How Do We Achieve Ecosystem-Based Sediment Management?

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SedNet European Sediment Research Network

COBO

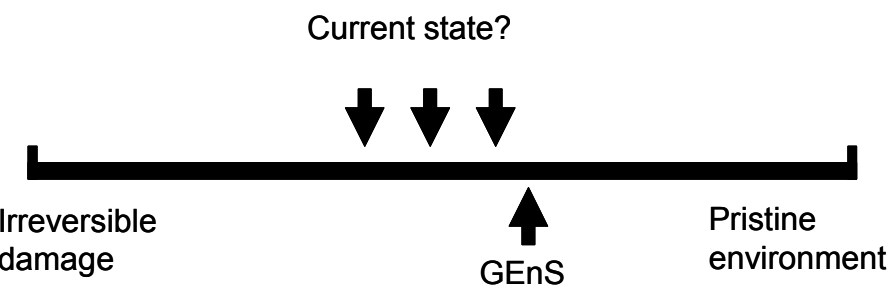
Emerging EU policy will result in an ecosystem-based management of the environment from land to the open sea

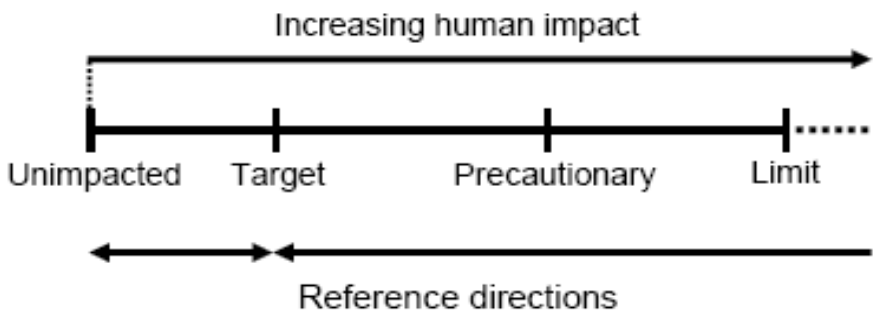
Recent or Emerging European Environmental Directives (a)	Environmental Focus of the Directive				
	Land	**Freshwater**	**Estuaries (b)**	**Coastal**	**Open Sea**
Habitats Directive	✓	✓	✓	✓	**Applicable only in the UK**
Water Framework Directive	-	✓	✓	✓	-
Integrated Coastal Zone Management Recommendation	-	-	**✓? (c)**	✓	-
European Commission Marine Strategy	-	-	**✓?**	✓	✓
Proposed Marine Framework Directive	-	-	**✓?**	**✓?**	✓

Apitz SE, Elliot M, Fountain M, Galloway T. 2006. European Environmental Management: Moving to an Ecosystem Approach. Integrated Environmental Assessment and Management: 2:80-86 .

Objectives and measures of ecosystem-based management

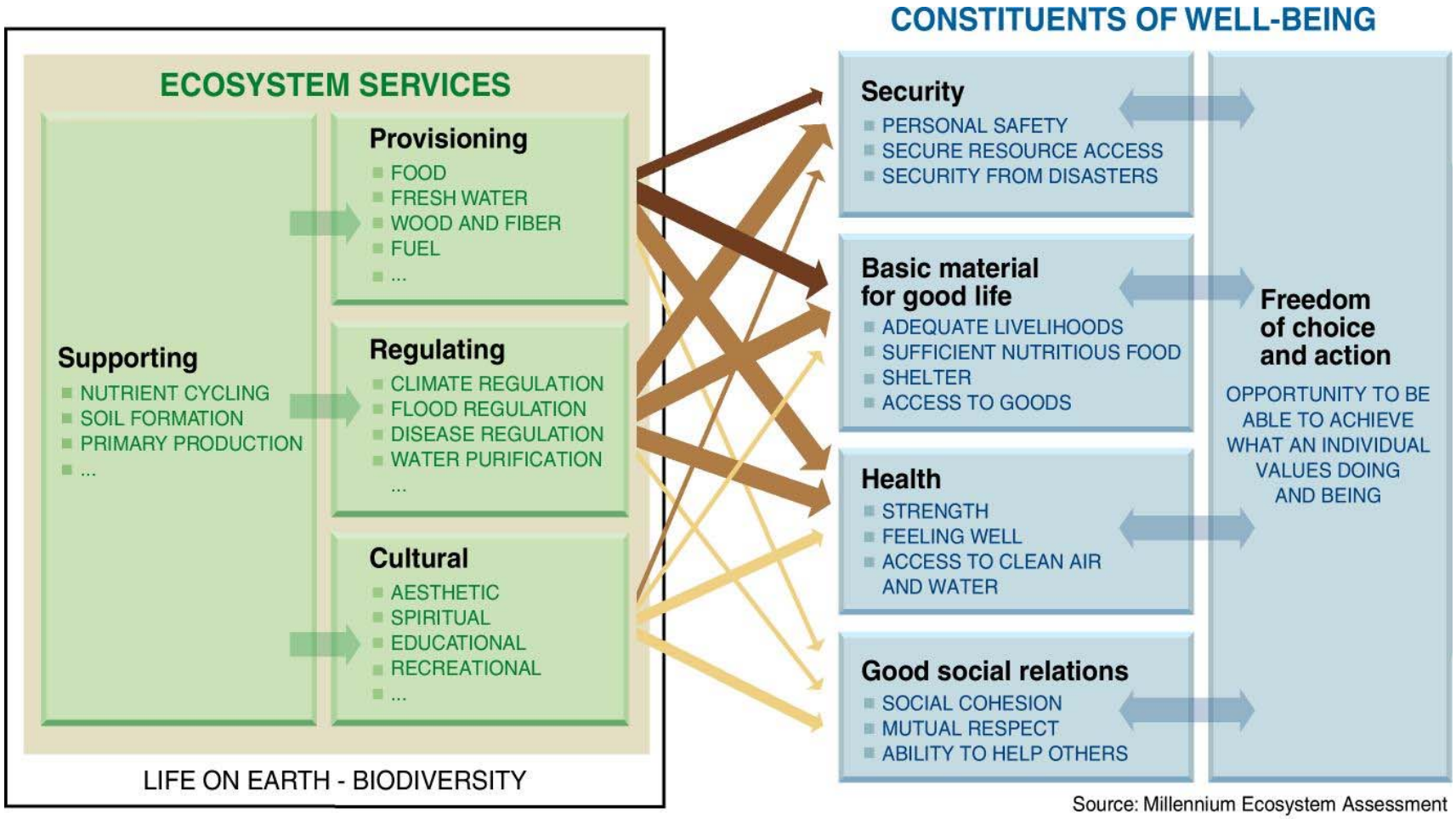
- Good Ecological Status (GEcS), is defined in the WFD in terms of the biological community which would be expected under conditions of minimal anthropogenic impact
- Good Environmental Status (GEnS) in the European Marine Strategy allows for human use and sustainability
- Statutes define their ecosystem goals differently, depending on their objectives, drivers and criteria. However, since many of these overlap, they will have to be reconciled
- Although none specifically mandate "ecosystem health," the term is used extensively in discussions on most of these statutes, and must be addressed, and possibly defined





Why do we want to protect ecosystem health?

