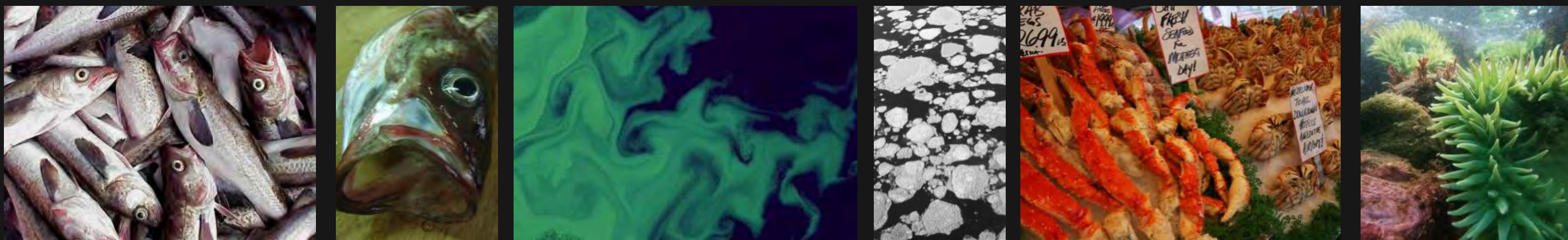

Methods to characterize risk of Alaskan marine habitats to multiple stressors and establish ecosystem reference points

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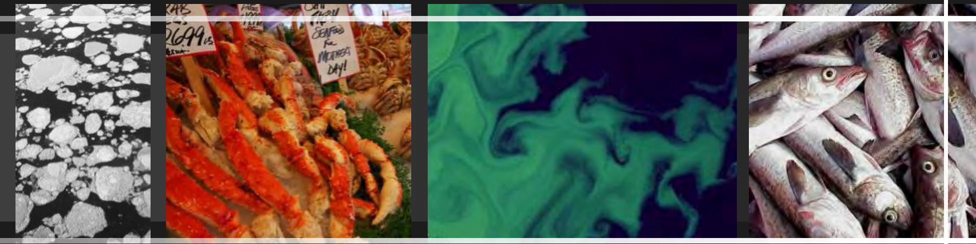
Risk Assessment



"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

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Risk Assessment

- Use ecosystem models/analysis to determine changes in indicators in response to changes in human-induced pressures
- Risk analysis must explicitly consider uncertainties involved in understanding and quantifying ecosystem dynamics and their positive and negative impacts on social systems
- Must include pressures that occur on land (e.g., coastal development, etc.), in the air (e.g., weather, climate), and in the ocean itself (e.g., shipping, fishing) (Halpern et al. 2009)
- "Need to be conducted relatively quickly, adaptable to data limitations, and easy to update (Astles et al., 2009)" From Samhouri & Levin 2012

Levels (Hobday et al. 2011)

- A 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.
- A level 2 analysis considers the exposure of an ecosystem component to a pressure, and the sensitivity of the component to that pressure.
- The Level 3 analysis takes a quantitative approach such as is used in stock assessments & population viability analyses

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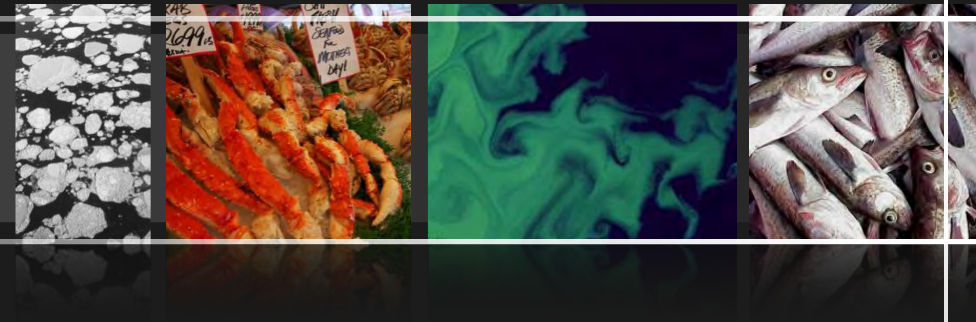
Levels (Hobday et al. 2011)

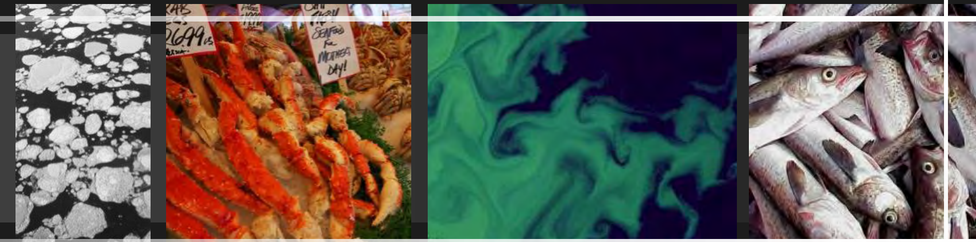


- A level 1 analysis for each pressure qualitatively scores each human activity or natural perturbation for its impact on the focal ecosystem components of the IEA. Those pressures receiving a high impact score move onto level 2 analyses.

- A level 2 analysis considers the exposure of an ecosystem component to a pressure, and the sensitivity of the component to that pressure.

- The Level 3 analysis takes a quantitative approach such as is used in stock assessments & population viability analyses

Habitat Risk



Samhouri and Levin (2012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ELSEVIER

BIOLOGICAL CONSERVATION

Linking land- and sea-based activities to risk in coastal ecosystems

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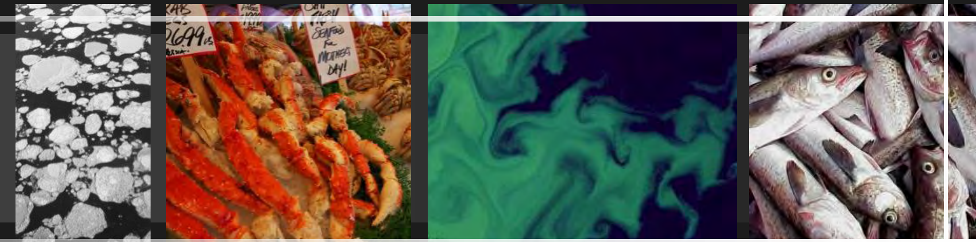
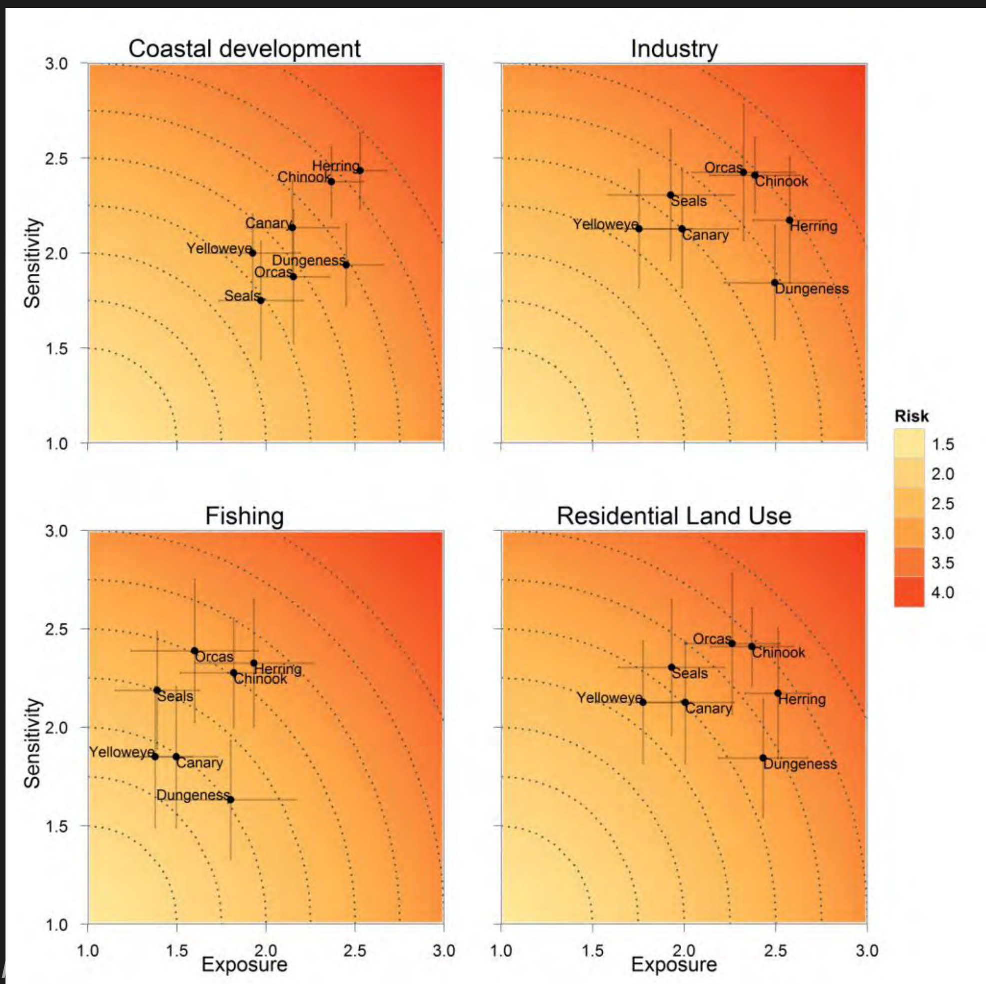
ABSTRACT

