THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Implications of trawling impacts to seafloor biodiversity and Marine Spatial Planning

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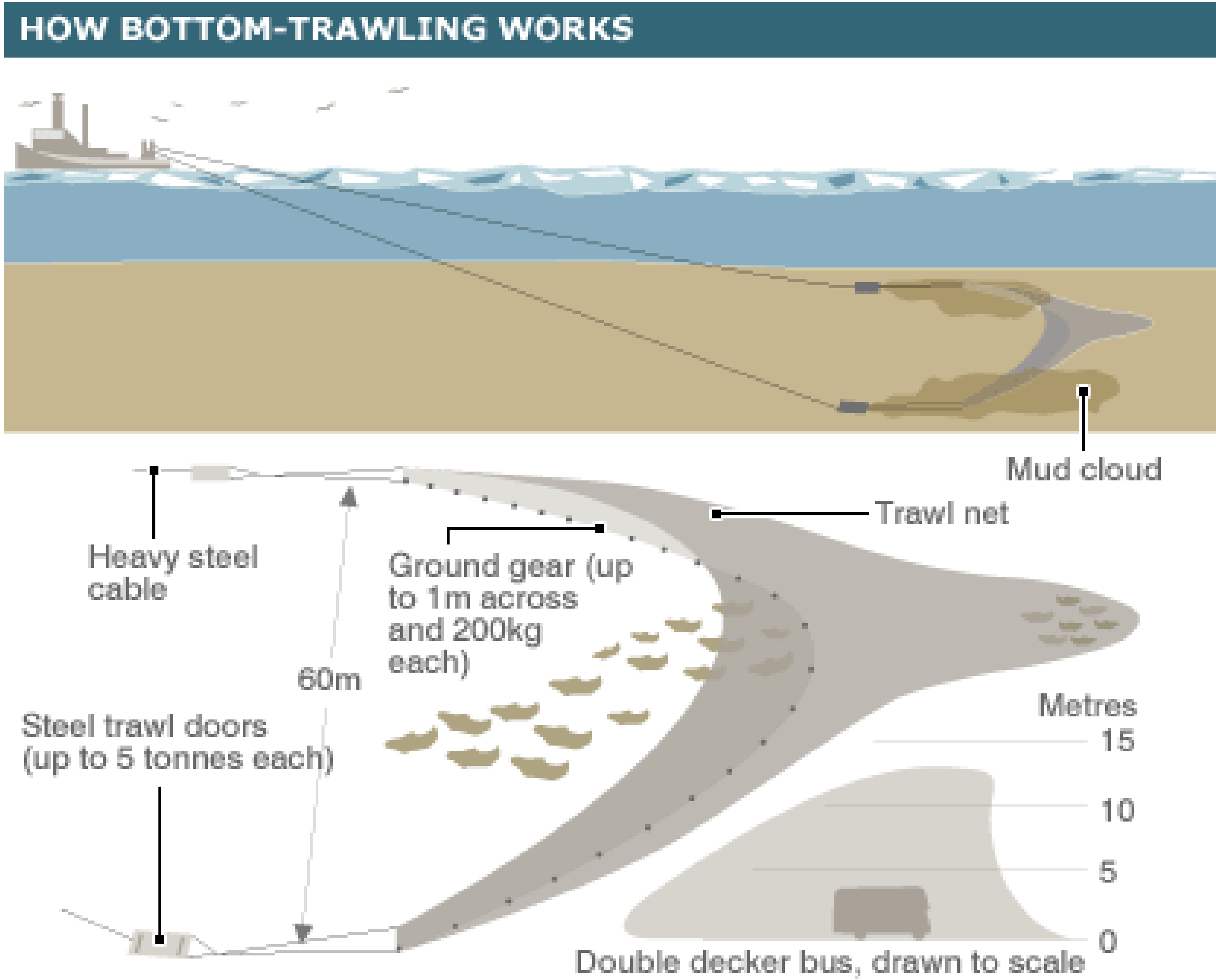
Presentation to Sea Change 29 July 2014, Auckland

Issues to consider

- Catching target species
- Commercial enterprise
- Employment

- By catch
- Habitat disturbance
- Sediment resuspension
- Scale of effects



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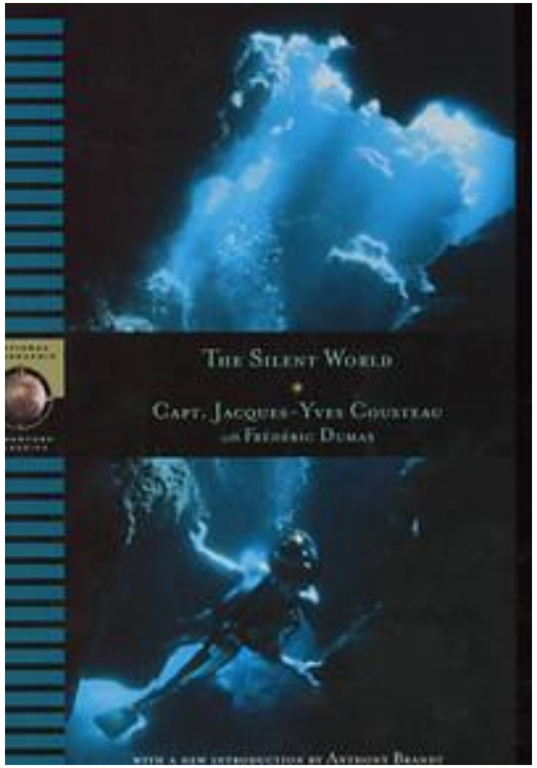
Knowledge to action can be a slow process

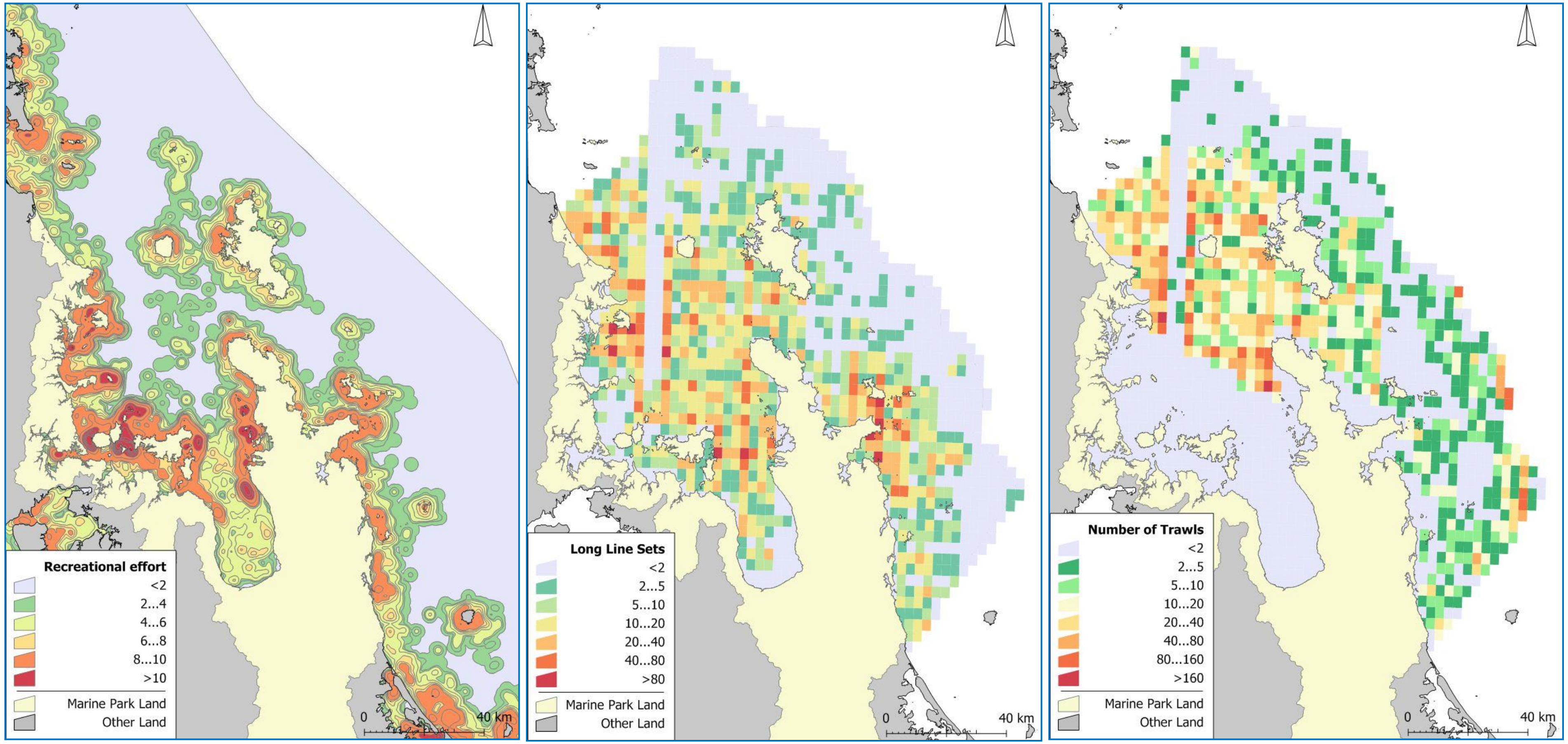
Jacques Cousteau , The Silent World 1953

