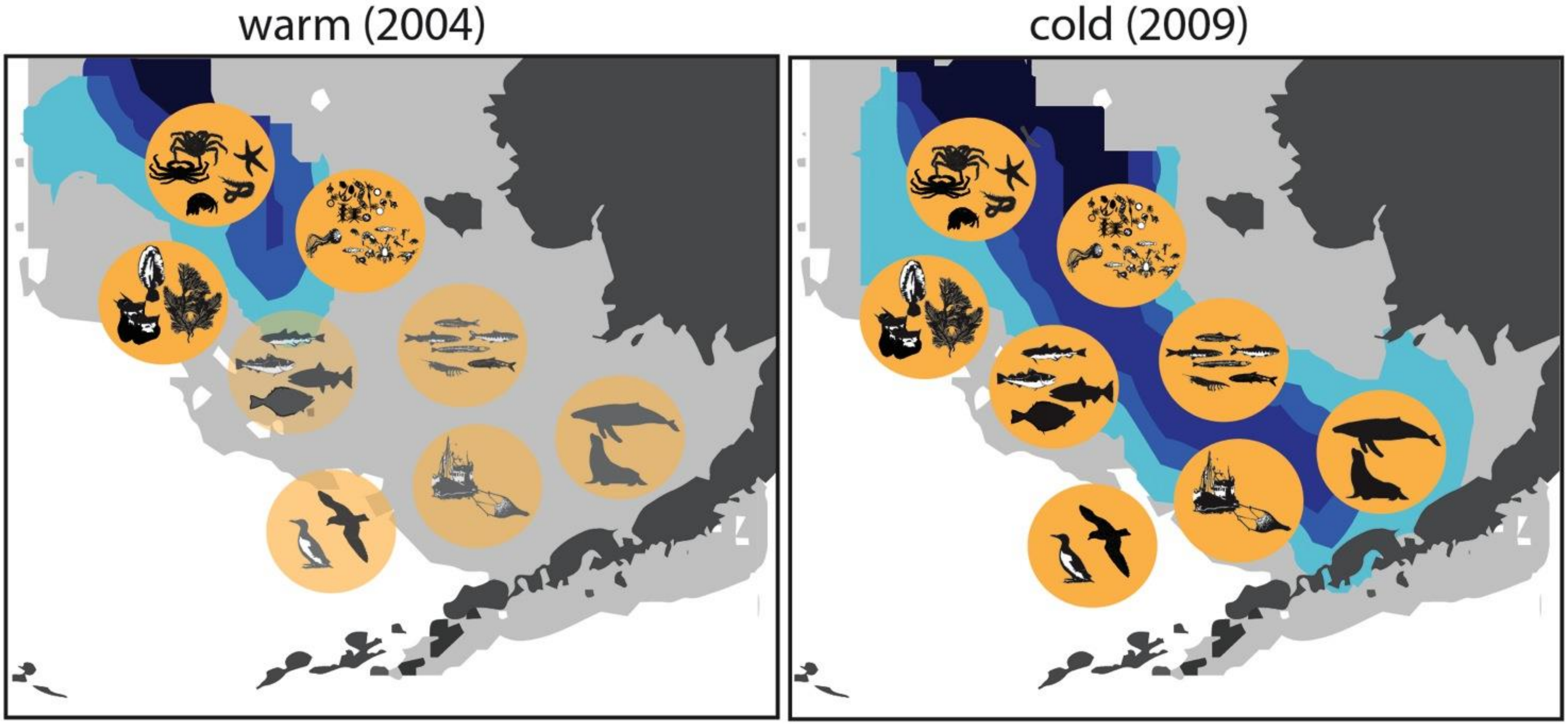
Bering Sea Models

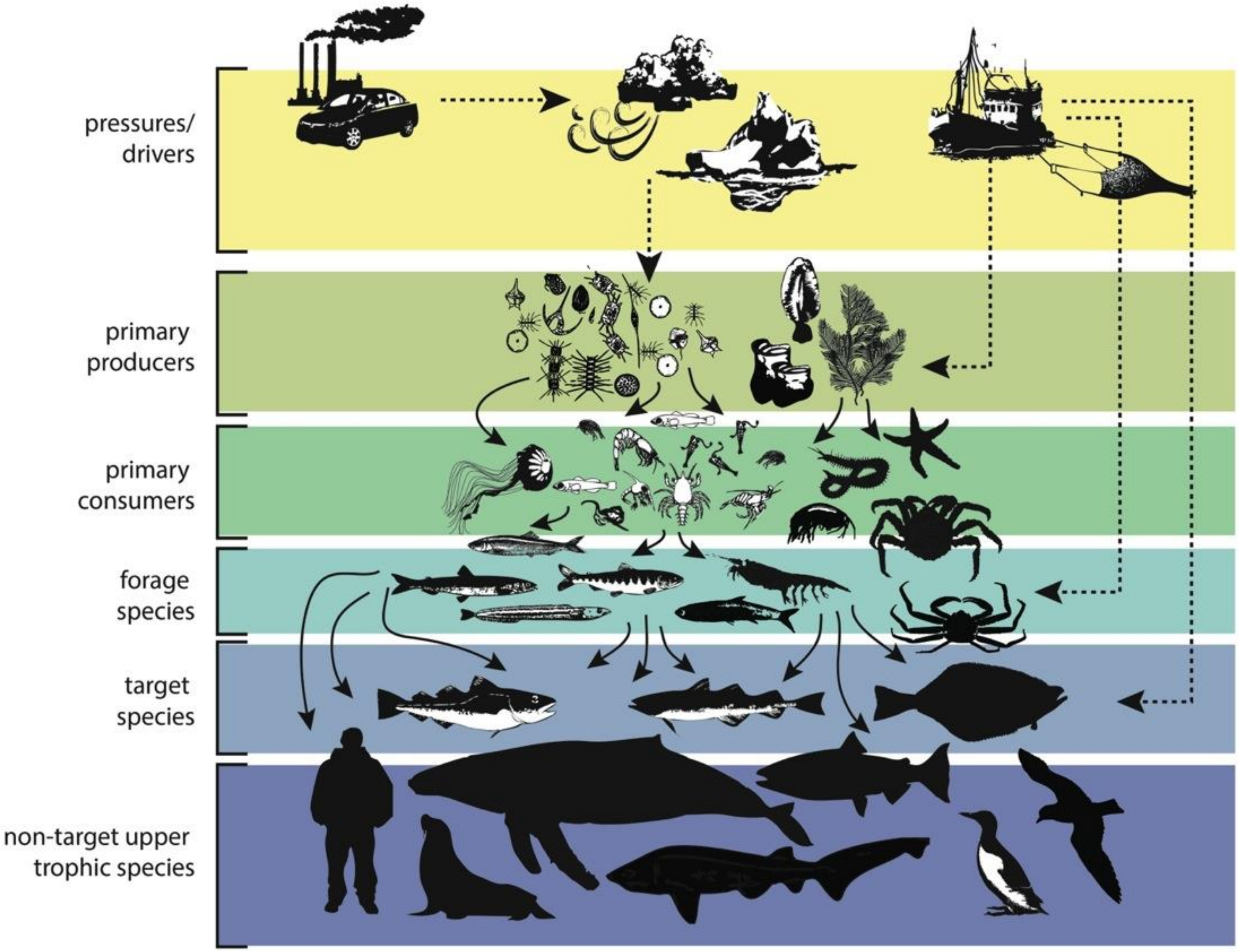


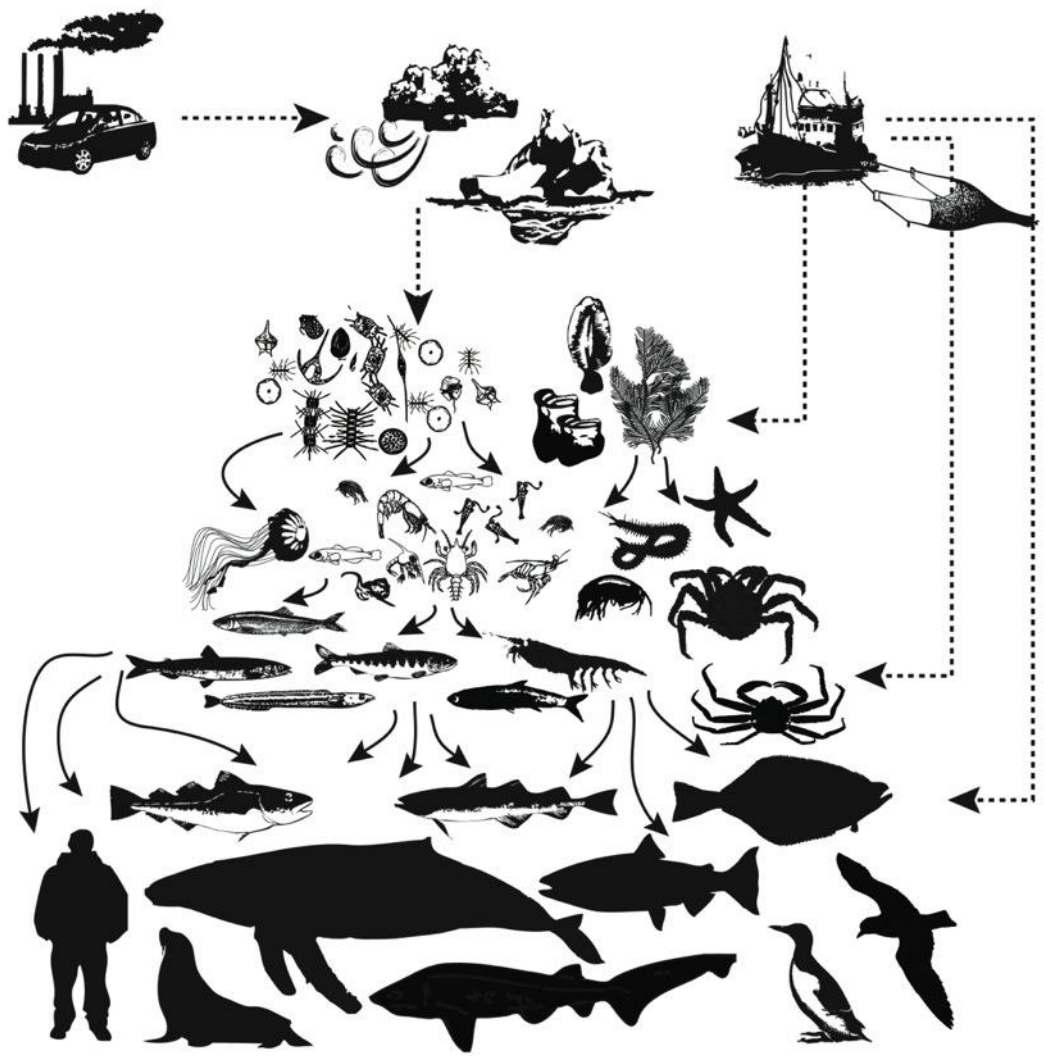
Bering Sea Models

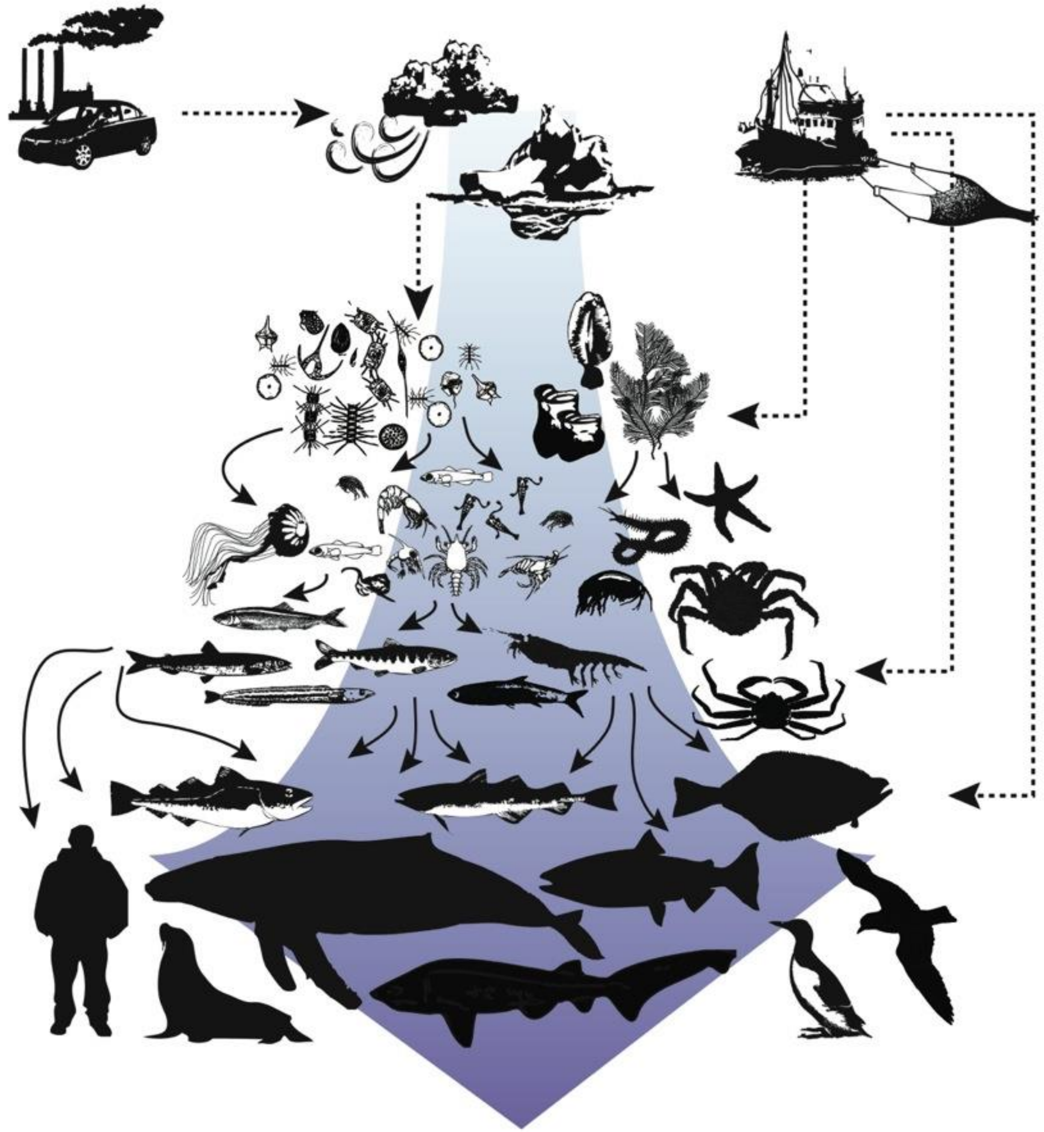


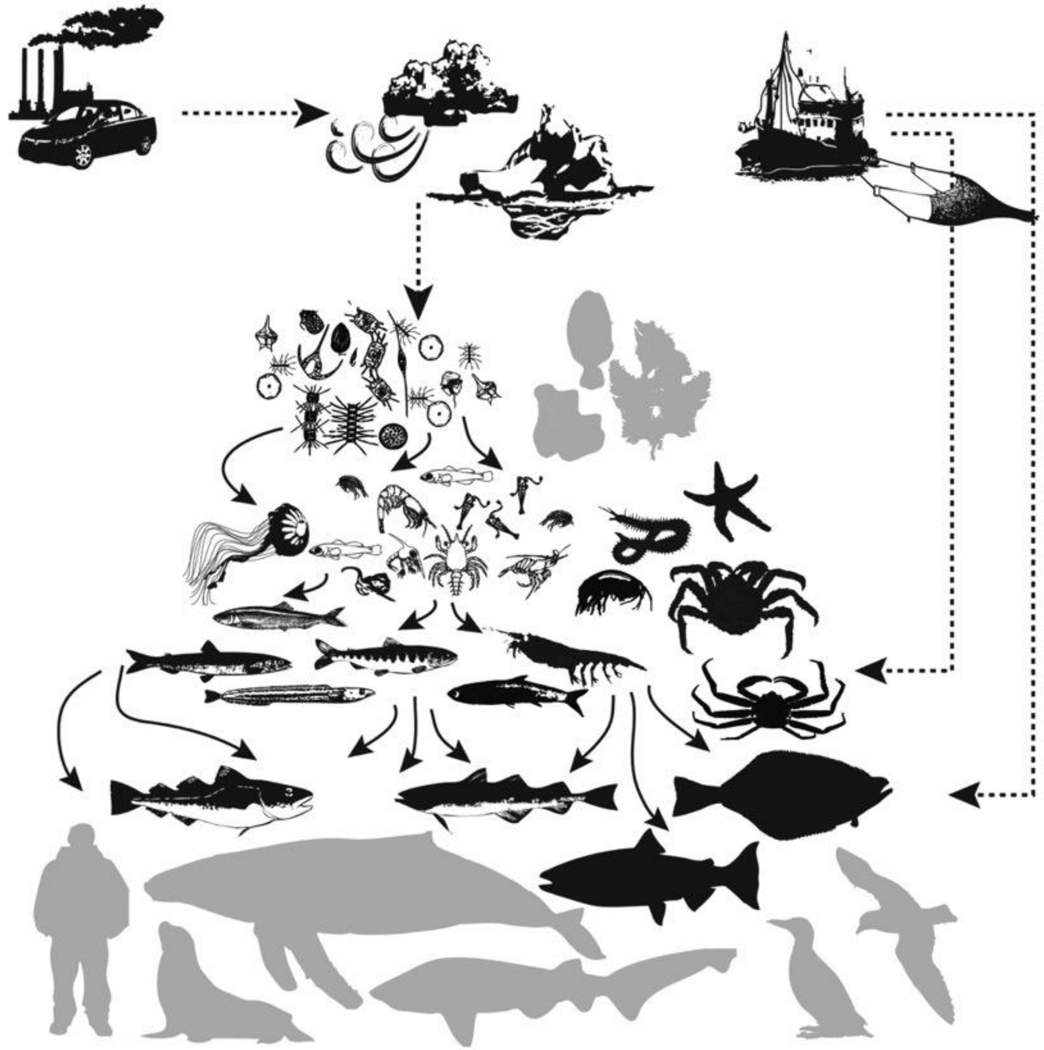
