APPLICATION OF WEIGHTED CRITERIA AND INTEGRATED APPROACH TO ASSESS SEDIMENT QUALITY IN MARINE AND FRESHWATER ECOSYSTEMS

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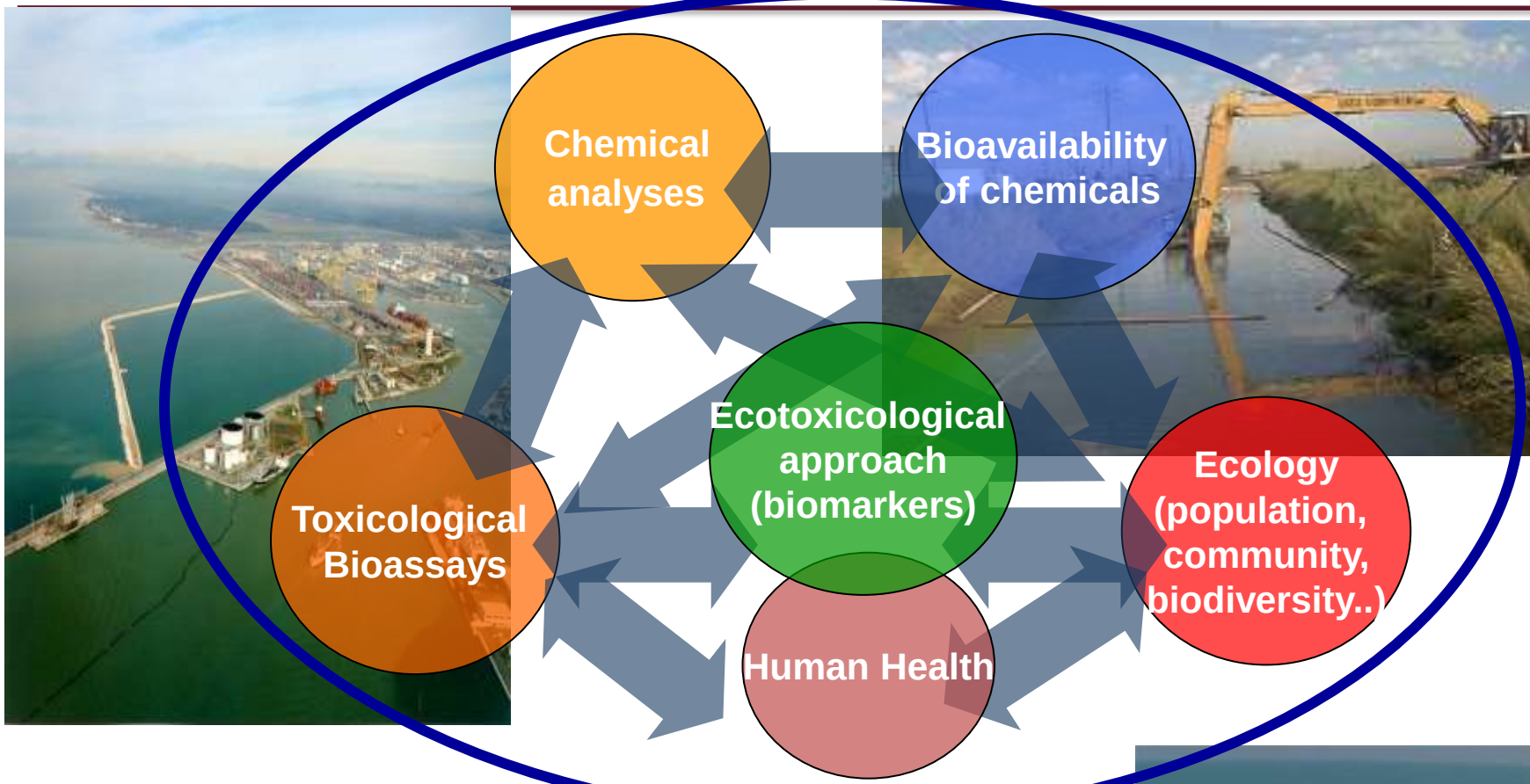
11th International SedNet Conference

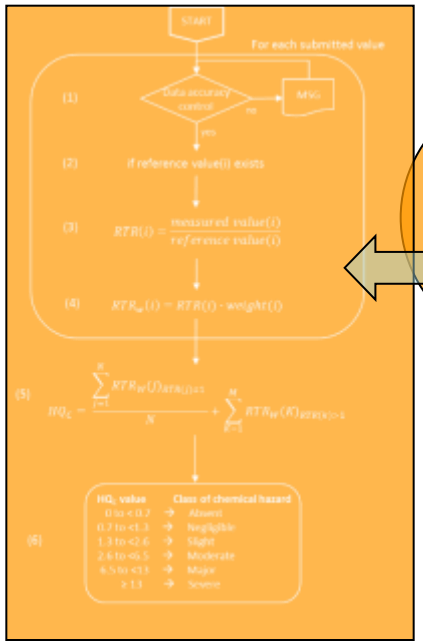
Dubrovnik (HR) 3-5 April 2019

Integrated models for ecological risk assessment



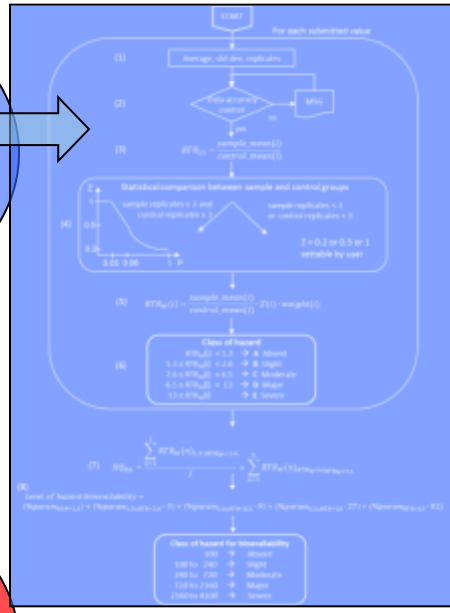
"the process that evaluates the likelihood that adverse ecological effects may occur as a result of exposure to one or more stressors"
(USEPA, 1998)