a clean wreck newly received by the sea, its nets neatly folded on deck and cork floats tugging at the panels. We did not profane the innocent boat, but the net gave us an idea. We would film a commercial trawl net moving across the floor. No one had seen a trawl net in action. Fishermen who spent their lives dragging the bottom knew the net only in theory. If one found the right spot it brought up fish: that was the existing body of information on trawl nets.

Perched above the grassy floor I saw the towline of the net arrive. It looped back to the rigid gate which scraped along the bottom, breaking down grasses and spreading destruction to the tiny creatures of the prairie. Fish leaped away like rabbits running from a reaper. The vast envelope of net passed me, puffed up with water. The broken grass arose slowly in the track of destruction. I was astonished to see how many fish escaped the monster, and how much it destroyed of future fish stocks and pasturage. Man's method of undersea farming seemed to consist of blighting the acre while reaping a small part of the crop. Didi hung head-down on the towrope and filmed into the dragon's mouth to bring up evidence of how many fish got away and how much of the nursery was being ruined.



Recreational boat effort | Commercial long line effort | Commercial trawl effort



Taken from - Tikapa Moana – Hauraki Gulf State of the Environment Report 2011, Hauraki Gulf Forum

From 2004–05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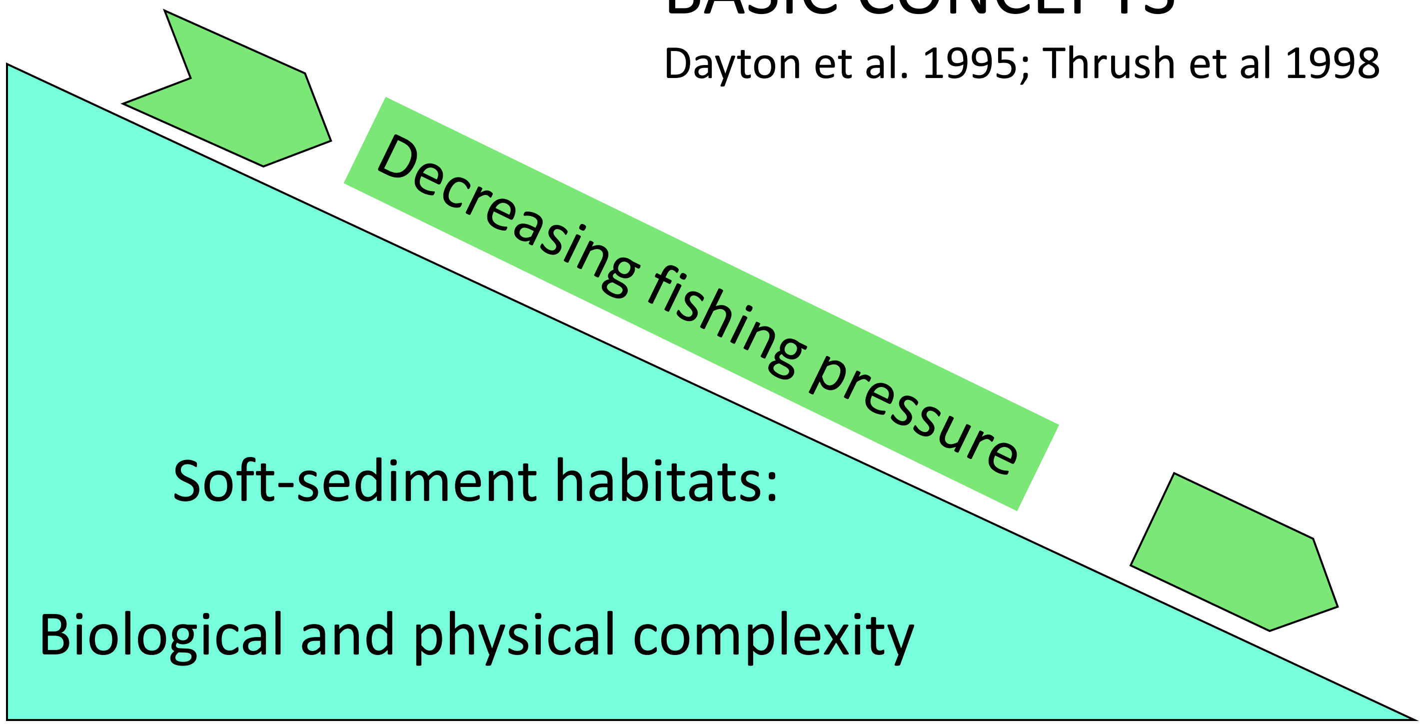
BASIC CONCEPTS

Dayton et al. 1995; Thrush et al 1998



Simple
Low diversity

Complex
High diversity
Settlement and
nursery areas

Predicted changes in benthic communities along a gradient of decreasing habitat disturbance
-core data

Prediction	**Right**	**Can't tell**
Decrease Scavengers		?
Decrease deposit feeders	Yes	
Decrease small opportunists	Yes	
Decrease polychaetes/molluscs	No	
Decrease small/large individuals	Yes	
Increase species diversity	Yes	
Increase long-lived near surface dwellers	Yes	
Increase echinoderm density	Yes	
Increase total number of individuals		?

Ecological Applications, 8(3), 1998, pp. 866–879

DISTURBANCE OF THE MARINE BENTHIC HABITAT BY COMMERCIAL FISHING: IMPACTS AT THE SCALE OF THE FISHERY

S. F. Thrush,[1] J. E. Hewitt,[1] V. J. Cummings,[1] P. K. Dayton,[2] M. Cryer,[3] S. J. Turner,[1] G. A. Funnell,[1] R. G. Budd,[1] C. J. Milburn,[1] and M. R. Wilkinson[1]

Even the loss of low numbers of animals that define seafloor habitats affect biodiversity…

Vol. 223: 277–286, 2001 | MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser | Published November 28

Fishing disturbance and marine biodiversity: the role of habitat structure in simple soft-sediment systems

Simon F. Thrush[1,*], Judi E. Hewitt[1], Greig A. Funnell[1], Vonda J. Cummings[1], Joanne Ellis[1], Diane Schultz[1], Drew Talley[2], Alf Norkko[1]

…and the abundance of juvenile snapper and scallops

Vol. 245: 273–280, 2002 | MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser | Published December 18

Habitat structure in soft-sediment environments and abundance of juvenile snapper *Pagrus auratus*

Simon F. Thrush[1,*], Diane Schultz[1], Judi E. Hewitt[1], Drew Talley[2]

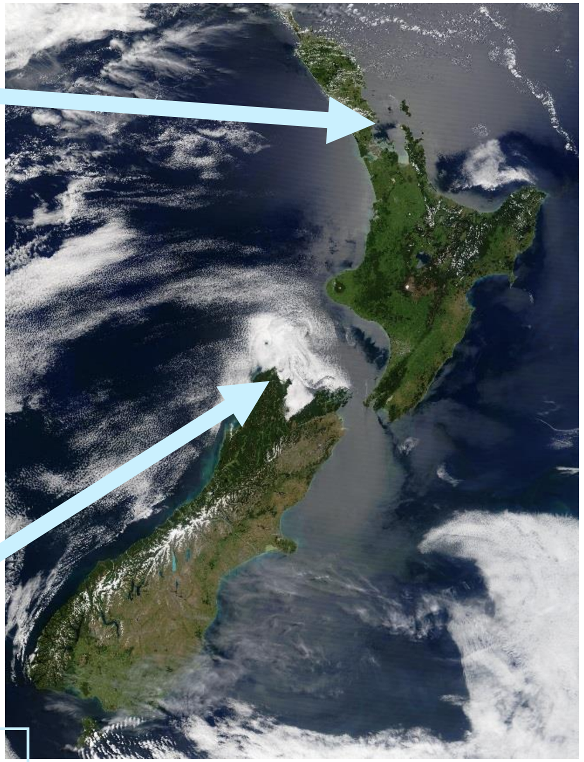
Vol. 269: 197–207, 2004 | MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser | Published March 25