Bering Sea Models

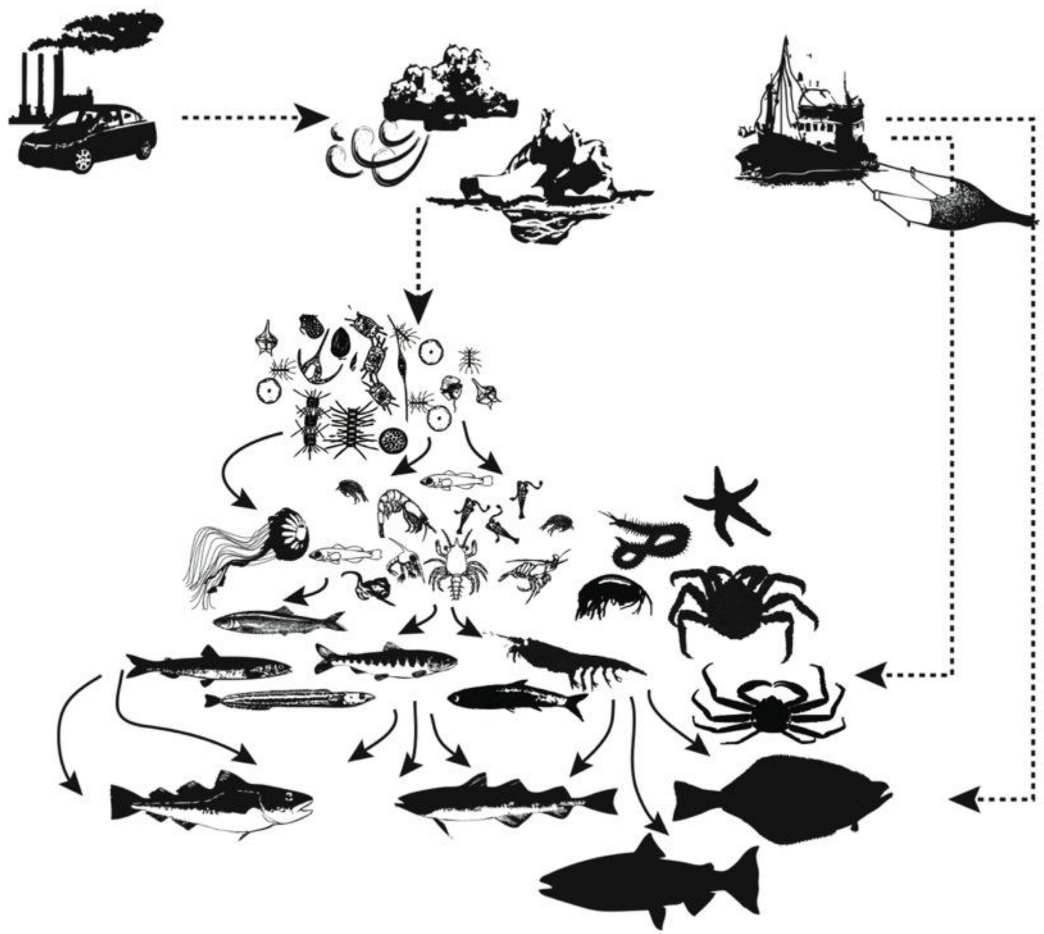


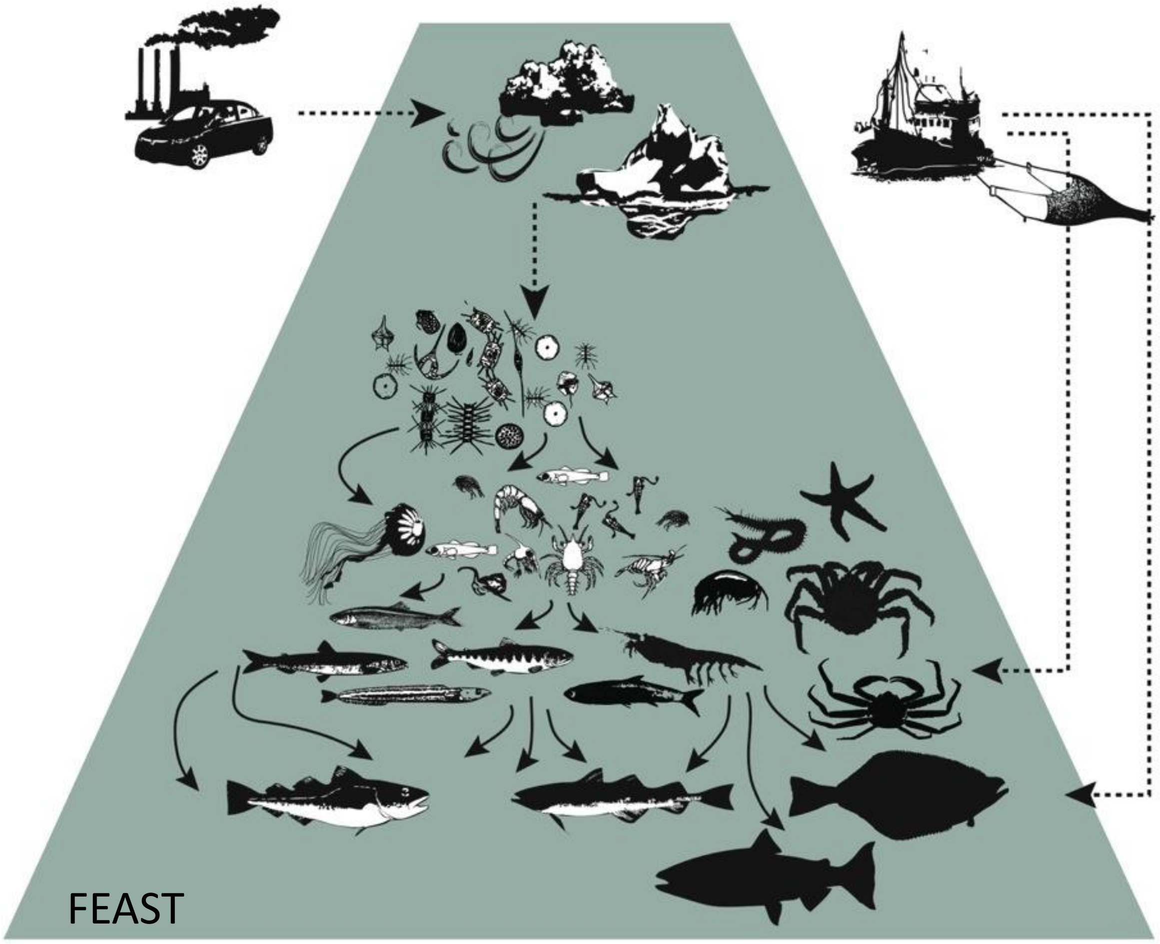

pressures/
drivers
primary
producers
primary
consumers
forage
species
target
species
non-target upper
trophic species

