



Full length article

## Marine strategy framework directive: A comprehensive cost assessment for the Italian seas

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### ARTICLE INFO

#### Keywords:

Marine strategy framework directive  
MSFD  
Cost analysis  
Cost assessment  
Italy

### ABSTRACT

In 2008, the EU launched the Marine Strategy Framework Directive (MSFD) to protect European waters and achieve Good Environmental Status (GES) of marine ecosystems. The implementation of the strategy requires Member States to assess the costs associated with the realization of MSFD measures to determine their feasibility and cost-effectiveness. Here we conducted a comprehensive analysis along 8300 km of the Italian coastline, to provide a cost analysis of the 23 new measures proposed for the second cycle of MSFD implementation in Italy. We used “unit-transfer” methodology to estimate the costs of each measure, grouping them into three categories: a) prevention, b) management, and c) monitoring and control. The “management” group included 12 measures and accounted for 65 % of total costs, followed by the “monitoring and control” group (5 measures, 28 % of total costs) and the “prevention” group (5 measures, 7 % of total costs). One measure had a double goal, and its implementation was attributed both to “prevention” and “monitoring and control”. The cost of implementing all the measures in Italy is approximately € 1.5 billion (~0.07 % of Italian GDP in 2023). These results provide, for the first time, comprehensive and detailed quantitative information useful for policy makers to enable efficient financial planning for future actions required to achieve the GES in marine ecosystems. The approach developed here could also serve as a standard framework for assessing the costs of future measures under the MSFD, providing a benchmark or a methodological term of reference for all interested EU Member States.

### 1. Introduction

The EU Marine Strategy Framework Directive (MSFD) is a key instrument adopted by the European Union in 2008 (EU Directive 2008/56/EC) to protect marine ecosystems and biodiversity, and to achieve a good environmental status (GES) in territorial waters. This Directive, which covers all European waters, was designed as a follow-up to the previous EU Water Policy (e.g., Water Framework Directive 2000/60/EC; [12]). The MSFD is the first attempt to undertake an ecosystem-based management approach for the protection of marine environment and the sustainability of marine-related activities [2,11,22,27]. To achieve this objective, the MSFD considers all ecosystem components, their dynamics, and interactions [10,28,32]. The aim is to ensure that there is no significant harm or adverse impact on marine biodiversity, marine habitats, human health, or legitimate uses of the sea

[30].

MSFD measures are based on five key principles: 1) Precaution, 2) Prevention, 3) Damage limitation, 4) “Polluter Pays” and 5) Sustainable development, which have been developed through various measures, and that require an accurate assessment of the socio-economic impacts is needed (EU, 2008). The socio-economic assessment is a crucial element in the implementation of the Marine Strategy, as it allows the integration of the economic dimension into the sustainable management of marine ecosystems [1]. This is necessary both for the implementation of the MSFD measures and for the estimation of costs imputable to ecosystem degradation if targets are not met [20,33]. Economic activities related to the sea territory —such as fishing, maritime transport, tourism, and offshore energy — can determine several impacts on marine ecosystem [15,19,34] thus significant influencing the achievement of the on the good environmental status. When assessing the costs of inaction — i.e.,

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<https://doi.org/10.1016/j.marpol.2025.106715>

Received 12 November 2024; Received in revised form 21 March 2025; Accepted 7 April 2025

Available online 26 April 2025

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the actual and potential damages caused by the degradation of marine ecosystems — it is essential to also to take into account the costs associated with the implementation of the Programs of Measures (PoMs) outlined in the Marine Strategy Framework Directive. This approach seeks to find a balance between environmental protection and economic growth, avoiding overly restrictive measures while ensuring the effectiveness and proportionality of interventions. Without adequate measures, marine ecosystem degradation results in economic losses due to declining fishery resources, reduced tourism appeal, damage to marine habitats, and increased health costs from pollution (see [14], and citations therein). Member States are therefore required to assess the effectiveness of their PoMs, conceived to achieve the GES of marine ecosystems in their territorial waters, to preserve their biodiversity and ensure the maintenance of the ecosystem services they provide [3,24, 29].

The assessment of GES is based on 11 descriptors covering a wide range of variables that have been identified to assess marine ecosystems health (and consequently preventing risks for human health), including i.e. biodiversity, environmental pollution and seafood contamination and the impact of fisheries. Each descriptor includes a set of criteria and indicators.

To improve the cost-effectiveness of the MSFD measures, the European Union foresees regular assessments (every 6 years) after which targets are revised and updated. The aim is to improve cooperation between regions, develop the best regional policies and increase stakeholder involvement in updated monitoring programs. Following the completion of the first implementation cycle of the MSFD in 2018, all Member States prepared and started implementing their PoMs which were then revised by 2022 according to the criteria set out in EU Decision 2017/848. Here, by combining costs and policy assessments, we provide the first comprehensive analysis of the costs associated with the implementation of the 23 MSFD measures adopted by the Italian Government (Appendix 1). The analysis is conducted through the unit transfer methodology, which provides a practical and scientifically sound approach to estimate costs based on existing assessment studies and also facilitates comparability across EU Countries.

We have applied these analyses to the Italian territorial waters, which cover 8 300 km of Mediterranean coastline, divided into 5 regional seas (Ligurian, Tyrrhenian, Sicily channel, Ionian and Adriatic seas). In response to the requirements of the MSFD, the socio-economic dimensions of the use of marine waters in the dynamic context of Italy have been considered through a comprehensive data collection and analysis, focusing on three fundamental economic variables: employment, value added and production value [4].

By analyzing the financial dimensions of MSFD implementation, the present study aims to provide quantitative insights that can contribute to decision-making processes, to plan environmental cost-effective strategies to achieve and maintain GES in marine waters. The results of this analysis are relevant not only for Italy, but also for all the EU Member States called upon to implement the MSFD. The Directive, in fact, requires States to adopt concrete measures to achieve a GES, but does not provide for specific spending obligations, leaving a margin of flexibility to national governments [24].