Human well-being is dependent upon services provided by a functioning ecosystem

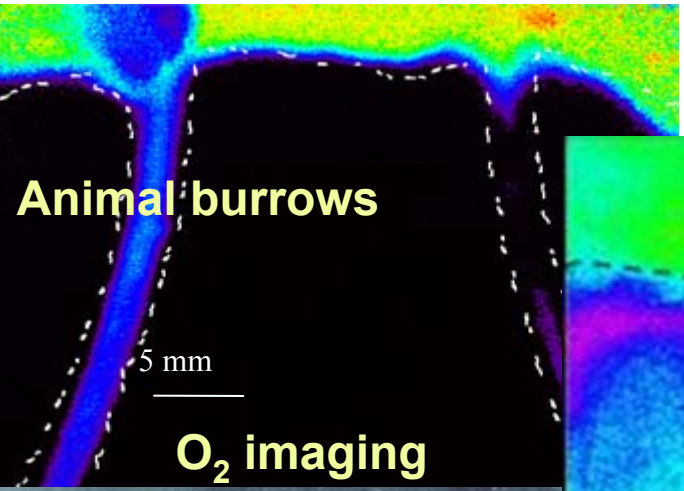


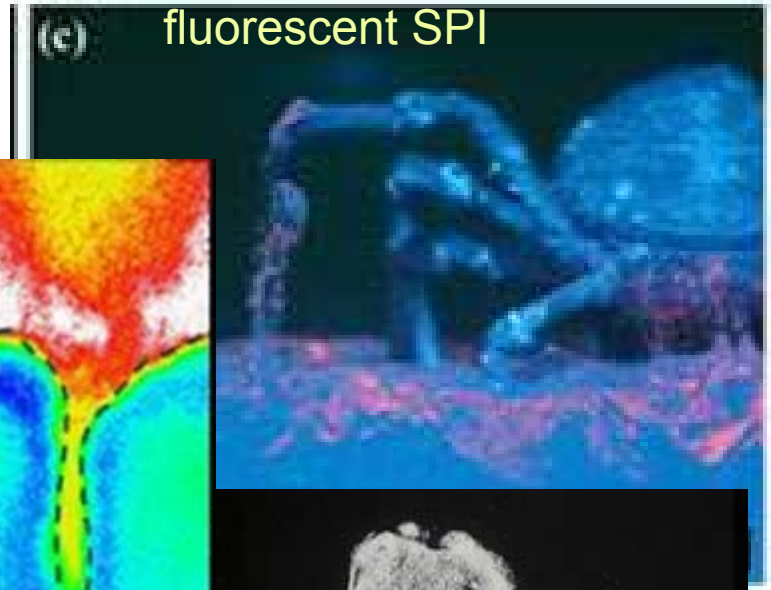
Source: Millennium Ecosystem Assessment

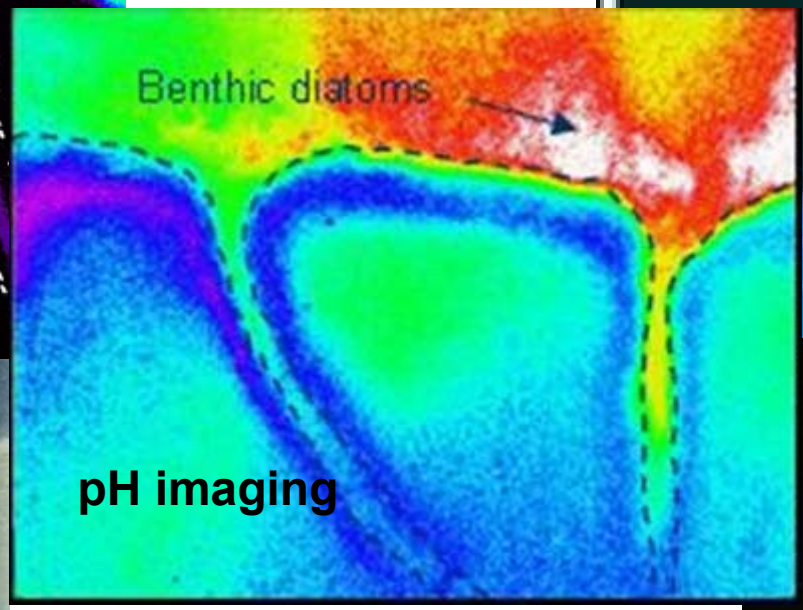
WFD and Marine Strategy Directive Indicators of *Benthic* Ecosystem Health are Based Upon Community Structure

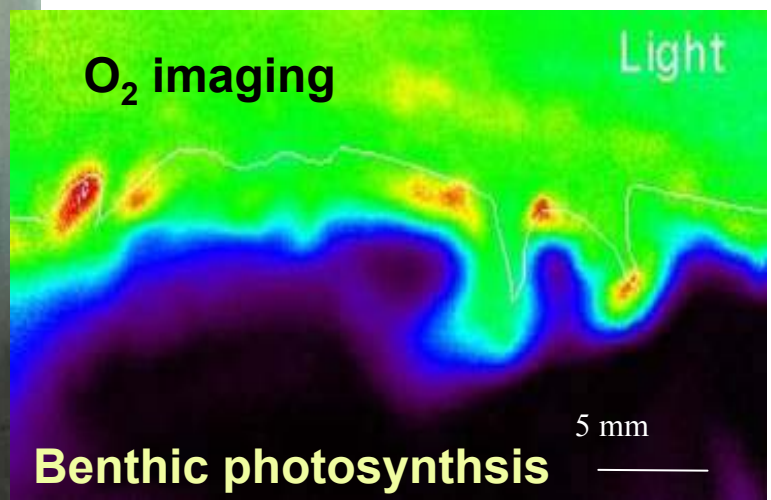
- However, benthic community structure is highly dynamic and sensitive to a variety of natural and anthropogenic factors
- Evaluating benthic "health" based upon structure provides little insight into causality
- Even if extensive programs of measures are carried out to "remediate" systems, community structure may never return to the "original" state
- "It is probable that the diversity of function is more important for the sustainability of ecosystem goods and services than species diversity per se…" Wall, 2004; SCOPE 64
- More meaningful measures of benthic community health are selected aspects of benthic community ***function***, *and their relationships to* ***ecosystem services***

Sediment organisms play a critical role in ecosystem functioning









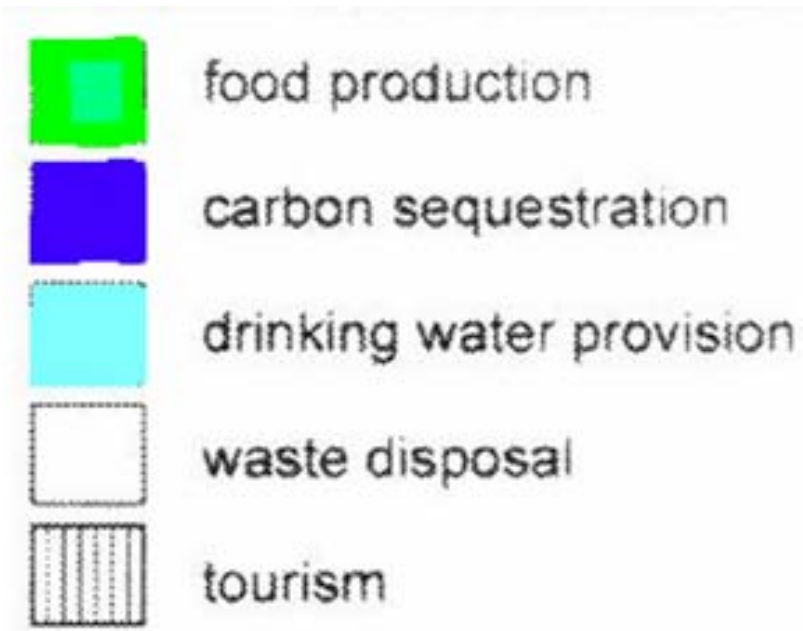
Soil and sediment ecosystems provide important services as a result of their ecosystem functions

