Marching forward or flying blind? Ensuring that sediment management strategies and frameworks meet our objectives

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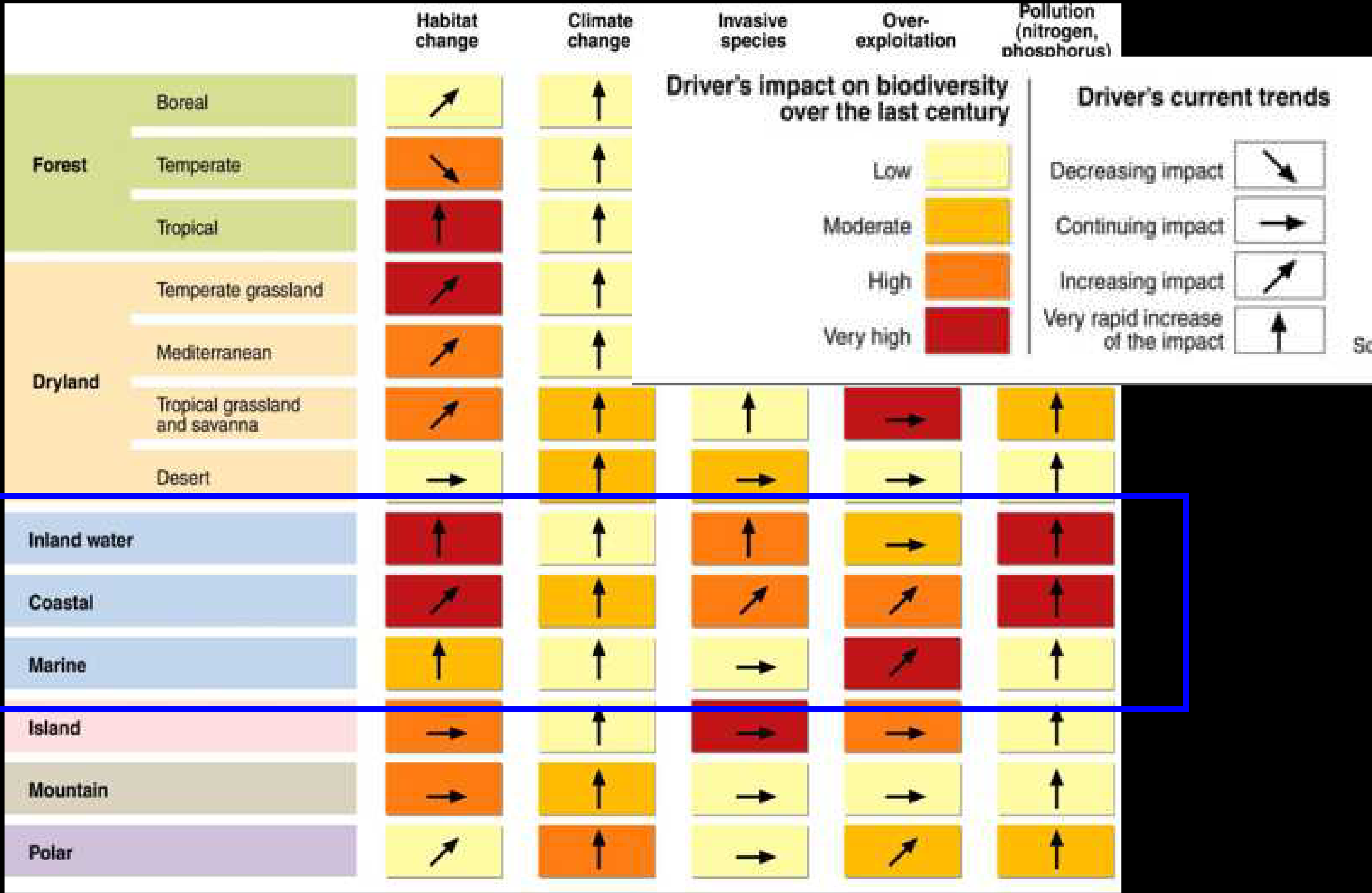
Coasts and inland waters are among the most heavily impacted areas



Trends in Drivers

WFD and MSD seek to address this

Source: Millennium Ecosystem Assessment

Basic Goals of a Sediment Manager

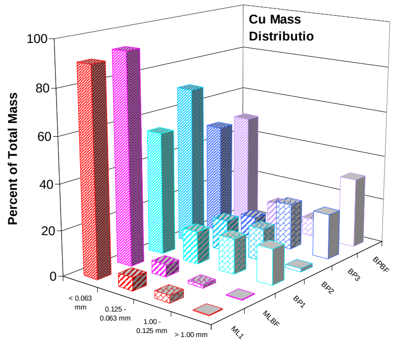
- Managers and decision makers must evaluate how to balance ecological and socioeconomic objectives for sediments
- Managers often have parallel (but possibly competing) drivers:
  - Maximizing goods and services
  - Minimizing risk to the environment and human health and
  - Minimizing cost

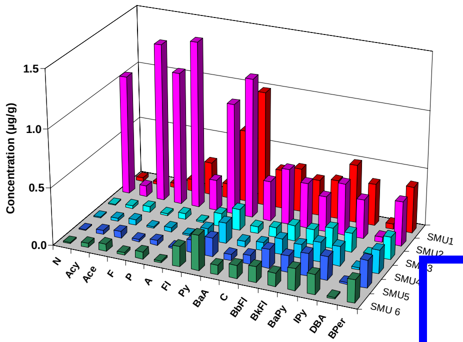
…but we've argued that the role of sediment manager should not stand alone – we should be addressing how sediments affect our goal of sustainable river basin, coastal and marine management