## 2. Methodology

For all the 23 MSFD measures, we applied unit transfer methodology which allows estimated costs and/or benefits to be transferred from one location to another in an efficient, timely and cost-effective manner [17, 26]. “Simple unit transfer” is a valuation methodology that belongs to the wider group of value transfer methodologies, where the estimated values are transferred from previous studies that identify similar aspects of environmental quality. The site where the original valuation study is carried out is named “study site”, and the site where the new value estimate is projected is named “policy site”. Value transfer can be across different sites (spatial value transfer) or at a specific site over time

(temporal value transfer; see [25] and citation therein). In this study, the unit transfer methodology was applied following a data mining process that included the analysis of scientific literature, grey literature and other documents published by Italian institutions (e.g., Ministry of Environment, Environmental Agencies, NGOs).

An extensive search was carried out using online databases, spanning from academic publications (Scopus, Google Scholar) to governmental and technical reports, to identify analogous cases where similar measures have been implemented. Where a measure has required the employment of a skilled worker, for instance, we have considered the current market rates, labor cost and salary data for that specific expertise, within the relevant geographical and industry context. In estimating the costs of spatial expansion of a Marine Protected Area (MPA), we reviewed publicly available balance sheets and financial reports of the existing MPAs to calculate the average management costs normalized to square kilometer of protected area, to use it as a cost estimate. In some cases, where “study site” information was not available (or non-existent), the cost analysis was based on the “expert opinion”, a widely accepted tool that found application in several environmental studies [21].

Alternative approaches, such as direct cost-benefit analysis (CBA) or willingness-to-pay (WTP) surveys, were considered. However, these methods require extensive primary data collection, which was beyond the scope of our study with its large geographical scale. Furthermore, unit transfer methodology allows comparability with other EU studies assessing the implementation of the MSFD, ensuring methodological consistency across different regions.

The 23 measures defined for the Italian MSFD have been grouped into three main categories according to the framework [23]: 1) prevention, 2) management and 3) monitoring and control (Table 1 illustrates the grouping of the 23 measures into the three categories). For six measures we also present different implementation scenarios for the proposed solutions to quantify the investments needed to achieve the expected results: choosing to invest in one solution rather than another could imply different costs but also different target achievements. The individual costs estimated for each of the 23 specific measures were then aggregated within the three categories reported above and summed up to provide a comprehensive overview of the total costs for the MSFD implementation in Italy.

To ensure the robustness of the estimates, we cross-checked the data using multiple sources wherever possible with similar studies or case reports. When more than one solution was deemed cost-effective for the realization of a single Measure, we took into consideration the average value of the two realization scenarios. Finally, to validate the accuracy of the unit cost estimates, we consulted 3–5 experts in marine ecosystem management and economics. Each expert assessed whether the initial cost estimates were over- or underestimated and rated the reliability of these estimates on a scale from low to very high, based on their individual expertise.

This methodological approach, graphically represented in Fig. 1, allowed us to refine and confirm the validity of the cost estimates for the implementation of the MSFD measures in Italy. By integrating the cost-transfer method with expert cross-verification, we ensured that the final estimates were both accurate and contextually relevant.

## 3. Results

The analysis was focused on 23 measures of which 5 belong to the prevention category, 12 to management and 5 to monitoring & control: one measure (n. 4) was targeting two different objectives and hence was split in two groups, prevention and monitoring & control. For all measures, we estimated the costs associated to the implementation of the different strategies that can be pursued to achieve the targets set by MSFD. The cost for all measures planned in the Italian MSFD amount to € 1 484 249 995 (Table 2). Prevention costs account for 6.9 % of the total budget; management measures are the most relevant component,

**Table 1**

Categorization of the MSFD measures with associated targets. Legenda: MADIT – Italian Adriatic Sea; MWE-IT – Italian Western Mediterranean Sea; MICIT – Italian Ionian and Central Mediterranean Seas (Appendix 1).

Measure code	Prevention	Management	Monitoring & Control
	Measure Target	Measure Target	Measure Target
MADIT -M031-NEW2; MICIT -M031-NEW2; MWEIT -M034-NEW2	Implement technical solutions to reduce (prevent) the phenomenon of collisions with cetaceans		
MADIT -M032-NEW3; MICIT -M032-NEW3; MWEIT -M035-NEW3			Acquisition, systematization and homogenization of the monitoring data from EIA procedures
MADIT-M083-NEW10, MICIT-M082-NEW10, MWEIT-M085-NEW10.		Design and implementation of measures for improving the management of waste generated by fishing and aquaculture activities (including disused equipment) encouraging its recycling and recovery.	
MADIT -M089-NEW12, MICIT -M088-NEW12, MWEIT -M091-NEW12	Implementation of training and awareness-raising measures to increase knowledge towards prevention and fight against marine litter.		
1		Increase in the surface of MPAs to reach the target of 20 % of territorial waters under protection	
2	Implementation of awareness and information measures aimed at reducing damages to benthic habitats by boaters (anchors), diving centers (involuntary damage or withdrawal while submerged), tourist operators (waste) and fishermen (bycatch)		
3		Increase the surface of marine habitats of conservational interest in waters of national jurisdiction, to reduce the impacts	

**Table 1 (continued)**

Measure code	Prevention	Management	Monitoring & Control
	Measure Target	Measure Target	Measure Target
4 (a, b)	Creation of an informative campaign for Port Authorities, fishing associations and cooperatives, fish markets, aimed at informing about the main edible alien species and promote their sales on the market.	of anchoring on protected habitats	Monitoring of edible non-indigenous species (NIS) that can be included in the market.
5			Protocol for the implementation of the early warning system" in reference to alien and dangerous aquatic species, including the containment / mitigation measures to be adopted (EEA Technical report No 5/2010).
6			Creation of a measure to make traceable all data relating to movements of batches of bivalve mollusks: this includes imports from other countries and transfers of batches from one plant to another at a national level in order to limit the spread and introductions of non-indigenous species
7		Development of a guideline for the control and management of biofouling on boats.	
8	Development of training actions for operators in the fishing sector regarding the sustainability aspects of professional fishing.		
9		Development of a measure for the authorization of Sewage Treatment Plant systems on vessels dislocating within territorial waters	
10		Expand the collection, treatment and disposal of sewage in tourist harbors through the	