Habitat structure and the survival of juvenile scallops *Pecten novaezelandiae*: comparing predation in habitats with varying complexity

Sonia G. Talman[1,2,*], Alf Norkko[1], Simon F. Thrush[1], Judi E. Hewitt[1]

Broader implications for biodiversity

Kawau Bay



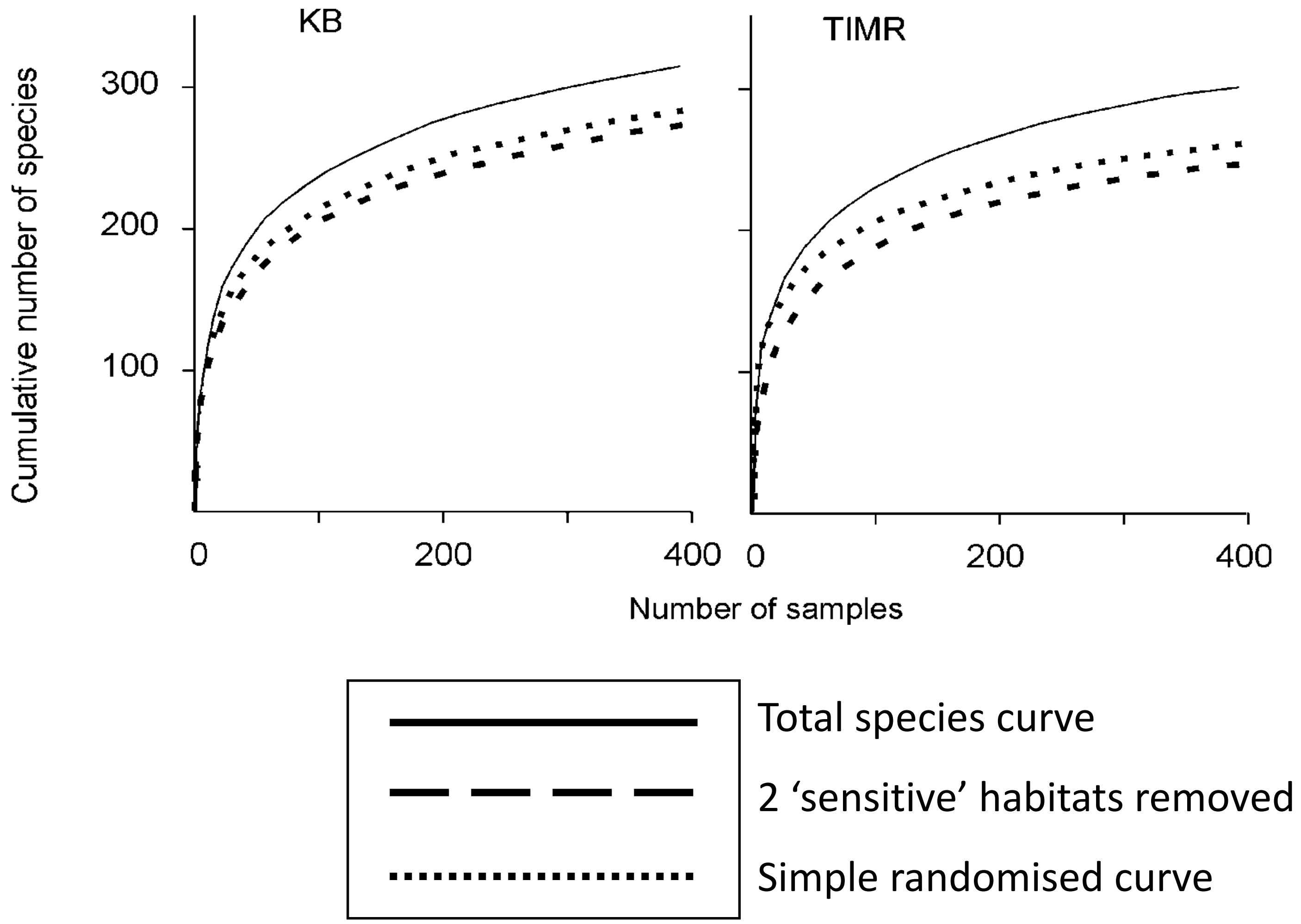
Tonga Island
Marine Reserve

Ecological Applications, 16(5), 2006, pp. 1636–1642

PREDICTING THE EFFECTS OF HABITAT HOMOGENIZATION ON MARINE BIODIVERSITY

SIMON F. THRUSH,[1,3] JOHN S. GRAY,[2] JUDI E. HEWITT,[1] AND KARL I. UGLAND[2]

Scenarios of habitat homogenisation



Functional implications of habitat removal

- Most species' distributions indicate some level of habitat specificity.

  12 out of 194 species were common across all habitats in TIMR, while 9 out of 221 species were common in KB.

- Removal of habitats also resulted in a significant drop in the proportion of species with different functional attributes in both locations ($\chi 2$ for each location $P < 0.05$).

  Habitat removal demonstrated a consistent loss of large individuals, epifauna, surface dwellers and deposit feeders for each location. However, TIMR showed larger proportional decreases compared to KB.