Quantitative risk assessment model on Weight of Evidence (WOE) approach

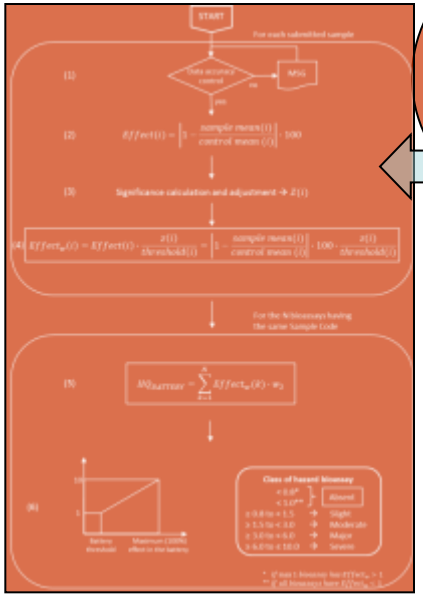


LOE 1
Chemical analyses

LOE 2
Bioavailability

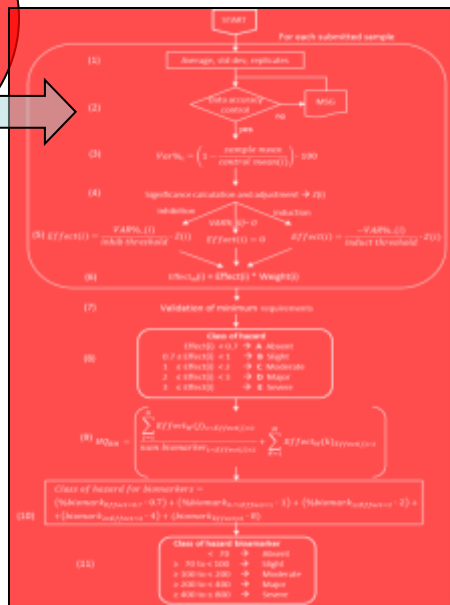


LOE 5
Benthic communities

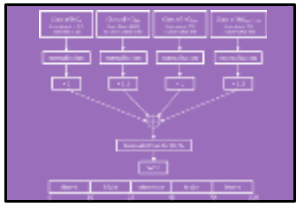


LOE 4
Bioassays

LOE 3
Biomarkers



Integrated Risk Index using WOE approach



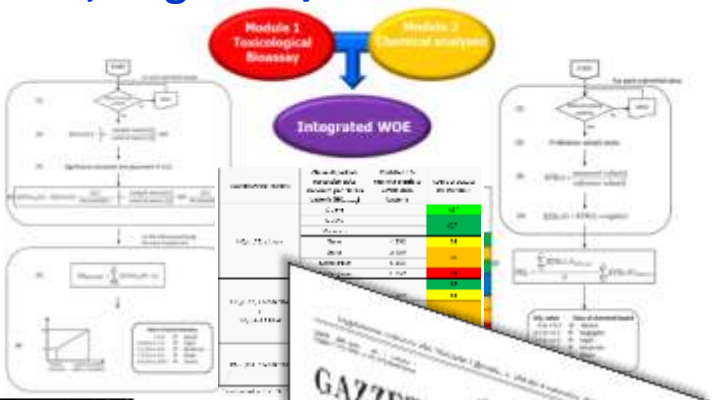
Weighted criteria are included in the Italian legislation on classification and management of dredged marine sediments