(continued on next page)

Table 1 (continued)

Measure code	Prevention	Management	Monitoring & Control
	Measure Target	Measure Target	Measure Target
11		promotion of disposal facilities. Preparation of a regulatory tool for the implementation of a collection and disposal chain for waste accidentally collected by fishermen, in implementation of Directive 883/2019.	
12		Design and creation of a supply chain for fish boxes to facilitate the transition from the use of disposable polystyrene boxes to washable and reusable boxes.	
13			Establishment of a technical table/committee for the monitoring and quantification of the marine litter
14		Preparation of a Ministerial Decree for the creation of EPR (extended producer responsibility) systems for the products referred to in article 8 of Directive 904/2019 and in the Annex PART E Section 1, for the correct deployment of fishing nets, mussel farming and other aquaculture.	
15	Tools for the collection of litter from river estuaries also through the use of experimental sustainable prototypes for their interception.		
16		Design and creation of a marine waste recycling chain.	
17		Launch of experimental prototypes for the removal of micro-litter and plastics in sewage treatment plants	
18		Moratorium on recreational (non-professional) fishing of specimens of species of high conservation value, such as groupers and brown meagre	

Table 1 (continued)

Measure code	Prevention	Management	Monitoring & Control
	Measure Target	Measure Target	Measure Target
19	5.5/23	12/23	Identification, geo-localization and monitoring of abandoned fishing gears with negative impacts on marine habitats. 5.5/23

equivalent to 65 % of total costs; monitoring & control measures accounted for 28 % of total costs.

### 3.1. Prevention measures

The purpose of prevention measures is to implement solutions aimed at avoiding environmental damages deriving from human activities and to inform stakeholders about possible consequences of human behavior on the environment. In this study we estimated the costs needed to address the threats of vessel collisions with marine cetaceans (MADIT -M031- NEW2; MICIT -M031- NEW2; MWEIT - M034 - NEW2), marine litter (MADIT - M089 - NEW12, MICIT - M088 - NEW12, MWEIT - M091 - NEW12; Measure 15), damages to benthic habitats including bycatch (Measure 2, 8) and identification of alien species (Measure 4). The results of prevention measures are summarized in Table 3. Results are reported according to the order of the measures reported in this Table.

Two targets set by the measures belonging to the prevention group could be addressed with the acquisition with specific technologies.

For Measure MADIT -M031- NEW2; MICIT -M031- NEW2; MWEIT - M034 - NEW2, two possible solutions were identified: “Whale-Safe buoys” and Real Time Plotting of Cetacean System (REPCET) software installed onboard. These tools differ from each other because the first gives a fixed area of prevention depending on the position of the buoy, while the second covers the route of the vessel on which the tool is installed with the support of an operator. Unit transfer methodology allowed to determine the cost of a single REPCET installation at € 113,830.80 per vessel [6,7], while the cost of a Whale Safe equipped buoy was estimated at € 31,500, [31], composed by: 12,000€/buoy for hydrophones and connectors; 2 500€/buoy for data/power cable and its connectors; 7000€/buoy for the mooring system; 10,000€/buoy for buoy deployment. Whale-Safe equipped buoys could be installed in 35 relevant sites in Italy i) 3 systems in the Pelagos sanctuary - Liguria, Tuscany, Northern Sardinia ii) 3 systems in the Sicilian Channel (Trapani, Pelagie Islands and Lampedusa) as they are on the migration route of the *Balaenoptera physalus* towards the Pelagos sanctuary, iii) 29 systems in the Italian MPA (also on pre-existing systems/infrastructure), in the areas where vessel traffic is permitted. On the contrary, REPCET should be installed on 1353 vessels registered in the Italian Merchant Navy Register. Depending on the solution chosen to prevent vessels collisions with cetaceans, it emerges that the implementation cost of this measure could range from € 1102,500 to € 173,236,645 with an average cost of € 77,557,786.20.

Measure 15 deals with waste management from river sources, following prototypes of floating barriers (e.g., in the regions of Lazio, Emilia Romagna and Piemonte, Annex 1) installed at the estuaries to retain floating litter and prevent its discharge into the sea. It was possible to estimate the implementation costs for the 57 Italian main rivers (here defined as those longer than 100 km): installing an average of 9 floating barriers (55.2 m average overall length) in all the above-mentioned rivers, the initial implementation costs, including the first six months of barriers management and waste discharging, would be of € 5862,851.28.

