Marine Ecosystem Health and Biodiversity

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Marine Ecosystem Health and Biodiversity

Background

Measuring health

- Overview
- Current tools
- Gaps and challenges in measurement
- Operational needs for an observation network

Measuring biodiversity

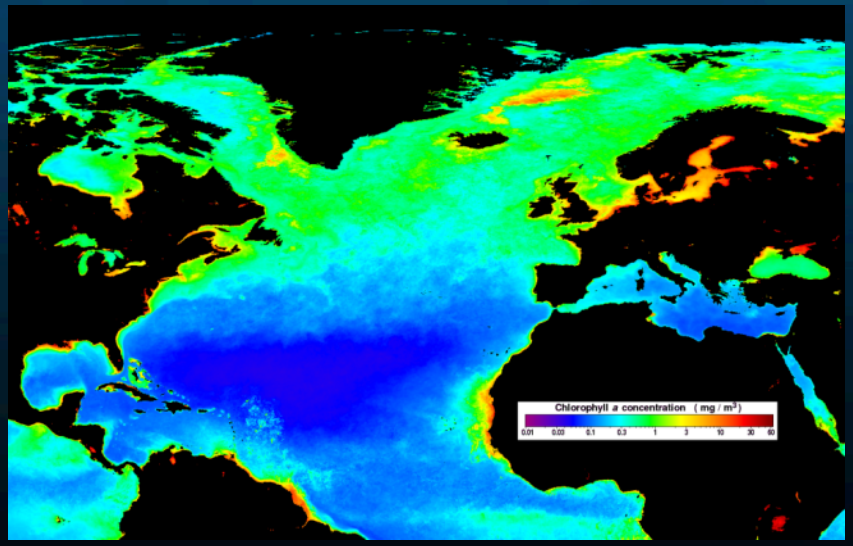
- Overview
- Current tools (taxa specific)
- Gaps and challenges in measurement
- Operational needs for an observation network

Priority locations and systems

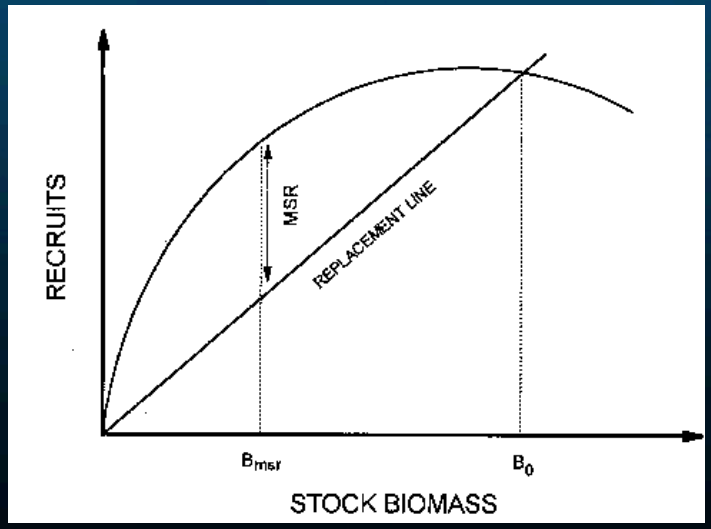
- Developing criteria for selection
- Examples

Marine Ecosystem Health and Biodiversity

How we used to "see" oceans



How we used to "manage" oceans



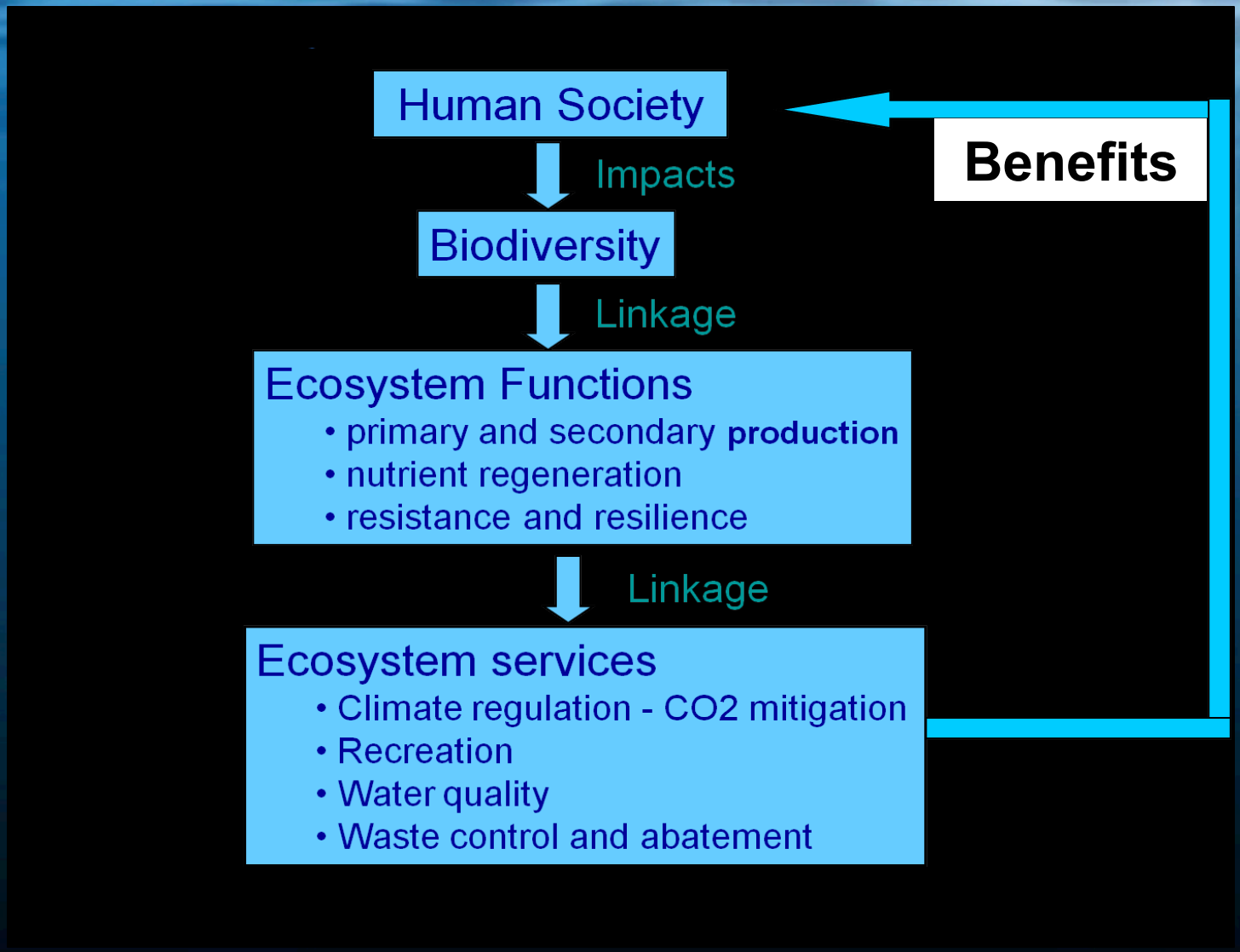
Recognition of Functions & Services

$33 trillion, 21 from oceans

From Costanza et al. (1997)

1. Gas regulation
2. Climate regulation
3. Disturbance regulation
4. Water regulation
5. Water supply
6. Erosion control
7. Soil formation
8. Nutrient cycling
9. Waste treatment
10. Pollination
11. Biological control
12. Habitat / Refugia
13. Food production
14. Raw materials
15. Genetic resources
16. Recreation
17. Cultural

Recognition of Functions & Services



Ecosystem Based Management (~Ecosystem Approach)

EBM Objectives	
Maintain…	
Communities	Multispecies data
Species	Multispecies data
Populations	Species data
Primary production	Pigment data
Trophic structure	Multispecies data
Generation times	Single species data
Bottom habitat	Multispecies data
Water column	Multispecies data
Water quality	Environmental data

Different data needs and challenges depending on specific objectives…

After M. Sinclair, BIO, 2005

Good Environmental Status (EU)

"The Marine Strategy Framework Directive (MSFD) adopted in July 2008 aims at achieving or maintaining a good environmental status by 2020 at the latest. It is the first legislative instrument in relation to the marine biodiversity policy in the European Union, as it contains the explicit regulatory objective that "biodiversity is maintained by 2020", as the cornerstone for achieving good environmental status. It enshrines in a legislative framework the ecosystem approach to the management of human activities having an impact on the marine environment, integrating the concepts of environmental protection and sustainable use."

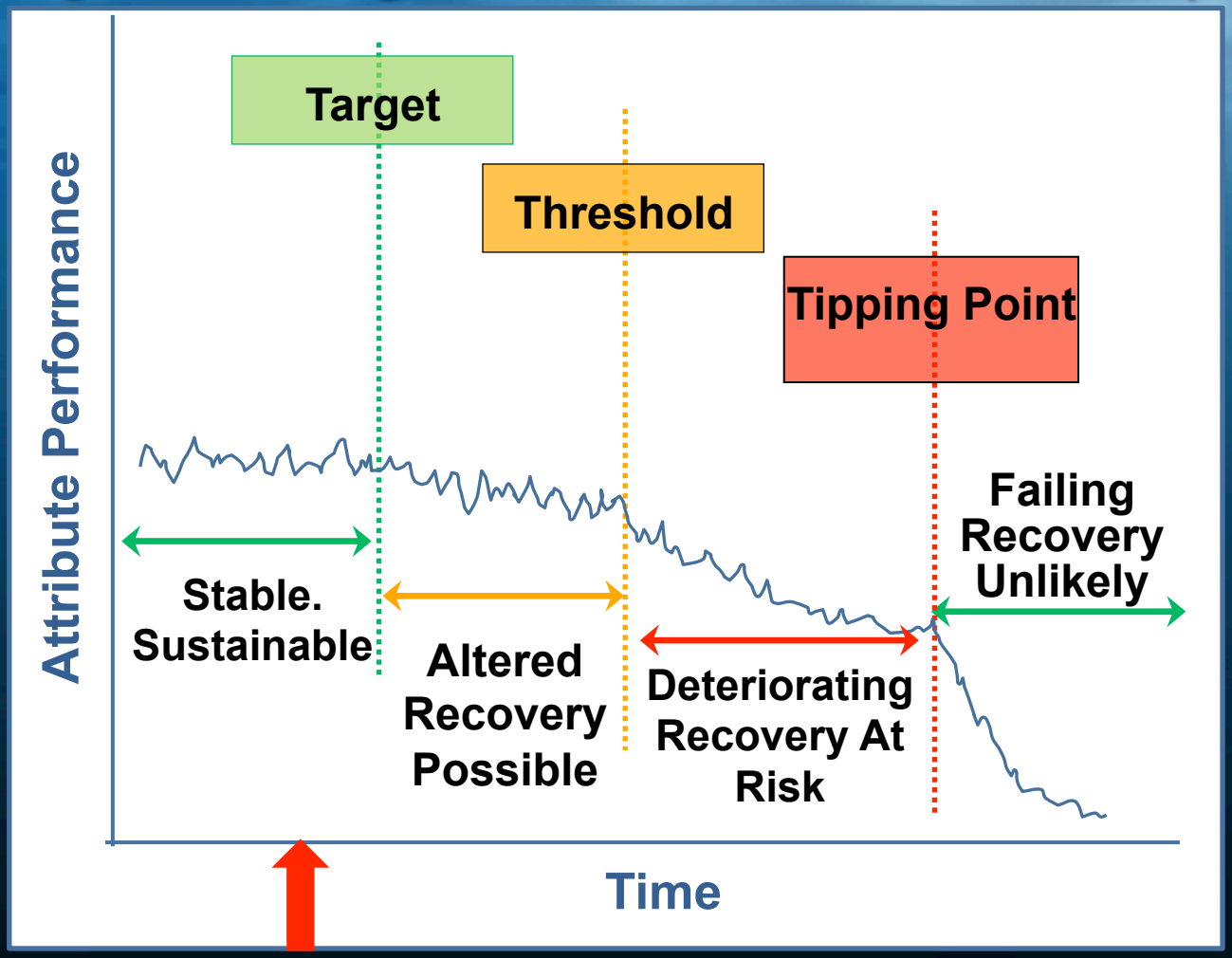
Good Environmental Status (EU)

- Biological diversity
- Non-indigenous species
- Population of commercial fish / shell fish
- Elements of marine food webs
- Eutrophication
- Sea floor integrity
- Alteration of hydrographical conditions
- Contaminants
- Contaminants in fish and seafood for human consumption
- Marine litter
- Introduction of energy, including underwater noise

Measures of Status

How do we measure ecosystem health?

What is good enough? The need for reference points



When does "time" begin?

Colleen Mercer-Clarke (2012)

Marine Ecosystem Health and Biodiversity

How do we measure ecosystem health?

How do we measure biodiversity?

Where should we prioritize efforts?

How do we measure ecosystem health?