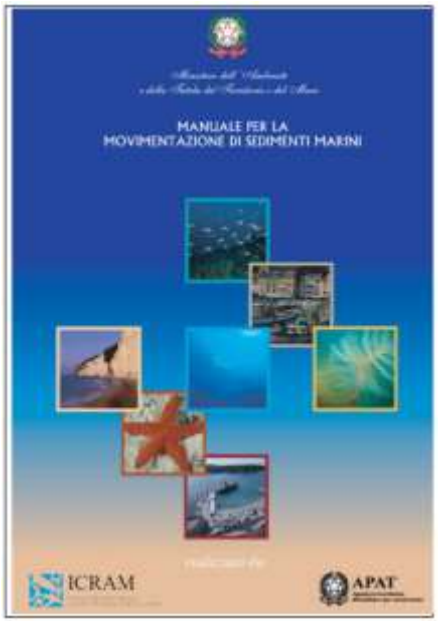
Manual ICRAM-APAT 2007

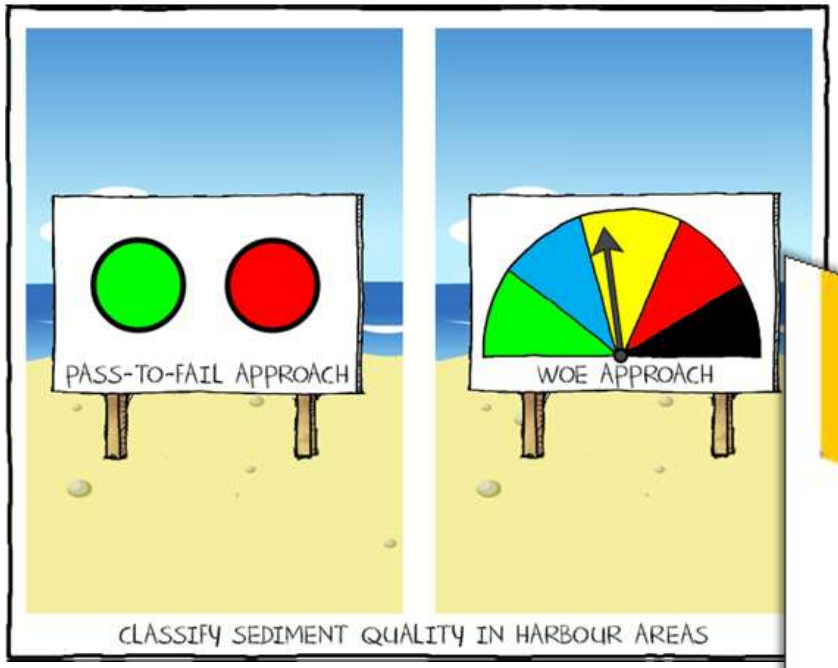
Art. 109, D.lgs. 152/2006 and *ss.mm.ii.*

Classificazione chimica	Classificazione ecotossicologica		CLASSE QUALITA'
	Colonna	Tossicità elu/elu	
≤ LCB	A	n.c.	A1
	A	n.c.	A2
	B	n.c.	
	C	assente	B1
	C	≥ Colonna C	B2
	D	assente	
	D	= Colonna D	C1
compresa tra LCB e LCL	A	n.c.	A2
	B	assente	B1
	B	= Colonna B	B2
	C	n.c.	
	D	assente	
	D	= Colonna D	C1
≥ LCL	A o B	n.c.	B2
	C	assente	C1
	C	= Colonna C	C2
	D	n.c.	

From «pass-fail» to weighted criteria

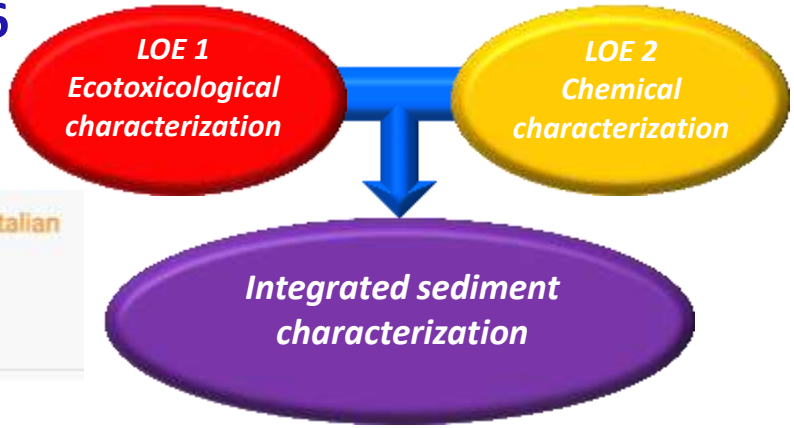






10th International SedNet Conference **"Sediments on the move"**
14-17 June 2017 at the Palazzo San Giorgio, Genoa, Italy

ENVIRONMENT MINISTRY DECREE N. 173/2016



Sediment quality classification based on Weight of Evidence approach in the recent Italian regulation

Cristian Mugnai, ISPRA, Italy

Ecotoxicological hazard	Chemical hazard	Quality classes
Absent	HQ_C (L2) ≤ Negligible	A
	Slight ≤ HQ_C (L2) ≤ Moderate	B
	HQ_C (L2) = High	C
	HQ_C (L2) > High	D
Slight	HQ_C (L1) ≤ Slight	A
	HQ_C (L1) ≥ Moderate and HQ_C (L2) ≤ Slight	B
	Moderate ≤ HQ_C (L2) ≤ High	C
	HQ_C (L2) > High	D
Moderate	HQ_C (L2) ≤ Slight	C
	HQ_C (L2) ≥ Moderate	D
≥ High	HQ_C (L2) ≤ Slight	D
	HQ_C (L2) ≥ Moderate	E

Chemosphere 83 (2011) 475–483

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Assessing sediment hazard through a weight of evidence approach with bioindicator organisms: A practical model to elaborate data from sediment chemistry, bioavailability, biomarkers and ecotoxicological bioassays

Francesco Piva [a], Francesco Ciaprini [b], Fulvio Onorati [b], Maura Benedetti [a], Daniele Fattorini [a], Antonella Ausili [b], Francesco Regoli [a,*]

Environmental Pollution 163 (2012) 196–126

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Environmental hazards from natural hydrocarbons seepage: Integrated classification of risk from sediment chemistry, bioavailability and biomarkers responses in sentinel species

Maura Benedetti, Stefania Gorbi, Daniele Fattorini, Giuseppe D'Errico, Francesco Piva, Davide Pacitti, Francesco Regoli*

Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Via Brecce Bianche, 60000 Ancona, Italy