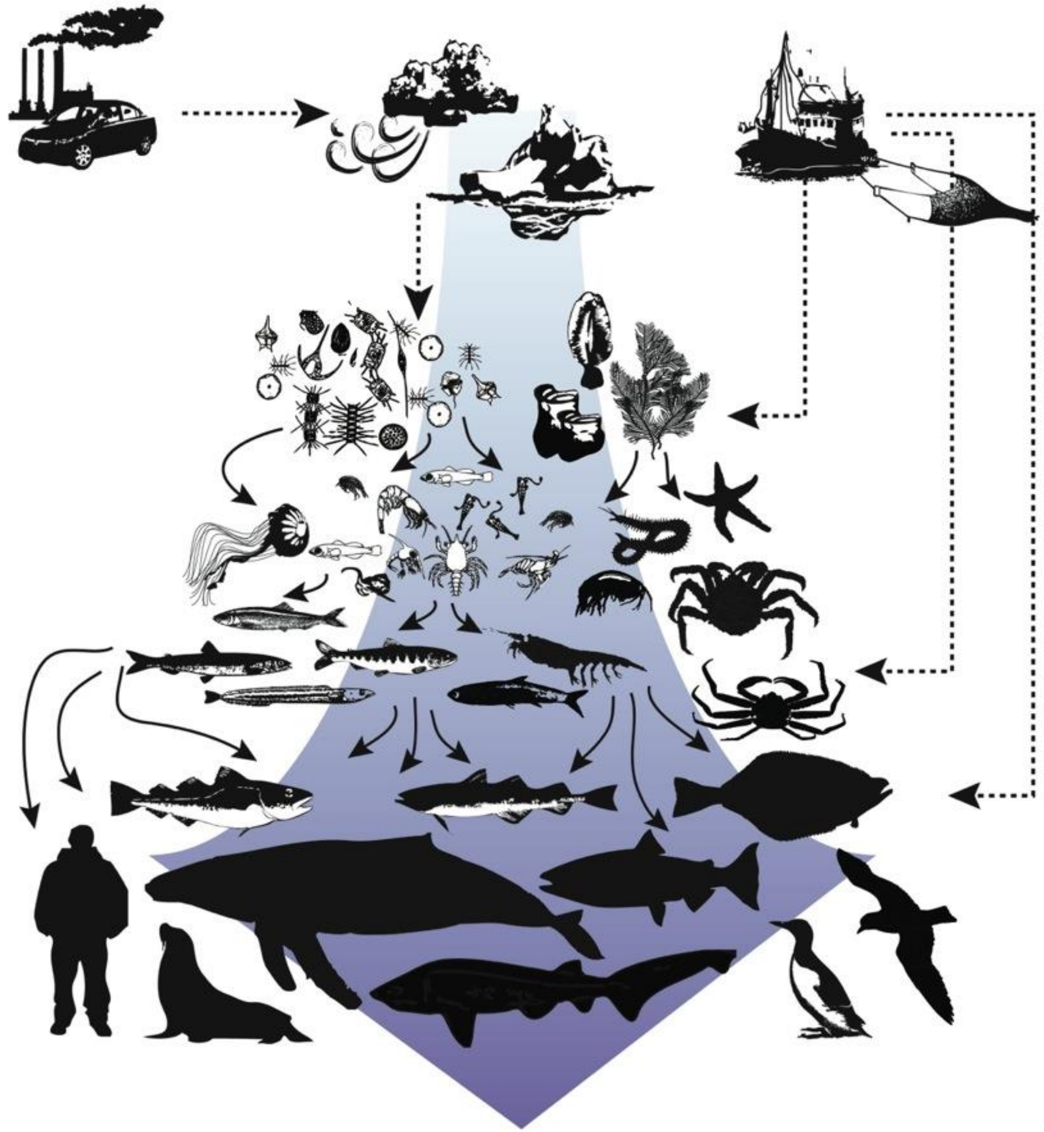


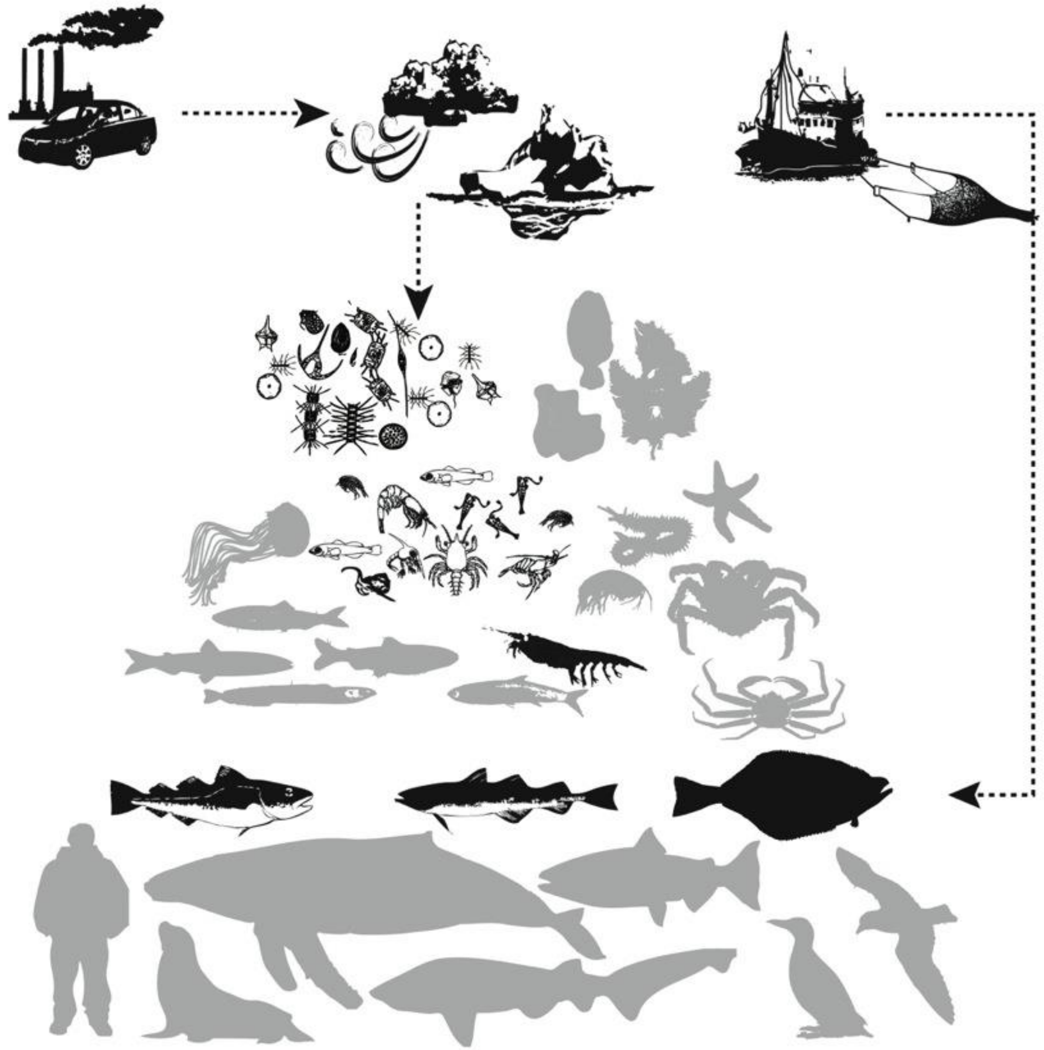


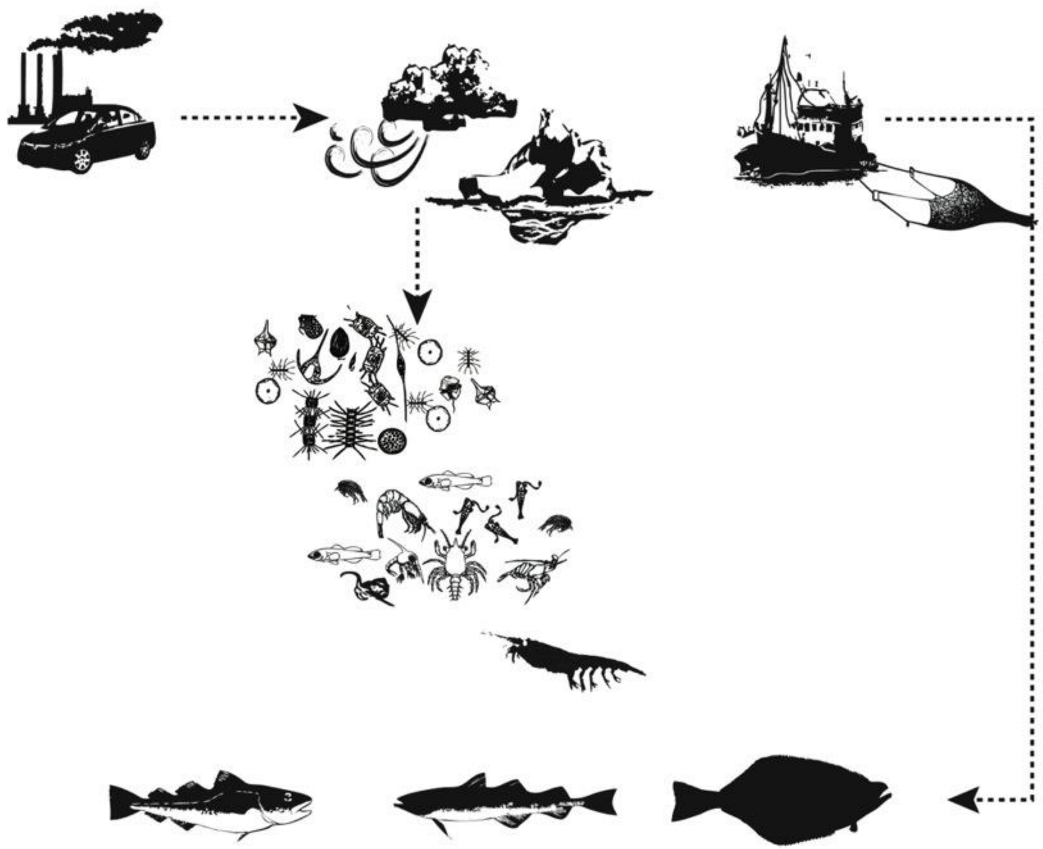


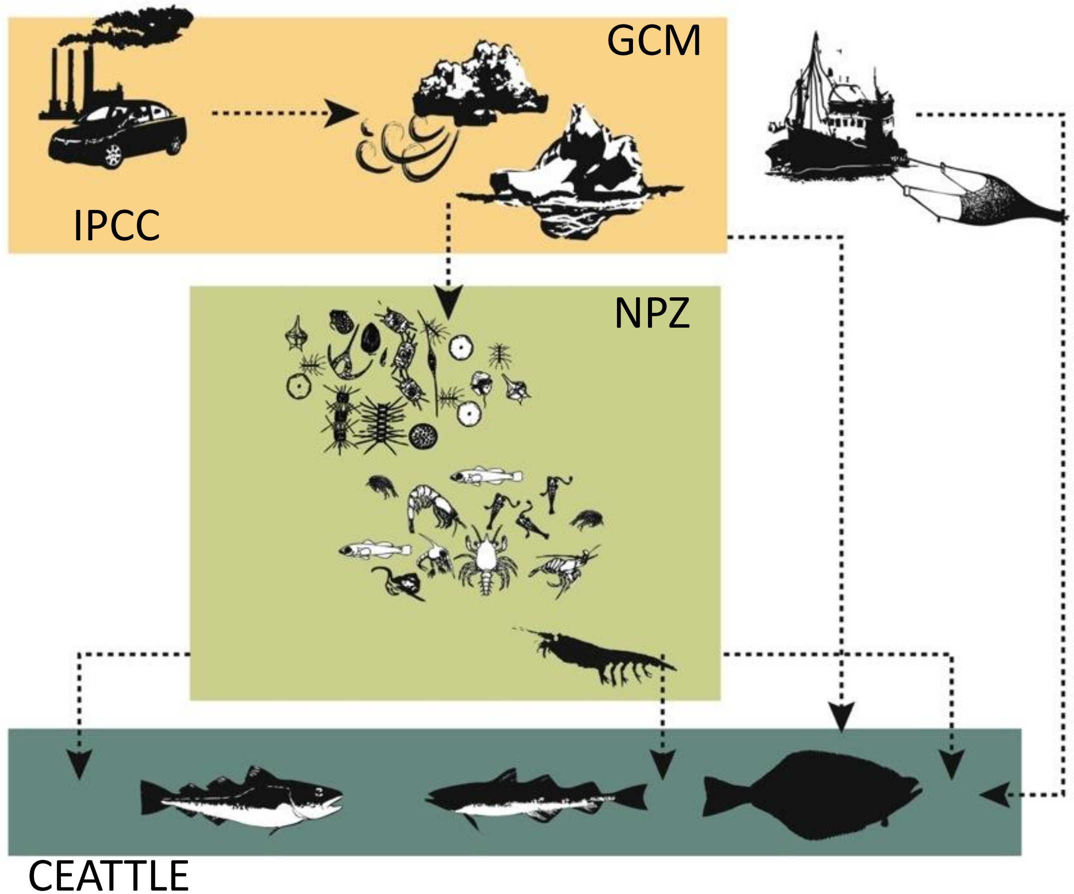


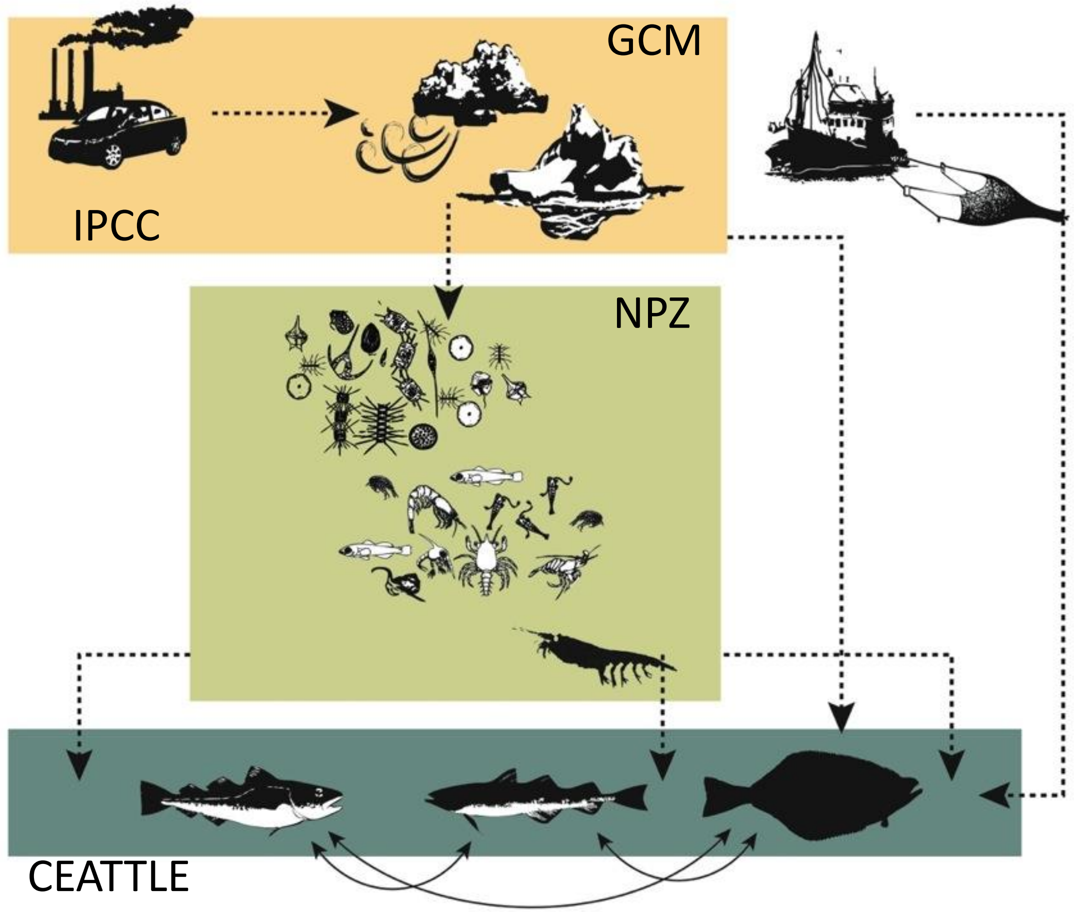

FEAST



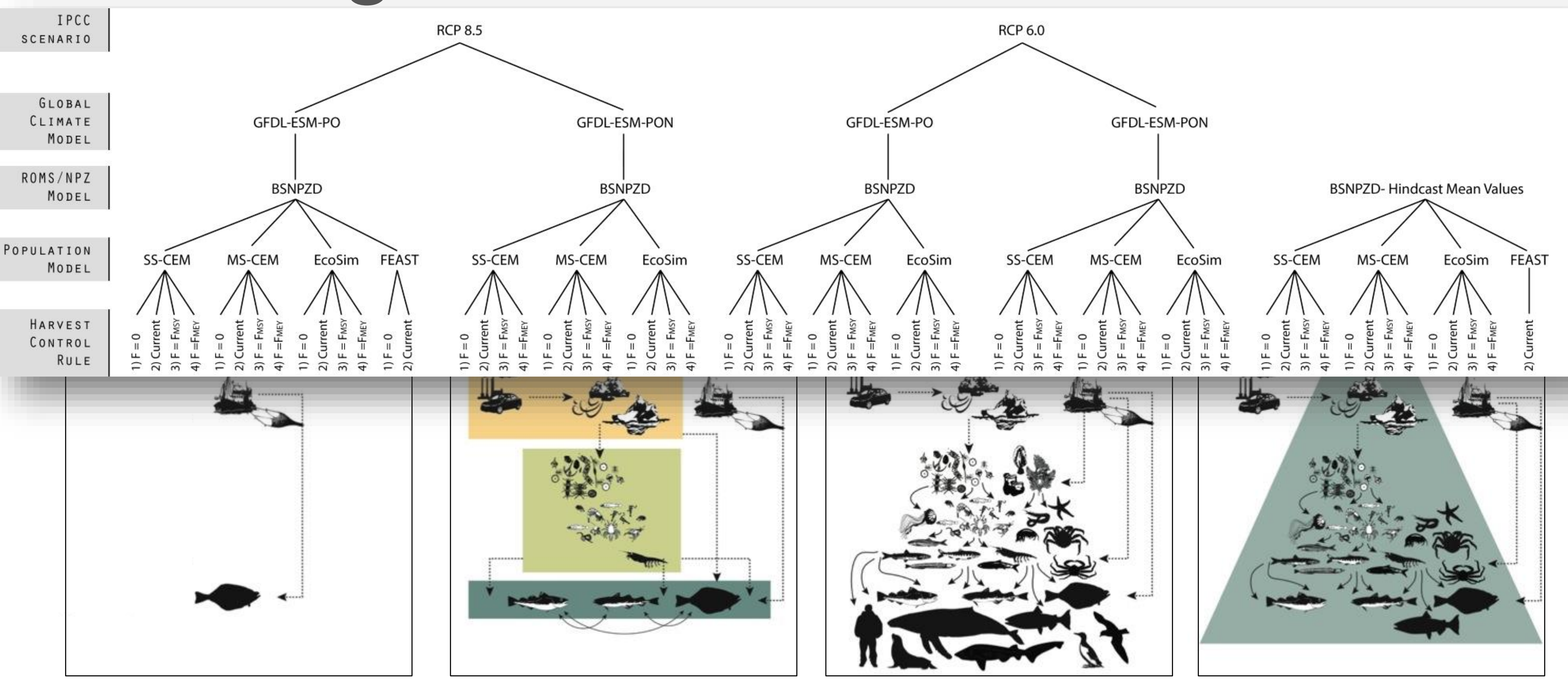





GCM
IPCC
NPZ
CEATTLE


GCM
IPCC
NPZ
CEATTLE

Bering Sea Models



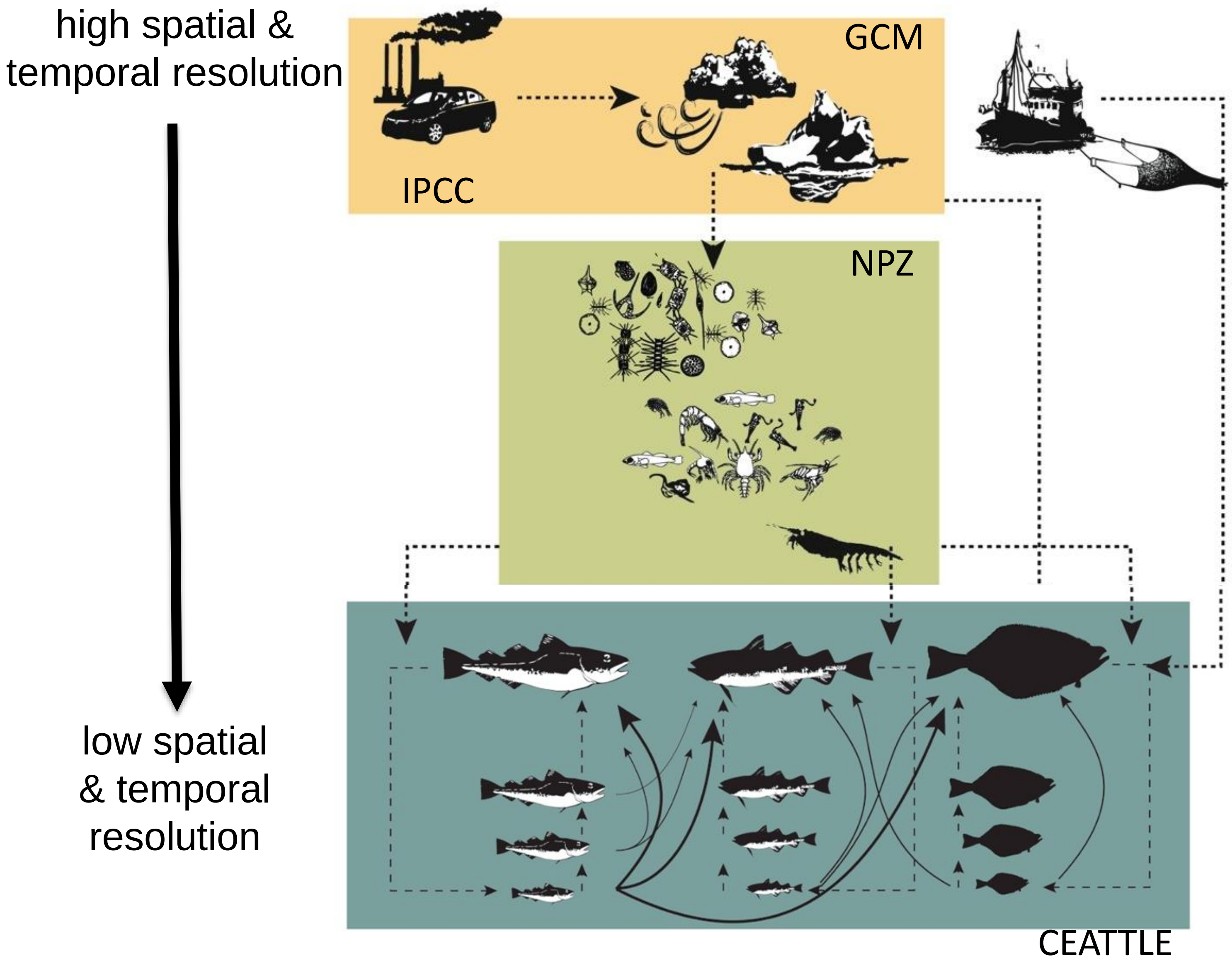
Single Species | CEATTLE | Ecosim | FEAST

Additive Pressures

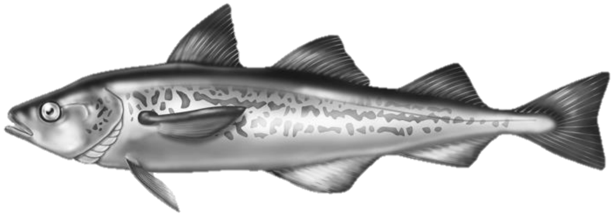
Multiple Interacting (non-linear) Pressures