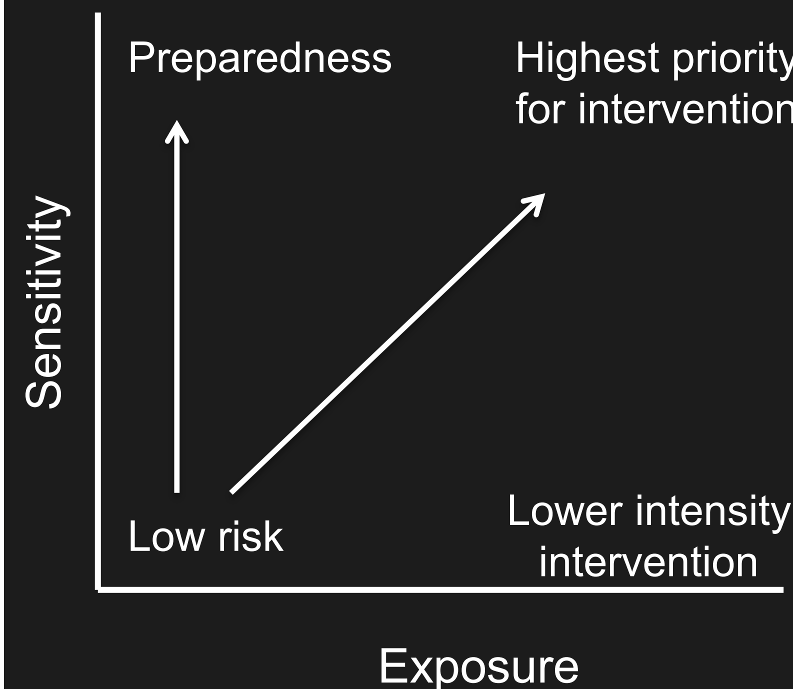
The emerging science and policy arena of marine ecosystem-based management is beset with the challenging question of how to assess the urgency of problems influencing different ecosystem components. In this paper, we introduce a synthetic and efficient framework to identify land- or sea-based activities that pose the greatest risk to valued members of marine ecosystems, including mammals, fishes, and invertebrates. Ecosystem-based risk is scored along two axes of information: the exposure of a population to an activity, and the sensitivity of the population to that activity, given a particular level of exposure. Risk is illustrated in a variety of ways, including two-dimensional contour plots and maps showing regional variation in risk. We apply this risk assessment framework to regional populations of indicator species in Puget Sound, WA, USA. This case study provides insight into how risk varies for particular activity–

Habitat Risk



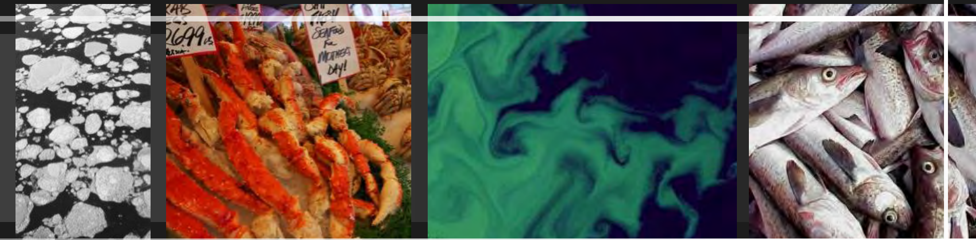
Samhouri and Levin (2012)





Adapted from Dawson et al. 2011

Habitat Risk



$$K_h = \frac{V_h}{R_h}$$

where,

$$V_h = \sum^{p} V_{ph}$$

$$R_h = \sum^{p} R_{ph}$$

$$V_{ph} = X_{ph} \cdot \left(\frac{\sum V_{phi}}{n_V} \right)$$

$$R_{ph} = X_{ph} \cdot \left(\frac{\sum R_{phi}}{n_R} \right)$$

$$q_p = 100 \cdot \frac{q_p^{'} - q_{min}}{q_{max} - q_{min}}$$

where,

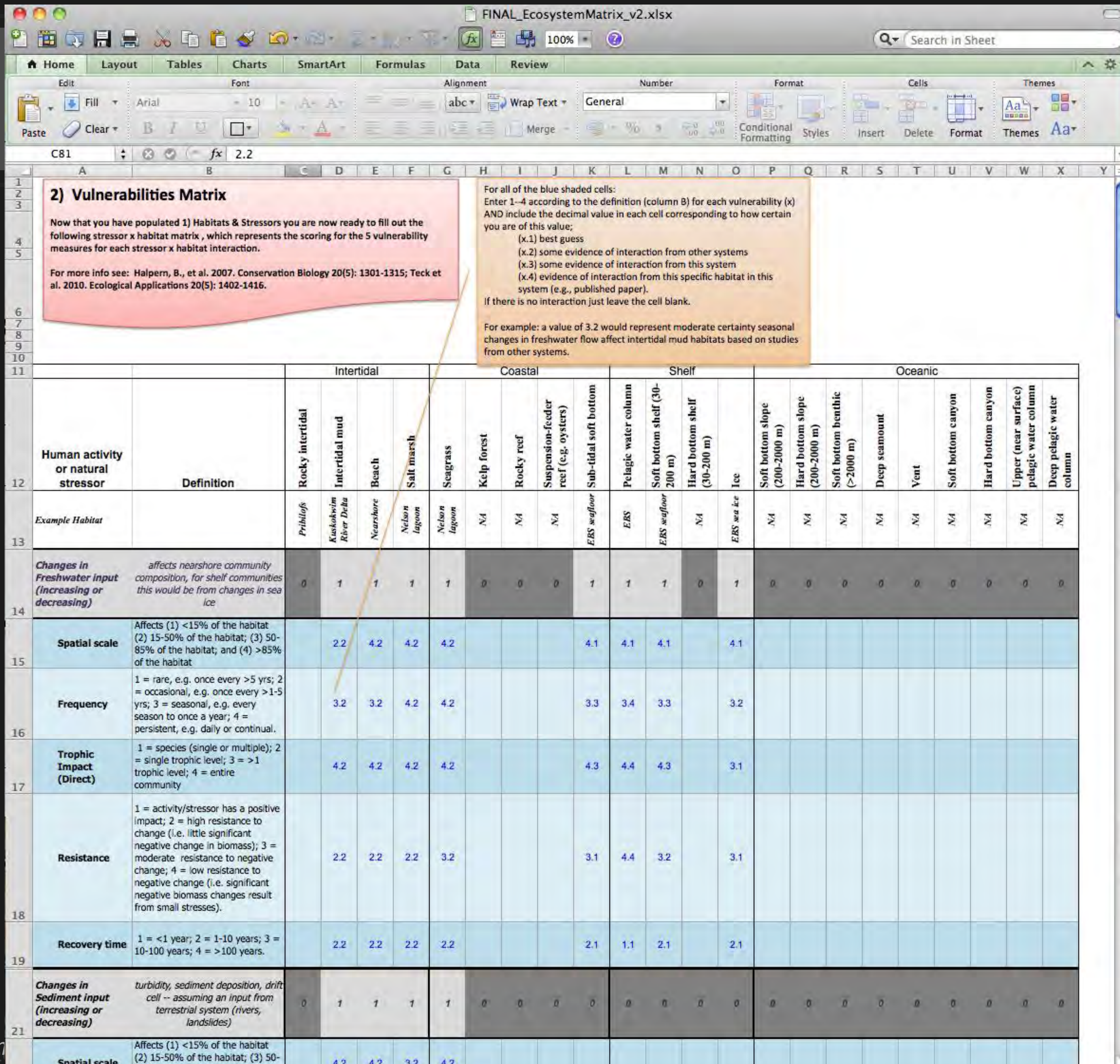
$$q_p^{'} = \left[\sum^{n_h} \left(\frac{A_h \cdot X_{ph}}{\sum A_h \cdot X_{ph}} \right) \cdot q_{ph} \right]^{-1}$$

$$q_{ph} = \left(\frac{\sum V_{phi}}{n_V} + \frac{\sum R_{phi}}{n_R} \right) \cdot \frac{1}{2}$$

$$V_{phi} = I_{V_{phi}} \cdot e^{\left(1 - \alpha_{c_{phi}}\right)}$$

$$V_{phi} = I_{V_{phi}} \cdot e^{\left(1 - \alpha_{c_{phi}}\right)}$$

Parameter	Definition
c	Certainty
p	Pressure
h	Habitat
v_h	Habitat specific vulnerability
r_h	Habitat specific resiliency
V_p	Pressure specific vulnerability
R_p	Pressure specific resiliency
A_h	Habitat specific area
n_R	Number of resiliency categories
n_V	Number of vulnerability categories
n_h	Number of habitats
n_p	Number of pressures
$I_{V_{phi}}$	Vulnerability index for each category i of p x h interaction (1-4; L to H)
$I_{R_{phi}}$	Resiliency index for each category i of p x h interaction (1-4; H to L)
$I_{c_{phi}}$	Certainty index for each category i of p x h interaction (1-4; L to H)
$\alpha_{c_{phi}}$	Uncertainty penalty for each index $I_{C_{phi}}$ [0.15, 0.5, 0.75, 1.0]
X_{ph}	h X p interaction value (0 or 1)
K_h	Habitat-specific risk score
q_p	Pressure-specific ecosystem condition



FINAL_EcosystemMatrix_v2.xlsx

2) Vulnerabilities Matrix

Now that you have populated 1) Habitats & Stressors you are now ready to fill out the following stressor x habitat matrix , which represents the scoring for the 5 vulnerability measures for each stressor x habitat interaction.

For more info see: Halpern, B., et al. 2007. Conservation Biology 20(5): 1301-1315; Teck et al. 2010. Ecological Applications 20(5): 1402-1416.

For all of the blue shaded cells:
Enter 1--4 according to the definition (column B) for each vulnerability (x) AND include the decimal value in each cell corresponding to how certain you are of this value;
(x.1) best guess
(x.2) some evidence of interaction from other systems
(x.3) some evidence of interaction from this system
(x.4) evidence of interaction from this specific habitat in this system (e.g., published paper).
If there is no interaction just leave the cell blank.

