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EFFECTIVE

PROTECTION AND RESTORATION MANAGEMENT · MEDITERRANEAN MPAS

Enhancing social well being and economic prosperity by reinforcing the eFFECTIVEness of protection and restoration management in Mediterranean MPAs

D3.2 Provisioning Ecosystem Services Report

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EXECUTIVE SUMMARY

This report assesses the provisioning ecosystem services of Pilot Area 1 within the EFFECTIVE project, focusing on the Empordà Sea (Costa Brava), the Marine Protected Area (MPA) of Montgrí–Illes Medes–Baix Ter, and the Life Boosting Units (LBUs). It establishes the methodological and analytical foundations for integrating provisioning ecosystem services into a Natural Capital Accounting (NCA) framework in line with SEEA-EA standards.

The study identifies and prioritizes the key provisioning services delivered by marine ecosystems in the northwestern Mediterranean. Using the CICES v5.2 classification and complementary approaches such as IPBES Nature's Contributions to People and the TNFD ENCORE tool.

Results show that the Empordà Sea provides significant provisioning outputs, which are influenced by socio-economic pressures including fishing, nautical tourism, aquaculture and coastal infrastructure, highlighting the importance of managing drivers within the D(a)PSWR(m) framework.

At the MPA scale, provisioning services include extractive resources such as aquatic animals and *Posidonia oceanica* remains, complemented by regulating and cultural services that underpin ecosystem health and societal well-being. The LBU scale demonstrates how nature-based solutions installed on artificial infrastructures can enhance provisioning services by increasing biomass, supporting genetic material availability, reinforcing nursery habitats, and improving water quality.

The report demonstrates that provisioning ecosystem services are essential for local economies and coastal community livelihoods. Their condition is tightly linked to human pressures and ecosystem states, underscoring the need for adaptive management and restoration actions. The findings support the development of a transferable and replicable Natural Capital Accounting system for Mediterranean MPAs.

The work undertaken here will feed directly into Deliverable D3.3 (2026), which will expand the analysis to include regulating and cultural services, and establish full physical and monetary accounts for natural capital assets. This contributes to the broader objective of strengthening evidence-based management, advancing ecosystem-based governance, and improving protection and restoration of Mediterranean marine ecosystems.

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SYMBOLS, ABBREVATIONS AND ACRONYMS

CICES	Common International Classification of Ecosystem Services
EBM	Ecosystem Based Management
ES	Ecosystem Services
EEA	European Environment Agency
OECM	Other Effective area-based Conservation Measures
MPA	Marine Protected Area
NCA	Natural Capital Accounting
LBU	Life Boosting Unit
UNSD	United Nations Statistics Division
SEAA-EA	System of Environmental Economic Accounting - Ecosystem Accounting

INTRODUCTION

EFFECTIVE Project is a European Union's Horizon Europe innovation program whose main objective is to develop a comprehensive scientific knowledge base and practical guidance, combining science, technological nature-based solutions, digitalization and social engagement for the application of the Ecosystem Based Management (EBM) approach to the protection and restoration management of the EU's Mediterranean Blue Natural Capital.

Reinforcing ecosystem (ES) services to increase https://www.youtube.com/watch?v=zIVHKI88d_Mse the resilience of the blue natural capital in MPAs is one of the main aims of the project. To pursue this goal, the project has been working on ES identification, prioritization, and, in the case of the provisioning services, valuation at three different scales: the Empordà Sea. The Natural Park of Montgrí, Illes Medes i Baix Ter, and the Life Boosting Systems (LBUs).

A second objective of this work was to link these ES with marine restoration actions to assess in which way better management and restoration practices can contribute to the improvement of such ES.

To fulfil this objective in 2024, Ecoacsa proposed a methodological guide for accounting provisioning, regulating and cultural ES that are transversal for marine environments and can be found in Mediterranean MPAs such as Pilot area 1. The guide will be added in the future presentation of Deliverable 3.3 – Natural capital assets evaluation report.

In 2025, Pilot Area 1 was used to develop this objective in relation to activities carried out in the Parc Natural del Montgrí, les Illes Medes, i el Baix Ter, a Marine Protected Area (MPA) in Costa Brava (Catalonia, Spain). In addition, a Natural Capital Accounting (NCA) system was applied not only to the MPA, but also to a Life Boosting Unit (LBU).

Throughout this year, Ecosystem Services Prioritization activities (i.e. questionnaires) were distributed to capture not only Spanish north-Catalan coast perception on MPA's most significant ES, but also north-Basque country coast's viewpoints - due to the synergies created with OCEAN + project.

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Throughout 2025, efforts to link human pressures with ecosystem services in Pilot Area 1 were undertaken to better assess and monitor, in the future, the condition of marine ES based on the pressures affecting the area.

This study contributes then, to the development of a system that is transferable and replicable for all MPAs in the Mediterranean. Therefore, it is intended to contribute to an effective management of MPAs through a Natural Capital Accounting (NCA) system.