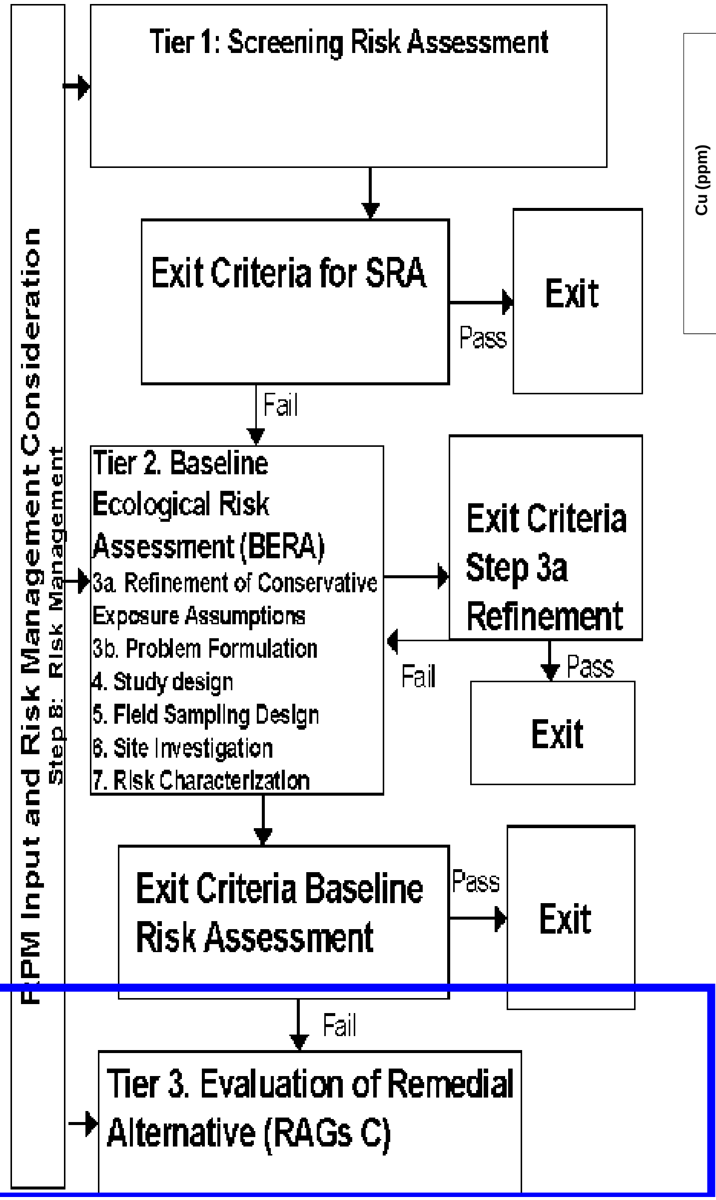
International review of sediment assessment/ management frameworks and approaches

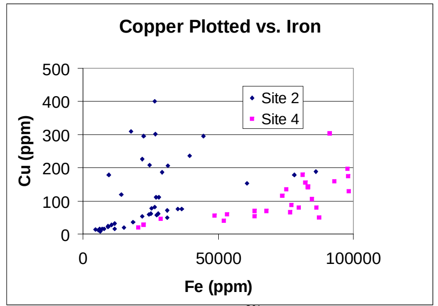
- Reviewed frameworks for ecological assessment and dredged material management
- Examined the technical and policy drivers
- Seemingly subtle differences can result in significantly different decisions
  - Frameworks are ***not*** interchangeable without careful analysis of decision drivers and program needs
  - Whilst science can inform, many of these choices are policy decisions
  - There need to be explicit links between what we measure and what we wish to achieve

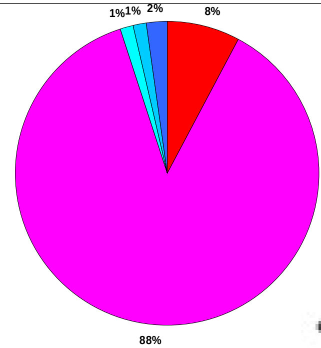
There are various ways to look at your sediment data, depending upon the management questions being asked

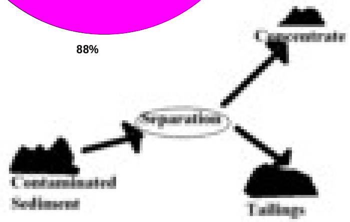








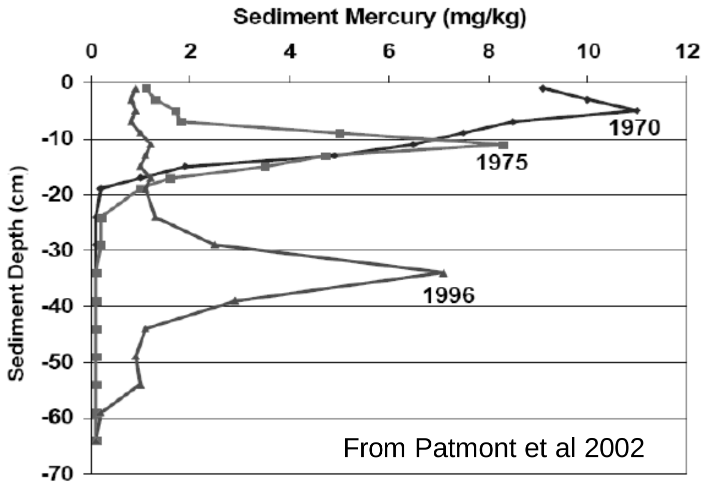




- One of the consequences of [European regulatory] complexity seems to be that in Europe there is less regulatory acceptance of risk-based (rather than mass-based or chemical threshold-based) decisions…
  Förstner and Apitz (2007) *JSS* **7(6):**351-358
- As in the US some time ago, “presumptive remedies” are being pushed by a number of agencies, and in-place management is meeting great resistance
- However, risk-based remedy selection is entirely consistent with European policy, and generic presumptive remedies may actually fall foul of policy
  Apitz, 2008, in prep
- As we develop decision frameworks, it will be important that they are tailored to European objectives

Examples – unintended consequences

- Due to reductions in contaminant inputs over time, presumptive removal of sediments may actually expose water and biota to higher, more bioavailable concentrations



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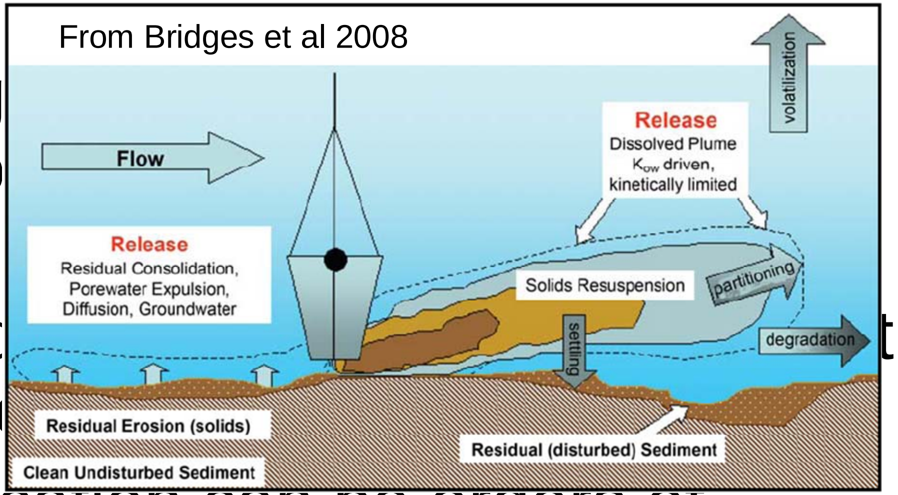

