

A Joint Model of Science, Citizens and Stakeholder Engagement: Shaping a Blue Future for the Adriatic Sea

The **Interreg Italy-Croatia 2021-2027 “BlueDiversity” project** is advancing innovative approaches to safeguard the Adriatic Sea, tackling major challenges such as invasive species, marine litter, climate change and biodiversity preservation. At the heart of its work are cutting-edge monitoring and control tools that transform environmental challenges into opportunities for sustainable management, economic development, and community engagement.

In recent decades, the ecological pressures acting on the Adriatic Sea have grown at an alarming rate, exponentially intensified and accelerated by the effects of climate change. Issues such as biodiversity conservation, spreading of non-indigenous species (NIS), marine litter, and the increasing presence of micro- and nano-plastics now represent critical priorities for safeguarding vulnerable marine ecosystems and the benefits they provide. The coordinated efforts put in place by Croatian and Italian partners to co-design replicable solutions, share data, and align strategies are essential toward achieving long-term conservation and management goals.

One concrete example of pressure acting on the Adriatic Sea fostered by climate change is the rapid and widespread expansion of the non-indigenous blue crab (*Callinectes sapidus*). Originally native to the western Atlantic, this species has increasingly colonized the Adriatic Sea in recent years, facilitated by changing environmental conditions such as rising sea temperatures and altered ecosystem dynamics. Its expansion has raised growing concerns due to its interactions with native species and habitats, as well as its potential impact on fisheries and coastal activities (Figure 1).





Figure 1. Detailed examples of two non-indigenous species (in the left picture *Callinectes sapidus*, the blue crab, and *Penaeus aztecus*, the brown shrimp; in the right picture *Callinectes sapidus* collected using BlueDiversity novel traps).

The invasion dynamics of this non-indigenous species were assessed through a comprehensive dataset of scientific data and local ecological knowledge (LEK) records, compiled to analyse the species' spatial and temporal patterns of diffusion in the Adriatic Sea (Shauer et al., 2025; animation blue crab invasion). The results, published in an open-access scientific journal (Scientific Reports, Nature group; Shauer et al., 2025), demonstrate that the Adriatic coastlines of both Croatia and Italy are amongst the most influenced by the presence of this NIS, further underscoring the need for common strategies aimed at biodiversity preservation and sustainable resource management (Figure 2a; Figure 2b).



