

CHARACTERIZATION OF DDT AND MERCURY CONTAMINATED SEDIMENT IN TOCE RIVER AND LAKE MAGGIORE (PALLANZA BAY)

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INTRODUCTION

Manufacturing facilities settled in the first half of 1900 along the River Toce, about 20 km from Pallanza Bay (Lake Maggiore). To evaluate the need for remedial action in Lake Maggiore (North Italy) and in its tributary (Toce River), sediment characterization activities were performed in 2009–2010.

To support decision-making about Lake Maggiore sediment, a wide sediment characterization plan was performed in 2009–2010; data interpretation and consequent proposal (Figure 1) were performed according to international guidelines and recommendations.

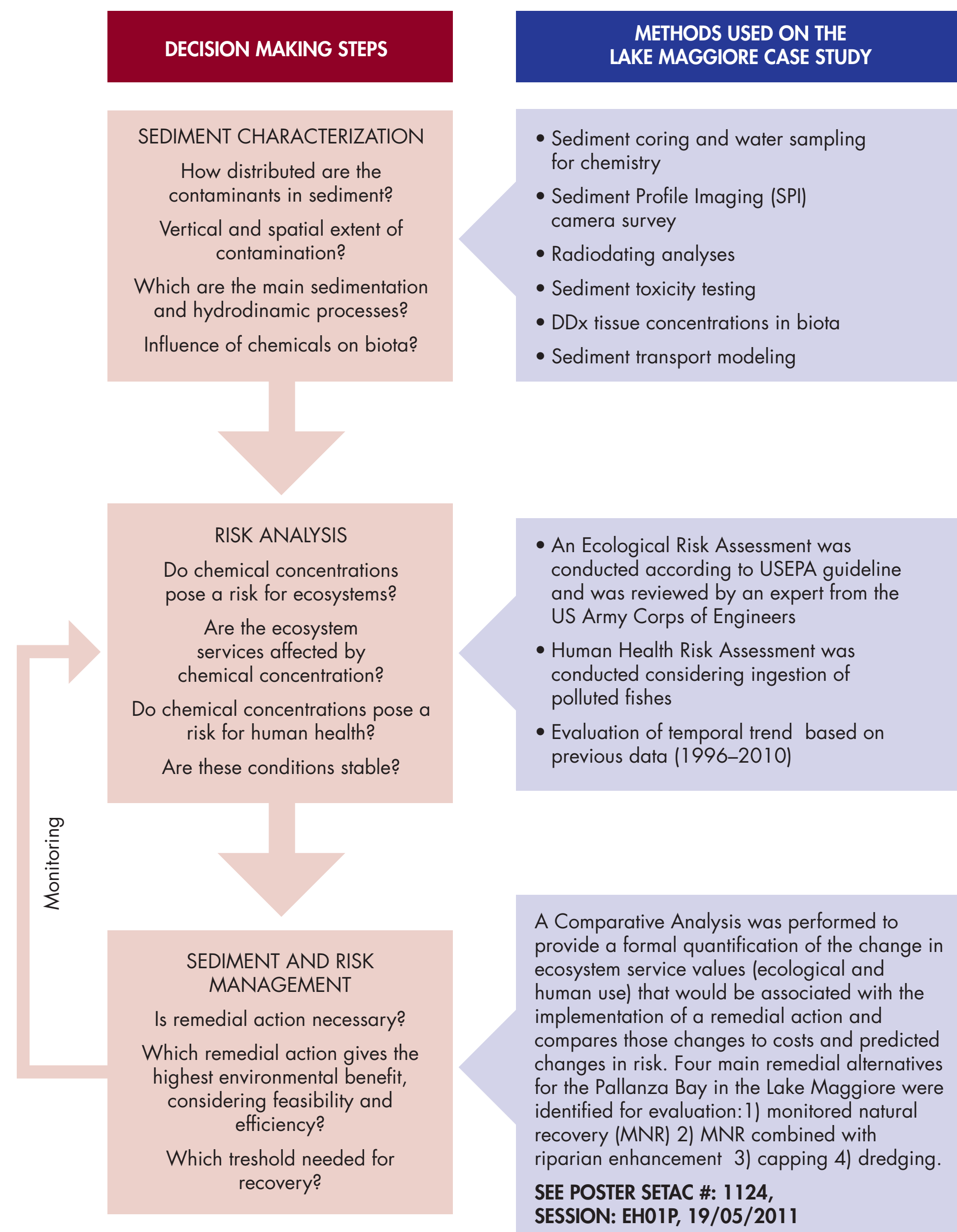


Figure 1. Sediment characterization plan.

SEDIMENT CHARACTERIZATION

To investigate temporal and spatial distribution of DDx and mercury in sediment and their influence on lake ecosystems, with the objectives of evaluating potential ecological risk and assessing the need for sediment remediation, the following activities were performed:

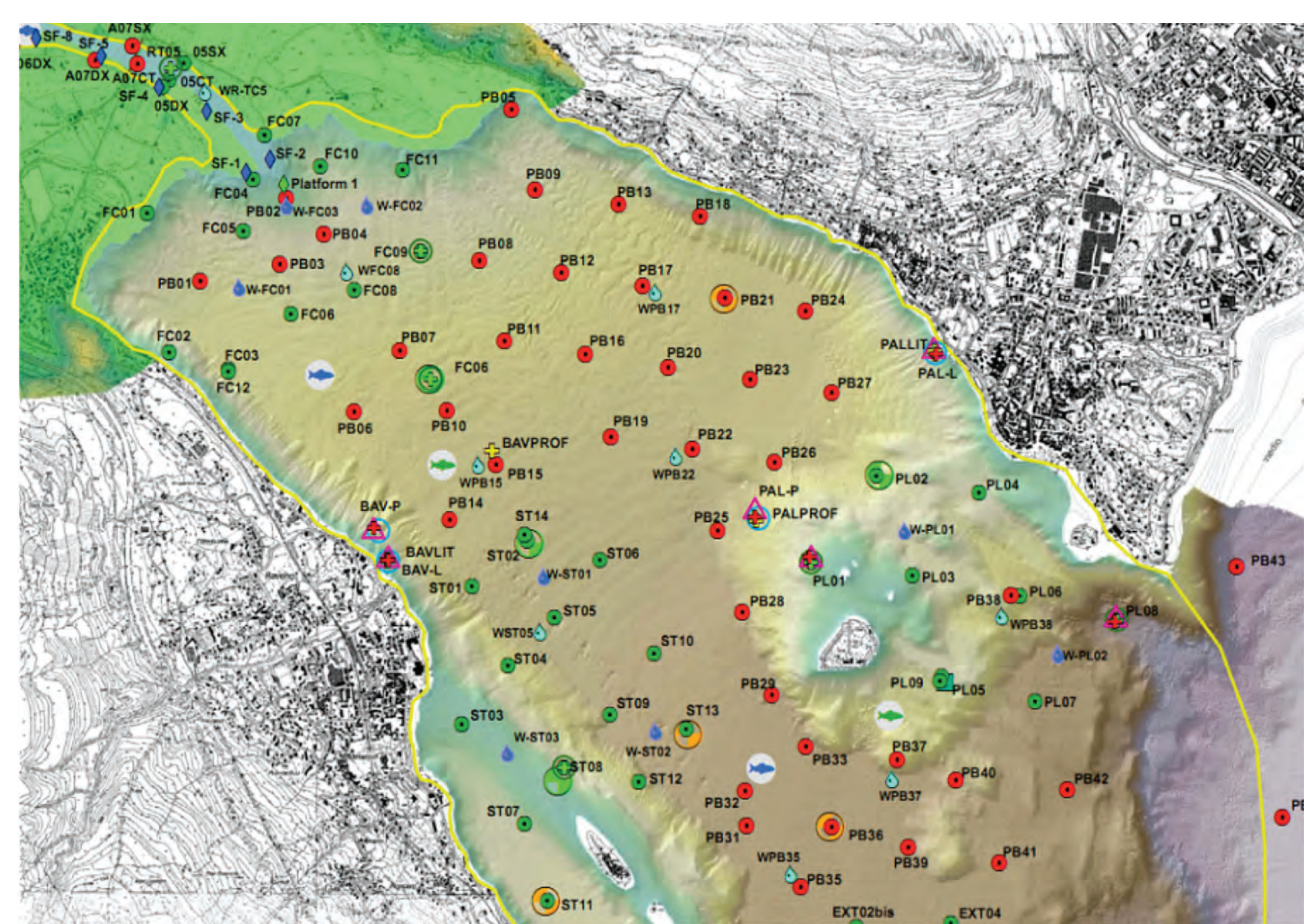


Figure 2. Map of sediment coring and water and biota sampling in Lake Maggiore.

- Chemical concentrations were investigated at various depths in 125 sediment cores (Figure 2). To collect high quality sediment chemistry data, a lightweight sediment-water interface gravity corer was used. This corer collected undisturbed cores (Figure 3), crucial for realistic evaluation of chemical stratification. Chemical concentrations in subsurface sediment are significantly higher than those in surface sediments (SETAC poster # 1518, Session HM01P, 16/05/2011).



Figure 3. A sediment core collected by gravity corer.

- A Sediment Profile Imaging (SPI) camera survey was performed at 150 sites throughout Pallanza Bay and mouth of Toce River to investigate benthos-sediment relationships by documenting gradients in sediment grain size, transport patterns, geochemical processes, and benthic community dynamics.
- Radiodating analyses (Cs-137 and Pb-210) were undertaken to better understand sediment accumulation rates and to examine historical trends in chemical loading to the bay. Radiodating analysis showed that the highest DDx concentrations in sediments are related to the 1970s (SETAC poster #1518, Session HM01P, 16/05/2011).
- Sediment toxicity to invertebrates was studied with several lines of evidence, including site-specific sediment toxicity studies, site-specific invertebrate community analysis, studies relating DDx tissue concentrations with adverse effects on invertebrates