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  gnification can be orders of magnitude higher in terrestrial than in aquatic food chains
- Barring in-water disposal of sediments based on over-conservative standards rather than regional levels may limit beneficial use and habitat enhancement schemes

Management Strategies - One Man's Risk is Another's Recovery

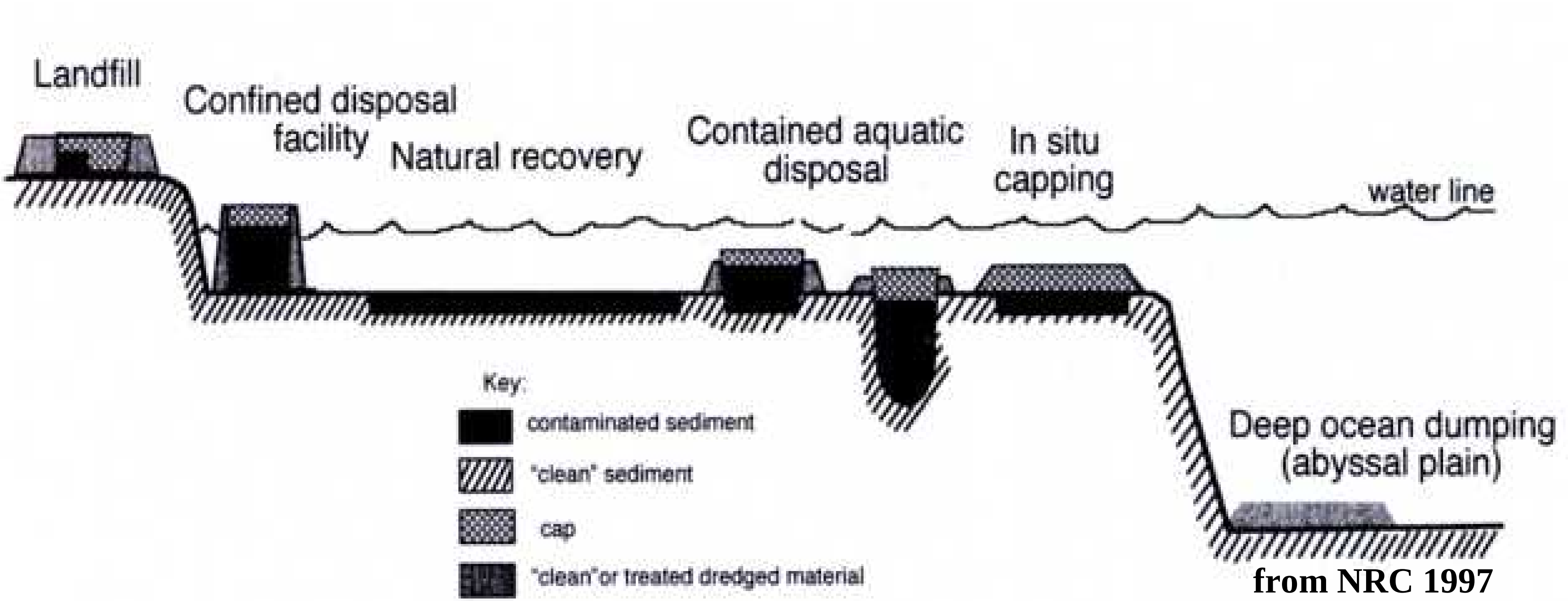
High Index	Risk	Recovery	Example Control Strategies
Diffusion	Contaminant flux to biota	Contaminant attenuation	Reactive/sorptive cap Thicker cap Predict recovery
Bioirrigation	Contaminant flux to biota	Contaminant attenuation	Barrier
Advection	Contaminant flux to biota Contaminant flux to sediments from offshore	Contaminant attenuation O_2, nutrient delivery	Reactive/sorptive/impermeable caps Groundwater interdiction Predict recovery, Permeable cap
Erosion/Resuspension	Contaminated particle transport – site spreading Exposure to biota	Mixing/dilution of contaminants Enhanced degradation (aerobic)	Removal, containment Predict bioremediation
Sedimentation	Continued input (if contaminated)	Burial (if clean)	Control source Predict recovery
Bioturbation	Exposure to biota Upward mixing	Dilution O_2, nutrient delivery	Barrier
Biodegradation	------------	Loss of contaminants	Enhance biodegradation Avoid blocking O_2

An understanding of the relative importance of these processes at sites will focus site conceptual models and help risk managers balance these processes

The site-specificity of sediment/contaminant/ecosystem interactions demands that there are no presumptive remedies – site-specific evaluation is always required

Sediment containment and disposal options

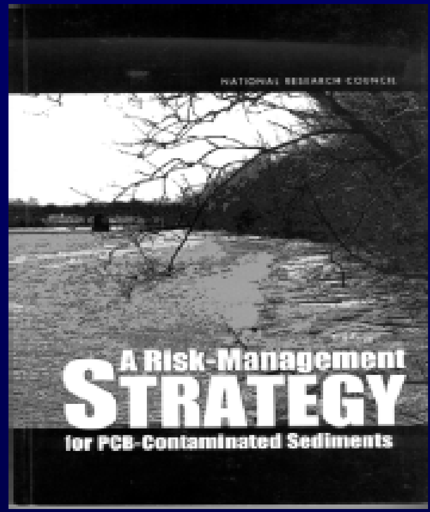
There is a need to add beneficial use and habitat enhancement/restoration to the options in a balanced way

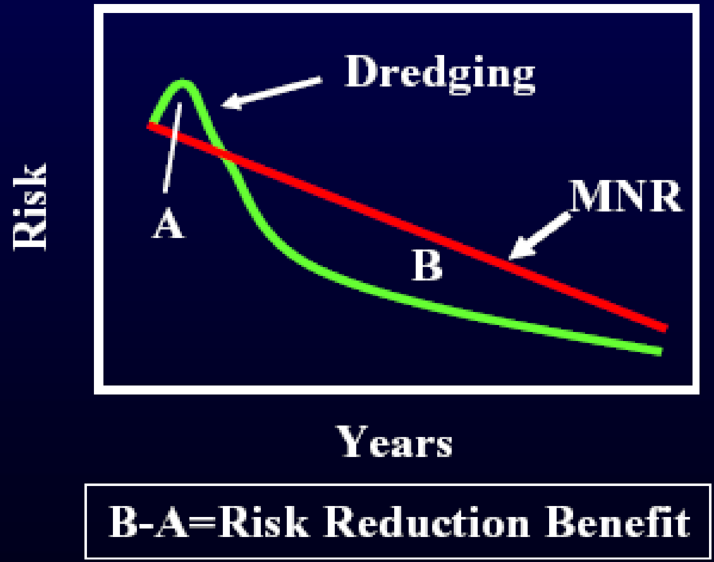


from NRC 1997

The Mysteries of Remedial Decision Making

- Value of comparative approaches, e.g., NAS report
- Risks and uncertainties exist for each management alternative
  - There is no zero-risk option
  - More complex remedial designs = larger pool of uncertainty
- We need rigorous methods!



