



Mercury levels in demersal fish and coastal sediments of Tuscany: spatial trends and implications for ecosystem health

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Introduction

In Tuscany, mercury represents an important environmental and public health concern due to the combination of natural deposits and long-standing human activities. The central part of the region is rich in cinnabar (HgS) formations, and mercury was extracted and processed there for centuries, leaving a legacy of contamination in soil, vegetation, air, and agricultural products. Rivers draining these areas have transported mercury toward the coast, contributing to elevated levels found in several edible marine species. Industrial sources have played a major role: for many years, the coastal area near Livorno hosted one of Europe's largest chlor-alkali facilities, releasing mercury into the marine environment (Seritti et al., 1982; Lafabrie et al., 2007).

This context highlights the need to evaluate mercury contamination across different environmental compartments such as sediments and fish to better understand the extent of the contamination across the years and its implications for ecosystem and human health. Within this framework, the present study investigates mercury (Hg) contamination in demersal fish and coastal sediments along the Tuscan coast (Western Mediterranean Sea). It is based on monitoring activities carried out by the Regional Agency for the Protection of the Environment of Tuscany (ARPAT) within the framework of the Marine Strategy framework Directive (descriptor 8) and the EU WFD 2000/60/CE.

Materials and methods

Fish species were collected from four coastal areas (Secche di Vada, Viareggio, San Vincenzo, and Punta Ala) over a three-year monitoring period (2022–2024), in collaboration with professional fishermen using bottom trawl nets, ensuring that all specimens exceeded the minimum legal catch size. Muscle tissue from *Mullus barbatus* (Linnaeus, 1758) and *Merluccius merluccius* (Linnaeus, 1758) was removed and homogenized in pooled (approximately 10 specimens per pool). Surface sediment samples were collected using a Van Veen grab sampler, targeting the superficial layer (0–5 cm) representative of recent depositional conditions. Samples were kept at ~4 °C and homogenized prior to analysis. Hg was extracted using organic solvents and analyzed by GC-MS.

