A NUMERICAL-BASED APPROACH TO PREDICT PLASTIC LITTER PATHWAYS IN COASTAL AREAS

Martina Stagnitti, University of Catania, martina.stagnitti@unict.it
Rosaria Ester Musumeci, University of Catania, rosaria.musumeci@unict.it
Luca Cavallaro, University of Catania, luca.cavallaro@unict.it
Enrico Foti, University of Catania, enrico.foti@unict.it

INTRODUCTION

The problem of marine plastic litter is an issue of great concern, because of the long time needed for its complete decomposition, from ten to several thousand years, and the impacts on marine ecosystems and human health (Lebreton and Andrady, 2019, Soares et al. 2020). In Europe, about 500.000 tons of plastic litter are released into the sea every year (Interreg Europe, 2021), most of which is produced inland by agricultural, industrial and urban activities, and then transported by rivers towards the sea (Lebreton and Andrady, 2019). Moreover, the COVID-19 pandemic caused more than 25,000 tons of pandemic-associated plastic waste entering the global ocean (Peng et al., 2021).

On one hand, the reduction of marine plastic waste should be pursued through the development of a greater environmental conscience based on education and dissemination of scientific knowledge (Soares et al., 2020), as well as through the implementation of circular economy management models (Lee, 2021; Wang et al., 2022). On the other hand, the removal of already produced plastic litter through both beach cleanup and technologies should be performed according to strategic and efficient intervention schemes based on the knowledge of its trajectories, destinations and fates (Critchell and Lambrechts, 2016; Van Sebille et al., 2020; Guerrini et al., 2021). Numerical models are the only existing tools for the prediction of marine plastic pathways. In this context, the present work proposes an open-source numerical modeling chain to predict pathways and fates of marine plastic transport in coastal regions, which is able to provide useful information for the management of cleaning operation in the study area. The proposed numerical-based approach is applied to the coastal region that includes the Marine Protected Area (MPA) of Capo Milazzo (Italy).

METHODS AND MATERIALS

A coupled open-source hydrodynamic and Lagrangian particle tracking model is employed to simulate the transport of marine plastics in coastal areas, including beaching and washing-off processes, and considering the effects of seasonal circulation due to the combination of astronomical tide, waves and wind, as well as the influence of river discharges. In particular, the outputs of the hydrodynamic model Delft3D FM developed by Deltares are on-purpose post-processed to become the inputs of the particle tracking model TrackMPD (Jalón-Rojas et al., 2019). Figure 1 shows the sketch of the employed modelling chain.

Here, the case study of the coastal region including the MPA of Capo Milazzo (Italy) is considered, which is significantly affected by the presence of plastic litter mainly produced by the highly urbanized adjacent areas as well as by the local touristic activities (see Figure 2). The input marine climate of the hydrodynamic model is defined by the astronomical tide derived from the Italian National Sea Monitoring Network, the wave reanalysis data are provided by Korres et al. (2021), and the wind reanalysis data are the ones of Hersbach et al. (2018). Moreover, river discharges are included, which are calculated from the rain data provided by the Water Observatory of the Sicilian Region through a rainfall-runoff model.

The position of the release points and the physical and chemical characteristics of plastic litter to be employed for the Lagrangian simulations are derived from field surveys and laboratory analysis of collected plastic samples.

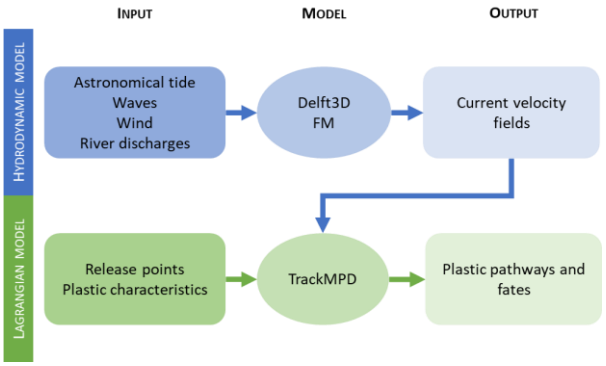

Figure 1 – Sketch of the proposed modelling chain for the prediction of plastic pathways and fates in coastal areas.

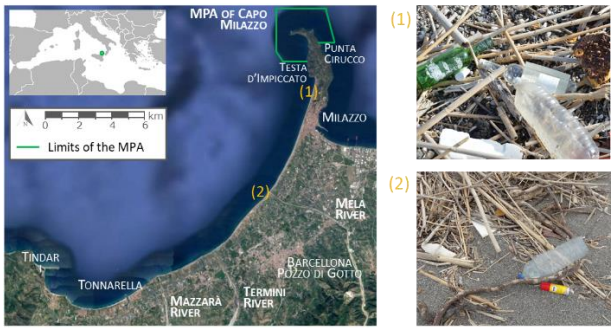

Figure 2 – Geographic location of the study area (satellite view from Google Earth 2022) and pictures of plastic samples acquired during a field survey carried out on-site in February 2022.