- **History**
  - Aldo Leopold on Ecosystem Health
- **Current tools**
  - MSFD Holistic Assessment (HOLAS) Tool
  - Ocean Health and Benefits Index
- **Gaps and challenges** in measurement
- **Operational needs** for an observation network

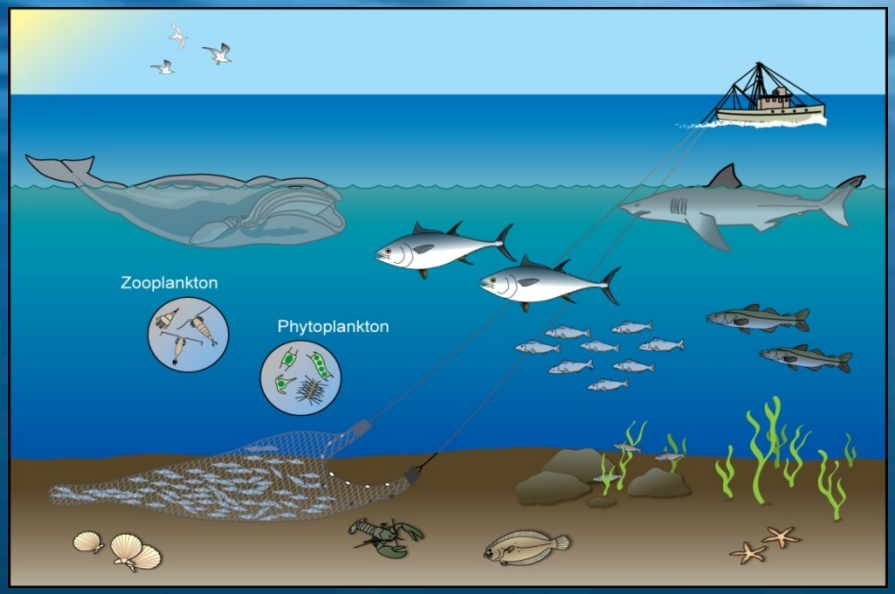
Health as a Metaphor for Ecosystem Condition and Status

'The land consists of soil, water, plants, and animals, but *health* is more than a sufficiency of these components. It is a state of vigorous self-renewal in each of them. Such collective functioning of interdependent parts for the maintenance of the whole is characteristic of an organism …and conservation deals with its functional integrity, or *health*.' (Aldo Leopold (1944)

Aldo Leopold on Maintaining Biodiversity

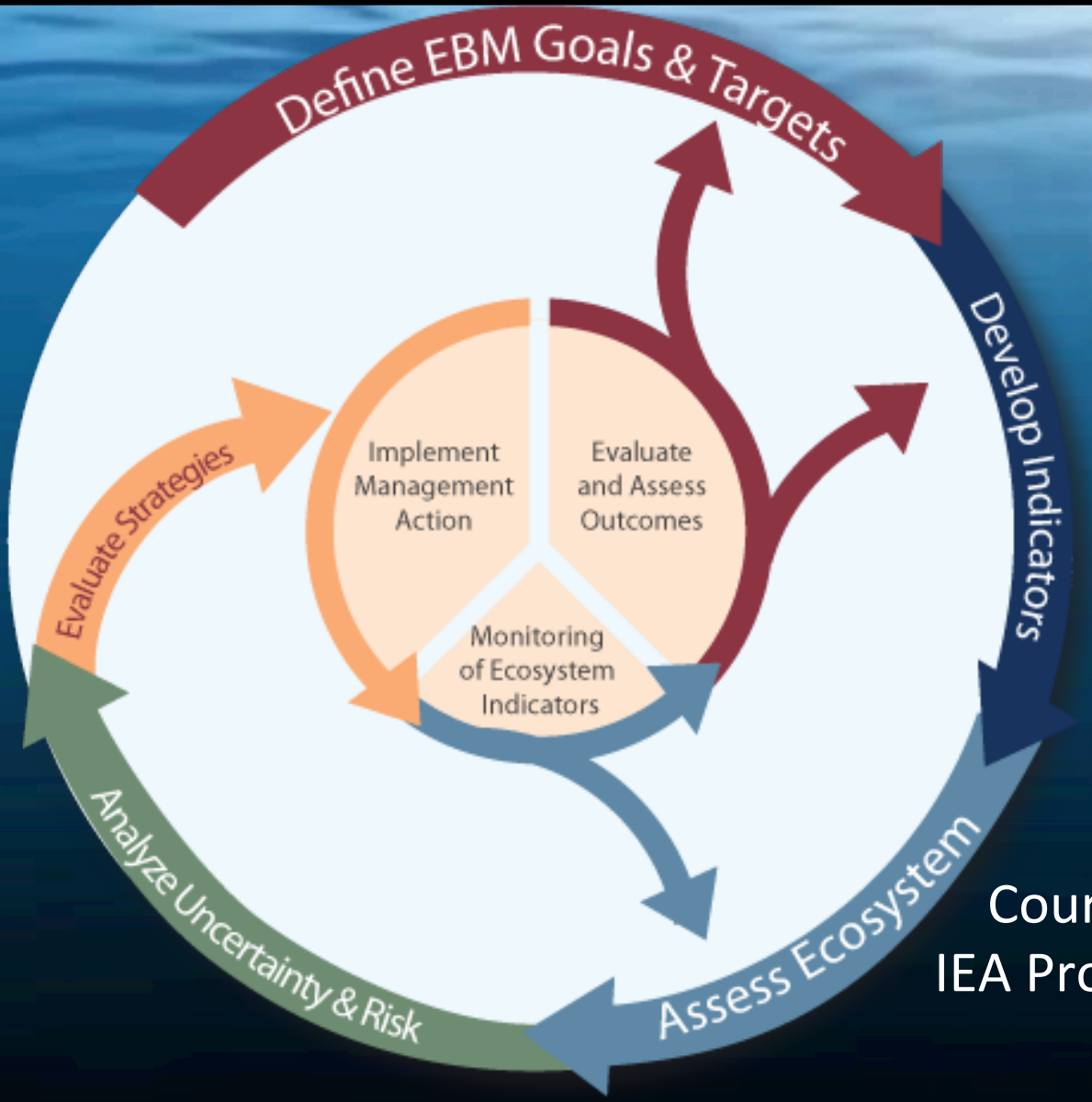
”To keep every cog and wheel is the first precaution of intelligent tinkering.”

Marine Ecosystem-Based Management



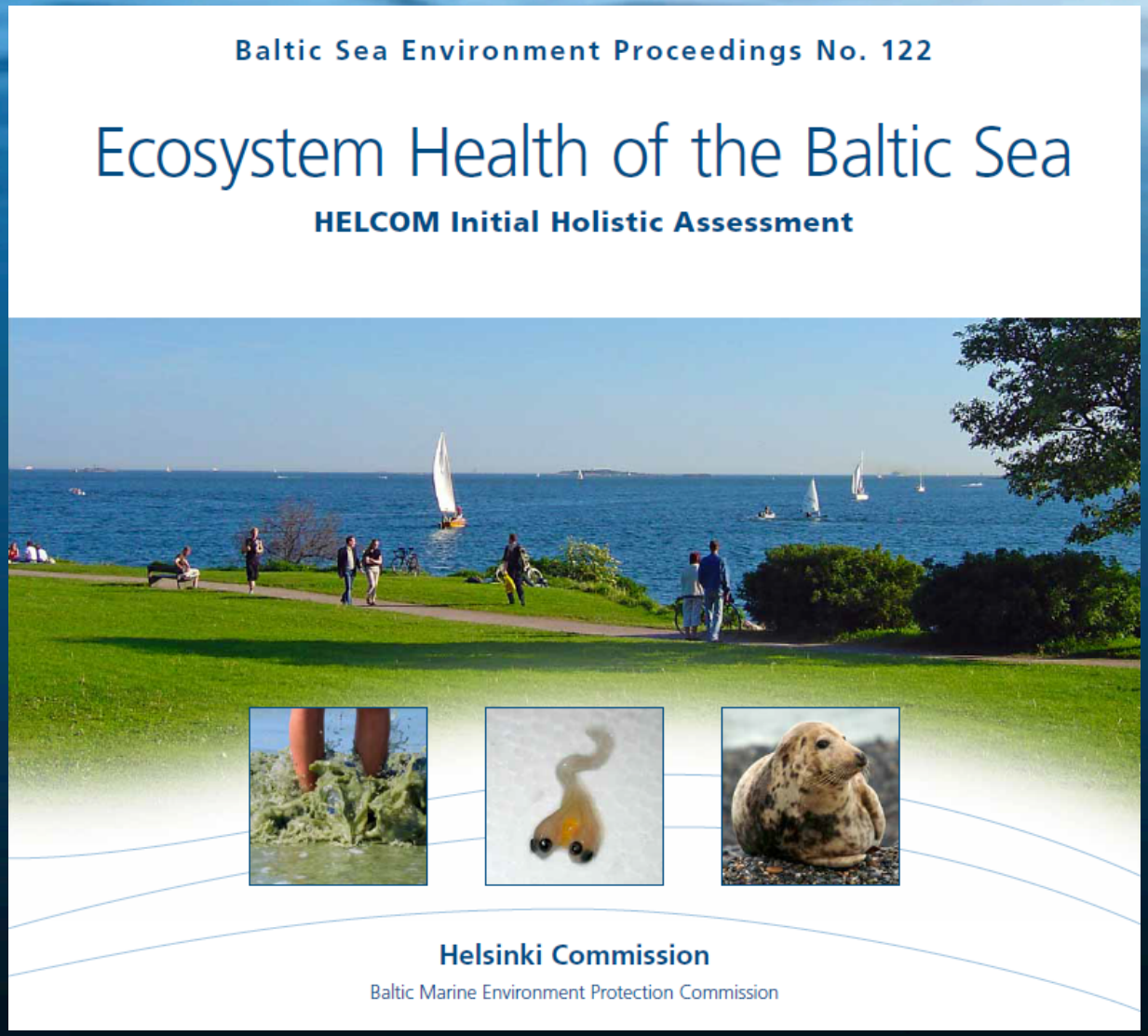
Ecosystem-based management is an Integrated approach to management that considers the entire ecosystem, including humans. The goal of ecosystem-based management is to maintain an ecosystem in a healthy, productive and resilient condition so that it can provide the services humans want and need (McLeod et al. 2005).

Integrated Ecosystem Assessments



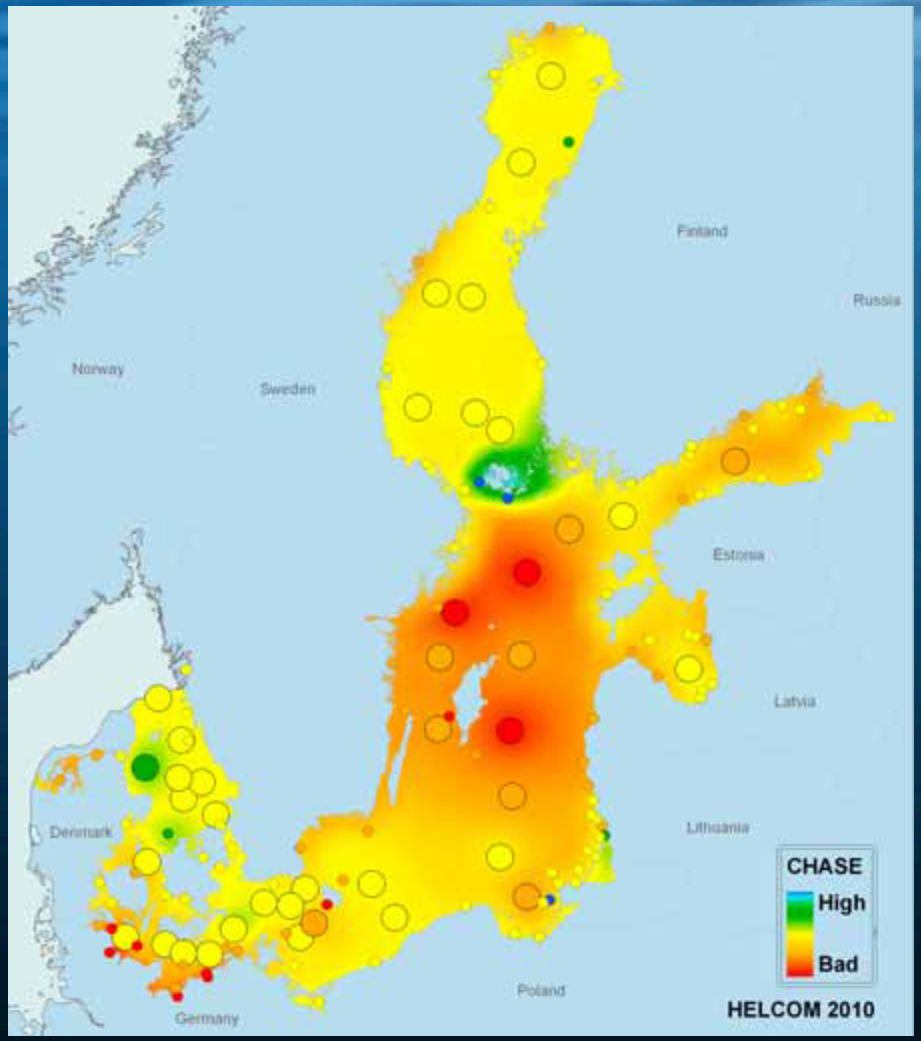
Courtesy NOAA IEA Program

How do we measure ecosystem health?