This pilot study is used to capture and visualize the links between changes in the marine environment and its economic impact in the Medes Islands. To do this, initially this research provides information about the services given by the Pilot 1 region to focus later on the provisioning ones.

Based on the 2024 methodological guide for accounting provisioning, regulating and cultural ES, and EFFECTIVE's upcoming tasks for 2026 -particularly task 3 and the deliverable D3.3 – Natural capital assets evaluation report. This current report aims to build a bridge between theory (methodology) and practice (Pilot 1 actions on the ground and primary data generation). Furthermore, the current report seeks to facilitate the results for the provisioning ecosystem services, to the natural capital evaluation (to be conducted between January-May 2026), so that by then, only data for regulatory and cultural ES is gathered and assessed. The overall aim for 2026 and D.3.3 is then to create a robust and coherent accounting framework to describe the extent, status and value of natural capital assets and the services and benefits derived from MPAs. In order to fully capture the real impact on ocean assets.

The research carries out an identification and monetization of the natural assets and ecosystem services provided by the MPA and the LBU (Table 1). That in turn, allows for the development of a natural capital accounting model that efficiently and robustly informs decision-makers in the region.

This report aims to answer the three questions below, with a strong focus on the pilot study of **Medes Islands' MPA and in the LBUs**.

- Ecosystem Services identification in the Pilot 1 area (Empordà Sea)
- What provisioning services do MPAs provide?
- What provisioning services do LBUs provide, and what is the approximate economic value of those benefits (services)?

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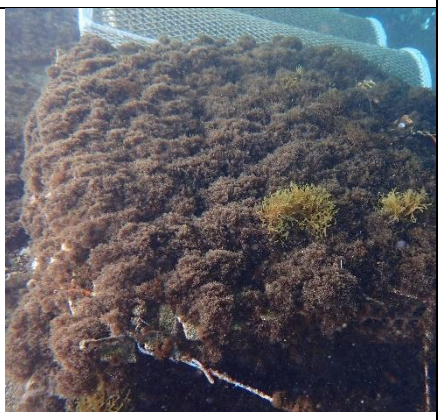
Table 1. Scope of study

BROAD SCOPE - LOCAL	BROAD SCOPE – MPA (HA)	NARROW SCOPE (M2)
Empordà SEA (Costa brava)	Parc natural del Montgrí, les Illes Medes, i el Baix Ter (Catalonia, Northewestern Mediterranean	Life Boosting Units
		

The Ecosystem Services Concept within Social-Ecological Systems

The natural systems generate a multitude of functions that are fundamental for its functionality, such as water purification, coastal protection, and carbon sequestration, among others, which ultimately serve as a vital and essential support for human development as a species. The ecosystem also provides a whole range of relational aspects between humans and nature, which help us experience pleasure and well-being, nourish our aesthetic and spiritual senses, and provide entertainment. All these tangible and intangible benefits that humans receive from nature have been encompassed for several decades under the now widely popular concept of ecosystem services (ES), which groups together a whole range of environmental goods and services provided by nature (Daily, 1997; de Groot et al., 2002; Gómez-Baggethun et al., 2010; Sardá, 2013).

The concept of ecosystem services (ES), initially referred to as "environmental services," was first mentioned in the report "Study of Critical Environmental Problems" (SCEP, 1970; revised by Daily in 1997). Any degradation of these services was intrinsically linked to poor ecosystem health and functionality. Subsequently, the concept was slightly modified by Ehrlich et al. (1977) under the new name "public services of the global ecosystems," and later by Westman (1977) as "nature's services," finally arriving at its definition as ecosystem services (ES), a definition accepted and used in numerous works (Boyd & Banzhaf, 2007; Costanza et al., 1997; Daily, 1997; De Groot, 1992; de Groot et al., 2002; Ehrlich & Ehrlich, 1981; Gilbert & Janssen, 1998, and numerous subsequent works). For years the definition of this concept was prevailed by the description made by Daily (1997) "*conditions and*

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processes through which natural ecosystems, and species that make them up, sustain and fulfil human life".

The concept, however, was revitalized by the publication of the United Nations Millennium Ecosystem Assessment (2005), which more concisely defined ecosystem services (ES) as "*the benefits that people obtain from ecosystems*". Both definitions (Daily, 1997; Millennium Ecosystem Assessment, 2005) establish clear links between ecosystem services and human well-being by recognizing that ecosystems, if managed and protected sustainably, can benefit people and societies now and in the future. The concept of ecosystem services thus illustrates the flow of benefits that nature provides to humankind and offers a conceptual framework that can be applied to the management of these natural public goods, whether in managing their protection and restoration or in planning their sustainable uses.

However, natural resources cannot be treated as discrete entities to be analyzed independently of the human variable, as they are dependent on the social and economic systems with which they interact. For some years now, to analyze this complexity, this relationship has often been invoked using another concept: that of social-ecological systems (Berkes & Folke, 1994). In fact, the Millennium Ecosystem Assessment report (2005) strongly introduced the social-ecological paradigm, the paradigm within which sustainable development strategies should be studied. A social-ecological system (Image 1) is a complex adaptive system in which humans are part of nature and the dynamics of both dimensions are strongly linked. The definition of a social-ecological system is entirely adaptable to the geographical boundaries established for its study at three different scales: a) Empordà Sea, b) Parc Natural del Montgrí, les Illes Medes, i el Baix Ter, and c) Life Boosting Units.

