ECASA
Stakeholders conference

The Indicators of interactions between environment and marine aquaculture

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IFREMER

Heraklion, 18-19 September 2007

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Introduction

Ecosystem approach : global view of interactions,
At the ecosystem scale

Ecosystem structures

Ecosystem functions and services

How a set of indicators
can describe the interactions
between ecosystem and marine aquaculture?

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Ecosystem structures

Benthic communities: macrofauna, macroflora, and meiofauna

Pelagic communities: Phytoplankton, zooplankton, necton

Marine environment: sediment and water quality

Ecosystem functions and services

Rearing environment of good quality

Food furniture and biological productivity

Coastal biodiversity

Attractivity: shoreline, visual landscape

Wastes treatment

Economic and social gains

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Indicators of ecosystem status

Indicator: an operational measure of trend

Should be:

Simple

Adequate

Sensitive

How many indicators an an EIA?
Need to prioritize the effects of aquaculture

ECASA Methodology for selecting indicators

The use of frameworks

1. DPSIR framework
2. Framework of European marine Aquaculture
3. ECASA framework

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ECASA framework for an ecosystem approach

Sediment biogeochemistry
Benthic flora and fauna
Biomarkers
Escapes
Water quality and pelagic ecosystem
Coastal zone management
Socio economy

The processus for selecting indicators

1- Proposals from partners experience and expertise

The main questions:

Frameworks belonging?
Species and environments?
Indicators computations?
Significance of indicators?
Interpreting the results: values and thresholds?
Criteria for a Quality Assesment of indicators?

Name

DPSIR classe

ECASA subgroups

Proposed by participant

Definition, computation,

Data required

Summary, scientific meaning, implementation

Species concerned (fishes/molluscs)

Related type of aquaculture

Relevant environments for this indicator

Geographic scale

Direct relevance to objectives

Clarity in design.

Realistic collection or development costs

High quality and reliability

Appropriate spatial and temporal scale

Obvious significance

advantages

disadvantages

references

State of validation

Recommendations

- Why using this indicator
- How to use it (sampling...)

Name	Redox potential, E_H, profile in surficial sediment
DPSIR classe	Impact
ECASA subgroups	Sediment
Proposed by participant	Venice University
Definition, computation,	Values of E_H [mV] on the top 5 cm of sediment.
Data required	Eh measurements
Summary, scientific meaning, implementation	The oxidation-reduction (redox) conditions in the surficial sediment depend on the degree of organic enrichment and can be assessed by measuring the vertical the redox potential profile in the top 15 cm (expressed in mV) (Zobell, 1946). The decrease in E_H with the depth is related to the decrease in the concentration in dissolved oxygen concentration in the pore water. Negative redox-potentials are therefore associated with anoxic conditions, in which the degradation of the organic matter is carried out by anaerobic bacteria, which use mainly sulphate as electron acceptor and release hydrogen sulphide. (Porrello et al., in press; Chamberlain, 2002; Aleffi et al., 2006; Danovaro et al., 2004).
Range of validity	
Species concerned (fishes/molluscs)	All fishes All molluscs
Related type of aquaculture	1) ussel culture: Longlines (Aleffi et al., submitted; Chamberlain, 2002; Danovaro et al., 2004) ; Rafts (Chamberlain, 2002) ; 2) Fish cages (Porello et al., in press). 2) ish culture
Relevant environments for this indicator	Coastal waters (Danovaro et al., 2004) ; Sheltered areas (Chamberlain, 2002); Coastal waters not protected by bays (Aleffi et al., submitted).
Geographic scale	Near vicinity of aquaculture operations Scale A
Direct relevance to objectives	A
Clarity in design.	A
Realistic collection or development costs	B
High quality and reliability	B
Appropriate spatial and temporal scale	B
Obvious significance	A
advantages	Refer directly to the input and degradation of organic mater from aquaculture (feces, pseudo feces, uneaten food)
disadvantages	Other sources of organic matter main interfere with the aquaculture source. Hydrodynamic regime has to be considered for data interpretation
references	leffi, I.F., Bettoso, N., Solis-Weiss, V., Tamberlich, F., Predonzani, S., Fonda-Umani, S., submitted to ICES – Journal of Marine Science. Effects of suspended mussel culture on the macrozoobenthos in the Gulf of Trieste (Northern Adriatic Sea, Italy). hamberlain, J., 2002. Modelling the environmental Impacts of Suspended Mussel (Mytilus edulis L.) Farming. Ph-D Thesis, Napier University, Edimburgh. anovaro, R., Gambi, C., Luna, G.M., Mirto, S., 2004. Sustainable impact of mussel farming in the Adriatic Sea (Mediterranean Sea): evidence from biochemical, microbial and meiofaunal indicators. Marine Pollution Bulletin, 49: 325-333. orrello, S., Tomassetti, P., Manzueto, L., Finoia, M.G., Persia, E., Mercatali, I., Stipa, P., in press. The influence of marine cages on the sediment chemistry in the Western Mediterranean Sea. Aquac. egnier, P., O'Kane, J.P., Steefel, C.I., Vanderborght, J.P., 2002. Modeling complex multi-component reactive-transport systems: towards a simulation environment based on the concept of a Knowledge Base. Applied Mathematical Modelling, 26: 913-927.
State of validation	Submitted to ECASA field tests
recommendations	Parameter to be considered in sheltered environments