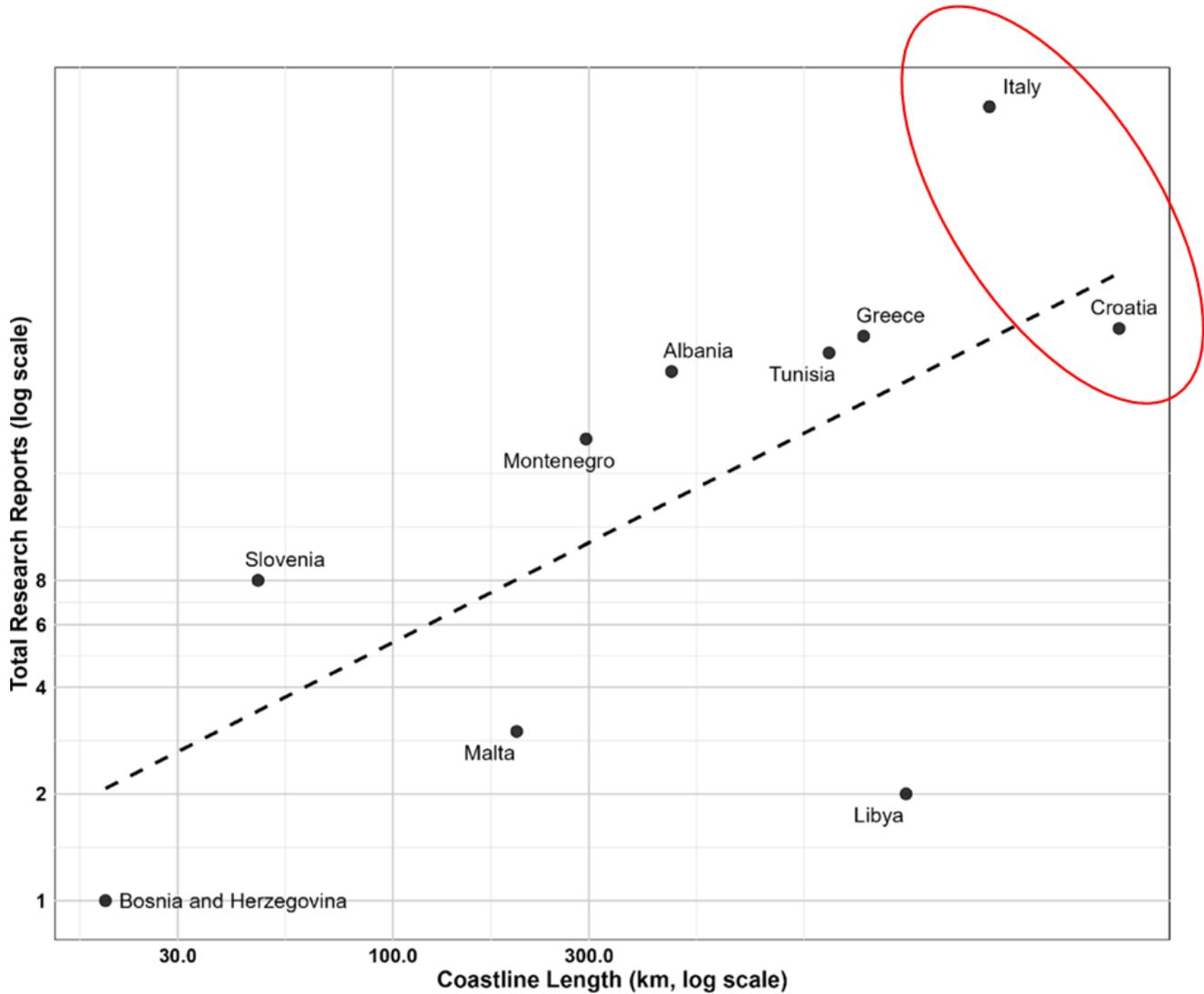


Figure 2a. Relative research effort by Mediterranean Countries for Blue crab, standardized by the time span of reported records and the length of national coastline within the study area (from Shauer et al., 2025, Scientific Reports, Nature group, open access). The red circle highlights the most influenced countries by the presence of *Callinectes sapidus*, further underscoring the need for joint actions and common strategies like the BlueDiversity project.