RESULTS

Numerical simulations of marine plastic litter coastal transport are performed under representative climate scenarios of the four seasons, considering different combinations of external forcing, as well as of the Lagrangian model parameters (e.g. diffusivity coefficients

and particle density, settlement velocity and half-life on the beach). Further climate scenarios corresponding to actually occurred sea storms are also simulated.
The preliminary analysis of the numerical results reveals that wave motion is the main contributor to the generation not only of longshore currents, but also of macro-vortexes. Moreover, river discharges significantly influence the hydrodynamic regimes close to the river mouths. Figure 3 shows an example of plastic litter pathways and fates obtained from the Lagrangian simulations. The most frequent final destination of buoyant and non-buoyant particles is floating at the sea surface and settling at the sea bottom, respectively.
A deeper discussion of the results of the numerical simulations and of their implications for the optimal planning of removal interventions will be provided at the conference.

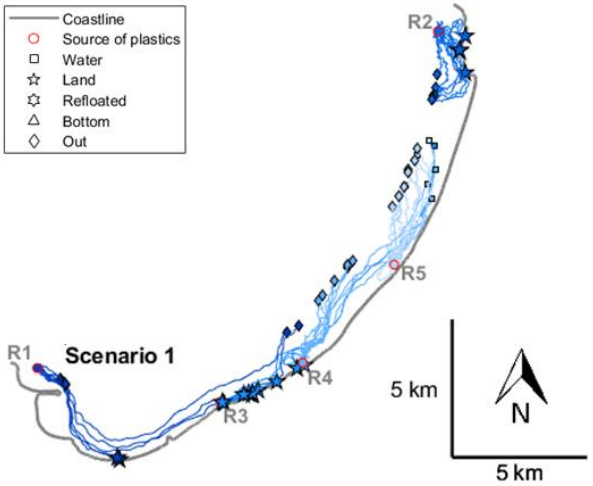

Figure 3 - Example of plastic litter pathways and fates obtained from the Lagrangian simulations run for the study area.

ACKNOWLEDGMENTS
This work is funded by: the project BIOBLU, financed by the European Fund for Regional Development in ten context of the program Interreg Italia-Malta; the project PLATONE, financed by the PRIN 2022 fund in the context of the PNRR; the project VARIO, financed by the program PIACERI of the University of Catania.

REFERENCES
Critchell, Lambrechts (2016): Modelling accumulation of marine plastics in the coastal zone; what are the dominant physical processes? Estuarine, Coastal and Shelf Science 171, 111-122.
Guerrini, Mari, Casagrandi (2021): The dynamics of microplastics and associated contaminants: Data-driven lagrangian and eulerian modelling approaches in the mediterranean sea. Science of the Total Environment 777, 145944.
Hersbach, Bell, Berrisford, Biavati, Horányi, Muñoz Sabater, Nicolas, Peubey, Radu, Rozum, et al. (2018): Era5 hourly data on single levels from 1979 to present. Copernicus 750 climate change service (c3s) climate data store (cds) 10. doi:10.24381/cds.adbb2d47.
Interreg Europe (2021): Halting ocean plastics pollution. A policy Brief for the Policy Learning Platform on Environment and resource efficiency. Technical Report. European Union. European Regional Development Found.
Jalón-Rojas, Wang, Fredj (2019): A 3d numerical model to track marine plastic debris (TrackMPD): sensitivity of microplastic trajectories and fates to particle dynamical properties and physical processes. Marine pollution bulletin 141, 256-272.
Korres, Ravdas, Zacharioudaki, Denaxa, Sotiropoulou, (2021): Mediterranean Sea waves reanalysis (cmems med-waves, medwam3 system) (version 1) dataset. CopernicusMonitoring EnvironmentMarine Service (CMEMS) doi:10.25423/CMCC/MEDSEA_MULTIYEAR_WAV_006_012.
Lebreton, Andrady (2019): Future scenarios of global plastic waste generation and disposal. Palgrave Communications 5, 1-11.
Lee (2021): Plastic pollution mitigation-net plastic circularity through a standardized credit system in asia. Ocean & Coastal Management. 210, 105733.
Peng, Wu, Schartup, Zhang, (2021): Plastic waste release caused by covid-19 and its fate in the global ocean. Proceedings of the National Academy of Sciences 118, e2111530118.
Soares, Miguel, Venâncio, Lopes, Oliveira (2020): Perspectives on micro (nano) plastics in the marine environment: biological and societal considerations. Water 12, 3208.
Van Sebille, Aliani, Law, Maximenko, Alsina, Bagaev, Bergmann, Chapron, Chubarenko, Cózar, et al. (2020): The physical oceanography of the transport of floating marine debris. Environmental Research Letters 15, 023003.
Wang, Miao, Chen (2022): Circular economy and the changing geography of international trade in plastic waste. International Journal of Environmental Research and Public Health 19, 15020.