Soil

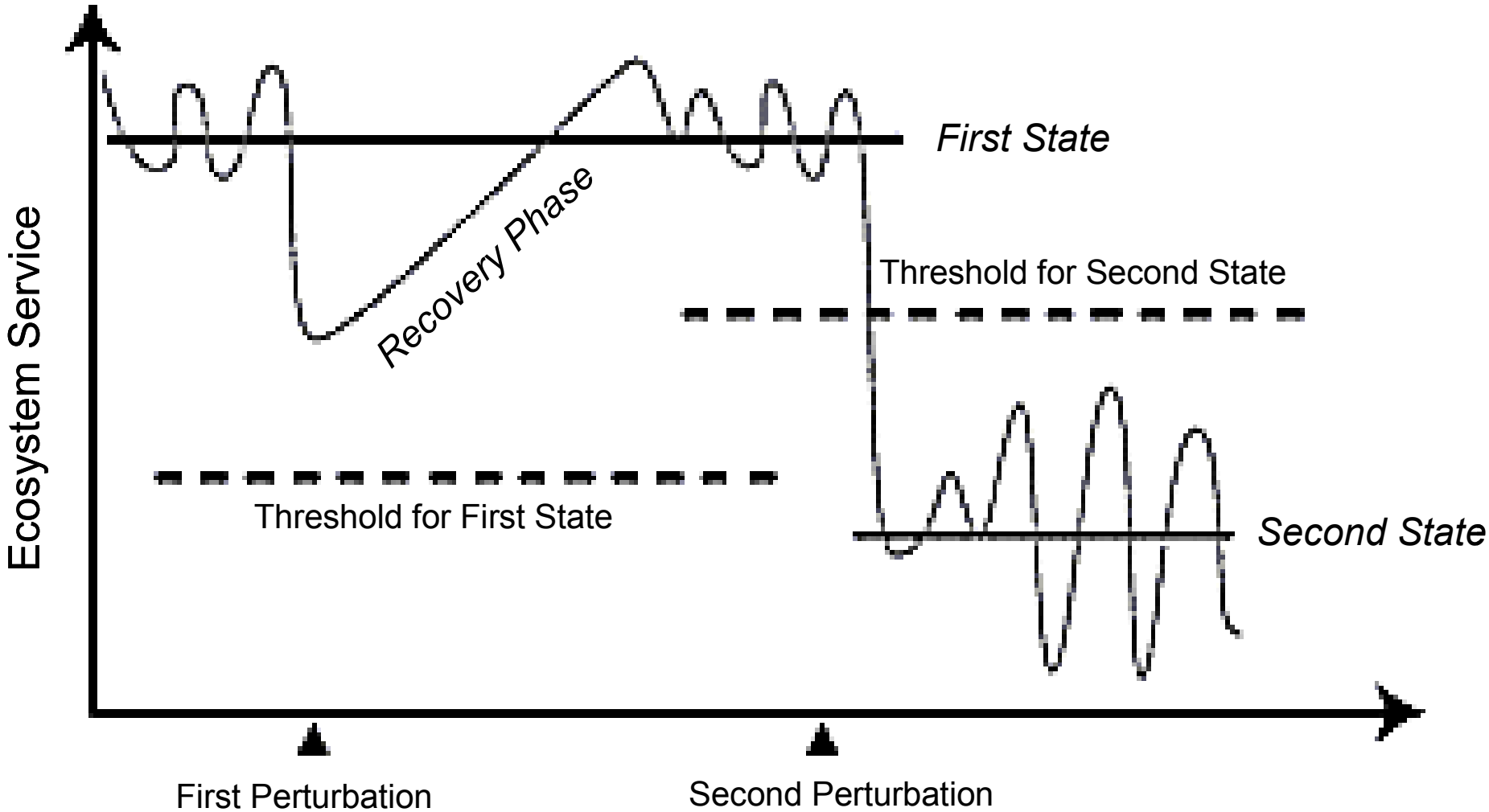
Fresh water Sediment

Marine Sediment

from: **Wall DH,** editor. 2004. Sustaining Biodiversity and Ecosystem Services in Soils and Sediments. Washington D.C.: Island Press. 275 p.

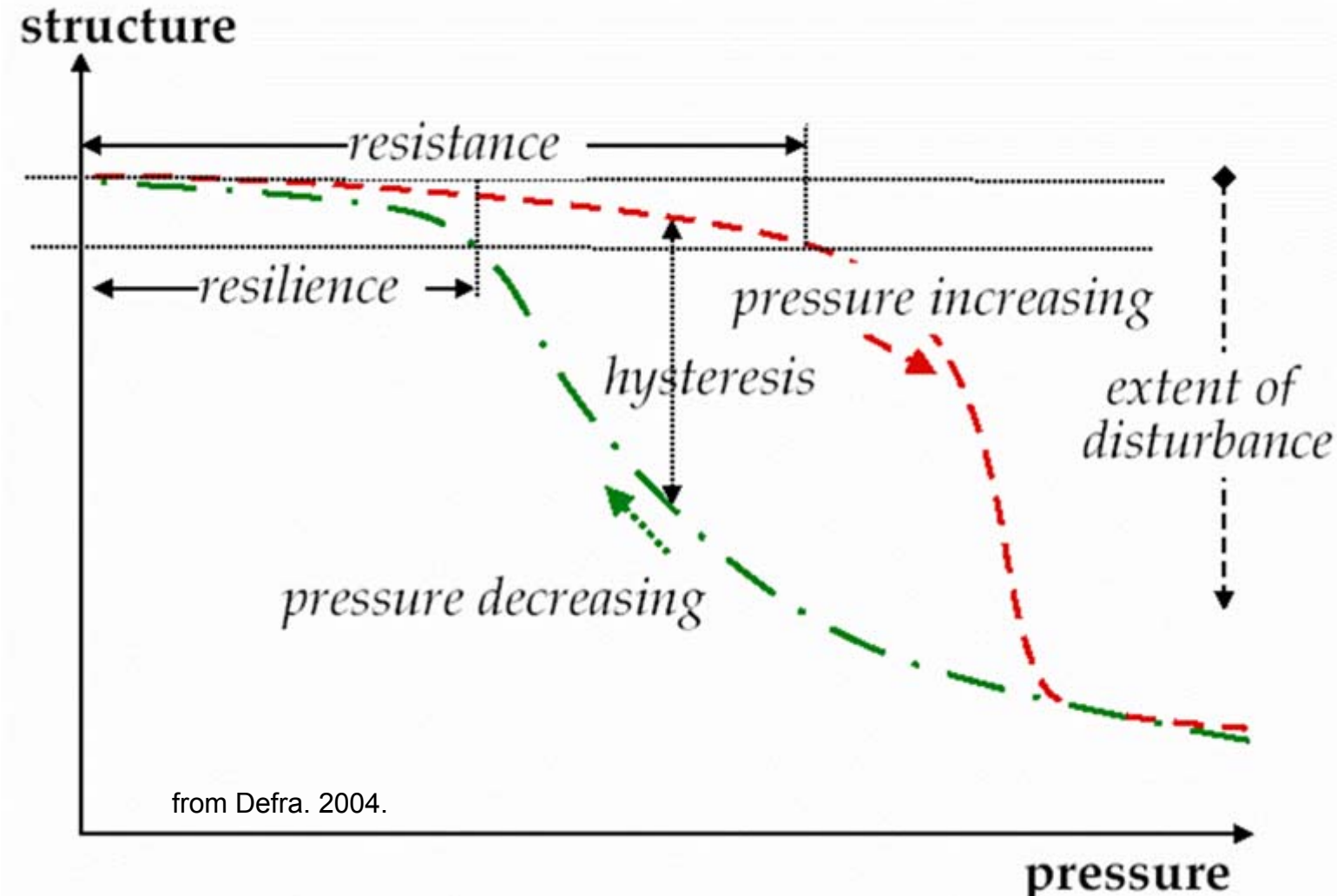


Many models of ecosystem response examine how services can recover from an impact, or reach a “tipping point” in which they move to an alternative stable state