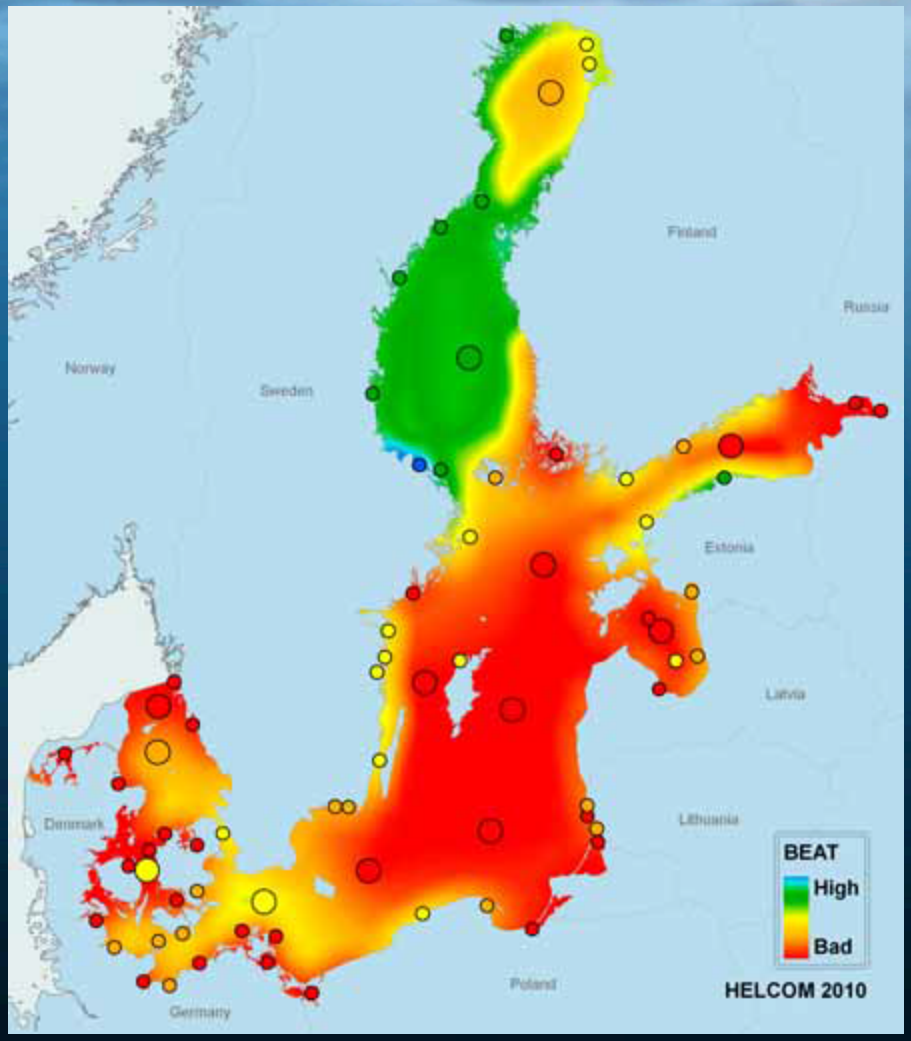


Marine strategy framework directive approach

Baltic Sea Ecosystem Health Assessment

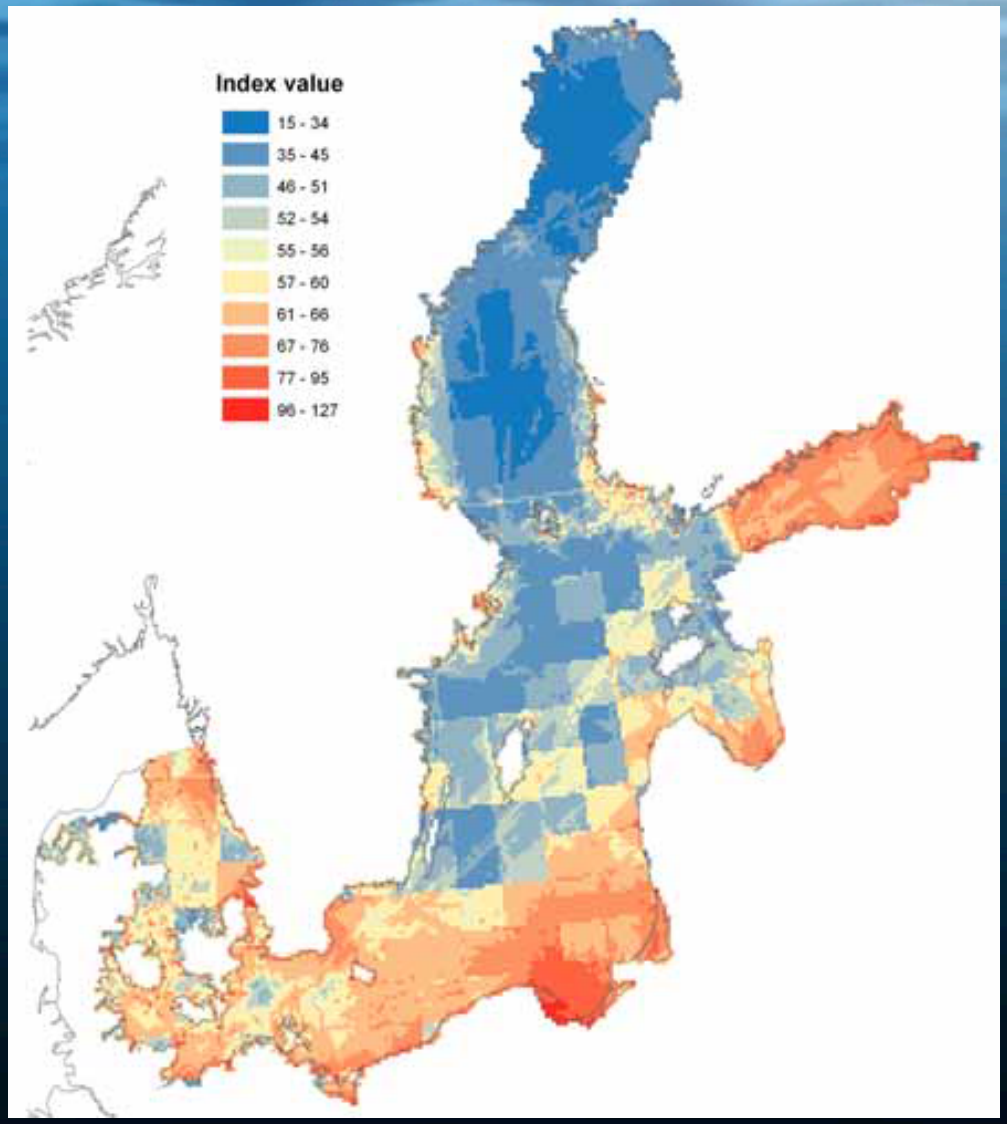


Hazardous Substances

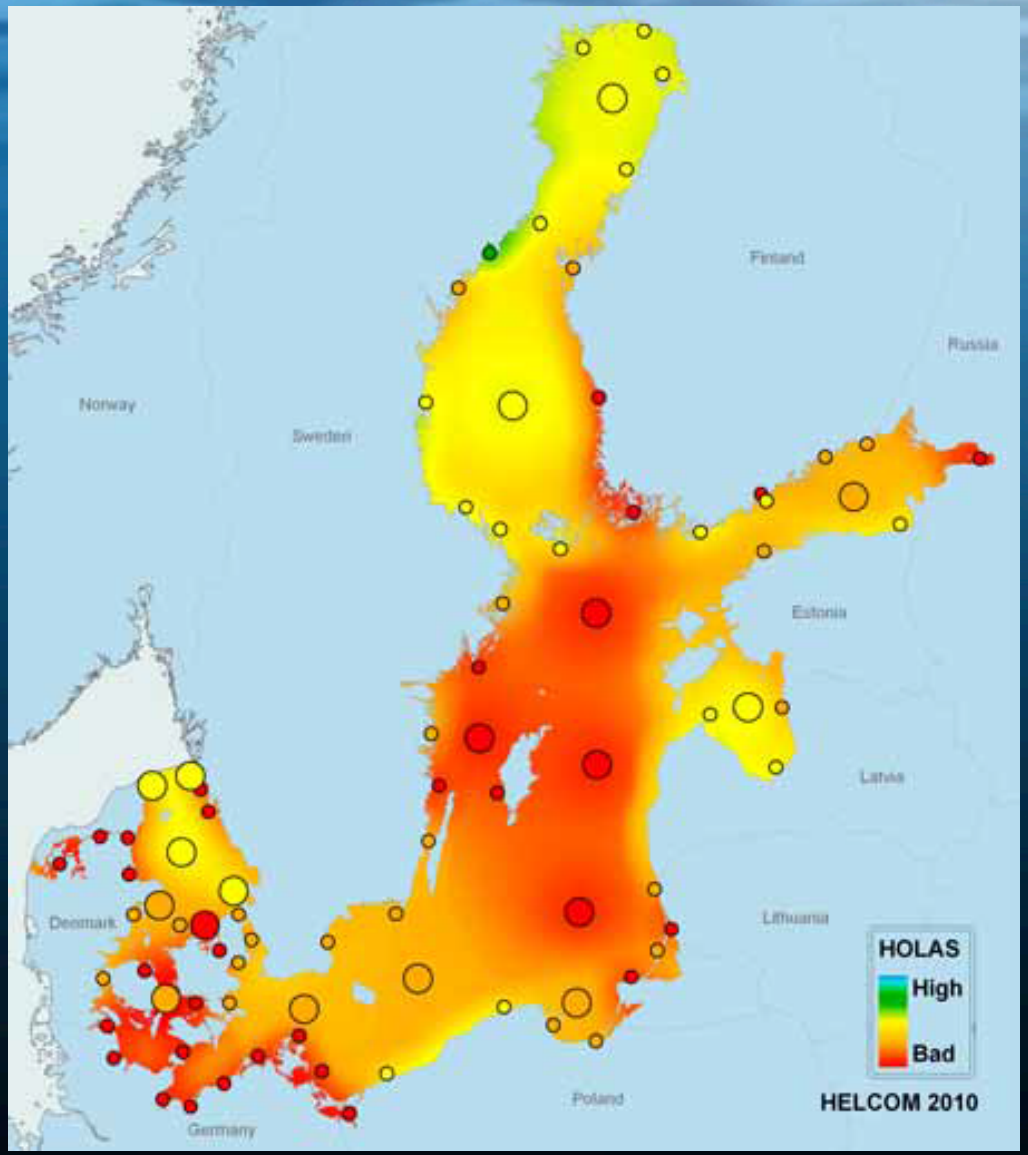


Biodiversity

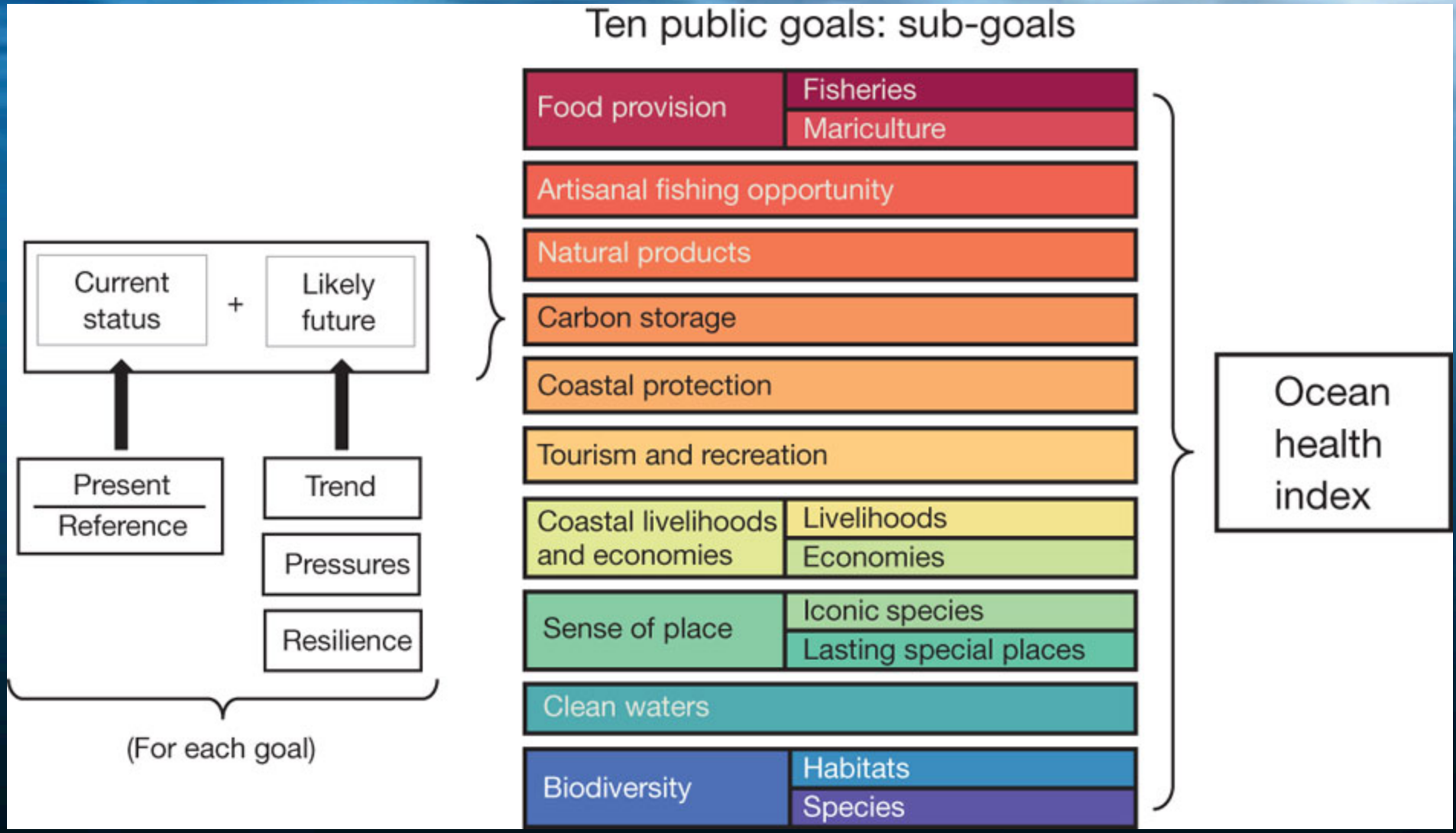
Baltic Sea Cumulative Impact Map



Baltic Sea Holistic Assessment (HOLAS) Tool

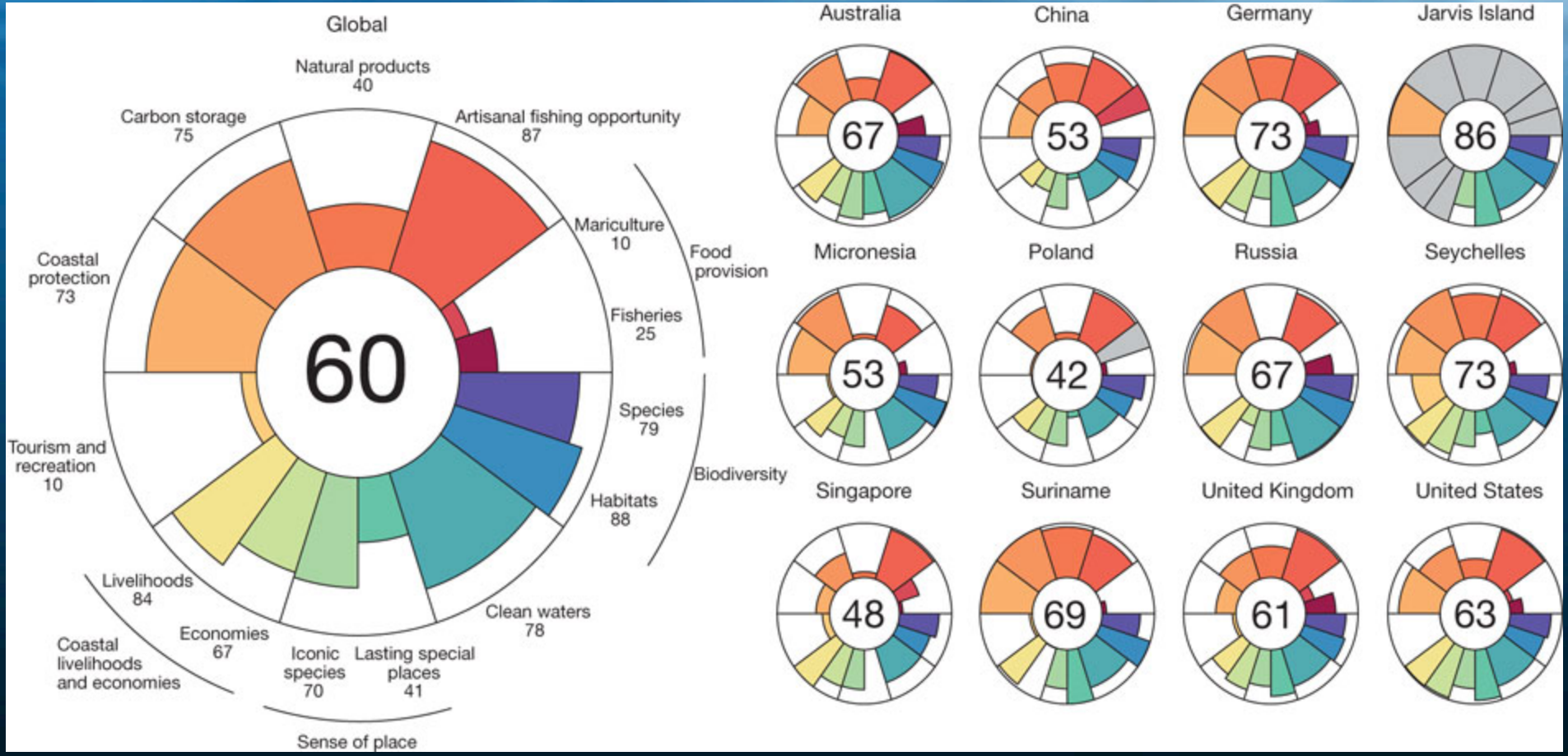


Humans as Part of the Ecosystem: Ocean Health and Benefits Index