Marine Environmental Research 96 (2014) 92–104

Contents lists available at ScienceDirect

Marine Environmental Research

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A multidisciplinary weight of evidence approach for environmental risk assessment at the Costa Concordia wreck: Integrative indices from Mussel Watch

Francesco Regoli [a,*], David Pellegrini [b], Anna Maria Cicero [c], Marco Nigro [d], Maura Benedetti [a], Stefania Gorbi [a], Daniele Fattorini [a], Giuseppe D'Errico [a], Marta Di Carlo [a], Alessandro Nardi [a], Andrea Gaion [b], Alice Scuderi [b], Silvia Giuliani [b], Giulia Romanelli [c], Daniela Berto [e], Benedetta Trabucco [c], Patrizia Guidi [d], Margherita Bernardeschi [d], Vittoria Scarcelli [d], Giada Frenzilli [d]

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Science of the Total Environment 514 (2015) 92–107

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Integrated approach to assess ecosystem health in harbor areas

M.J. Bebianno [a,*], C.G. Pereira [a], F. Rey [a], A. Cravo [a], D. Duarte [a], G. D'Errico [b], F. Regoli [b]

[a] CIMA, University of Algarve Campus de Gambelas, 8005-139 Faro, Portugal
[b] Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona, Italy

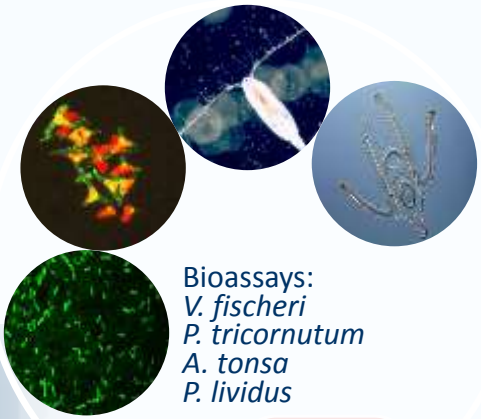
Contents lists available at SciVerse ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

A multidisciplinary weight of evidence approach for classifying polluted sediments: Integrating sediment chemistry, bioavailability, biomarkers responses and bioassays

Maura Benedetti [a], Francesco Ciaprini [b], Francesco Piva [a], Fulvio Onorati [b], Daniele Fattorini [a], Alessandra Notti [a], Antonella Ausili [b], Francesco Regoli [a,*]



Bioassays:
V. fischeri
P. tricornutum
A. tonsa
P. lividus

LOE 4

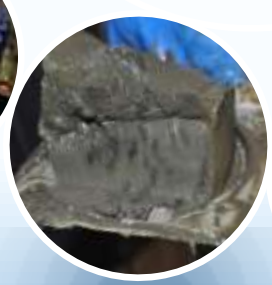
Analysis
of benthic communities

LOE 5

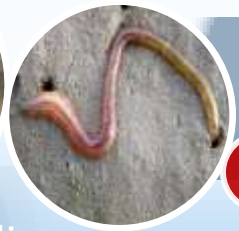
Weight of evidence

Chemical
analyses

LOE 1



Sediment sampling



Bioaccumulation test
with
H. diversicolor

LOE 2

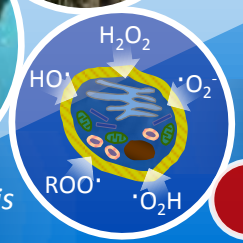
LINES OF EVIDENCE

LOE 1: Sediment chemistry
LOE 2: Bioaccumulation
LOE 3: Biomarkers
LOE 4: Bioassays
LOE 5: Benthic communities

Bioaccumulation

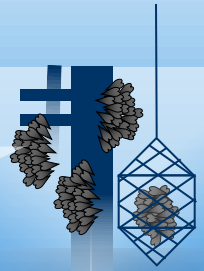
LOE 2

M. galloprovincialis



Biomarkers

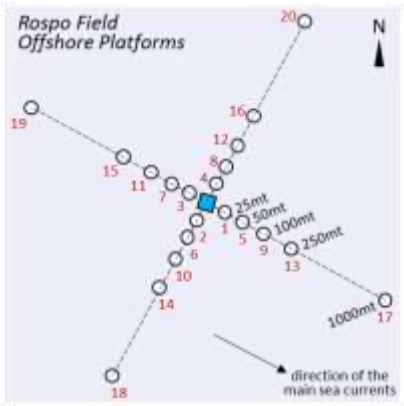
LOE 3



Native and
transplanted mussels

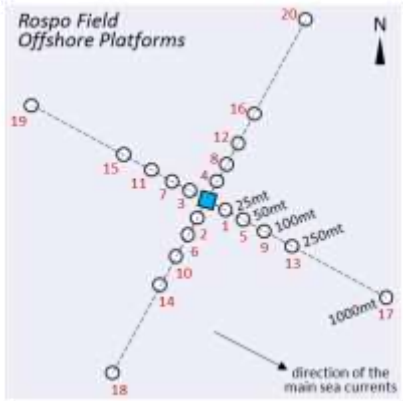
20 sampling stations
in each platform

Chemical analyses on sediment

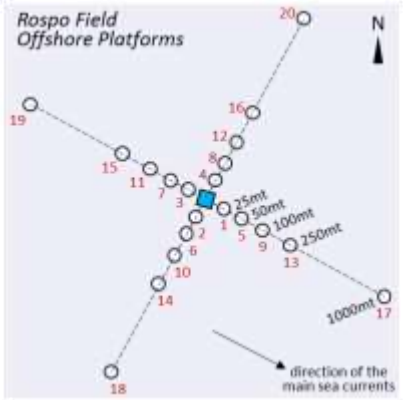


RSM-A

RSM-B



RSM-C



- **3 platforms**

- **60 sampling points**

- **53 parameters:**

Grain size
Total Organic Matter
Total Organic Carbon(TOC)
Metals (Al, As, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V, Zn)
PAHs
Total hydrocarbons

