

# Coupling Impact Assessment and Ocean Circulation Modelling for Reef Litter Mitigation

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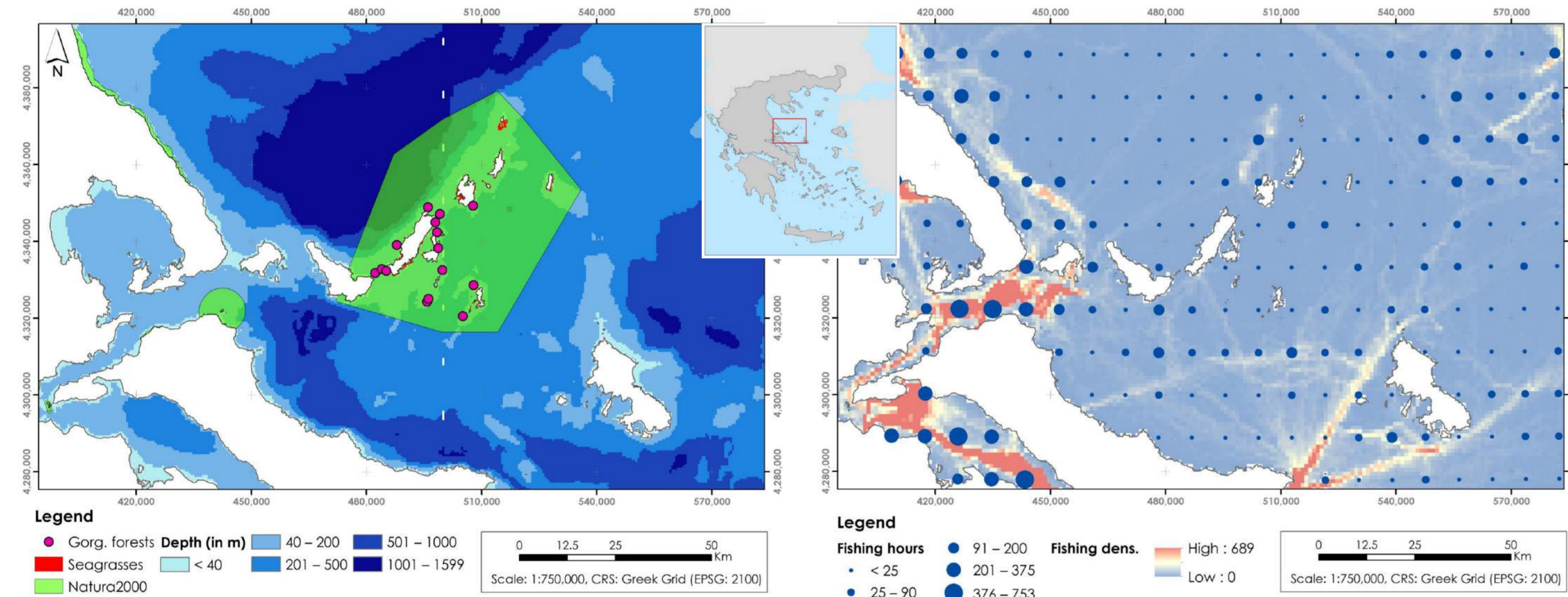


## Scope

Marine Litter (ML) from fishing activities constitutes a significant threat to Mediterranean marine ecosystems, particularly in protected areas. Derelict fishing gear, lost or abandoned during operations, can then be transported by ocean currents before settling on the seafloor [1,2]. In Europe, the Marine Strategy Framework Directive (MSFD) identified anthropogenic litter as a dominant pressure and the main source of pollution in the coastal habitats [3]. This study presents a multi-method cumulative impact assessment framework that integrates: **1) Fishing vessel hours data (2012–2024)** from the Global Fishing Watch (GFW) database [4], **2) 3D ocean currents** from the Mediterranean Sea Physics Reanalysis database (MEDSEA, Copernicus), and **3) Lagrangian particle tracking with dual-release scenarios** via the OceanParcels simulation tools [5]. The framework identifies hotspot areas of ML accumulation (via the Deposition Index - DI) and explores their overlap with the Marine Park of Alonnisos (NMPANS), a large marine protected area in the eastern Mediterranean that includes conservation-priority habitats (i.e. seagrass, coral reefs) whose status is often compromised by ML.