Non-linear Species Interactions; Non-linear Cumulative Effects

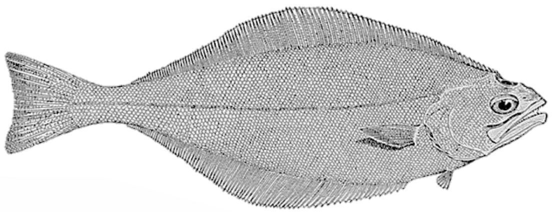
Estimation of Error/ multiple random iterations


high spatial & temporal resolution
low spatial & temporal resolution
GCM
IPCC
NPZ
CEATTLE

MSMt (Multi-species stock assessment model)

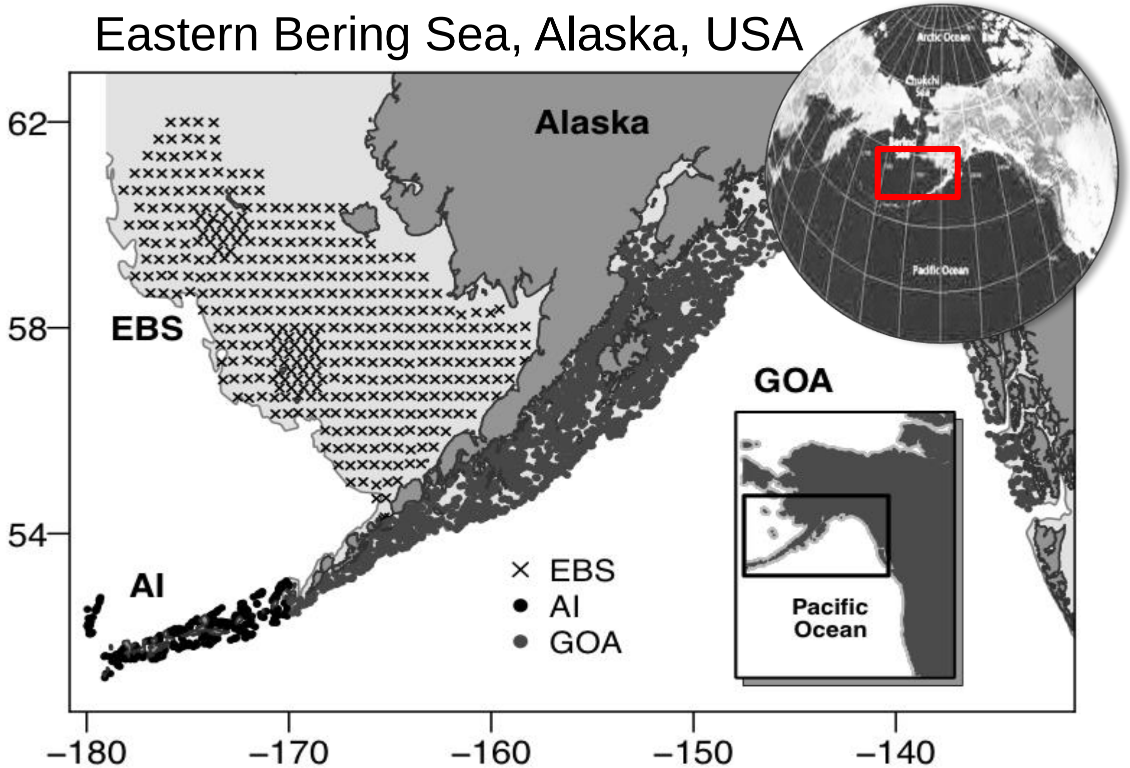


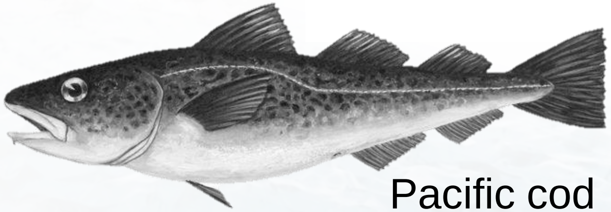
Walleye pollock
(*Gadus chalcogrammus*)



Arrowtooth flounder
(*Atheresthes stomias)*

Eastern Bering Sea, Alaska, USA





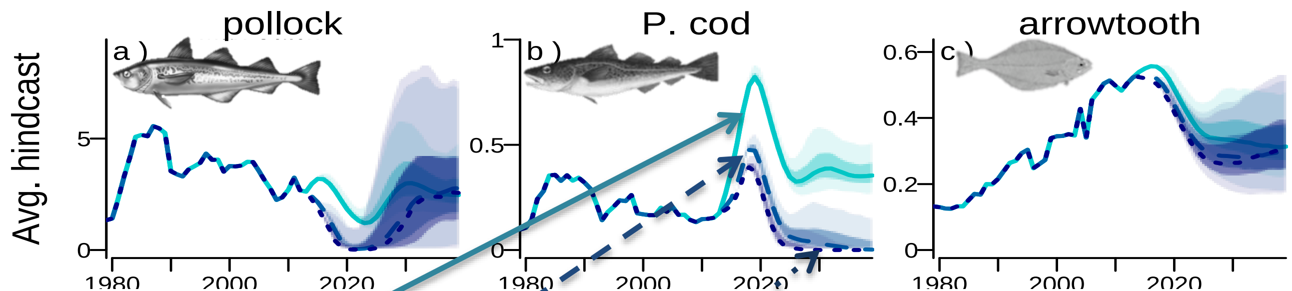
Pacific cod
(*Gadus macrocephalus*)