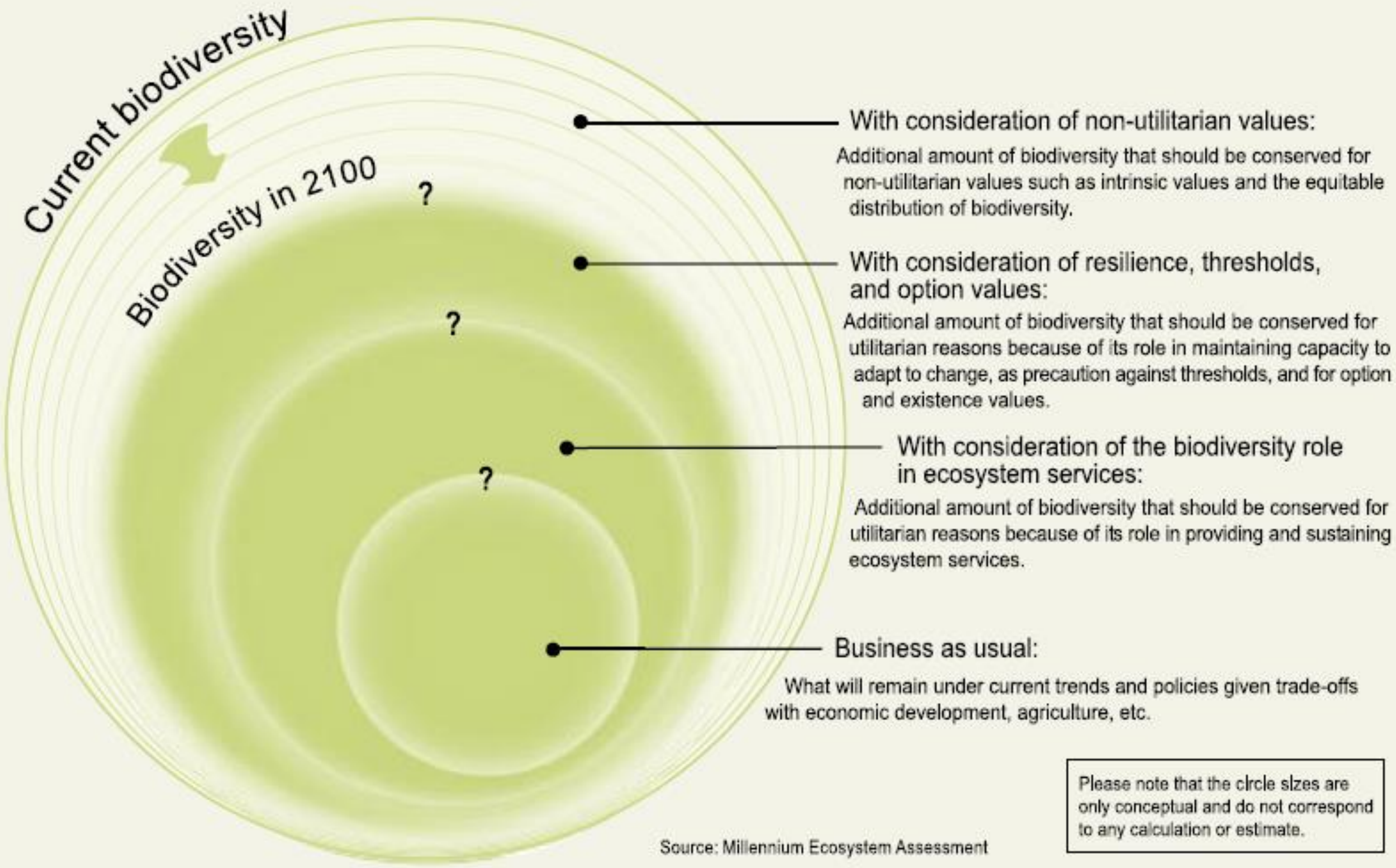
Shrinking biodiversity

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

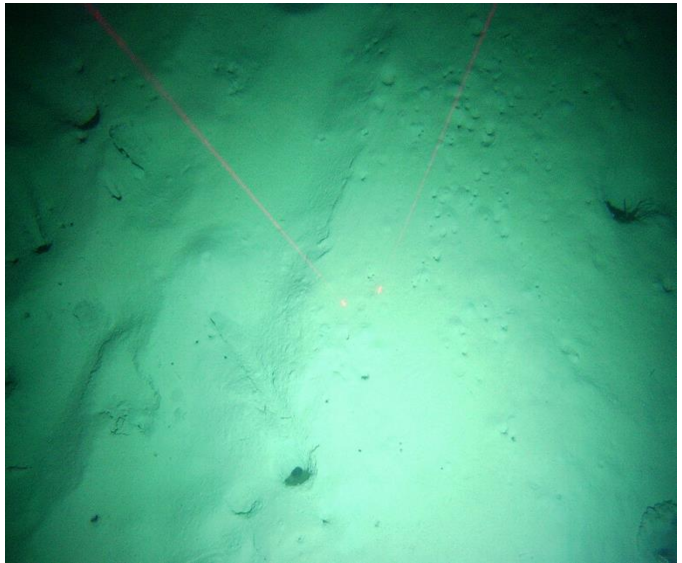
Loss of ecological function and natural heritage values

- Homogenisation of habitats results in the risk of the loss of ecological function and natural heritage values in marine ecosystems

- If these losses reduce resilience, this may predispose the system to sudden and dramatic change

Human impacts as disturbance phenomena

- Knowledge of the frequency, extent and intensity can be used to help identify when the rate of human induced change exceeds the rate at which nature can respond

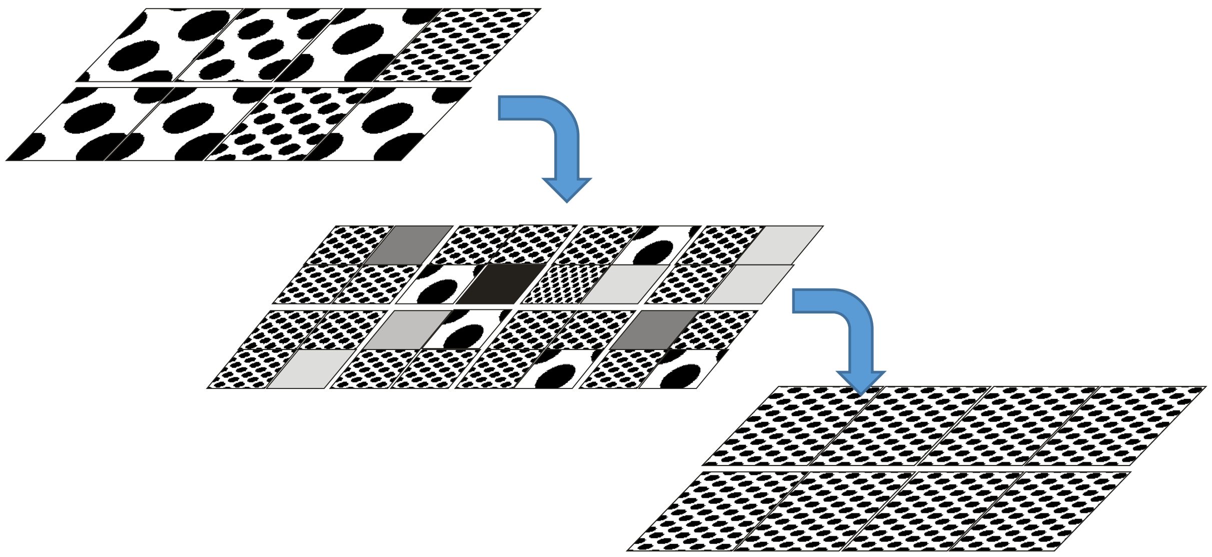



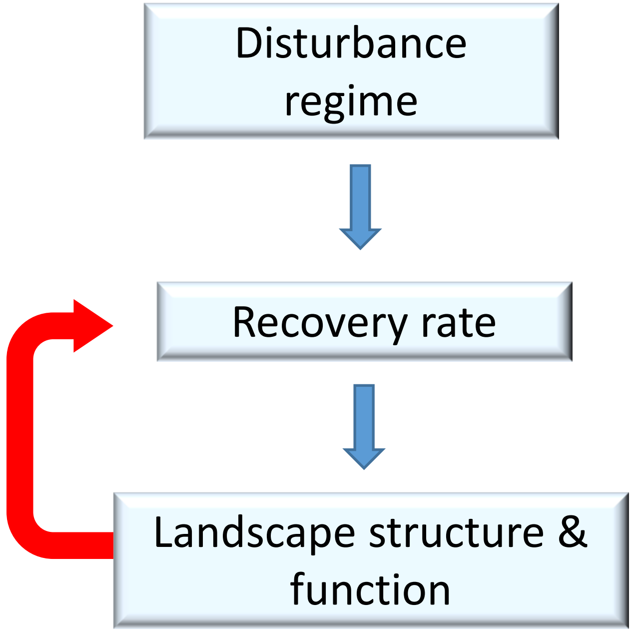

Terrestrial Ecosystems

- 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.

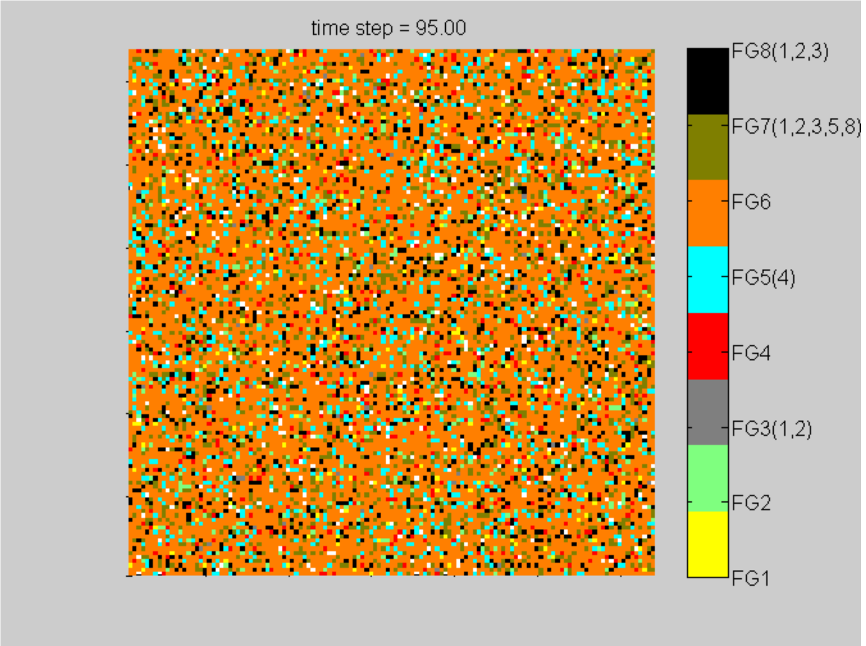
A positive feedback process -Changes in the frequency and extent of disturbance can outstrip recovery rates, leading to habitat loss and fragmentation

