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Case Study: Sediment Contamination by Mercury and DDT and Ecological Risk Assessment for Aquatic Biota, Lake Maggiore, Italy

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ENVIRON

Content

- Background
- Approach
- Conceptual site model
- Implemented works and assessments
- Environmental risk assessment (ERA) conclusions
- Evaluation of management alternatives

Lake Maggiore Watershed

Pieve Vergonte Industrial Site History

1915

Production facilities construction for the chlorine production line

1948

Implementation of DDT production line

1996

Fishing banned due to DDT in fish (>0.05 mg/kg)

Shutdown of DDT production line

2006

Public authorities prescribed dredging/capping of Pallanza Bay

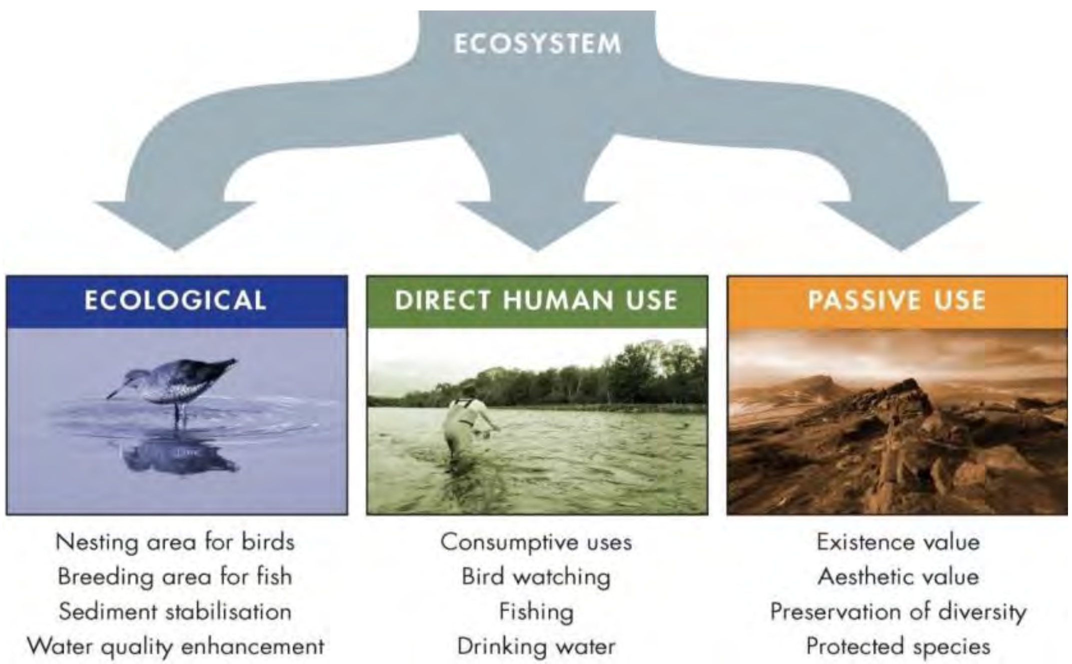
2008-2010

Sediment characterisation to support remedial decision making

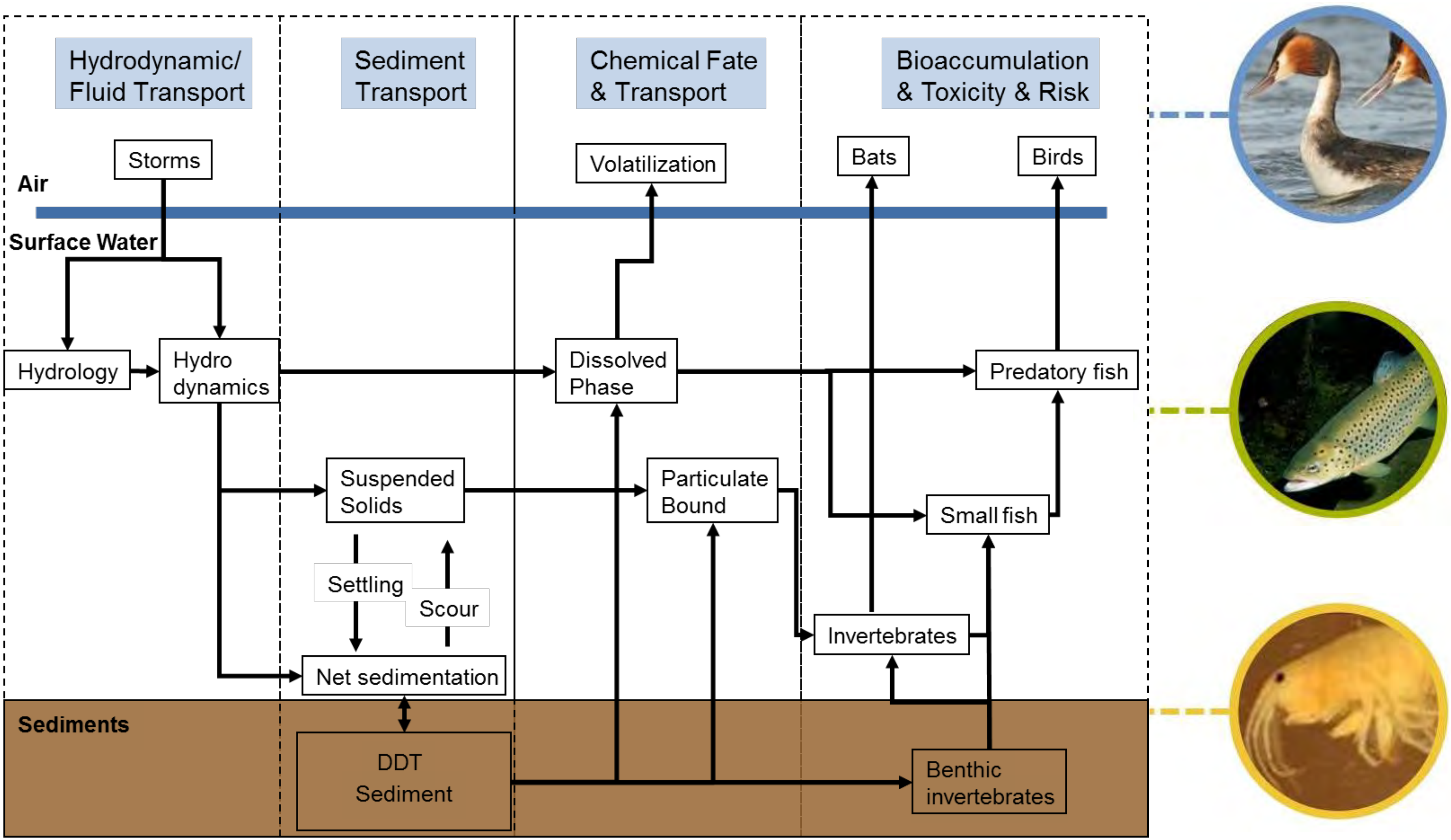