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

kirstin.holsman@noaa.gov

Spawning Biomass

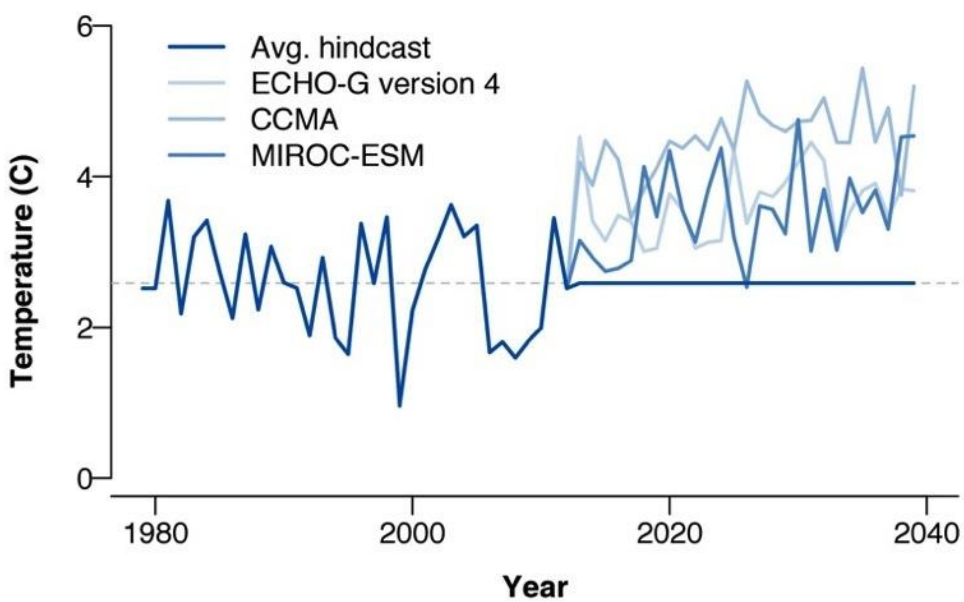
From Ianelli et al. *accepted*



Project with no fishing

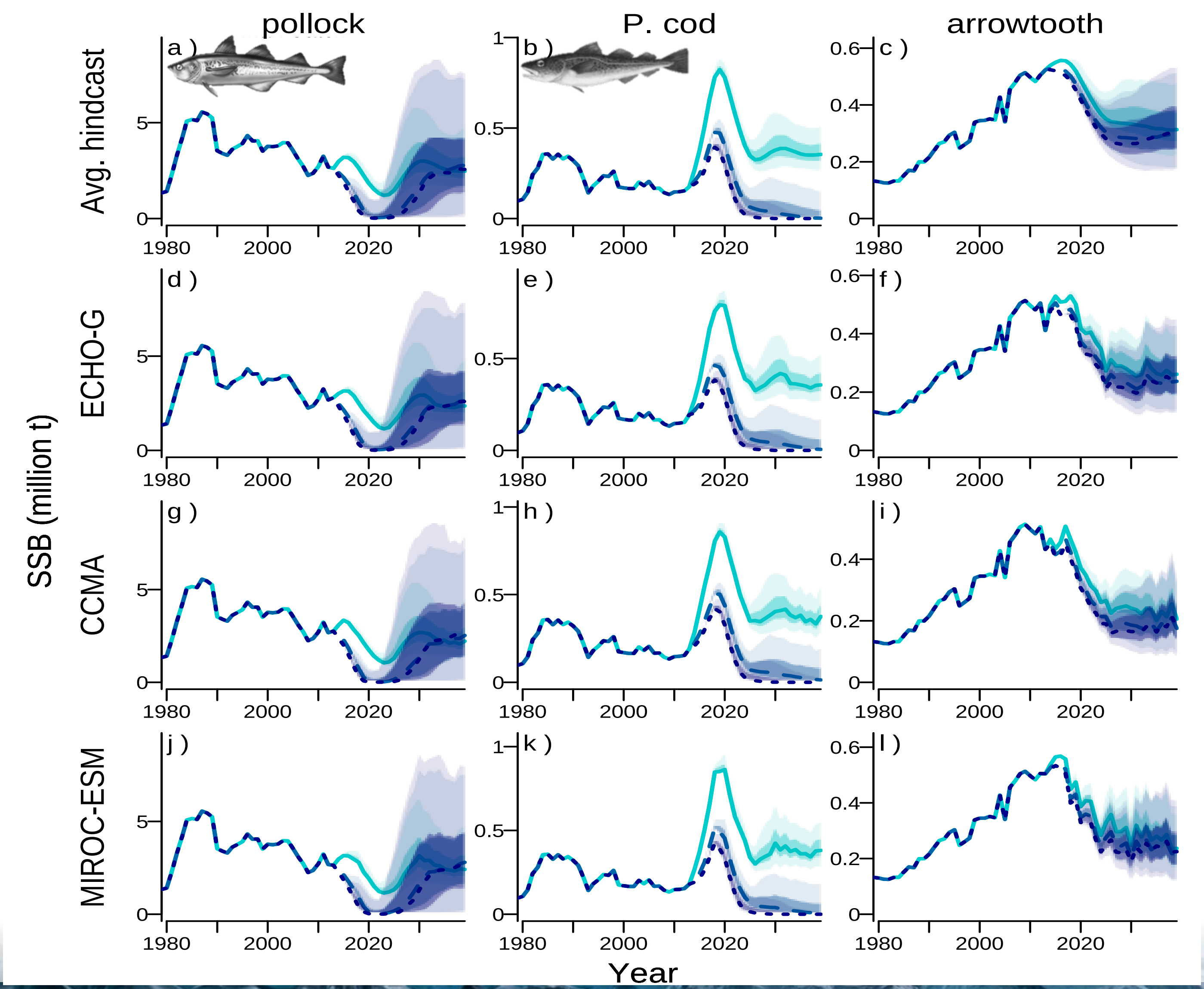
Project under mean historical catch

Project under max historical catch



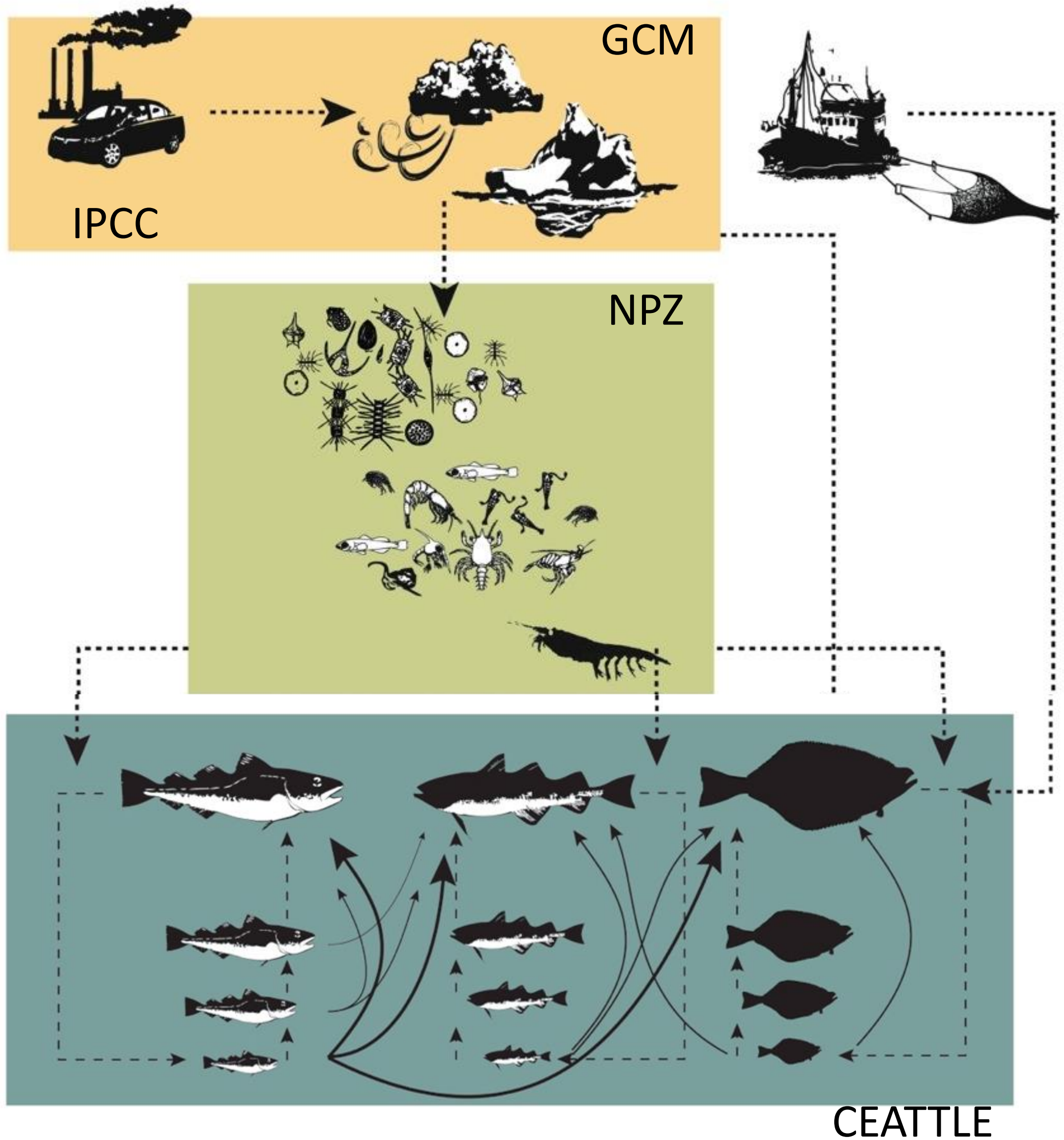
Spawning Biomass

From Ianelli et al. *accepted*

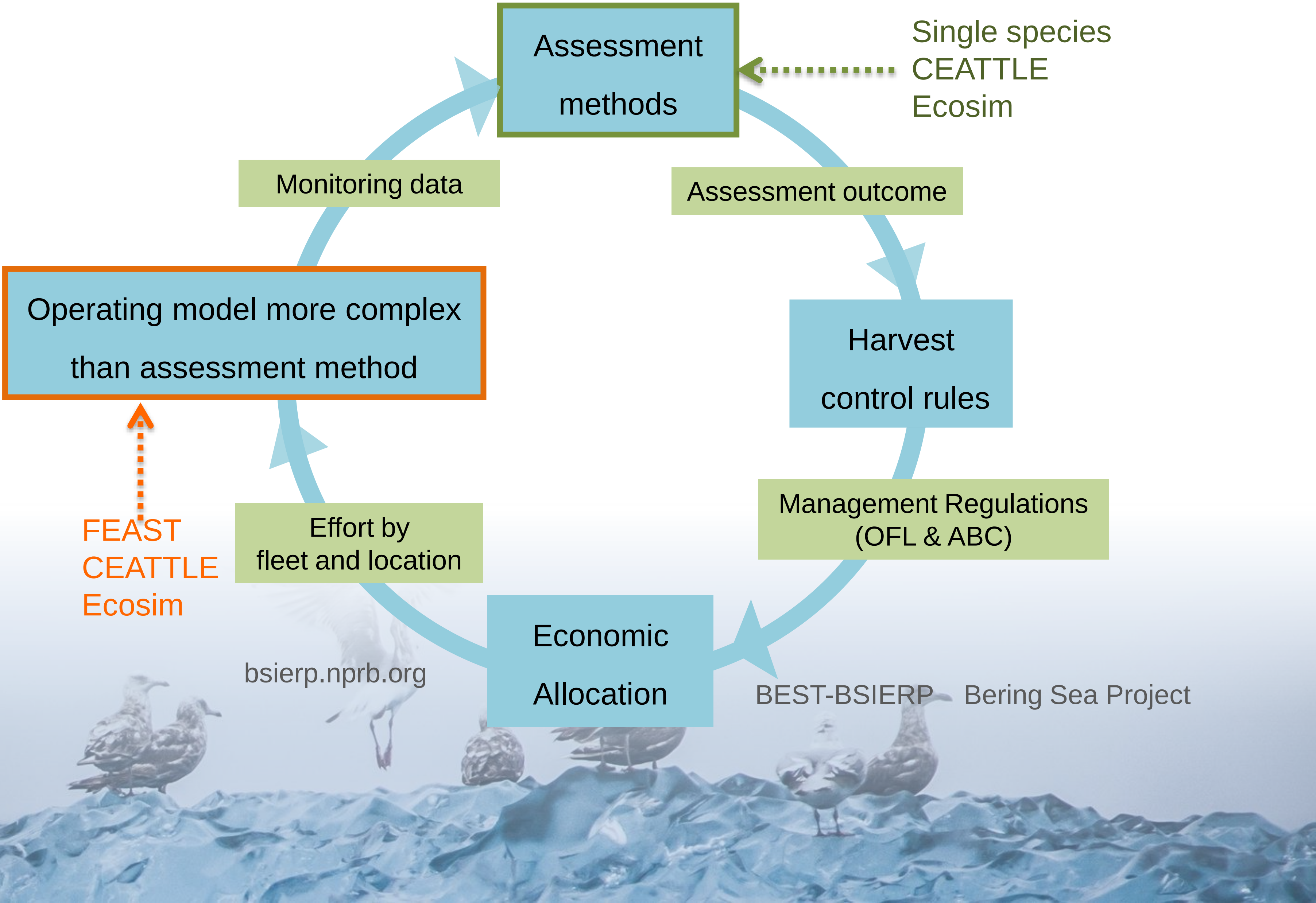


high spatial &
temporal resolution

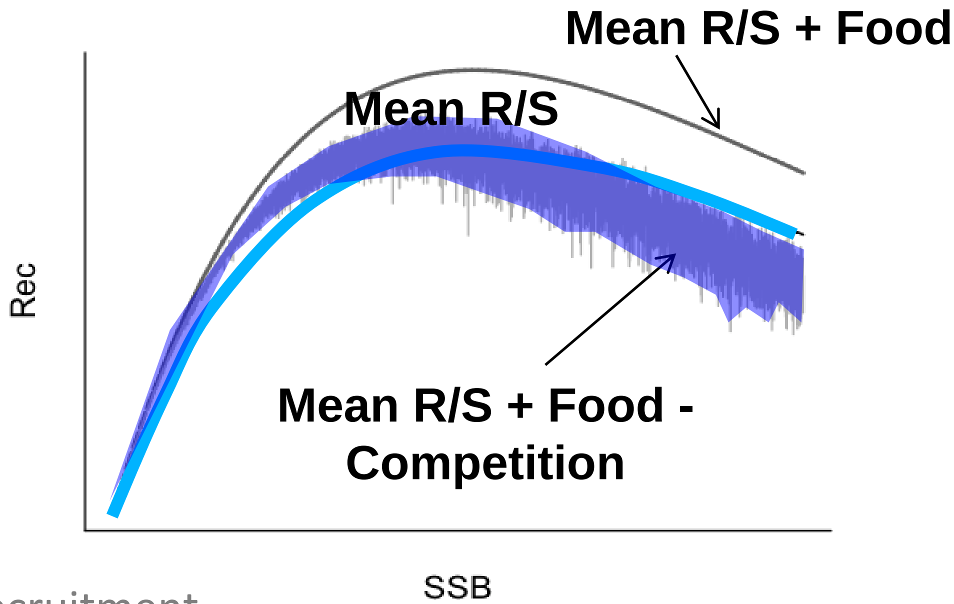
low spatial
& temporal
resolution



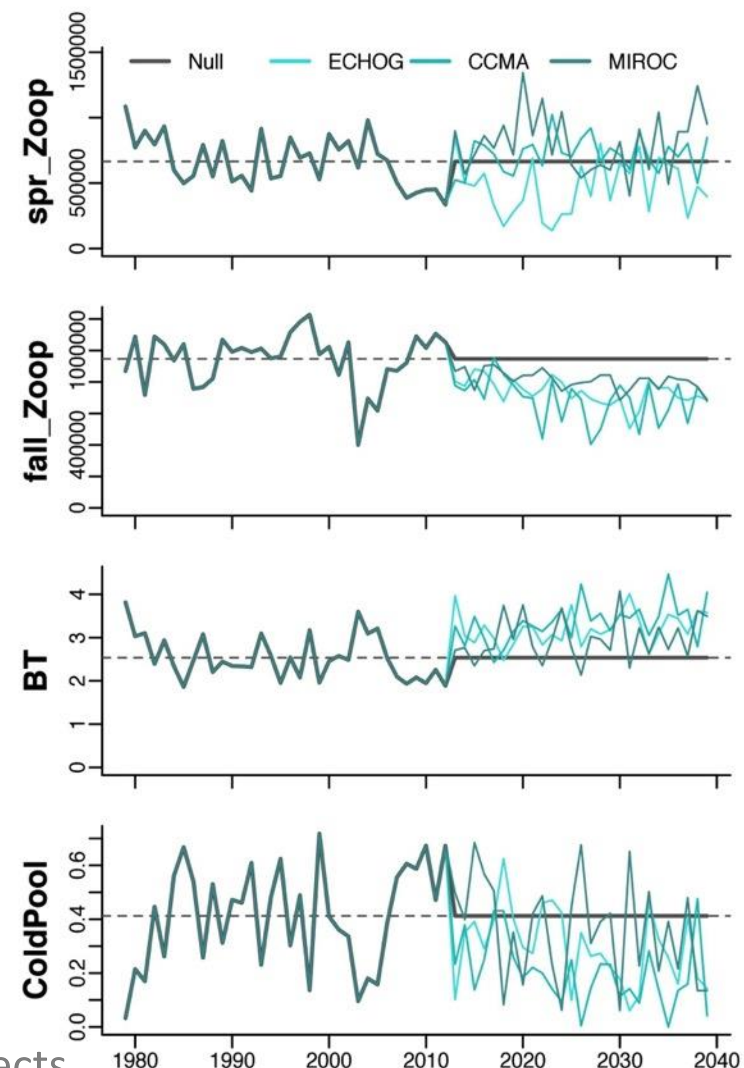
MSE : "manage" simulated ecosystems & summarize performance (relative to management objectives)



MSMt Recruitment



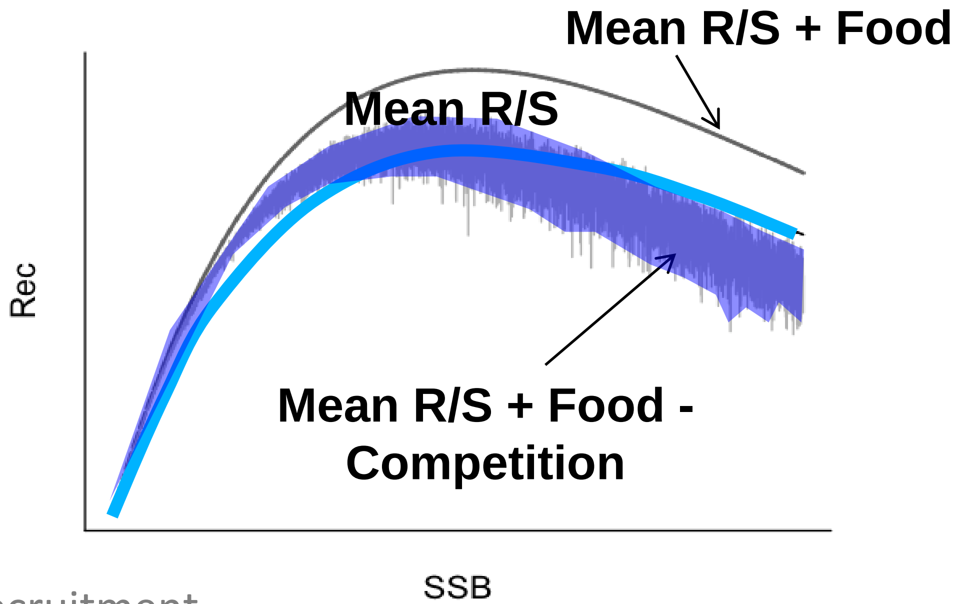
ROMS/ NPZ Indices



recruitment

$$log(R_t) = \underbrace{log(\alpha \cdot B_{t-1})}_{\text{productivity}} - \underbrace{\beta_1 \cdot B_{t-1}}_{\text{carrying capacity}} + \underbrace{\sum \beta_k \cdot X_{k,t}}_{\text{environmental effects on carrying capacity}} + \varepsilon$$