LOE 5: Benthic Communities

SediQualSoft®

LOE 1 Chemical analyses

LOE 2 Bioavailability of chemicals

LOE 3 Sublethal effects Biomarkers

LOE 4 Toxicological Bioassays

LOE 5 Benthic Communities

Simple community descriptors

Numerical density (*N*)

N = number of macroinvertebrates per unit area (ind/m^2).

Taxonomic richness (*S*)

S = number of species or taxa per sample.

Ecological indicators

AMBI = [(0 × %GI) + (1.5 × %GII) + (3 × %GIII) + (4.5 × %GIV) + (6 × %GV)] /100

GI = group of sensitive species; GII = group of sensitive/tolerant species; GIII = tolerant species; GIV = group of second-order opportunistic species; GV =group of first-order opportunistic species or taxa. (Borja et al., 2000).

M-AMBI = Multivariate index: AMBI, Shannon diversity index and taxonomic richness. (Muxika et al., 2007)

M-AMBI* = Multimetric index: AMBI, Shannon diversity index and taxonomic richness. (M-AMBI revisited; Sigovini et al., 2013)

BENTIX = [6 × %GI + 2 × (% GII + %GIII)]/100

GI = group of sensitive species or taxa; GII = group of tolerant/ second-order opportunistic species or taxa; GIII = group of first-order opportunistic species or taxa. (Simboura and Zenetos, 2002).

BOPA (benthic opportunistic polychaetes amphipods) (ratio between the frequency of opportunistic (tolerant) polychaetes and the frequency of amphipods to classify the state of a community) (Gomez Gesteira and Dauvin, 2000).

BITS (Benthic Index based on Taxonomic Sufficiency) = log [(6fI+fII)/(fIII+1)+1] + log[nI/(nII+1)+nI/(nIII+1)+0,5nII/(nIII+1)+1]

fI, fII and fIII is the frequency (ratio of the number of individuals belonging to those families to the total number of individuals in the sample) of sensitive, tolerant and opportunistic families; nI, nII and nIII is the number of sensitive, tolerant and opportunistic families in the sample (Mistri and Muntari, 2008)

Taxonomic diversity indices

Shannon–Weaver index (*H'*)

$H' = -\sum p_i \log_e p_i$ where p*i* is the proportion of species *i* in a community with S species or taxa. (Shannon & Weaver, 1963)

EcoQ$_i$ (*H'*) Simboura and Zenetos (2001)

EcoQ$_{ii}$ (*H'*) Vincent (2002)

Margalef index (*D*) (Margalef, 1969)

D = (S −1)/ln(N) where S is the number of species or taxa in the sample and N is the total number of macroinvertebrates.

Pielou index (*J'*) (Pielou, 1969)

J' = *H'*/log(S) where *H'* is the Shannon–Weaver index and S is the number of species or taxa in a sample.