Approach

ECOLOGICAL RISK ASSESSMENT

- Assess potential effects of DDT and mercury
- Define remediation needs and design as necessary
- Support decision making process



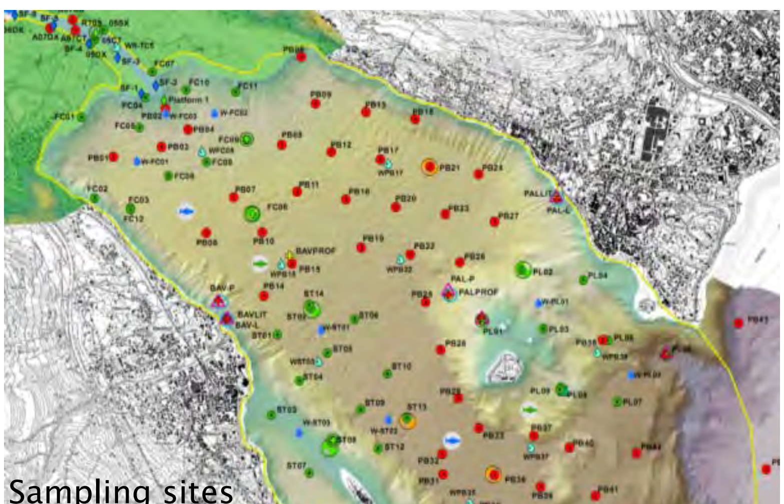
Conceptual Site Model



Field Work and Assessments

- Sediment transport (key processes and modelling)
- Geochronology
- Sediment sampling for chemical characterisation
- Sediment Profile Imaging (SPI camera)

Undisturbed sediment core



Sampling sites

- Toxicity test (lab)
- Bioaccumulation test (lab)
- DDT analysis in aquatic biota (fish, indigenous invertebrates)
- Ecological surveys (benthos, fishes, birds)
- Ecological risk assessments

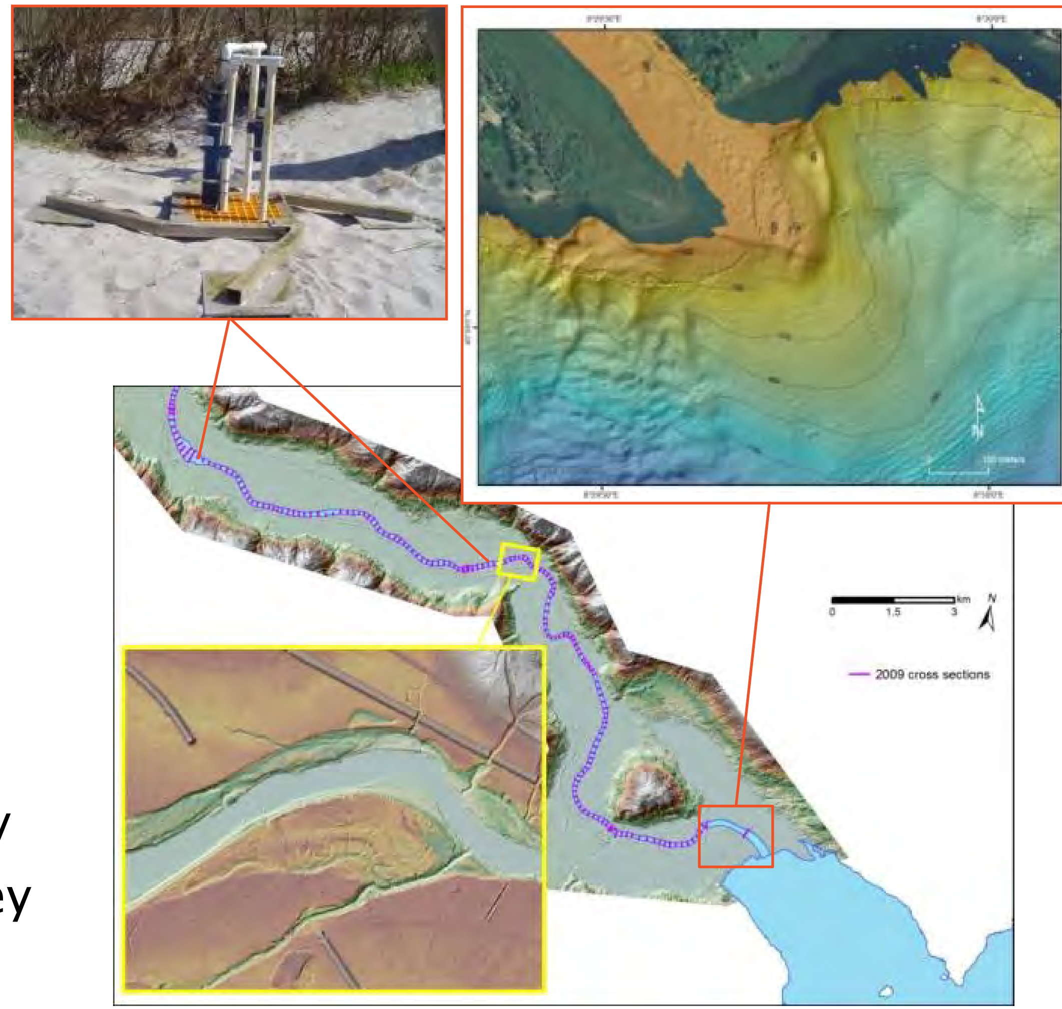
Sediment Transport – Input Data

FLOW VELOCITIES AND TURBIDITY MEASUREMENTS

- Aquadopp current metres, optical backscatter metres (OBS) and Acoustic Doppler Current Profiler (ADCP)