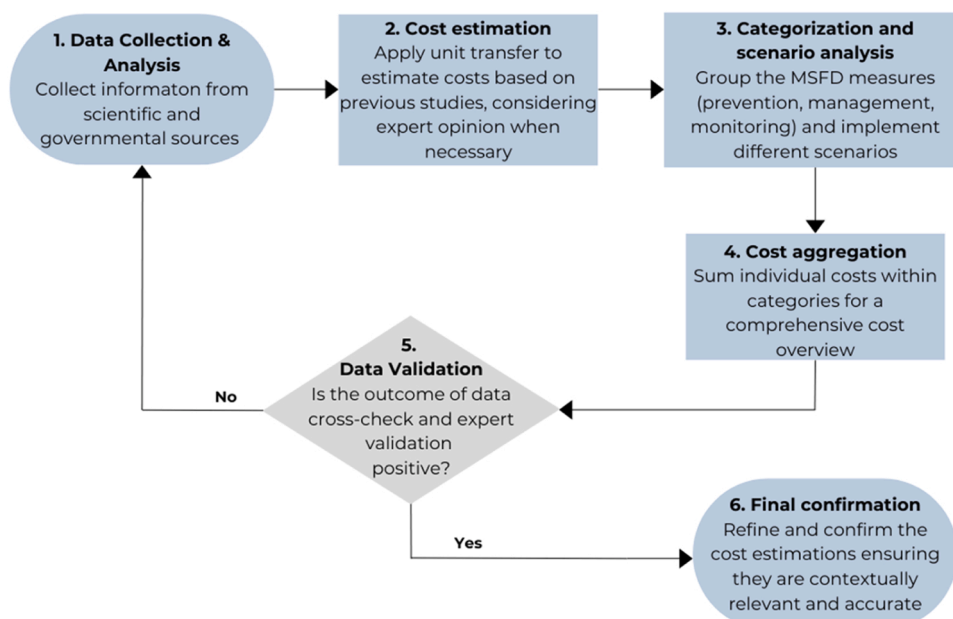


Fig. 1. Cost-effectiveness analysis logical framework.

Table 2

Overview of implementation costs for 23 MSFD measures and share on total budget.

	Prevention	Management	Monitoring & Control
Cost for all Measures implementation	102,578,505 €	965,884,951 €	415,786,539 €
Share on total costs	6.9 %	65.1 %	28 %
<b>Total cost of MSFD implementation</b>	<b>1484,249,995 €</b>		

Information is a key tool for prevention: in fact, four out of the six prevention targets may be achieved through the organization of informative campaigns. Measure **MADIT - M089 - NEW12**, **MICIT - M088 - NEW12**, **MWEIT - M091 - NEW12** aims at reducing the quantity of marine litter through the prevention of its dumping in the environment. This measure proposes to organize training courses and awareness initiatives open to Italian citizens to achieve the target: value transfer from previous experiences carried on in the MPA of Plemmirio (Annex 1, AMP Plemmirio, Presidential Determination, 2017) suggests that the cost of a single initiative is € 35,000. The minimum implementation cost to achieve the target would be € 840,000 if the awareness initiatives were carried out only in the 24 main Italian coastal cities (Imperia, Savona, Genoa, La Spezia, Pisa, Livorno, Grosseto, Rome, Campania, Naples, Salerno, Catanzaro, Reggio Calabria, Trieste, Venice, Ravenna, Ancona, Pescara, Bari, Taranto, Lecce, Messina, Palermo, Cagliari, Sassari) or would be € 14,105,000 if the campaigns were carried out in all the 403 Italian coastal cities with more than 5,000 inhabitants. The same scenario could be applied to **Measure 2** aimed at reducing damages to benthic habitats by boaters, diving centers, tourists, and fishermen. Also in this case, the cost would range between € 840,000 for campaigns carried out in 24 main coastal cities and €14,105,000 if the campaigns were carried out in all the 403 Italian coastal cities with more than 5000 inhabitants.

Targets of Measure 4 and Measure 8 can be achieved through the promotion of information/education campaigns. **Measure 4** aims at raising awareness of non-indigenous edible species to promote their introduction into the fish market in two following steps. For this reason, the costs have been split between prevention and monitoring and control categories; the target can be achieved through informative

campaigns whose unit cost was once again valued at € 35000, shared at 50 % with the implementation of Measure 4b (Annex 1, MPA Plemmirio, 2019). Conversely, **Measure 8** could be carried out with specific training campaigns aimed to operators in the fishery sector: considering an average unitary cost of €136.11 per participant in case of collective groups (Annex 1, Chamber of Commerce of Genoa, 2021) and assuming that the 21,309 workers employed in the fishing sector in Italy would be included in the course, the total cost would be € 2900,368.

The total cost of the prevention measures implemented in Italy is € 102,578,505.47.

### 3.2. Management measures

Management measures proposed in the MSFD pursue several objectives, including reduction of waste and pollution from various sources, promotion of a sustainable use of marine resources and increase of protected areas/species. 60 % of management measures include solutions that can be carried out with the implementation of specific tools or management chains, i.e. waste management processes. The results of measures related to management are summarized in Table 4 and reported in the order shown in this table.

The first measure (coded as **MADIT-M083- NEW10**, **MICIT- M082 - NEW10**, **MWEIT-M085 - NEW10**) is aimed at the creation of a waste management chain for litter generated and collected by fishery activities: the cost per square kilometer of litter management actions was of € 883.97 (€ 604.55 for inspection costs, € 105.65 for active removal costs, € 2.15 for disposal costs, € 126.61 for monitoring; Annex 1, LIFE Ghost, 2016). Assuming that the collection activity is carried out on 1 km<sup>2</sup> of seafloor (i.e., 8300 km of shores x 1 km distance from the shore), the cost of the measure could amount to € 7336,951.

**Measure 7** implies the implementation of a management strategy to deal with biofouling on boats: the cost of a biofouling tracing system managed by a trained operator could amount to €52,000 (Annex 1). If adopted in the 58 Italian ports of national interest, the total cost of the measure would be of € 3016,000.

**Measure 10** requires the creation of waste management chains in tourist ports for the collection, treatment, and disposal of sewage through the promotion of disposal facilities. In this case, the cost estimate was provided by ISPRA (Annex 1, Italian Ministry of Environment and Energy Security, 2022) and ranged between € 25,000–50,000 per