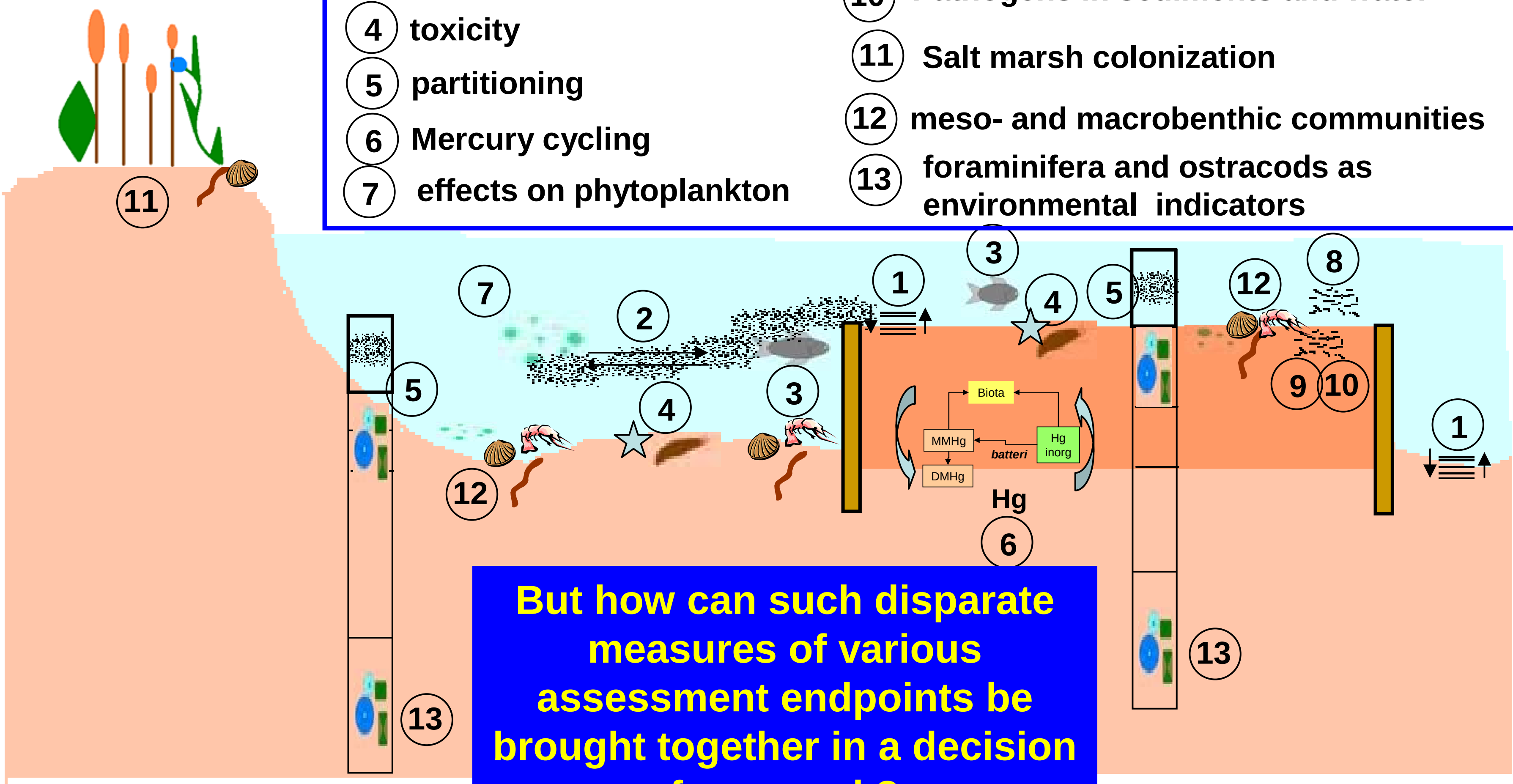


From Bridges, 2005

For sustainable management we must consider the interconnected effects of actions on multiple assessment endpoints

Ecosystem risks and benefits of subtidal habitat restoration using DM were examined using standard and novel methods

1. erosion/sedimentation
2. currents and solid transport
3. bioaccumulation
4. toxicity
5. partitioning
6. Mercury cycling
7. effects on phytoplankton
8. microbial communities in water
9. microbial communities in sediment
10. Pathogens in sediments and water
11. Salt marsh colonization
12. meso- and macrobenthic communities
13. foraminifera and ostracods as environmental indicators



But how can such disparate measures of various assessment endpoints be brought together in a decision framework?

Slide courtesy of Cristina Nasci, Thetis SpA

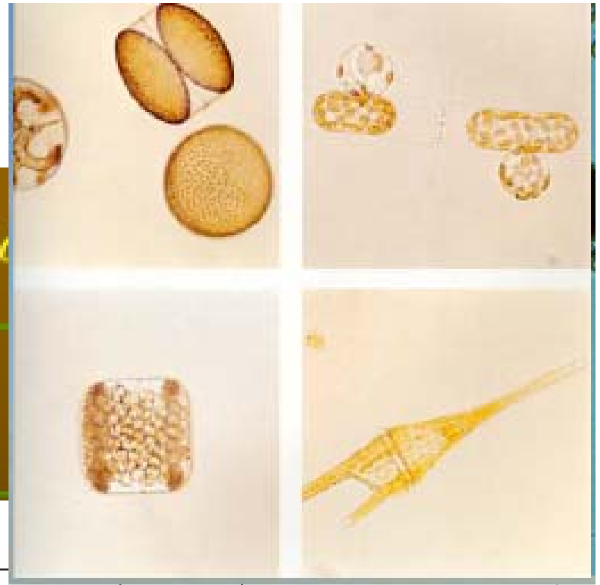
In the Netherlands, suspended solids from dredging and other activities are blocking light and affecting photosynthesis – **sediment excess is a problem that needs to be included in management plans**