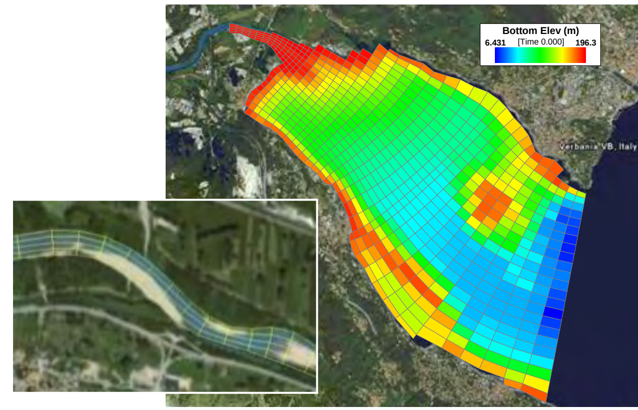
TOPOGRAPHIC SURVEYS

- Multi-beam bathymetry in lake and river mouth
- Cross-section river survey
- Alluvial plain LIDAR survey



Sediment Transport – Modelling

- Used models: ERODE and EFDC
- Gridding using curvilinear orthogonal grid
- Average cell size in Pallanza Bay is 150m by 200m; average cell size in the river is approximately 20m cross stream and 50m downstream; seven vertical sigma layers



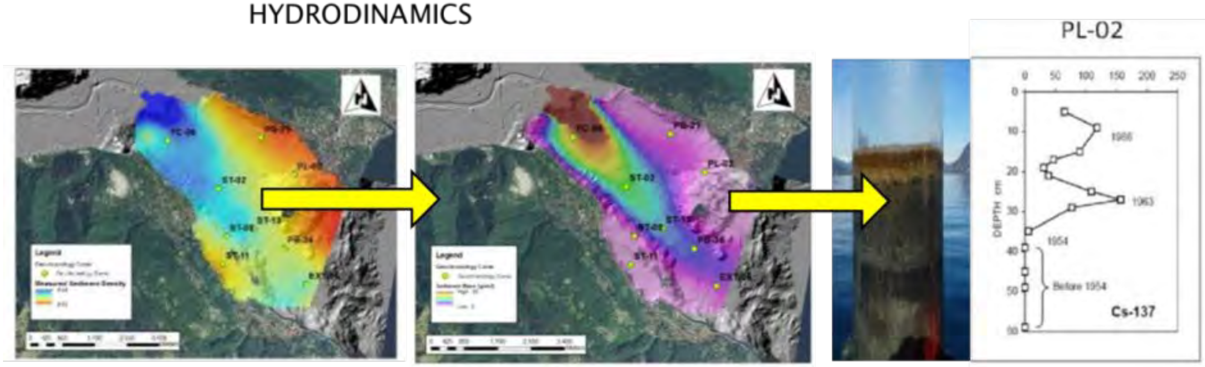
Sediment mass modelled with ERODE Sediment distribution modelled with EFDC

$\Delta z = m / \rho_{DRY}$

HYDRODINAMICS

Thickness of deposited sediment

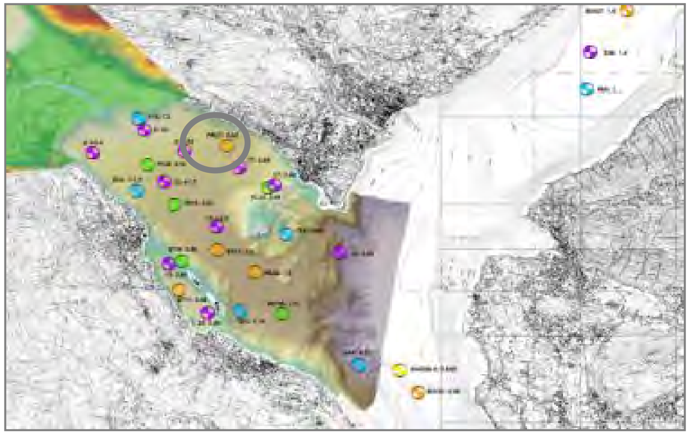
Model Thickness matched and validated with Cores Thickness from Geo Crones