Social-ecological systems can be studied through various information platforms. In the EFFECTIVE project, we initially decided to follow up on an adaptation of the one developed by Cooper (2012) to properly organize information on the interrelationship between human and natural subsystems. This framework, DPSWR-"Driver-Pressure-State-Welfare-Response" was an evolution of the former DPSIR framework (DPSIR - "Drivers-Pressures-State-Impacts-Responses"). Some authors have added extra elements to this framework, such as the D(A)PSI(W)RM model (Elliott et al., 2020). Departing from this latest proposal, we have been working on the information pillar of the Ecosystem-Based management System that the project has generated, the proposed framework D(a)PSWR(m). Human systems constitute the driving forces of change ("Drivers" - D) through their activities (a). These activities exert pressures on the natural systems with which they interact ("Pressures" - P). Consequently, natural systems (their structural units and the functions they perform) can alter their states ("States" - S). This can ultimately lead to the degradation of fundamental natural resources used by humans (ecosystem goods and services), thereby diminishing human well-being ("Welfare"). Recognizing this degradation should enable society to develop appropriate formal or informal responses ("Responses" - R) by implementing suitable measures (m) to manage any observed patterns of degradation. The information generated through the DPSWR framework expresses these problems in a highly interconnected way, which is difficult to observe using other sets of indicators that report on the different elements of the social-ecological system in isolation. **In the aforementioned framework, being able to determine how these ecosystem services affect human well-being ("Welfare") is**

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essential for making the best possible decisions for managing the social-ecological system under study.

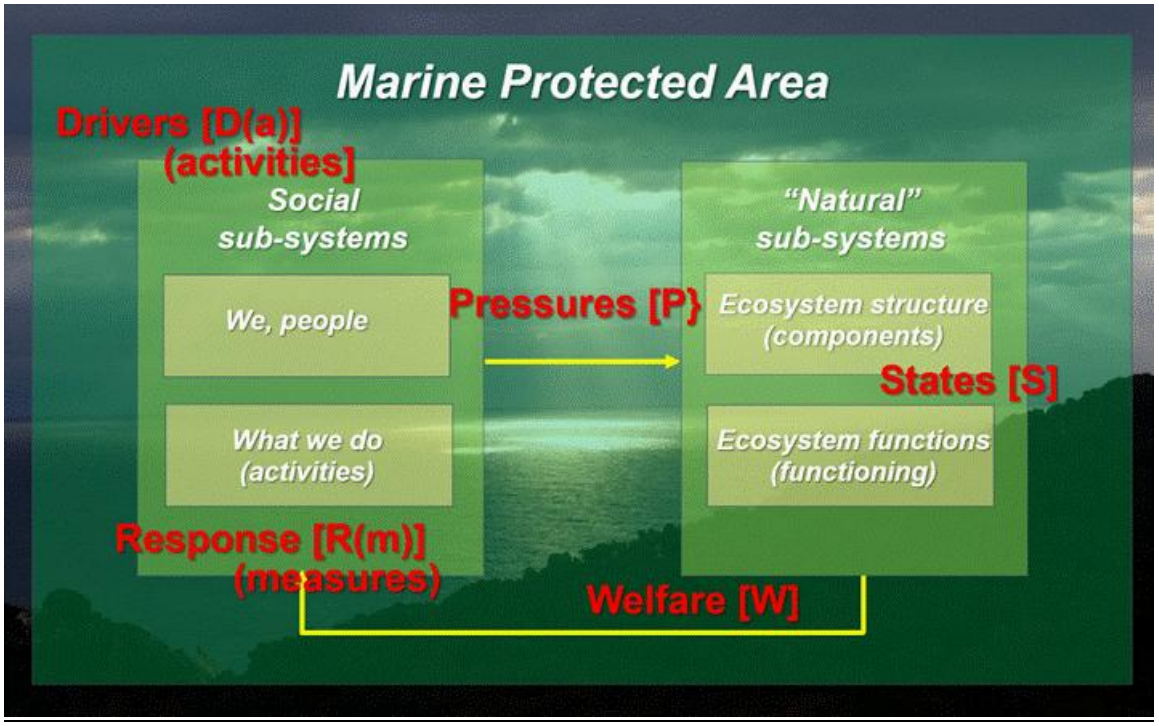

Figure 1. The D(a)PSWR(m) accounting framework

Methodological approach: From Ecosystem Services in CICES methodology to a prioritized list for provisioning Ecosystem Services

Departing from the classical work of Daly (1997), in the literature, we can find different classifications to hierarchically arrange ecosystem services. Just centering our findings in the last 25 years, two studies from the first decade of this century, "Millennium Ecosystem Assessment (2005),"and "Economics of Ecosystems and Biodiversity" (TEEB, 2012), classified four categories of ecosystem services (ES): provisioning services, regulating services, supporting services (including habitat services, which appear as a fifth group in some studies), and cultural services. However, since 2009, a new international classification of ES has been developed, **the Common International Classification of Ecosystem Services (CICES) (EU Commission/JRC 2013),** which has gained wider acceptance within the scientific community. The most recent version of this classification is v. 5.2. Although initially the generation of an ecosystem service was thought to involve processes carried out from living organisms (showing

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dependence on them), today it is accepted today that abiotic components of the system can also provide ecosystem services and are therefore included in the classification.