For example: a value of 3.2 would represent moderate certainty seasonal changes in freshwater flow affect intertidal mud habitats based on studies from other systems.

		Intertidal				Coastal					Shelf				Oceanic								
Human activity or natural stressor	**Definition**	Rocky intertidal	Intertidal mud	Beach	Salt marsh	Seagrass	Kelp forest	Rocky reef	Suspension-feeder reef (e.g. oysters)	Sub-tidal soft bottom	Pelagic water column	Soft bottom shelf (30-200 m)	Hard bottom shelf (30-200 m)	Ice	Soft bottom slope (200-2000 m)	Hard bottom slope (200-2000 m)	Soft bottom benthic (>2000 m)	Deep seamount	Vent	Soft bottom canyon	Hard bottom canyon	Upper (near surface) pelagic water column	Deep pelagic water column
Example Habitat		*Pribilofs*	*Kuskokwim River Delta*	*Nearshore*	*Nelson lagoon*	*Nelson lagoon*	*NA*	*NA*	*NA*	*EBS seafloor*	*EBS*	*EBS seafloor*	*NA*	*EBS sea ice*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Changes in Freshwater input (increasing or decreasing)	*affects nearshore community composition, for shelf communities this would be from changes in sea ice*	0	1	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0
Spatial scale	Affects (1) <15% of the habitat (2) 15-50% of the habitat; (3) 50-85% of the habitat; and (4) >85% of the habitat		2.2	4.2	4.2	4.2				4.1	4.1	4.1		4.1									
Frequency	1 = rare, e.g. once every >5 yrs; 2 = occasional, e.g. once every >1-5 yrs; 3 = seasonal, e.g. every season to once a year; 4 = persistent, e.g. daily or continual.		3.2	3.2	4.2	4.2				3.3	3.4	3.3		3.2									
Trophic Impact (Direct)	1 = species (single or multiple); 2 = single trophic level; 3 = >1 trophic level; 4 = entire community		4.2	4.2	4.2	4.2				4.3	4.4	4.3		3.1									
Resistance	1 = activity/stressor has a positive impact; 2 = high resistance to change (i.e. little significant negative change in biomass); 3 = moderate resistance to negative change; 4 = low resistance to negative change (i.e. significant negative biomass changes result from small stresses).		2.2	2.2	2.2	3.2				3.1	4.4	3.2		3.1									
Recovery time	1 = <1 year; 2 = 1-10 years; 3 = 10-100 years; 4 = >100 years.		2.2	2.2	2.2	2.2				2.1	1.1	2.1		2.1									
Changes in Sediment input (increasing or decreasing)	*turbidity, sediment deposition, drift cell -- assuming an input from terrestrial system (rivers, landslides)*	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spatial scale	Affects (1) <15% of the habitat (2) 15-50% of the habitat; (3) 50-85% of the habitat; and (4) >85%		4.2	4.2	3.2	4.2																	

FINAL_EcosystemMatrix_v2.xlsx

1) Habitat & Stressors:

This worksheet represents an overview of stressors that affect each habitat. After populating both the spatial extent row (green) and the subsequent stressor x habitat matrix (blue) below you will then proceed to the next worksheet: 2) Vulnerabilities matrix, which represents the scoring for the 5 vulnerability measures for each stressor x habitat interaction.

For more info see: Halpern, B., et al. 2007. Conservation Biology 20(5): 1301-1315; Teck et al. 2010. Ecological Applications 20(5): 1402-1416.

Name:	John Doe
Who do you work for?	NOAA AFSC
Where do you work?	Seattle, WA
Your contact Email:	John.Doe@noaa.gov
Your expertise:	fisheries manager
Ecosystem Name	Eastern Bering Sea Shelf, northern boundary 60o/st. matthews.

Please fill out the following information about yourself

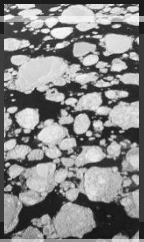
		Intertidal				Coastal					Shelf				Oceanic								
Human activity or natural stressor	Definition	Rocky intertidal	Intertidal mud	Beach	Salt marsh	Seagrass	Kelp forest	Rocky reef	[illegible]	[illegible]ttom	[illegible]umn	[illegible] (30-	[illegible]lf	Sea Ice	Soft bottom slope (200-2000 m)	Hard bottom slope (200-2000 m)	Soft bottom benthic (>2000 m)	Deep seamount	Vent	Soft bottom canyon	Hard bottom canyon	Upper (near surface) pelagic water column	Deep pelagic water column
Example Habitat		*Pribilofs*	*Kuskokwim River Delta*	*Nearshore*	*Nelson lagoon*	*Nelson lagoon*	*NA*	*NA*	[illegible]	*ER[illegible]*	[illegible]	*ER[illegible]*	[illegible]	*EBS sea ice*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Spatial Extent	*% of total areal extent of the ecosystem (not mutually exclusive): (1) minimal (<15%); (2) small (15-50%); (3) large (50-85%); and (4) majority (>85%)*	1	1	1	1	1	[illegible]	[illegible]	[illegible]	3	4	3	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Changes in Freshwater input (increasing or decreasing)	*affects nearshore community composition, for shelf communities this would be from changes in sea ice*	0	1	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	0	1	0	0	0	0	0	0	0	0	0
Changes in Sediment input (increasing or decreasing)	*turbidity, sediment deposition, drift cell -- assuming an input from terrestrial system (rivers, landslides)*	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Changes in Nutrient inputs (increasing or decreasing)	*can include upwelling*	1	1	1	1	1	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0
Inputs of Pollution and Contaminants from land sources	*urban and mine run-off, pcbs*	1	1	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0
Coastal engineering	*seawalls, piers, jetties, sand mining*	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coastal development	*landfill, reclamation, dredging*	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

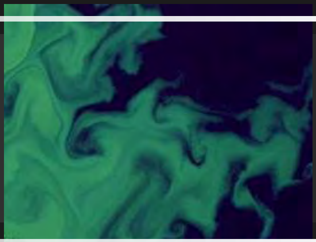
Enter 0-4 in this row corresponding to the % of areal extent of the whole ecosystem represented by each habitat (note habitats can overlap so these are not mutually exclusive).

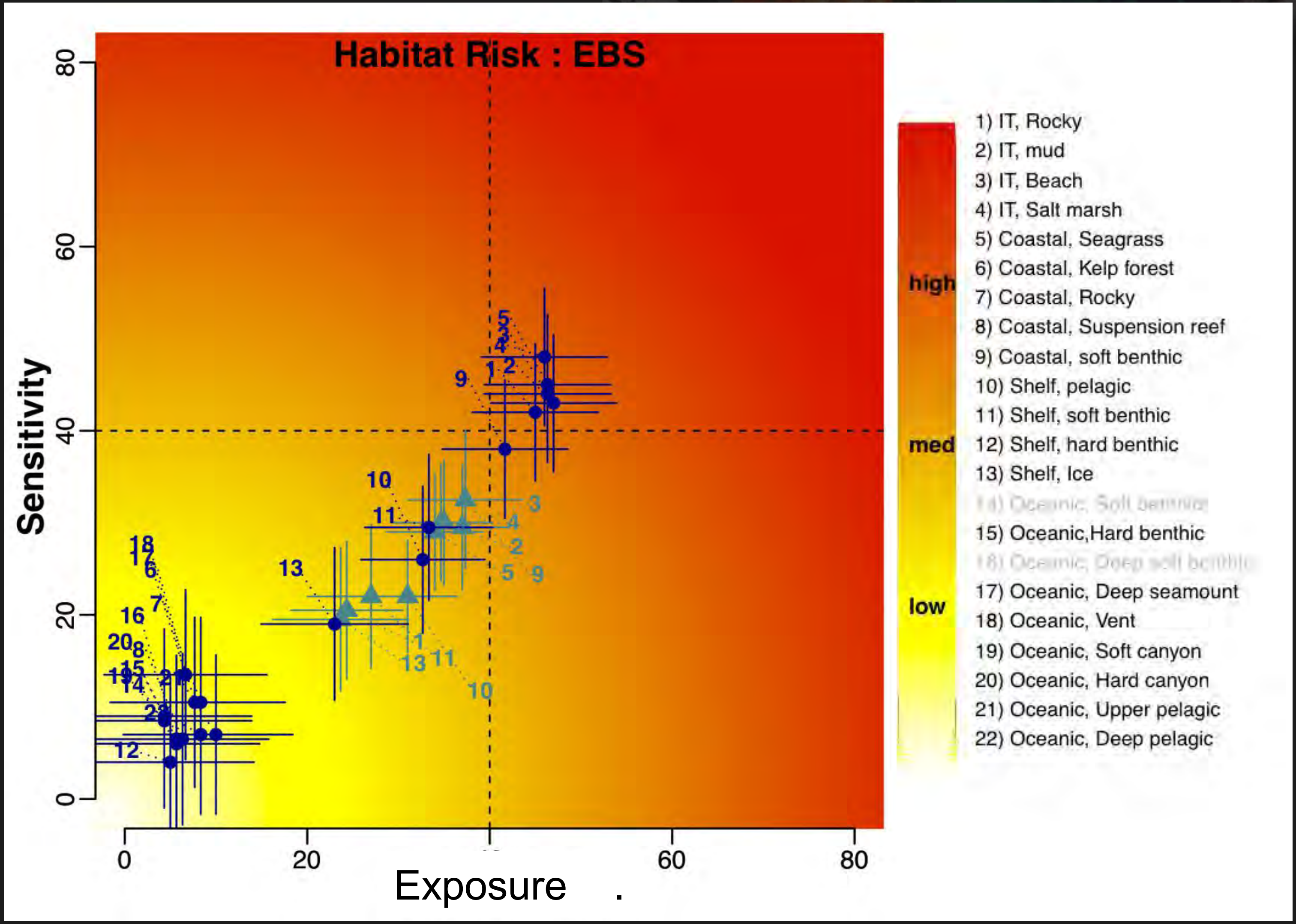
Enter 0 if the habitat does not occur in the ecosystem.