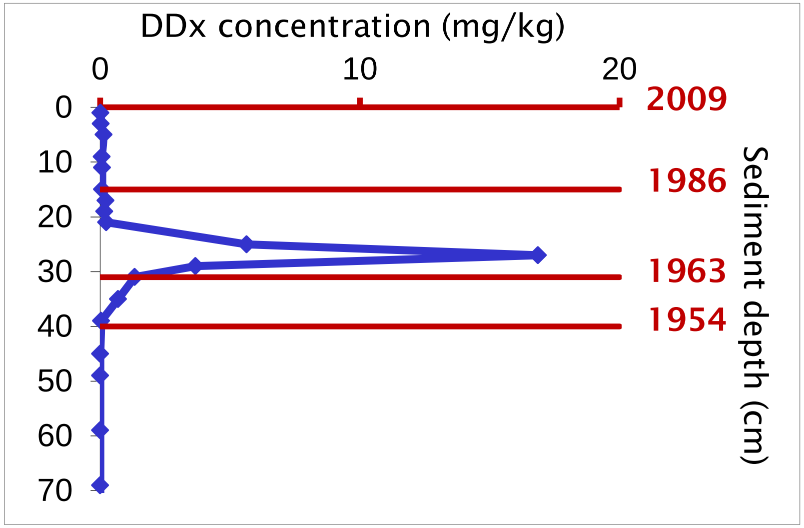


DDx Distribution Analysis

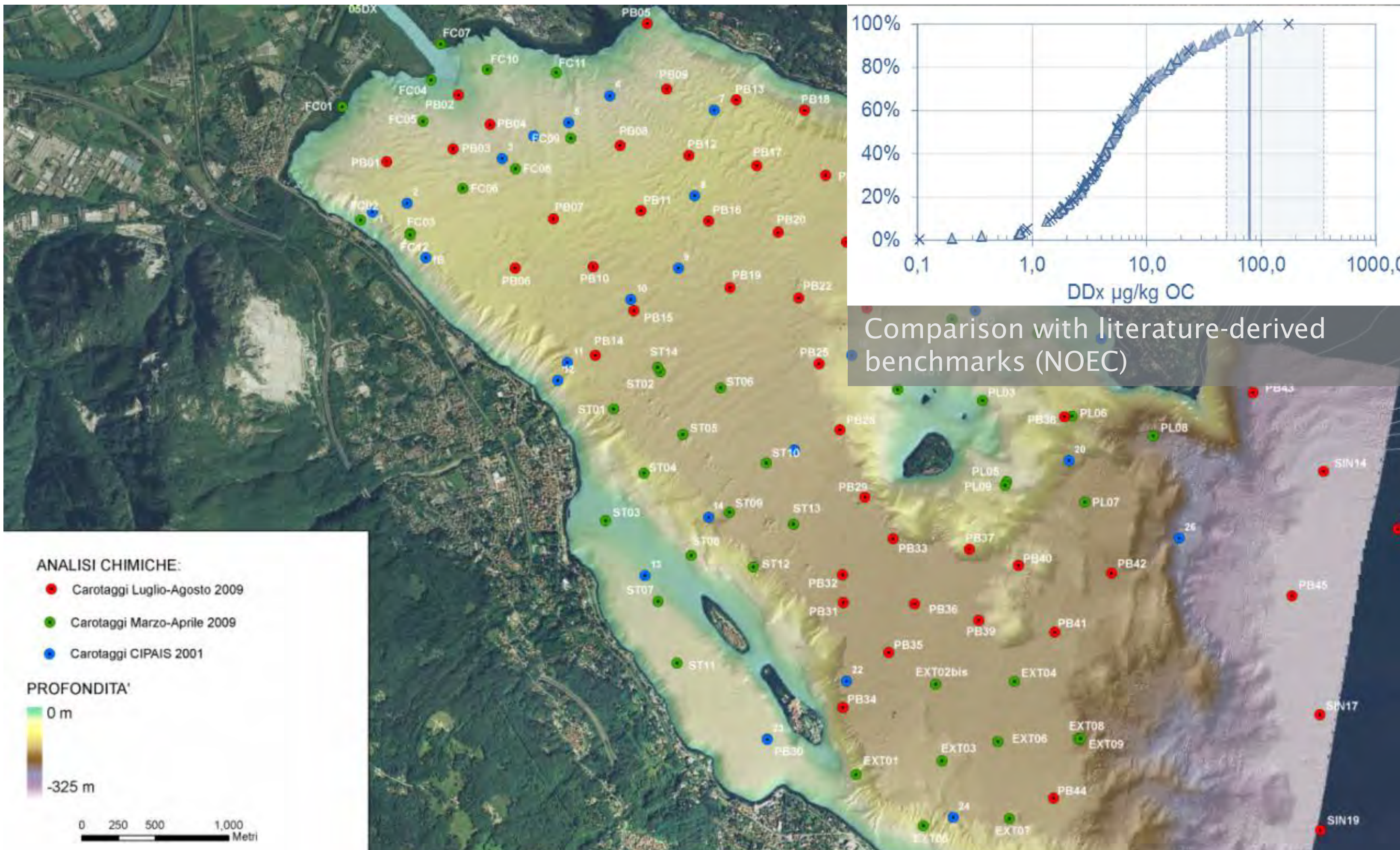
Incoming Bay DDx Decrease

- DDx, as a hydrophobic contaminant, is associated to the organic matter around the flocculated particles of silt and very fine sand – field evidence (geochron cores) shows that DDx concentrations are decreasing in the bay
- Sediment transport and distribution in the Pallanza Bay was reconstructed accurately by the EFDC model; the modelled patterns of deposition were representative to those measured in the geochronology cores
- Sediments not at risk of erosion based on the 500-year flood results and measured critical shear stresses in the bay
- Shear stresses in the bay remain low enough to allow for settling of fine sediments during all extreme events simulated





