Implications of fisheries impacts to seafloor biodiversity and Ecosystem-Based Management

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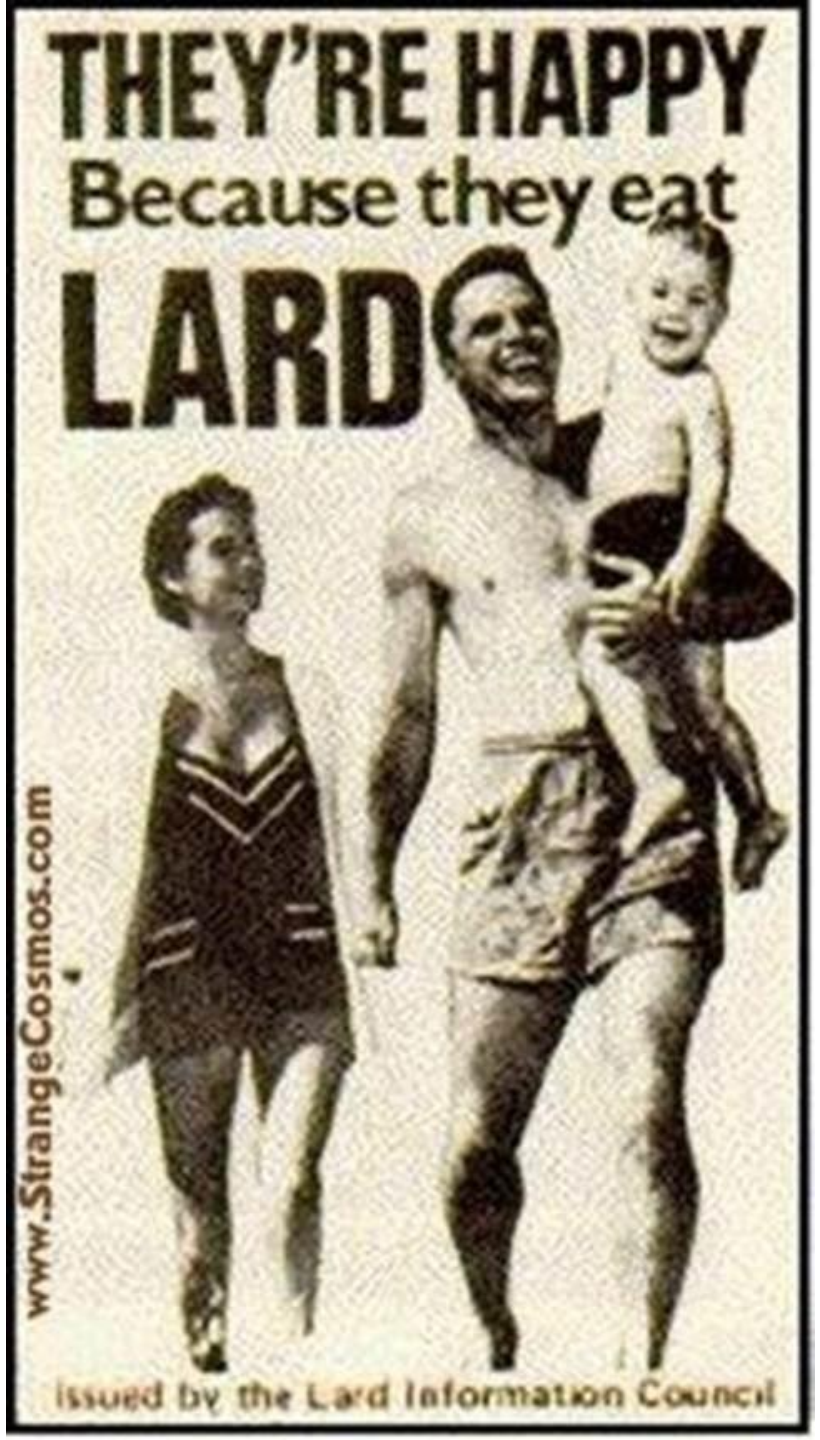
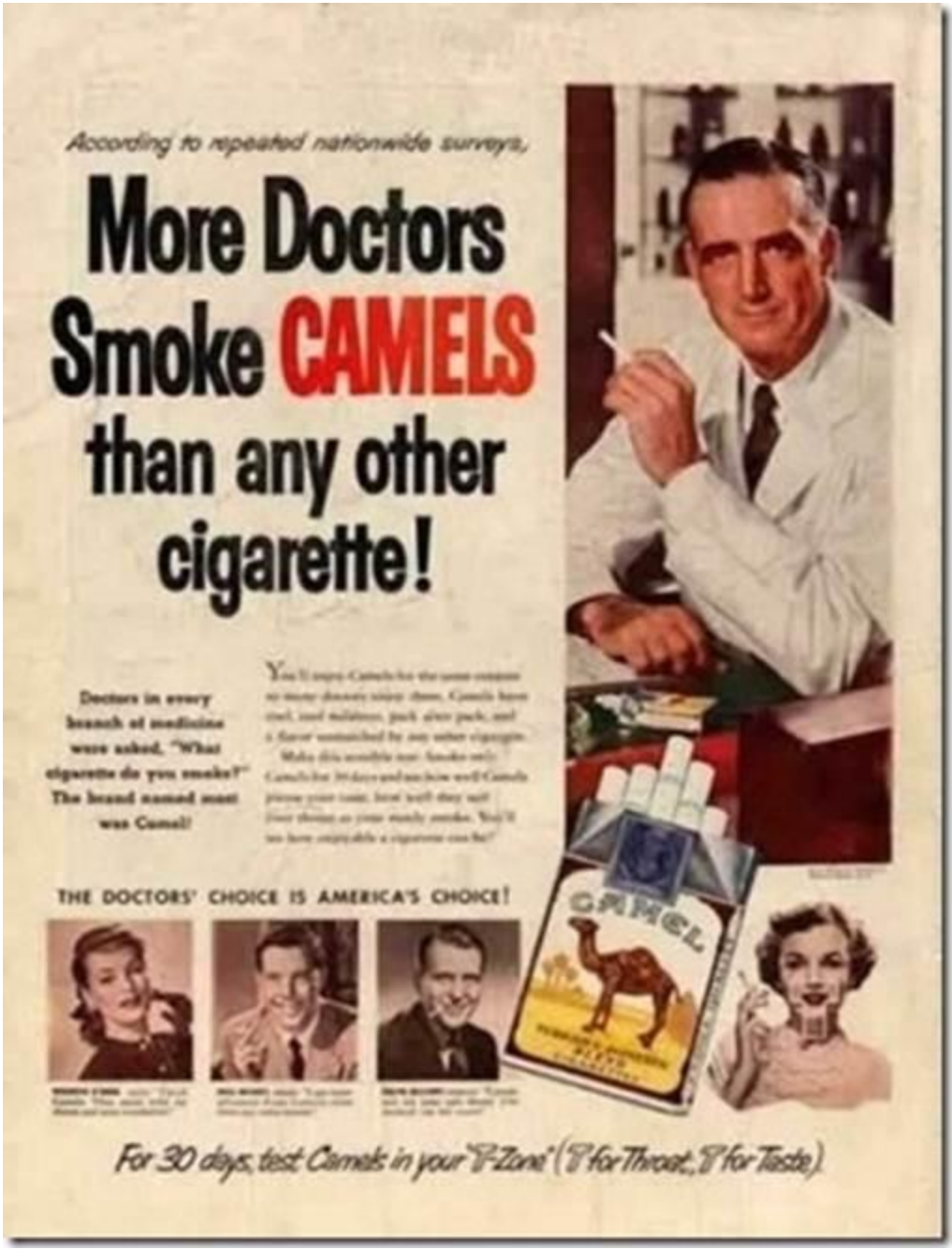
New Zealand

ICES symposium - The Effects of Fishing on Benthic Fauna, Habitat and Ecosystem Function, Tromsø, June 16-19.


THEY'RE HAPPY
Because they eat
LARD
www.StrangeCosmos.com
issued by the Lard Information Council


According to repeated nationwide surveys,
More Doctors Smoke CAMELS than any other cigarette!
Doctors in every branch of medicine were asked, "What cigarette do you smoke?" The brand named most was Camel!
THE DOCTORS' CHOICE IS AMERICA'S CHOICE!
CAMEL
For 30 days, test Camels in your "T-Zone" (T for Throat, T for Taste)

So the point is societal values change

Figure 1-VIII
The average size of cod has fallen over the last fifty years[12]

TURNING THE TIDE:

ADDRESSING THE IMPACT OF FISHERIES ON THE MARINE ENVIRONMENT

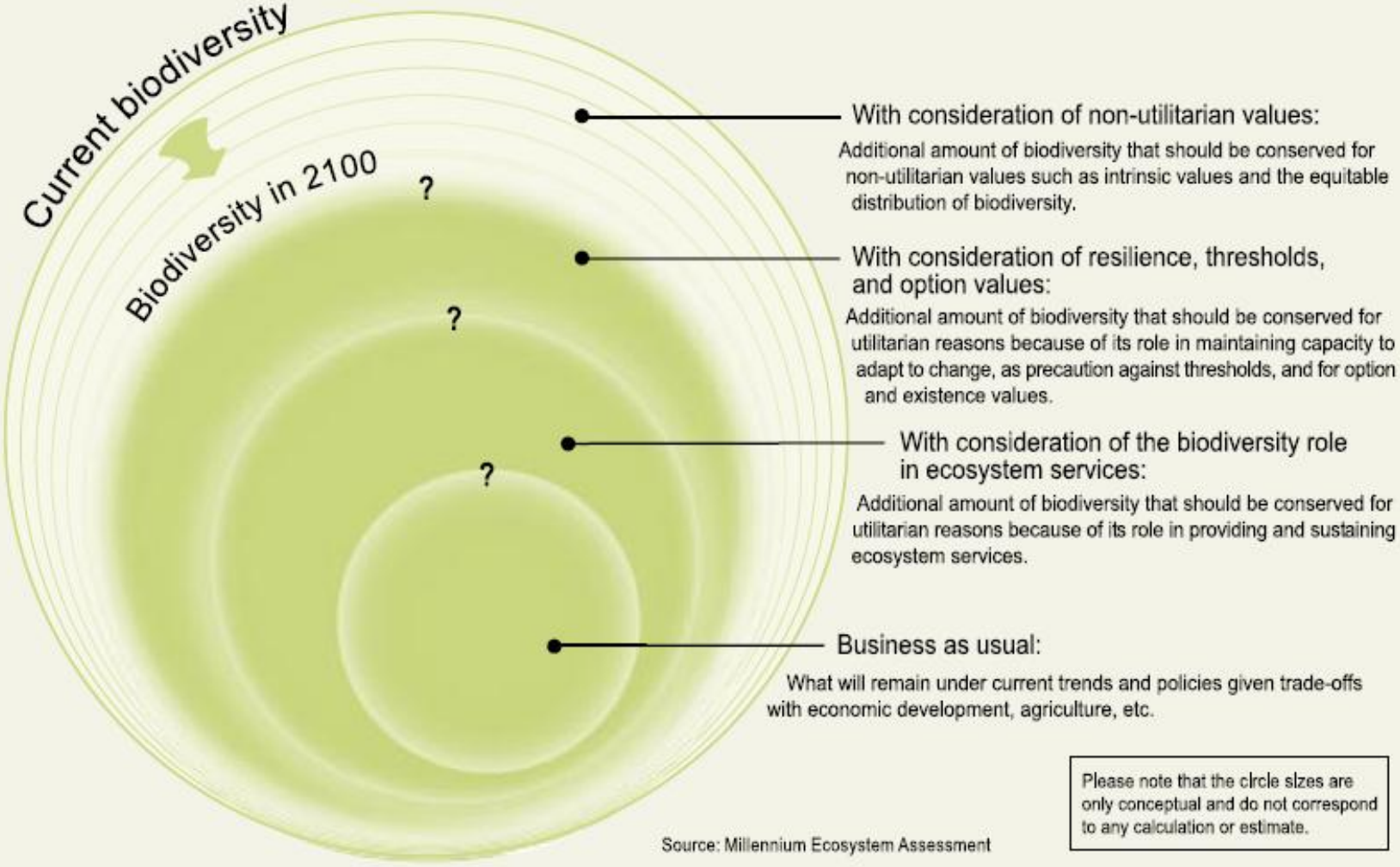
Shrinking biodiversity

Recognition of critical issues

Future values and services

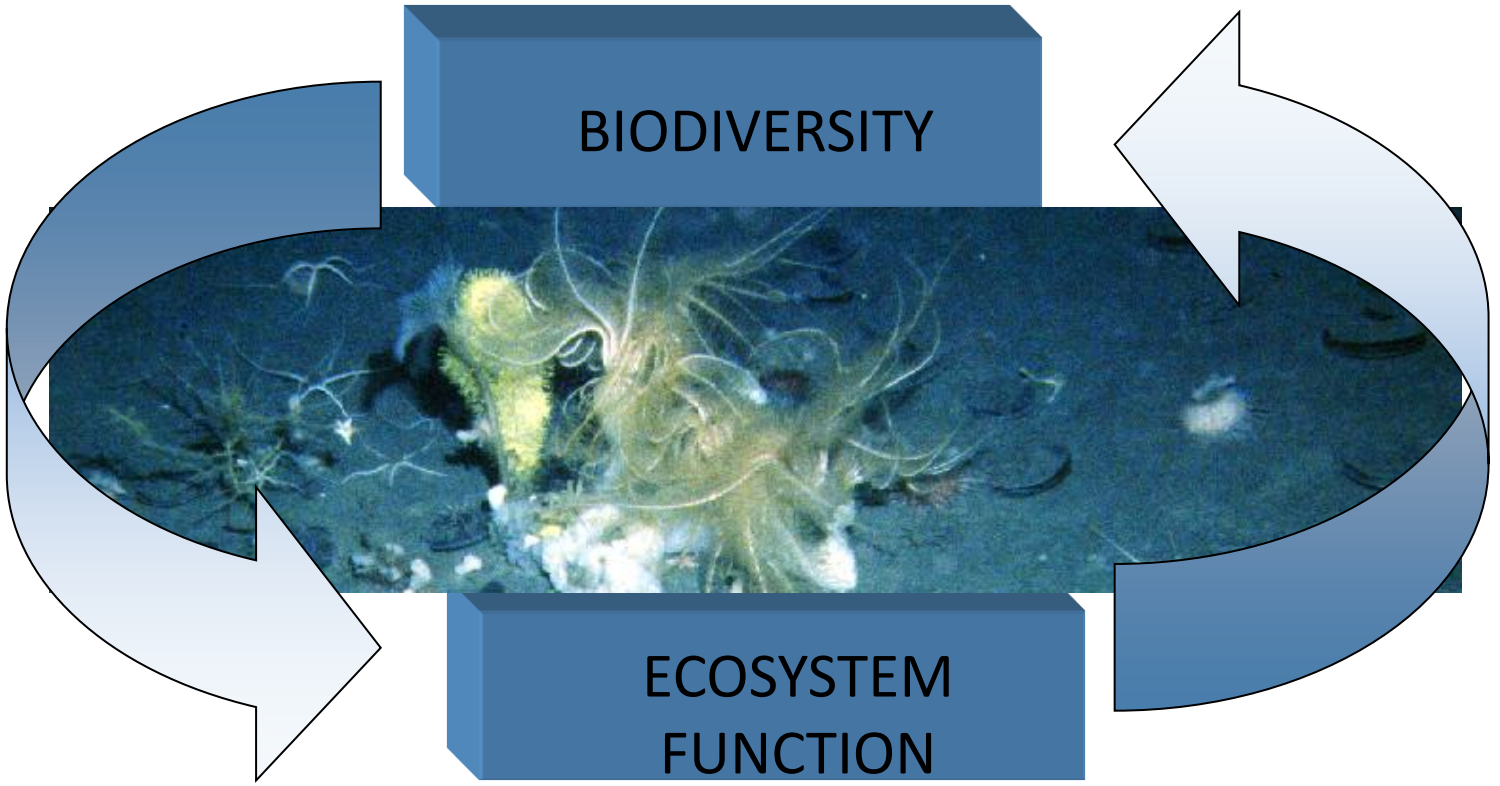
Figure 2. How Much Biodiversity Will Remain a Century from Now under Different Value Frameworks?

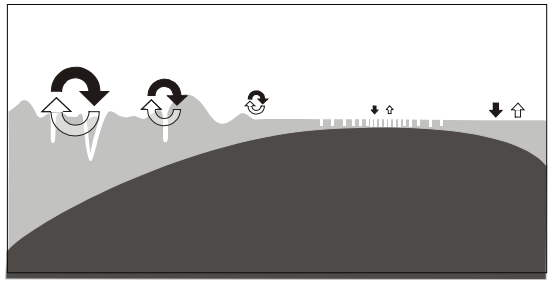
The outer circle in the Figure represents the present level of global biodiversity. Each inner circle represents the level of biodiversity under different value frameworks. Question marks indicate the uncertainties over where the boundaries exist, and therefore the appropriate size of each circle under different value frameworks.

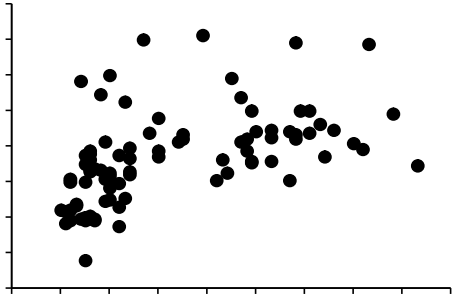


Source: Millennium Ecosystem Assessment

Why biodiversity matters





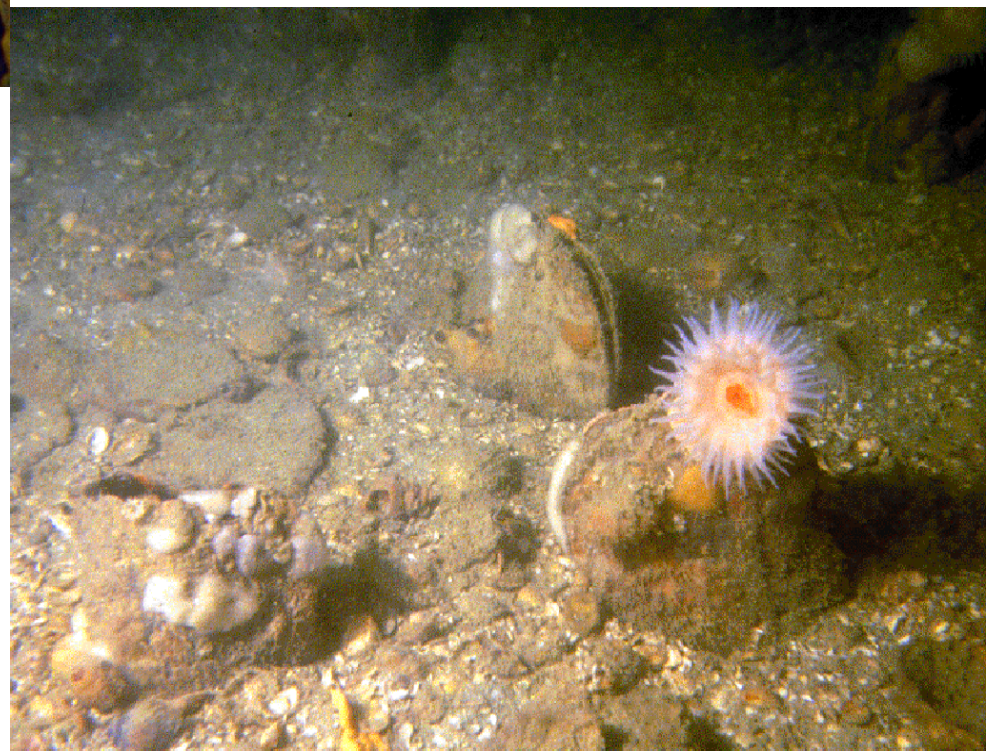


Thrush, S. F., and A. M. Lohrer. 2012. *in Marine biodiversity futures and ecosystem functioning Frameworks, methodologies and integration. Oxford University Press*