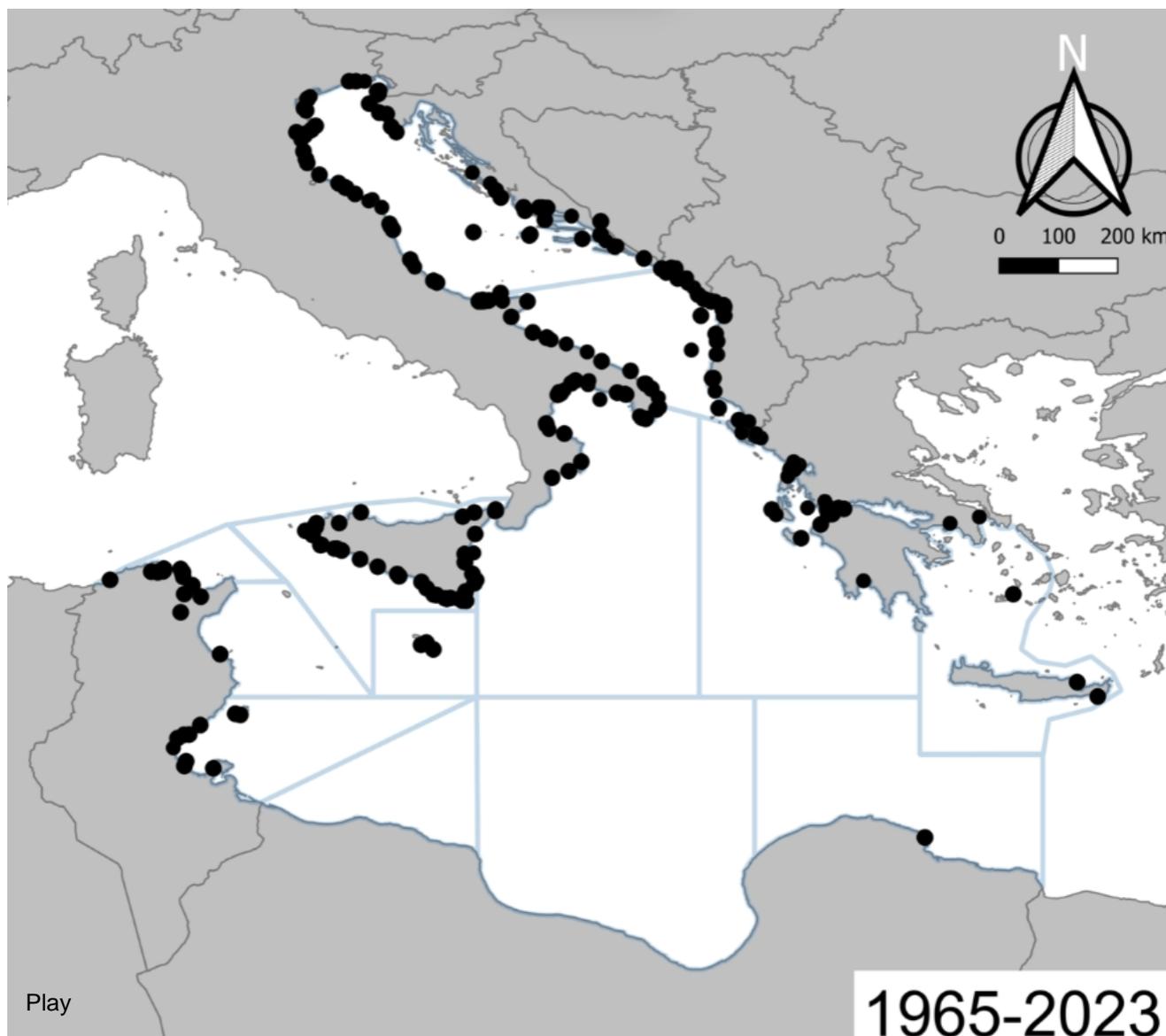


Figure 2b. Occurrence records of the blue crab from 1965 to 2023. Map created with QGIS version 3.42.1. Supplemental Animation in Shauer et al., 2025. The animation is available at the following link (<https://www.youtube.com/watch?v=gaEJ13kt2sM&t=3s>).



In light of this, the **BlueDiversity** project confronts these challenges through a combination of science, citizen engagement, and stakeholder collaboration, with the aim of turning scientific research into practical actions.

Innovative Monitoring and Control Tools

Central to the project are several innovative tools applied to monitor biodiversity and manage environmental threats. To foster collaboration with local fishers, **custom fishing traps** for the blue crab were developed and tested to help controlling this NIS while minimizing the bycatch. To improve the analysis of biodiversity and relate it with the abiotic factors characterizing the study areas identified across Croatia and Italy, a common survey based on **Environmental DNA (eDNA)** metabarcoding (Figure 3) from water samples collected in all the pilot areas interested by the presence of blue crab allows the team to assess the actual biodiversity across the Croatian and Italian Adriatic coastlines.

The method demonstrates its reliability in identifying native species and describes the ecological communities, while at the same time providing a powerful early-warning system concerning the presence of non-indigenous species never recorded before in a certain area. Furthermore, **RNAs analysis** provides insights into molecular responses of living indicators to environmental stress. Meanwhile, regular water quality testing monitors nutrient and chemical pollutant levels, helping identify and mitigate habitat degradation.