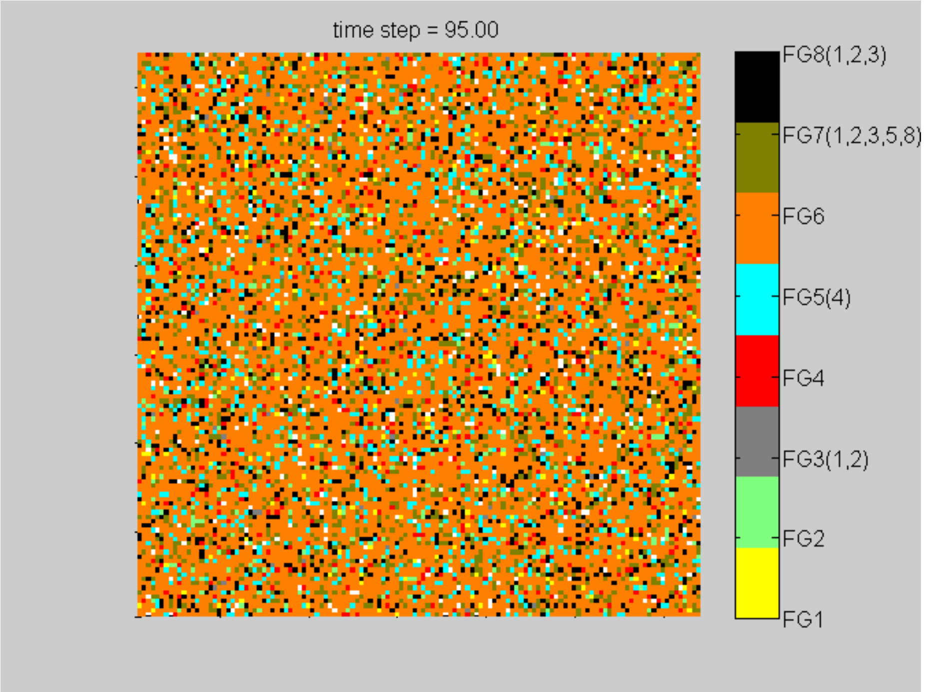




- Think about thresholds vs gradual degradative change

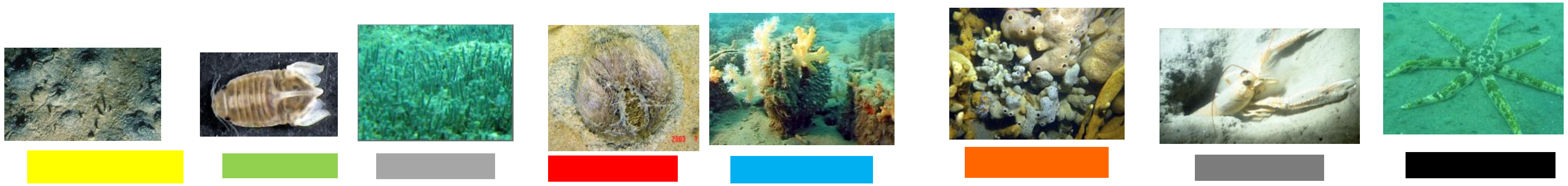
Model cartoons: A work in progress to illustrate how changes in the frequency and intensity of disturbance can change seafloor landscapes





25 x 25 disturbance between years 25 & 63 equating to approximately **15 % of landscape** disturbed per year (4 time steps/yr)

10 x 10 disturbance between years 25 & 63 equating to approximately **2 % of landscape** disturbed per year (4 time steps/yr)



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

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.

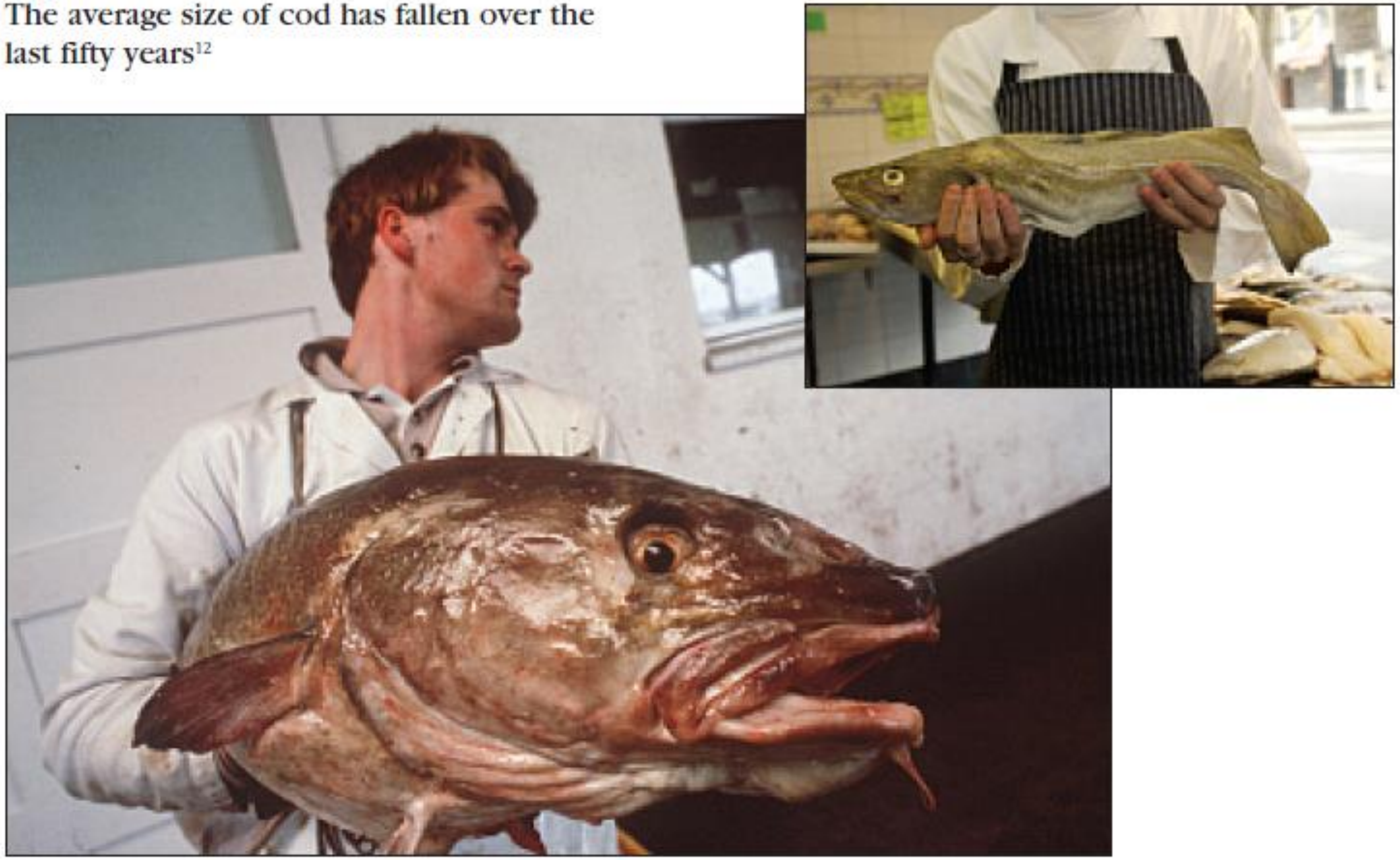
Is this the marine equivalent of a ‘dust-bowl’ scenario? - with significant potential impacts on ecosystem function and the delivery of ecosystem services – it is estimated that slope sediments are 7% of the surface of the oceans and contribute about 52% of marine carbon mineralisation[1]

www.kshs.org

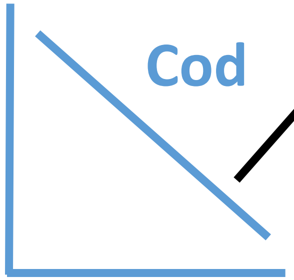
Pusceddua, A., S. Bianchellia, J. Martínb, P. Puig, A. Palanques, P. Masque, and R. Danovaro. in press. Chronic and intensive bottom trawling impairs deep-sea biodiversity and ecosystem functioning. Proceedings of the National Academy of Science.