Source: Millennium Ecosystem Assessment

As pressures are introduced and/or removed, community structure and function respond based upon resistance and resilience

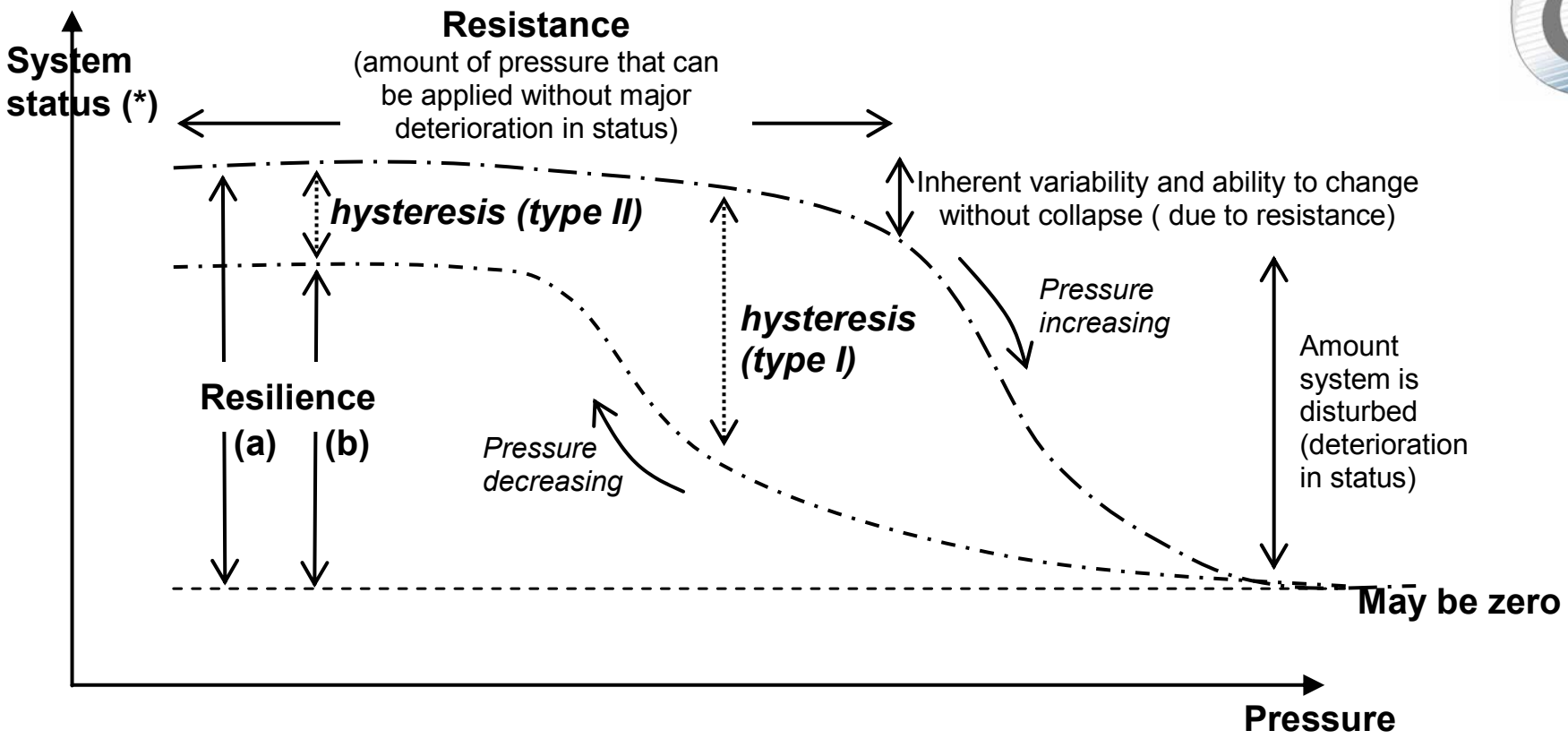


However, this model, developed to examine eutrophocation, assumes that systems can return to an original state, in reality, the final state may be different than the original one

Ecosystems and "State"

- If one considers ecosystems in terms of "climax communities", then a disturbance can shift from one stable state to another, and, possibly, return
  - Trees to grasslands, eelgrass to eutrophic
- More recent ecological theory suggests that communities respond to environmental gradients, have "memory" and that change is inherent
- So, if ecosystem status is measured as a set of multidimensional parameters of structure and function, then changes in this complex system may move in various directions, to countless alternative states.
  - If a pressure is removed, a given parameter may return to a lower, the same or a higher level

This revised conceptual framework allows us to begin to put benthic community (and other) ecosystem functions and services in terms of "health" or status measures



Key:

(*) relative to a defined metric of structure or function

(a) total resilience

(b) partial resilience

M Elliott, D Burdon, K L Hemingway and S E Apitz (2007) Estuarine, Coastal and Marine Habitat and Ecosystem Restoration: confusing management and science, accepted by Estuarine, Coastal and Shelf Science.

Costanza (1992) proposed that ecosystem health should include three components:

- **Vigour** (throughput or productivity of the ecosystem)
- **Organization** (species diversity and complexity of trophic and other interactions),
- **Resilience** (an ecosystem's ability to maintain structure and patterns of behaviour in the face of stress)
- **(V-O-R):** A healthy ecosystem, then, is one that is actively producing (V), maintains its biological organization over time (O), and is resilient to stress (R)

- Although Costanza proposed detailed quantitative indices for these factors, they can also provide a narrative framework or "triad" under which to organise structural or functional measures

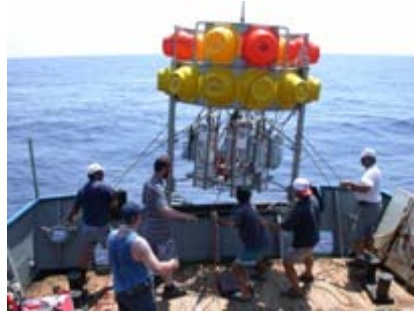
How do we link ecological response to sustainable management?