For each row of the blue matrix (stressor), enter 0 if interaction does not occur or is NA or 1 if it does occur.

Habitat Risk







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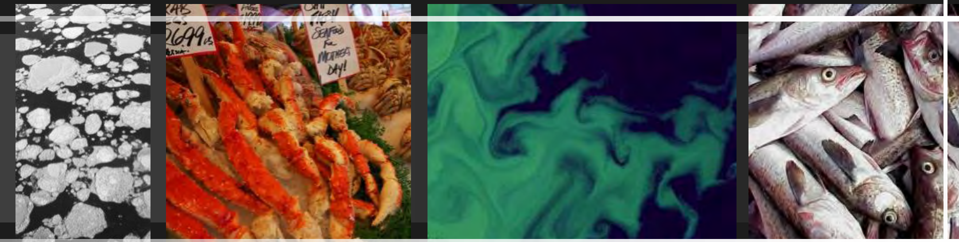
Levels (Hobday et al. 2011)



- A 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.

- A level 2 analysis considers the exposure of an ecosystem component to a pressure, and the sensitivity of the component to that pressure.

- The Level 3 analysis takes a quantitative approach such as is used in stock assessments & population viability analyses

EBM GOALS

- Fishery management plan goals for AK groundfish (2004)
  1. Prevent overfishing
  2. Promote sustainable fisheries & fishing communities
  3. Preserve the food web
  4. Manage incidental catch & reduce bycatch & waste
  5. Avoid impacts to seabirds & marine mammals
  6. Reduce and avoid impacts to habitat
  7. Promote equitable & efficient use of fishery resources
  8. Increase Alaskan native consultation
  9. Improve data quality monitoring & assessment

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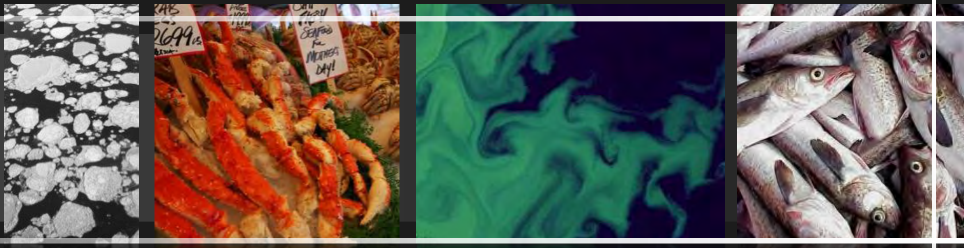
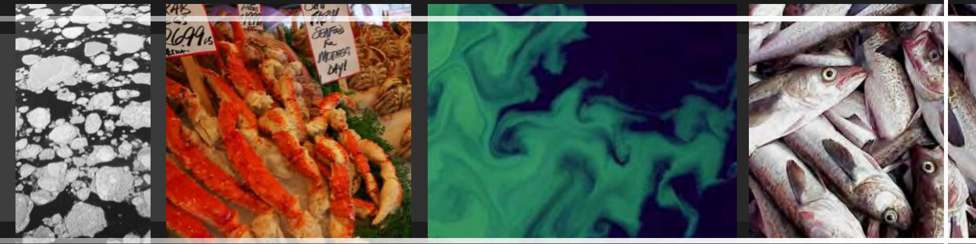
EBM ACTIONS



- EAM/EBM actions
  1. Implement conservative exploitation rates
  2. Limit bycatch & discards
  3. Implement habitat protection measures
  4. Consider endangered & protected species
  5. Consider humans as part of the ecosystem

Ecosystem Reference Point (ERP)



Do EBM actions have effect on ecosystem indices?

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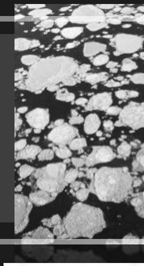
Ecosystem considerations chapter & report card




- Ecosystem Considerations report (~200 p)
- Produced annually by NOAA ecosystem scientists
- Goal: to provide an overview of marine ecosystems in Alaska for the North Pacific Fishery Management Council
- Stock assessment recommendations are evaluated within an ecosystem context (EBFM, qualitative)

December 2011 *Ecosystem Considerations*

Appendix C

Ecosystem Considerations for 2012

Edited by:
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With contributions from:

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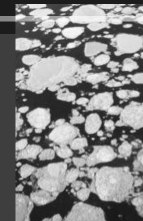
Reviewed by:
The Plan Teams for the Groundfish Fisheries of the
Bering Sea, Aleutian Islands, and Gulf of Alaska

Ecosystem considerations chapter & report card





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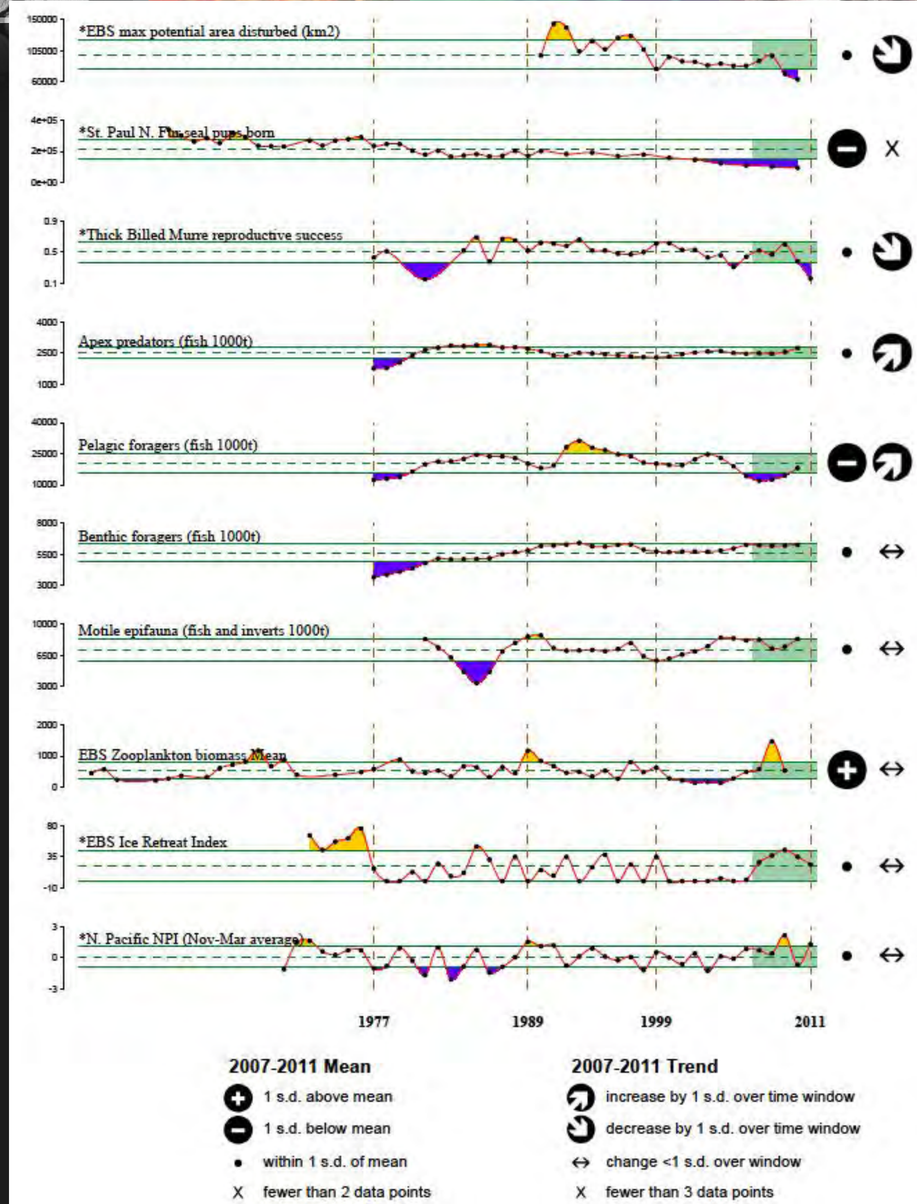