The processus

for selecting indicators

2- Subgroup evaluation, From ECASA partners

Each subgroup has selected
the most pertinent indicators,
based on a processus of consensus
among the partners members of the subgroup

The processus for selecting indicators

3- Field testing in aquaculture sites

Ten sites were chosen in European waters

The main species of fishes and shelfish were covered

The main aquacultural techniques used in Europe were studied

The processus for selecting indicators

4- Stakeholders comments on the list of indicators

for an ecosystem approach of aquaculture impact

The Heraklion meeting

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No	Participant name	Participant short name	Country	Type of Indicators to be produced
1	Scottish Association for Marine Science Tom and Chris Cromey, Shona MAGill	SAMS	UK	Benthic ecosystems : Ambi and other benthic indices Trophic index Wild fish indicator Pharmaceuticals antibiotics = Public attitude social impacts Porsthmouth
2	Centre for the Economics and Management of Aquatic Resources David Whithmarsh	UOP	UK	Economy indicators to be developed Damage costs Employment multipliers Productivity Output Profit Producers prices Consumer prices Public attitude social impacts
3	Napier University Paul Tett andhis group	NNUE	UK	Eutrophication from OSPAR Phytoplankton community index ICZM Trophic groups Optical indicators Secchi SPI Biomarkers EROD ACEtylcholinesterase intersex Oxydative stress
4	National Institute of Biology	NIB	Slovenia	Geochemical indicators Genetic impact on wild fish Nutrients Phytoplancton pigment s and communtity Meiofauna macrofauna Pharmaceuticals antibiotics IFREMER Biomarkers EROD ACEtylcholinesterase intersex Napier univ Oxydative stress Genetic effect IFREMER? Banyuls
Cr of au na	Leibniz-Institute of Marine Science	IFM-GEOMAR	Germany	***Validated distance*** Interaction with wild fish Spatial Effects of aquaculture Spatial aspects and landscape ICZM
6	Akvaplan Niva	Akvaplan	Norway	
7	University of Haifa	HAIFA	Israel	1 **Chlorophyll** benthic trophic groups wild fish Spatial effects

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8	University of Crete	UOC	Greece	1 **Aquaculture impact on benthic trophic groups** **Biomass fractionation** **Benthic TOC** Optical PAR Sediment Profiles POC Phosphorus Posidonia Beds Plankton productivity grazing Spatial aspects and landscape ICZM Kiel
9	Plymouth Marine Laboratory	PML	UK	
10	Institute of Marine Research	IMAR	Portugal	**ASSETS eutrophication PSR Chloro a O^2 HAB**[1]
11	Central Institute for Marine Research	ICRAM	Italy	
12	Institut Français de Recherche pour l'Exploitation de la Mer Alain Bodoy H JeanLous Martin	IFREMER	France	1- **distance along shoreline** Renewal capacity Organic matter Heterotrophic bacteria Assimilation number (chlorophyll) extensive aqua Carrying capacity CT<RT x PP Biodeposition Pharmaceuticals antibiotics Spatial aspects and landscape ICZM Genetic effect Banyuls
13	Instituto Tecnológico Pesquero y Alimentario Angel Borja	AZTI	Spain	**AMBI** Sediment TOC or redox Water column Chloro nutrients optical properties
14	University of Venice	DCF_UNIV	Italy	Mussel culture
15	Rudjer Boskovic Institute	RBI	Croatia	Mussel culture Tuna culture Public attitude social impacts Porsthmouth Fish disease : regional approach
16	University of Göteborg	UGOT	Sweden	Eutrophication effect Secchi disk Normoxic conditions macrofauna