[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.**

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



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

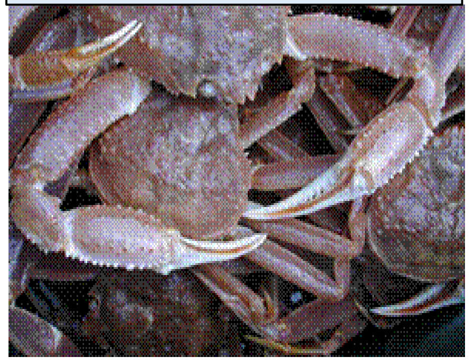


Photo: DFO Canada

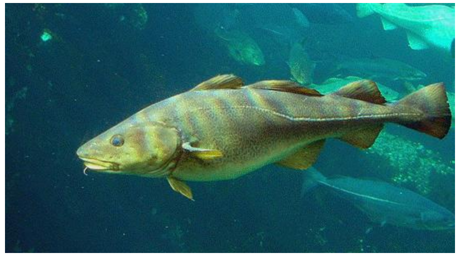
Changes in seafloor communities

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



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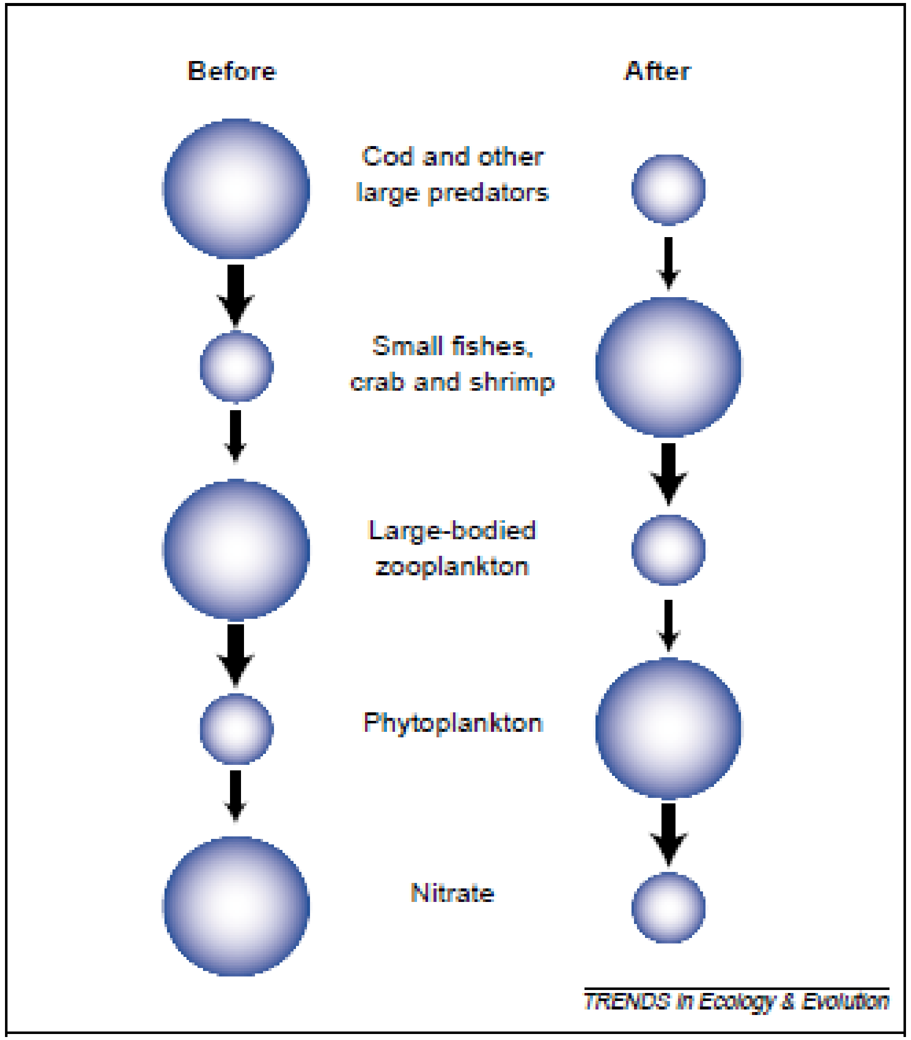
Crustaceans and small pelagic fish dominated community

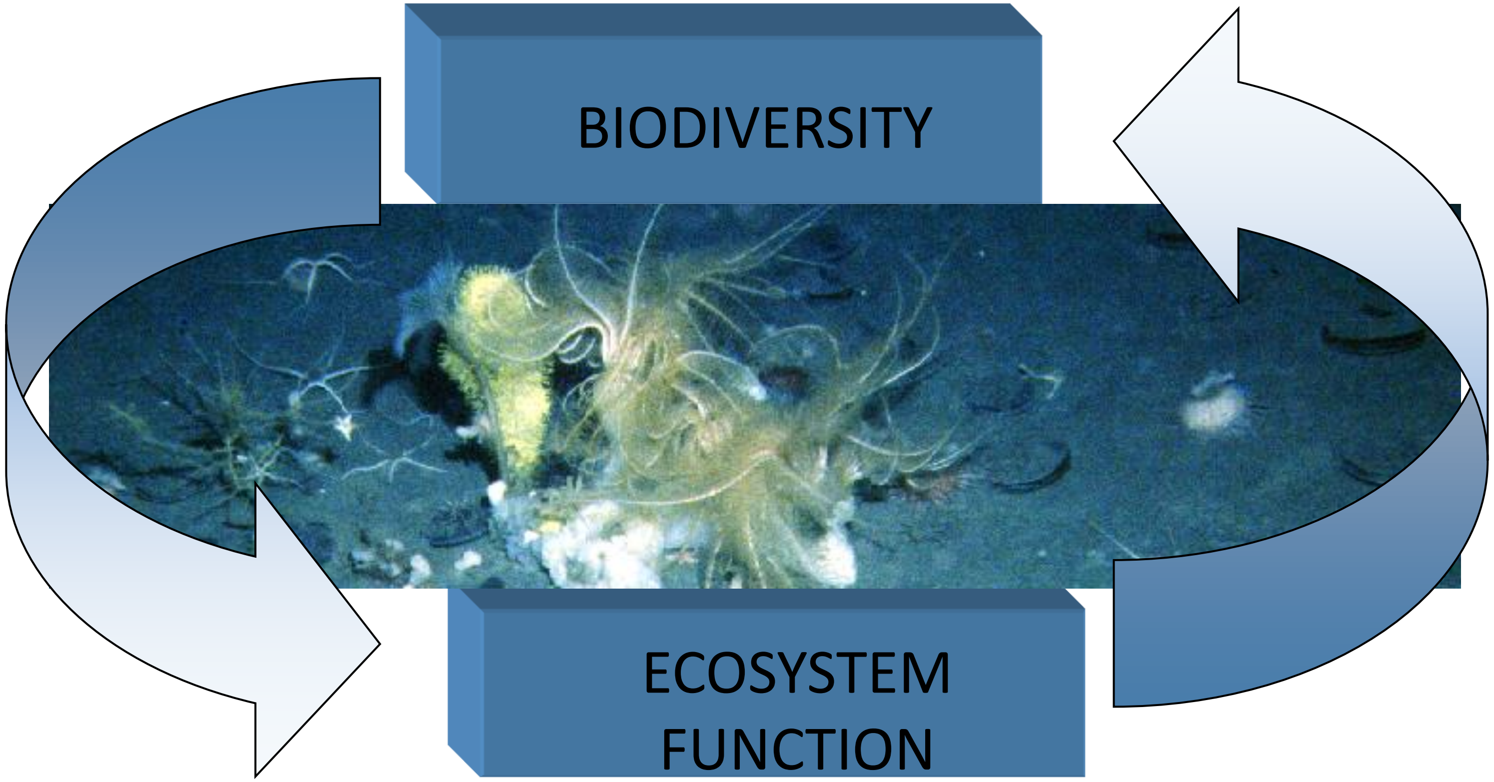
- - - →

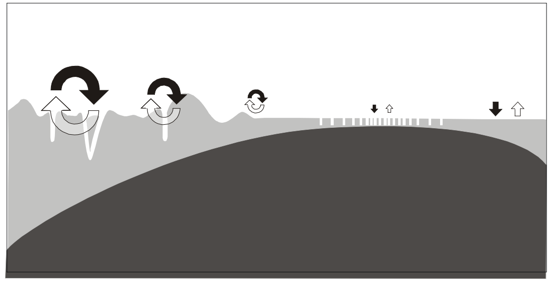


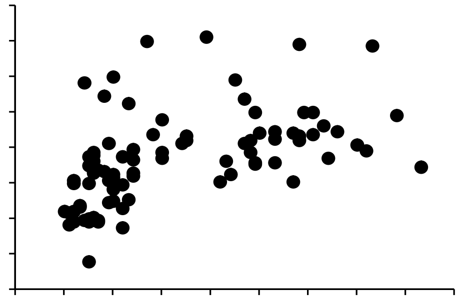
Frank et al. (2005). Science, 308, 1621-1623; Frank et al. (2011). Nature, 477, 86-89.