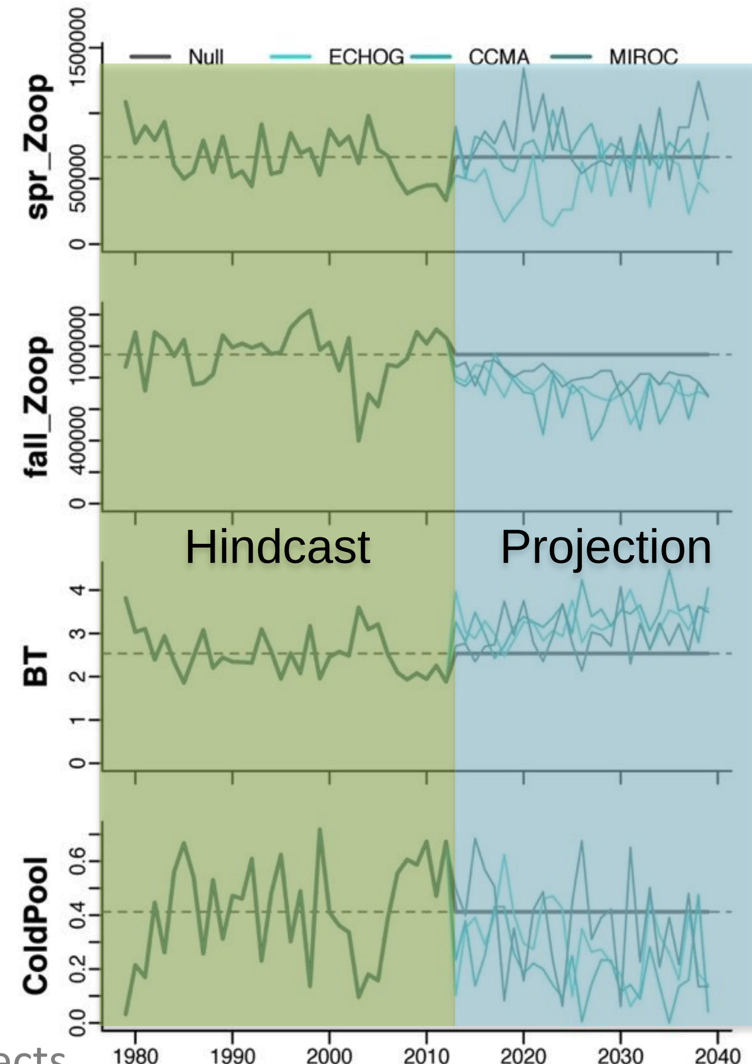
MSMt Recruitment



recruitment

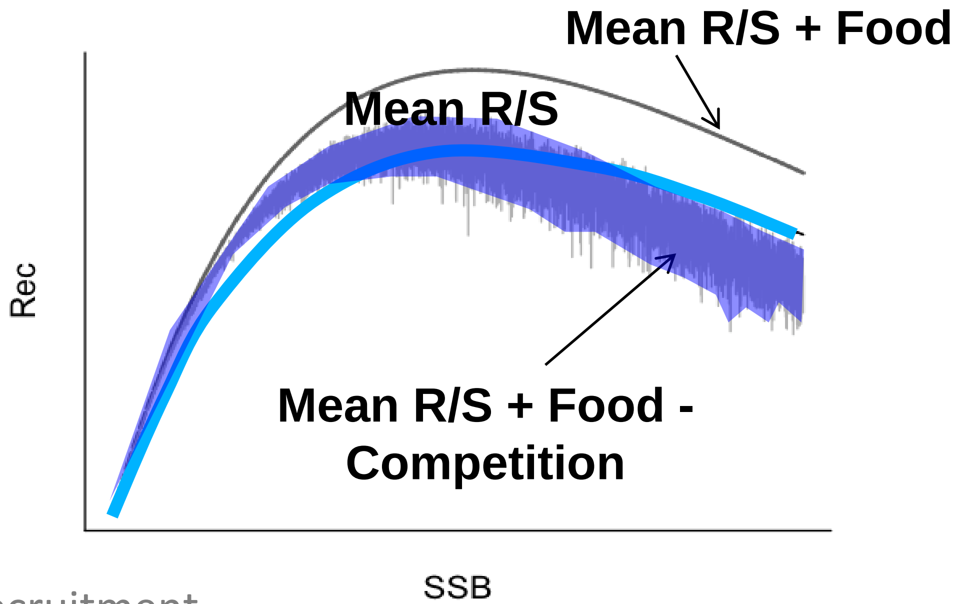
$$log(R_t) = \underbrace{log(\alpha \cdot B_{t-1})}_{\text{productivity}} - \underbrace{\beta_1 \cdot B_{t-1}}_{\text{carrying capacity}} + \underbrace{\sum \beta_k \cdot X_{k,t}}_{\text{environmental effects on carrying capacity}} + \varepsilon$$

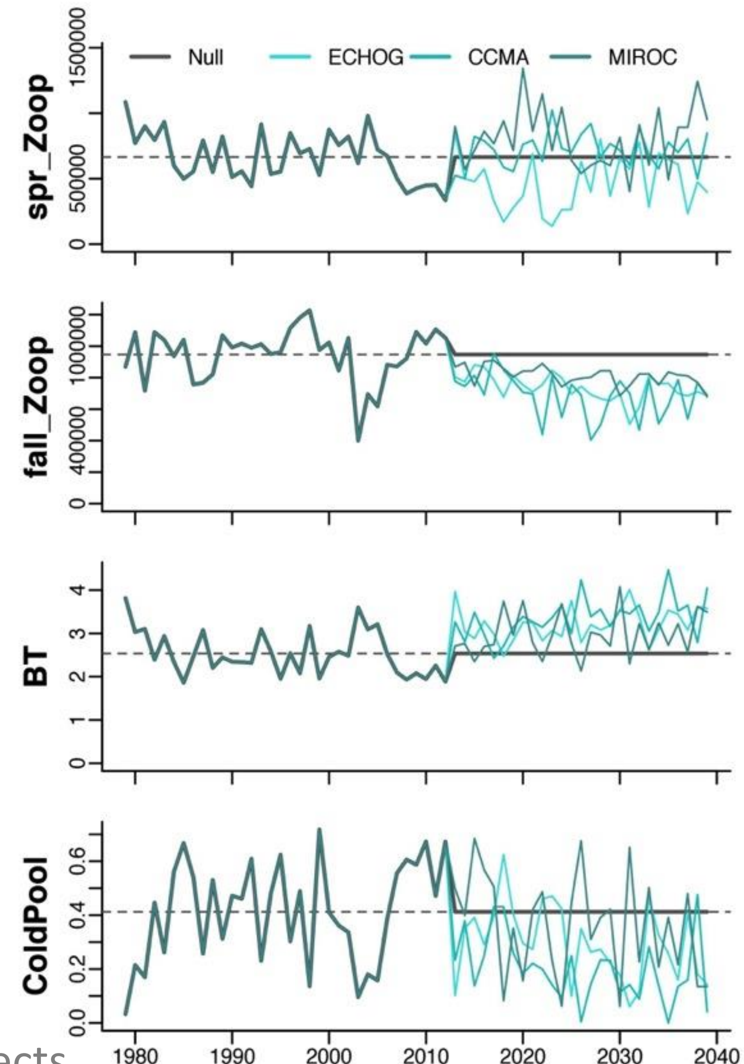
ROMS/ NPZ Indices



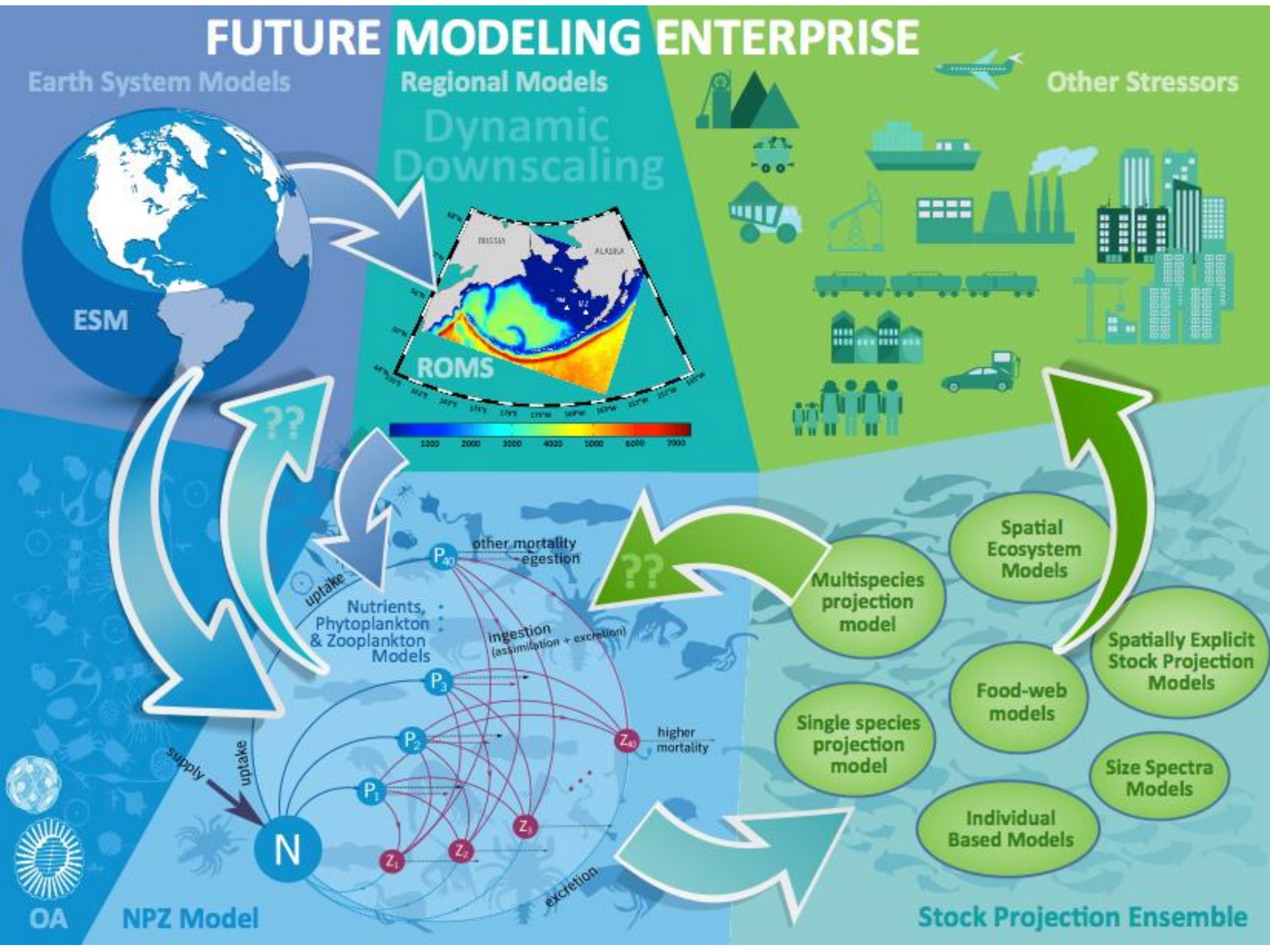
MSMt Recruitment

ROMS/ NPZ Indices



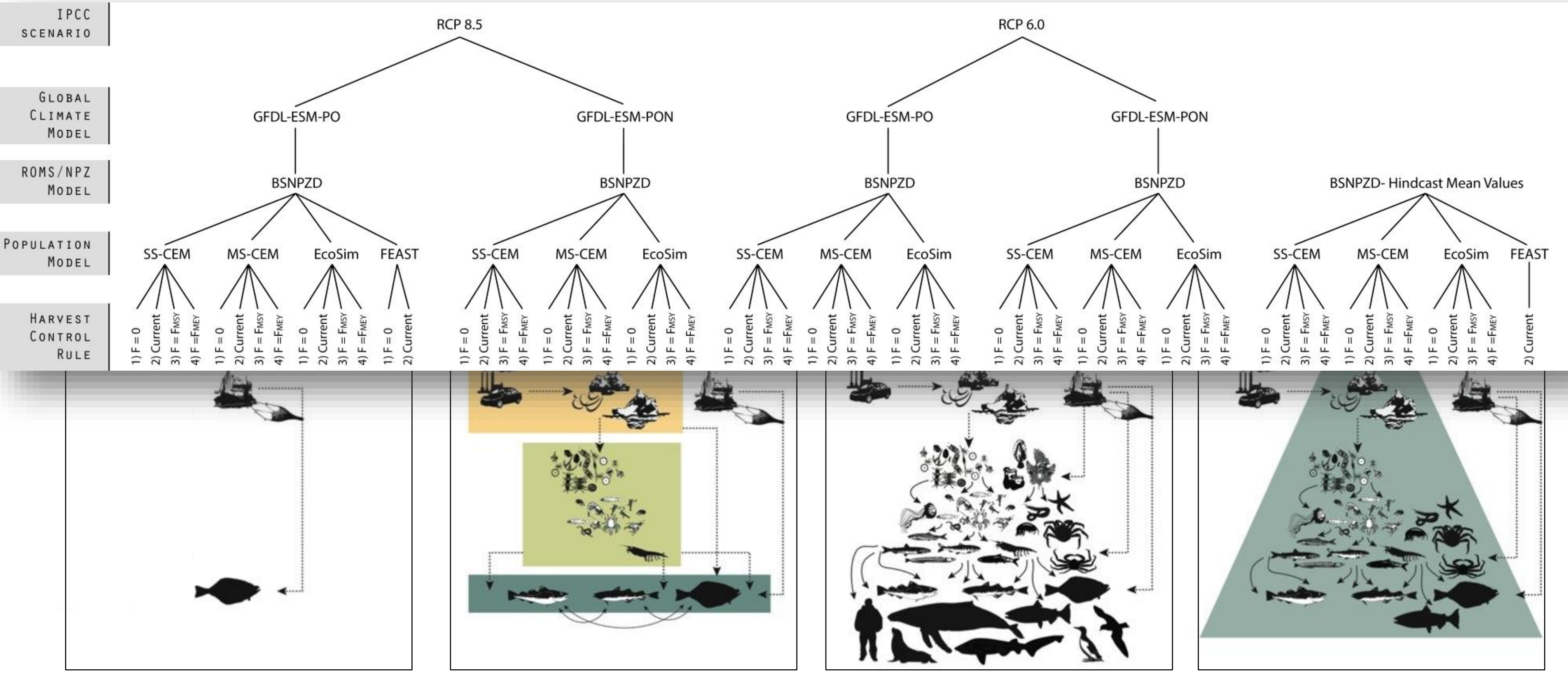


$$\overbrace{log(R_t)}^{\text{recruitment}} = \underbrace{log(\alpha \cdot B_{t-1})}_{\text{productivity}} - \underbrace{\beta_1 \cdot B_{t-1}}_{\text{carrying capacity}} + \underbrace{\sum \beta_k \cdot X_{k,t}}_{\text{environmental effects on carrying capacity}} + \varepsilon$$



FUTURE MODELING ENTERPRISE
Earth System Models
Regional Models
Dynamic Downscaling
Other Stressors
ESM
RUSSIA
ALASKA
ROMS
1000
2000
3000
4000
5000
6000
7000
??
other mortality
egestion
uptake
Nutrients,
Phytoplankton
& Zooplankton
Models
ingestion
(assimilation + excretion)
higher
mortality
supply
uptake
excretion
N
OA
NPZ Model
Spatial
Ecosystem
Models
Multispecies
projection
model
Spatially Explicit
Stock Projection
Models
Food-web
models
Single species
projection
model
Size Spectra
Models
Individual
Based Models
Stock Projection Ensemble

Bering Sea Models



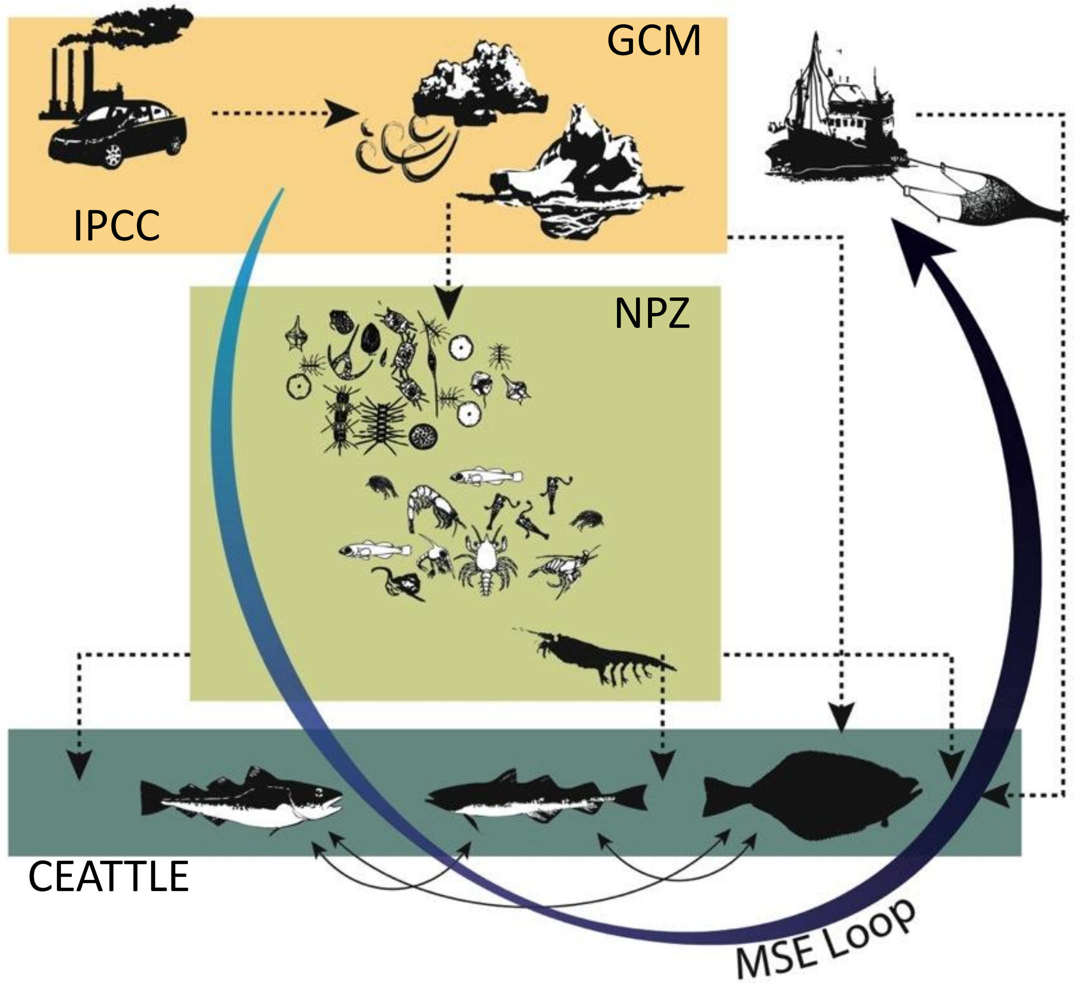
Single Species | CEATTLE | Ecosim | FEAST