The deliverable we are presenting makes use of the CICES methodology. CICES categorizes the ES offered by different assets while offering a standardized and regulated framework that identifies more than 90 ES. In addition, it classifies the different ES according to section, division, group, class, and type and it makes the following distinction of ES. At the very beginning, CICES classified ES into three categories: provisioning. regulating and maintenance, and cultural services:

- Provisioning services: materials or products we obtain from ecosystems. Food, water, raw materials, medicinal resources, ornamental resources, and genetic resources.
- Maintenance and regulating services: benefits obtained from the regulation of ecosystem processes. Climate regulation, carbon sequestration, disease regulation and biological control, water flow regulation and purification, air quality management and climate regulation, soil fertility maintenance, erosion prevention, and pollination. Also included are certain supporting services such as soil formation, nurturing, and genetic protection.
- Cultural services: non-material (intellectual/cognitive/symbolic) uses of ecosystems. Spiritual and religious uses, recreation and ecotourism, aesthetic enjoyment, inspiration for culture, art and design, educational and cognitive development, and cultural heritage.

Furthermore, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), that serve as advisor for the UN Conference on Biological Diversity, defined the concept Nature's Contributions to People (NCPs) as those contributions, both positive and negative, of living nature (i.e., all organisms, ecosystems, and their associated ecological and evolutionary processes) that affect the quality of human life. NCPs can be related also to the Ecosystem Services classification. In this case, IPBES identifies 18 categories of NCPs, which are assigned to three broad groups within the general perspective: material, non-material, and regulatory (Figure 2).

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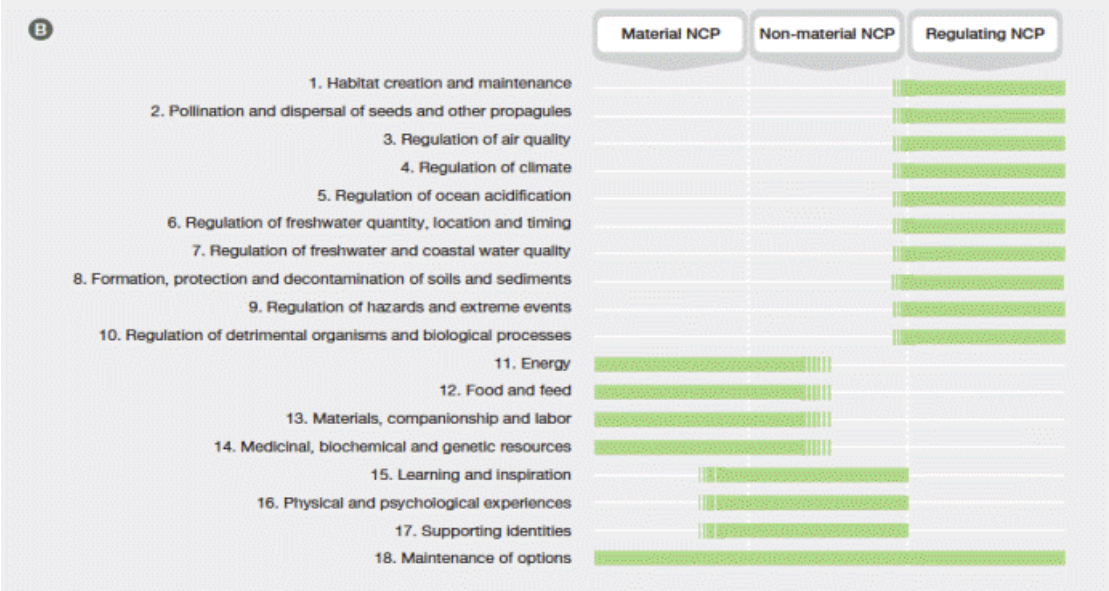

Figure 2 The 18 CNP categories and their assignments to the three groups: material, non-material, and regulatory non-material.

Provisioning Ecosystem Services

Provisioning ecosystem services in the marine environment are the **tangible goods and resources** that humans directly obtain from marine and coastal ecosystems. As seen in the latest classification, NCPs could be grouped into 4 different topics: food, energy and water, inert materials, and genetic resources. Using the ENCORE tool for TNFD's LEAP approach, we can describe basically these services as observed in Table 2.