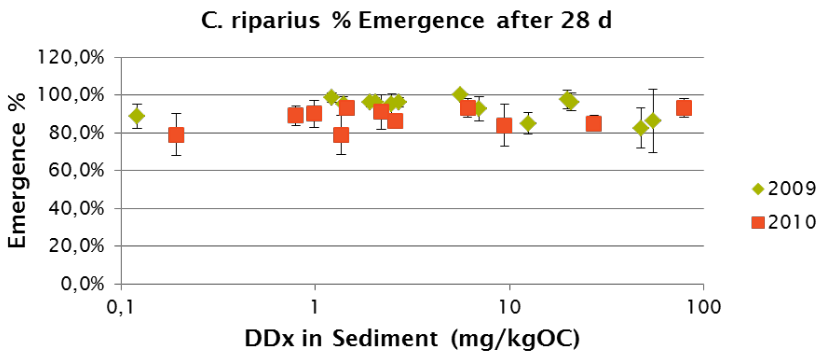
Sediment Chemistry



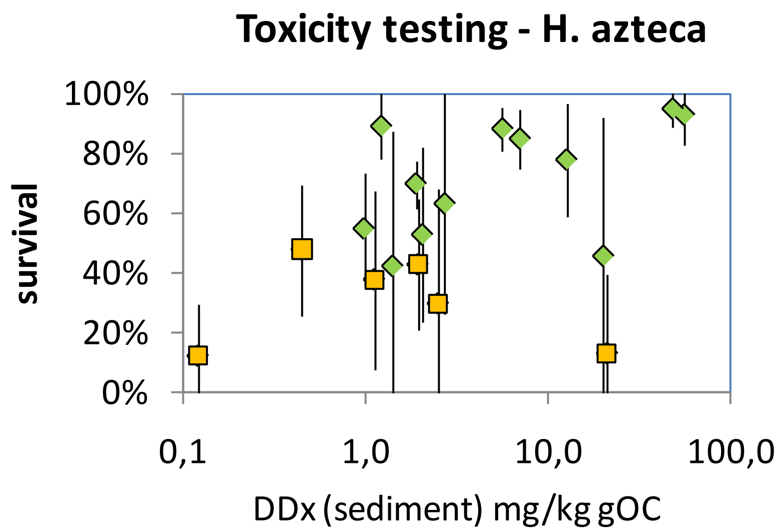
Comparison with literature-derived benchmarks (NOEC)

Benthos Toxicity Testing

C. riparius: 28 days exposure



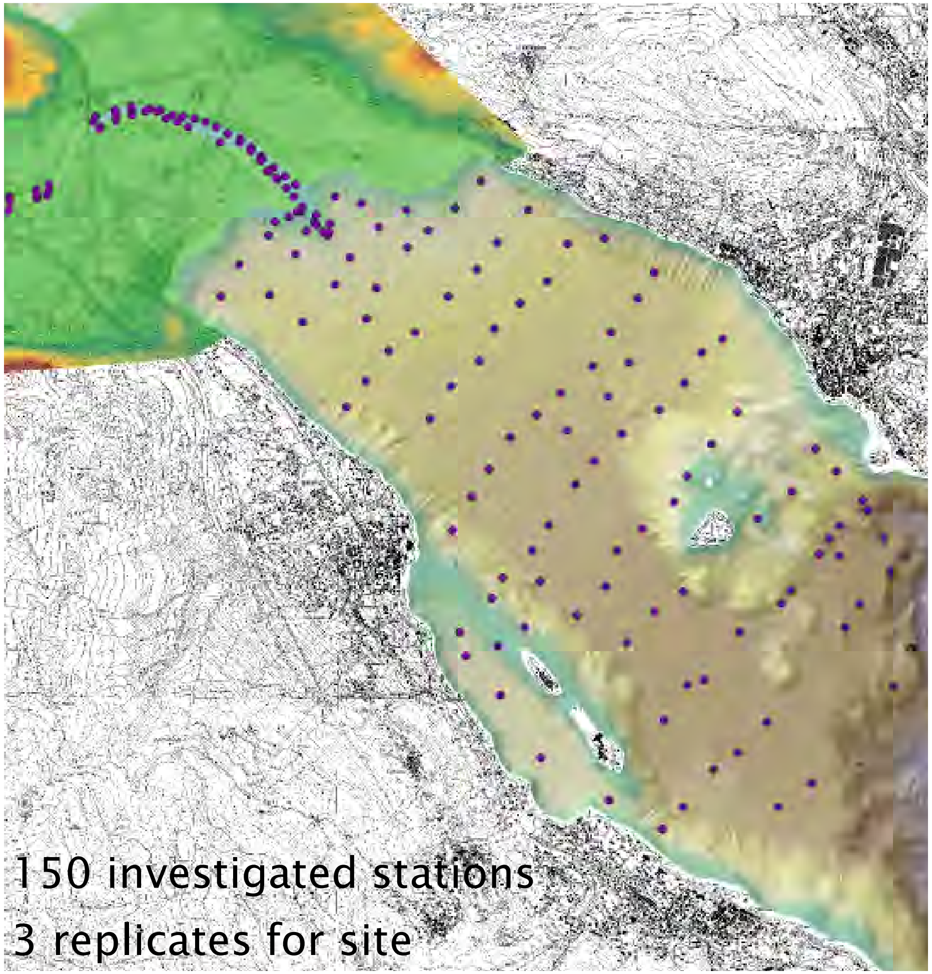
H. Azteca: 42 days exposure (2009)