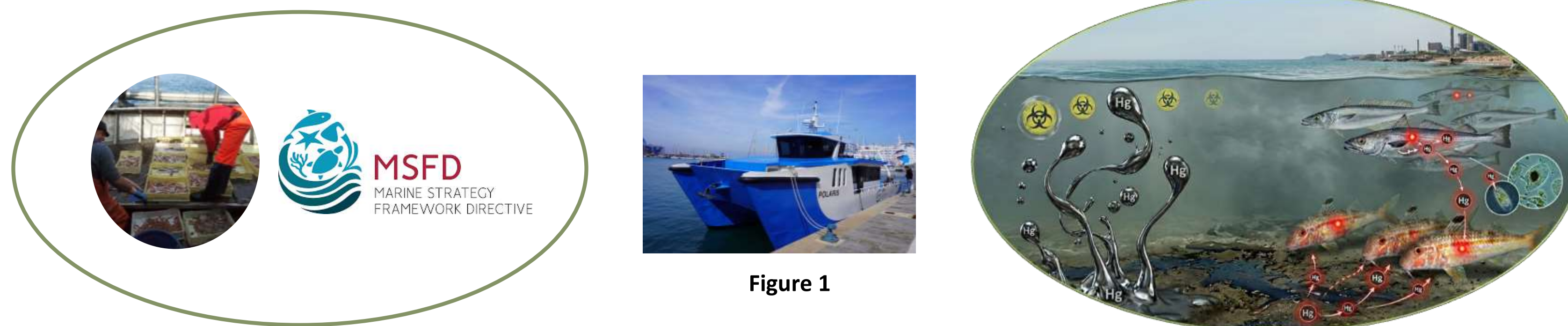


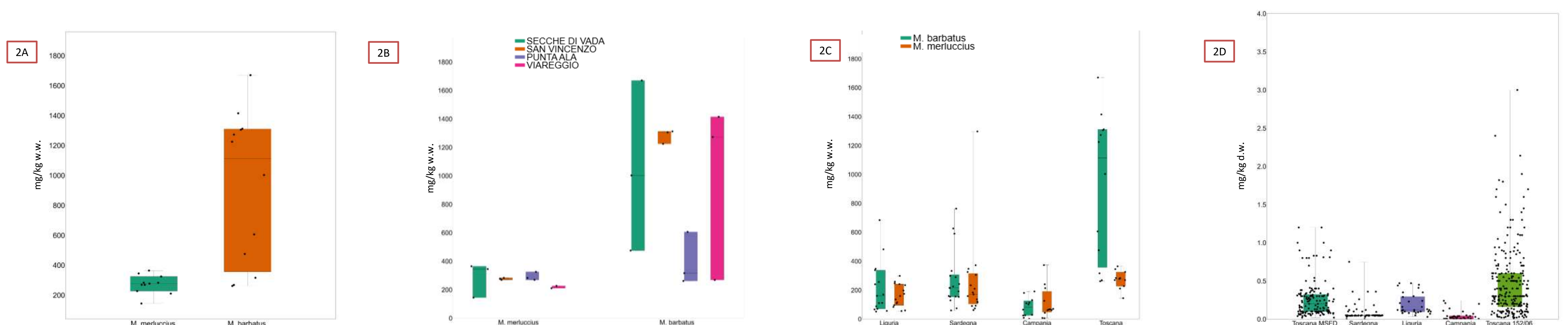
Figure 1

Results and discussion

The results show that *M. barbatus* exhibits significantly higher Hg concentrations (mean $927.45 \pm 509.36 \mu\text{g}/\text{kg w.w.}$) in muscle tissue than *M. merluccius* (mean $261.72 \pm 70.22 \mu\text{g}/\text{kg w.w.}$). No differences were found between the four sampling sites. Particularly, the mercury levels measured in Tuscan red mullet were also markedly higher than those reported for other Italian regions, such as Liguria, Sardinia and Campania, and these differences were statistically significant (test Kruskal-Wallis $p < 0.05$) (Fig. 2C). Notably, Hg concentrations in *M. barbatus* largely exceeded the maximum level established for human consumption in fish ($500 \mu\text{g}/\text{kg w.w.}$; European Commission Regulation No 1881/2006) and were also far above the Environmental Quality Standard (EQS) set by the Water Framework Directive for biota ($20 \mu\text{g}/\text{kg w.w.}$; Directive 2013/39/EU).

Concerning the **sediment contamination** by mercury, the ARPAT dataset, covering the years from 2008 to 2024, reveals several coastal areas with high concentrations of Hg, especially in Antignano ($1.33 \pm 0.56 \text{ mg}/\text{kg d.w.}$), Ansedonia ($0.93 \pm 0.44 \text{ mg}/\text{kg d.w.}$), and Rosignano ($0.86 \pm 0.64 \text{ mg}/\text{kg d.w.}$). Comparisons with sediment data from other regions (Liguria, Sardinia and Campania) confirm that Tuscany is the most impacted area, again with statistically significant differences (Fig. 2D). However, it is important to note that previous studies, including the assessment of natural background levels conducted by ARPAT, have highlighted how in some coastal sectors of Tuscany elevated Hg concentrations in sediments may also reflect naturally high geochemical background levels, rather than exclusively anthropogenic inputs

A strong and plausible link emerges between mercury concentrations in *Mullus barbatus* and those in underlying sediments, especially given the species benthic feeding strategy — it actively forages in the sediment for prey, a behavior that promotes direct exposure to sediment-bound Hg. Studies have shown that benthic organisms and sediments are key reservoirs and transfer pathways for mercury into food webs, particularly in species that inhabit or feed on the bottom (Marziali et al., 2021).



Conclusion

Overall, these findings point to a potential link between sediment contamination and mercury accumulation in demersal fish species, highlighting spatial patterns along the Tuscan coast and their implications for ecosystem health, including bioaccumulation, trophic transfer, and potential ecological stress in coastal communities.

References

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