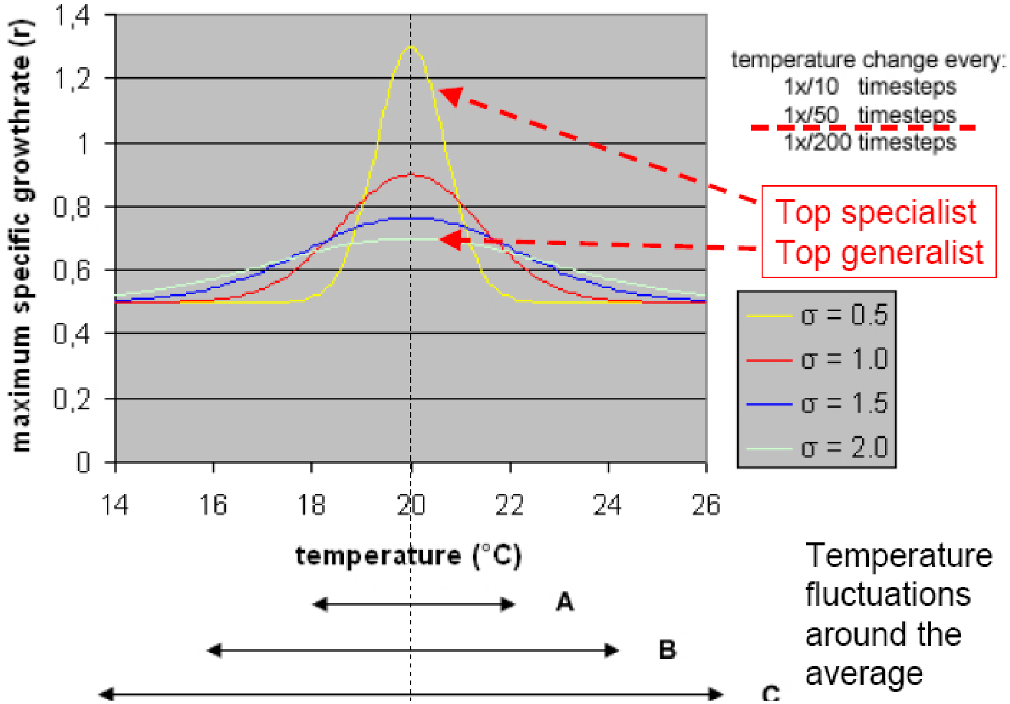
Source: Functions of Mud in Estuarine and Coastal Ecosystems, V N de Jonge, University of Groningen, SedNet Conference, Venice November 2006

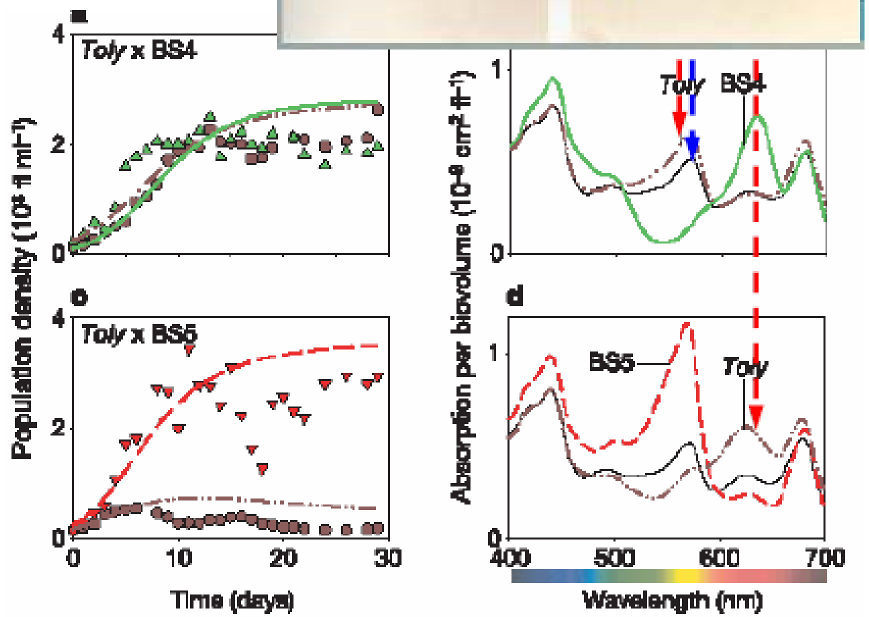
$106CO_2 + 106H_2O + 16NH_4 + 1PO_4 + 16\,(SiO_4) \rightleftharpoons (CH_2O)_{106}(NH_3)_{16}PO_4 + 10\ldots$

a. Light
b. Nutrients: N, P, Si

a. System functioning
b. Species structure
c. Species interactions







In the UK, DM is being used for mitigation, compensation and beneficial use, creating higher value habitat and increased flood defence **- there is a need to balance these benefits with risks in disposal permitting processes**

- To determine the overall risks and benefits of remedial actions, habitat restoration, programmes of measures, etc., systematic weight of evidence methods integrate disparate measures of various relevance and uncertainty to multiple assessment endpoints
- This allows for both scientifically- and policy-based weighting to consistently and transparently tailor decisions to site-specific conditions
- The approach presented here adapts the WOE approach of Johnston et al 2002 and The Massachusetts Weight of Evidence Workgroup 1995 to include risks, benefits and multiple AEs

WOE methodology for multiple assessment endpoints

Step 1: Define assessment endpoints – what is to be proteced/enhanced? Determine what assessment measures (AMs) are being used to evaluate these AEs

Step 2: Establishing weights (uncertainty) for AMs
- 10 attributes for each AM, based on data quality, relevance to AE, field design, etc.
- Score the attribute for each AM of each AE (1-3)
- Mean score for each AM – weight (uncertainty)

Step 3: Determine the degree of exposure or effect, based on each AM
- For a site, time point, treatment, etc., assign a magnitude to all the AMs (-3 to +3, increments 0.5)

Step 4: WOE determination for each AE
- Calculate the centroid for each AE, based on all relevant AMs
- $X_w = (\Sigma(M_i \cdot W_i))/ \Sigma W_i$
- *integrated estimate of exposure and effects*
- *Confidence is estmated by mean weight of AMs*

Step 5a: Risk/benefit estimate for each AE
- Estimate the overall Impacts: combining the centroid of exposure and effect using the risk matrix table for each AE

Step 5b: Risk/benefit comparison for all AEs
- Compare the risks and benefits to various assessment endpoints (these can be weighted)