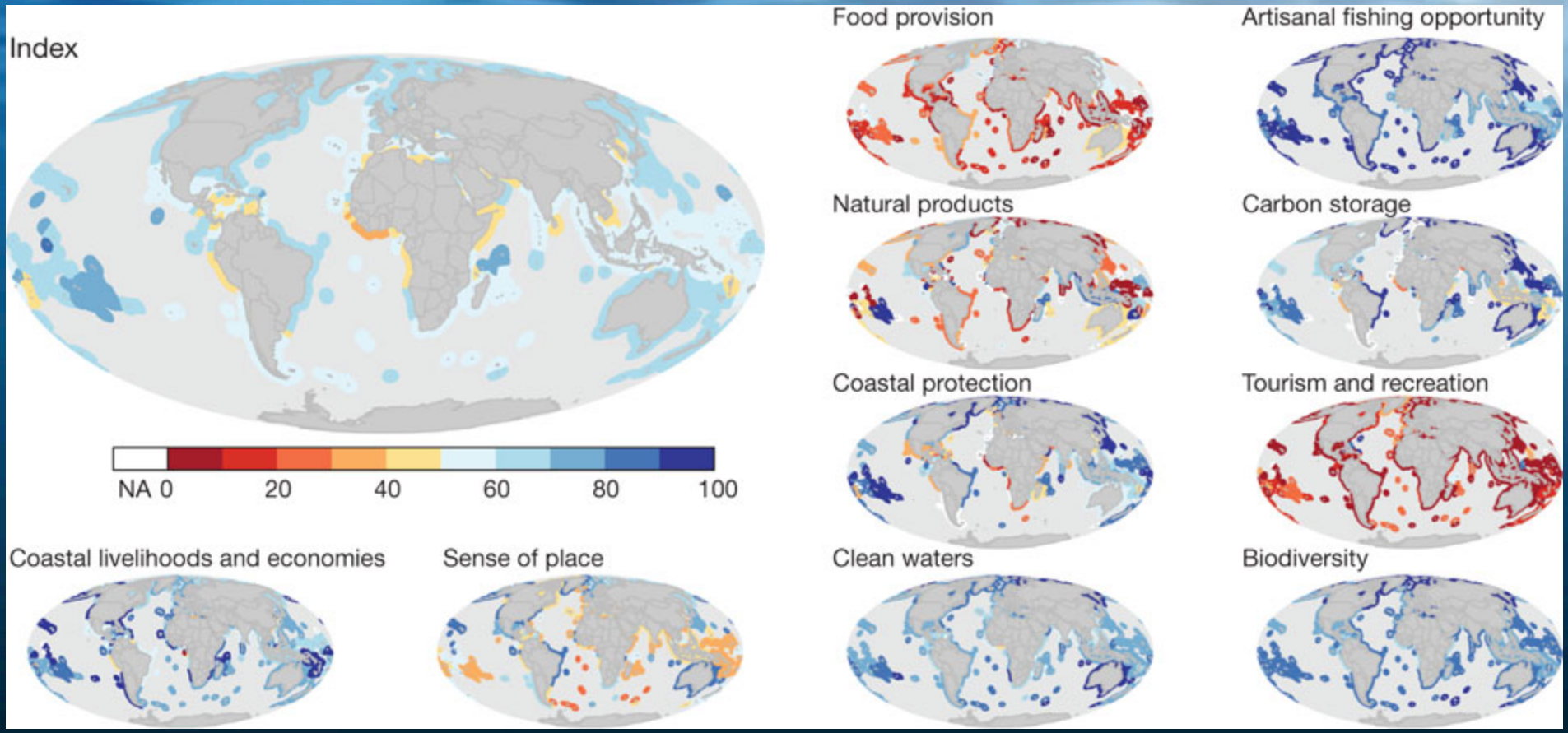
Source: Halpern et al. 2012. Nature 488: 615-622.

Global Score for Ocean Health and Benefits Index



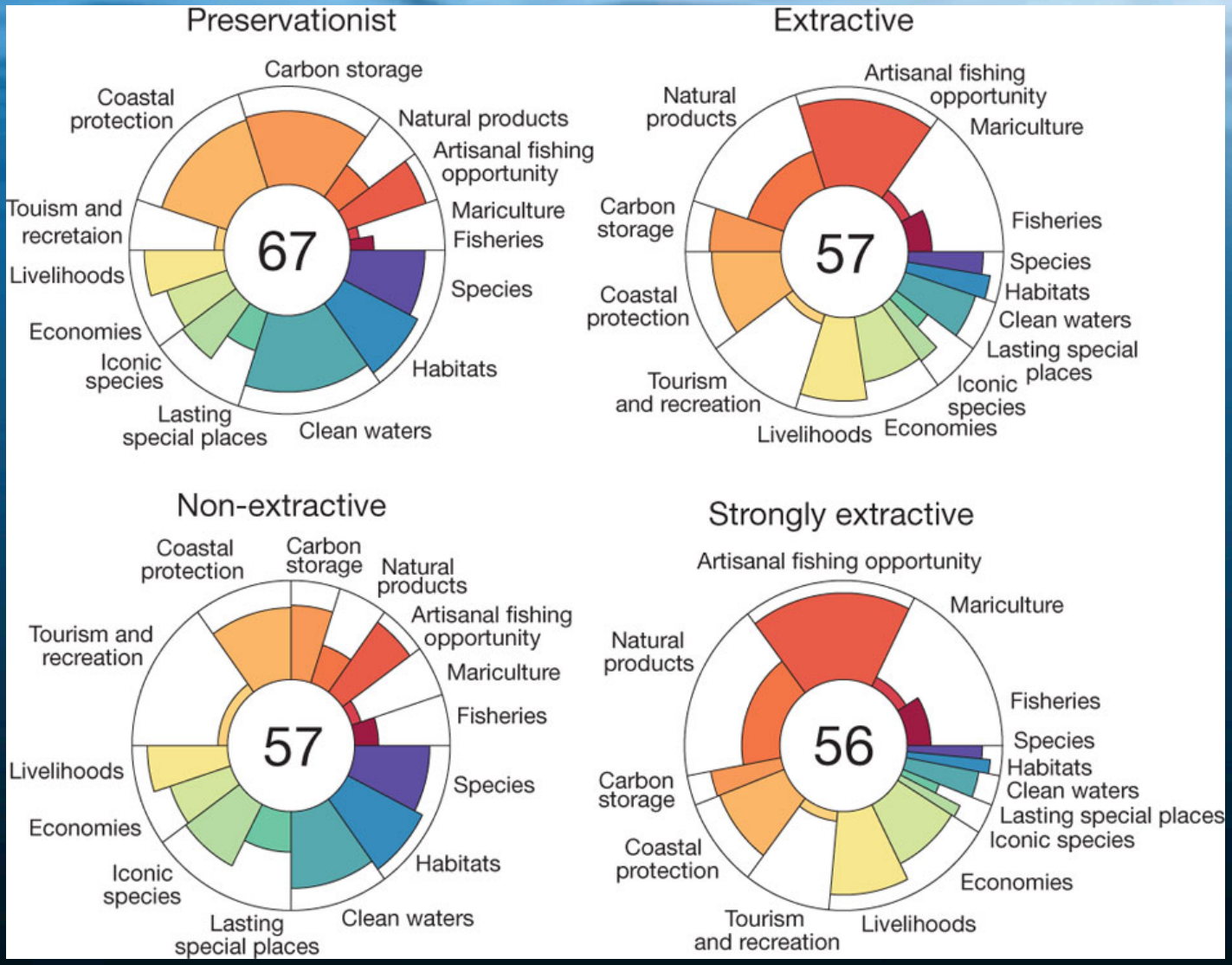
Source: Halpern et al. 2012. Nature 488: 615-622.

Global Distribution of Ocean Health and Benefits Index



Source: Halpern et al. 2012. Nature 488: 615-622.

Effects of Different Value Systems on Ocean Health and Benefits Index



Source: Halpern et al. 2012. Nature 488: 615-622.