**Table 3**  
proposed solutions and costs estimated to achieve the targets of MSFD prevention measures.

Prevention				
Measure code	Measure Target	Solution 1	Solution 2	Realization Cost (Average cost when 2 solutions are possible)
<b>Interventions realizable with the acquisition/installation of specific technologies</b>				
MADIT -M031-NEW2; MICIT -M031-NEW2; MWEIT - M034 -NEW2	Implement technical solutions to reduce (prevent) the phenomenon of collision with cetaceans	35 Whale Safe Buoys	REPCET Software with Marine Mammal Observer onboard	77,557,786 €
15	Tools for the collection of litter from river estuaries also using experimental sustainable prototypes for their interception.	Installation of floating barriers for waste collection		5862,851 €
<b>Interventions realizable through the organization of training/informative campaigns</b>				
MADIT - M089 - NEW12, MICIT - M088 - NEW12, MWEIT - M091 - NEW12	Implementation of training and awareness raising measures to increase knowledge towards prevention and fight against marine litter.	Training/informative campaigns in 24 main Italian coastal cities	Training/informative campaigns in 403 Italian coastal cities with over 5.000 inhabitants	7472,500 €
2	Implementation of awareness and information measures aimed at reducing damages to benthic habitats by boaters (anchors), diving centers (involuntary damage or withdrawal while submerged), tourist operators (rubbish) and fishermen (bycatch)	Training/informative campaigns in 24 main Italian coastal cities	Training/informative campaigns in 403 Italian coastal cities with over 5 000 inhabitants	7472,500 €
4a	Creation of an informative campaign for Port Authorities, fishing associations/cooperatives, fish markets, aimed at informing about the main edible alien species and promote their sales on the market.	One campaign in each Italian province (n = 75), cost shared with measure 4b		1312,500 €

**Table 3 (continued)**

Prevention				
Measure code	Measure Target	Solution 1	Solution 2	Realization Cost (Average cost when 2 solutions are possible)
8	Development of training actions for operators in the fishing sector regarding the sustainability aspects of professional fishing.	Training campaigns targeted to operators of the fishery sector		2900,368 €
			Total cost:	<b>102,578,505 €</b>

harbor. Considering 649 tourist ports in Italy, the minimum implementation cost would be € 162,250,000, the maximum € 324,500,000.

**Measure 11** deals with management of litter accidentally collected by fishermen through the implementation of a collection and disposal chain for waste. Through experts' opinion and data from Lazio and Tuscany Regions (Annex 1, PO FEAMP, 2020), we assessed at € 10,930 the unitary cost of each waste management system, therefore adding up to € 634,027 the total for the 58 Italian national ports considered. Recycling and transition to sustainable materials is the core of **Measure 12**, aimed at facilitating the transition from the use of disposable polystyrene boxes to washable reusable boxes. The values are taken from ongoing projects (Annex 1, UK Seafood Innovation Fund, FS093). Considering a cost of €50,000 for an average size port, which includes the acquisition of one waste compactor and the tools to wash and sterilize fish boxes, the total cost of implementing this measure in 58 ports would be of € 2900,000.

**Measure 16** aims at providing a recycling chain for marine litter. The implementation cost for starting a recycling chain depends on the costs of *in-situ* installation of floating system for litter collection (average cost of € 4400 per unit) that would amount to € 255,200 for all Italian ports of national interest.

**Measure 17** once again deals with waste management with a particular focus on technologies able to filter microplastics. According to a study by ISPRA (Annex 1, Italian Ministry of Environment and Energy Security, 2022) the installation cost of prototypes for the removal of microplastics on depuration plants could amount to € 250,000 per system. In Italy there are 3665 wastewater treatment plants, of which 1322 treat 90.44 % of total discharge. Assuming to install the prototypes in these 1322 plants, the measure could be carried out with an investment of € 330,500,000.

**Measure 1:** Shifting the focus from waste management-related actions, this measure requires an increase in the proportion of territorial waters covered by protection regimes by 2026, by expanding the surface area of existing MPAs or Natura2000 sites to achieve the minimum share of 20 % of national waters under protection. This could be further implemented to reach the 30 % target of protected areas to meet the objective of the 2030 Agenda. The analysis of the balance sheets of existing Italian MPAs (Annex 1) allowed to assess the average yearly management cost per km<sup>2</sup> of MPA at € 59,018.30. The total surface area of Italian territorial waters is 154,597 km<sup>2</sup>; at present, approximately 28,550 km<sup>2</sup> are protected (Annex 1). The 30 % protection target corresponds to 46,378 km<sup>2</sup>, while the 20 % corresponds to 30,919 km<sup>2</sup>. Given an average cost of € 59,018.30 for the annual management of 1 km<sup>2</sup> of MPA, the cost of the measure to reach an intermediate target of 25 % would be € 595,993,273.

**Measure 9** requires the creation of a correct path for the authorization of STP (sewage treatment plants) on board ships with national

**Table 4**  
Proposed solutions and estimates of costs to achieve the targets of MSFD management measures.

Management				
Measure code	Measure Target	Solution 1	Solution 2	Realization Cost (Average cost when 2 solutions are suggested)
<b>Interventions targeting waste management processes</b>				
MADIT-M083-NEW10, MICIT-M082 - NEW10, MWEIT-M085 - NEW10.	Design and implementation of measures for improving the management of waste generated by fishing and aquaculture activities (including disused equipment) encouraging its recycling and recovery.	Waste collection and management for garbage generated by fishery activities, 1 km <sup>2</sup> per each km of Italian coast		7336,951 €
7	Developing guidelines for biofouling control and management on boats	One operator per harbor dealing with biofouling		3016,000 €
10	Expand the collection, treatment and disposal of sewage in tourist harbors through the promotion of disposal facilities.	Waste management in tourist harbors (25,000€)	Waste management in tourist harbors (50,000€)	24,337,500 €
11	Preparation of a regulatory tool for the implementation of a collection and disposal chain for waste accidentally collected by fishermen, in implementation of Directive 883/2019.	Waste management of debris accidentally caught by fishermen		634,027 €
12	Design and creation of a supply chain for fish boxes to facilitate the transition from the use of disposable polystyrene boxes to washable and reusable boxes.	Facilitating the transition from the use of disposable polystyrene boxes to biodegradable and reusable boxes		2900,000 €
16	Design and creation of a marine waste recycling chain.	Recycling management chain for marine waste		255,200 €
17	Launch of experimental prototypes for the removal of micro-litter and plastics in sewage treatment plants	Installation of prototypes in purification plants serving > 10.000 inhabitants		330,500,000 €
<b>Interventions targeting other processes</b>				
1	Increase in the surface of MPAs to reach the target of 20 % of territorial waters under protection	Increase the extension of km2 of seas included in MPA to reach 20 %	Extension of km2 of seas included in MPA to reach 30 % (new objective under 30 × 30 agenda)	595,993,273€
9	Development of a measure for the authorization of Sewage Treatment Plant systems on vessels dislocating within territorial waters	Consultancy services		42,000 €
18	Moratorium on recreational (non-professional) fishing of specimens of species of high conservation value, such as groupers and brown meagre	Hiring of one operator for monitoring or training of existing employees in 60 maritime provinces		870,000 €
<b>Interventions with no additional implementation costs</b>				
3	Increase the mapped surface of biogenic seafloors of conservational interest in waters of national jurisdiction, in order to reduce the impacts of anchoring on protected habitats and quantification of the total km <sup>2</sup> of mapped surface.		Not Applicable	0 €
14	Preparation of a Ministerial Decree for the creation of EPR (extended producer responsibility) systems for the products referred to in article 8 of Directive 904/2019 and in the Annex PART E Section 1, for the correct deployment of nets for mussel farming and for fishing and aquaculture equipment.		Not applicable	0 €
			Total cost:	<b>965,884,951 €</b>