Organisms create much of their habitat's structure

- Habitat diversity

Organisms provide refugia, juvenile habitat, settlement sites and food



Hydrodynamic interactions influence sediment stability and the transport of food, larvae, sediments and chemical

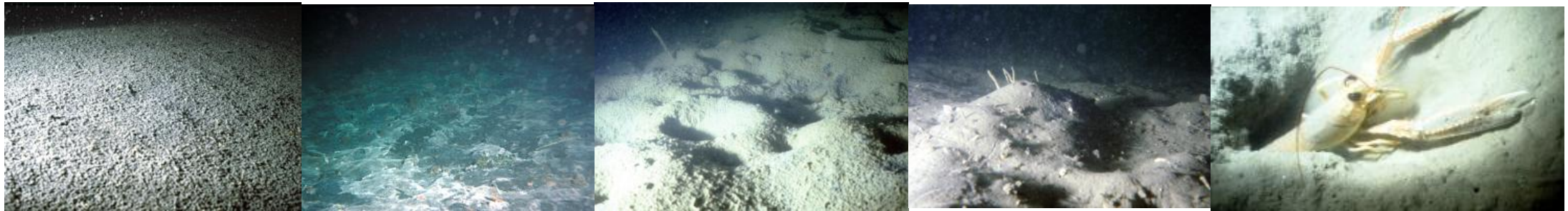
Organisms influence biogeochemical processes, such as carbon and nutrient exchange

Density, size and the spatial arrangement of organisms can be important influences on ecological, hydrodynamic and biogeochemical processes

Disturbance to the seafloor - Cumulative impacts and resilience - When small changes matter

"Loss of resilience frequently implies escalating degradative ecological change as alterations in the disturbance regime feedback onto local and regional changes in ecological communities"

Folke, *et al.* (2004) *A. Rev. Ecol. Syst.* 35, 557-581



Terrestrial Ecosystems

- Habitat loss, fragmentation, and homogenization of natural communities alter the patterns of connectivity, potentially isolating populations and communities and limiting them to suboptimal habitats
- A major threat to biodiversity

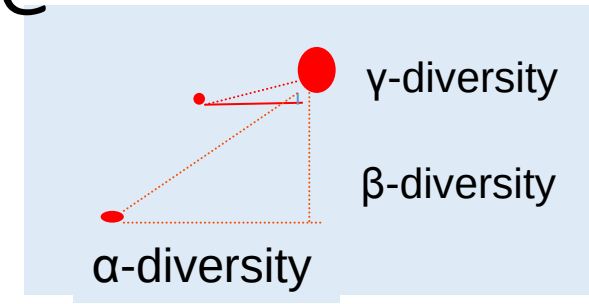
Fahrig, L. 2003. Annual Review of Ecology and Systematics 34:487–515.

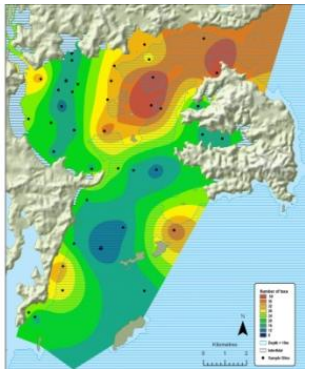
Marine Ecosystems?

- Marine ecosystems are not so open
- Limits to dispersal and decreased connectivity are important constraints on the resilience of benthic communities

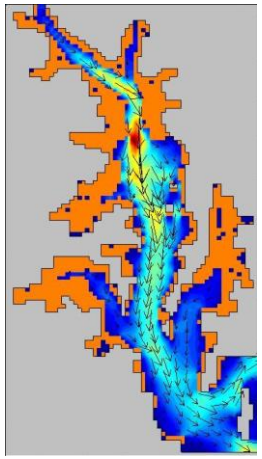
Disturbance & Resilience

Is there a potential for cumulative effects and loss of resilience?

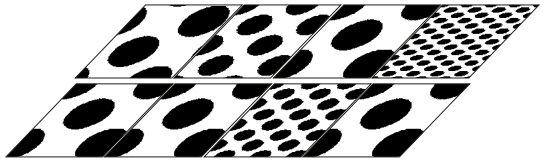




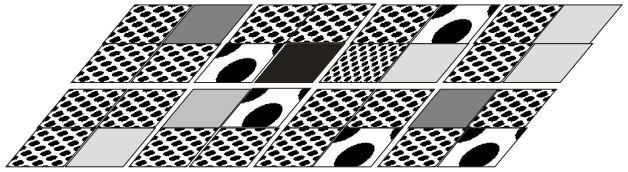
Ecological connectivity



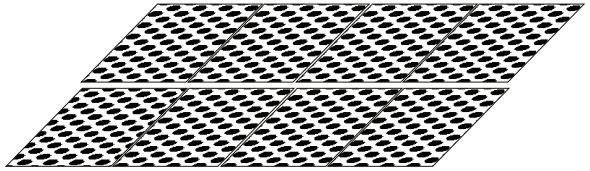
Natural rate of disturbance



Fragmentation

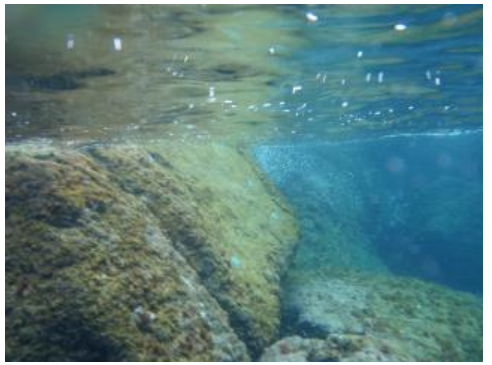


Homogenisation



Thrush et al. 2008. Cumulative degradation in estuaries: The effects of habitat, loss fragmentation and community homogenization on resilience. *Ecological Applications* **18:12-21.**

Exploring cumulative impacts and loss of resilience via field experimentation

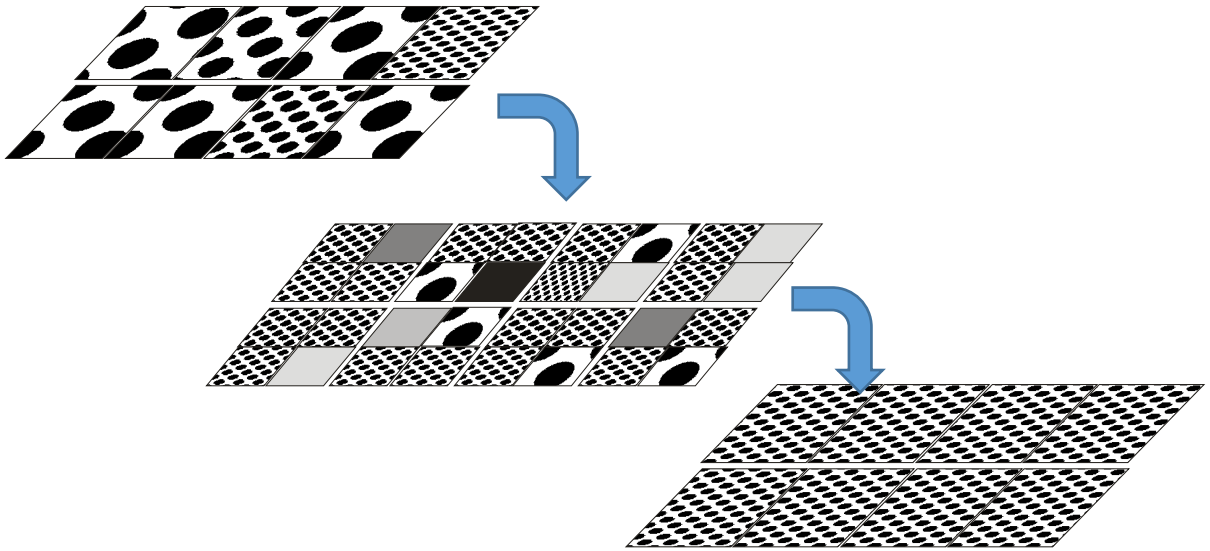


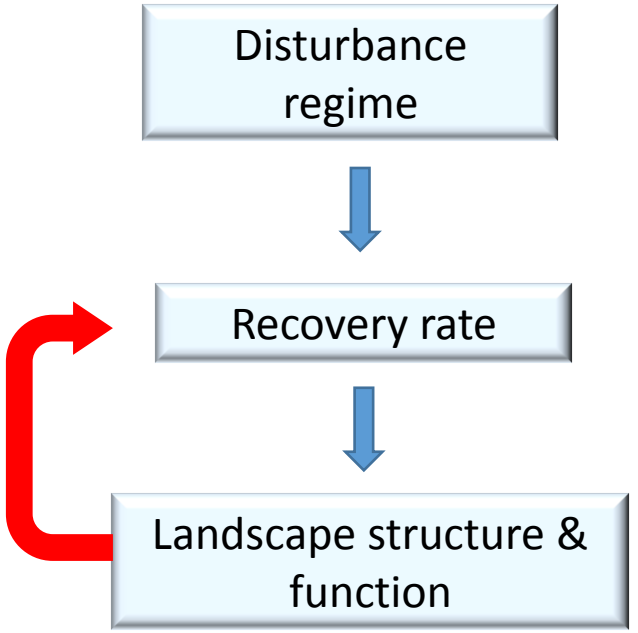
Defaunate plots at multiple sites → Assess differences in recovery rates → Assess the role of local vs regional connectivity variables in explaining differences in recovery rates

- Cumulative effects are a real threat

Thrush, S. F., J. Halliday, J. E. Hewitt, and A. M. Lohrer. 2008. Ecological Applications **18:12-21.**
Thrush, S. F., J. E. Hewitt , A. Lohrer, and L. D. Chiaroni. 2013. Ecological Applications **23:226-238.**

A positive feedback process -Changes in the frequency and extent of disturbance can outstrip recovery rates, leading to habitat loss and fragmentation





- Think about thresholds vs gradual degradative change

Carolyn Lundquist's talk

Trawling degrading our natural capital?