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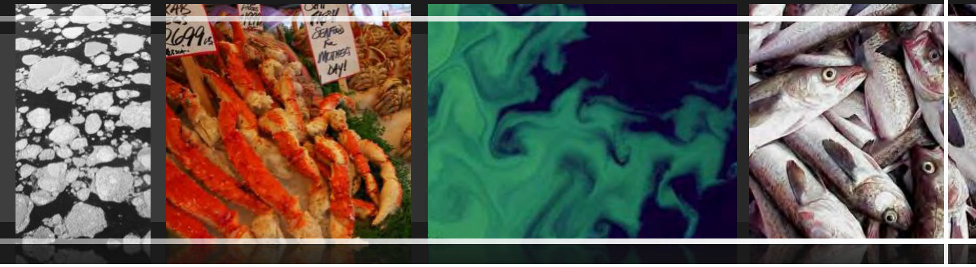
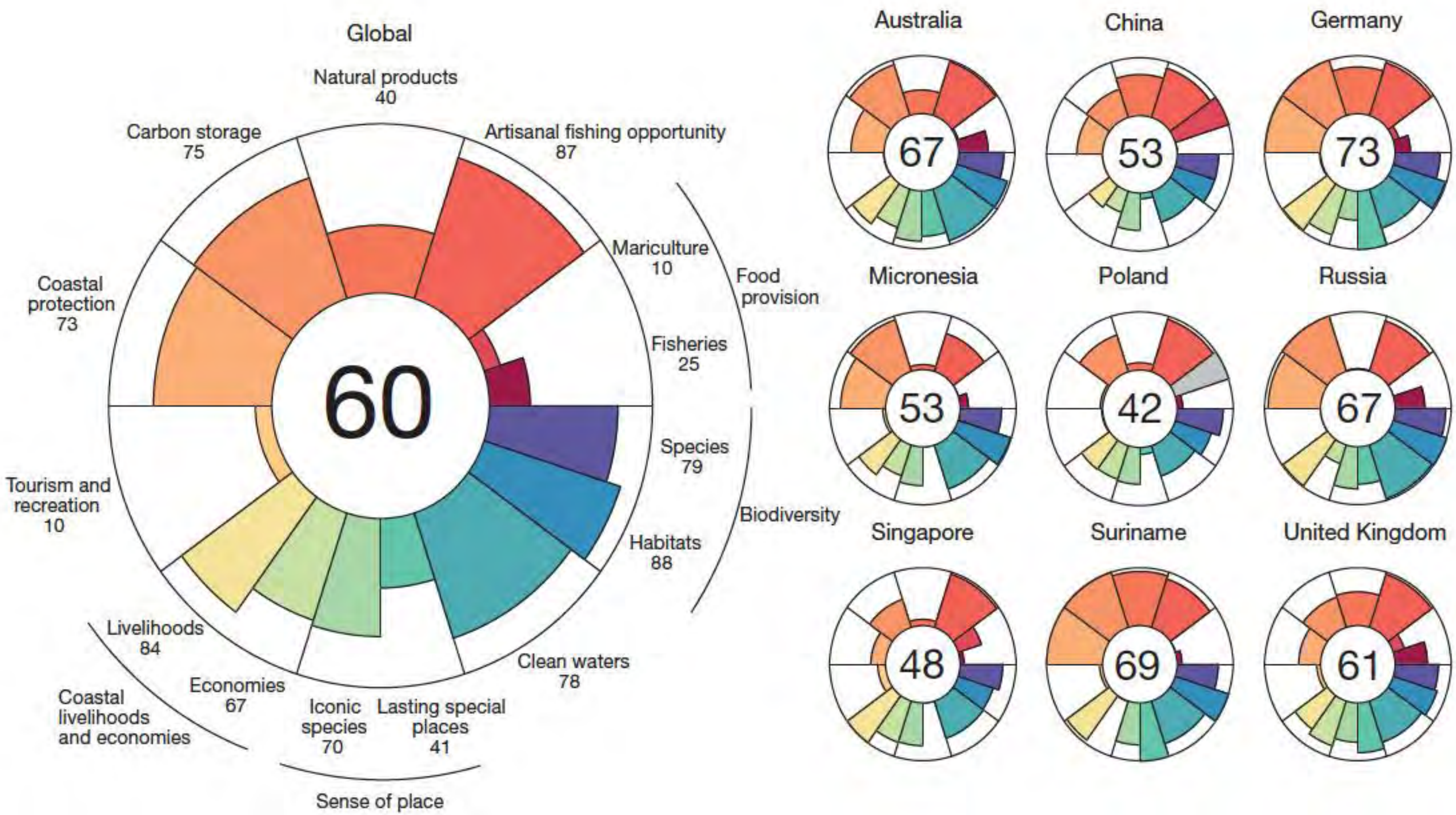
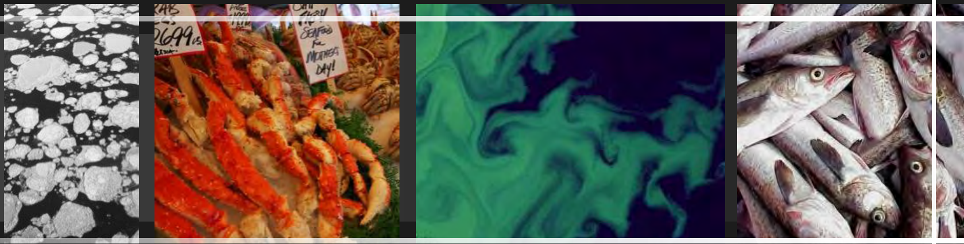
Ocean Health Index





HALPERN et al. | N AT U R E | VO L 4 8 8 | 3 0 AU G U S T 2 0 1 2

Ocean Health Index

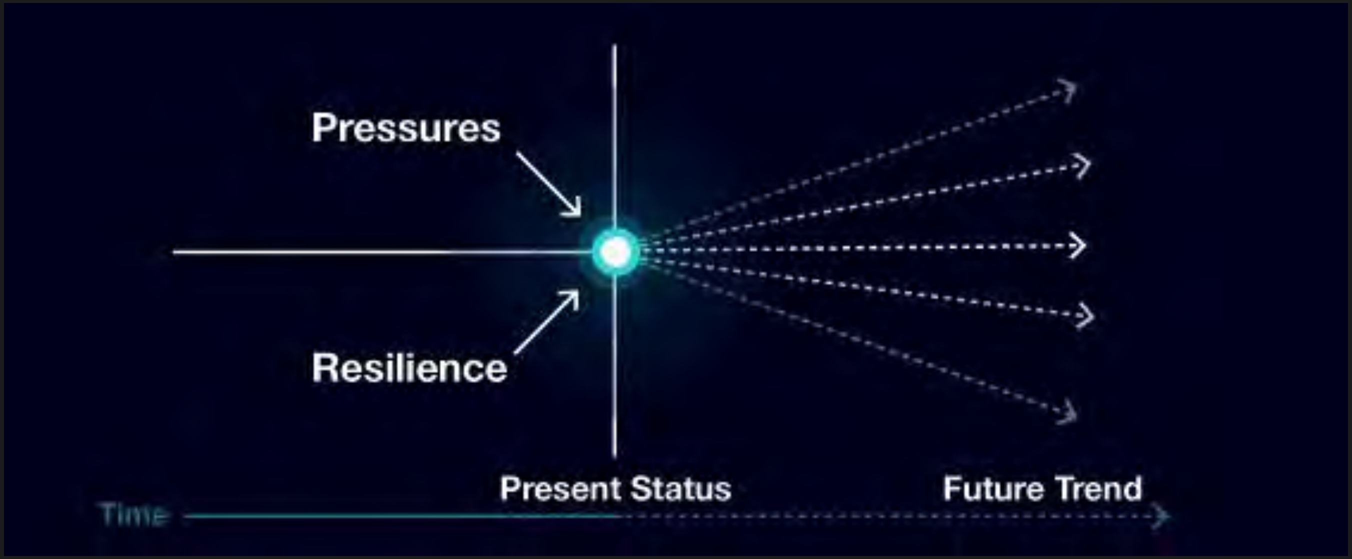


www.oceanhealthindex.org/

OHI = sum (Goal Score* Weight)

Goal Score = (Present Status + Likely Future Status) / 2

Likely Future Status= 1+ 2/3 * Trend + 1/3*(Resilience - Pressure)



 HALPERN et al. | N AT U R E | VO L 4 8 8 | 3 0 AU G U S T 2 0 1 2

Ecosystem Reference Point (ERP)

$$Score_y = \sum_{i=1}^{n_i} S_{i,y} W_i$$

$$S_{i,y} = \frac{S_{i,y} + S_{i,fut}}{2}$$

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

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

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

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

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

y	Year
i	Index
$v_{i,y}$	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 yrs
n_i	Number of indices

