

Ecological evaluation of the Douro estuary: considering microplastics in ecological framework

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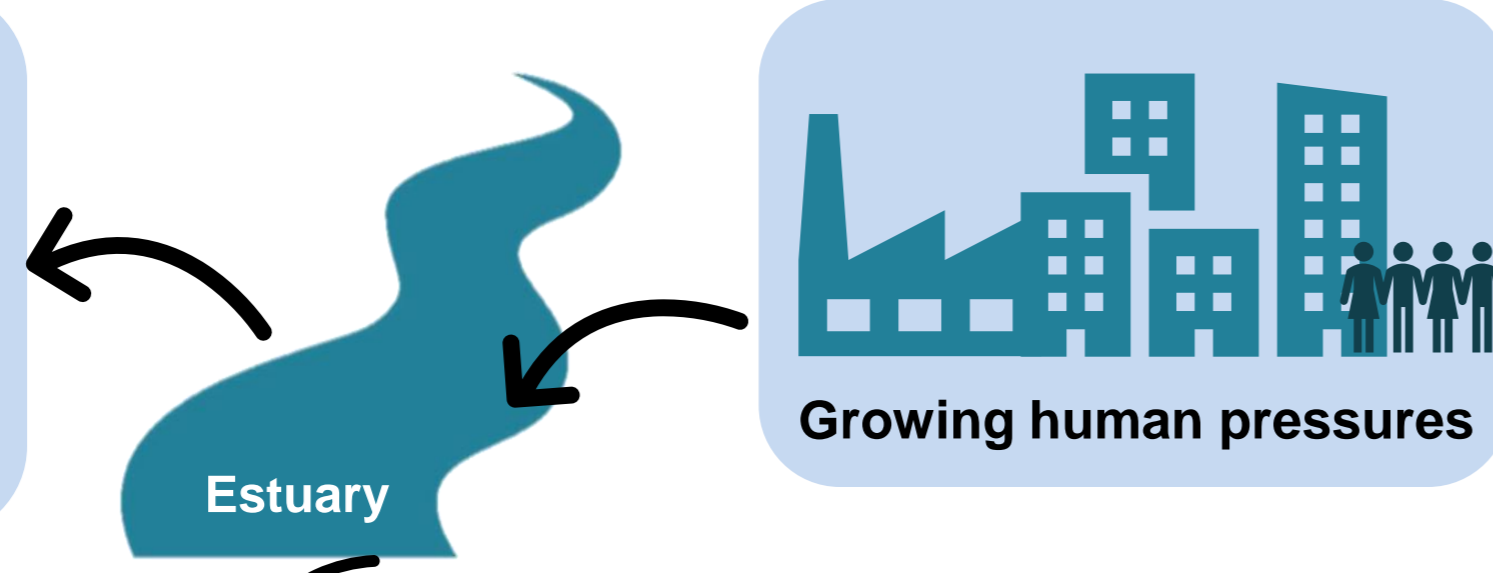
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INTRODUCTION

Ecosystem services [1]:

- Regulation of the nutrient cycle
- Refuge of biodiversity
- Elimination/recycling of waste
- Science education
- Production of food
- Genetic resources



Water Framework Directive (WFD)

Water Framework Directive (WFD) does not establish regulatory standards for microplastics (MPs) nor require their monitoring.



AIM

- ✓ Evaluate the **Ecological Status of the Douro estuary**, according to the WFD.
- ✓ Evaluate the **presence and characterization of Microplastics (MP)** in the water and sediments of the Douro estuary.

METHODS

Sampling campaigns:

- Summer 2024
- Winter 2025

4 transects (T), each comprising 3 sites, were established in the lower Douro estuary.



Water quality parameters were analyzed according to the WFD for the A1.1 Narrow-North transitional water body [2][3]:

General physical-chemical elements:

- Dissolved oxygen (%);
- Nutrient concentrations: Nitrite + Nitrate (mg N/L); Phosphate mg P/L); Ammonia nitrogen (mg N/L).