- "Quantitative information gained at the multi-species level from a number of robust experiments at small and large spatial scales and longer temporal scales must be conducted regionally and globally for a greater predictive capability concerning threats to, and controls on, different ecosystems and their services"
- "A priority for future research is incorporating effects of multiple stressors into experiments regionally"

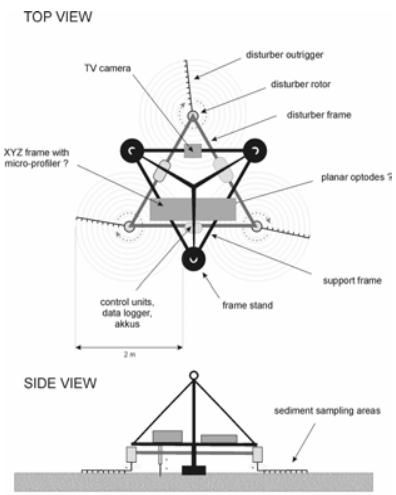
Wall DH (ed). 2004. Sustaining Biodiversity and Ecosystem Services in Soils and Sediments. Washington D.C.: Island Press. 275 p.

Integrated studies of benthic ecosystems

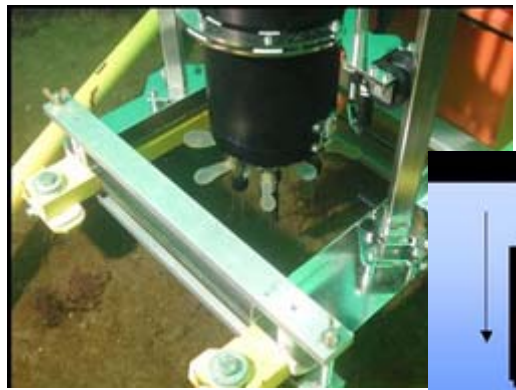
- Coastal Ocean Benthic Observatories (COBO) integrates innovative in situ technologies to study how benthic ecosystem structure and function respond to various perturbations
  - 13-partner consortium funded by EC Framework 6
  - In last year of 3-year programme
  - www.cobo.org.uk
- Others in Europe and elsewhere are focusing on microbial function, novel biomarkers, etc.

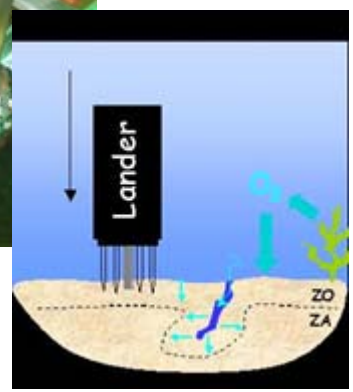


Biogeochemical lander (MPIMM)

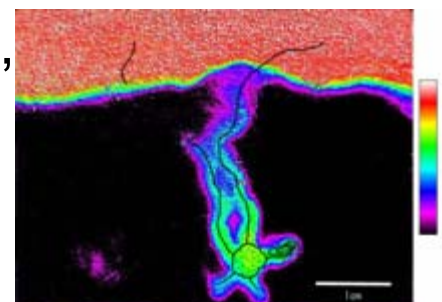


Integrated Sediment Disturber (AWI)





Lander with microprofiler and conceptual drawing (LCSE)

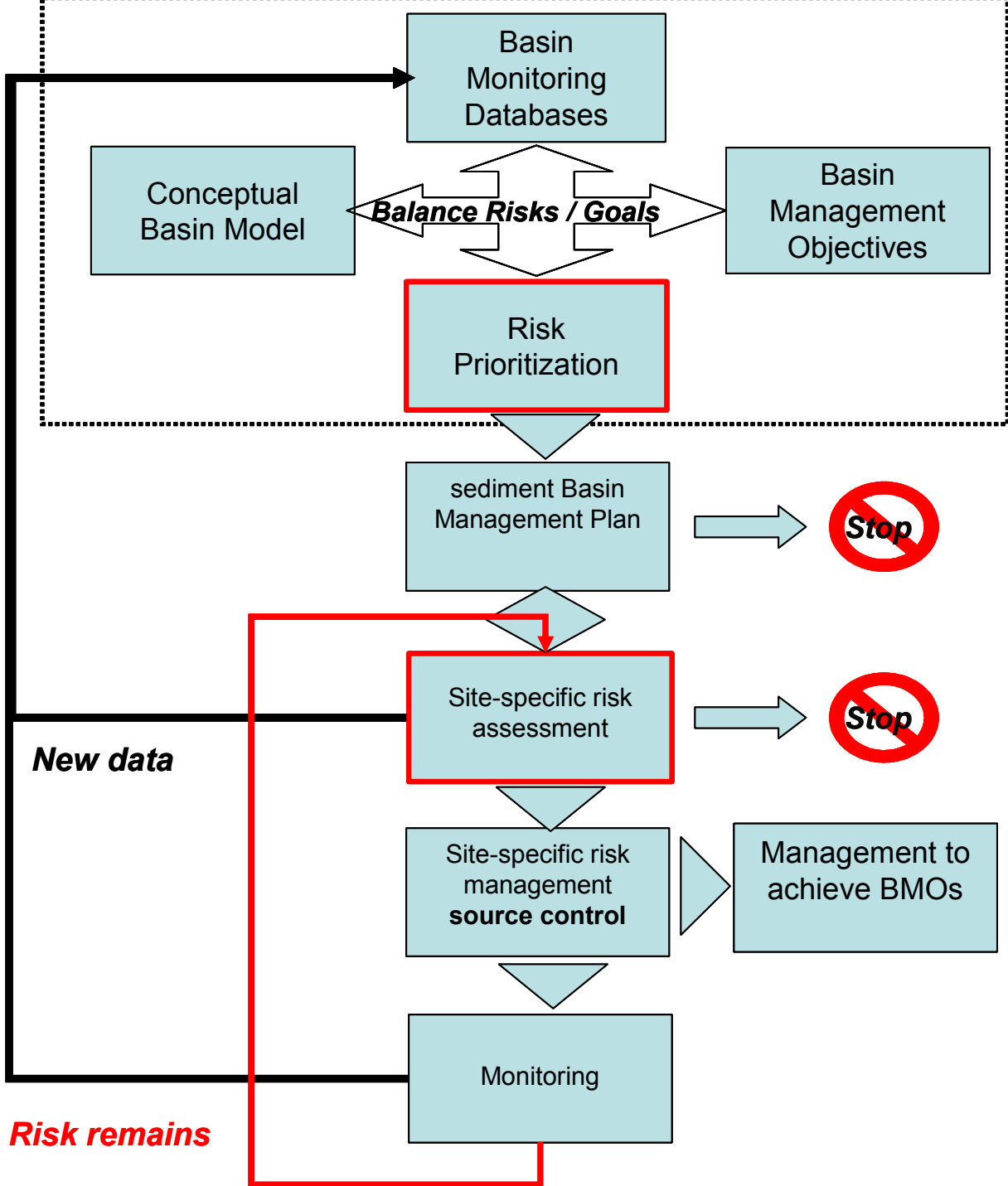


In situ image of organism effects on oxygen dynamics (U-COP)

Management of systems in support of one service (fishing, dredging, forestry…) can inadvertently impact other services, in the same system, or in others