Table 2. Provisioning Services description following ENCORE

Biomass provisioning services	Biomass provisioning services include the ecosystem contributions to the growth of the following: cultivated plants that are harvested by economic units for various uses including food and fibre production, fodder and energy; grazed biomass that is an input to the growth of cultivated livestock; cultivated livestock and livestock products (e.g., meat, milk, eggs, wool, leather); animals and plants (e.g. fish, shellfish, seaweed) in aquaculture facilities that are harvested for various uses; trees and other woody biomass in both cultivated (plantation) and uncultivated production contexts that are harvested for various uses including timber production and energy; fish and other aquatic biomass that are captured in uncultivated production contexts for various uses; wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts for various uses. Biomass provisioning services are final ecosystem services (except the grazed biomass provisioning services, which may also be an intermediate service to livestock provisioning services). • Capacity for marine species cultivation (aquaculture) • Provision of marine species (fishing, shellfish harvesting, seaweed collection)

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Water and Energy provisioning services	Water and Energy supply services reflect the combined ecosystem contributions of energy provision, water flow regulation, water purification, and other ecosystem services to the supply of energy for human purposes and water of appropriate quality to users for various uses including household consumption. This is a final ecosystem service. • Capacity for the use of marine waters (desalination, medicinal materials, wave energy, or extraction for industry or leisure - spas) • Capacity for offshore wind energy production
Inert Material provisioning services	Inert Materials providing services related to the supply of materials that are not chemically or biologically reactive, such as concrete, brick, stone, and soil, for various uses like construction, landscaping, or security training. These services can involve the provision of new materials and may constitute a final ecosystem service. • Provision of mineral and non-mineral substances (extraction of salt, petroleum, gas, sediments)
Genetic Materials provisioning services	Genetic material services are the ecosystem contributions from all biota (including seed, spore or gamete production) that are used by economic units, for example (i) to develop new animal and plant breeds; (ii) in gene synthesis; or (iii) in product development directly using genetic material. This is most commonly recorded as an intermediate service to biomass provisioning. • Provision of genetic material (for organism reproduction and conservation)

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Natural Capital Accounting

The information compiled in this deliverable provides the basis for the Natural Capital Accounting analysis to be developed in D3.3. Specifically, it offers:

The identification and scope of the provisioning ecosystem services relevant to Pilot Area 1, preliminary economic values available for fisheries and aquaculture, description of the ecosystem assets linked to provisioning services and the indicators and categorization that support the integration of provisioning services into the SEEA-EA framework.

These elements will be further developed in D3.3 to establish coherent physical and monetary accounts for the natural capital present in the pilot area.

Those questions raised above, are consistent with all natural capital accounting processes derived from the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA - EA) framework, namely they are aligned with international level guidance (Figure 3).

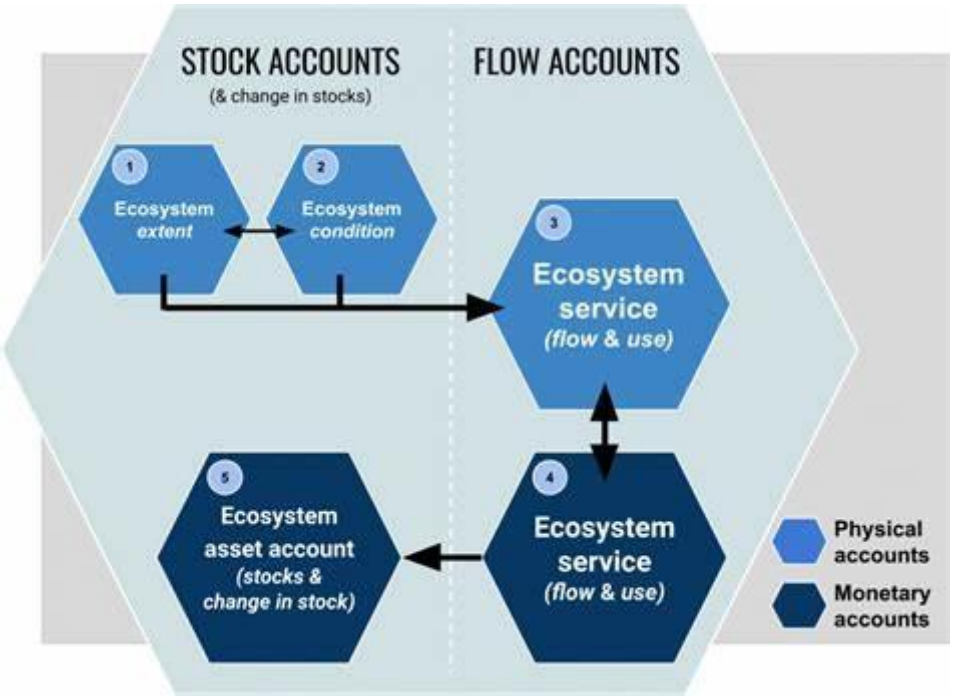

Figure 3. Conceptual diagram of the different accounts that constitute the Natural Capital Accounting framework. [Source: United Nations, SEEA EA]

Regarding the pre-identification of Ecosystem Services (ES), this study makes use of the CICES methodology – which was developed by the European Environment Agency (EEA) and is directed by the United Nations Statistics Division (UNSD). CICES categorizes the ES offered by different assets while offering a standardized and regulated framework that identifies more than 90 ES. In addition, it classifies the different ES according to section, division, group, class, and type and it makes the following distinction of ES.