Results

Sediment

Redox Eh in surficial sediment
sulfate and ammonia gradient
Sediment carbon quality Index
Sediment oxygen consumption experiment
Toc in sediment
Sediment fluxes (trap)
Total Organic Carbon in surface sediment
ammonia-pore water
Sulphide/oxygen
Total Nitrogen in sediment
P-PO4 in pore water
Heavy metals in sediment
Nitrifier bacterial population
total phosphorus
Mono unsaturated fatty acid in benthos

Benthos

AMBI
benthic trophic groups
Biomasse Fractionation
macrofauna
Macrofauna-univariate
Macrofauna-ITI
Macrofauna-multivariate
Meiofaunal diversity
Sediment test on .meiofauna

Results

Water quality

Minimum O2 in bottom water
Secchi disk
Maximum production with respect to water quality in farm
Phytoplankton chlorophyll
Chlorophyll a
Chloro a water column
Winter nutrients concentration
Particulate organic Carbon (POC)

Escapees

Coastal zone management

Aquaculture production on shoreline
validated distance
water availability
Assets

Genetic and molecular markers

DNA-damages
Microsatellites DNA
mitochondrial DNA
EROD

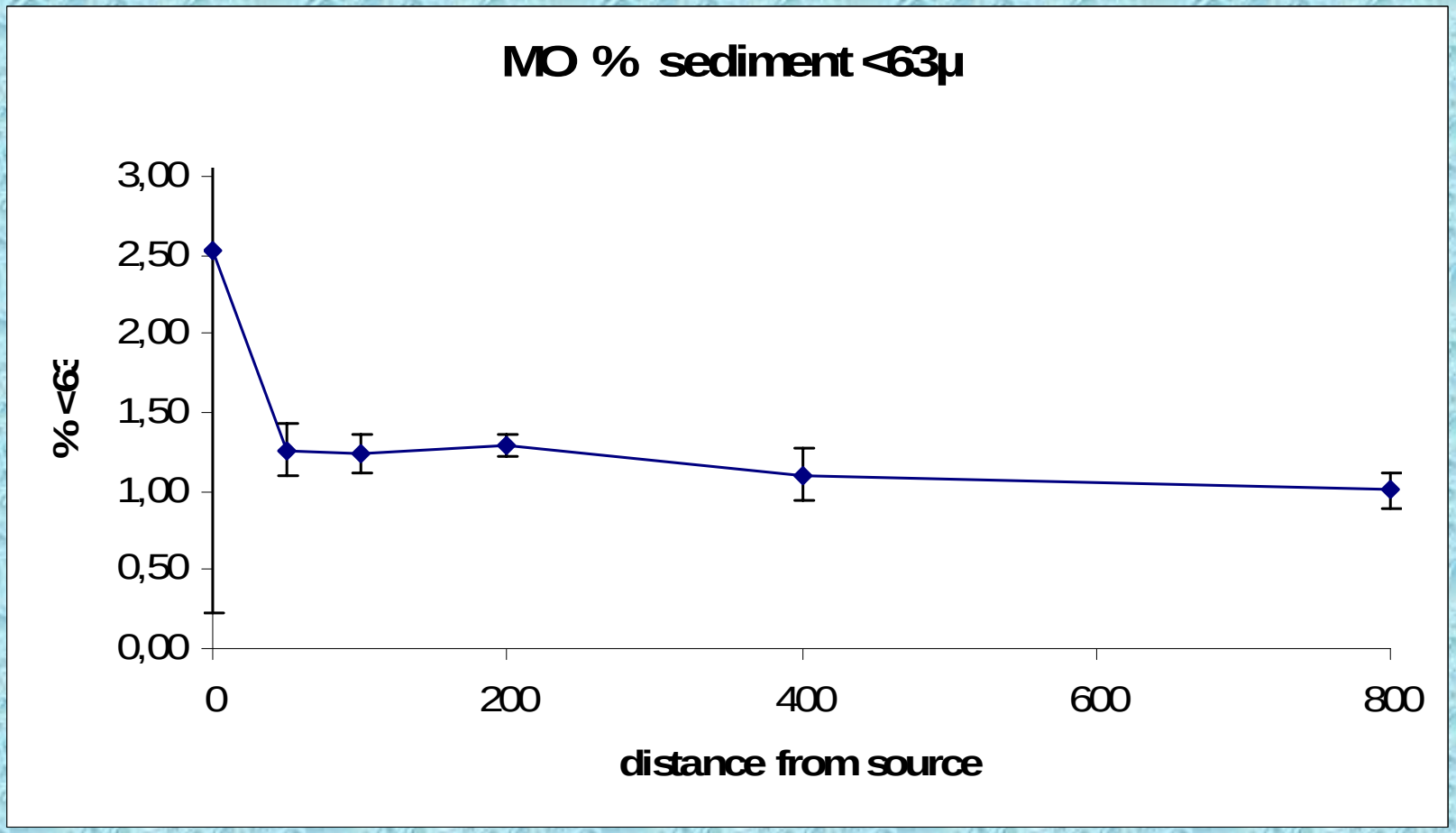
Results

Socio economy

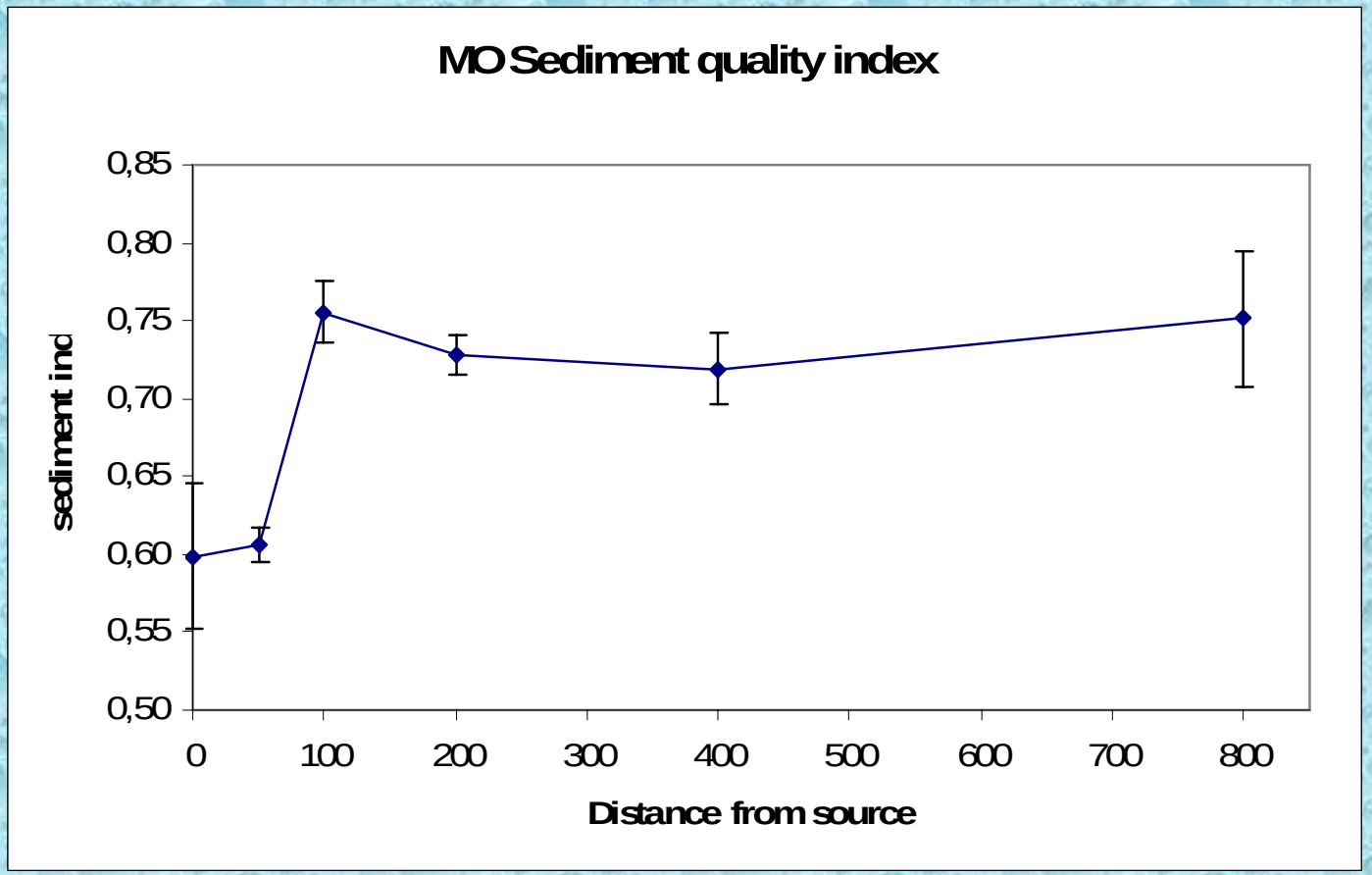
attitudes
conflicts
consumer prices
consumption share
damage costs
employment
income
multipliers
output
producer prices
productivity
profit
protection costs
regional dependency