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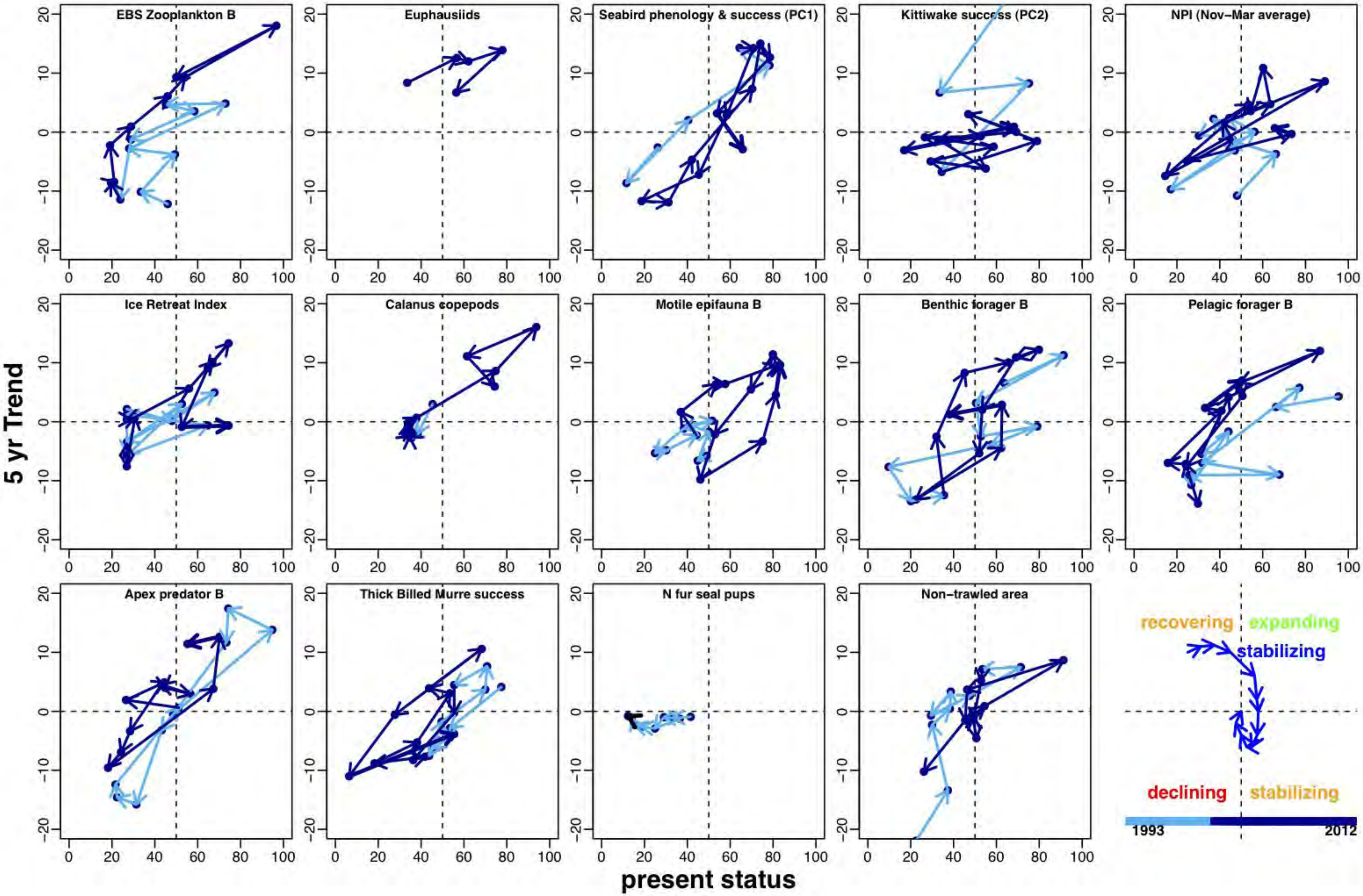
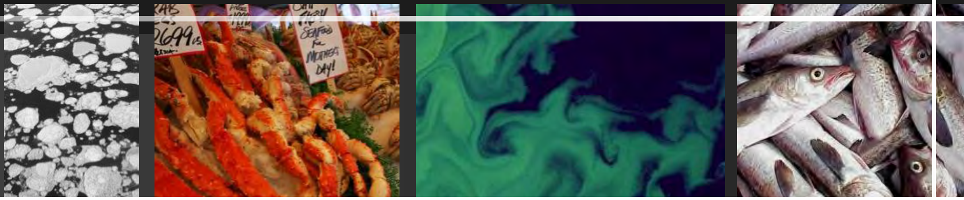
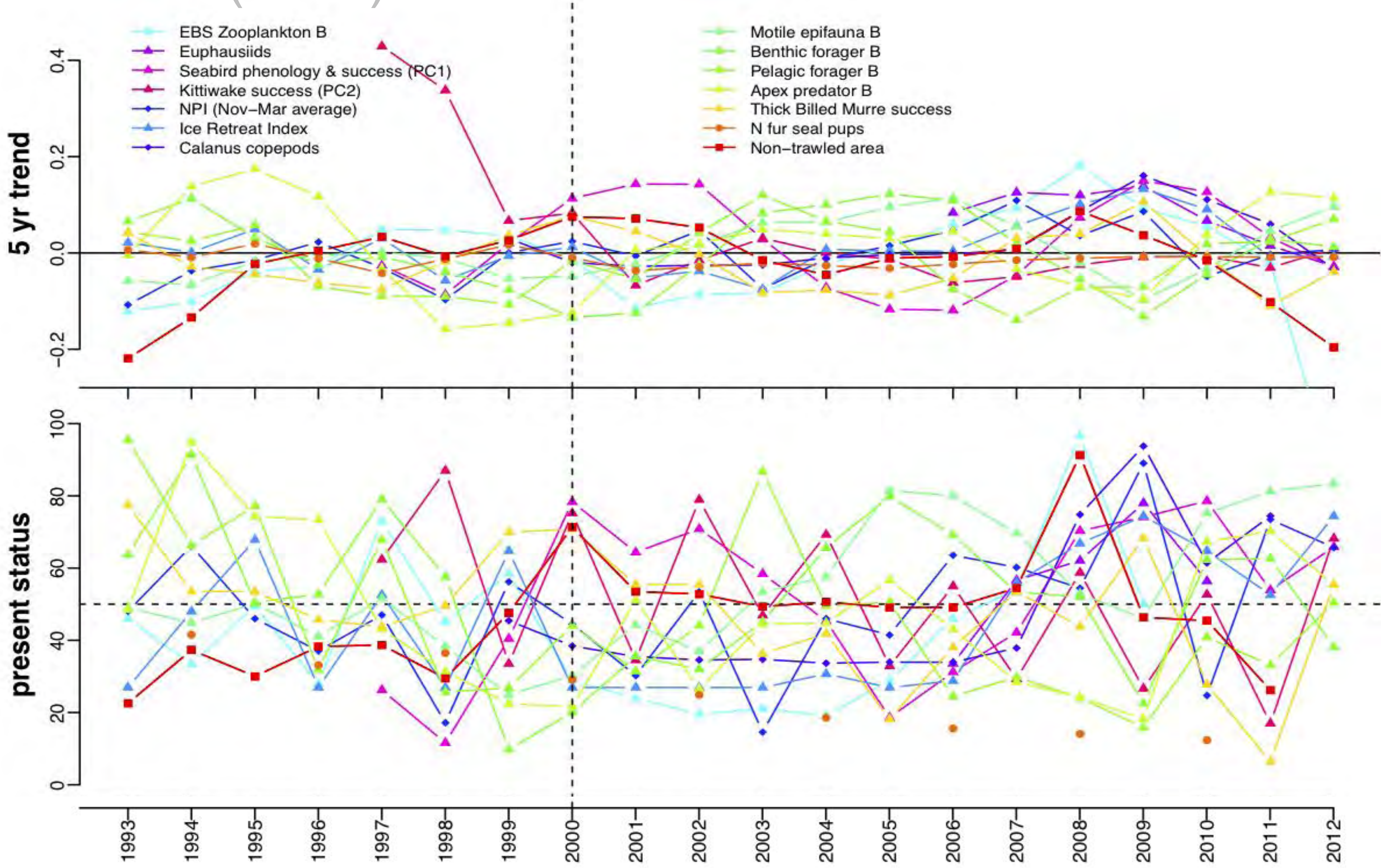

EBS Zooplankton B
Euphausiids
Seabird phenology & success (PC1)
Kittiwake success (PC2)
NPI (Nov−Mar average)
Ice Retreat Index
Calanus copepods
Motile epifauna B
Benthic forager B
Pelagic forager B
Apex predator B
Thick Billed Murre success
N fur seal pups
Non−trawled area
recovering
expanding
stabilizing
declining
stabilizing
1993
2012
5 yr Trend
present status

Ecosystem Reference Point (ERP)





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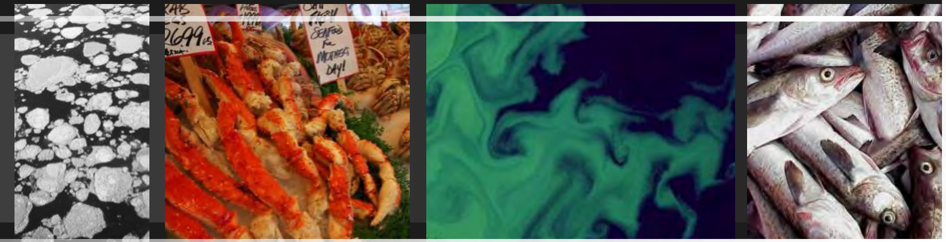