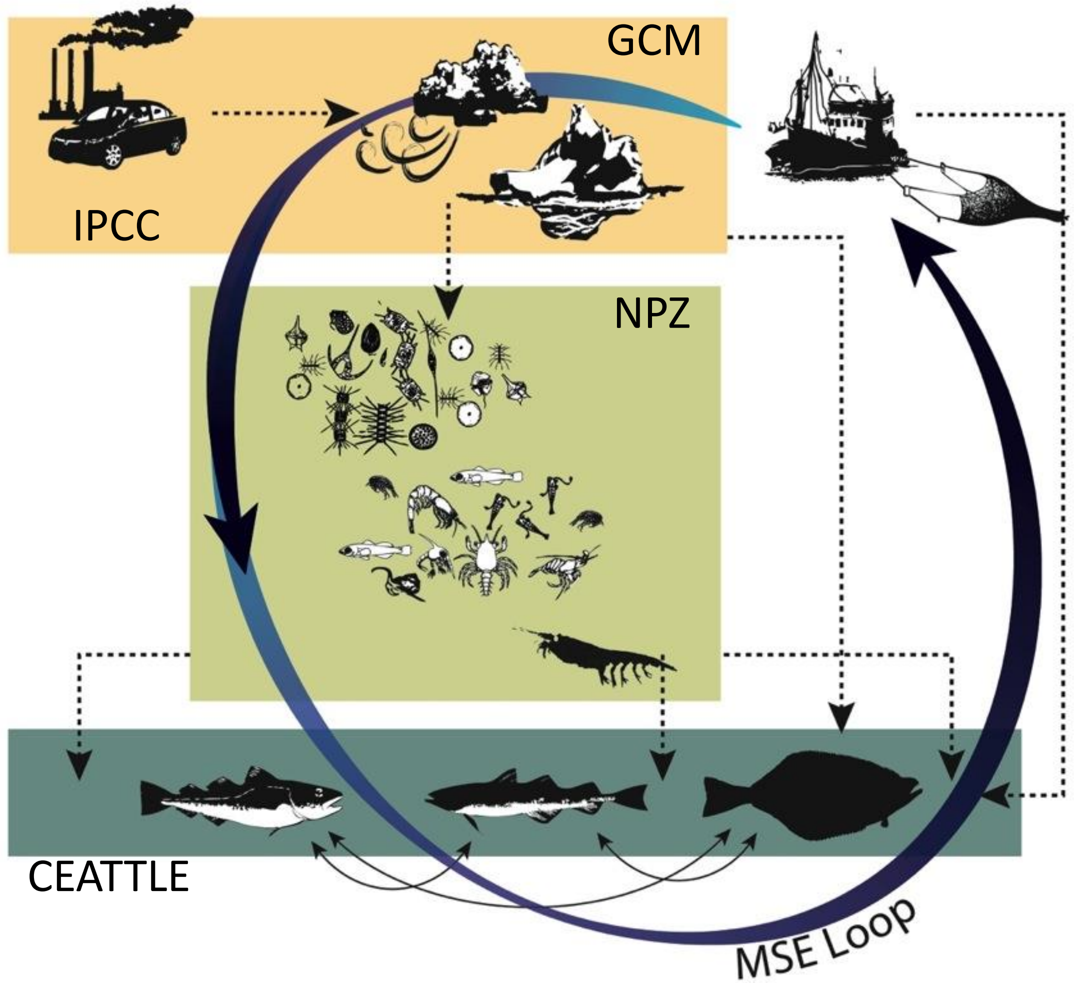
Additive Pressures

Multiple Interacting (non-linear) Pressures

Non-linear Species Interactions; Non-linear Cumulative Effects

Estimation of Error/ multiple random iterations

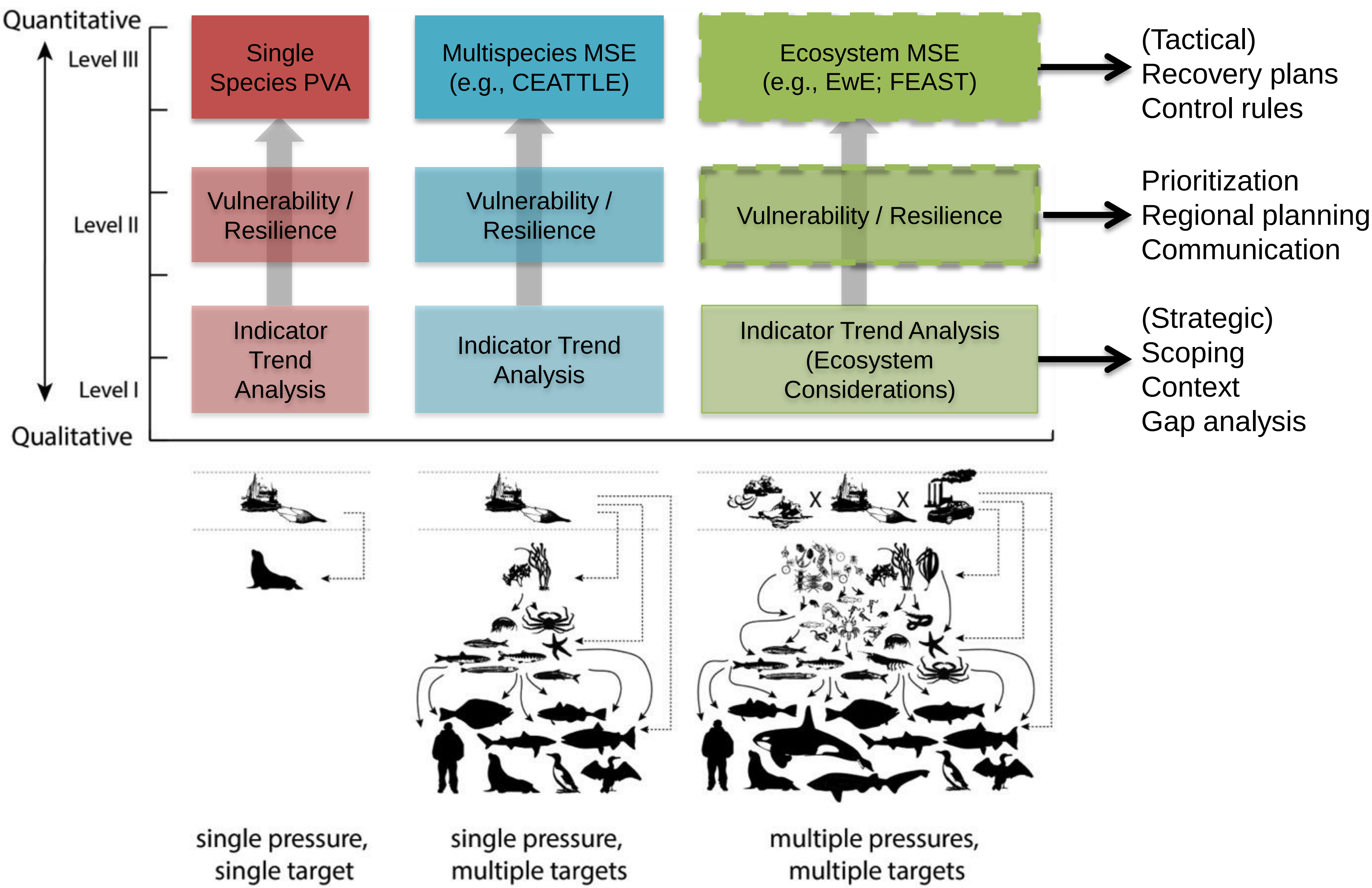

GCM
IPCC
NPZ
Repeat Each Year
CEATTLE
MSE Loop


GCM
IPCC
NPZ
Repeat Each Year
CEATTLE
MSE Loop

1. MSE has been a key component of fisheries management science in the US and elsewhere. The focus of MSE is not on identifying optimal solutions but rather solutions which are robust to **uncertainty**. It is starting to enter management of terrestrial systems.

2. There is likely tremendous uncertainty in any system but once we move beyond single-species considerations “uncertainty about uncertainty” can become overwhelming so we need to avoid “modelling everything” but rather should focus on **“modelling the right stuff”**.

Ecosystem Risk Assessment



EXTRA SLIDES FROM HERE OUT

Ecosystem Reference Point (ERP): OHIAK

$$Score_y = \sum_{i=1}^{n_i} \left(\frac{S_{i,y} + S_{i,fut}}{2} \right) W_i$$

$$S_{i,fut} = S_{i,y} \left(1 - \frac{2}{3} \cdot \frac{\beta_{i,y}}{100} \right) + \frac{1}{3} (R_i - P_i)$$

$$\beta_{i,y} = \left(S_{i,y} - S_{i,y-n_y} \right) / n_y$$

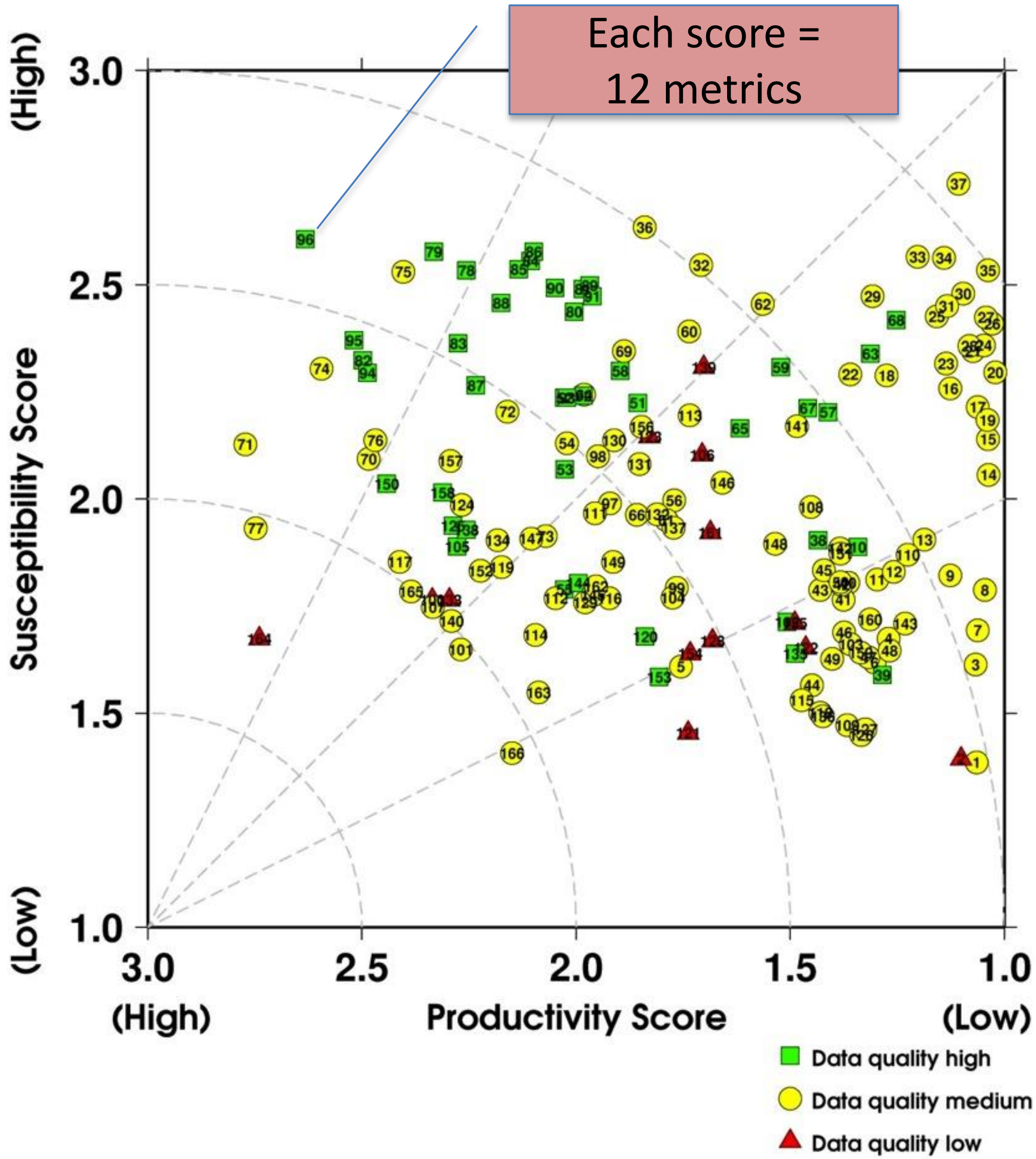
$$S_{i,y} = 100 \cdot \frac{e^{x_{i,y}}}{(1 + e^{x_{i,y}})}$$

$$x_{i,y} = (\Delta x_{i,y} - \overline{\Delta x_i}) / sd(\Delta x_{i,y})$$

$$\Delta x_{i,y} = (v_{i,y} - a_i)$$

y	Year
i	Indicator
$v_{i,y}$	Annual value
a_i	Target value
$x_{i,y}$	Z-scored value
$S_{i,y}$	Present status
$S_{i,fut}$	Likely future status
R_i	Resiliency
P_i	Pressure
W_i	Weight
$\beta_{i,y}$	Trend
n_y	Number of trend years
n_i	Number of indices