and analysis of benchmark and toxicity testing from major DDx and mercury contaminated sites. In detail, toxicity testing was investigated under chronic exposure condition (42-d for *H. azteca* and 28-d for *C. riparius*) on samples collected from 16 location in Pallanza Bay and 4 locations in the Toce River, spanning a range of mercury (0.016 to 5.22mg/kg) and DDx (0.001 to 1.35mg/kg) concentrations.
- The fish community was investigated by analyzing several species, considering tissue concentrations with adverse effects on fish, comparison of water concentrations with benchmark values and performing fitness evaluation.
- Fish and invertebrate tissue analyses were performed to understand the impact of sediment contamination on biota and to support estimation of wildlife exposure to evaluate potential ecological risk.
- Bathymetric and morphologic surveys were performed and hydrodynamic parameters were measured to implement a sediment transport model, to understand system variability under different hydrological scenarios.

RISK ANALYSIS

Resultant data from sediment investigation plan were used for characterizing ecological risk and to evaluate human health risk deriving from fish ingestion.

Based on the local ecology of the river and lake, as well as the species' relative exposure and sensitivity to mercury and DDx, the following were selected as receptors of interest for the Ecological Risk Assessment (ERA): benthic invertebrates, fish, piscivorous birds (grebe) and insectivorous mammals (bat).

