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RECOGNIZING THE VALUE OF BIODIVERSITY AND ECOSYSTEM HEALTH TOWARD A MORE SUSTAINABLE FISHERY IN THE MEDITERRANEAN: INSIGHTS FROM SPOKE 2 - ACTIVITY 1.1

RICONOSCERE IL VALORE DELLA BIODIVERSITÀ E DELLA SALUTE DEGLI ECOSISTEMI MARINI IN MEDITERRANEO: ESPERIENZE DALLO SPOKE 2 – ATTIVITA' 1.1

Abstract - *The Mediterranean Sea, despite being one of the most biodiverse marine regions on Earth, is currently experiencing severe anthropogenic pressures that compromise ecosystem resilience and productivity. Within the framework of the National Biodiversity Future Center (NBFC), SPOKE 2 – Activity 1.1 addressed multiple drivers of biodiversity loss from September 2022 up to today, including fishing impacts, non-indigenous species (NIS), marine litter, recreational fisheries, vulnerable marine ecosystems (VMEs), and pelagic biodiversity hotspots. Innovative approaches were tested, ranging from selective fishing devices and AI-based pingers to satellite monitoring of illegal fishing and citizen science programs. Results highlight the value of integrating ecological knowledge with technological innovation and stakeholder participation to promote sustainable fisheries and safeguard Mediterranean biodiversity.*

Keywords: *Sustainable fisheries, biodiversity conservation, invasive species, marine litter, ecosystem monitoring*

Introduction - The Mediterranean Sea is widely recognized as a global hotspot of marine biodiversity, hosting an estimated 17,000 marine species, many of which are endemic (Coll *et al*., 2010). At the same time, it is also one of the most heavily exploited and impacted seas in the world. Overfishing, habitat degradation, climate change (Lejeusne *et al.,* 2010), marine litter, and the spread of non-indigenous species (NIS) are eroding the ecological integrity of the basin, often acting in synergy to reduce resilience and ecosystem services. Commercial fishing represents one of the most pervasive pressures, affecting marine ecosystems through bycatch, discards, benthic disturbance, and greenhouse gas emissions. In parallel, biological invasions are increasing at an unprecedented rate, fueled by climate warming and global maritime traffic, making the Mediterranean one of the most invaded seas worldwide. Marine litter and microplastics, largely derived from fishing, aquaculture, and terrestrial inputs, have become a symbol of unsustainable resource use, threatening marine life and human well-being. In this context, the NBFC launched SPOKE 2 – Activity 1.1 with the overarching aim of 'recognizing the value of biodiversity and ecosystem health toward a more sustainable fishery.' This activity was designed to combine technological innovation, participatory science, and ecological monitoring.

Materials and methods - The methodological framework of SPOKE 2 – Activity 1.1 was intentionally interdisciplinary and multi-scalar (Fig. 1). It combined controlled experimental trials, field-based monitoring, laboratory analyses, remote sensing, and participatory approaches. To assess and mitigate fishing impacts, technical trials were conducted on commercial vessels using juvenile sorting grids (JSGs), turtle excluder devices (TEDs; Petetta *et al*., 2025), AI-based pingers (De Marco *et al.*, 2023; Di Nardo *et al*., 2023), and squid jigging machines. Dyneema cables were introduced to replace steel warps, aiming to reduce towing weight and fuel consumption. For non-indigenous

species, the ORMEF geoportal was updated with georeferenced occurrence records and species distribution models (Azzurro *et al*., 2024a). Pilot studies assessed the market potential of *Callinectes sapidus* (Ratbun, 1896) (Azzurro *et al*., 2024b) and *Anadara* spp., while exploratory research considered *Lagocephalus sceleratus* (Gmelin, 1789) skin tanning. Marine litter monitoring included Fishing-for-Litter campaigns, onboard waste compaction, and microplastic analyses using Raman spectroscopy. Illegal fishing was investigated through SAR and optical imagery combined with AIS, supported by low-cost IoT trackers and a citizen science mobile application. Recreational fisheries were monitored using tagging, drones, and logbooks. VMEs were mapped with biodiversity surveys and ecosystem service assessments. Finally, pelagic biodiversity was investigated at seamounts and upwelling systems using acoustics, isotopes, and eDNA.