routes or which do not fall under the application of MARPOL. In this case, the target could be achieved through specific consultancy services to prepare guidelines for the promulgation of the legislation: the cost, according to the balance sheets of the Italian House of Representatives (Annex 1) is € 42,000.

**Measure 18** aims to establish a moratorium on recreational fishing of species of high conservation value such as groupers and brown meagre, by non-professional recreational and underwater fishing activities. The moratorium will apply to the following species: Brown grouper (*Epinephelus marginatus*), Golden grouper (*Epinephelus costae*), Black grouper (*Epinephelus caninus*), Red grouper (*Mycteroperca rubra*), Bottom grouper (*Polyprion americanus*), Corvina (*Sciaena umbra*). The introduction of specialized operators, together with the provision of information/education campaigns aimed at raising awareness of these species, could be the tools to reach the measure targets. It was estimated to hire one operator for each Italian maritime province (n = 60) at an average annual cost of €26,000 (Annex 1, Almalaurea, 2018) for a total cost of € 1560,000. The implementation cost of informative campaigns at a national level could be, like Measure 6, of € 3,000 for about 30 professional operators, for a total of € 180,000. For two measures

belonging to the Management group (no. 3 and no. 14) it was not possible to estimate the implementation costs using the value transfer methodology as they do not involve any additional costs other than the “business as usual” management of Italian policies.

The total cost related to management measures carried out in Italy is of € 965,884,951.

### 3.3. Monitoring and control measures

Monitoring measures support the assessment of current state in the marine environment, including biodiversity, habitats, and ecosystems. This assessment provides a baseline for future valuation of changes and develops effective management tools. The results are summarized in Table 5 and reported in the order displayed in the table.

In Monitoring and Control category, four out of six targets can be achieved through the introduction or training of professional profiles. The total costs for the implementation of the measure aimed at the acquisition, systematization and recognition of the data coming from the monitoring activities through the introduction of a professional figure for data analysis (i.e., MADIT - M032 - NEW3; MICIT - M032 - NEW3;

**Table 5**  
Proposed solutions and estimates of costs to achieve the targets of MSFD monitoring & control measures.

Monitoring and Control				
Measure code	Measure Target	Solution 1	Solution 2	Realization Cost (Average cost when 2 solutions are suggested)
<b>Interventions realizable through training or hiring of professional figures</b>				
MADIT - M032 - NEW3; MICT - M032 - NEW3; MWEIT - M035 - NEW3	Acquisition, systematization and homogenization of the monitoring data from EIA procedures	An operator working on systematization of datasets and one data analyst		53000 €
4b	Identification of edible non-indigenous species that, after a health assessment, can be included in the market.	One campaign in each Italian province (n = 75), cost shared with measure 4a		1312,500 €
5	Protocol for the implementation of the early warning system" in reference to alien and dangerous aquatic species, including the containment / mitigation measures to be adopted (EEA Technical report No 5/2010).	Consultancy cost for the draft of the early warning protocol	Active intervention costs relatable to mitigation of the impacts on alien species	863,038 €
6	Creation of a measure to make traceable all data of batches of bivalve mollusks: includes imports from other countries and transfers of batches from one plant to another at a national level to limit the spread and introductions of non-indigenous species	Training existing professional figures (for example Port Authority, Coast Guard...) in the identification of alien species.	Control system conducted by specifically trained new professional figures, expert in the identification of alien species	9318,000 €
13	Establishment of a technical table/committee for the monitoring and quantification of the marine litter	40 members included in the technical committee		240,000 €
19	Identification, geo-localization and monitoring of abandoned fishing gears with negative impacts on marine habitats.	Install specific geo-localization tools in the 20 200 Italian fishing vessels		404,000,000 €
			Total cost:	415,786,538 €

**MWEIT - M035 - NEW3** can be detailed as follows: € 24,000 per year for each trained operator working on the systematization of datasets and € 29,000 per year (Annex 1, Alamalaurea, 2018) for each data analyst. Assuming two full-time workers, the total cost would be of € 53,000.

In this section of monitoring measures there is the second part of **measure no. 4** which implies the identification of alien species. The implementation cost, equally to the share of costs attributed to the prevention category for this measure, is of € 1312,500 to carry out informative campaigns in all the Italian maritime provinces.

**Measure 5** requires the creation and implementation of an Early Warning system for alien species, in accordance with the EEA Technical report No 5/2010: the value transfer from Life Project RelionMed (Annex 1, RelionMed LIFE, 2022) allowed to establish at € 1676,077 the active intervention costs related to mitigation of the impacts of alien species, while the consultancy costs alone for the draft of the early warning protocol would amount to € 50,000.