Risks to aquatic invertebrates were evaluated using multiple lines of evidence, including:

- Sediment bioassays under chronic exposure (Figure 4): samples with the highest mercury and DDx concentrations consistently showed responses (or lack thereof) most similar to those of controls. Therefore, site-specific toxicity tests did not provide evidence of a sediment concentration that is a threshold for toxicity due to DDx or mercury.
- Invertebrate community structure from benthic sampling and sediment profile imaging (SPI); SPI camera results did not show obvious impact on benthic community.
- Comparison of invertebrate tissue concentrations to effects thresholds; invertebrate concentration was generally below literature-derived benchmarks.
- Comparison of site-specific concentration to benchmark selected from published studies where DDx and mercury were the primary contaminants and where site specific conditions were comparable to Lake Maggiore (Sferra et al. 1999, Milani and Grapentine 2000, Swartz et al. 1994, Ferraro and Cole 1997, Hoke et al. 1997): about 99% of surface sediment concentrations were below literature-derived sediment benchmark.

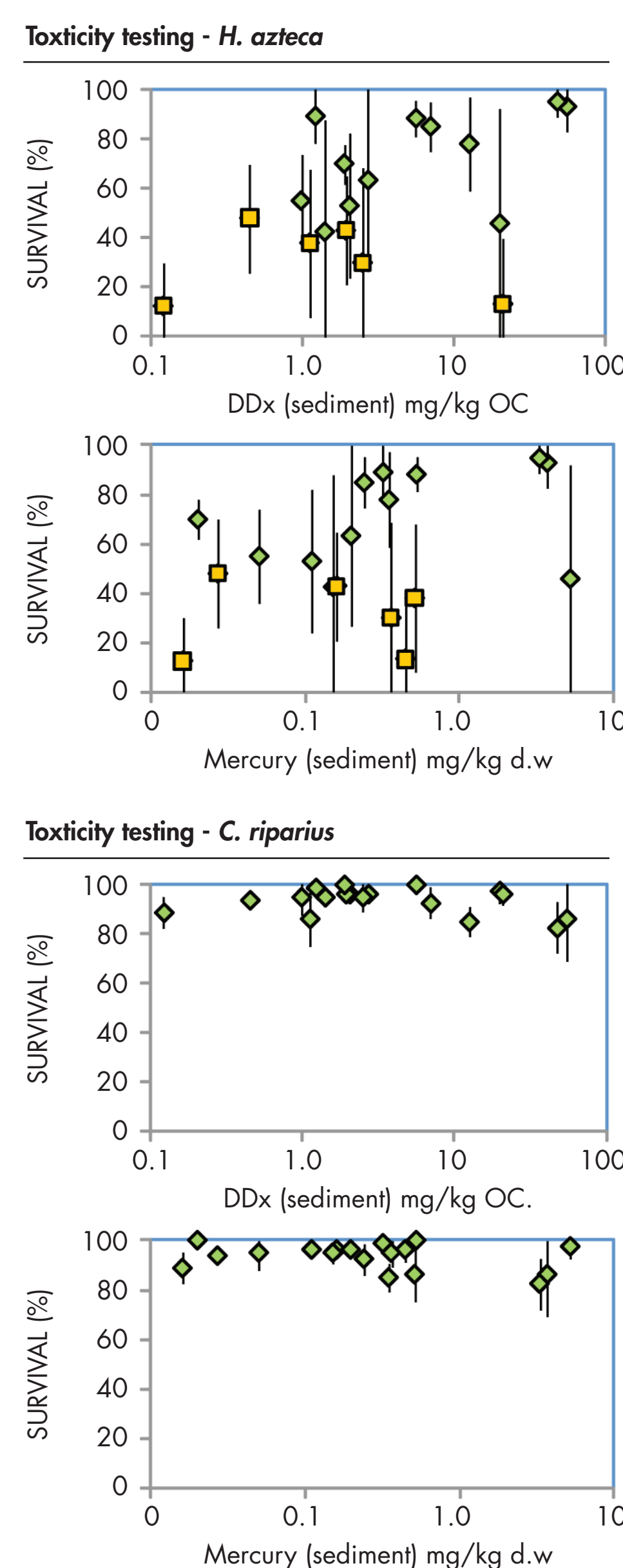


Figure 4. Toxicity testing on site-specific sediments was performed on sediment concentration up to 1.35mg/kg dw DDx (55mg/kg OC) and 5.2 mg/kg mercury using the amphipod *Hyalalella azteca* (42 days) and the midge *Chironomus riparius* (28 days). Despite the limited number of results that differed significantly (in orange) from controls, no significant relationships were observed between any of the endpoints and either mercury or DDx concentrations, regardless of whether responses were tested as reported or relative to control responses.