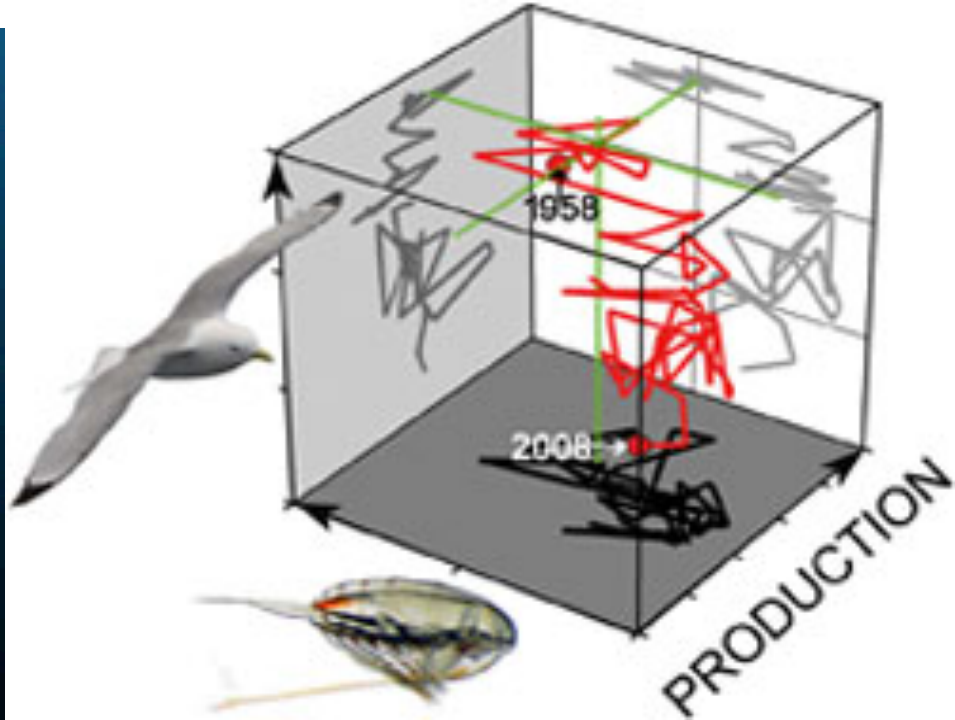
State-Space Approach

FREE ACCESS

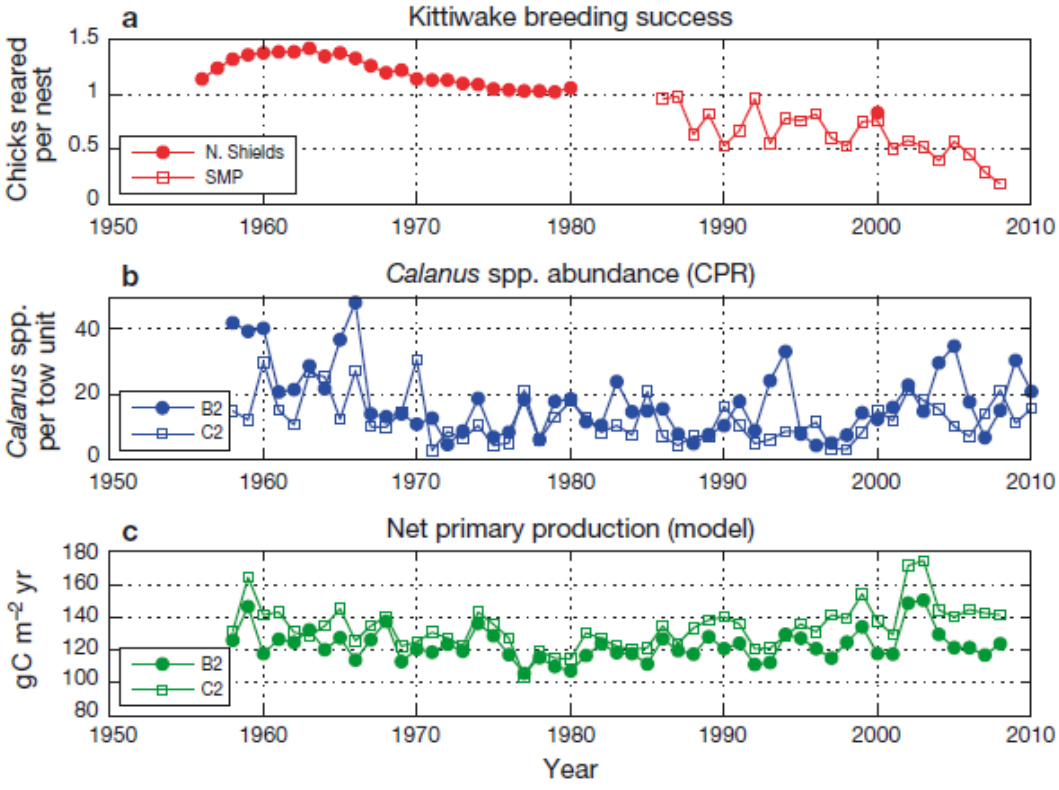
FEATURE ARTICLE: REVIEW

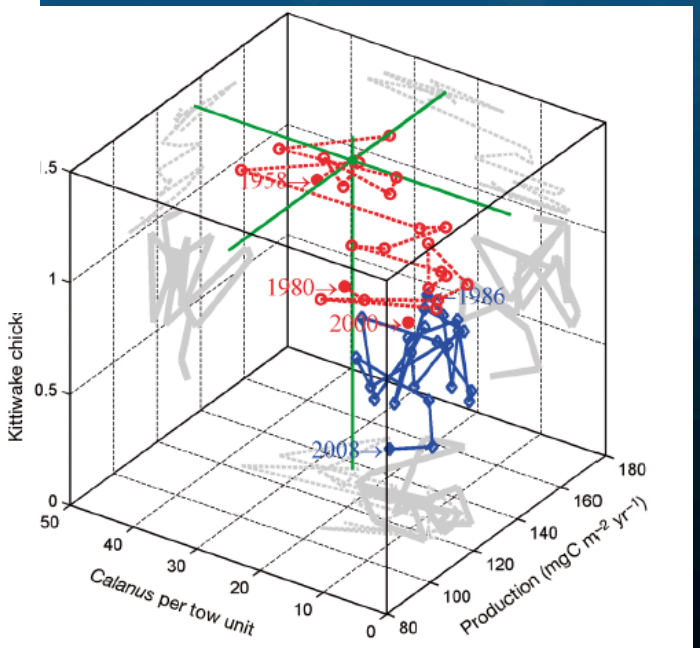
Framework for understanding marine ecosystem health

P. Tett[1,*], R. J. Gowen[2], S. J. Painting[3], M. Elliott[4], R. Forster[3], D. K. Mills[3], E. Bresnan[5], E. Capuzzo[3], T. F. Fernandes[6], J. Foden[3], R. J. Geider[7], L. C. Gilpin[8], M. Huxham[8], A. L. McQuatters-Gollop[9], S. J. Malcolm[3], S. Saux-Picart[10], T. Platt[10], M.-F. Racault[10], S. Sathyendranath[10], J. van der Molen[3], M. Wilkinson[6]



State-Space Approach





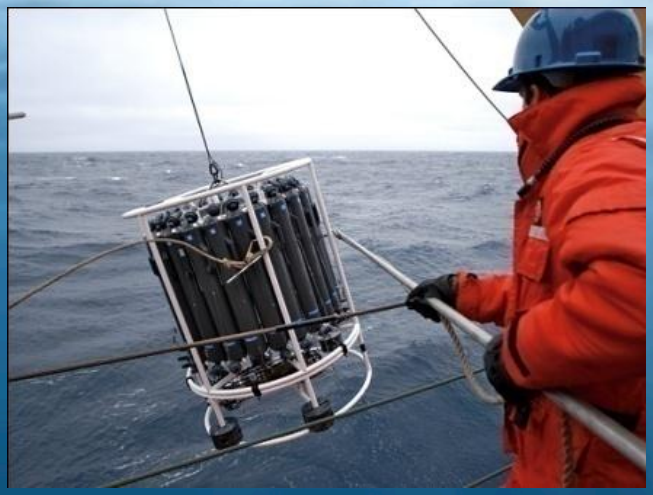
How do we measure biodiversity?

- Overview
- Current tools
- Gaps and challenges in measurement
- Operational needs for an observation network

How do we measure biodiversity?

Nets

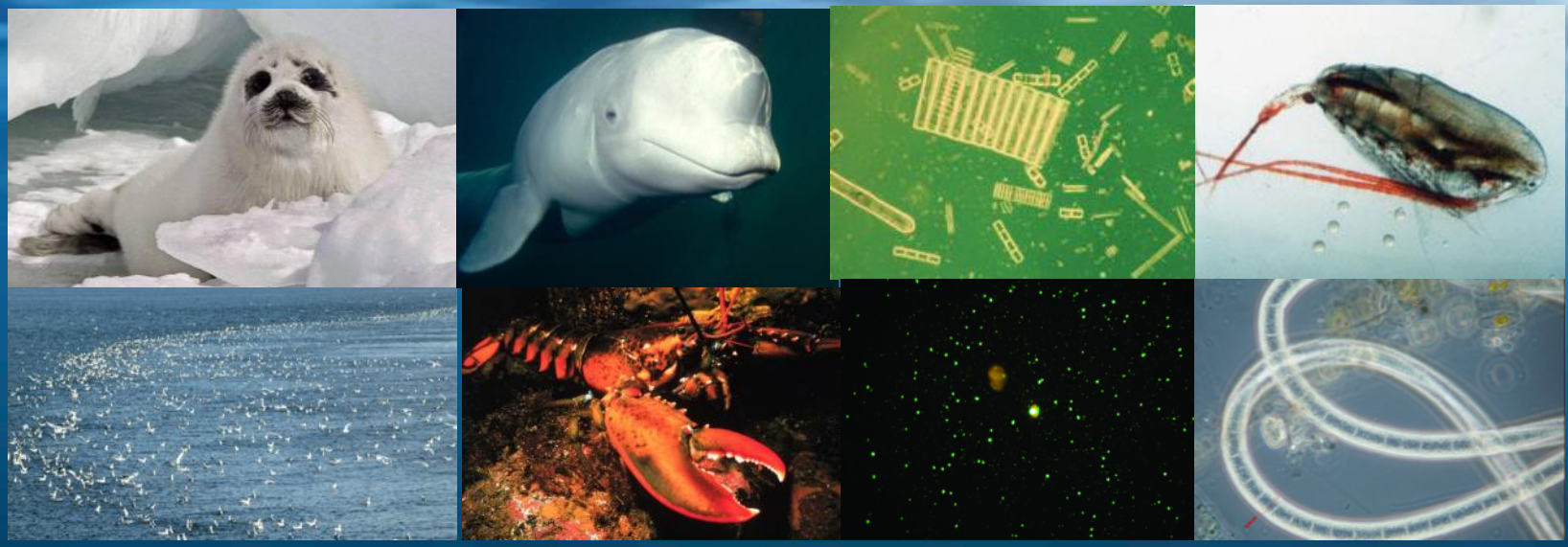
Bottles



Corers

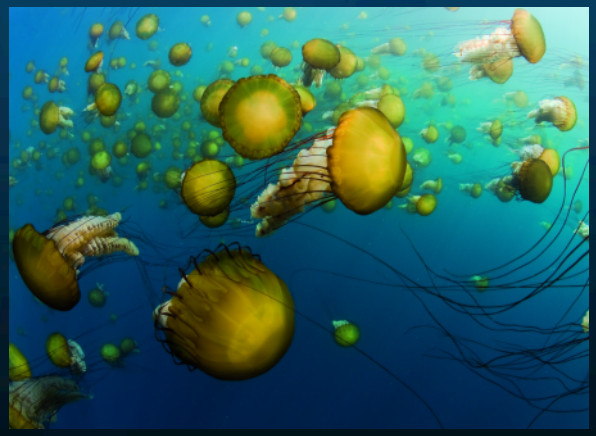
How do we measure biodiversity?

How do we measure biodiversity?



Large

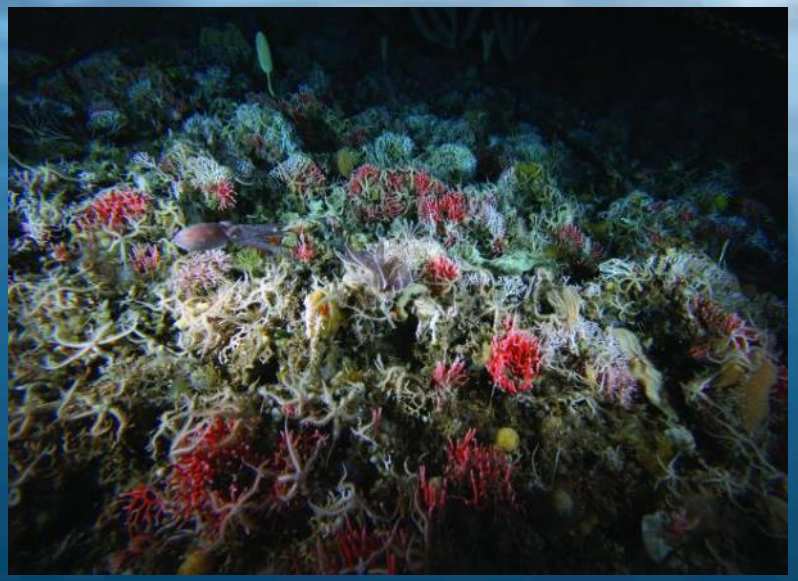
Small



Delicate

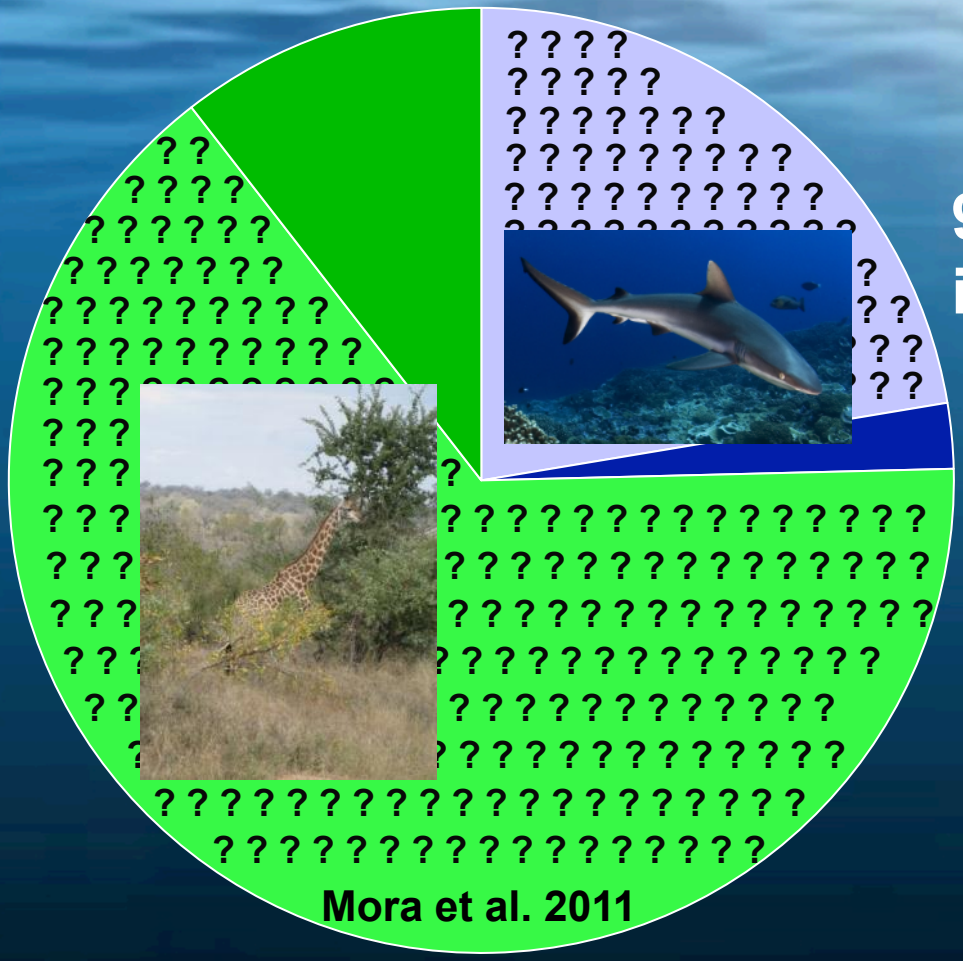
Mobile

How do we measure biodiversity?