Chronically trawled sediments along the continental slope show significant decreases in organic matter content (up to 52%) and slower organic carbon turnover (ca. 37%)

60–100% of the input of primary food resources in this deep-sea system is subducted down slope.

Is this the marine equivalent of a ‘dust-bowl’ scenario? - with significant potential impacts on ecosystem function and the delivery of ecosystem services – it is estimated that slope sediments are 7% of the surface of the oceans and contribute about 52% of marine carbon mineralisation[1]

www.kshs.org

Pusceddua, A., S. Bianchellia, J. Martínb, P. Puig, A. Palanques, P. Masque, and R. Danovaro. in press. Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. Proceedings of the National Academy of Science.

[1]Middleburg, J. J., K. Soetaert, and P. M. J. Herman. 1997. Empirical relationships for use in global diagenetic models. Deep-Sea Research **44:327-344.**

Disturbance to the seafloor- basic lessons from experimental benthic ecology

- Important implications to the dynamics of patches and landscapes
- Time-scale of recovery for even simple benthic communities are much longer than 1 year.
- Initial and subsequent disturbance events in the same place may not have the same effects
- Far field effects are important - elevated suspended sediment concentrations and lost gear
- Multiple resource users may affect the seafloor’s disturbance regime

Looking up from the seafloor

- Over-exploitation and collapse of large apex predators are well recognized in marine systems
  - The cod populations have collapsed in Northwest Atlantic:
    - Newfoundland-Labrador Shelf
    - Northern and southern Gulf of St. Lawrence
    - Eastern Scotian Shelf
- What are the consequences of the reduction of cod for biodiversity?

«Natural experiment in time» The Scotian Shelf

Overfishing has resulted in the reduction of cod and other predatory benthic fish species

- Collapse of cod in 1992

Photo: Wikipedia

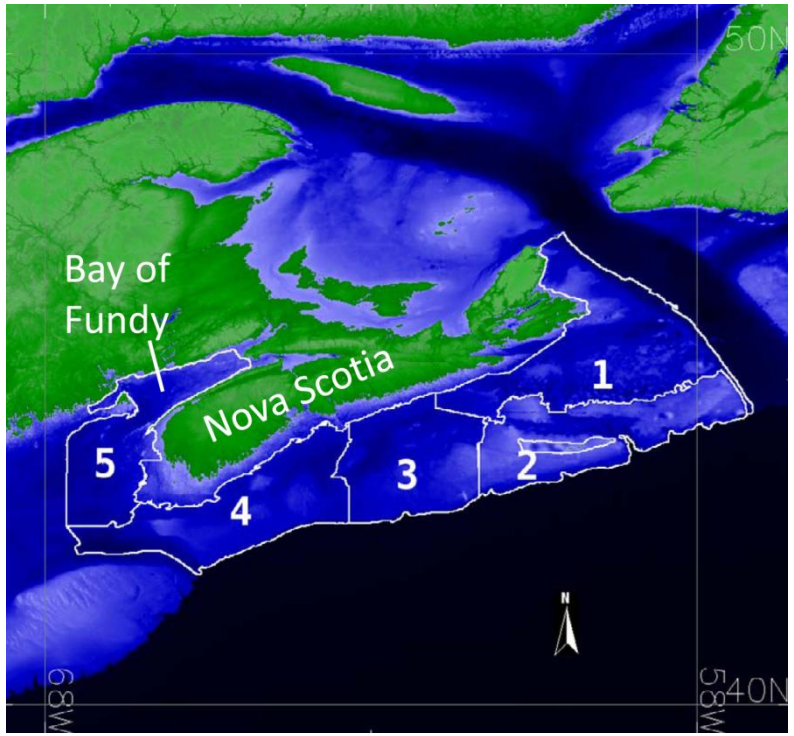
?

Changes in fish community composition

Frank et al. (2005). Science, 308, 1621-1623.

The Scotian Shelf – losing a top predator?

- Annual demersal trawl surveys from >40 years
- >150 fish species

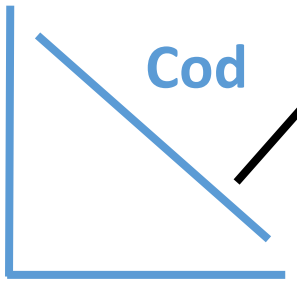


- Alpha fish diversity increases with decline in cod
- Beta diversity of fish increases with decline in cod, meaning that the heterogeneity in the fish community increases
- Climate had less importance than cod in explaining biodiversity

Method used: Anderson, M.J., Ellingsen, K.E. & McArdle, B.H. 2006. Multivariate dispersion as a measure of beta diversity. Ecology Letters, 9, 683-693.

Ellingsen, K.E., Anderson, M.J., Shackell, N.L., Tveraa, T., Yoccoz, N.G., Frank, KT. The role of a dominant predator in shaping biodiversity over space and time in a marine ecosystem (manuscript).

Why changes in fish communities can matter to seafloor biodiversity



Changes in fish community composition

Changes in function/ diet

Laboratory and field experiments

Increase in snow crab and other predatory crustaceans

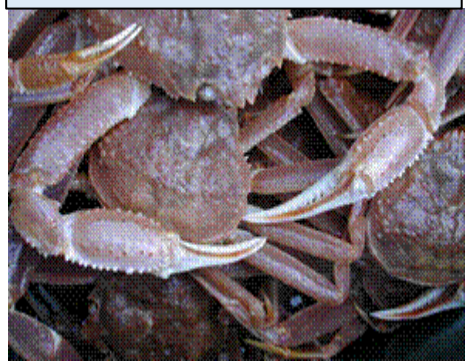


Photo: DFO Canada

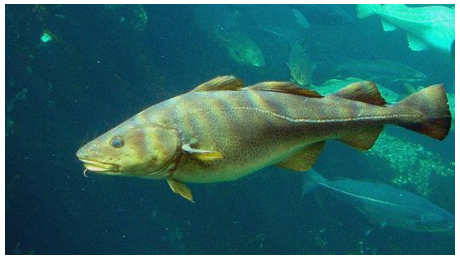
Changes in seafloor communities

Quijón, P.A. & Snelgrove, P.V.R. (2005). Oecologia, 144, 125-136.

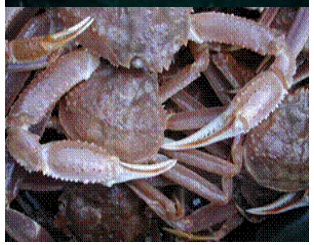
Regime shifts- The Scotian Shelf – early 1990s

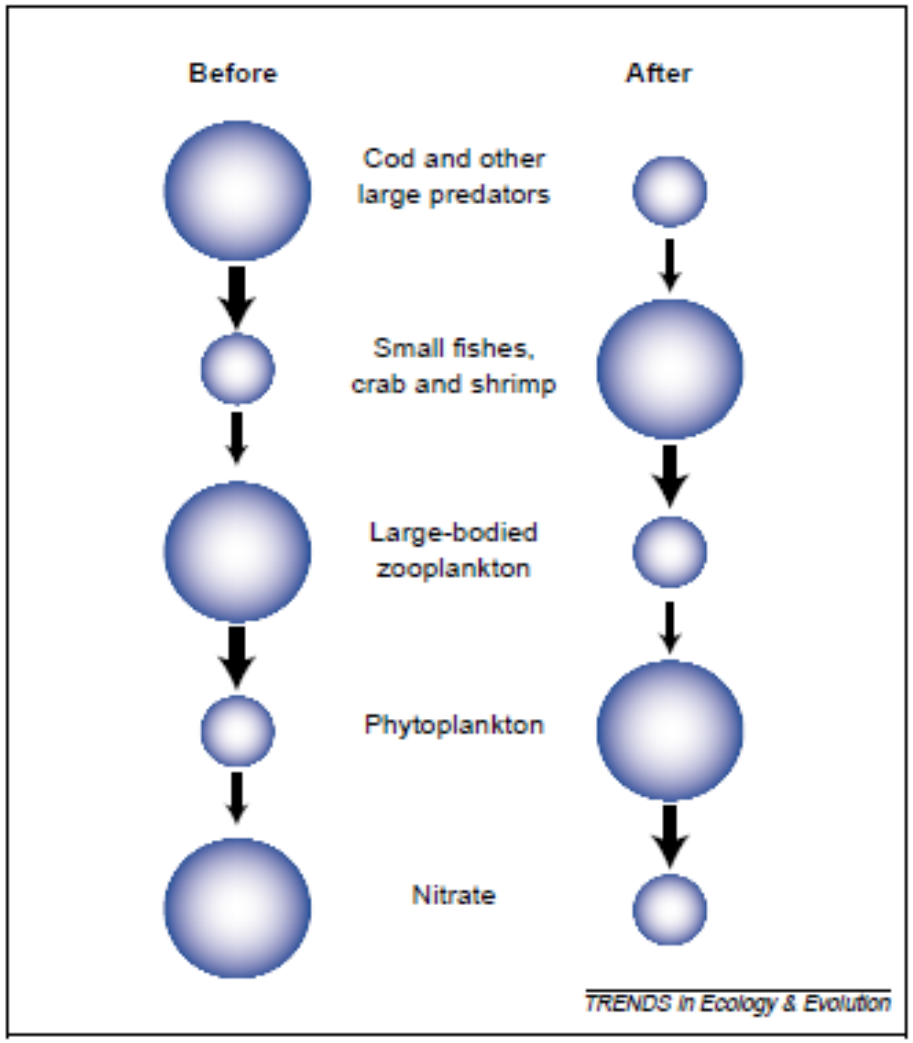
- Largely a result of overfishing of cod and other groundfish