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Results Obtained

This section presents results obtained in the identification, prioritization and valuation of ES for the three scales worked out in the project, 3.1, the Empordà Sea (Costa Brava), 3.2, the Parc Natural del Montgrí, les Illes Medes, i el Baix Ter, and 3.3, the LBUs scale.

However, all these ES must be filtered and prioritized using specific criteria linked to the EFFECTIVE project EBM framework. Such criteria shall in turn be aligned with:

1. Local ecosystem assets presented in the Medes Islands MPA.
2. Asset components related to marine natural capital.
3. Economic relevance to activities within the area.
4. Quantification is technically affordable for the LBUs scale.

Empordà Sea (Costa Brava)

Socio-economic context and sectoral pressures in the study area

The Empordà Sea and the Parc Natural del Montgrí, Illes Medes i Baix Ter are influenced by socio-economic activities closely linked to marine resources. The sectors with the strongest interaction with provisioning ecosystem services include small-scale fisheries, aquaculture, tourism, nautical activities, and port operations.

Fishing and aquaculture contribute to local employment and supply chains, while tourism generates strong seasonal demand for marine-related services. These activities also contribute to the pressures affecting marine ecosystems.

The main sectoral pressures influencing provisioning ecosystem services include:

- Fisheries: extraction of marine biomass and interaction with sensitive habitats.
- Tourism and nautical activities: anchoring, vessel traffic, increased turbidity and waste.
- Aquaculture: localised organic inputs and potential eutrophication.
- Coastal and port infrastructures: habitat loss and artificialisation of the coastline.

Identifying these pressures supports the interpretation of changes in the state of ecosystem assets and their provisioning capacity within the DPSWR framework used by the Project.

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The Empordà Sea occupies around 80% of the littoral and platform sea area of the Costa Brava (Northwestern Mediterranean Catalonia-Spain). It is a Key Biodiversity Area located in Spain with 7 different MPAs coexisting on it, including Special Areas of Conservation (SAC) and Sites of Community Importance (SCI) under the EC Habitats Directive (92/43/EEC), Special Protection Areas (SPA) under the EC Birds Directive (2009/147/EC), and Specially Protected Areas of Mediterranean Importance (SPAMI) under the Barcelona Convention of 1976. The ecosystem richness of this pilot area is highlighted by the presence of important species such as red coral (*Corallium rubrum*) and rocky habitats of community importance formed by gorgonians and sponges, seagrass meadows of *Posidonia oceanica* and *Cymodocea nodosa*, and a large number of protected species.

In a previous work (Ocean+ project), a general compilation of ES literature in Spain was carried out. The review listed 37 papers that contain information on ES in the coastal and marine regions of the country. A total of 63 ES were identified and ordered following the categories established in the CICES classification (provisioning, regulation and maintenance, and cultural). The category with the most ES identified is regulation and maintenance, with 25 ES, followed by provisioning ES (21 ES) and cultural ES (17 ES). The ES category that appears most frequently in the literature was cultural ES (18%), followed by regulation and maintenance ES (15%) and finally provisioning ES (11%). A general report was carried out with this information (Murilllas et al., 2024).

Departing from these 63 ES, we adapted the list to several ones to be followed in Pilot 1 (Empordà Sea, Costa Brava region), in relation to the information pillar of the Ecosystem-Based Management System. For the presented deliverables, we put special attention to the provisioning ones. Table 3 contains all the complete list for the Empordà Sea.

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Table 3. ES identified for the Costa Brava region