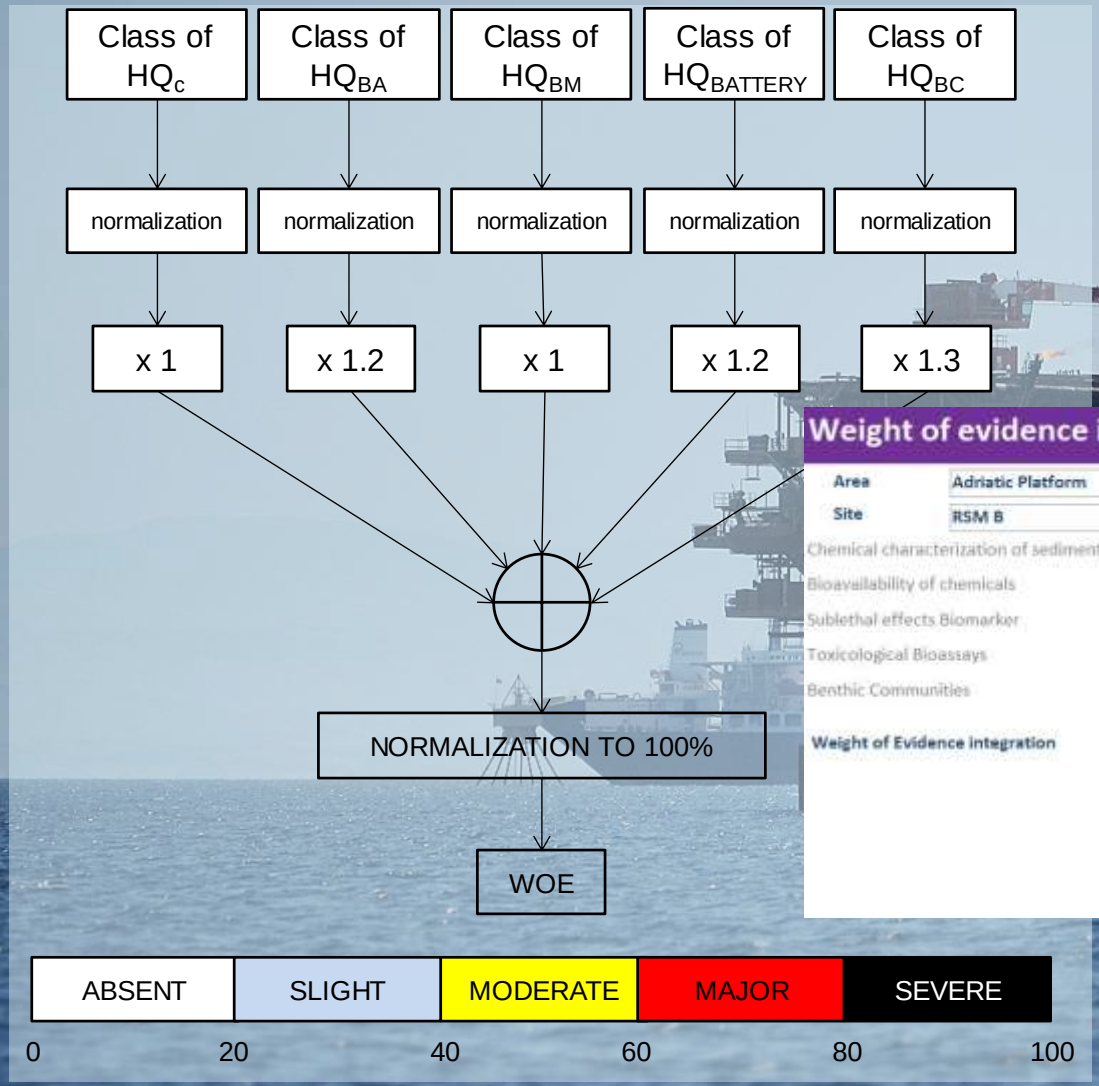
Normalization

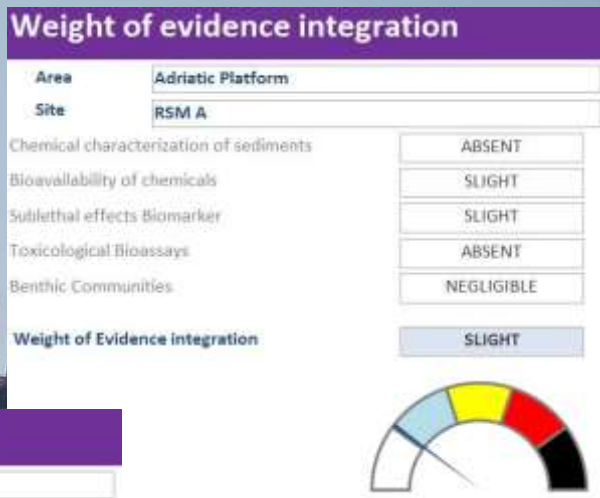
Index selection

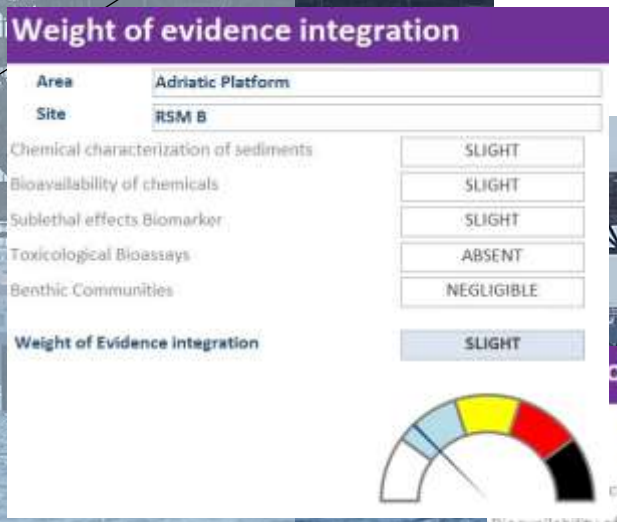
Level of hazard

Absent Slight Moderate Major Severe

Flow chart for integration of various LOEs into WOE and class of Risk

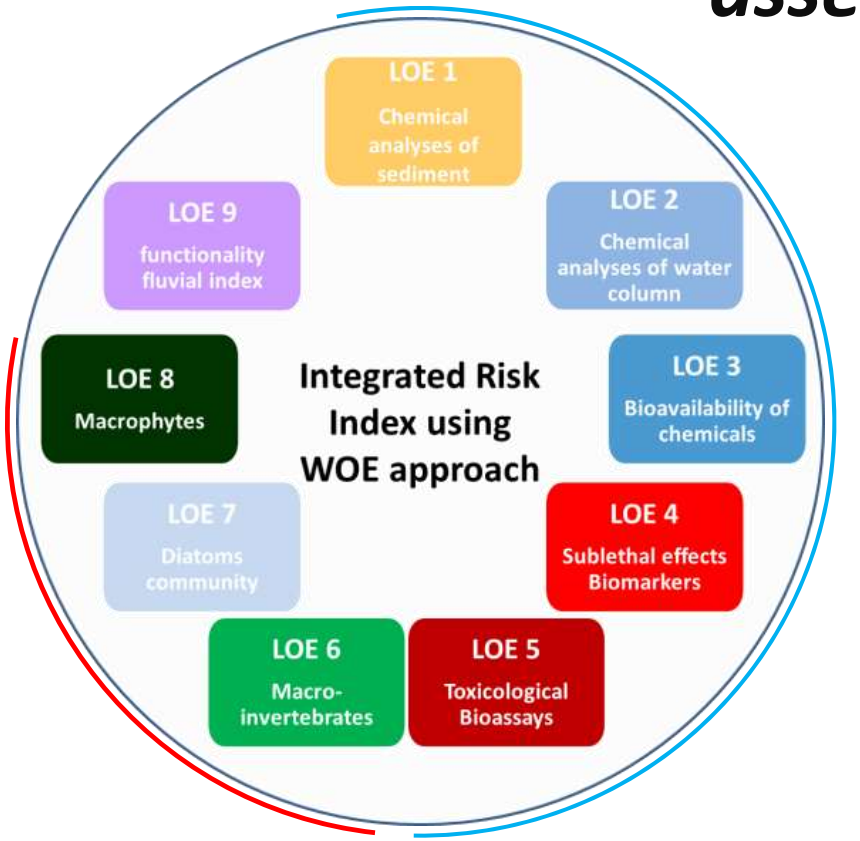






Total of 6696 analyses to interpret

General structure of the model for freshwater quality assessment



— Modules developed in Sediqualsoft model

— Modules provided by D.M 260/10

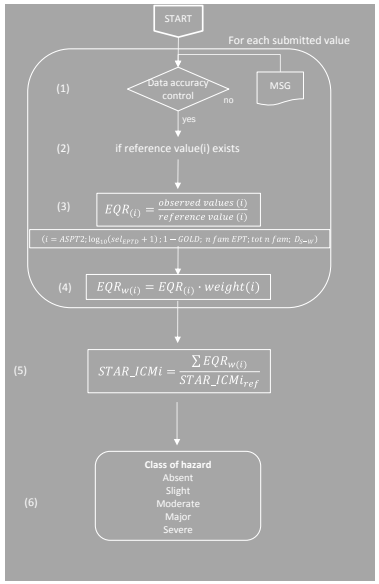
Additional LOEs for freshwater ecosystems