Note: AM assessment measure, AE Assessment endpoint

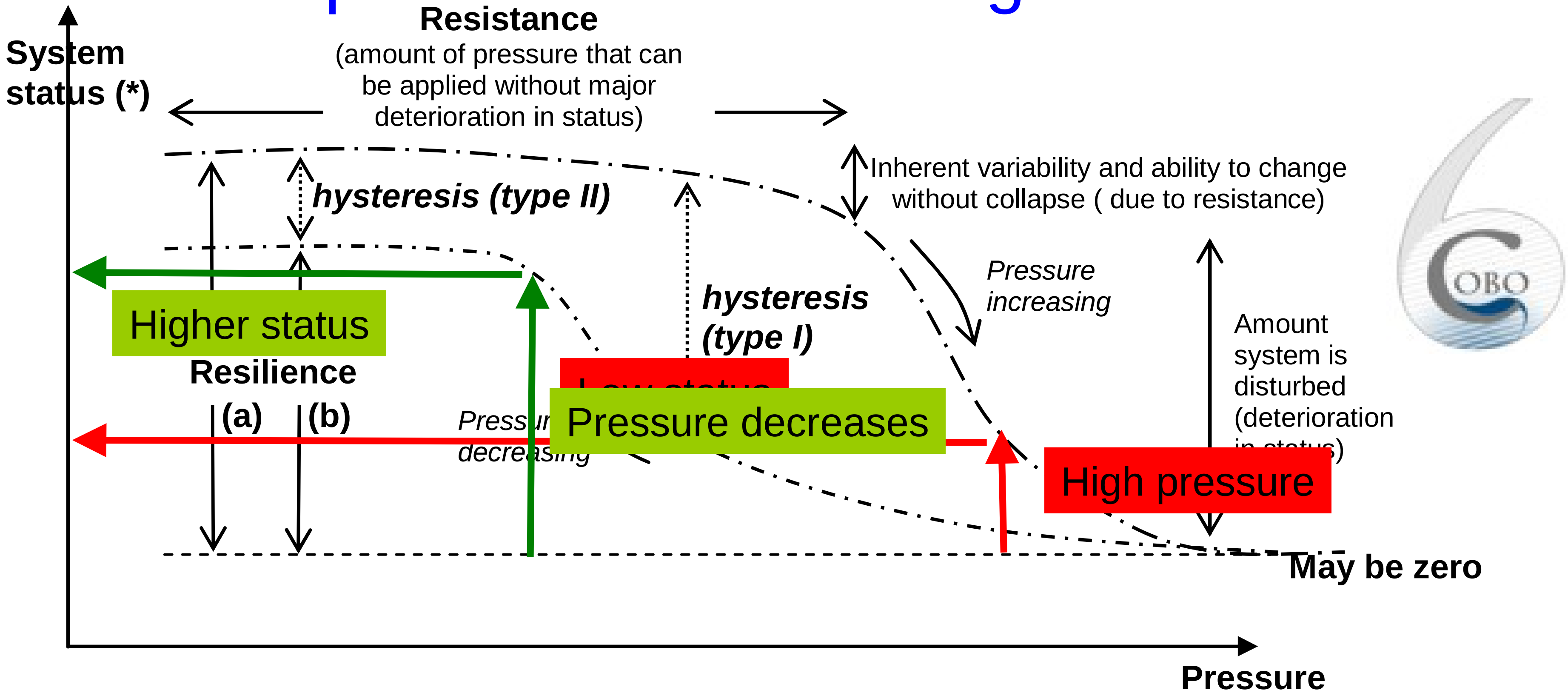
Multiple LOEs for one assessement endpoint (AE) do not necessarily reduce uncertainty

- Dozens of measures not well linked to an AE are more uncertain than one well-designed indicator
- LOEs can be weighted based upon data quality, scientific relevance and study design
- Centroid values for a given AE provide a weighted average based upon the value and uncertainty of each LOE
- Centroid = $X_w = (\Sigma(M_i \cdot W_i))/ \Sigma W_i$, where M_i is the magnitude assigned for each LOE and W_i is the weight assigned to that LOE

Because the work presented was part of a paper being prepared for publication, several slides are not in this on-line version. Please contact drsea@mudineye.plus.com for more details or paper when published

We can examine how resistant and resilient AEs are to pressures and management actions

Conceptual Approach:



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 – A revision of concepts, *Estuarine, Coastal and Shelf Science* 74, 349-366

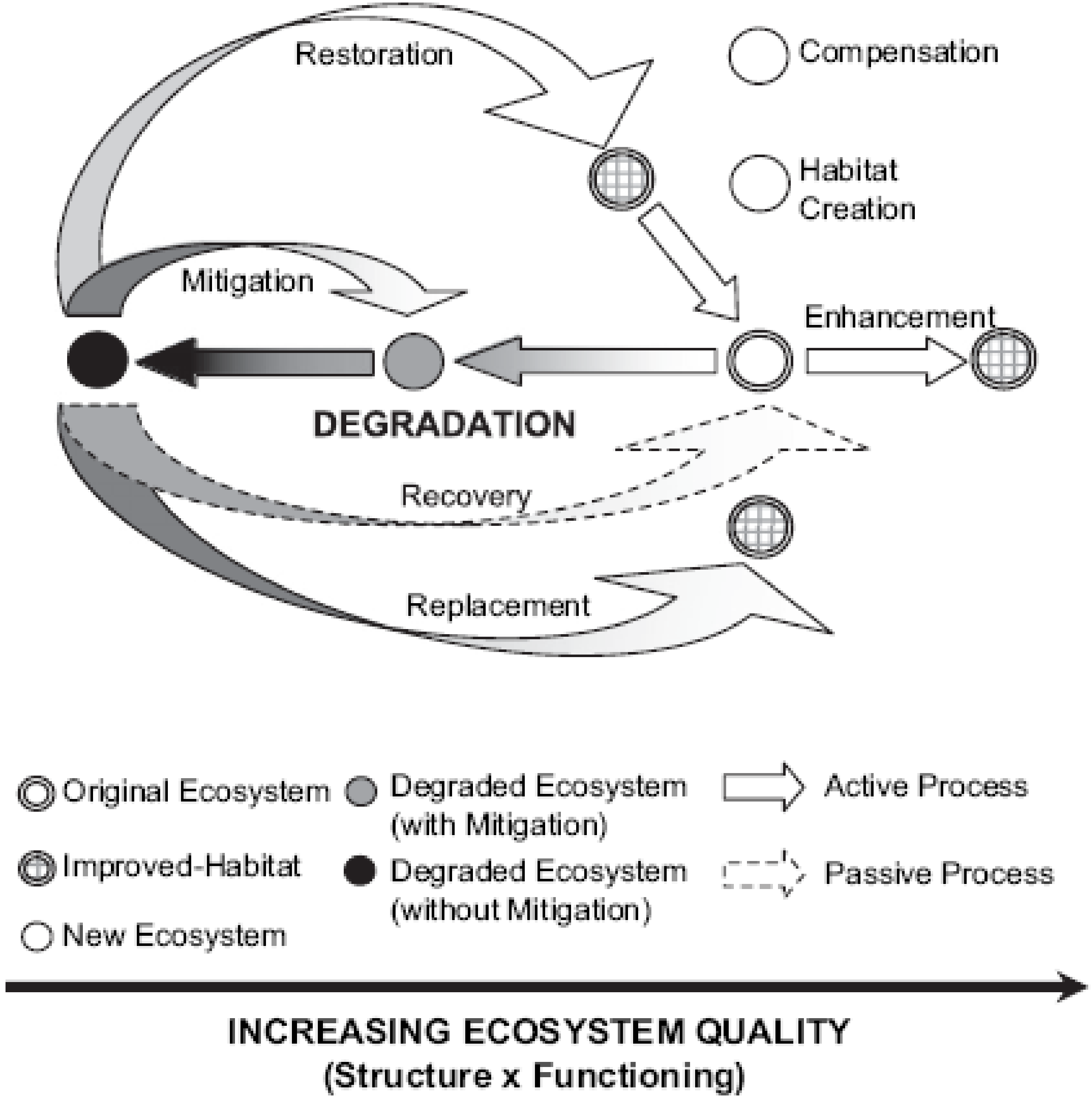
Assessment measures can reflect either positive or negative exposures and effects; these can be quantified