Groundfish (cod) dominated community



Crustaceans and small pelagic fish dominated community



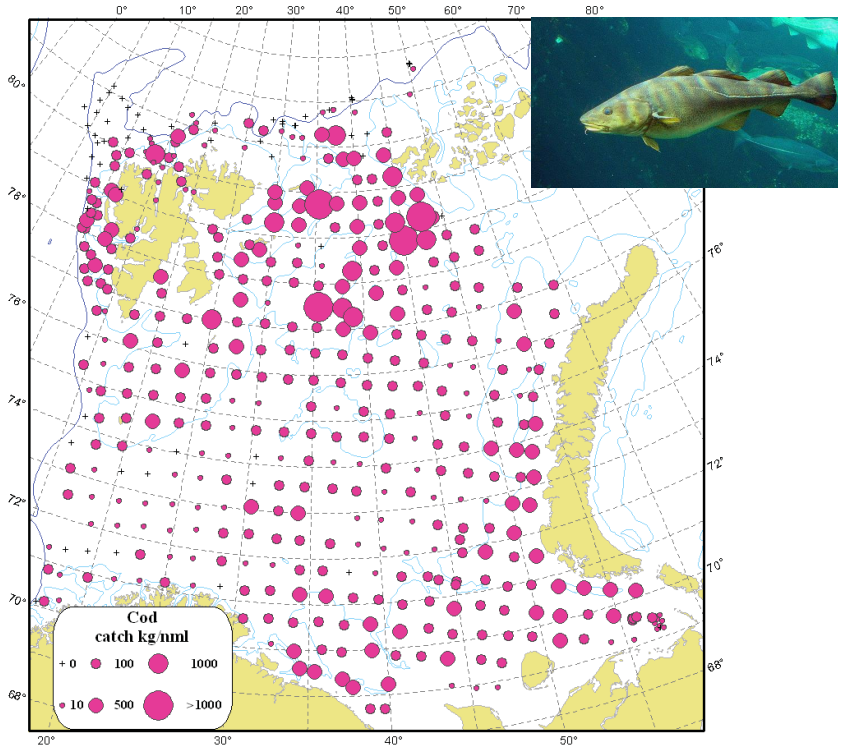


Frank et al. (2005). Science, 308, 1621-1623; Frank et al. (2011). Nature, 477, 86-89.

Scheffer et al. TREEVol.20 No.11 November 2005

Looking up from the seafloor in the Barents Sea

Distribution of cod (*Gadus morhua*)
Aug-Sep 2012



Map: Survey Report from the Joint Norwegian/Russian Ecosystem Survey in the Barents Sea, August – October 2012, www.imr.no

- The Barents Sea cod stock is currently the largest in the world; it has increased and the distribution limit has shifted northwards
- Climate is changing
  - The sea temperature has increased
  - The sea-ice is declining

Snow crab in the Barents Sea

Biomass in the Barents Sea
- estimated relative numbers

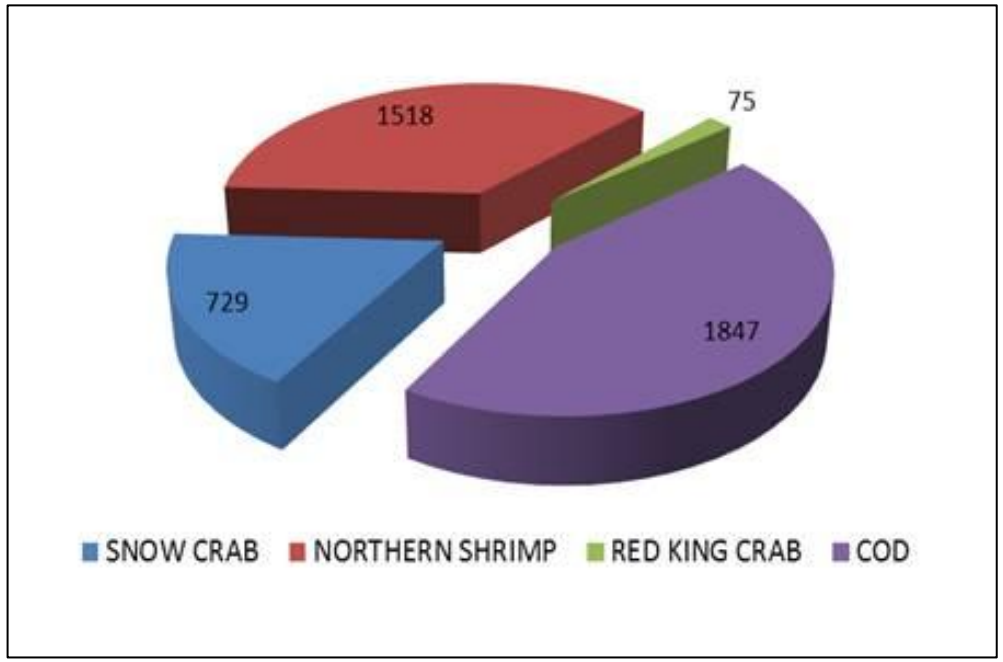
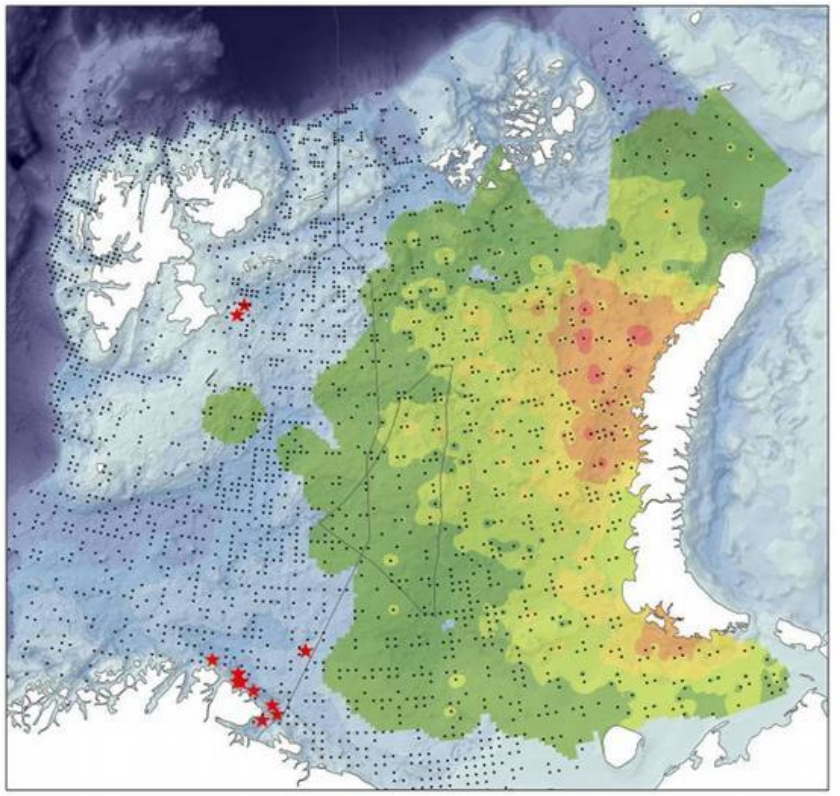


Figure : www.imr.no, published 23.04.2013 (from Sergej Bakanjov/Pinro)

The biomass estimates are based on by-catch data from the joint Norwegian (IMR)/Russian (PINRO) Ecosystem Survey.

Snow crab is increasing and moving west

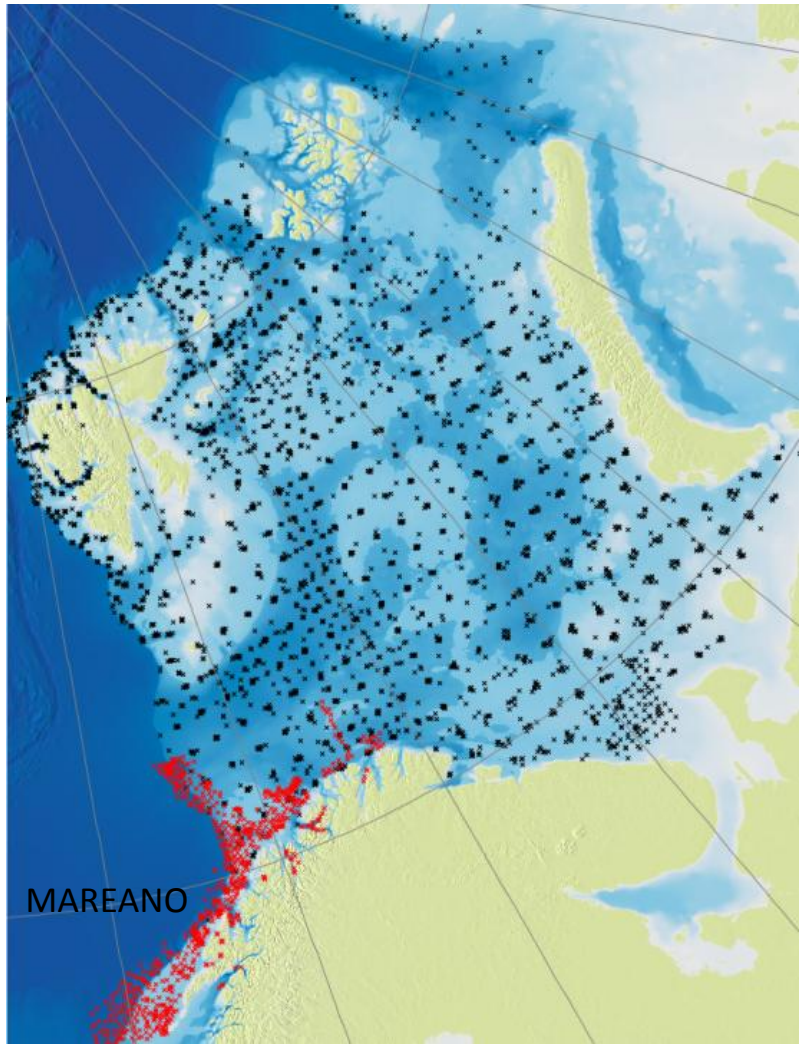


Map: www.imr.no, published 23.04.2013 (from Pinro)

The Barents Sea is changing – opportunities for stewardship in managing ecosystem and biodiversity effects

- What are the combined effects of different drivers?
- Can we investigate the relationships between fisheries, cod, fish biodiversity, snow crab, climate and seafloor biodiversity?
- Can we develop managment strategies other than BAU?