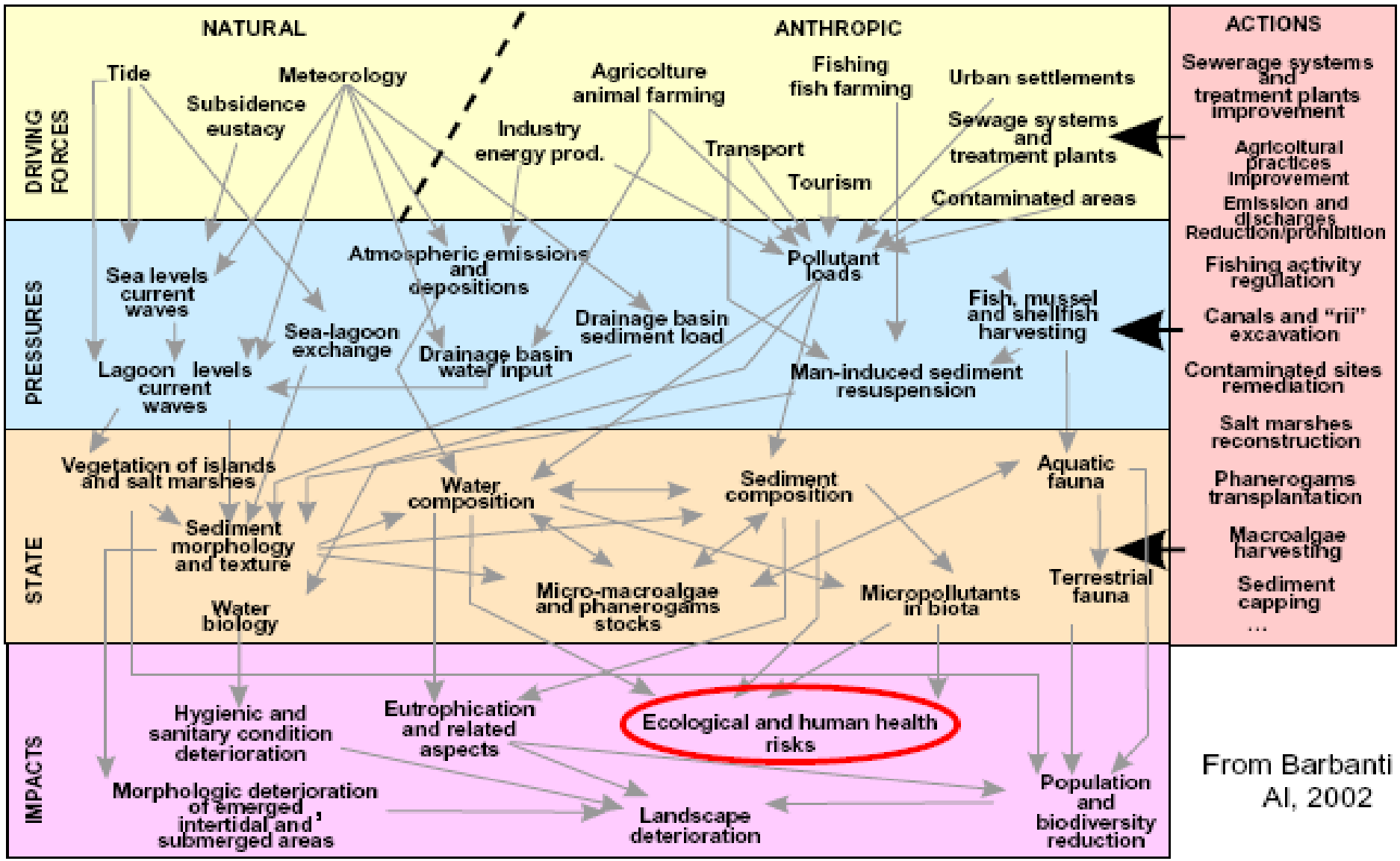
from: Wall DH, editor. 2004. Sustaining Biodiversity and Ecosystem Services in Soils and Sediments. Washington D.C.: Island Press. 275 p.

- In SedNet, we recommended that basin-scale risk management framework should be comprised of two principal levels of decision making
- basin-scale evaluation and
- site-specific management
- **It is important that any risk management is evaluated in terms of all services and functions it may impact**



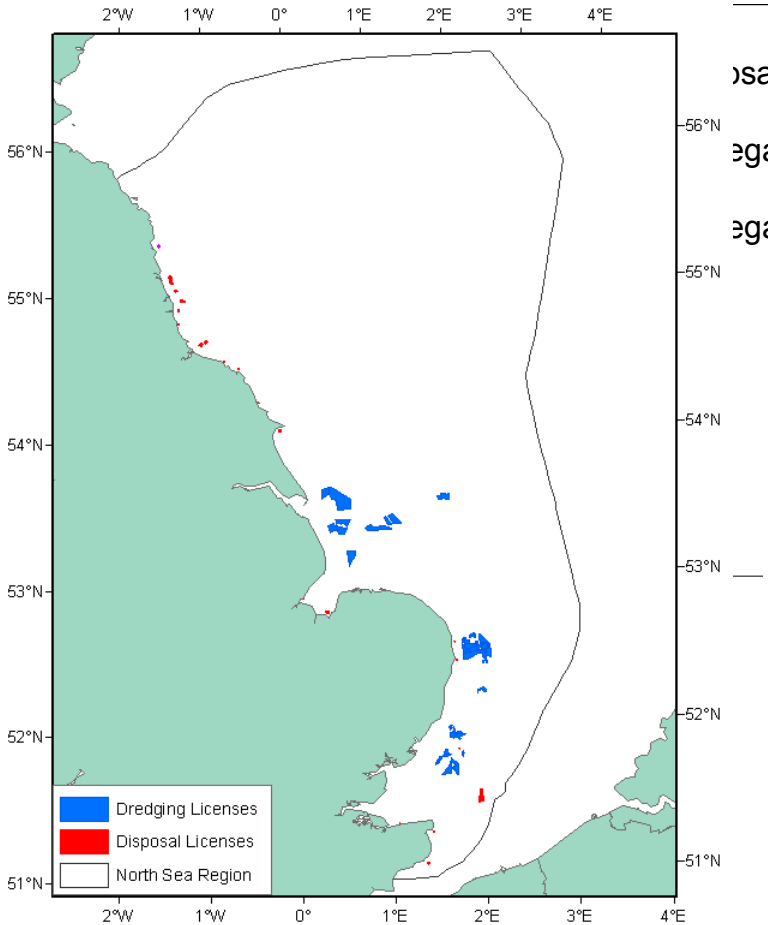
S E Apitz, C Carlon, A Oen and S White (2006b). Strategic Frameworks for Managing Sediment Risk at the Basin and Site-Specific Scale. In: Heise S, editor. *Sediment Risk Management and Communication*: Elsevier (in press).

