Assessing Pollution and Environmental Risk in the Adriatic Sea through Multi-Hazard Modelling

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Napoli 3-5 dicembre 2025

Spokes involved: VS4

OBJECTIVES

A suite of ***modelling tools*** to predict the fate and transport of different pollutants based on environmental conditions was applied to the ***Northern Adriatic Sea*** to improve the understanding of ***pollutants dynamics and risks*** to marine ecosystems from single and multiple pollutants (Fig. 1).

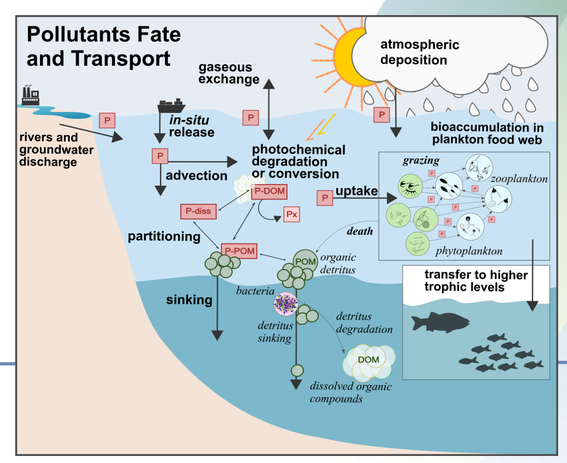


Fig. 1. Conceptual model of the fate and transport of different pollutants in the marine ecosystem

METHODS



Fig. 2. Location of pollution point-sources for the Adriatic Sea. Rivers discharge mercury, pharmaceuticals, macro- and micro- plastics, WWTPs emit pharmaceuticals and micro- plastics, while navigation cause oil releases to the sea. Mercury is input also through the atmosphere.

The most relevant ***point-sources*** of ***oil, mercury, plastics, and pharmaceuticals*** were mapped and quantified (Fig. 2).

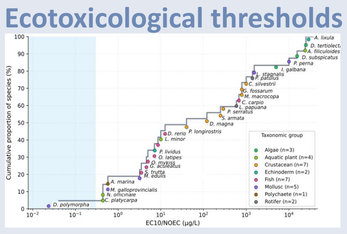
Different model frameworks[1,2,3] were used to track the ***release, transport, transformation/degradation*** of each pollutant. ***Bioaccumulation*** in the plankton food web was also simulated for methylmercury, a highly bioaccumulative pollutant.

The modelled distributions of each pollutant (***hazards***) were combined with ***ecotoxicological thresholds*** and ***vulnerabilities*** to estimate the ***risk to the ecosystem.*** Single risk indexes were combined into a ***multi-risk index*** through multi-criteria decision analysis and the TOPSIS method[4].

$$Risk\ Quotient = \frac{Hazard}{Treshold}$$

Pharmaceuticals and microplastics: *evaluation of water concentration that potentially impact 5% of the ecosystem (HC_5)[5].*
Mercury*: evaluation of risk from dietary exposure for planktivorous fish.*
Thresholds*: 116 ng L^{-1} for diclofenac, 159 ng L^{-1} for ibuprofen (HC_5 based on v.v. literature studies), 0.2 ug L^{-1} for microplastics [6], 0.04 ug g^{-1} of MeHg in food for impacts on reproduction and behavior[7]*

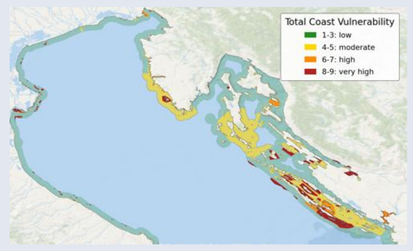
Ecotoxicological thresholds



$$Risk = Hazard\ x\ Vulnerability$$

Oil: *evaluation of the likelihood of oil stranding affecting sensitive ecosystem, defined based on socioeconomic, environmental, and geomorphological vulnerability factors*