What data are needed to answer the questions?

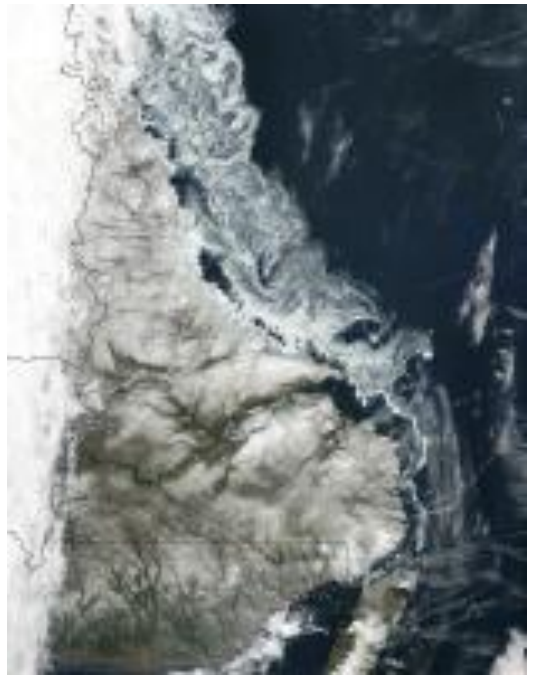


- Time series (like the joint IMR/PINRO Ecosystem Survey in the entire Barents Sea) are valuable; in particular when changes occur
- There is (only) a small overlap between the Ecosystem Survey and the MAREANO mapping of the seabed (benthos)
- Can we answer the questions based on existing data?
- What questions can we not answer?
- Do we need specific studies on top of this?

Regime shifts

(thresholds, step-trends, criticality, phase shifts, rapid transitions or tipping points)

- Increasingly reported in marine ecosystems as a result of anthropogenic stress, climatic/oceanographic change or the interaction of the two.
- Evidence is accumulating that interactions between the intrinsic ecological dynamics and chronic, cumulative, or multiple stressor effects can lead to regime shifts.



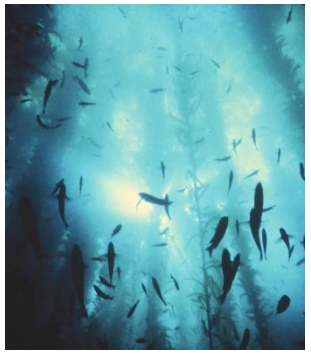
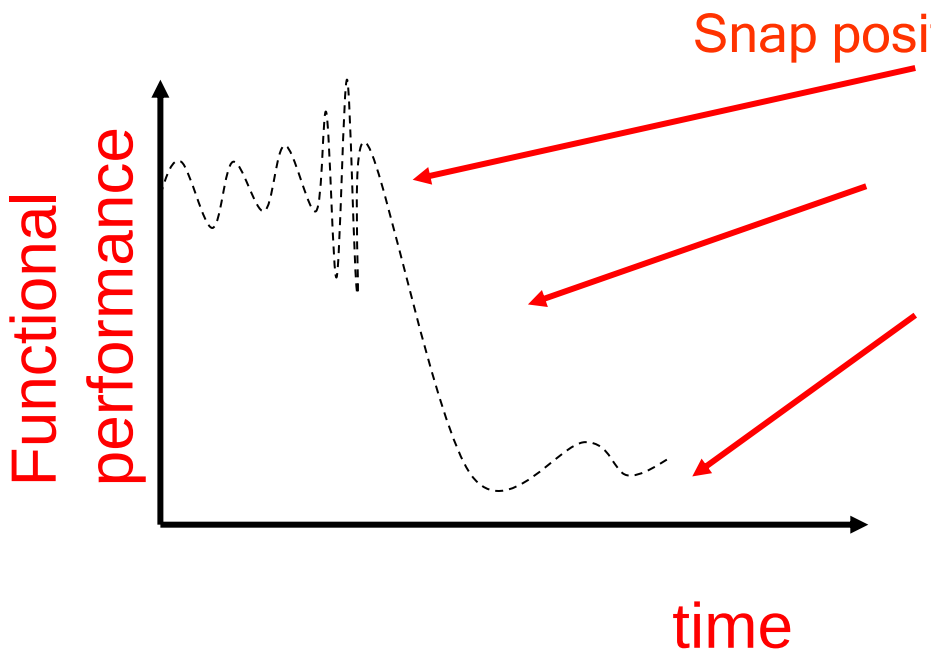


Photo credits: Visible earth; Paul Dayton, Rod Budd

Empirical tests of indicators forewarning of regime shift are rare

- Good time-series data
- Understanding of process and interactions
- Better links between theory and empirical research

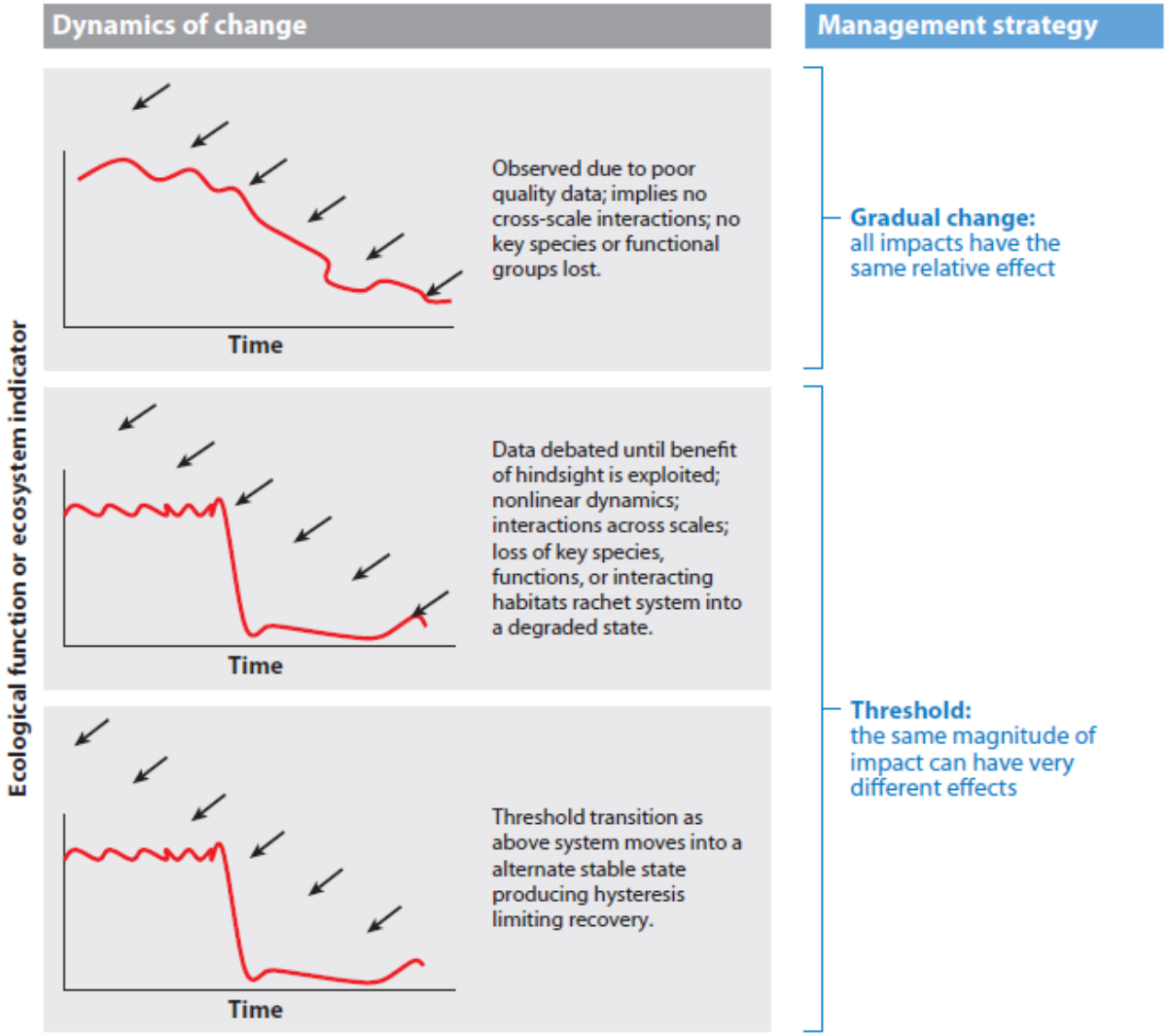


Unfortunate consequences and changing value:

- Loss of function
- Homogenisation of communities and ecosystems
- Loss in food web complexity
- Loss of biogenic habitat structure,
- Decreases in the size of organisms
- Slow recovery to previous state