For Venice Lagoon, a conceptual diagram lays out potential impacts to a more complex web of receptors – note that both natural and anthropogenic drivers are considered

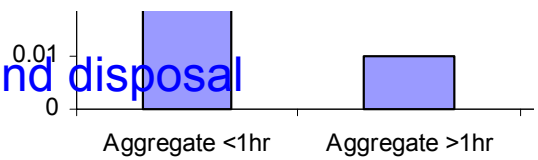


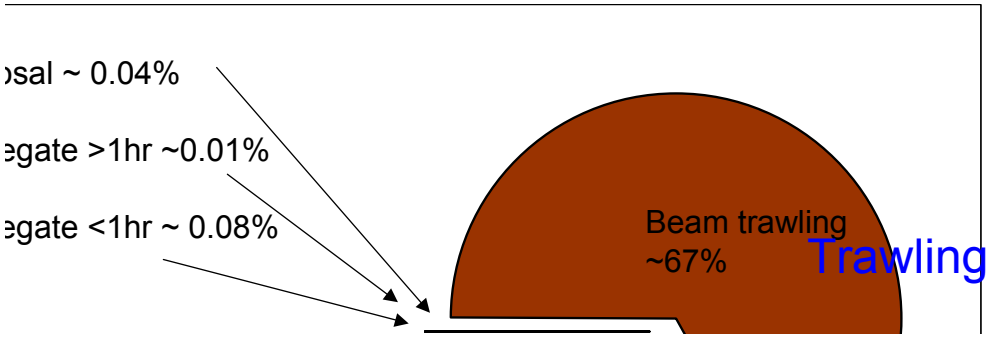
From Barbanti et Al, 2002

It is important to put your regulatory (and research) focus on where the issues are most important

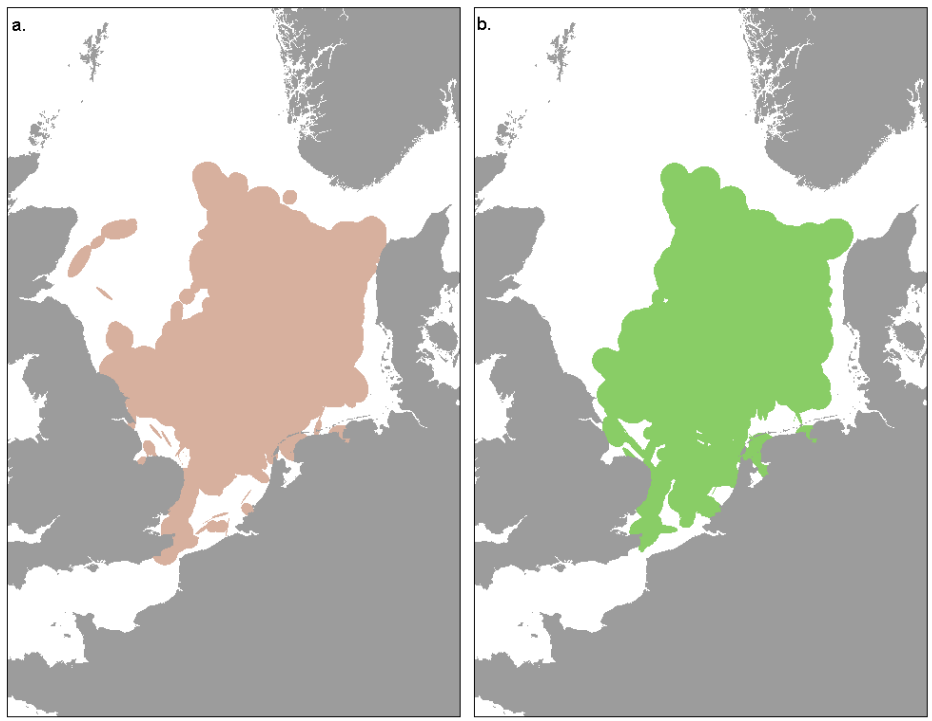


Dredging and disposal





Trawling



adapted from Ruth Parker

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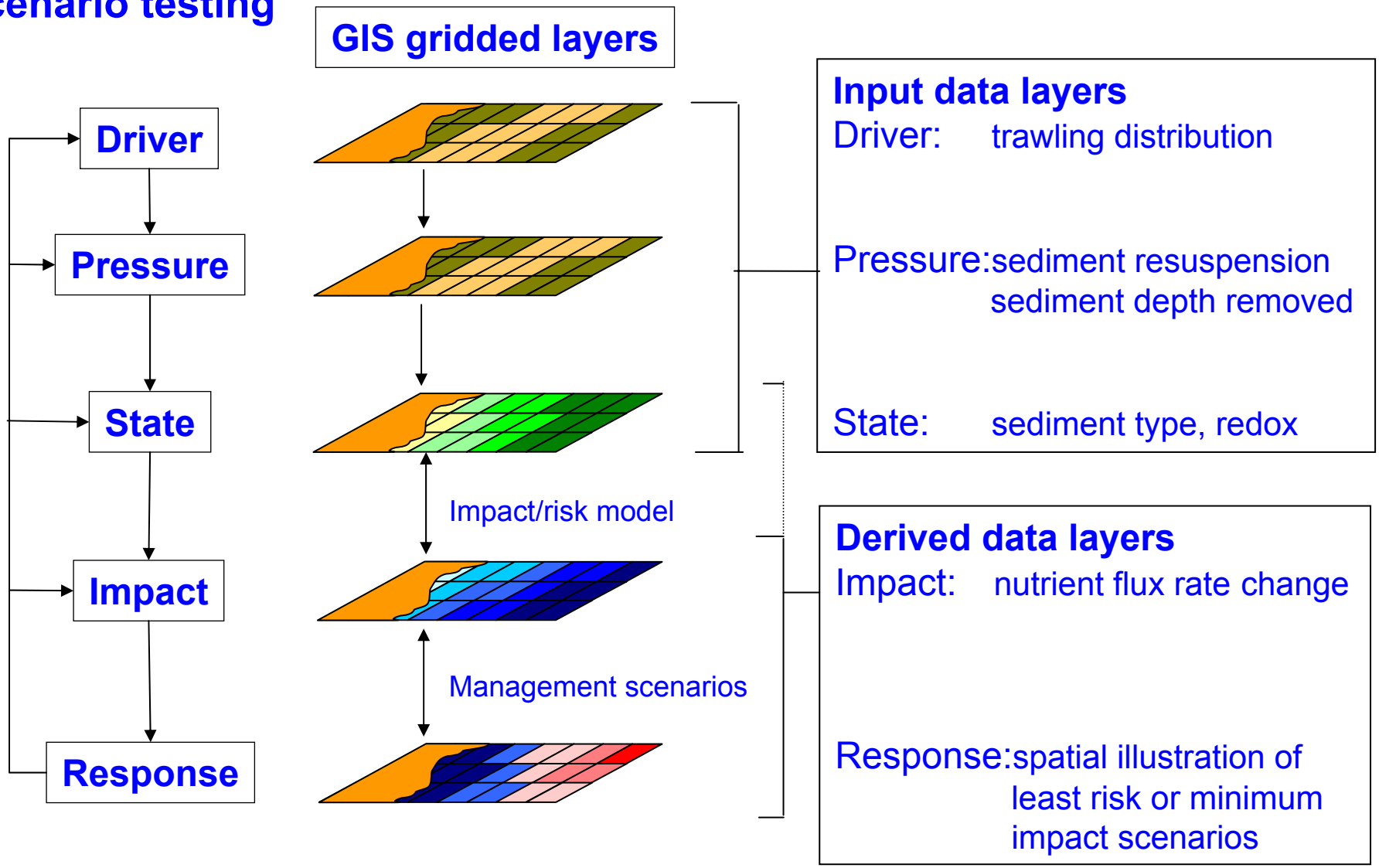
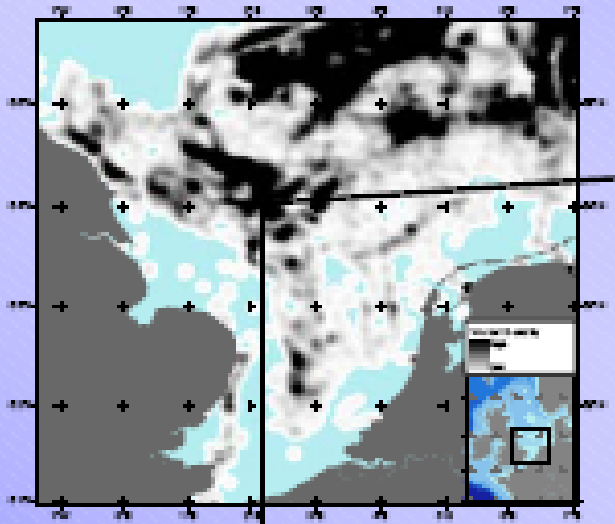
GIS tool for scenario testing