## Study area and data

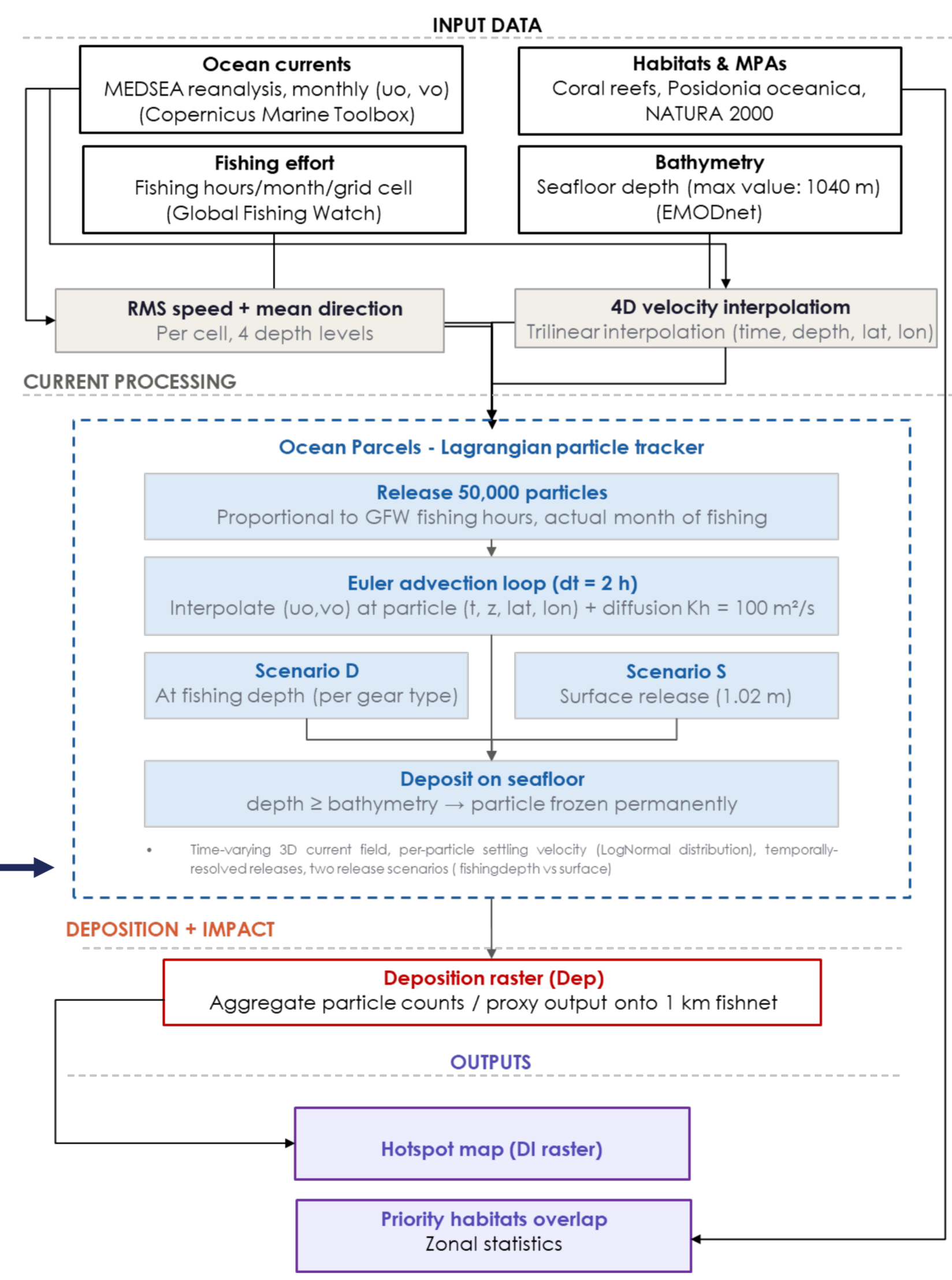
The study area encompasses the **Northern Sporades archipelago** in the western Aegean Sea, Greece (Fig.1). The area is characterised by complex bathymetry (0–1600 m) and semi-enclosed basins that seem to act as depositional sinks. It encompasses extensive meadows of the indigenous seagrass *Posidonia oceanica*, as well as biogenic reefs, which are crucial for supporting the rich biodiversity of the Mediterranean. Fishing activities, mainly small scale (SSF), take place there.