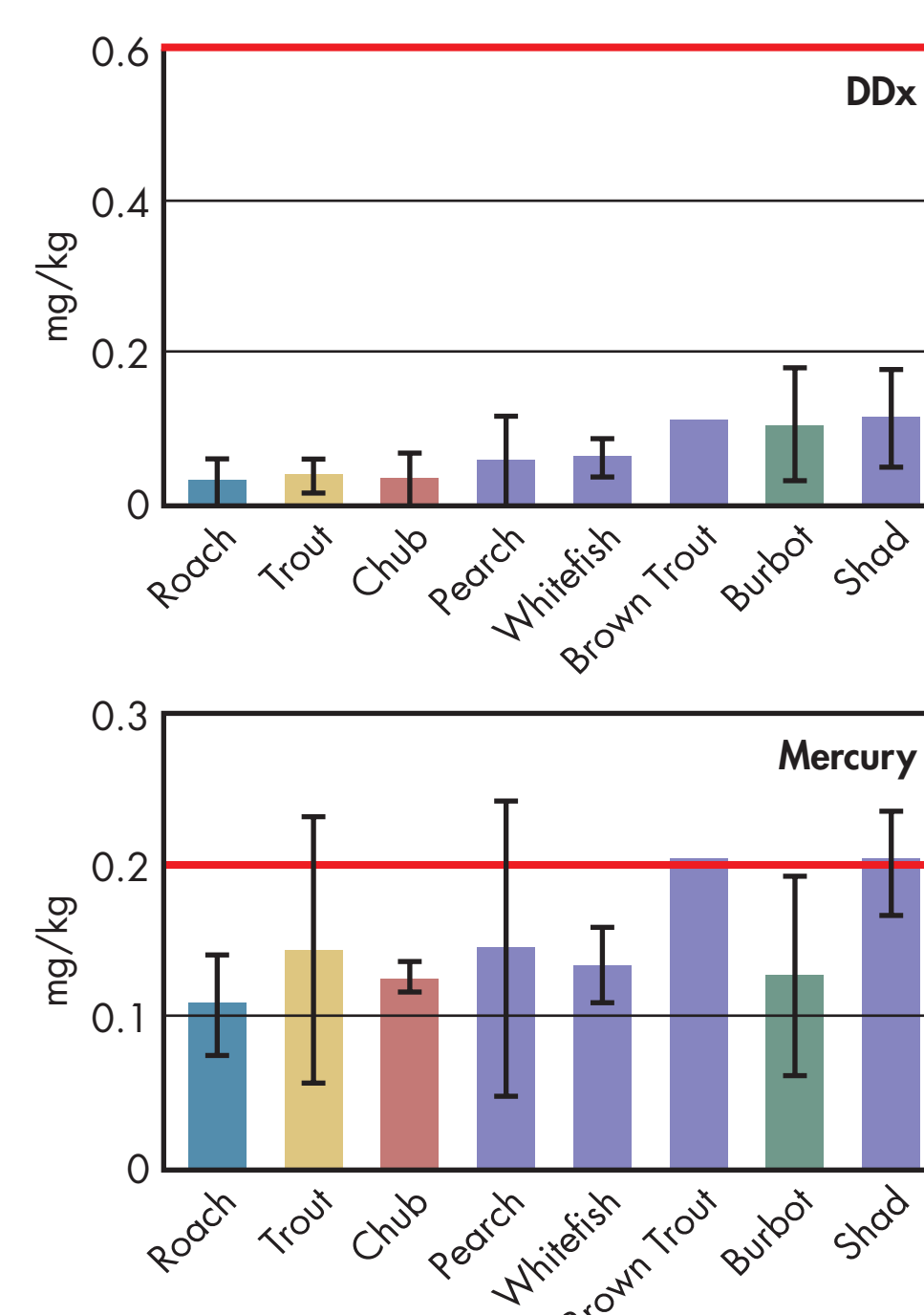


Figure 5. Comparison of fish tissue concentration (whole-body) and tissue benchmark derived by peer-reviewed scientific literature (Beckvar et al. 2005). Selected TRV considers several studies with respect to reproduction, development, survival, behavior, and growth in a variety of freshwater, estuarine, marine species.

Risks to fish were evaluated using the following lines of evidence:

- Comparison of fish tissue concentrations to effects thresholds (Figure 5). While DDx concentrations in fish were consistently below the toxicity reference value (TRV), mercury concentrations rarely exceed the TRV; however, data analysis didn't show any evidence of impaired fitness (weight/length) due to mercury.
- Comparison of water concentrations to benchmarks; in few cases mercury concentrations in water exceeded international benchmark such as the USEPA's Criterion Continuous Concentration.

Risks to wildlife (birds and bats) were estimated comparing chemical dose assumed by fish and invertebrate ingestion to affect thresholds from scientific literature: no significant risk emerged for wildlife at current condition.

SEDIMENT AND RISK MANAGEMENT

In general, ERA concluded that current conditions do not pose a significant risk to biota; moreover, radio-dating of sediment cores and historical fish tissue data (Figure 6) offer compelling evidence that conditions in Pallanza Bay are improving due to the natural deposition of relatively clean sediments over those deposited when the Pieve Vergonte facility was operating.

These results reflect the importance of natural recovery through the transport and deposition of relatively cleaner and cleaner sediment over historic deposits and suggest to avoid remediation by dredging: **remedial action beyond monitored natural recovery is not advised based on the data that are currently available.**