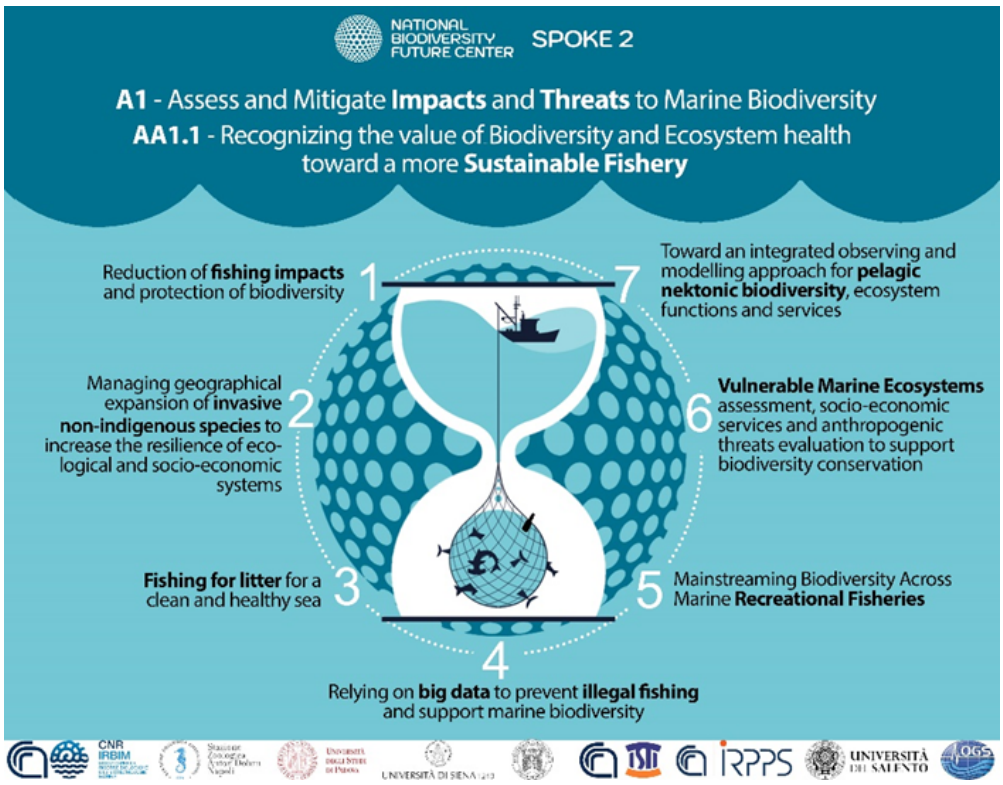

Fig. 1 - Integrated framework for the assessment and mitigation of impacts and threats to marine biodiversity towards sustainable fisheries (NBFC SPOKE 2 – Action A1, Sub-action AA1.1)
Framework integrato per la valutazione e la mitigazione degli impatti e delle minacce alla biodiversità marina verso una pesca sostenibile (NBFC SPOKE 2 - Azione A1, Sottoazione AA1.1).

Results - Selective gears such as JSGs proved effective in reducing juvenile bycatch, while TEDs were standardized through operational manuals. AI-based pingers achieved more than 90% accuracy in detecting dolphin whistles. Squid jigging machines showed high selectivity and minimal bycatch, while Dyneema cables significantly reduced towing weight. UAV-assisted whale-tracking proved feasible and allowed real-time monitoring. NIS management expanded the ORMEF database with more than 1900 records, highlighted underexploited *Anadara* spp. stocks, and confirmed consumer acceptance of *Callinectes sapidus*. Marine litter monitoring collected 745 kg of debris in four months, mostly aquaculture plastics, and confirmed widespread ingestion of microplastics by fish. AI pipelines improved SAR vessel detection and AIS trajectory imputation, while IoT trackers filled knowledge gaps in small-scale fisheries. Recreational fisheries

generated >50 records of rare species, and VMEs were identified in the Strait of Sicily. Pelagic hotspots confirmed the ecological importance of seamounts such as Vavilov. The outcomes of SPOKE 2 – Activity 1.1 underline the importance of integrated approaches to sustainable fisheries. Technical innovations such as JSGs, TEDs, and AI-based pingers illustrate how selective fishing can reduce ecological impacts and align with EU landing obligations. The valorization of invasive species represents a paradigm shift, turning ecological challenges into opportunities within the circular economy. Marine litter studies highlighted the urgency of mitigation, while historical interviews showed how practices have evolved over decades. Big data and AI applications provide new tools to combat IUU fishing, especially in small-scale fleets. Recreational fisheries and VMEs, often overlooked, were shown to have significant ecological roles. Collectively, these findings contribute to EU and international strategies, bridging science, policy, and practice.

Conclusions - By combining ecological monitoring, innovative technologies, and participatory approaches, SPOKE 2 – Activity 1.1 delivered new insights and practical solutions for Mediterranean fisheries sustainability. Future work should focus on scaling up successful practices, fostering cross-border collaboration, and strengthening the role of biodiversity in fisheries management.

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