**Measure 6** is established to make data related to all movements of batches of bivalve mollusks traceable and available at a national scale, including imports from other countries and transfers of batches from one plant to another at a national level. TRACES-NT System (TRAdE Control and Export System – New Technology), a veterinary Information Technology platform for reporting, certification and control of imports, exports and trade of animals and animal products was considered as tool to reach the target of the measure, as it already tracks the movement of shellfish between countries and between different plants within the same country. The system, which works as a link between the organizations (economic operators) and the institutional control officers, could be further exploited and integrated with additional monitoring by dedicated personnel. The target could be achieved with two different solutions and two different cost scenarios: the first implies a control system conducted by specifically trained new professionals, expert in the identification of alien species. In the second scenario, a control system was hypothesized by training existing professionals (for example Port Authority, Coast Guard, among others) in the identification of the alien species. Considering the total number of shellfish farming facilities,

shellfish purification centers (CDM), shellfish shipping centers (CSM), in Italy there are 714 centers to be monitored. At a unit cost of 26,000€ per year per operator, the implementation cost under Scenario 1 would be of € 18,564,000. Scenario 2 considers the training of already existing professionals operating in proximity of the 714 centers of interest (i.e., Port Authority, Sanitation Services) grouped in classes of approximately 30 people: assuming a cost of 3000€ per training campaign as suggested by expert opinion, and the need to conduct approximately 24 campaigns, the total cost of the measure would be of € 72,000.

The target of **Measure 13** can be reached through the establishment of a technical committee or by using consultancy services. Likewise Italian NRRP, it was estimated that 40 members should be included in the technical committee, for a unitary cost of € 6000 and a total cost of € 240,000 (Annex 1, Italian Ministry for Ecological Transition, 2021).

**Measure 19** aims at the identification and verification of functional tools for the geo-localization of fishing gear that have high negative impacts on ecosystems following loss at sea: to achieve the goal, it would be necessary to install specific geo-localization tools on the 20,200 (Italian Coast Guard data) Italian fishing vessels. Considering a unitary cost of € 20,000 as proposed by ISPRA (Annex 1, Italian Ministry of Environment and Energy Security, 2022), the total cost of the Measure would be of € 404,000,000.

The total cost of monitoring and control measures in Italy would amount to € 415,786,538.50.

#### 4. Discussion

Our study highlights that the cost of implementing the 23 MSFD measures in Italian seas is approximately €1.48 billion, which corresponds to 0.07 % of Italian GDP in 2023. Of the 8300 km of the total Italian coastline, we identified approximately 7470 km (90 % of the total) of coasts not occupied by infrastructure and other constraints. This allows estimating a cost of €188,000 per km of coastline on which MSFD measures are applied. Boschetto et al. [4], in an analysis of the characteristics of marine economic activities in the Italian coastal

municipalities based only on official statistics, estimated that in 2019, in Italy, there were 718,620 thousand employees in all marine activities, with a total production value of €115.6 billion and an added value of more than €37 billion. Notably, the estimated cost of implementing the MSFD measures in Italy represents just around 1 % of the total production value generated by marine activities, highlighting its relatively modest financial impact in relation to the economic significance of the marine sector.

The cost-analysis also highlighted that expenditure is unevenly distributed between the 3 main categories:

- i) Management measures were the most expensive group (about 65 % of the total costs). These costs expenditure include coordination, enforcement, and solutions development, which often require significant administrative and operational expenses. The prevalent investment in management measures reflects the need for immediate and tangible impacts but also shows the public administration and the (national/local) governments visible commitment in improving marine environmental quality. In addition, most of the solutions identified in management measures do not require heavy infrastructures and can be operated effectively in the short term. However, the success of these activities depends on complementary efforts in prevention and monitoring.
- ii) Monitoring measures rank second in the balance of the expenses, underlining the need for data collection in a standardized manner and their statistical analysis. Effective application of the MSFD requires a continuous assessment of environmental conditions, biodiversity, and human impacts, which entails significant technological and logistical investments. However, while effective monitoring is essential for adaptive management, allowing the identification of emerging issues and the effectiveness of management measures, monitoring alone cannot mitigate environmental degradation without preventive actions.
- iii) Prevention measures are therefore crucial for mitigating future environmental damage, although they account for 7.2 % of the total costs. A lower rate of expenditure in this category can be explained by the focus on reducing potential risks through education and awareness campaigns, which are generally less resource-intensive than other measures involving field-work activities or development of experimental equipment.

When computing the average cost for a single measure implementation (Table 6) it emerges that the cost of prevention measures (approximately € 18.65 million per measure) are 3–4 times lower than management and monitoring measures. This once again reflects the relatively lower resource demands for preventive actions, which often involve educational campaigns, awareness-raising activities, and policy development aimed at reducing future risks. However, their lower cost does not diminish their importance; rather, it highlights the cost-effectiveness of preventive approaches which have the potential to raise the awareness of millions of Italian citizens through educational campaigns conducted at local, regional or national level, even if measuring the penetration and retention of information can be challenging.

**Table 6**  
Average costs of measures in each of the three categories.

	Prevention	Management	Monitoring
Average cost of Measure Realization	18,650,637.36 €	80,490,412.58 €	75,597,552.45 €
Maximum cost of Measures	190,710,923.68 €	1430,867,082.00 €	425,845,577.00 €
Minimum cost of Measures	10,745,351.28 €	500,902,820.00 €	405,727,500.00 €

Almost 50 % of the measures address the issue of marine litter, a pervasive problem at a global scale that affects marine ecosystems and consequently human life [18,23]. This explains the relevance of measures dedicated to the waste-management, which highlights the effort dedicated to targets of Descriptor 10 (Marine Litter) of the MSFD. Other alternative measures, however, could be developed in the future to achieve also other targets of other descriptors once those of D10 will be achieved. The investments in prevention, for instance, should be further enhanced as they are the ones which will effectively bring about change towards the GES. Moreover, prevention is mainly dedicated to problems related to waste but does not include all other problems that cause habitat/ecosystem degradation.