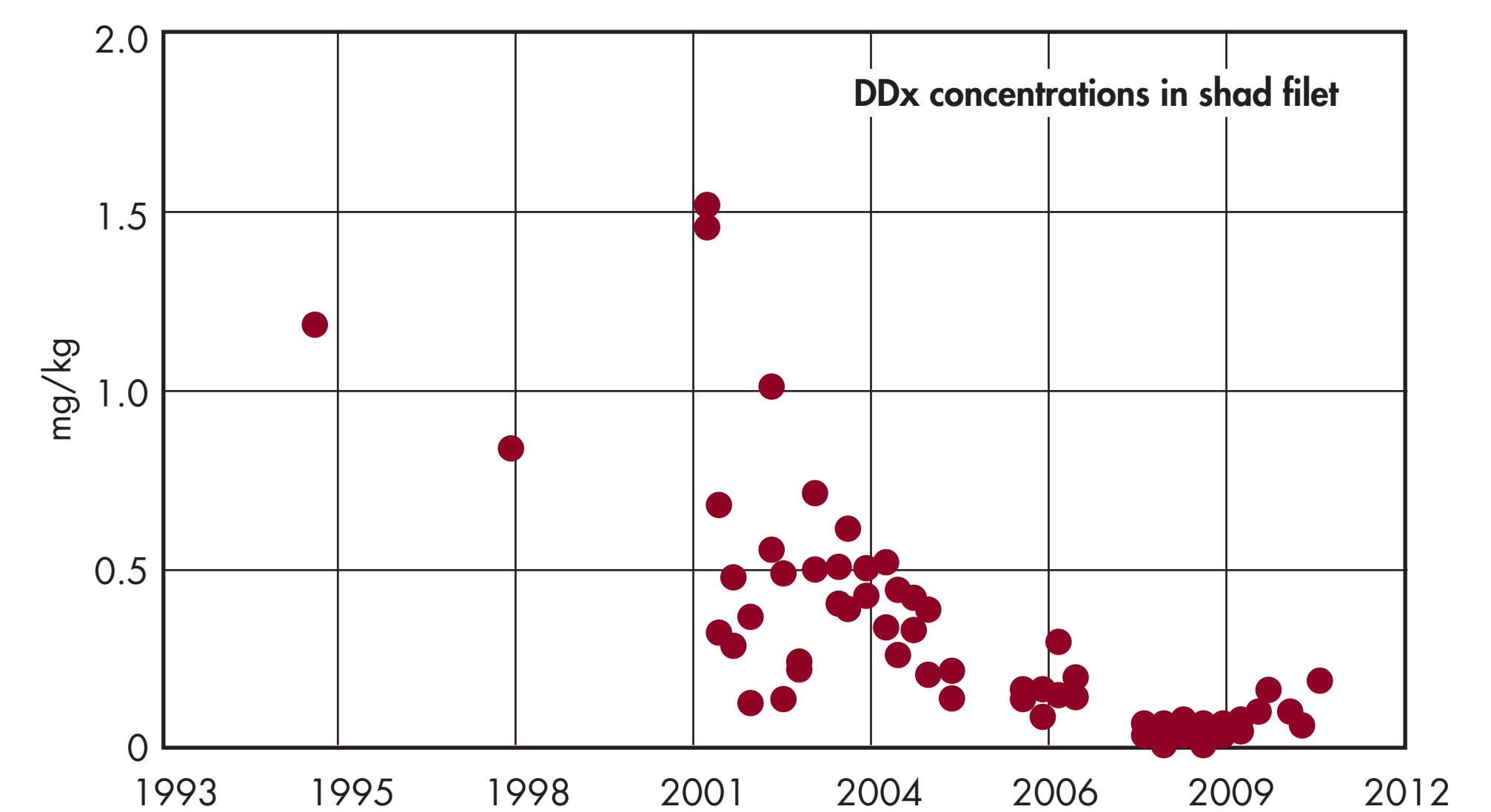


Figure 6. Trend of DDx concentration in shad file (data 1993–2008 from CIPAIS report).

Comparative Analysis

To support this statement in a quantitative way, a Comparative Analysis was performed quantifying changes in ecosystem service values (ecological and human use) associated with the implementation of different remedial actions.

The goal of a Comparative Analysis is to provide the necessary information to support the selection of remedial alternatives that maximize benefits to the public, while managing site risks and remedial costs; a Comparative Analysis is typically conducted to evaluate if the potential exists for a remedial action to create more natural resource harm and/or risk than that predicted by the risk assessment that drove the remedial action in the first place (ie create or increase natural resource liability) or provide a marginal benefit compared to the effort expended.

Four main remedial alternatives for the Pallanza Bay in the Lake Maggiore were identified for evaluation (see SETAC Poster # 1124, Session EH01P, 19/05/2011):

- Monitored Natural Recovery (MNR) of Pallanza Bay
- MNR of Pallanza Bay combined with riparian enhancement along the Toce River (tributary of Pallanza Bay)
- Capping of Pallanza Bay
- Dredging of Pallanza Bay

The Comparative Analysis required:

- The quantification of the ecological service losses and gains with the Habitat Equivalent Analysis, associated with implementation of each remedial alternative.
- Quantification of the human use service values relying on tools used in benefit-cost analysis (eg benefits transfer methodology) associated with implementation of each remedial alternative.
- Evaluation of how the human health and ecological risk profiles would change given implementation of each remedial alternative.
- Development of order-of-magnitude cost estimates for each remedial alternative.

CONCLUSION

Based on the results of the Comparative Analysis and Ecological Risk Assessment it is recommended that the engineered remedial alternatives (capping and dredging) not be considered as viable options for Pallanza Bay. Capping and dredging appear to provide no benefit associated with overall ecological and human health risk, result in substantial detrimental effect on both ecological and human use service values and are characterized by costs that appear disproportionate to incremental benefits derived.