**Figure 1:** Study area boundaries including depth profile, NATURA 2000 areas, reefs/gorgonian forests and seagrasses (left), fishing hours based on the GFW data and fishing density (EMODnet data portal) (right)

## Methods

The analysis employs Lagrangian modelling within a 1 km fishnet grid to assess cumulative ML impacts [2]. **Monthly uo/vo fields (2012–2024)** were processed at **5 depth levels** (1, 50, 200, 500, 1000 m). Using the **OceanParcels framework** [5], virtual heavy ML particles are released at **194 observed fishing grid points** [4]. Particles are advected through 3D time-varying currents, with horizontal diffusion ( $KH = 100 \text{ m}^2/\text{s}$ ), per-particle settling velocity (LogNormal, median 1.5 cm/s), and deposit upon reaching the seafloor.



Particles	50k	Output hours	4
Max days	30	Depth frac.	0.7
DT hours	2	WS median	0.01

**Figure 2:** Methodological representation of data input, OceanParcels set-up, calculation of the cumulative deposition index

## Conclusions

ML poses a significant threat to marine ecosystems; therefore, identifying accumulation zones is critical for optimizing monitoring efforts. Although OceanParcels enables efficient large-scale transport simulations, its accuracy depends on proper parametrization and the quality of the velocity fields, as well as on factors such as ML size, sinking velocity. Hence, beside existing uncertainties associated with ocean current and fishing data gaps, **this study sets the scene for monitoring needs to support improved assessments guiding ML mitigation actions.**