Filter	Section	Division	Group	Descriptive section	5.2 Code	OCEAN+ code	Class type	
CICES (Biophysical ecosystem services))	Provisioning (Biotic/Biophysical)	Biomass	Cultivated aquatic plants and reared aquatic animal for nutrition, materials or	Plants cultivated and animal reared by in- situ aquaculture grown for nutritional purposes	1.1.2 / 1.1.4	A1 / A2	*By source type*	AQUACULTURE
CICES (Biophysical ecosystem services))	Provisioning (Biotic/Biophysical)	Biomass	Wild plants and animals (terrestrial and aquatic) for nutrition, materials or	Wild plants and animals (terrestrial and aquatic, including fungi, algae) used for nutritionak purposes	1.1.5 / 1.1.6	A3 / A4	*By source type*	PLANTS OBTENTION
CICES (Geosystem outputs)	Provisioning (Abiotic/geophysical)	Water	Surface/Ground water used for nutrition, materials or energy	Seawater used for human uses	4.1.1/2	A7	*By type or source*	DESALINATION
CICES (Geosystem outputs)	Provisioning (Abiotic/geophysical)	Water	Other aqueous ecosystem outputs	Other: in this case, physical spaces that requires a licensing permit	4.1.X.X	A21	*Use nested codes to allocate other provisioning services*	PHYSICAL SPACE
CICES (Geosystem outputs)	Provisioning (Abiotic/geophysical)	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials or energy	Mineral substances used for material purposes, including geophysical support (foundations).	4.2.1	A22	*By type*	BEACH NOURISHMENT
CICES (Geosystem outputs)	Provisioning (Abiotic/geophysical)	Non-aqueous natural abiotic ecosystem outputs	Non-mineral substances or ecosystem properties used for nutrition, materials or	Wind energy	4.2.2	A17	*By type*	WIND ENERGY
CICES (Ecosystem Services)	Regulation & Maintenance (Biotic/Biophysical)	Transformation of biochemical or physical inputs to ecosystems	Reduction of nutrient loads and mediation of wastes or toxic substances of	Filtration/sequestration/storage/accumulatio n by micro-organisms, algae, plants, and animals	2.1.1	R1	*By type of living system, or by water or substance type*	WASTE REMEDIATION
CICES (Ecosystem Services)	Regulation & Maintenance (Biotic/Biophysical)	Regulation of baseline flows and extreme events	Hazard mitigation	Control of seawater and erosion. Flood and storm surge mitigation	2.2.1 / 2.2.3	R3	*By type of living system or geographical context*	HAZARD MITIGATION
CICES (Ecosystem Services)	Regulation & Maintenance (Biotic/Biophysical)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining or regulating nursery populations and habitats or breeding grounds (Includes gene pool protection)	2.3.2	R8	*By type of living system or geographical context*	HABITAT/SPECIES PROTECTION
CICES (Ecosystem Services)	Regulation & Maintenance (Biotic/Biophysical)	Regulation of physical, chemical, biological conditions	Water conditions	Regulation of the chemical condition of salt waters by living processes	2.3.5	R18	*By type of living system*	WATER CONDITION
CICES (Ecosystem-Geosystem Services)	Regulation & Maintenance (Biotic/Biophysical)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere by biotic and abiotic components	2.3.6 /5.2.2	R20-R21	*By contribution of type of living system to amount,*	CARBON CAPTURE
CICES (Geosystem outputs)	Regulation & Maintenance (Abiotic/geophysical	Regulation and maintenance of geophysical	Regulation of baseline flows and extreme events	Abiotic regulation of mass flows	5.2.1	R19	*By type*	ATMOSPHERE REGULATIOn
CICES (Ecosystem-Geosystem Services)	Cultural (Biotic/Biophysical)	Physical and experiential interactions with	Direct, in-situ and outdoor interactions with living systems that depend on	Elements of living and geological systems systems that that enable activities promoting health, recuperation or enjoyment through	3.1.1 / 6.1.1	C1	*By type of living system or geological characteristics or*	RECREATION
CICES (Ecosystem-Geosystem Services)	Cultural (Biotic/Biophysical)	Intellectual and representative interactions with	Direct, in-situ and outdoor interactions with living systems that depend on	Elements of living and geological systems that enable scientific investigation or the creation of traditional ecological knowledge	3.2.1 / 6.2.1	C5 / C6 / C7	*By type of living system or geological characteristics or*	SCIENCE-EDUCATION
CICES (Ecosystem-Geosystem Services)	Cultural (Abiotic/geophysical)	Spiritual, symbolic and other interactions with living and geophysical	Other biophysical elements of species or ecosystems that are	Elements or features ofliving organisms geophysical systems whose contemporary existence or conservation is important to	3,4,2 / 6.4.2	C8 / C9	*By type of geophysical characteristic or*	EXISTENCEVALUES
CICES (Geosystem outputs)	Cultural (Abiotic/geophysical)	Other characteristics of living systems that have cultural	Other	Other	6.5.X	C15	*Use nested codes to allocate other cultural services by*	CULTURAL ASPECTS

We measured ES using the year 2022 as the reference one. From the eight provisioning services selected at a CICES 5.2 group level (table2), four of them have no measurable action: the desalinayion plant in the Costa Brava is not located in the Empordà Sea; offshore wind energy still has not be implemented in the zone despite projects forecasted for the future; no becah nourishment was carried out during 2022, and no measures for physical space licensing was documented. We concentrate our measures in both aquaculture and fisheries provisioning services were data is presented in an aggregated manner (source: ocean+ project).

1.1.4.- Capacity for marine species cultivation (**aquaculture**)

- In particular, the marine aquaculture production for fattening marine animals in 2022 in the Levantino-Balear maritime delineation accounted for 41.479,88 tonnes, while only for the Costa Brava was 656,38 tonnes in 2022.

- On another note, the marine aquaculture production from marine animal farms in Spain in 2022 in the Levantino-Balear maritime delineation accounted for 69.012.372 units.

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- The monetization of such aquaculture ecosystem services in 2022 in the Levantino-Balear maritime delineation represented in turn 372.531.091,66 €, from which 4.630.942,39 € stem from Costa Brava.