How do we measure biodiversity?

Known & unknown



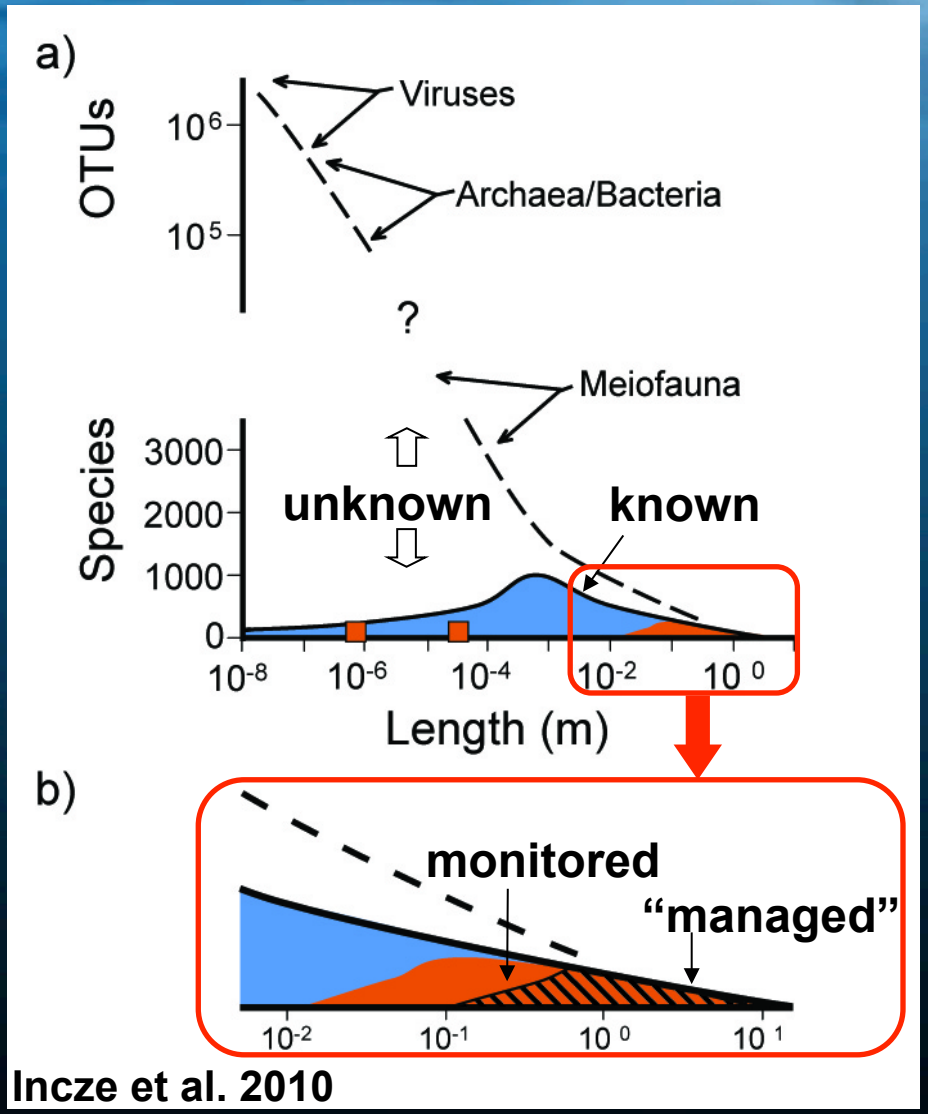
91% unknown in the ocean

2 million marine species (excluding bacterial groups)

WoRMS estimates about 230,000 legitimate named species

How do we measure biodiversity?

Some things harder to observe/monitor than others



Incze et al. 2010

A Directory of Marine Species

WoRMS
World Register of Marine Species

The Rise of WoRMS

- Misnamed
- Double names
- Misspelled names
- Shared names

56 names for *Halichondria panacea*

222,000 species so far

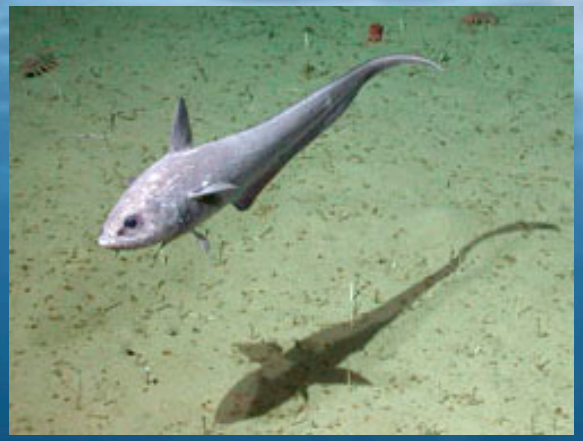
www.marinespecies.org

How do we measure biodiversity?

Defining biodiversity

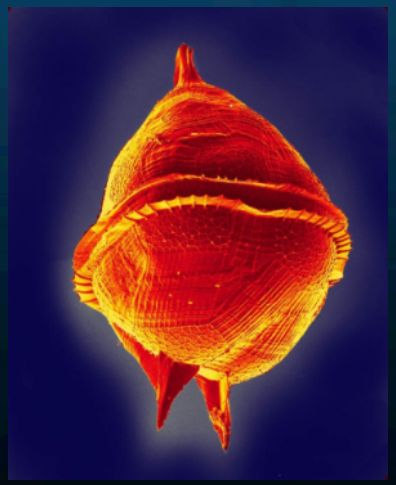
- Genetic
- Species
- Functional
- Habitat

How do we measure biodiversity?



Why genetics?

- Stress genes
- Function-linked genes (e.g. nitrification)
- Toxic species (e.g. PSP monitoring)



How do we measure biodiversity?

Why (individual) species?

- Species of economic/human interest

- Indicator species

- Problematic species

How do we measure biodiversity?

Why (multi-) species?

- Changes in diversity, dominance (richness, H', J' etc.)

- Ecosystem based
(function, food web linkages etc.)

How do we measure biodiversity?

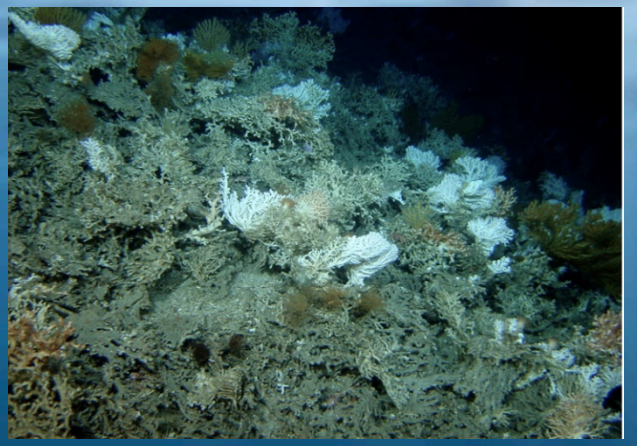
Why functional diversity?

- Keystone species
- Sustaining function

How do we measure biodiversity?

Why habitat diversity?

- Critical habitat
- Disturbance metric
- Surrogates



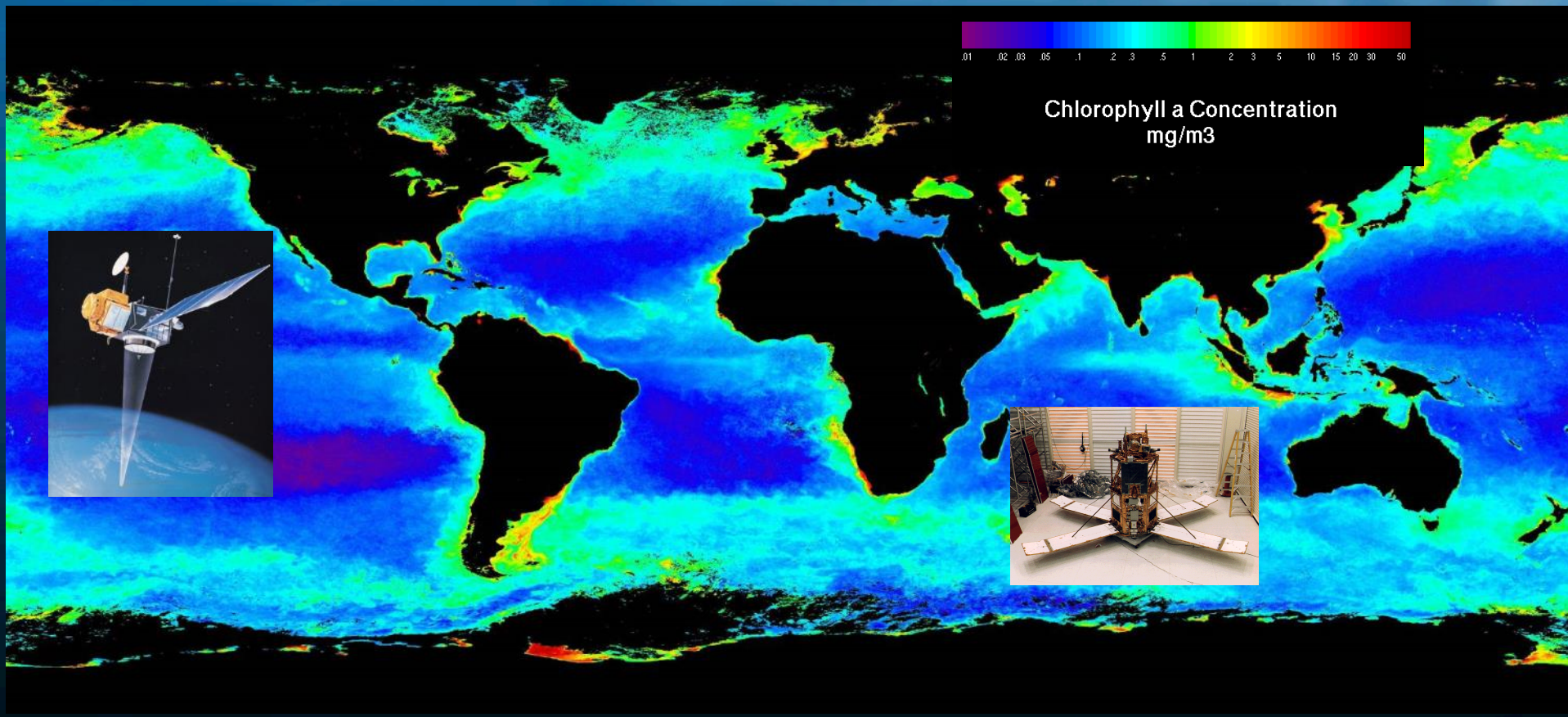
Towards a Biodiversity/Ocean Health Observation Network

The **SPATIAL** Challenge

The **SENSOR** Challenge

The **TEMPORAL** Challenge

The **PLATFORM** Challenge



What about non-pigmented organisms below the surface?