Examples of indicators

From a site of mussels long lines

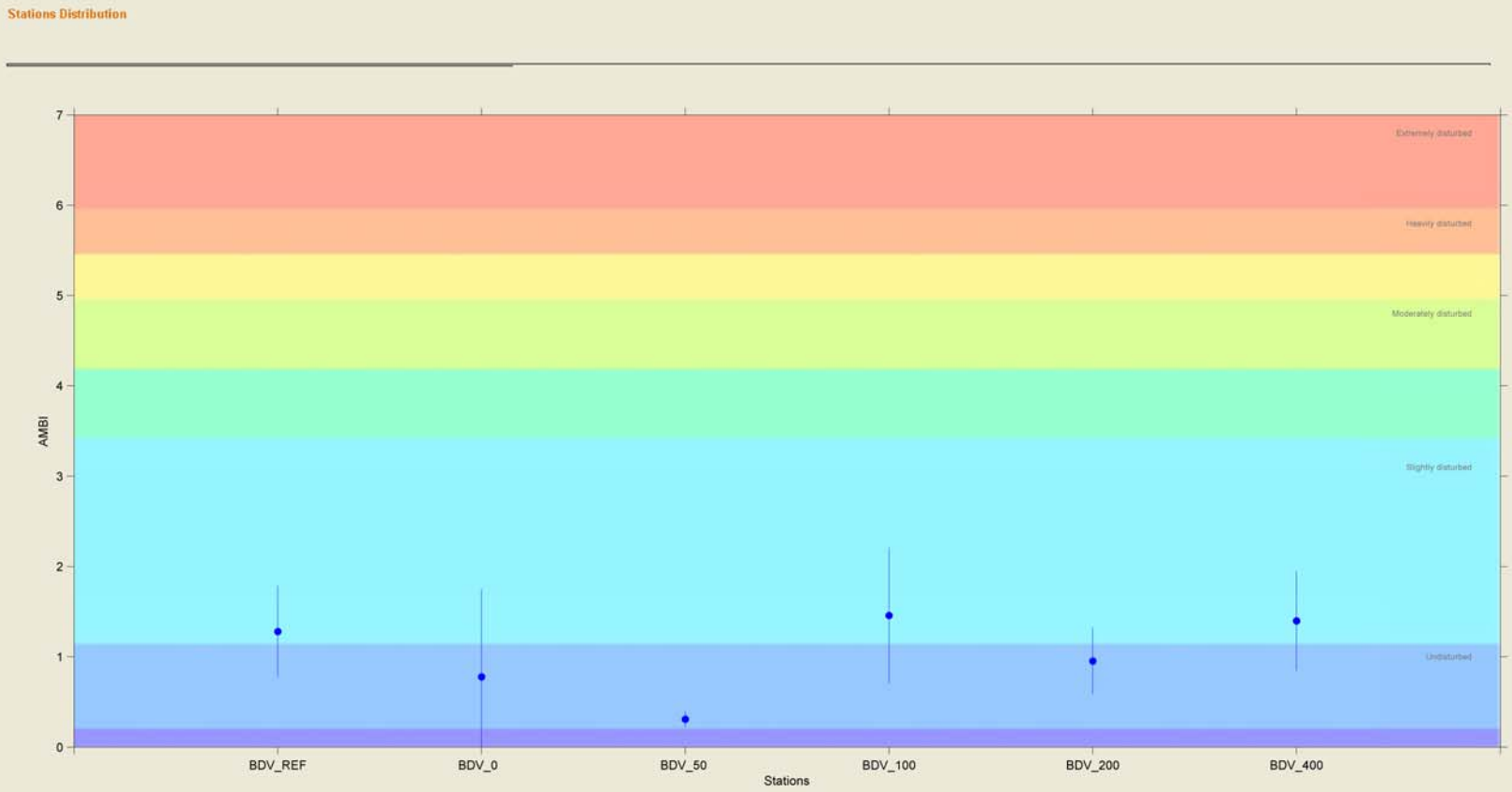


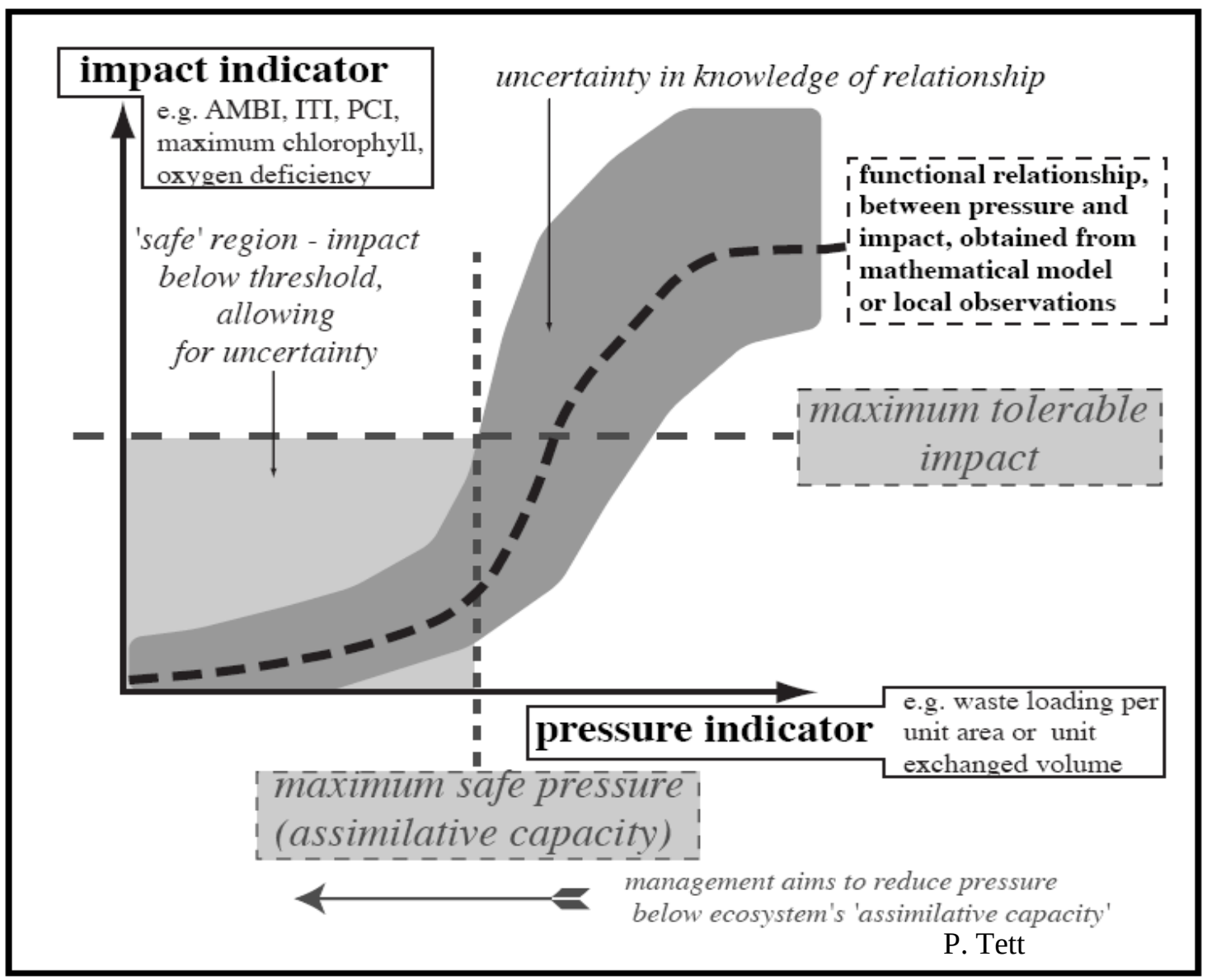
Examples of indicators



Examples of indicators

Macrofauna diversity: AMBI




impact indicator
e.g. AMBI, ITI, PCI, maximum chlorophyll, oxygen deficiency
uncertainty in knowledge of relationship
functional relationship, between pressure and impact, obtained from mathematical model or local observations
'safe' region - impact below threshold, allowing for uncertainty
maximum tolerable impact
pressure indicator
e.g. waste loading per unit area or unit exchanged volume
maximum safe pressure (assimilative capacity)
management aims to reduce pressure below ecosystem's 'assimilative capacity'