ELUTRIATE TOXICITY TESTING

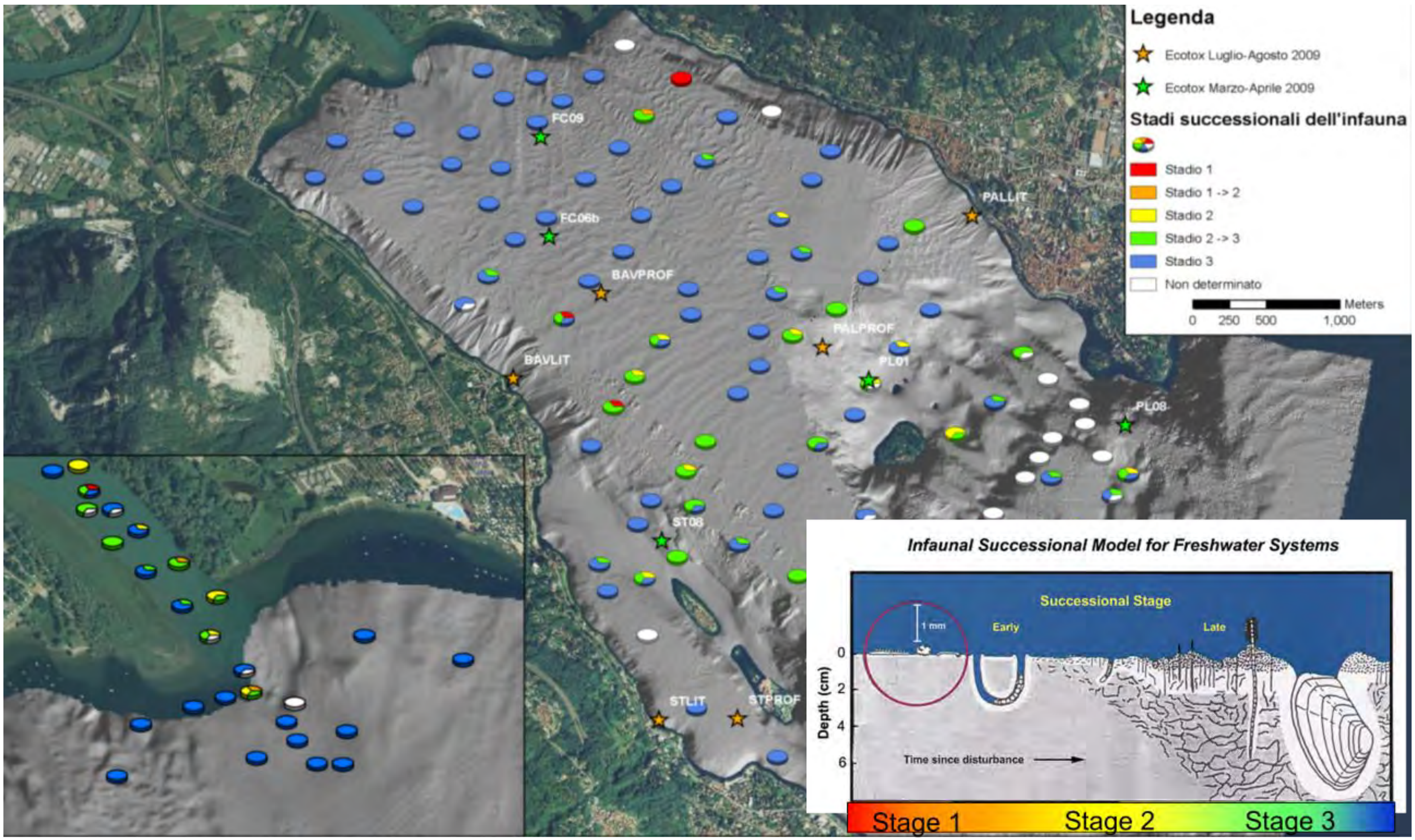
No observed toxicity in elutriate (tested organisms: *D. magna*, *P. subcapitata*) prepared from sediments collected in Pallanza Bay

Benthos Biology – SPI Camera



SPI camera and plan view camera survey

Benthos Biology
Successional Stages in Pallanza Bay



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Benthos: Risk Characterisation

CHEMISTRY

- ~ 99% of surface sediment < toxicity threshold (site specific test, case study and spiked test)

TOXICITY

- No significant relationships between any of the endpoints and DDx/Hg concentrations in sediments
- Tested concentrations represent full range of sediment concentrations

BENTHOS COMMUNITY

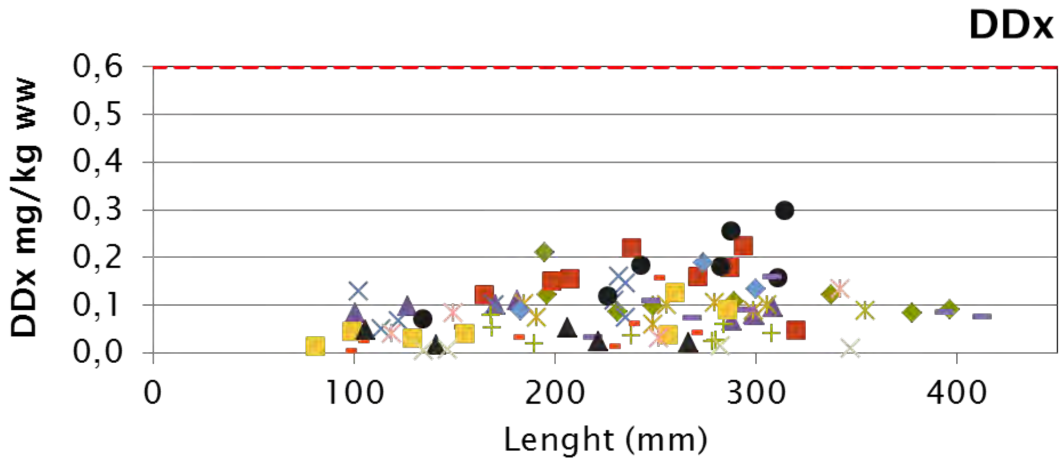
- No obvious impact on benthic community structure