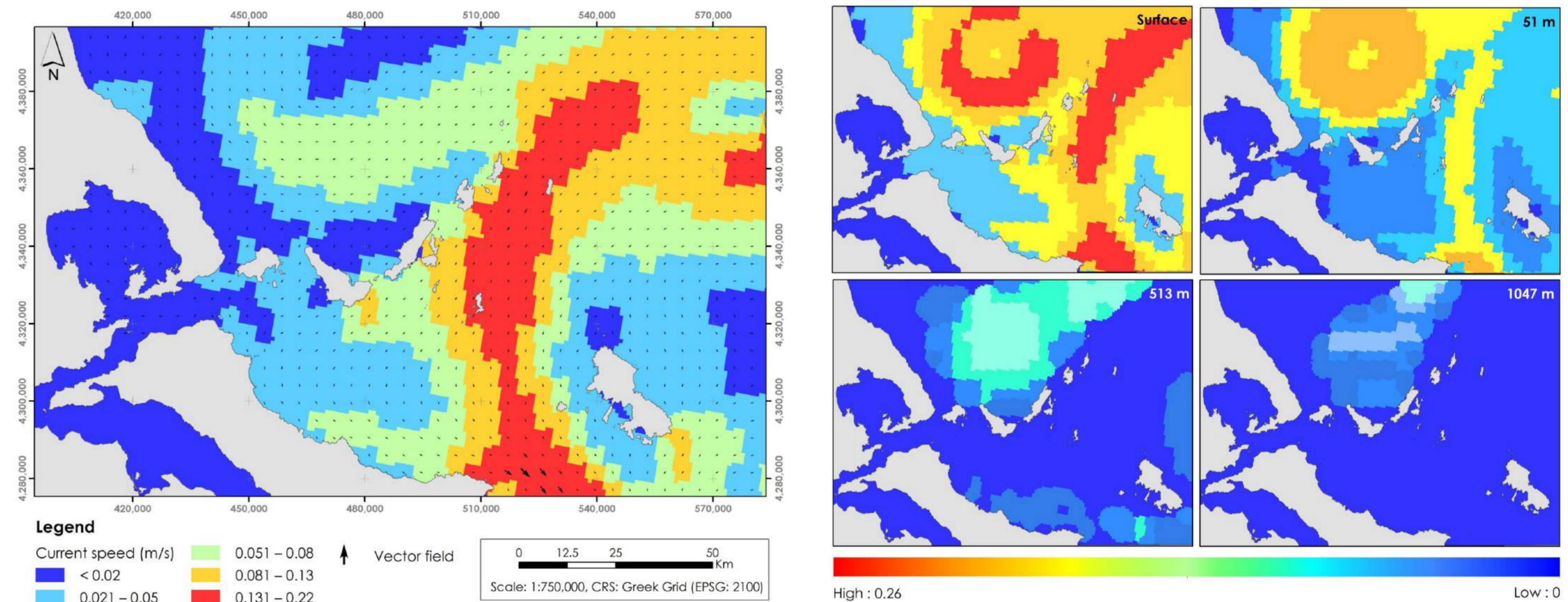
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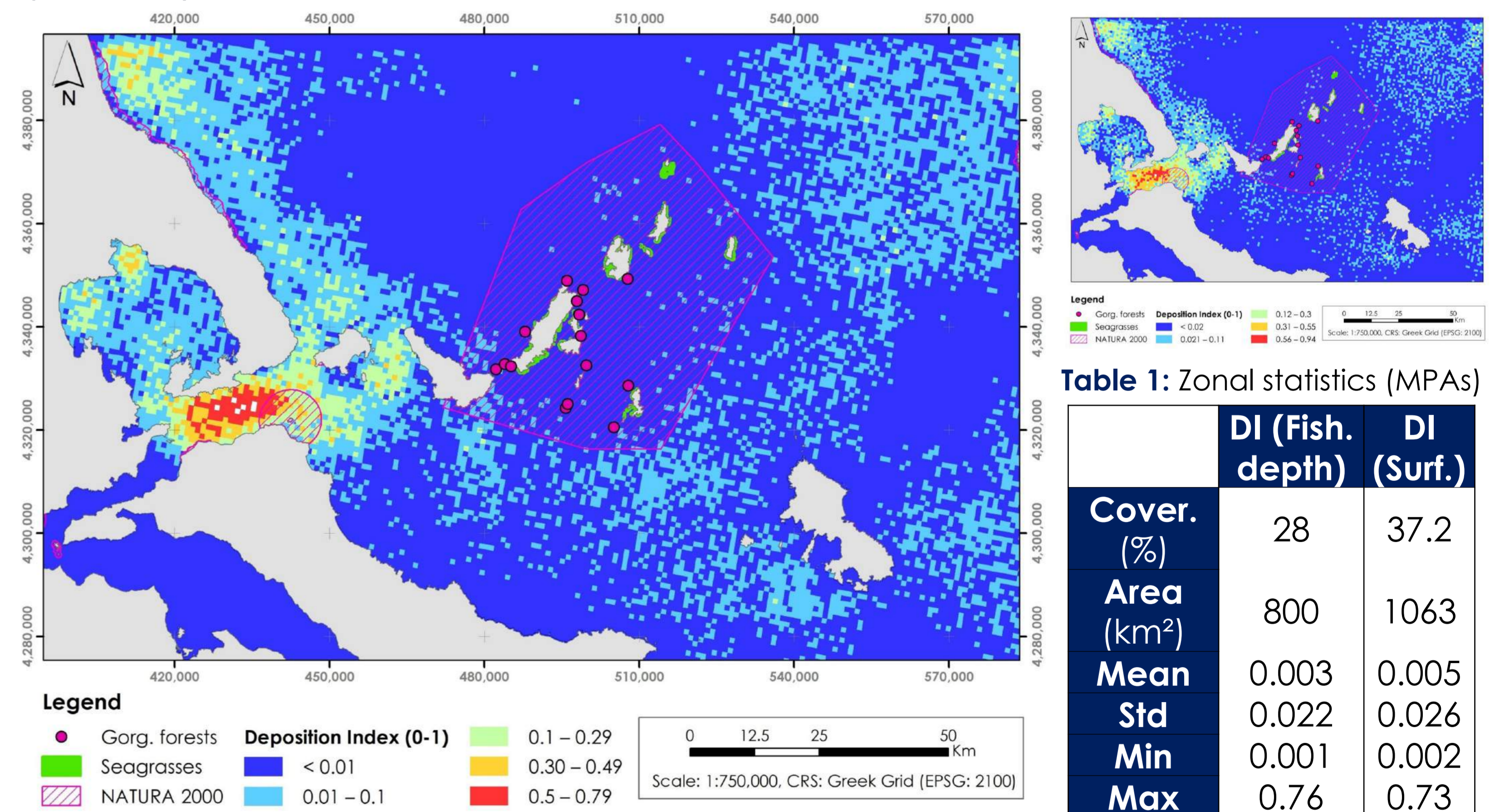
## Results and Discussion