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

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*

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

Thrush, S. F., and P. K. Dayton. 2002. Disturbance to marine benthic habitats by trawling and dredging - Implications for marine biodiversity. Annual Review of Ecology and Systematics **33:449-473.**
Thrush, S. F., and P. K. Dayton. 2010. What can ecology contribute to ecosystem-based management? Annual Review of Marine Science **2:419-441.**

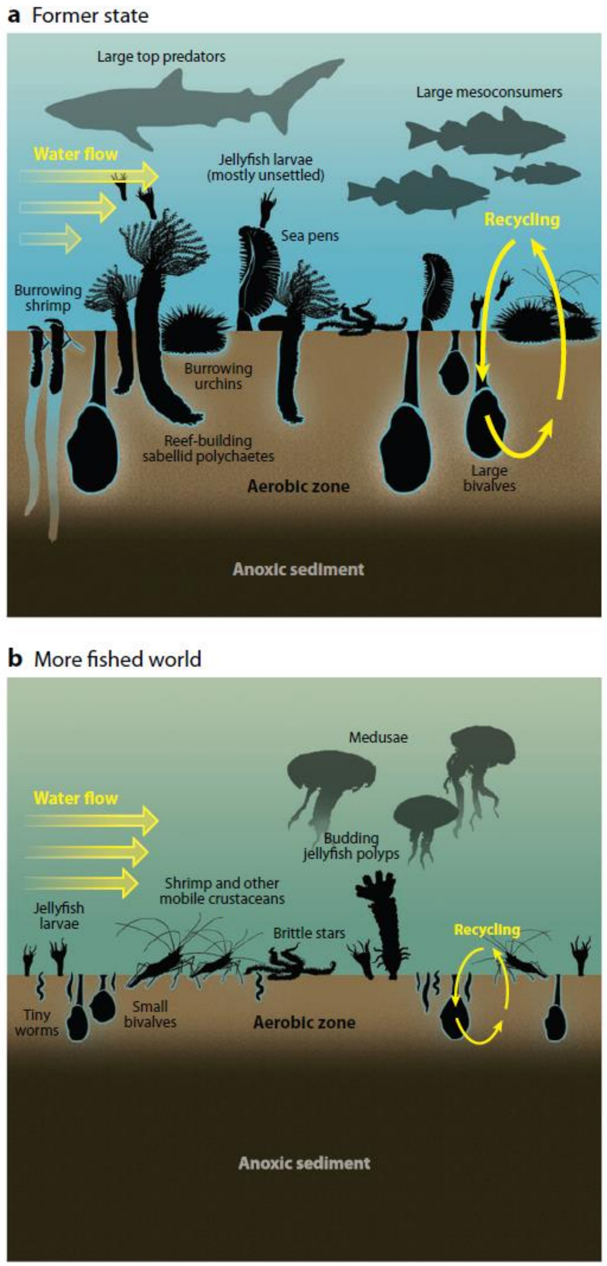
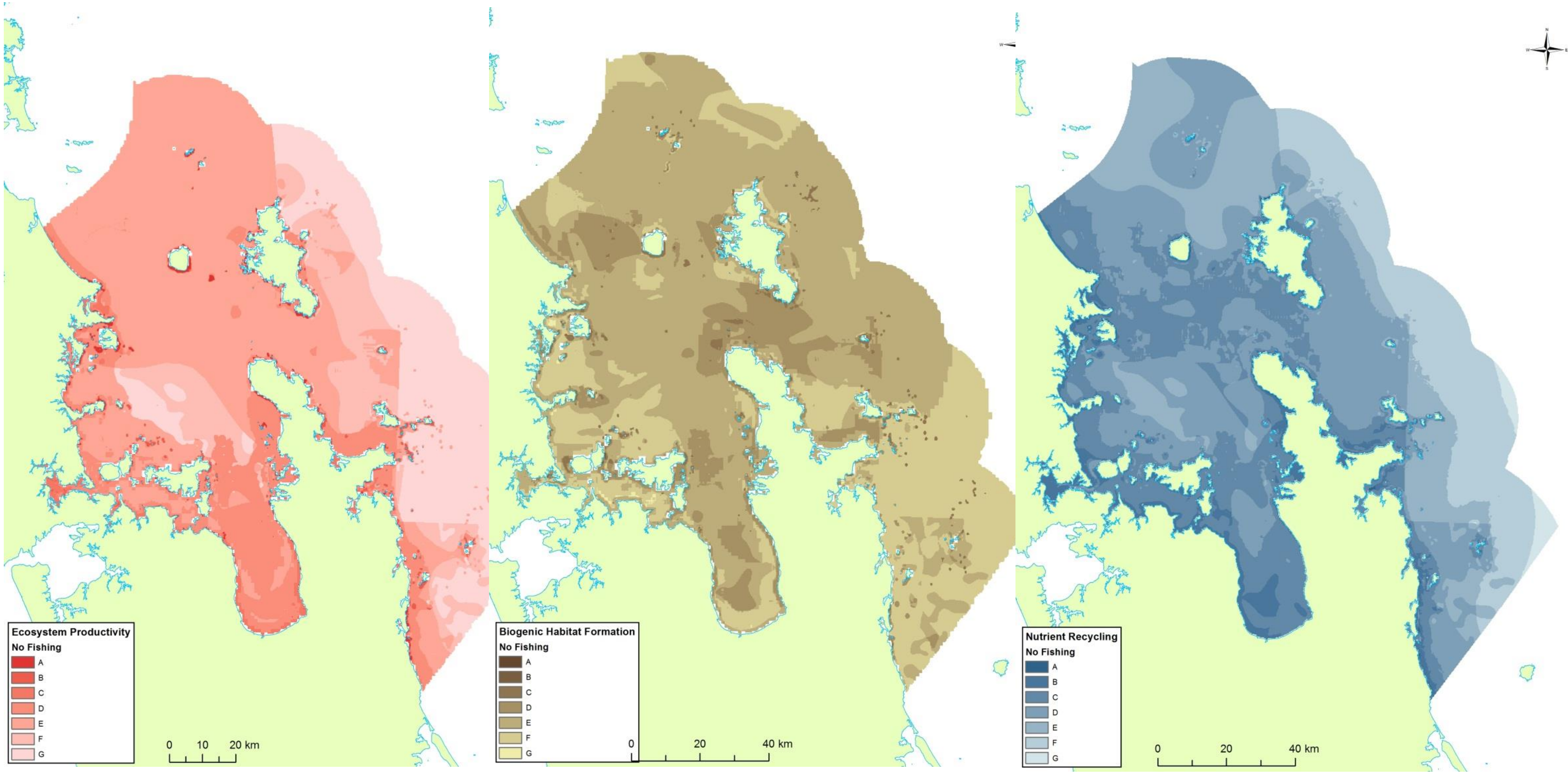


Figure 3
Ecological ratchets tighten their grip on marine ecosystems. Loss of top predators and habitat destruction removes environmental heterogeneity created by large and old organisms and decreases the depth and extent of sediment bioturbation and bioirrigation.