Towards a Biodiversity/Ocean Health Observation Network - Sensors

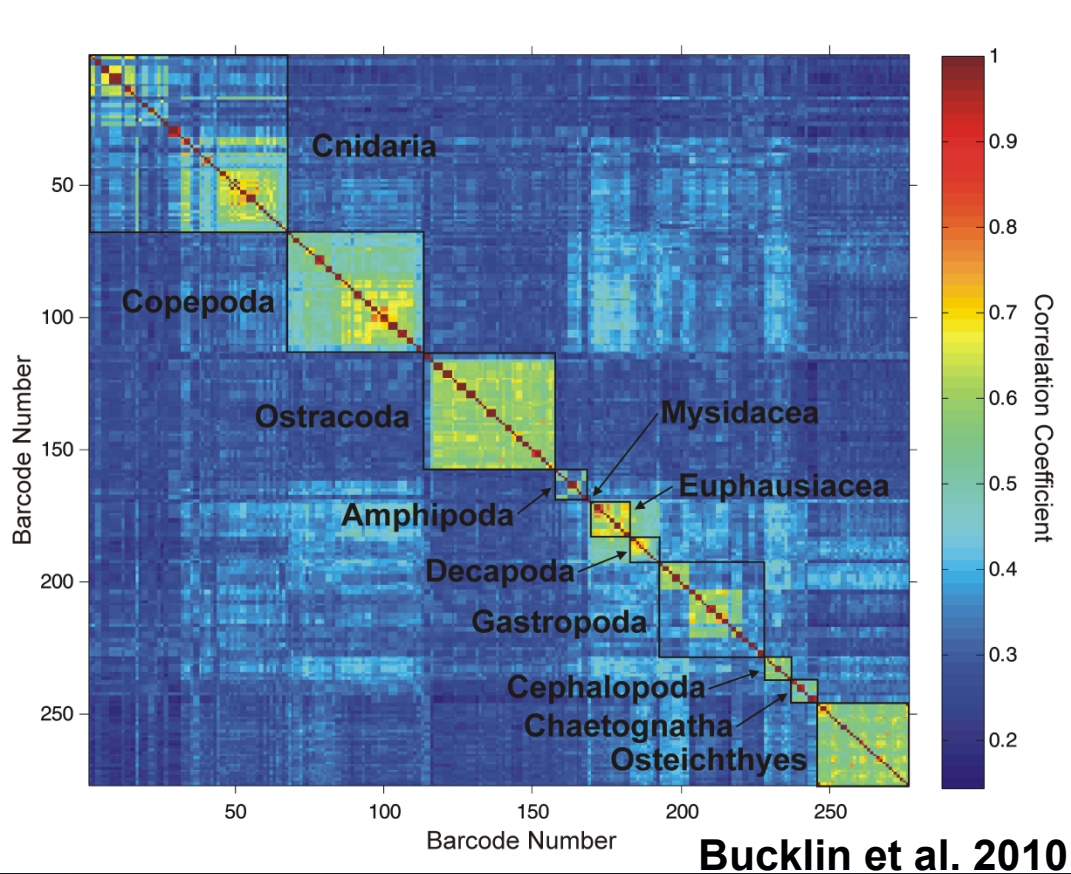
In situ / real time monitoring report card

		Health/ Function
Physics	A+	
Geochemistry	B-	
Biology		
Pigmented	A	A+
Microbes	B-	A-
Zooplankton	B-	B
Nekton	C	B
Benthic epifauna	B-	A
Benthic infauna	F	A-

Two major breakthroughs…

- Digital imaging & analysis
- Genetic tools

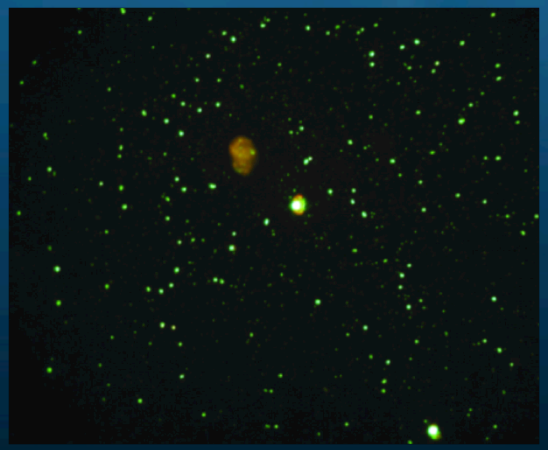
Towards a Biodiversity/Ocean Health Observation Network - Sensors



Bucklin et al. 2010

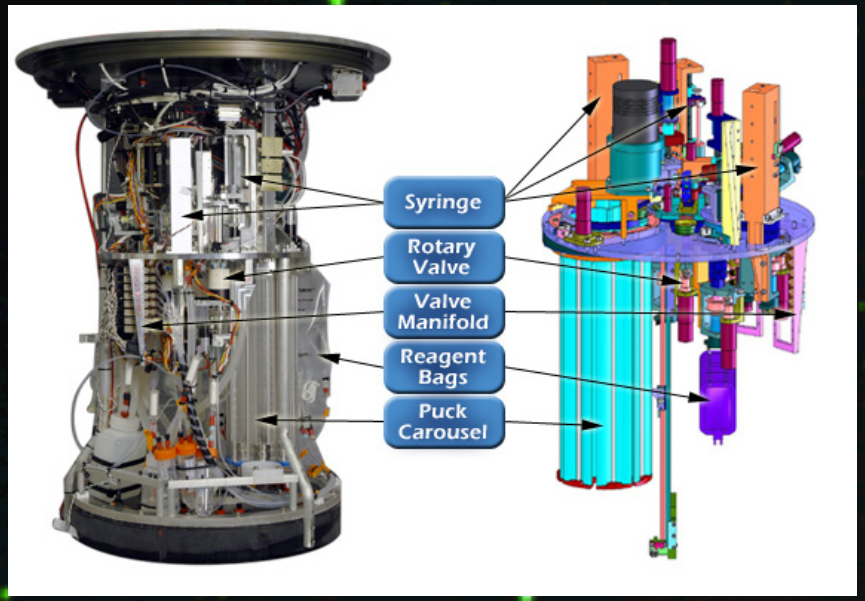
Genetic barcoding with COI gene,

Compare taxa over time, among regions



For microbes, 454 pyrosequencing

Towards a Biodiversity/Ocean Health Observation Network - Sensors

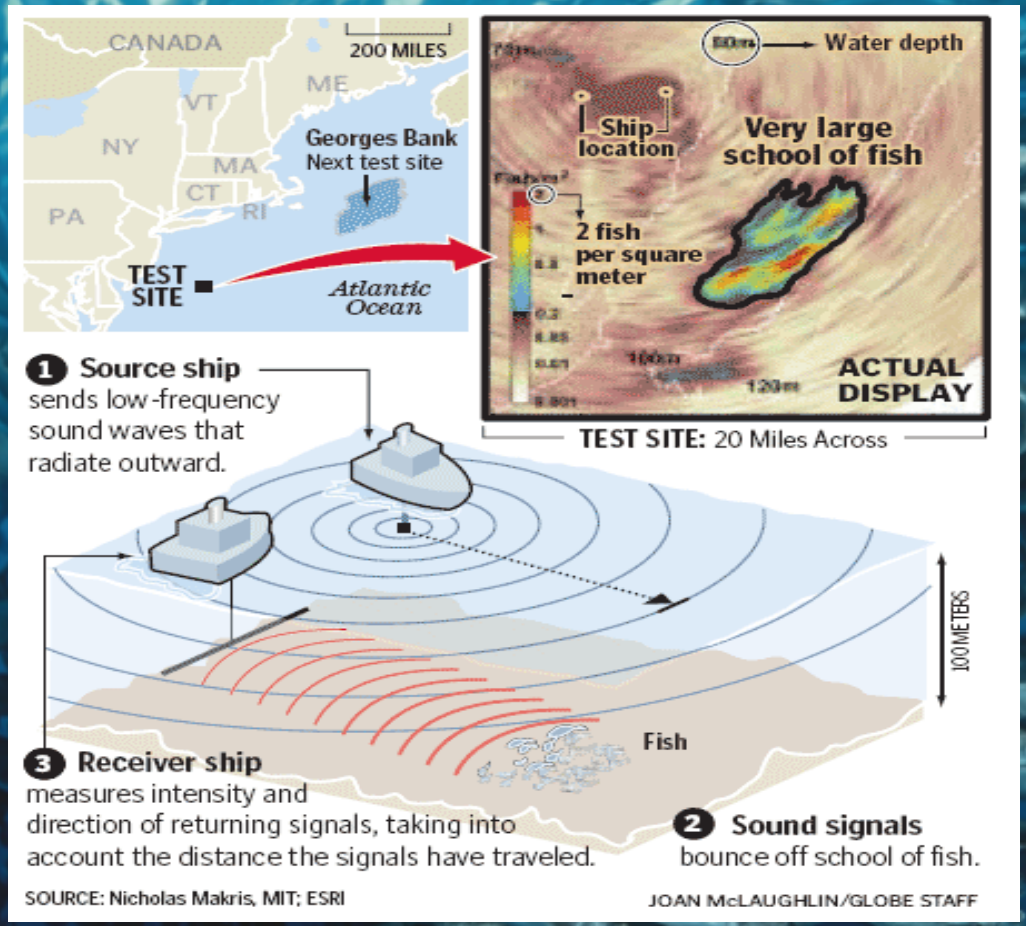


Environmental Sample Processor (*in situ* molecular lab)

Flow Cytobot (*in situ* flow cytometer)

Promising for real time microbial sampling (gene expression, community)

Towards a Biodiversity/Ocean Health Observation Network - Sensors

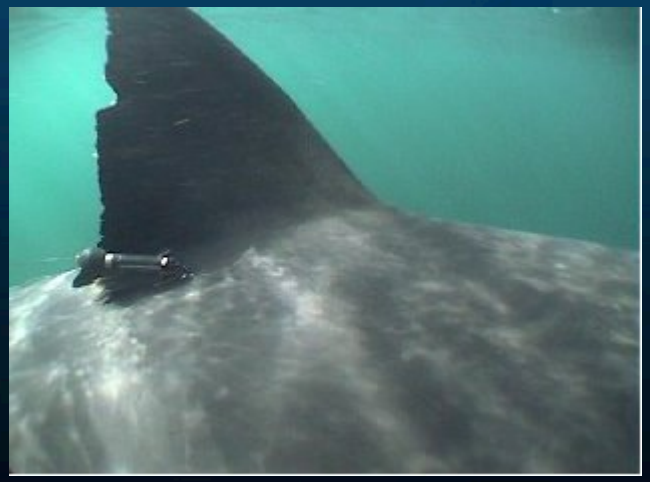


Promising for real-time nekton sampling

Towards a Biodiversity/Ocean Health Observation Network - Sensors

Promising for real-time zooplankton sampling

Towards a Biodiversity/Ocean Health Observation Network - Sensors



Good success in real time fish tracking

Towards a Biodiversity/Ocean Health Observation Network - Platforms

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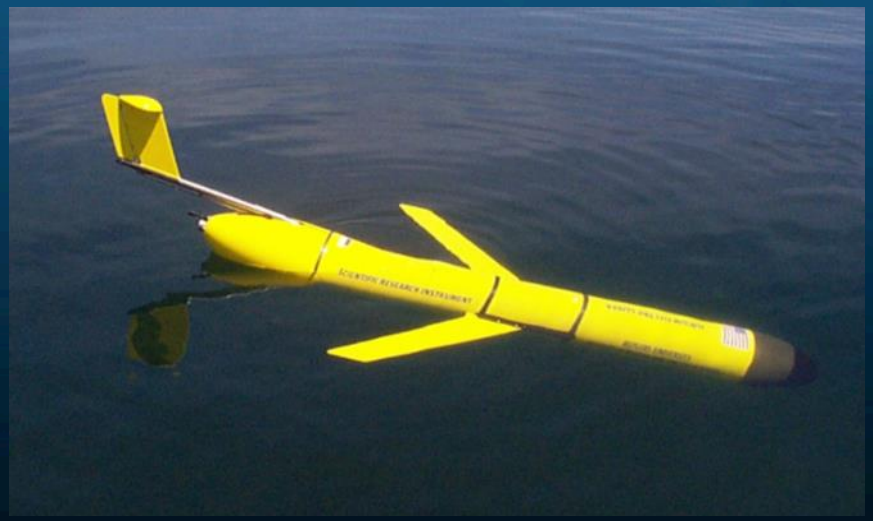
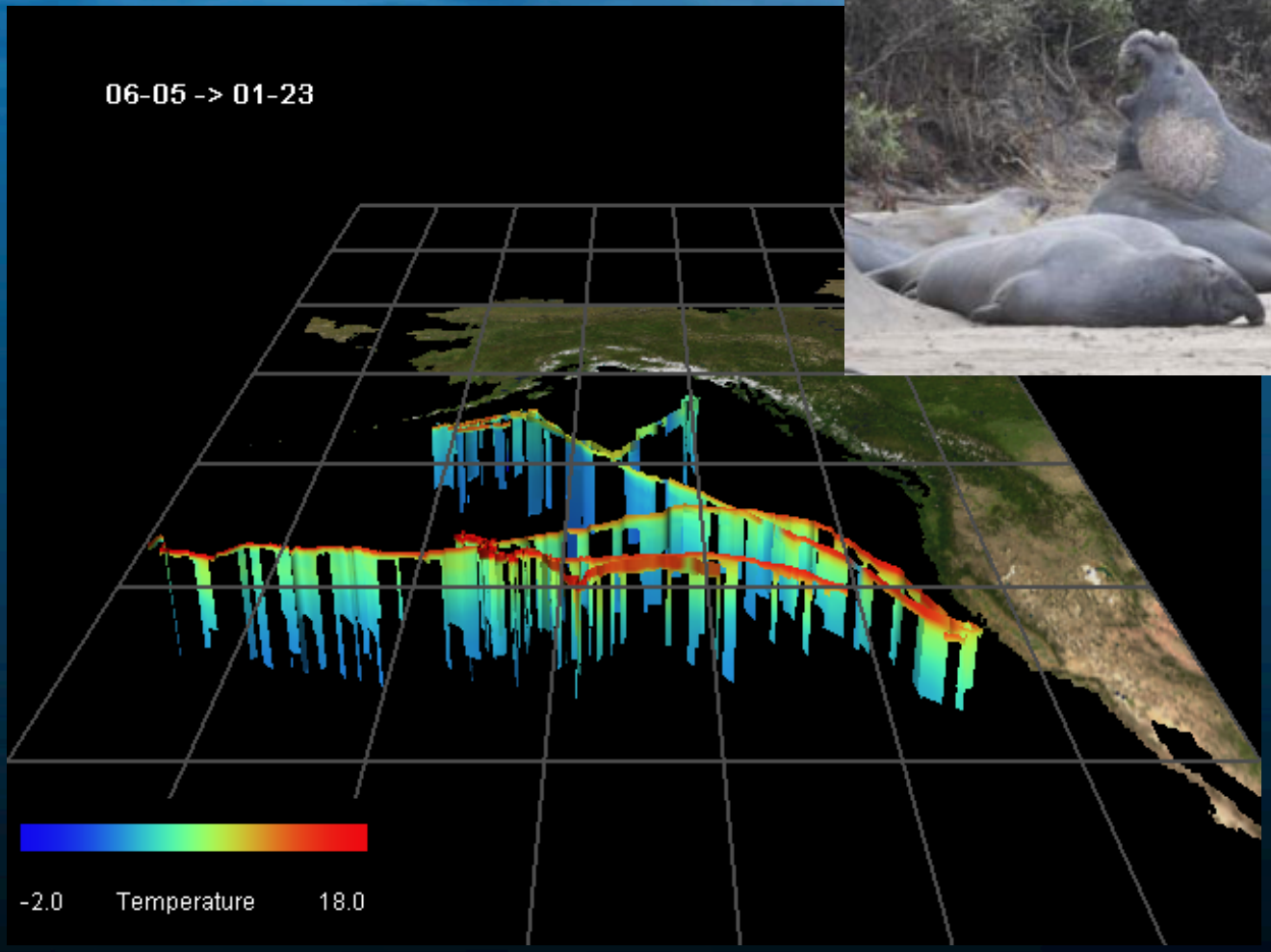