Example 1: very contaminated sediments with moderate toxicity

Example 2: Moderate decrease in turbidity results in strongly enhanced primary production

Overall Risk/Benefit		Evidence of Exposure						
Evidence of Effect		Stong decrease	Moderate decrease	Slight decrease*	none	Slight increase*	moderate increase	Strong increase
	Range of possible scores	+3 - +1.5	+1.5 - +0.5	+0.5 - 0	0	-0 - -0.5	-1.5 - -0.5	-1.5 - -3
Strong positive	+3 - +1.5	very high benefit	high benefit	moderate benefit	no link			
Moderate positive	+1.5 - +0.5	moderate benefit	moderate benefit	slight benefit	no link			
Slight positive	+0.5 - 0	slight benefit	negligible	negligible	no link			
none	0	negligible	negligible	negligible	negligible	negligible	negligible	negligible
Slight negative	-0 - -0.5				no link	negligible	negligible	slight risk
Moderate negative	-1.5 - -0.5				no link	slight risk	moderate risk	moderate risk
Strong negative	-1.5 - -3				no link	moderate risk	high risk	Very high risk

*from background, reference or time zero



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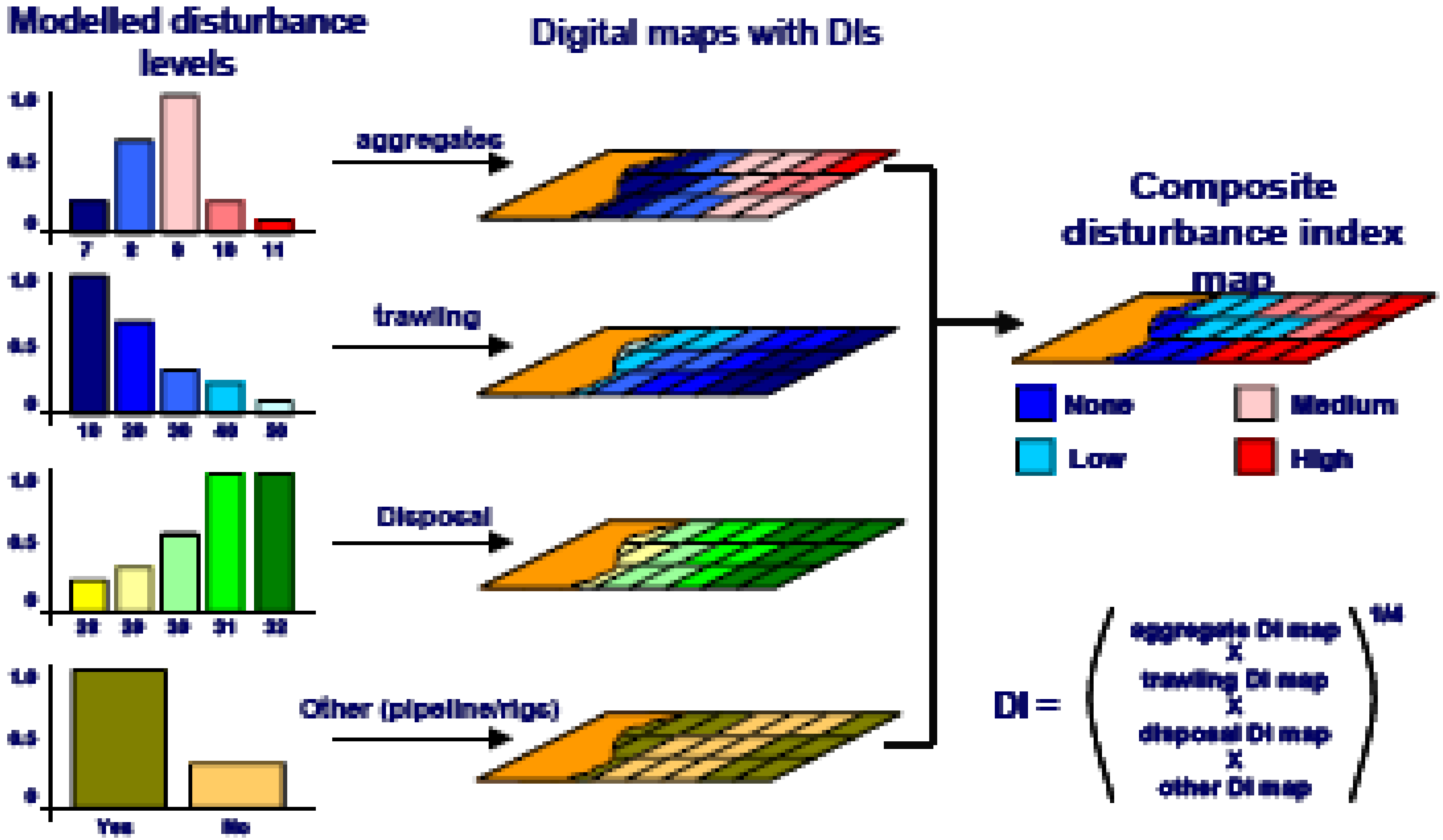
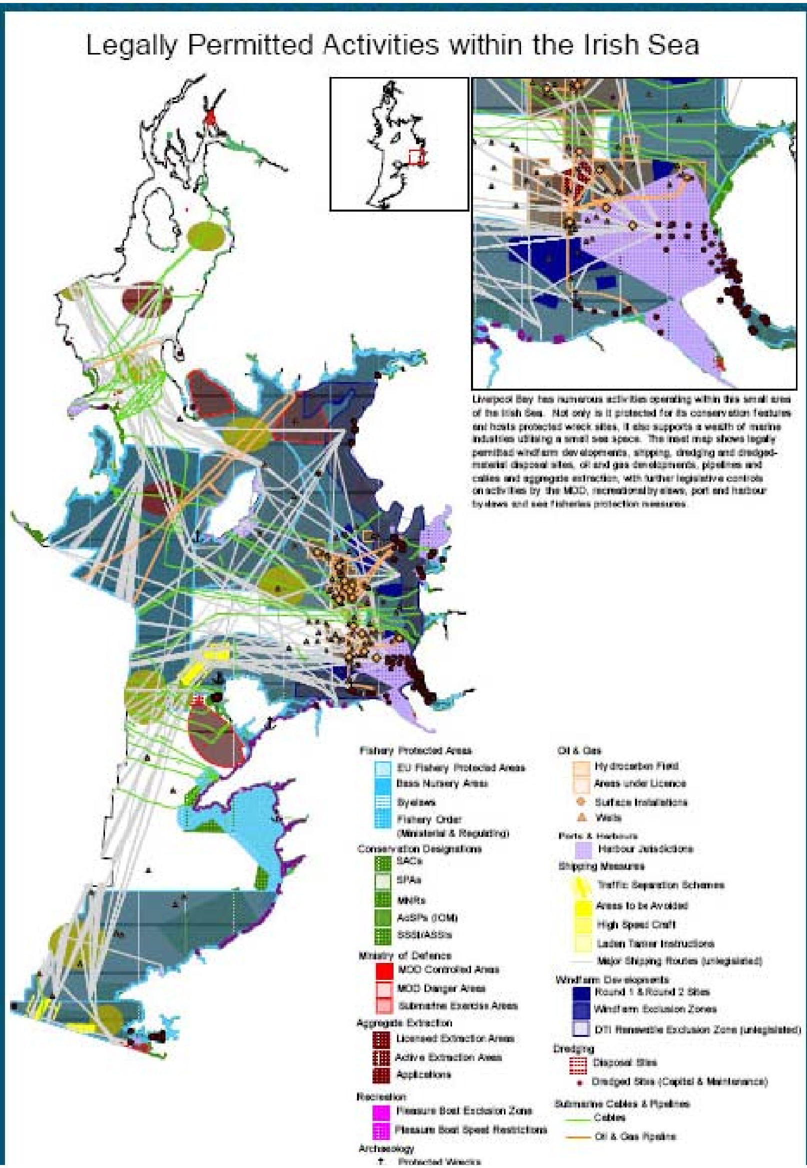
European objectives seek to restore, enhance or replace habitat, measures must be reflective of these goals