Coastal Vulnerabilities



RESULTS

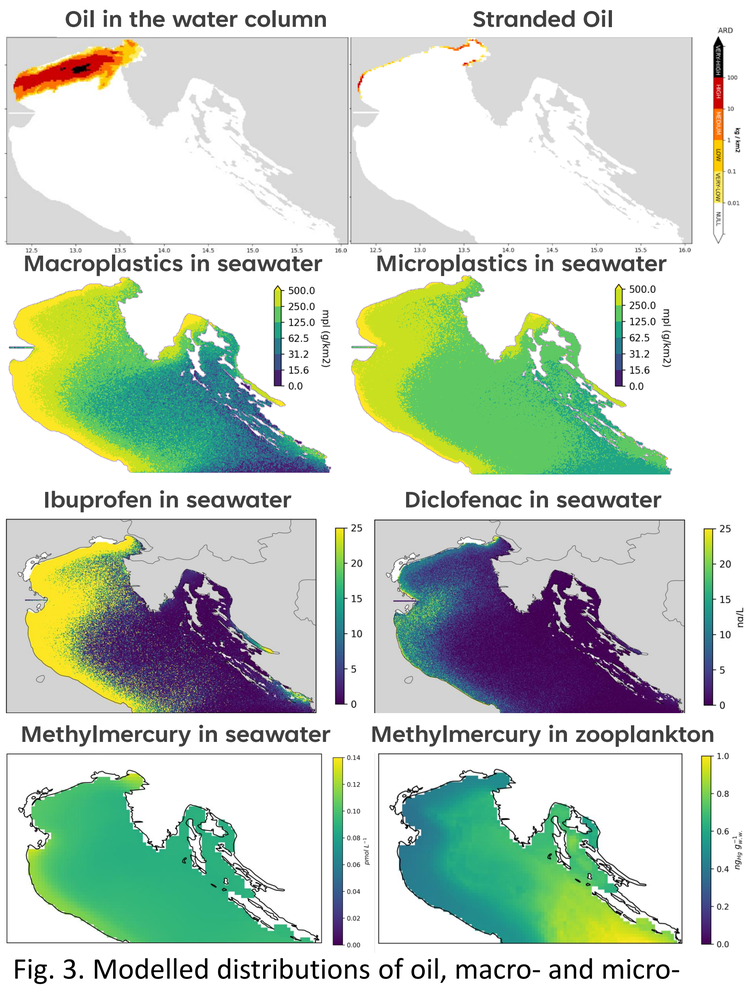


Fig. 3. Modelled distributions of oil, macro- and micro-plastics, pharmaceuticals, and mercury in the Northern Adriatic Sea.

High resolution simulations resolving the dynamic evolution of various pollutants in the Northern Adriatic Sea were run.

The average distribution differs among pollutants (Fig. 3) as an effect of diverse loadings and degradation rates, or other sink terms.

The ***western coastal areas*** are the most ***impacted by different hazards***, which is reflected in a higher risk both from single and multiple pollutants (Fig. 4).

The analysis also suggests that, among the hazards investigated, the ***higher risk*** for the Northern Adriatic Sea is posed by ***ibuprofen and microplastics,*** which exceed the safe exposure level in large areas.

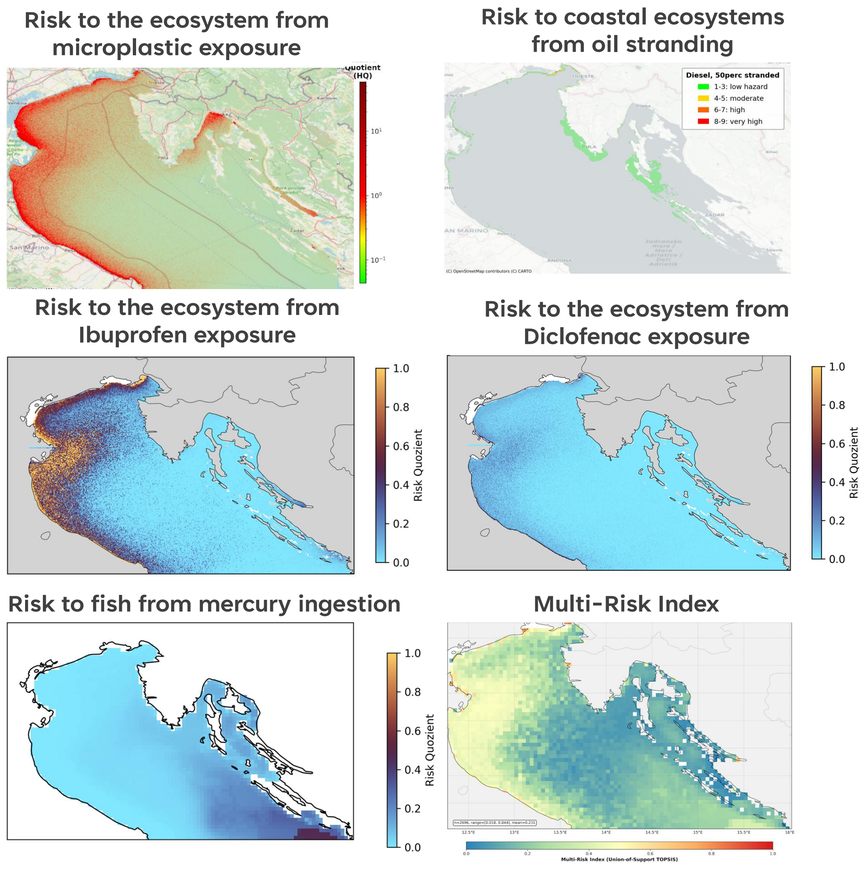


Fig. 4. Risk estimated to the ecosystem of the Northern Adriatic Sea from exposure to different pollutant based on the modelled concentrations of Fig.3 and ecotoxicological thresholds/vulnerability. All indexes were integrated in a multi-risk index (bottom right).

[1] *Rosati et al., 2022. Biogeosciences, 19(February), 3663–3682.*
[2] *Laurent et al., 2020. Env. Mod. Soft., 125.*
[3] *Melaku Canu et al., 2015. Mar. Poll. Bull., 94(1), 84–95.*
[4] *Steele et al., 2009. Risk Anal., 29(1), 26–33.*
[5] *ECHA, 2008. Guidance for the implementation of REACH.*
[6] *Adam et al., 2021. Aquat. Toxicol., 230, 105689.*
[7] *Depew et al., 2012 Environ. Toxicol. Chem., 31(7):1536–47.*

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

This study was carried out within the RETURN Extended Partnership and received funding from the European Union Next-GenerationEU (National Recovery and Resilience Plan – NRRP, Mission 4, Component 2, Investment 1.3 – D.D. 1243 2/8/2022, PE0000005)