The cost analysis presented here allows to make a first estimate of the implementation cost of a full cycle of MSFD measures but would require an *ex-post* valuation of the benefits. In fact, the effectiveness of the measures cannot be assessed *ex-ante* in most cases, as it depends on the specific service or product chosen to implement the measure itself (e.g., Whalesafe vs Repecet) or it may be difficult to assess with a uniform criterion, or may create long-term change through engagement with the public and resulting behavioral change (i.e. penetration of informative campaigns; aggregate result emerging at the macroscale from individual heterogeneous behaviors may be differing from the microscale - [16]). The implementation of some measures may show decreasing costs over time because technology must be purchased and then maintained until it becomes obsolete, or because the required training becomes less resource-intensive over time.

Despite the Italian commitment to marine environmental protection, the latest Commission report [13], in a comparative analysis of all Member States, reported a significant gap between projected and actual spending on MSFD measures, with only €2.4 billion currently allocated per year out of an estimated €5.8 billion needed. This underfunding of MSFD implementation suggests that several Member States, including Italy, may face relevant difficulties in achieving the targets. The spending needed for the MSFD implementation in Italy is substantial but is the result of a long history of underfunding, which has impacted the effectiveness of MSFD measures in achieving the GES. This could create a cycle of additional costs in the light of the recently adopted Nature Restoration Law (Regulation (EU) 2024/1991 on nature restoration and amending Regulation (EU) 2022/869), which requires Member States to restore at least 30 % of the areas of degraded terrestrial, inland water, and marine and coastal ecosystems, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity by 2030, 60 % by 2040 and 90 % on that surface by 2050 (Art. 4). It is therefore essential that all Member States align their financial commitments to their national priorities and European targets in order to avoid spending more on active restoration costs under the NRL than on the MSFD implementation, which can also work on prevention and monitoring [5,9].

## 5. Conclusions

This study provides for the first time a comprehensive cost valuation of the 23 MSFD measures proposed for the second cycle of MSFD in Italy, assessing their implementation costs considering the expected environmental benefits they can generate. By assessing these trade-offs, we developed a framework that ensures that resources are allocated to actions that maximize ecological impact, while remaining financially feasible.

Our analysis compared the costs and benefits of each measure, while taking into account both initial investments and ongoing operational expenditure. The benefits considered include improvements in biodiversity, ecosystem health and overall environmental quality, all of which contribute to the objectives set by the MSFD descriptors. Additional economic benefits can be envisaged by the lower costs projected for the MSFD implementation and in particular for its prevention measures, than those needed for the restoration of degraded marine habitats

[8].

We also explored several implementation scenarios, simulating different costs and levels of effectiveness. This approach allowed us to identify the scenarios with the best ecological return on investment. Aggregating individual cost-effectiveness scores across all 23 measures also allowed us to assess the overall efficiency of MSFD implementation, highlighting how these measures interact and complement each other. The results indicate that reallocating resources between the three categories of measures (prevention, management and monitoring) could improve cost-effectiveness in the long term. Future planning could therefore focus on redistributing the budget between the three groups of measures. In particular, prevention measures are emerging as a crucial and cost-effective strategy, providing long-term benefits that reduce the need for costly reactive interventions. Integrating prevention with management and monitoring actions within an ecosystem-based adaptive framework, supported by strong public engagement, can further strengthen marine conservation efforts. By providing data-driven insights, this study contributes to improving the planning and implementation of future MSFD measures and provides data for their future implementation to ensure healthier and more resilient marine environment for future generations. Enhanced regional cooperations, as advocated in the Commission's 2025 report, could lead to a more efficient use of Member State resources and sharing of the best and most economic-effective practices, ultimately contributing to reduce the costs and increase the success of the MSFD's targets. These results will help policy makers to optimize resource allocation and ensure a more effective approach to the protection and health of marine ecosystems, ensuring their provision of ecosystem services and the benefits for future generations.

#### CRedit authorship contribution statement

**S. Gallegati:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **S. Bianchelli:** Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **F. Marcellini:** Writing – original draft, Methodology, Formal analysis, Data curation. **R.G. Boschetto:** Writing – review & editing, Supervision, Conceptualization. **A. Capriolo:** Writing – review & editing, Conceptualization. **C. Corinaldesi:** Writing – review & editing, Validation. **G. Giorgi:** Supervision, Conceptualization. **R.A. Mascolo:** Writing – review & editing, Conceptualization. **E. Nepote:** Data curation. **A. Sagrati:** Data curation. **R. Danovaro:** Writing – review & editing, Project administration, Conceptualization.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Acknowledgements

This study was supported by the agreement between ISPRA and Università Politecnica delle Marche within the scope of art. 12 and art. 17 of Legislative Decree 13 October 2010, n. 190 concerning the implementation of Directive 2008/56/EC; by Project DiverSea (HORIZON-CL6-2022-BIODIV-01, Grant agreement 101082004); and by the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4—Call for tender no. 3138 of 16 December 2021, rectified by Decree no. 3175 of 18 December 2021 by the Italian Ministry of University and Research, funded by the European Union—NextGenerationEU, Award Number: project code CN\_00000033, Concession Decree No. 1034, of 17 June 2022, adopted by the Italian Ministry of University and Research, Project title “National Biodiversity Future Center—NBFC. We would like to thank the experts who supported

our cost estimations with their valuable insights and extensive experience in the field.

#### Annex 1. : Source of information at national/regional/local level from grey literature

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#### Appendix B. Supporting information

Supplementary data associated with this article can be found in the

online version at [doi:10.1016/j.marpol.2025.106715](https://doi.org/10.1016/j.marpol.2025.106715).

## Data availability

Data will be made available on request.

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