***according to requirements of D.M 260/10:* Ecological status of surface water bodies**

EQR: Ecological Quality Ratio

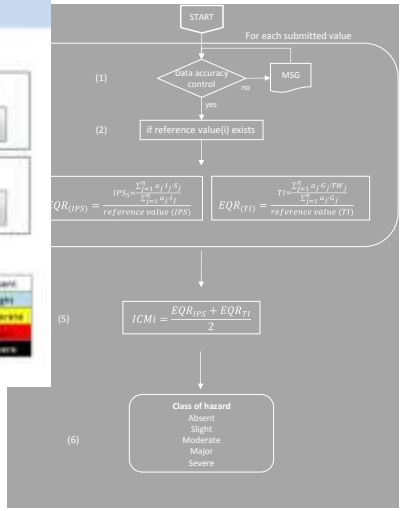
LOE6: Macroinvertebrates

STAR_ICMi

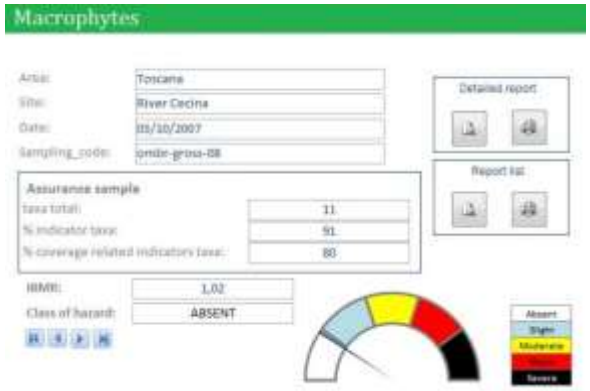


LOE7: Diatoms community

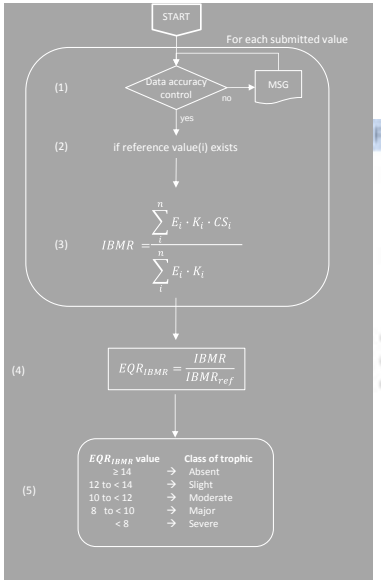
ICMi



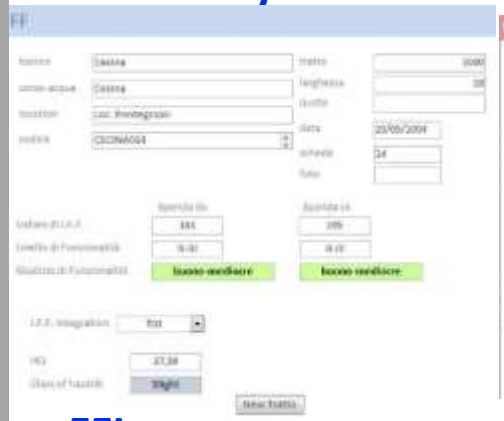
LOE8: Macrophytes



IBMR: *Indice Biologique Macrophyitique en Rivière*



LOE9: Synthetic assessments on fluvial functionality



FFI: *questionnaire*

Validation of model in field studies

Case study: **Development of a multidisciplinary, Weight of Evidence (WOE) model for ecological risk assessment (ERA) in freshwater environments**