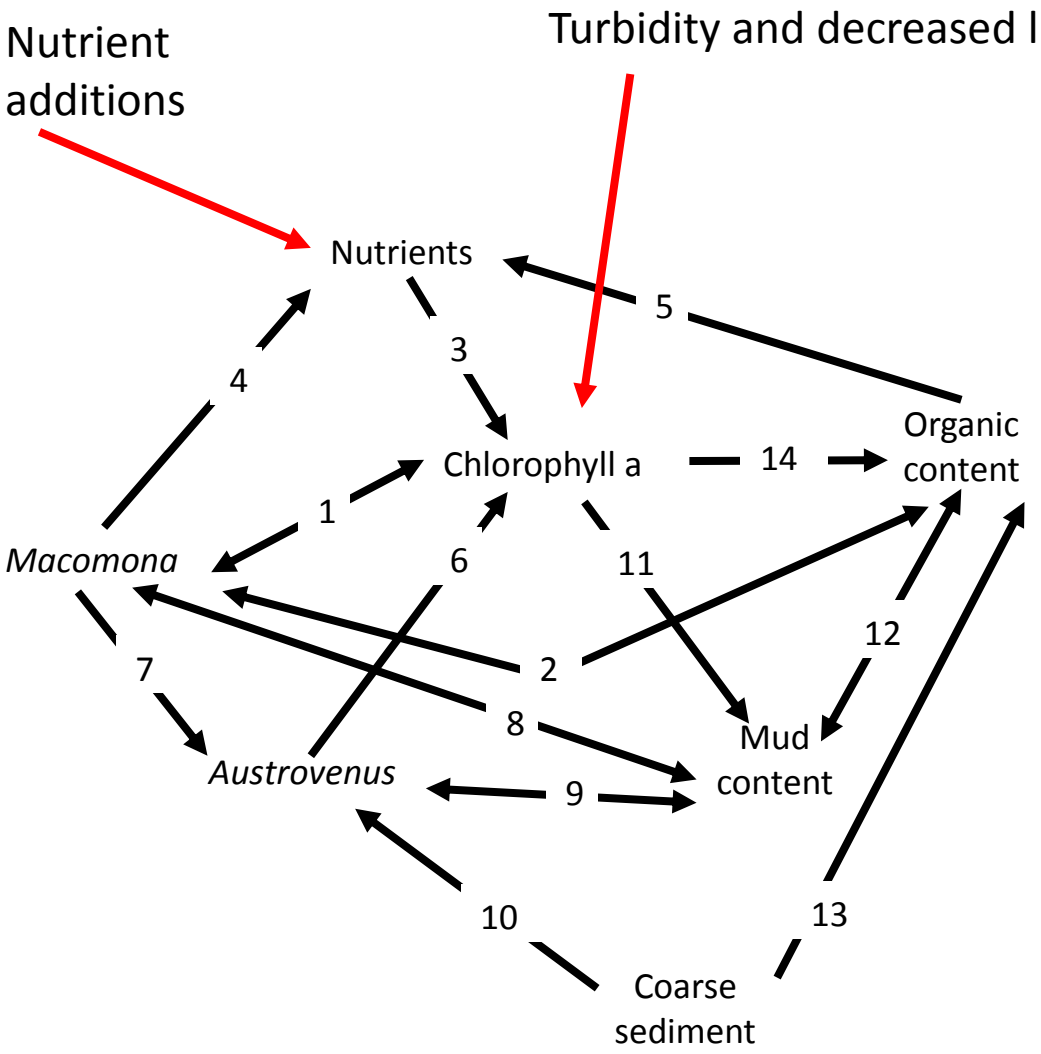
Thrush, S.F., et al., *2009.* Forecasting the limits of resilience: integrating empirical research with theory *Proceedings of the Royal Society B-Biological Sciences,* ***276: p. 3209-3217.***

Change over time: implications for management frameworks



Thrush, S. F., and P. K. Dayton. 2010. What can ecology contribute to ecosystem-based management? Annual Review of Marine Science **2:419-441.**

Positive feedbacks and clues to increased risk of regime shifts from ecosystem interaction networks

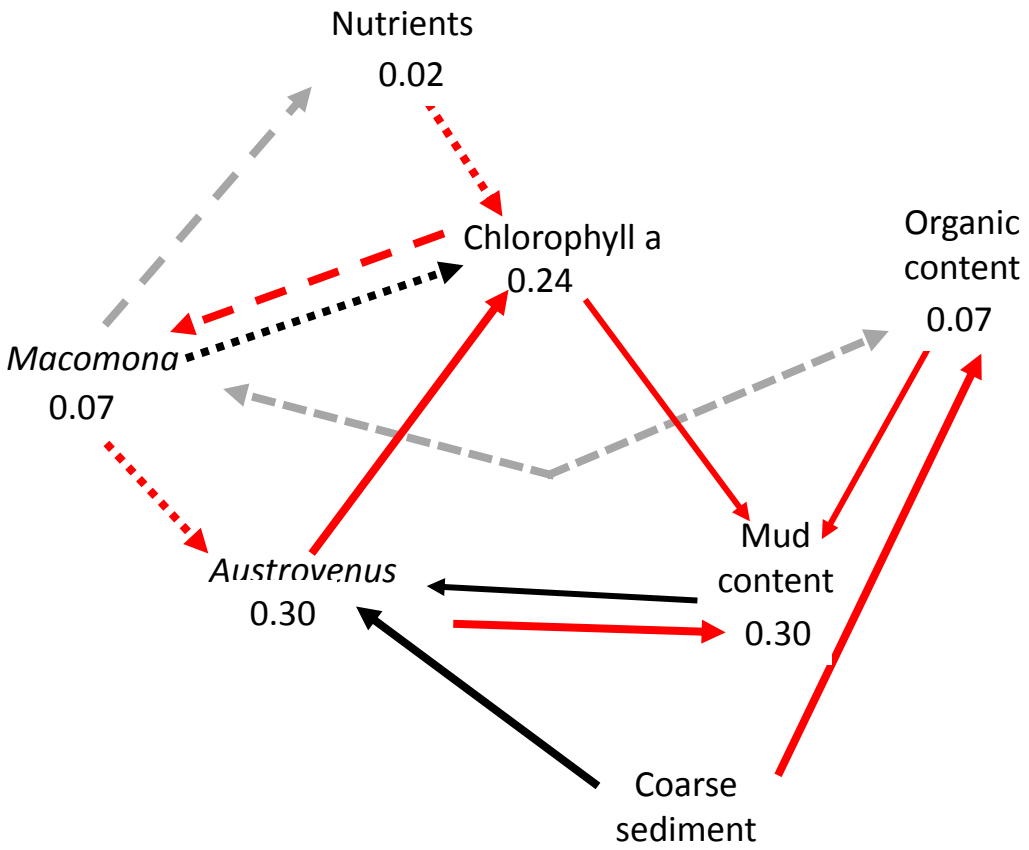


Drew Lohrer's talk

One hundred days later……

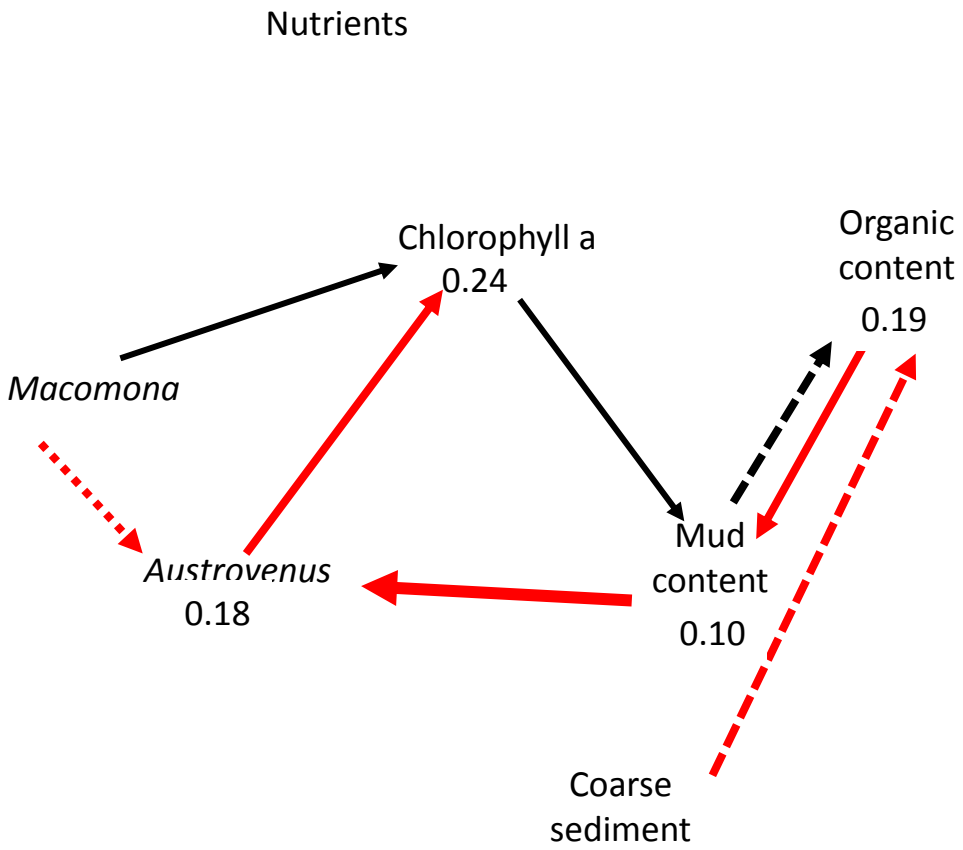
Unshaded

χ^2 (P = 0.269); RMSEA (P = 0.494); CFI = 0.989



Shaded

χ^2 (P = 0.942); RMSEA (P = 0.962); CFI = 1.000

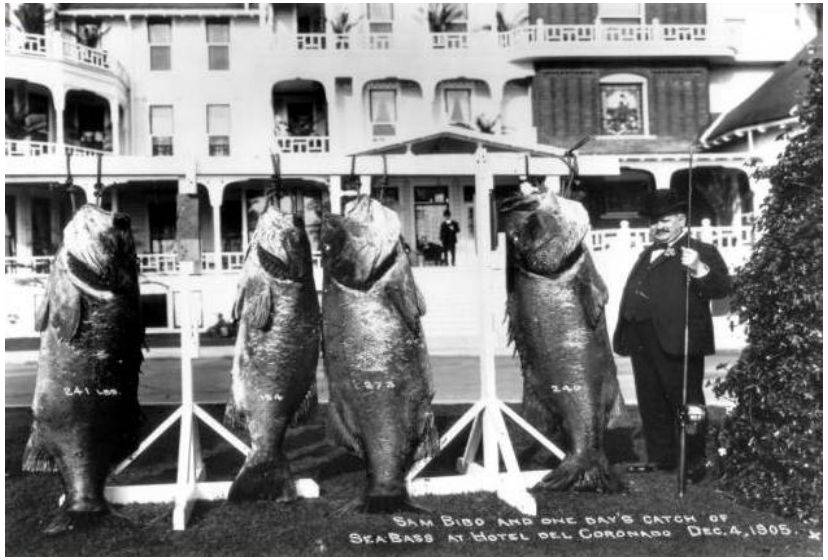


Unstressed is more positively connected

Thrush, et al. in press. Experimenting with ecosystem interaction networks in search of threshold potentials in real world marine ecosystems. Ecology

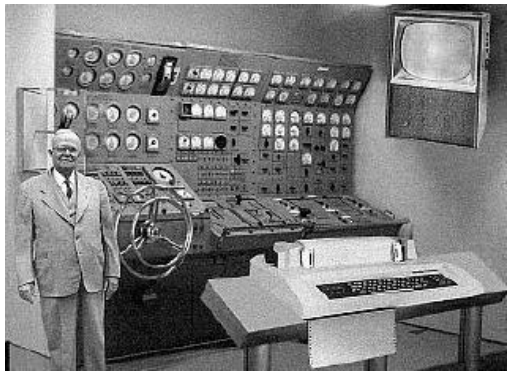
Expect surprises!