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Direct pressure category	**Generalized pressure indicator** (2) (3)	**Examples of ... pressure indicators**	**... directly affected state variables**	**... impacted state variables**	**Impact indicators**
soluble wastes, non-toxic (1)	- waste loading per unit exchanged water volume	nutrient loading, soluble BOD loading	nutrient concentration	amount and quality of phytoplankton; transparency; DO; phytobenthic variables	chlorophyll statistics, Secchi depth, PCI, oxygen statistic, phytobenthic health, PCI, migratory fish index
soluble wastes, toxic (1)	- ditto	pollutant loading	pollutant concentration	plankton variables	migratory fish index
disease release	- infectious organism loading per unit exchanged water volume	sea-lice larval loading	sea-lice larval concentration	infected wild salmon	lice infestation index
sinking particulate wastes, nontoxic component	- waste loading per unit seafloor	POM loading	POM content of sediment	SOD; benthic faunal composition	ITI, AMBI, intersex
sinking particulate waste,toxiccompounds	- ditto	particulate-associated toxin loading	toxin content of sediment	benthic faunal composition	ITI, AMBI, intersex
demand for planktonic food	- demand per unit exchanged water volume	mussel loading	phytoplankton amount and composition	phytoplankton amount and composition	chlorophyll statistics, PCI
Spatial variables					
distance	distance from pressure source to protected area (4)				
zone of effect	area around source enclosed by a perimeter at which EcoQO satisfied	AZE (allowable zone of effect) for seabed loading by salmonid farms (in Scotland)			
Health variables					
ecosystem health				WFD water quality	
economic health				employment profitability	
societal health				???	

Indicators and models

Properties	Indicators	models
Relevance to objectives	=	=
Clarity in design	=	-
Collection and developments costs	- / =	+
Quality and reliability	+	+
Spatial and temporal scales	=	+
Obvious significance	+	-

The pertinence of indicators

Indicators by types of Environments/Tide/Techniques/Species						
Pertinence Quotation from A to	A	B	C	D	E	
Environment	Offshore operations		Coastal operations			
Tide	> 5 km and no shelter		Subtidal environments		Intertidal environments	
Techniques	Cages	Long-lines	Cages	Long-lines	Bottom culture	Trestles culture
Species	fishes	shellfishes	fishes	shellfishes	shellfishes	shellfishes

ECASA	Indicators by types of Environments/Tide/Techniques/Species						
A.Bodoy	Pertinence Quotation from A to E	A	B	C	D	E	
	Environment	Offshore operations		Coastal operations			
	Tide	> 5 km and no shelter		Subtidal environments		Intertidal environments	
	Techniques	Cages	Long-lines	Cages	Long-lines	Bottom culture	Trestles culture
	Species	fishes	shellfishes	fishes	shellfishes	shellfishes	shellfishes
Sediment	Redox Eh in surficial sediment	A	B	A	B	B	B
Sediment	sulfate and ammonia gradient	A	C	A	C	C	C
Sediment	Sediment carbon quality Index	A	A	A	A	A	A
Sediment	Sediment oxygen consumption experiment	B	C	B	C	C	C
Sediment	Toc in sediment	A	C	A	C	C	C
Sediment	Sediment fluxes (trap)	A	A	A	A	A	A
Sediment	Total Organic Carbon in surface sediment	A	C	A	C	C	C
Sediment	ammonia-pore water	?	?	?	?	?	?
Sediment	Sulphide/oxygen	A	B	A	B	B	B
Sediment	Total Nitrogen in sediment	B	B	B	B	B	B
Sediment	P-PO4 in pore water	B	B	B	B	B	B
Sediment	Heavy metals in sediment	B	D	B	D	D	D
Sediment	Nitrifier bacterial population	A	B	A	B	B	B
Sediment	total phosphorus	B	B	B	B	B	B
Sediment	Mono unsaturated fatty acid in benthos	?	?	?	?	?	?

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Indicators are good communication tools, easy to understand and to appropriate

In the perspective of an ecosytem approach There is need for a **set** of indicators covering the main sustainability issues

Indicators only indicate, describe, help to communicate, but they cannot **predict**.

Together with the modelling process , they are a n essential part of the ECSASA toolbox

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