Ecosystem productivity **Biogenic habitat provision** **Nutrient recycling**

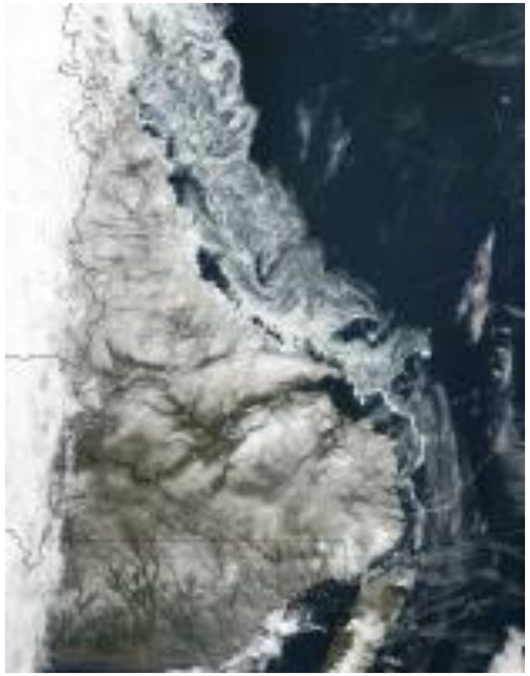


Townsend, M., S. F. Thrush, A. M. Lohrer, J. E. Hewitt , C. Lundquist, M. Carbines, and M. Felsing. In Press. Overcoming the challenges of data scarcity in mapping marine ecosystem service potential. Ecosystem Services.

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.



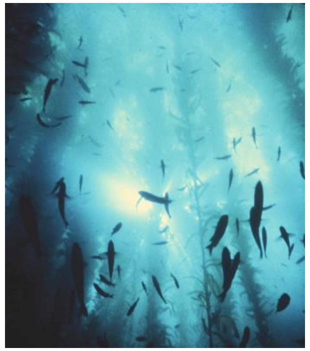


Photo credits: Visible earth; Paul Dayton, Rod Budd

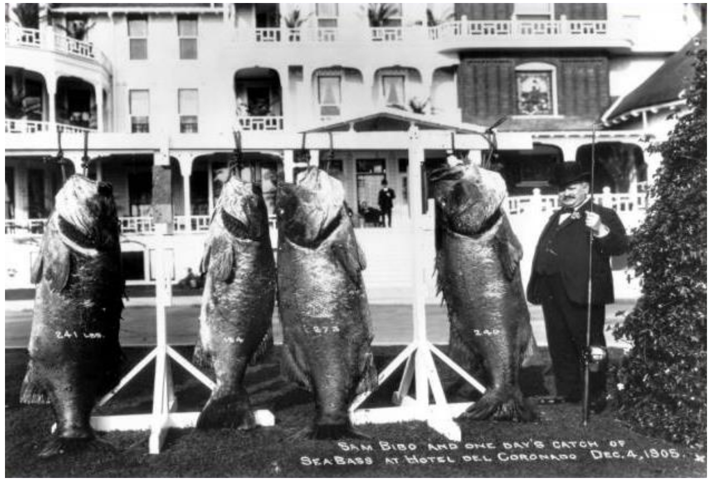
Thrush, S. F., J. E. Hewitt , P. K. Dayton, G. Coco, A. M. Lohrer, A. Norkko, J. Norkko, and M. Chiantore. 2009. Forecasting the limits of resilience: integrating empirical research with theory. Proceedings of the Royal Society B-Biological Sciences **276:3209-3217.**

Thrush, S. F., J. E. Hewitt , A. Lohrer, and L. D. Chiaroni. 2013. When small changes matter: the role of cross-scale interactions between habitat and ecological connectivity in recovery. Ecological Applications **23:226-238.**

Thrush, S. F., J. E. Hewitt, S. Parkes, A. M. Lohrer, C. Pilditch, S. A. Woodin, D. S. Wethey, M. Chiantore, V. Asnaghi, S. De Juan, C. Kraan, I. Rodil, C. Savage, and C. Van Colen. 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
- We need to think about insurance, buffers, resilience, agility and adaptation
- Empirical tests and gathering long-term data (monitoring) are critical

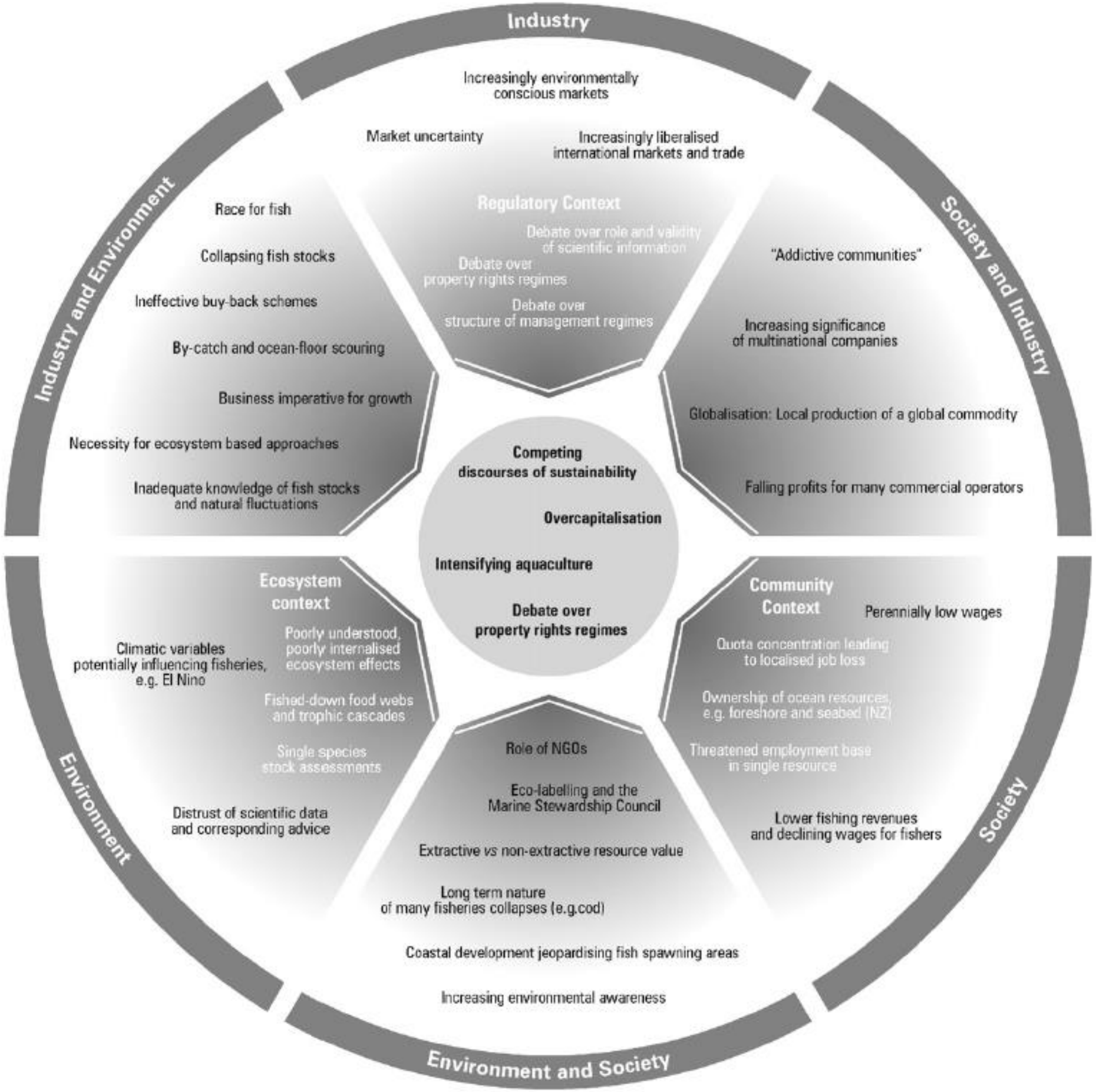


Ecosystem-based management must account for multiple values

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

Non–Integrative
Bureaucratic Structures
do not help

Key challenges involve societal-ecosystem interactions



LeHeron et al. 2008. Improving fisheries management in New Zealand: Developing a dialog between fisheries science and management (FSM) and ecosystem science and management (ESM) Geoforum **39:48-61.**

Options for the future

Marine Spatial Planning is an excellent way to address these issues

Restricting areas of bottom fishing – will have trade offs – spatially or with other methods that may have other impacts (e.g. seabirds)

Consider an adaptive approach

All users have to be considered

Cumulative impacts – potentially on juvenile life stages due to land use and climate change