- We now understand ecological systems enough to know that it is not only our ignorance that leads to surprises
- It is also a feature of the way ecosystem processes are wired up
- So empirical tests and gathering long-term data (monitoring) are critical



Rules of engagement have changed

Most losses in resilience are unintended consequences of narrowly focused optimization – Brian Walker, CSIRO and author of *Resilience Thinking* and *Resilience Practice*



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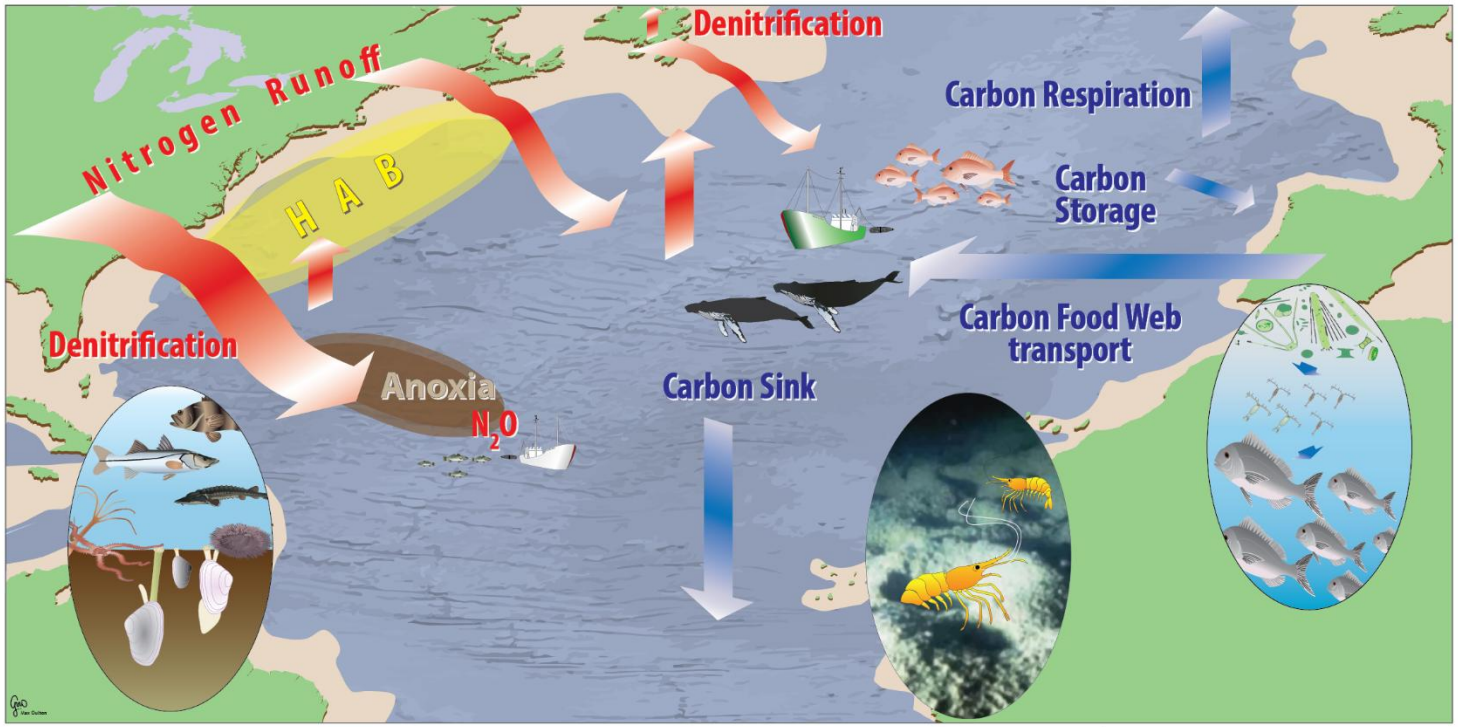
Seafloor ecosystems services

- Multiple uses and values in marine ecosystems
- Its not just fisheries and you do not have to eat it to value it



Snelgrove, Thrush, Wall & Norkko in press TREE

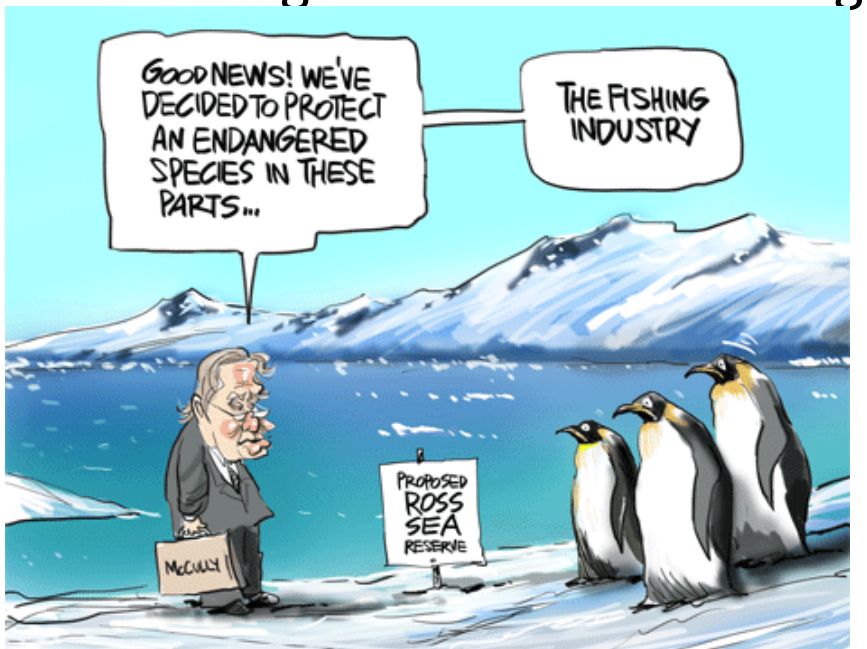
Ecosystem services are underpinned by multiple ecosystem functions

The functions involve interactions between species, hydrodynamics and biogeochemistry

Functional extinction means a change in service deliver

We need to change our values or change our impact

NZ Herald



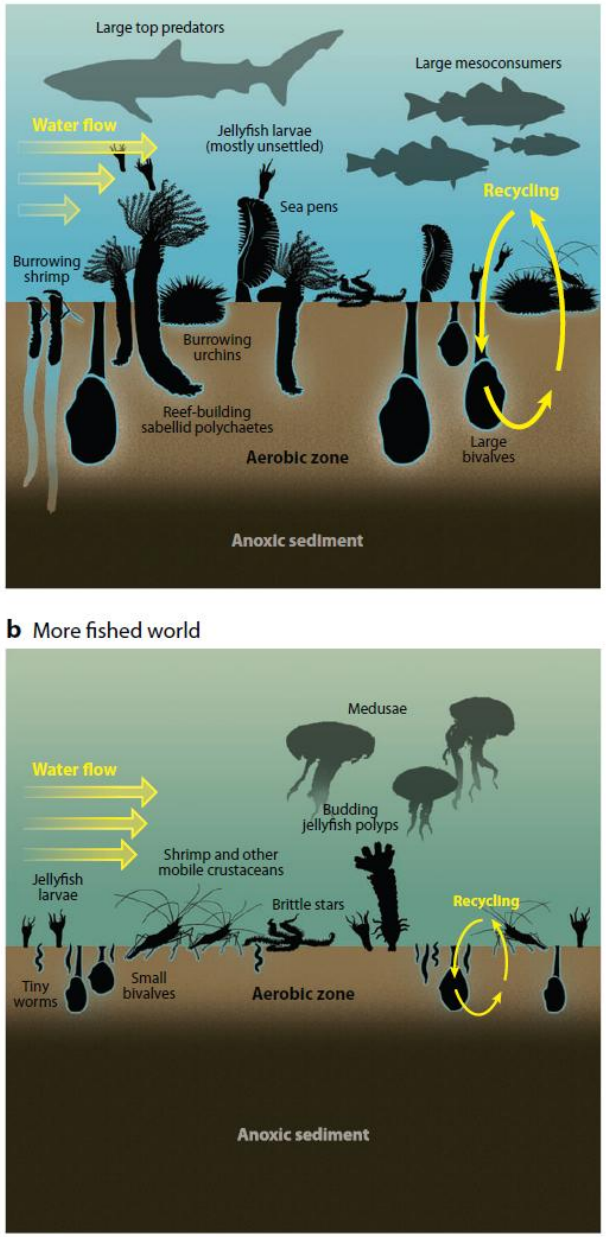


Figure 3
Ecological ratchets tighten their grip on marine ecosystems. Loss of top predators and habitat destruction removes environmental heterogeneity created by large and old organisms and decreases the depth and extent of sediment bioturbation and bioirrigation.

Thrush, S. F., and P. K. Dayton. 2010. What can ecology contribute to ecosystem-based management? Annual Review of Marine Science **2:419-441.**

Ecosystem-based management must account for multiple values

- Maintaining adaptive capacity
- Restoring biodiversity
- Enhancing multi-functionality
- Integrating management strategies

Non-Integrative
Bureaucratic Structures
do not help