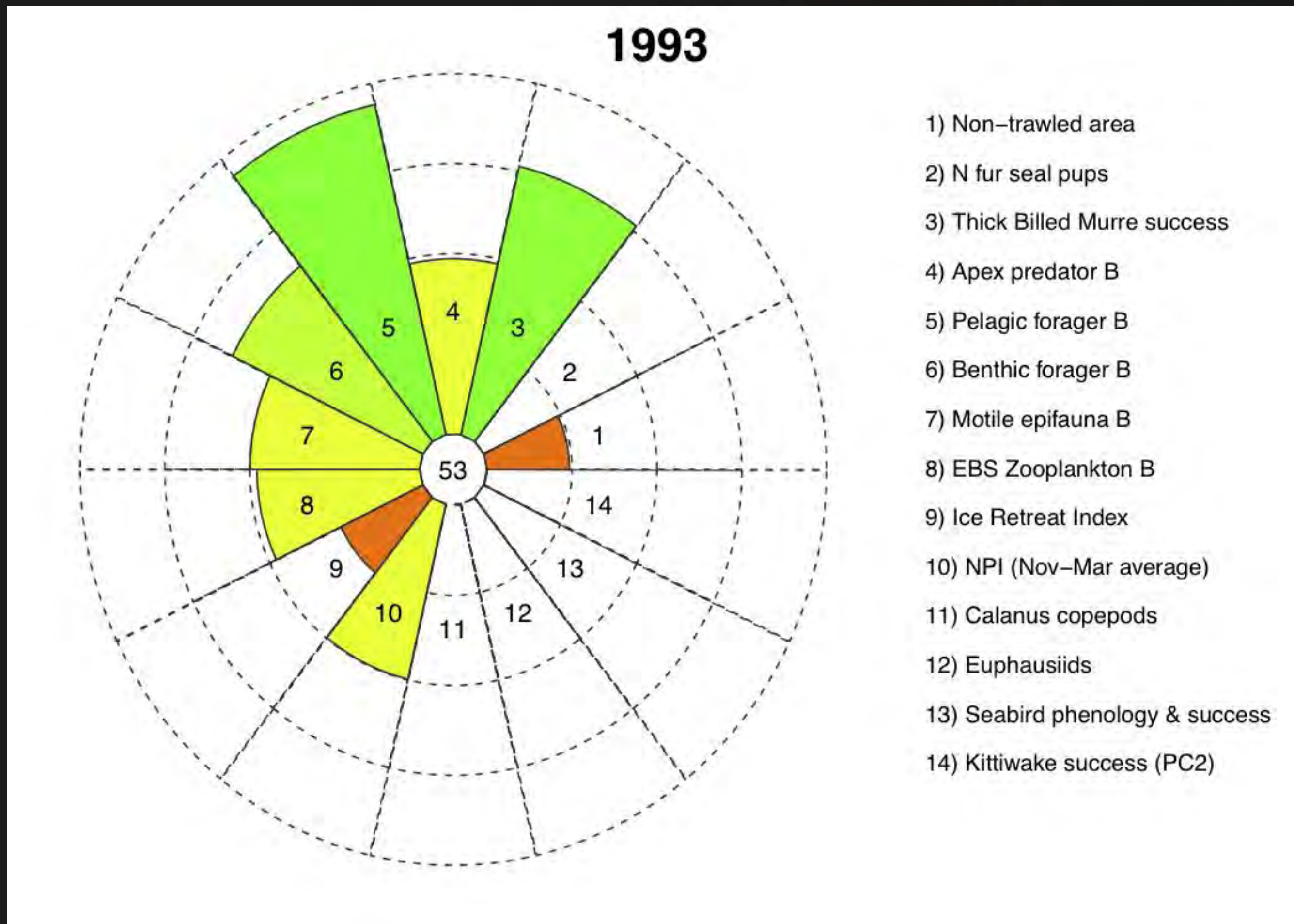

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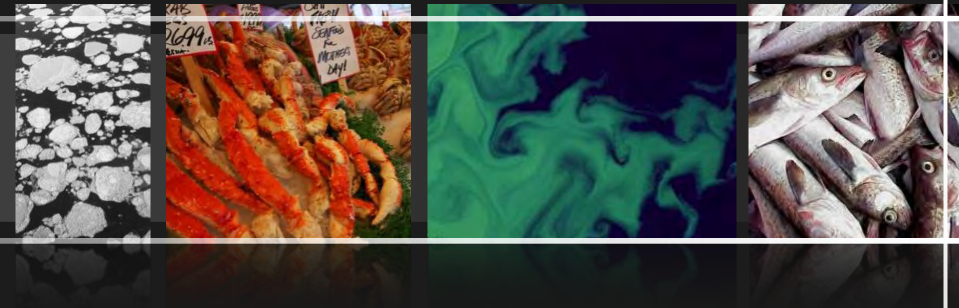

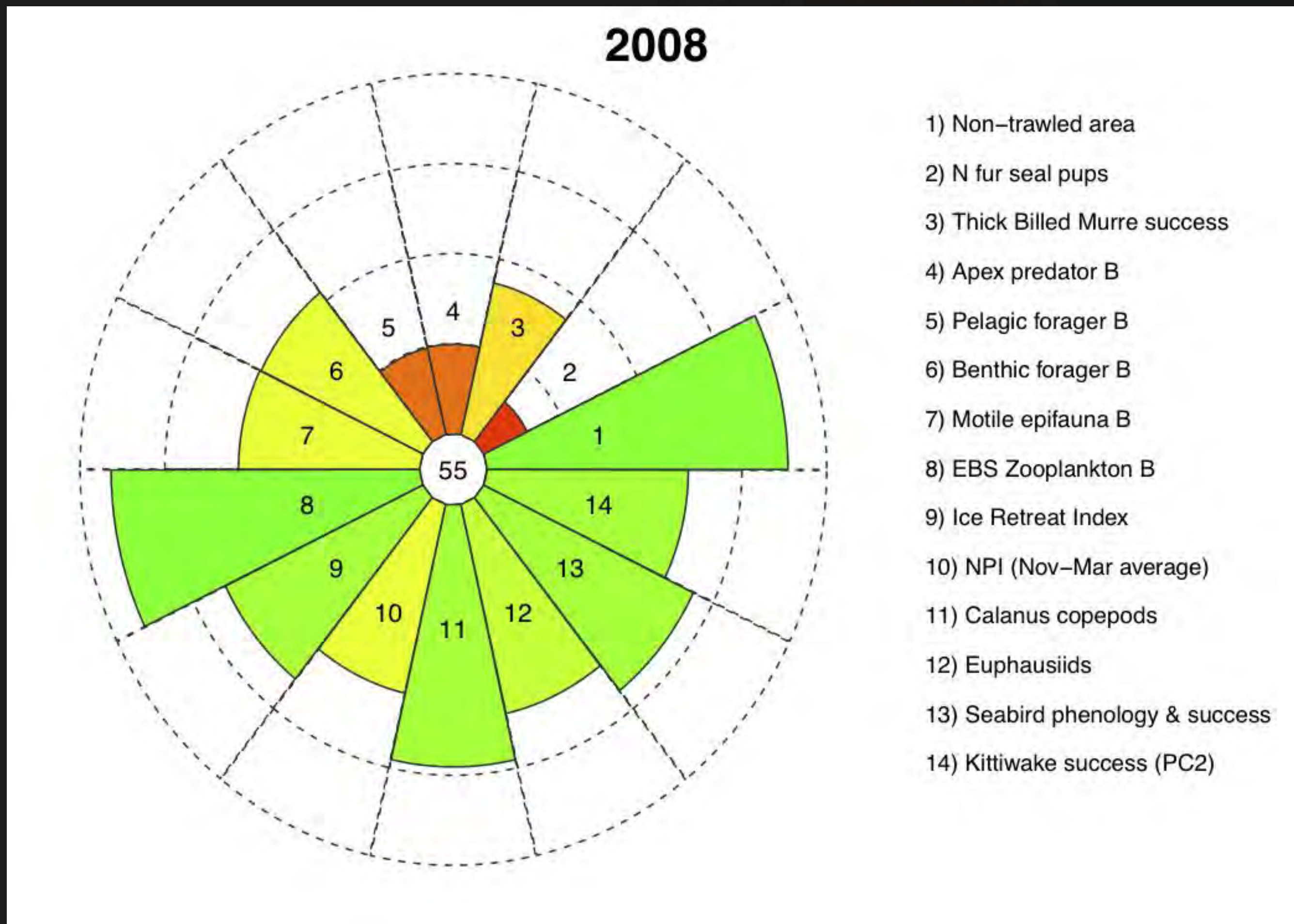

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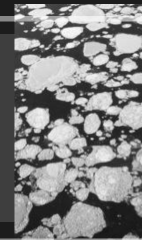
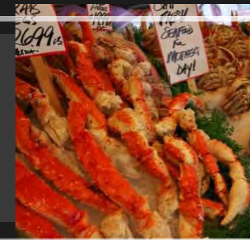