Figure 3 illustrates a high-energy southward-flowing jet, concentrated in the central channel, while **coastal areas are characterized by low-velocity sheltered zones** ( $< 0.02 \text{ m/s}$ ). At the surface, a prominent anticyclonic eddy dominates the north-central area, effectively dispersing ML toward the eastern archipelago. As depth increases, current speeds and RMS decay significantly, indicating that bottom shear stress is insufficient for remobilization; however, a high probability of eddy occurrence in the northern part of the Sporades may cause ML to drift towards their centres, acting as heavy ML traps [1].



**Figure 3:** Spatial distribution of current velocities and vectors across the Northern Sporades region (left). Root mean squared (RMS) current speed (m/s) at different depths (1.02, 51, 510 and 1047 m)

At fishing depth, **most particles are deposited within 30 hours, experiencing negligible horizontal transport** (Fig. 4). In the surface release scenario, particles traverse the full water column, producing more displaced deposition patterns. The DI reveals highly localized accumulation patterns, with maximum intensities (0.5–0.79), concentrated mainly off the northern Euboea Island.



**Figure 4:** Spatial distribution of the DI across the study area (At fishing depth: left, Surface: right)

The **ML footprint remains largely outside the MPAs and does not overlap with areas hosting biogenic reefs**, as derelict gear sinks rapidly rather than being transported over long distances toward the archipelago. Only 830 cells contain seagrasses, but these disproportionately overlap with low DI values (Table 1). While the identified ML hotspots appear to align with high-intensity fishing activities, these results likely suffer from significant observational bias. Most fishing operations are conducted by SSF vessels (typically  $< 10 \text{ m}$ ), which are currently exempt from mandatory AIS monitoring. Moreover, because SSF operate in high-complexity environments, such as rocky reefs, their gear is more prone to entanglement by these habitats.

**Table 1:** Zonal statistics (MPAs)

	DI (Fish. depth)	DI (Surf.)
Cover. (%)	28	37.2
Area (km <sup>2</sup> )	800	1063
Mean	0.003	0.005
Std	0.022	0.026
Min	0.001	0.002
Max	0.76	0.73

## Project info:

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