Figure 3. Extraction and processing of eDNA material from water samples to PCR amplification.

These tools enable **BlueDiversity** to collect real-time, accurate data, which guides adaptive, evidence-based responses to invasive non-indigenous species, pollution, biodiversity conservation, and climate change.

Pilot Areas Across Italy and Croatia

The project actively applies these innovative tools in six pilot areas, chosen according to their ecological, biological, and socio-economic importance. In Croatia, the Neretva Delta provides vital fish nurseries and bird habitats, despite facing threats from agriculture, urbanization, and non-indigenous species. Mali Ston Bay, renowned for oyster and mussel farming, intersects deeply with local culture and tourism. Around Split, the Cetina River and Estuary, Pantan Coastal Lagoon, and



Uvala Vrulja marine area are confronted with pressures from habitat disruption, invasive species, and pollution.

In Italy, Aquatina di Frigole and the Ionian Sea mariculture combine the conservation effects of a NATURA 2000 Site with innovative fish and mussel farming, balancing biodiversity with sustainable aquaculture innovation. San Benedetto del Tronto and the Sentina Natural Reserve integrate fishing, tourism, and habitat preservation, while the Venice Lagoon supports biodiversity and aquaculture, contending with pollution, non-indigenous species, and tourism pressures (Figure 4).



Figure 4. Poster showing the projects' Pilot Areas and the invasive non-indigenous species *Callinectes sapidus* (the blue crab, right picture).



Thanks to the combination of innovative monitoring tools with local ecological knowledge, the **BlueDiversity** project tailors solutions to each area’s specific challenges, fostering the common and shared design of replicable strategies across diverse ecological contexts.

Linking Biodiversity to Economic Opportunity

To reduce marine litter and support sustainable fisheries and aquaculture, **BlueDiversity** integrates circular economy principles encouraging the use of bio-based and recyclable materials for fishing gear and infrastructure as well as in the context of aquaculture. It also promotes the commercial valorisation of non-indigenous species like the blue crab, providing economic incentives for their removal while preserving biodiversity. For example, surveys in the Marche region indicate that 71% of respondents would consider tasting blue crab in restaurants — a concrete example of ecological management creating local economic value.

Education, Citizen Science, and Community Engagement

The project establishes “living laboratories” to train students, fishers, small and medium-sized enterprises, educators, and youth. Workshops, citizen science initiatives, and outreach campaigns fill knowledge gaps and raise awareness about biodiversity, ecosystem services, and sustainability. Residents, students, and tourists participate in species identification, blue crab monitoring, and pollution surveys, generating vital data while fostering a sense of stewardship and connection to the Adriatic Sea.



Cross-Border Collaboration and Governance

Collaboration between Italian and Croatian partners is a cornerstone of **BlueDiversity**. Together, they co-design replicable solutions, share data, and align strategies. The project's Roadmap, developed with input from fifty stakeholders per country, ensures local ownership and practical applicability.

In aquaculture areas, **BlueDiversity** supports the transition to biodegradable materials, helping producers adopt low-impact practices without compromising competitiveness or quality. Innovative fishing and species management techniques are tested directly with local communities, combining scientific monitoring with practical, community-driven action.

A Blue Future for the Adriatic basin

BlueDiversity demonstrates that biodiversity preservation, innovative monitoring, sustainable production and economic development are complementary goals. Its modular design ensures that successful practices in one area - whether a biodegradable fishing line in the Ionian Sea, a blue crab trap in the Venice Lagoon, or a school workshop in Split - can be replicated elsewhere.

In an era when seas are warming, species are shifting, and pollution is rising, **BlueDiversity** offers a hopeful model. By uniting science, citizens, and policy-makers, **BlueDiversity** protects the Adriatic Sea and secures its ecological, social, and economic value. Through innovation, education, and cross-border cooperation, the project charts a course toward a resilient and vibrant Adriatic, a true "blue future".



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