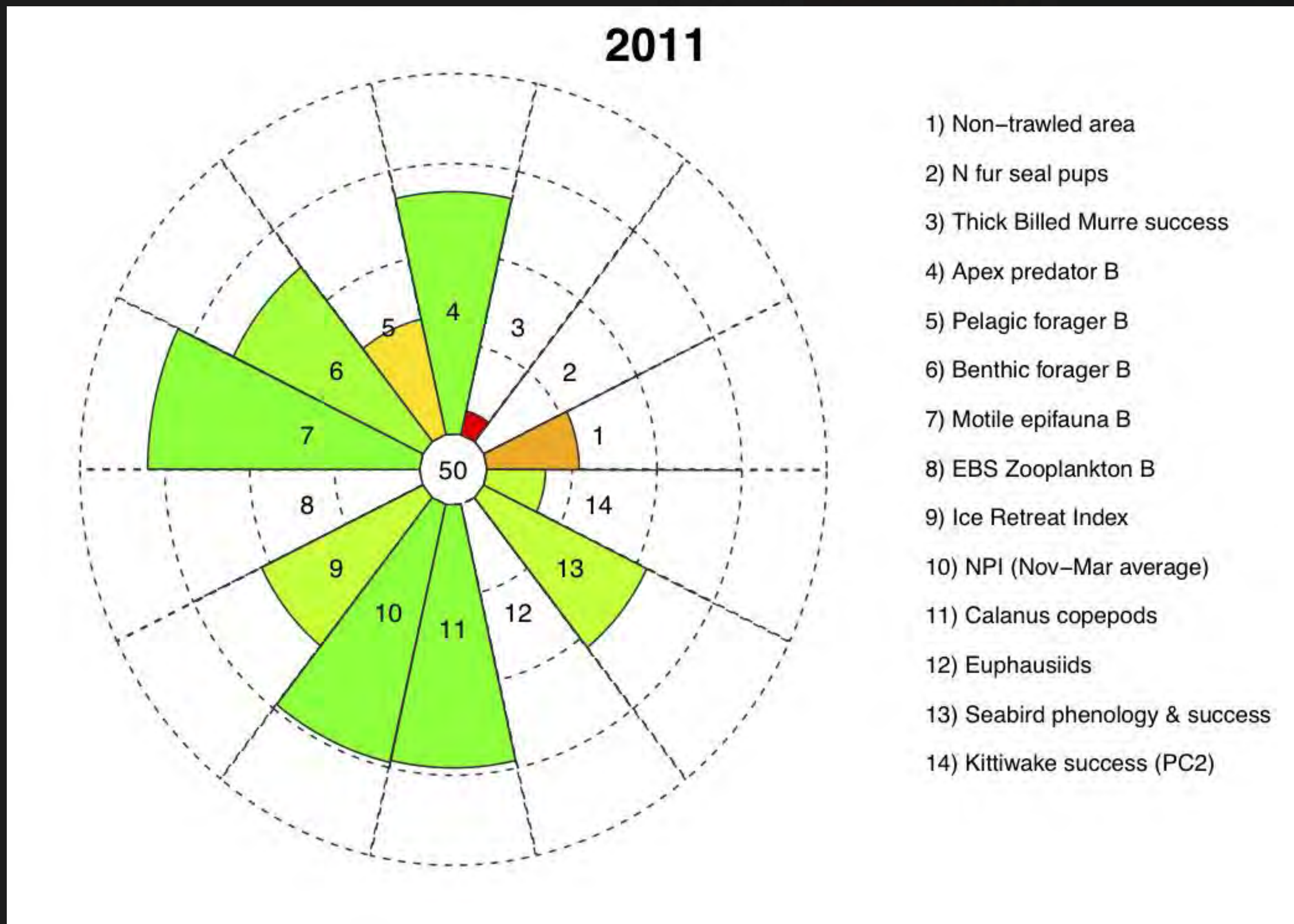

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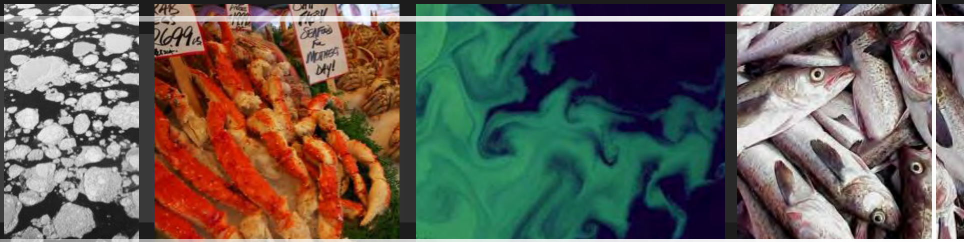

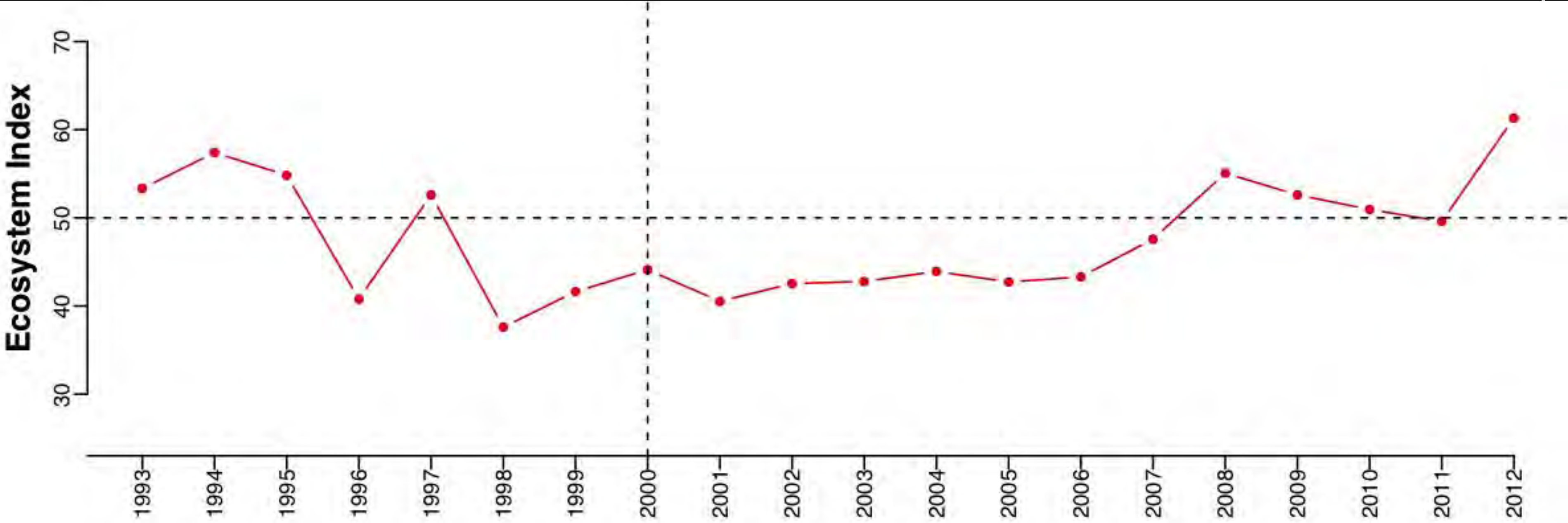

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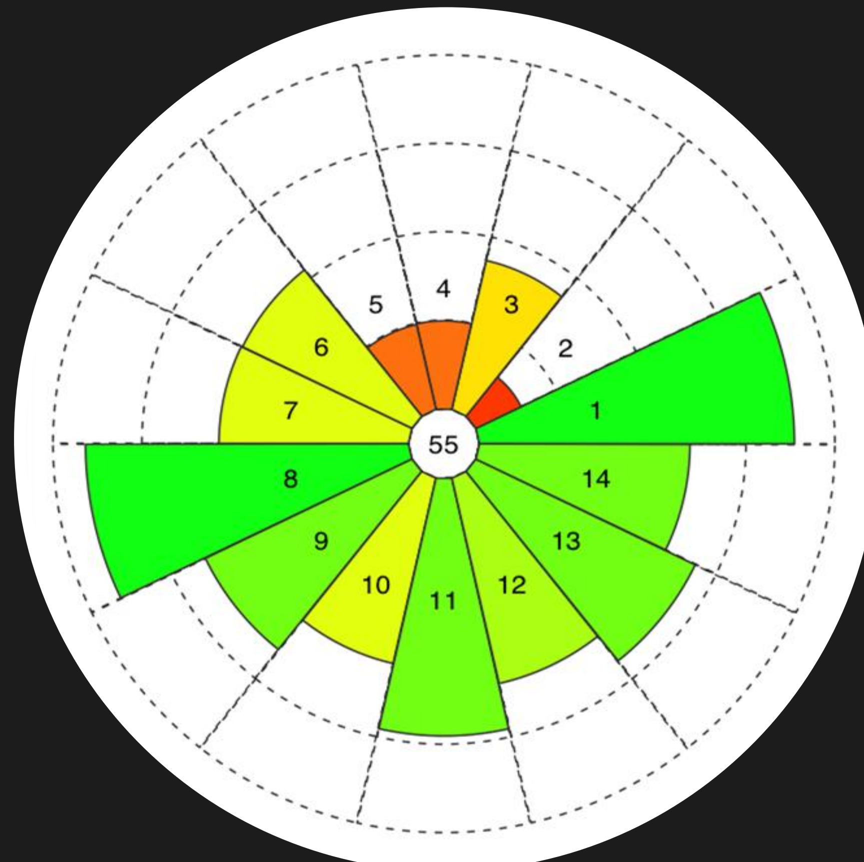
Next Steps

- Add uncertainty penalty to future status
- Run sensitivity analysis on scores
- Evaluate risk under various management actions (MSE)



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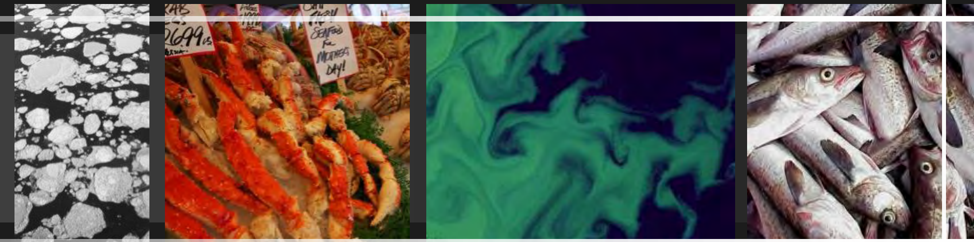
THANKS!



<u>Collaborators</u>

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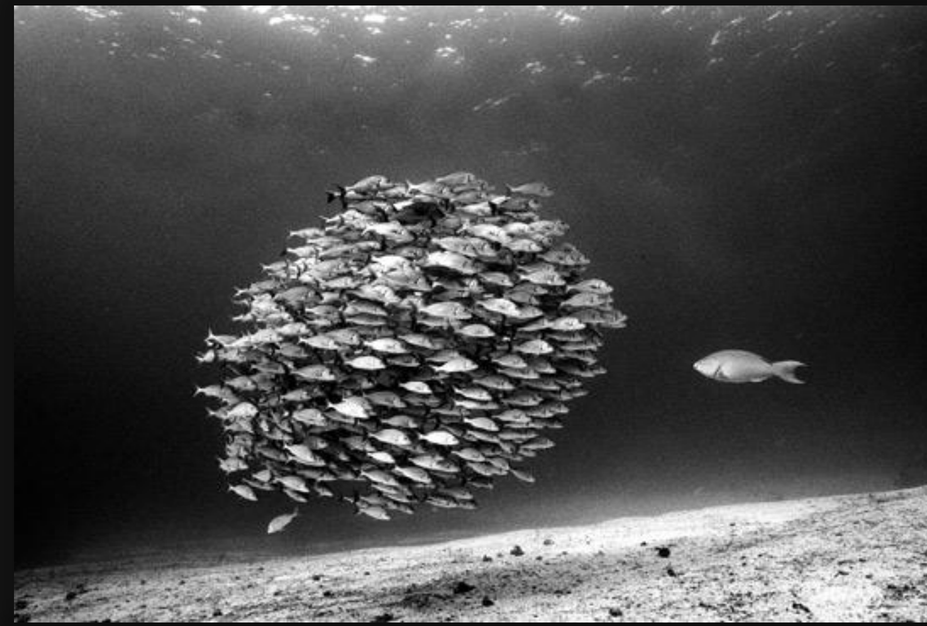
<u>Colleagues</u>

Jim Ianelli, Phil Levin, Matt Baker, William Stockhausen, Sarah Gaichas, P.Sean McDonald, Ivonne Ortiz



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