Area: **Cecina River**

Site: **Ponteginori**

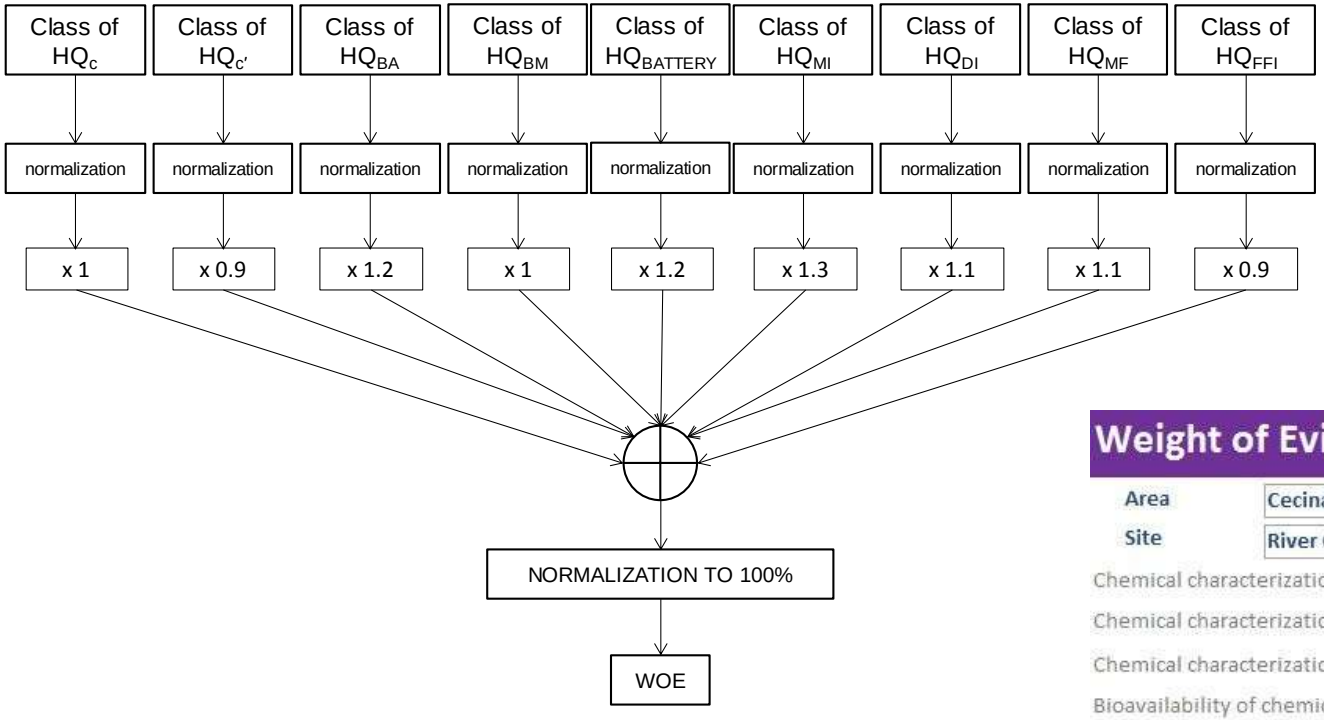
Period: **2007/08**

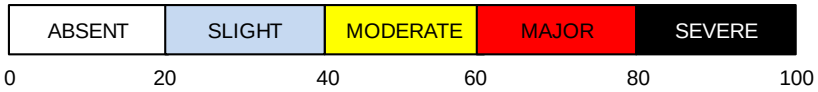
Reference data: **Guidi *et al*. 2010; ARPAT**

PROCESSED DATA

- LOE1: Chemical characterization of sediments
- LOE2: Chemical characterization of water column
- LOE3: Bioavailability
- LOE4: Biomarkers
- LOE5: Ecotoxicological bioassays
- LOE6: Macroinvertebrates
- LOE7: Diatoms community
- LOE8: Macrophytes
- LOE9: Synthetic assessments on functionality fluvial
- WOE: Weight of Evidence integration

Validation of Weight of Evidence (WOE) model for freshwater environments



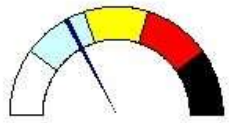


Weight of Evidence integration

Area	Cecina
Site	River Cecina

Chemical characterization of sediments	MAJOR
Chemical characterization of soil	
Chemical characterization of water column	MODERATE
Bioavailability of chemicals	SLIGHT
Sublethal effects Biomarkers	MODERATE
Toxicological Bioassays	ABSENT
Macroinvertebrates	MODERATE
Diatoms community	ABSENT
Macrophytes	ABSENT
Index of river functionality	MODERATE

Weight of Evidence integr	SLIGHT



CONCLUSIONS AND PERSPECTIVES

- **Importance of multidisciplinary WOE approach for characterizing environmental quality and risk assessment**

- **WOE models represent a fundamental tool for summarizing and interpreting large datasets of heterogeneous data, singularly or in an integrative approach**

- **They do not use “pass-to-fail” approach, enhancing the capability to discriminate different environmental conditions**

- **The developed model is versatile, easy to update or adapt to local or national specificities**

- **Scientifically sound but user-friendly format, to support a more comprehensive process of risk assessment and “site-oriented” management decisions**

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