Fish Community

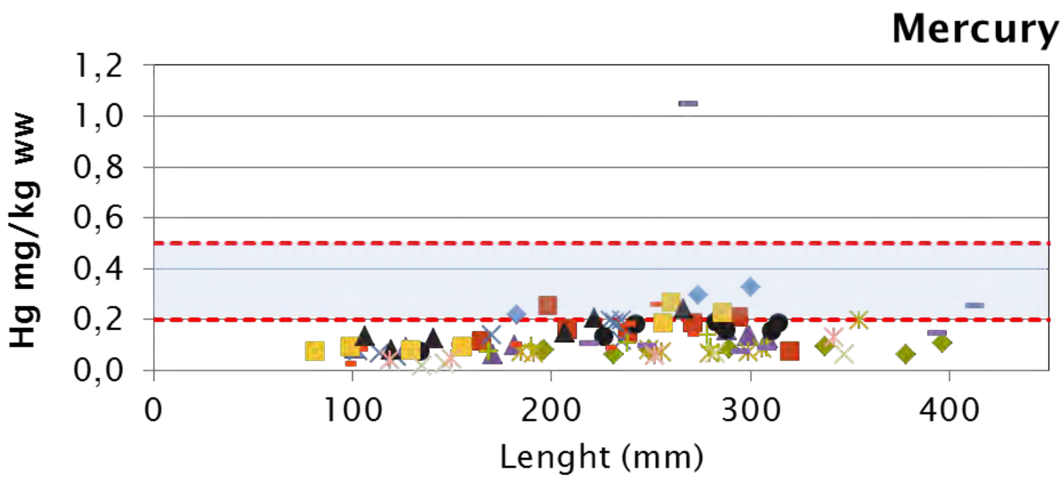
MEASUREMENT ENDPOINTS

- Comparison of fish tissue concentration to literature-derived benchmarks protective of fish (~200 analysis on fishes of different trophic levels and age)
- Comparison of surface water concentration to water quality benchmarks
- (Water sampling campaign and analysis of previous studies)
- Fish fitness as function weight-length (endpoint for mercury)
- Evaluation of site specific studies on reproductive success

Fish Community continued



Toxicity Reference Value (TRV)
DDx: 0,6 mg/kg
Hg: 0,2-0,5 mg/kg



Fish species

BP-COREG	CAN-PERSICO
BP-AGONE	LMER-COREG
BP-GARDON	LMER-AGONE
BP-PERSICO	LMER-GARDON
CAN-COREG	LMER-PERSICO
CAN-AGONE	TC1-TROTA
CAN-GARDON	TC2-TROTA

Fishes: Risk Characterisation

- Tissue concentrations: no relevant exceedances for DDx and Hg
- No evidence of impaired fitness due to mercury (fitness evaluation)
- Site specific studies did not show negative effect on reproduction success
- DDx water concentration never exceeded international benchmarks and Italian EQS (0,025 ug/L) (1998-2010)
- In a few cases, mercury concentrations in water exceeded USEPA’s Criterion Continuous Concentration (0,77 ug/L) and EU EQS (0,03 ug/L)

Fish community does not appear adversely affected by DDx and Mercury under current conditions

Wildlife

Evaluation of survival and reproduction of populations of fish-eating birds (grebes) and insectivorous mammals (bats):

- Comparison of contaminants ingested doses by diet with TRV protective reproductive success
- Evaluation of site specific studies on grebe eggs shell thickness and DDT concentration

Exposure Assessment

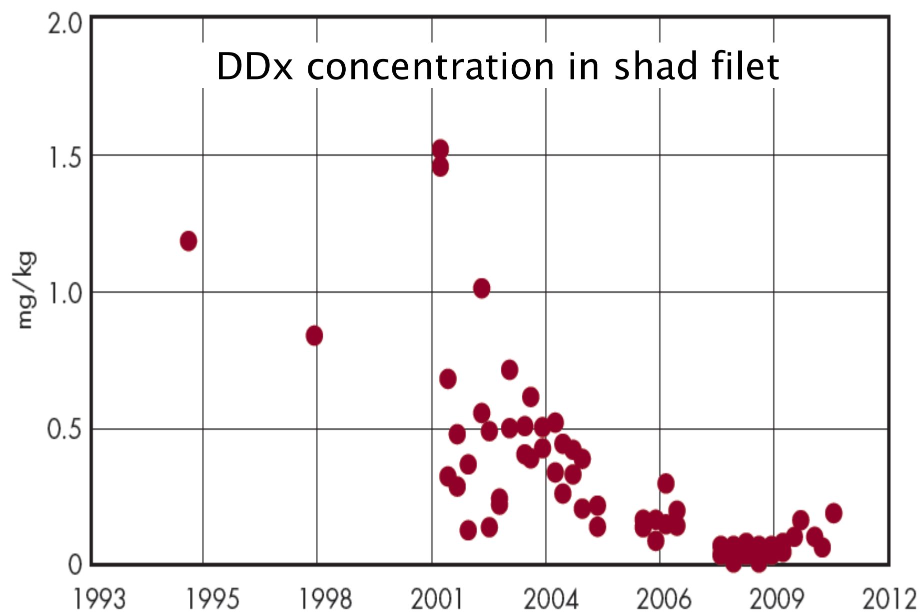
WILDLIFE (GREBE AND BAT)

Daily intake dose (mg/kg/day) via diet calculated according to USEPA (1993, 1998)

- Estimated doses (conservative scenarios) do not show exceedances of literature-derived benchmarks
- Site specific studies did not offer evidence of impacts

ERA Conclusions

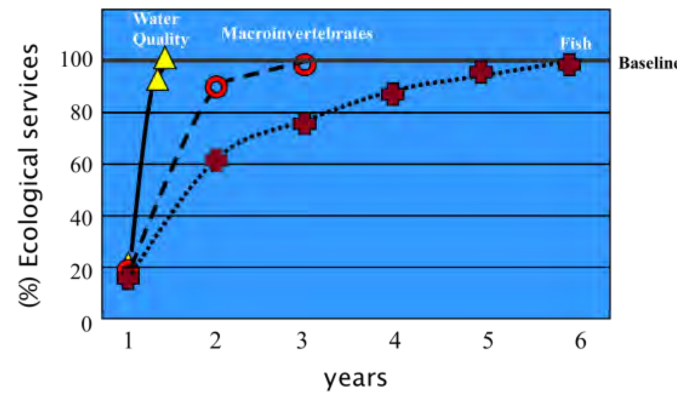
- At current condition, no ecological risks
- No human health risk
- Sediments in Pallanza Bay are not at risk of erosion (modelling results)
- Natural recovery is resulting from deposition of relatively clean sediments (evidences from fish concentration and dating analysis on sediment cores)