Patrick et al. 2010



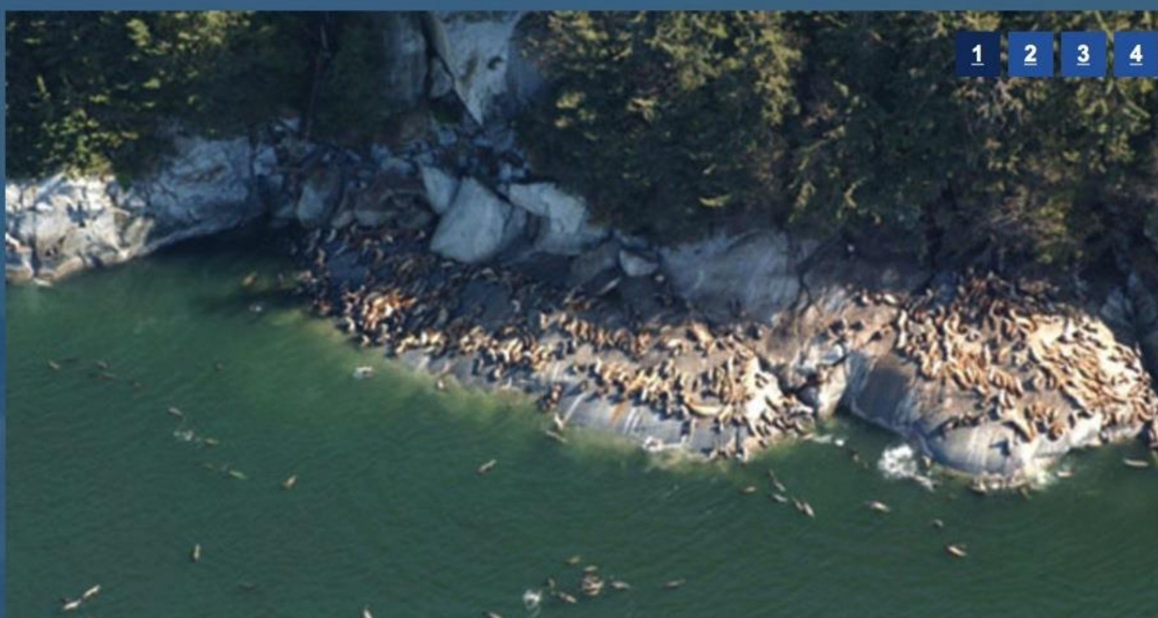
AK-IEA (www.noaa.gov/iea/regions/alaska-complex)

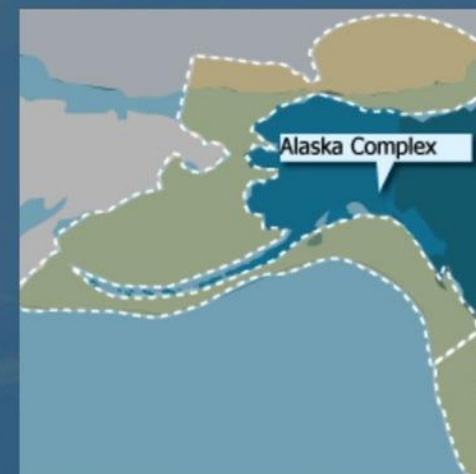
INTEGRATED ECOSYSTEM ASSESSMENT

Home | Regions | Contact | Publications | Multimedia

Alaska Complex

The Alaska Complex LME is made up of 5 distinct ecosystems: the Aleutian Islands, the Eastern Bering Sea, the Gulf of Alaska, the Beaufort Sea, and the Chukchi Sea. Read More...



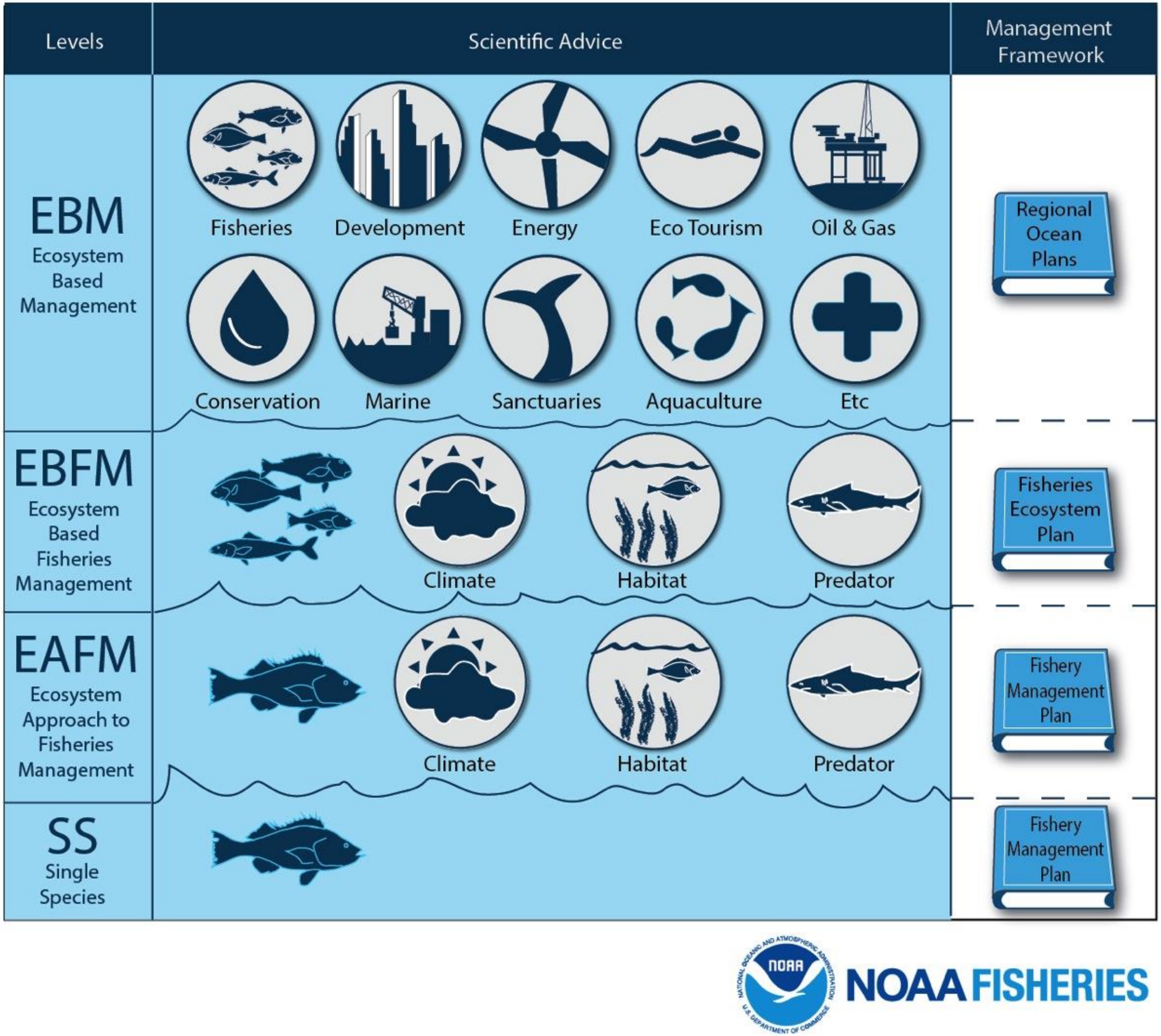


IEA Regions

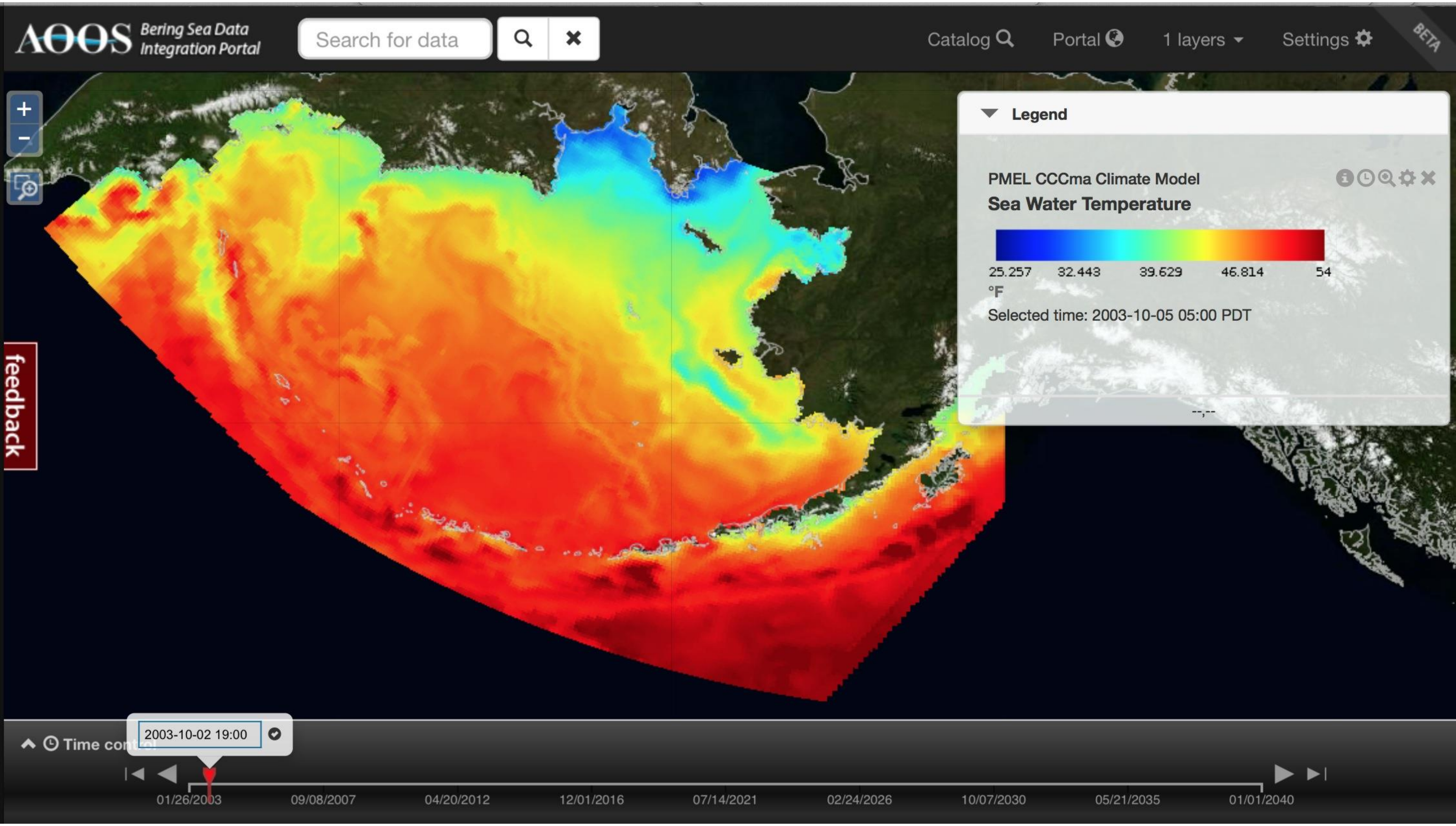
- Alaska Complex
- California Current
- Gulf of Mexico
- Pacific Islands
- Northeast

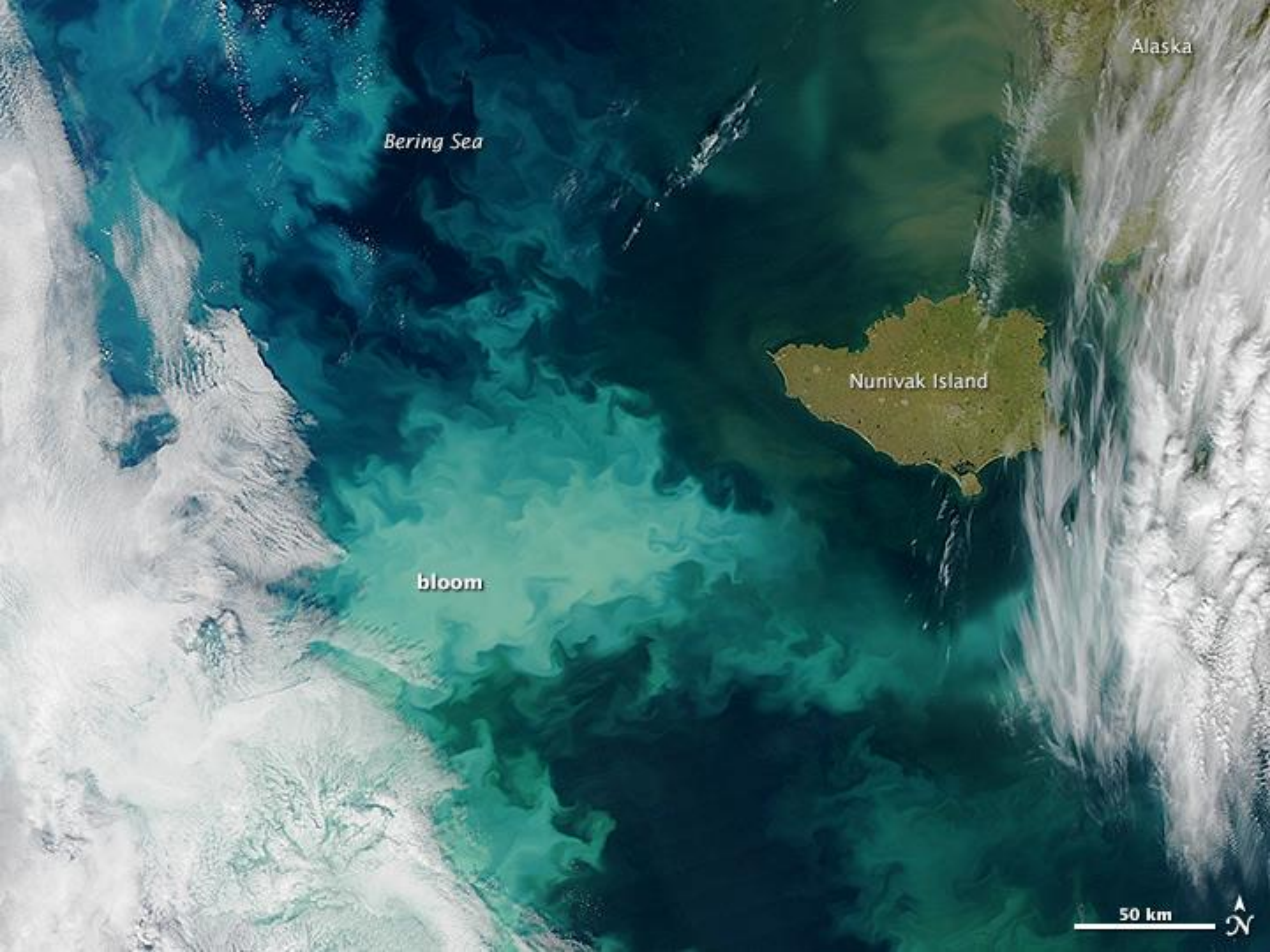
Alaska IEA: Key Topics

Alaska IEA: Current Work



Levels
Scientific Advice
Management Framework
EBM
Ecosystem Based Management
Fisheries
Development
Energy
Eco Tourism
Oil & Gas
Conservation
Marine
Sanctuaries
Aquaculture
Etc
Regional Ocean Plans
EBFM
Ecosystem Based Fisheries Management
Climate
Habitat
Predator
Fisheries Ecosystem Plan
EAFM
Ecosystem Approach to Fisheries Management
Climate
Habitat
Predator
Fishery Management Plan
SS
Single Species
Fishery Management Plan
NOAA FISHERIES


AOOS Bering Sea Data Integration Portal
Search for data
Catalog
Portal
1 layers
Settings
BETA
Legend
PMEL CCCma Climate Model
Sea Water Temperature
25.257 32.443 39.629 46.814 54
°F
Selected time: 2003-10-05 05:00 PDT
feedback
Time control
2003-10-02 19:00
01/26/2003 09/08/2007 04/20/2012 12/01/2016 07/14/2021 02/24/2026 10/07/2030 05/21/2035 01/01/2040


Alaska
Bering Sea
Nunivak Island
bloom
50 km
N

Building an understanding of ecosystem vulnerability to climate change

Is a vulnerable prey a vulnerable predator?

Pikitch et al. 2012