Biological quality elements:

- Chlorophyll a concentration (µg/L);
- Benthic macroinvertebrates community (Bentic Assessment Tool - BAT).

MP Evaluation Protocol

Sampling [4]:

- Summer 2024
- Transects: Subsurface (S) and Water column (W)
- Sites: Sediment

Sample pre-treatment [5][6]:

- For water samples: digestion with KOH 10 %
- For sediment samples: MPs were extracted using a density separation solution (1.036 g NaCl/cm³)

Laboratory procedure [5][6]:

- Sample were filtrated through a 1.2 µm pore size
- Identification and characterization of MPs according to: size, typology, and colour

Statistical Analysis [8]:

- Principal Coordinates Analysis (PCO)

RESULTS & DISCUSSION

General physical-chemical parameters:

- O₂ % values ranged between 88.1 % (3.2 summer) and 100.7 % (3.2 winter);
- Nutrient concentrations exceeded reference values (NO₃+NO₂ always above 1 mg N/L in winter), likely reflecting inputs from agricultural, wastewater, and urban sources [9].

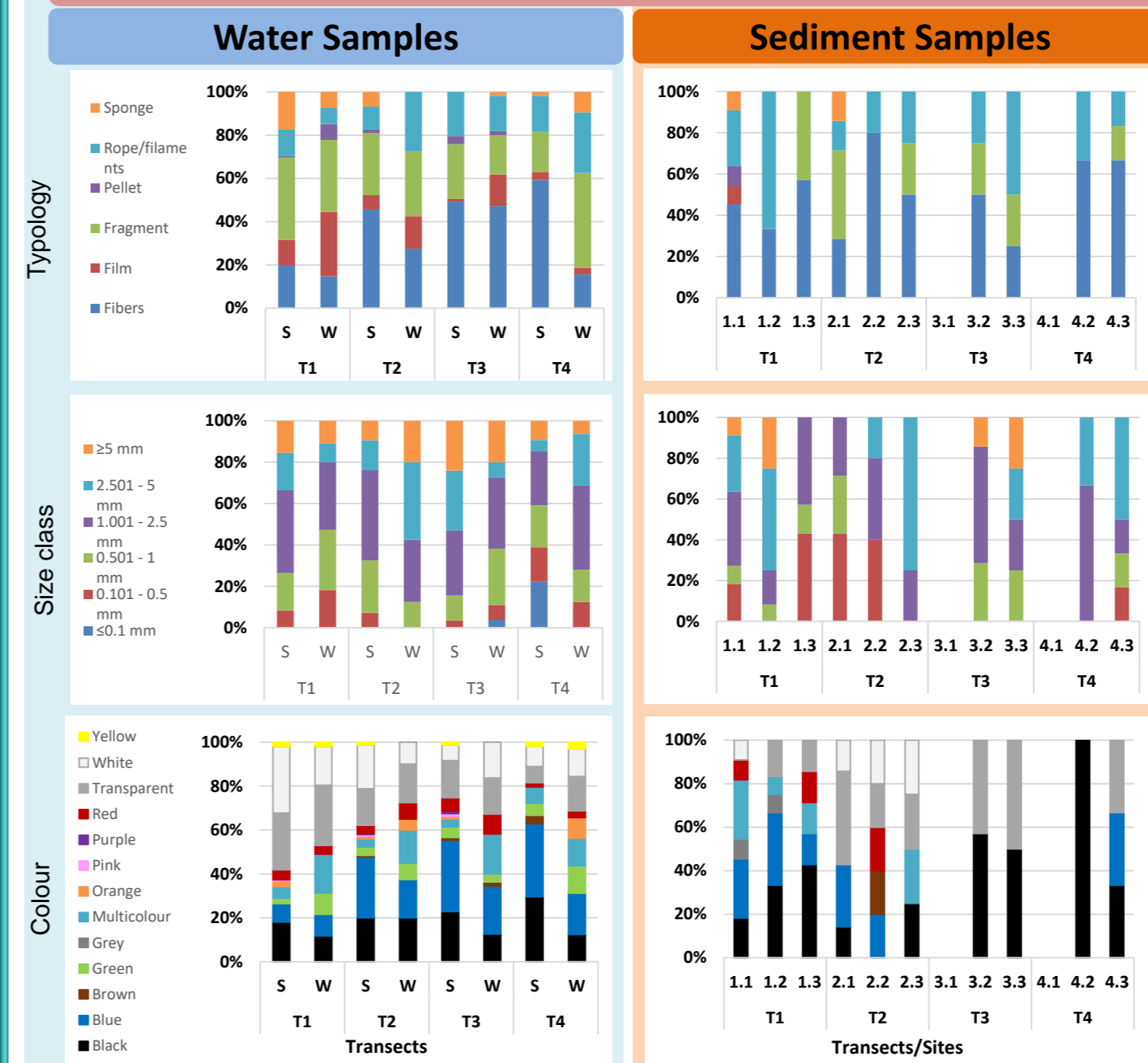
Biological parameters:

- Chlorophyll a values varied between 0 (3.1 summer) and 0.601 µg/L (4.1 summer);
- Macroinvertebrate community – BAT values ranged from 0.289 (4.3 summer) to 1.176 (4.1 summer), with a deterioration in status during winter, possibly linked to increased freshwater influx [10].

Site	Physical-Chemical Parameters	Biological Parameters	Ecological Status
1.1	Moderate	Good	Moderate
1.2	Moderate	Good	Moderate
1.3	Good	Good	Good
2.1	Moderate	Good	Moderate
2.2	Moderate	Good	Moderate
2.3	Good	Good	Good
3.1	Moderate	Good	Moderate
3.2	Moderate	Good	Moderate
3.3	Moderate	Good	Moderate
4.1	Moderate	Good	Moderate
4.2	Moderate	Good	Moderate
4.3	Moderate	Poor	Poor

This study identified **nutrient-related pressures as key ecological concerns in the Douro estuary**, a finding consistent with previous research [11].

MP Summer 2024



Highest MP/m³ and MP/Kg values were found in transects T1 and T2, and respective sites

- Possible pollution sources: Afurada Marina and in the WWTP discharge area

MP typology:

- **Water samples** (S and W) dominated by fragments (T4-W) and fibers (T4-S);
- **Sediment samples** dominated by fragments (T2.1), fibers (T2.2), and rope/filament (T1.2).

MP Size class:

- [0.501 - 1], [1.001 - 2.5], and [2.501 - 2.5] mm range are the most common in **water samples** across sites (~ 73 %);
- [0.101 - 0.05], [1.001 - 2.5], and [2.501 - 5] mm were the most predominant range size in **sediment samples** (~ 80 %).

MP Colours:

- **Black, blue, transparent, and white** were the most identified in both sampled matrix across sites (> 75%).

Total MP's found in the Douro estuary:

Water samples: 9.03 MP/m³

Sediment samples: 1650 MP/kg

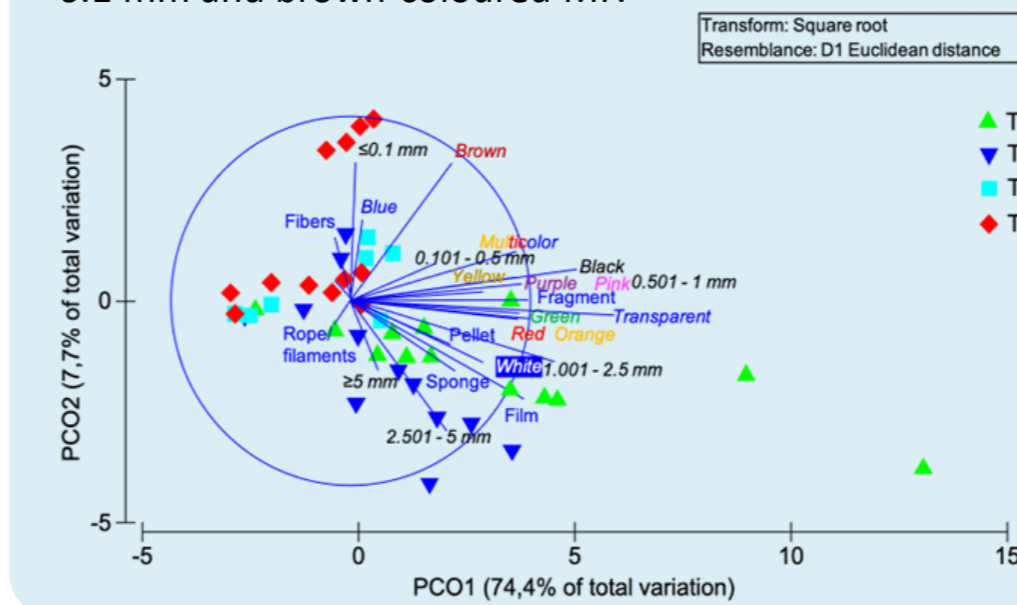
PCO Analysis of MP

T1 (affected by diverse pollution inputs): high diversity, predominantly associated with films and white MP's;

T2 (combined pressures and higher hydrodynamic exposure): dominated by fibers, with size classes of [2.501 - 5] mm and >5 mm;

T3 (combined pressures and higher hydrodynamic exposure): mainly blue and fibers;

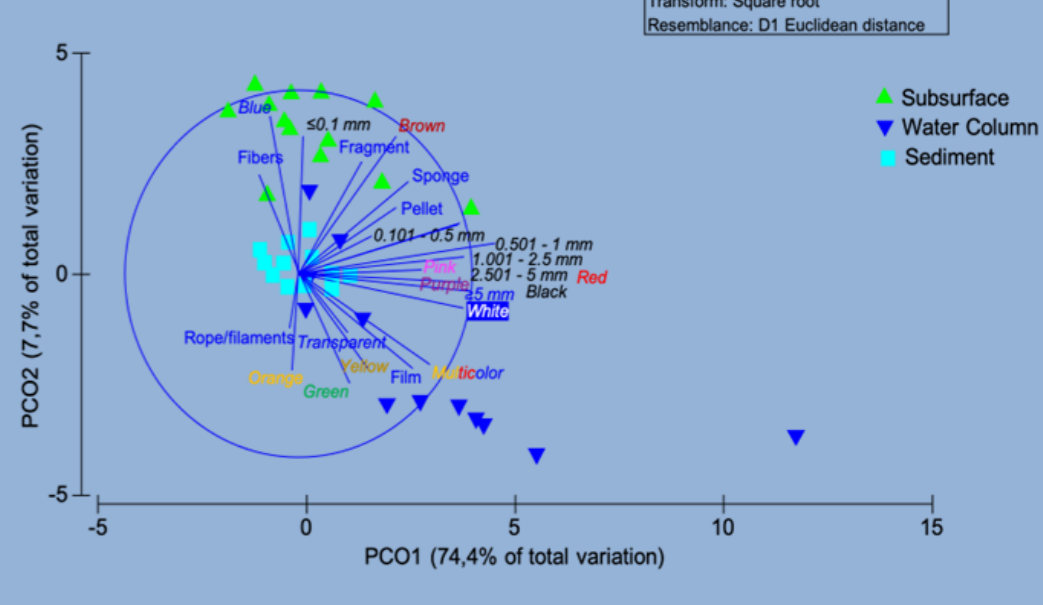
T4 (combined pressures and higher hydrodynamic exposure): size class <0.1 mm and brown-coloured MP.



Subsurface: dominated by smaller particles (<0.1 mm) and blue fibers;

Water column: larger particles and films;

Sediment: no clear relation with any MP's characteristics



CONCLUSION

- ✓ Douro achieves a **Poor Ecological Status** due to high nutrient concentrations and poor benthic macroinvertebrates community index results
- ✓ **Microplastic (MP) contamination is present in the Douro estuary** and further aggravates its already complex ecological status; therefore, **additional research is required to identify and quantify its multiple sources**. Reinforces the need for an **integrated and adaptive management strategy**.

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