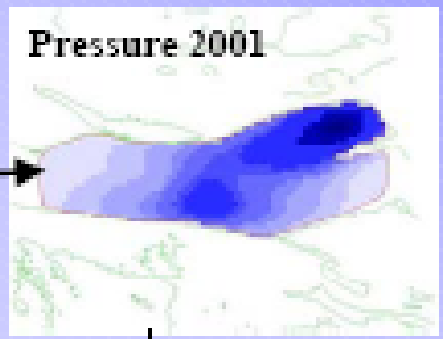
In this CEFAS project, disturbances are combined with modelled impacts to predict responses to various scenarios

GIS- based impact assessment: the effect of trawling patterns on benthic function

Driver – regional satellite 2001

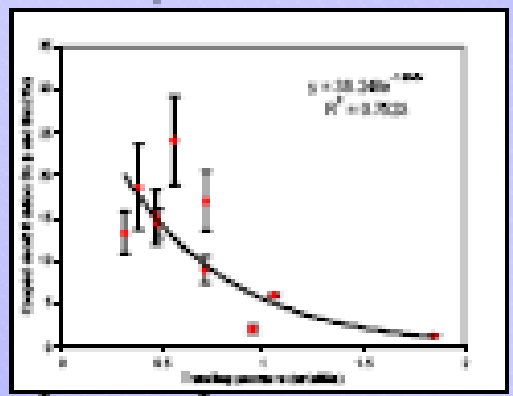


Pressure 2001



State Du 2001

Du Impact model

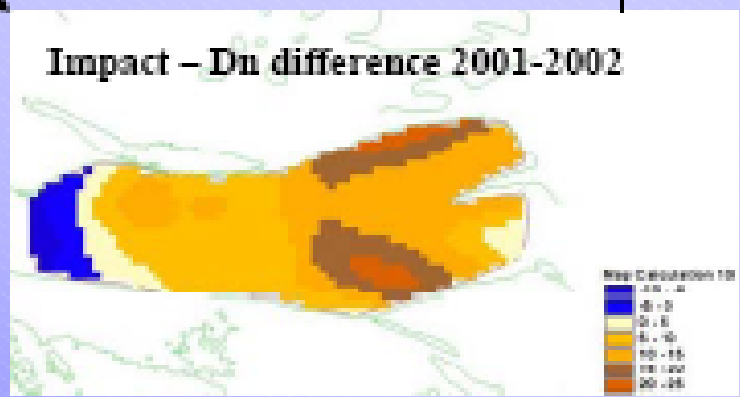


Response: impact assessment of
- Inter-annual variability
- Zero trawling scenario

Pressure 2002

State Du 2002

Impact – Du difference 2001-2002



from Parker et al., 2004

from Parker et al., 2004

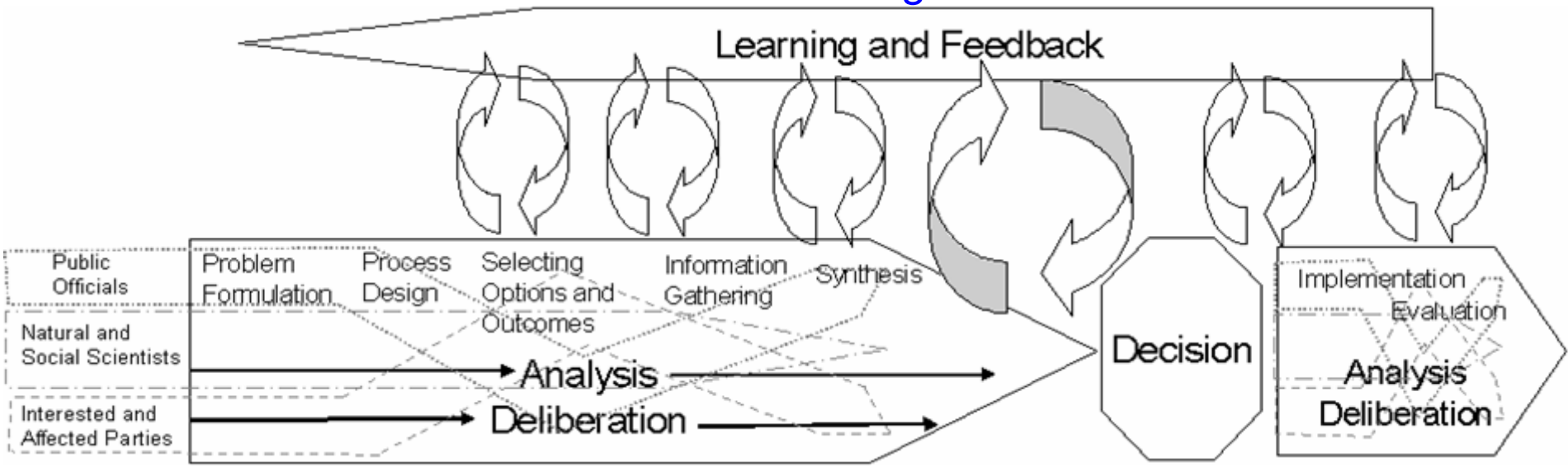
In future, sediment management will be considered in terms of overall spatial planning, which will force us to consider much more complex, systemic risk issues

Mapping and zoning for Marine Spatial Planning

Traditional indicators compared with emerging threats to coastal ecosystems (from Boesch and Paul, 2001)

What we currently measure	Emerging threats
Contaminant levels	Irreversible habitat change (loss of productivity and biodiversity)
Material inputs (e.g., nutrients, sediments)	Modification of the N cycle
Fish catch	Watershed landscape conversion (e.g., urban sprawl)
Extent of certain habitats (e.g., wetlands)	Effects of climate variability and change
Community structure	Non-indigenous species
Toxicity biomarkers	Sustainable fishing
Indicators of human pathogens	Release of hormones and antibiotics
	Teleconnections (atmospheric iron)

Some final thoughts



- We need to clearly define the role of sediment management in sustainable ecosystem management
- In future, management in support of ecosystem health and sustainability may dominate sectoral management
- This will result in the evaluation of complex, systemic risk issues at many scales
- Whilst science can advise these decisions, how it will be carried out is the choice of policy
- Scientists must learn to communicate in terms of informing decisions
- Complex risk decision making must have the continuous involvement of all parties, and should be a iterative and deliberative process
  - see figure, adapted from Stern and Feinberg 1996
- "Management decisions must be made, even when information is imperfect"* , but adaptive management and thinking allows us to learn as we go.
  - *National Research Council (NRC) (2001): A Risk-Management Strategy for PCB-Contaminated Sediments.

This presentation is a synthesis of many projects, and many people's work. In particular, the following should be acknowledged for their slides and/or collaboration

- Andrea Barbanti; Mike Elliott; SedNet (an EC-funded European Network) WG2; Sue White.

COBO partners…

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University Court of the University of Aberdeen - UK

Centre for Environment, Fisheries & Aquaculture Science

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