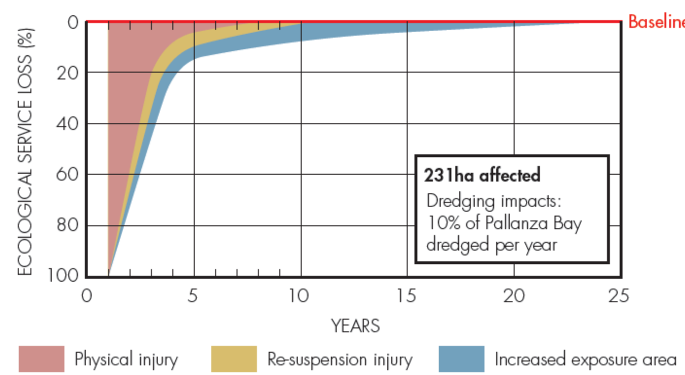
Remedial action beyond monitored natural recovery is not advised based on currently available data, but additional work underway to reduce uncertainty

Effects on Ecological and Human Use Services

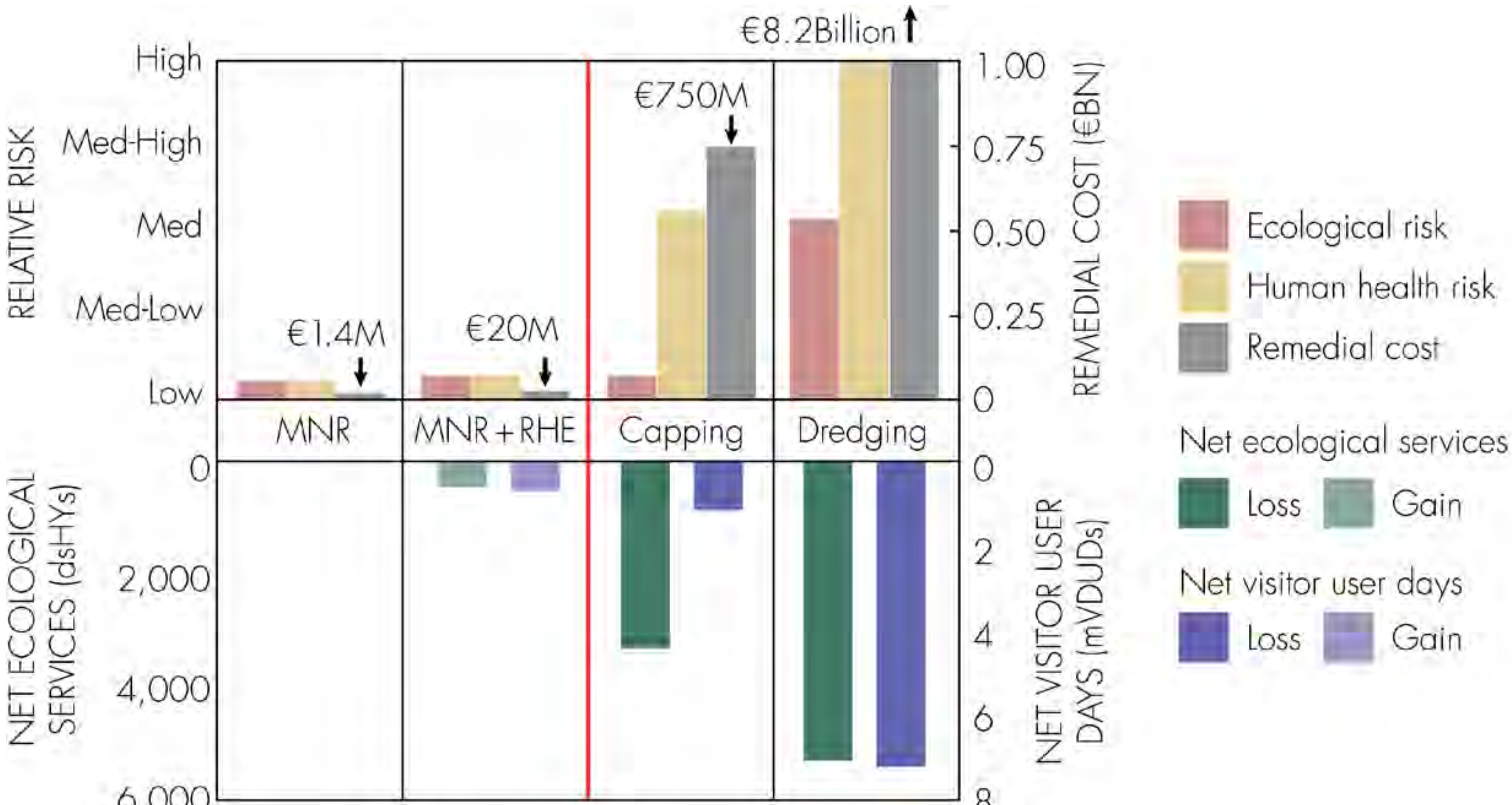
Remedial Alternative	Effects on Ecological Service
MNR	• No variation compared to the baseline
MNR + Riparian Enhancement	• Enhancements positively affect riverbank erosion, flood potential, and habitat
Capping	• Physical impacts to the benthic community
Dredging	• Physical habitat disturbance; • Re-suspension of contaminants; • Re-exposure of sediment contaminants previously buried and creation of direct exposure pathways for biota



Remedial Alternative	Effects on Human Use Service (tourism, fishing)
MNR	• No variation compared to the baseline
MNR + Riparian Enhancement	• Reduced risks associated with high flood events • A higher ecological quality will provide additional value to local residents as well as tourists
Capping	• Heavy construction equipment on the waters of the bay, with effects on the quality of trips to the area • Reduced fishing success due to potential impacts to benthos (fish prey).
Dredging	• Heavy construction equipment on the waters, with effects on the quality of trips to the area • Reduced fishing due to voluntary or regulated fishing restrictions and impacts on benthos



Comparative Analysis



Break-point

Remedial action causes more harm than the risk driving the action and there is a high cost for a marginal or increased change in risk, disproportional costs

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Thank you for listening

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