Towards a Biodiversity/Ocean Health Observation Network - Platforms



Towards a Biodiversity/Ocean Health Observation Network

Sensor limitations

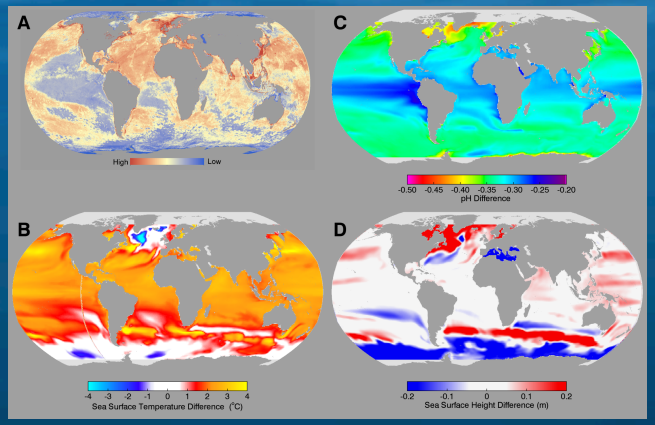
- **Very limited suite for biology**
- **Calibration, drift in others**

Platform limitations

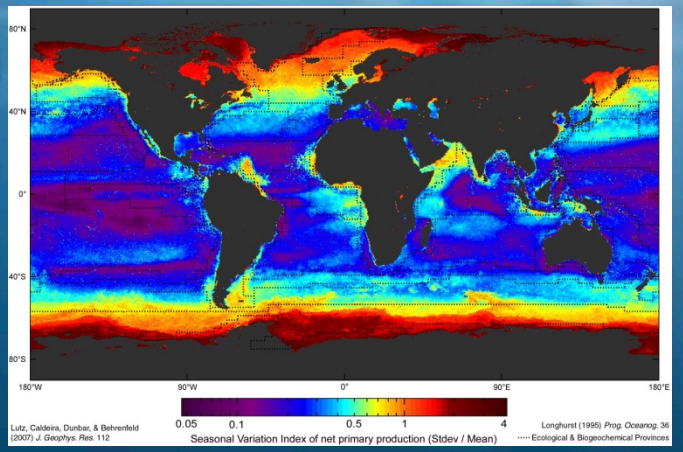
- Payload constraints (e.g. gliders)
- Spatial resolution (e.g. cabled observatories)

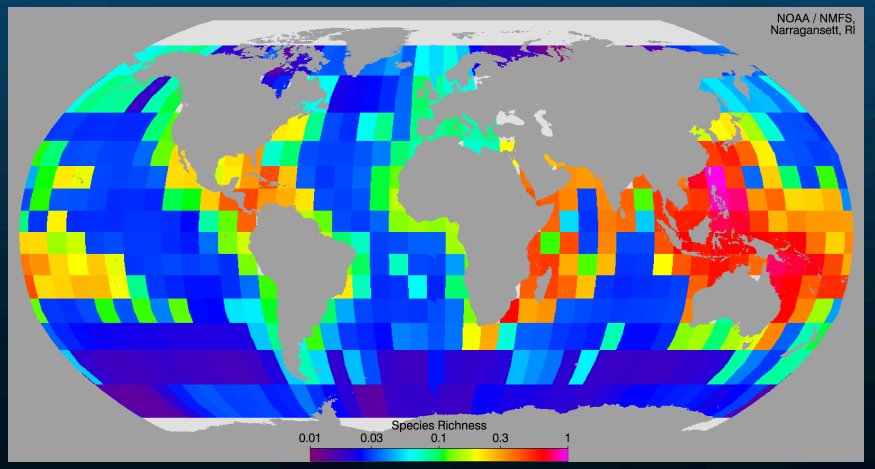
Towards a Biodiversity/Ocean Health Observation Network

Priority locations, systems…developing criteria for selection

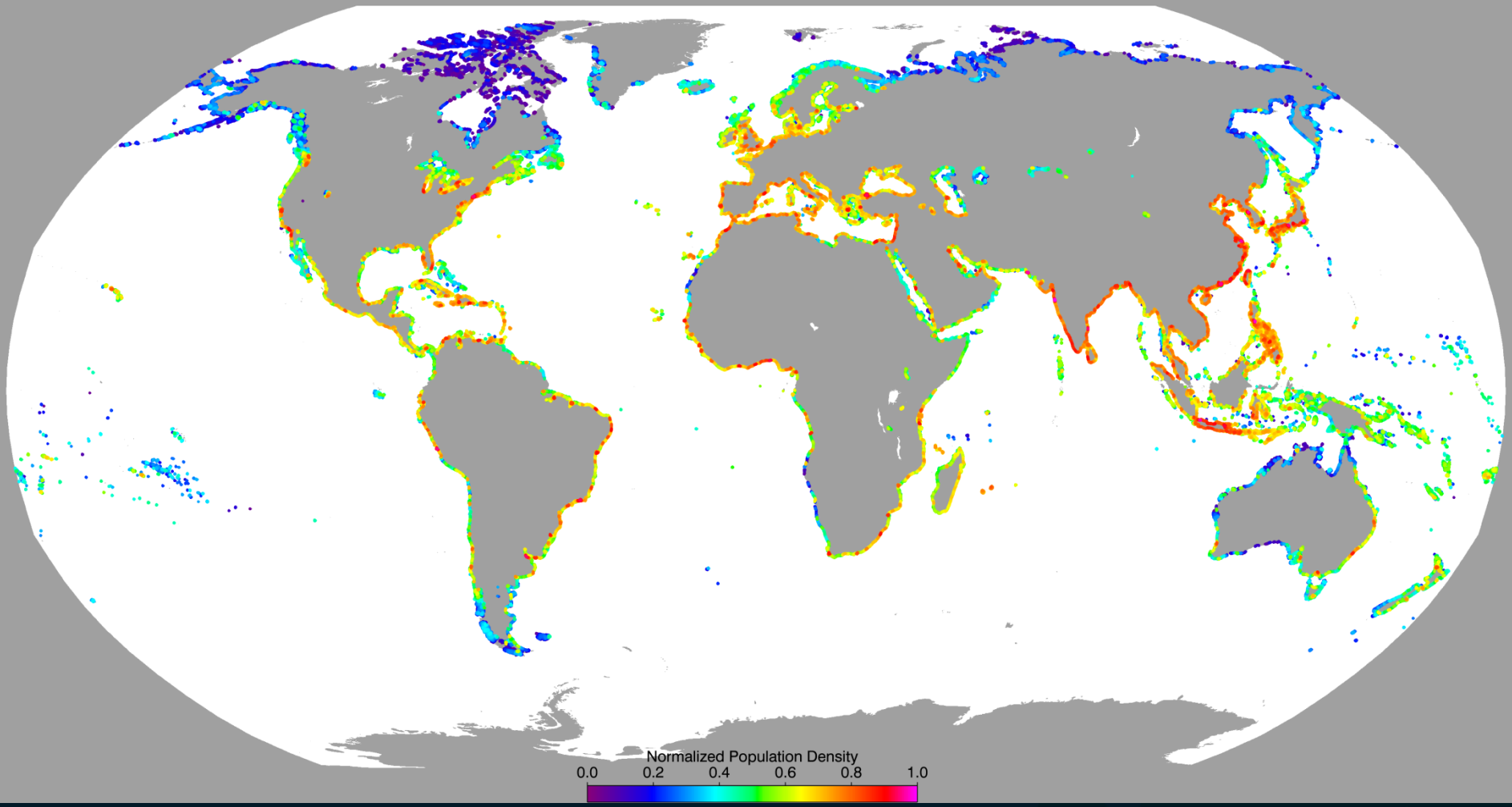


- Existing strengths vs. gaps
- Threats
- Functions
- Representation
- Hotspots



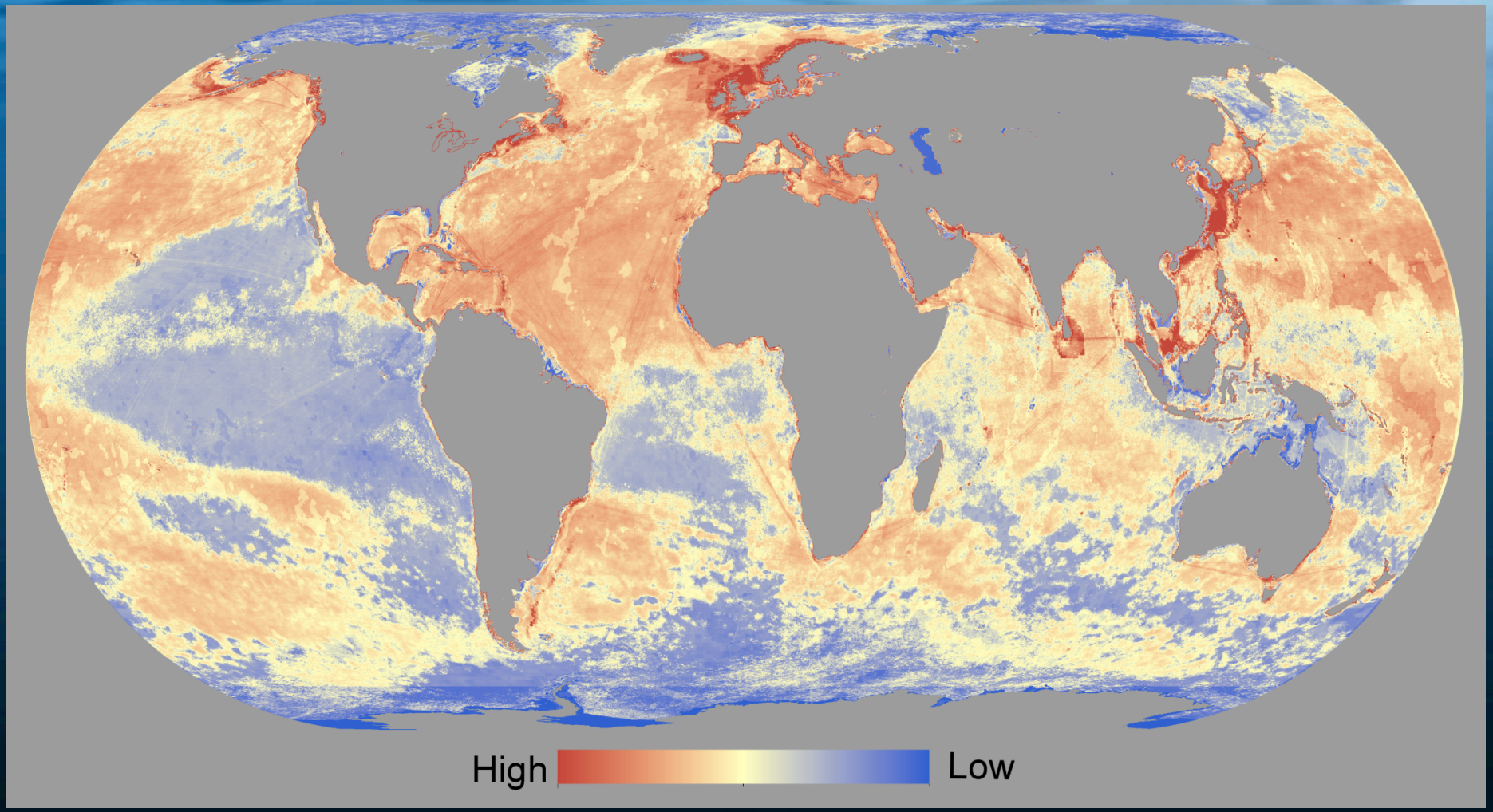


Drivers: Human Coastal Population Density



Source: Halpern et al. 2008. Science 319:948-952

Cumulative Impacts of Human Activities in the Ocean



Source: Halpern et al. 2008. Science 319:948-952