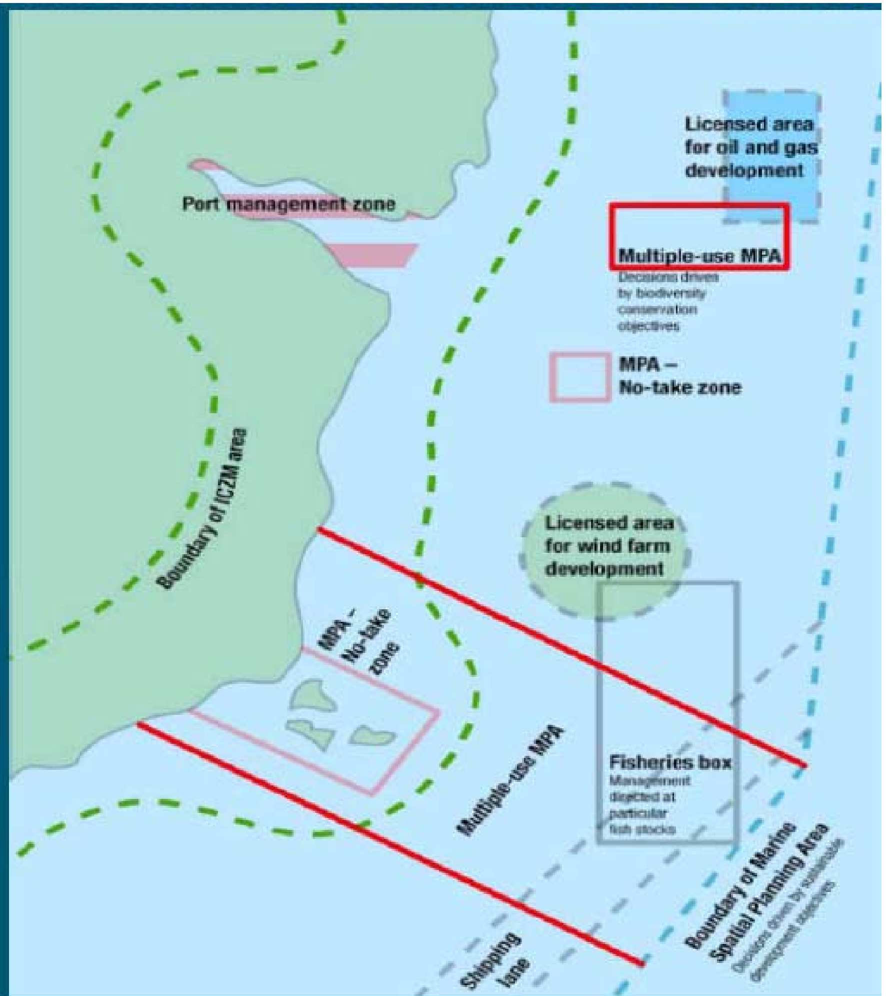
The composite impact of various uses and management strategies can be combined in common units to generate disturbance indices – or, eventually, risk/benefit indices or ecosystem service maps



Parker R, Aldridge J, Eastwood P, Houghton C, Mills C, Kershaw. P. 2004. The Ecosystem Effects of Sediment Disturbance: Development and application of a GIS based disturbance impact assessment tool. Lowestoft, UK: The Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Report nr AE1224. 48 p.

One goal is to provide spatially explicit maps of how integrated management might affect ecosystem services regionally





Mapping and zoning for Marine Spatial Planning

Conclusions

- Presumptive remedies are not protective or consistent with European policy
- Risk-based decision frameworks must be adapted to address complex ecosystem goals
- WOE approaches can be adapted to provide frameworks
- This provides simplicity to communicate and inform decisions, while still linking to measures in a transparent and adaptable manner

- The following are acknowledged for slides and/or collaboration Martina Bocci; Todd Bridges;Eugenia Delaney; Mike Elliott; SedNet (an EC-funded European Network) WG2; Lindsay Murray; Cristina Nasci; Ruth Parker; W Reid; DH Wall; Rick Wenning

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