1.1.5 / 1.1.6.- Provision of marine species (fishing, shellfish harvesting, seaweed collection)

- The value of wild plant provisioning services and wild marine animal provisioning services in 2022 in the Levantino-Balear maritime delineation was 228.424.086 €, and Costa Brava represented 32.576.564 €

- For the same year, in the same region the value of seaweed aquaculture resulted in 1,45 tonnes, and just 0,05 tonnes in Costa Brava. Which constituted a value of 193.226€ in the Levantino-Balear demarcation) and of 6.564,91€ in Costa Brava *.NOTE: This type of provisioning ecosystem service includes supply of food, materials or energy. This seaweed can be sold at commercial size or as seeds. Cyanobacteria, although currently classified as bacteria, are considered here, as in the past, to be algae because they contain chlorophyll (which enables them to perform photosynthesis). However, it is less common than the marine mammals' aquaculture as revealed by data.*

Parc Natural del Montgrí, les Illes Medes, i el Baix Ter

Table 4. Ecosystem Services pre-identified for the MPA. [Source: Own elaboration. Using CICES V5.1 (2023)]

	CICES CODE	SERVICE	Includes:
Provisioning	1.1.6.1	**Aquatic animals for nutrition**	Fishery resources that are extracted from the MPA
	1.1.5.3	**Posidonia remains**	Fallen leaves from *Posidonia oceanica* have several uses such as insulation for buildings, sewage water decontaminating element and composting element. The use of remains of *Posidonia oceanica* depends on national regulations.
Regulation	2.2.5.1	**Water quality improvement**	Posidonia oceanica meadows and other ecosystems improve water quality thanks to the retention of suspended particles, both living and dead, through their roots and leaves. In this way, these ecosystems act as a filter to improve the quality and transparency of the water
	2.2.1.3	**Protection of coastal erosion**	Posidonia oceanica meadows protect the coast from wave erosion by fixing and stabilizing sediments and preventing them from being mobilized by waves, thus eroding the coast. On the other hand, the leaves that separate from the planting each yearly cycle, end up on the beaches and help dissipate-absorb the energy

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			of the waves, thus protecting the coast from erosion.
	2.2.6.1	**Maintenance of biodiversity**	All marine ecosystems contribute to generate and nurture life. This service has to do with the capacity of ecosystems to sustain populations in their first stages of life.
	2.2.6.3	**CO2 capture**	Posidonia oceanica and Cymodocea nodosa meadows play an important role in capturing CO2 and are considered among the largest blue carbon sinks behind mangroves and kelp forests.
Cultural	3.1.1.1 and 3.1.1.2	**Active or passive recreational activities**	Active and passive interactions between human beings and biotic and abiotic systems, with the aim of promoting well-being, health or simply the enjoyment of natural environments. Such activities include diving, excursions, boat trips and visiting beaches.
	3.1.2.1 and 3.1.2.2	**Scientific research and education**	Activities that contribute to human knowledge. This service collects and values the function and quality that habitats have as a source of knowledge and field of transfer of teachings and training in theoretical-practical skills.
	3.2.2.1, 3.2.2.2 and 3.2.2.3	**Existence, option and legacy value**	Value given by society to some natural assets that show the interest that people have in conserving them to enjoy them, so that they simply exist or so that they are preserved for future generations.

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Life Boosting Units (LBUs)

Within the framework of the project, the Life Boosting Units (LBUs) represent a scalable nature-based solution that enhances the ecological functions of coastal and marine infrastructures. As part of the broader objective of reinforcing ecosystem services to improve the resilience of Mediterranean Blue Natural Capital, LBUs offer a relevant case study for understanding how localized restoration actions contribute to the provision, maintenance, and strengthening of key ecosystem services.

Building on the identification and prioritization work conducted in Pilot Area 1 (Empordà Sea, including the Natural Park of Illes Medes, Montgrí and Baix Ter), and drawing from the Natural Capital Accounting assessment carried out for both the MPA and the LBU,this section summarizes the ecosystem services directly supported by the LBUs.

Table 5. ES identified from the LBUs [Source: Own elaboration.]

Provisioning services	• Wild plants and animals for nutrition, materials, or energy The LBUs increase surface area and ecological complexity on artificial substrates, enabling accelerated colonisation by algae, invertebrates (e.g., bivalves, crustaceans), and associated fish. This biomass forms part of the wild resources that coastal societies and marine sectors depend on, indirectly supporting food provision, bio-materials and marine-derived energy sources. The contribution is not limited to commercially exploited species: the LBU-enhanced habitat improves the productivity of the lower trophic levels that sustain the whole system. • Genetic material from marine biota The structural heterogeneity created by LBUs promotes the formation of microhabitats where organisms can reproduce, spawn and develop early life stages. The presence of eggs, spores, gametes and larvae increases the availability of genetic material in the system, reinforcing population viability, adaptive capacity and gene-pool stability—critical elements in a warming and increasingly stressed Mediterranean.
Regulation & Maitenence services	• Mediation of anthropogenic nuisances, wastes or toxic substances LBUs support the establishment of filter-feeding organisms (e.g., mussels, ascidians, sponges) and biofilms that contribute to the natural attenuation of pollutants, turbidity and organic matter. In ports and marinas—environments typically characterized by low water renewal and high pollutant load—this function is particularly valuable, as it enhances water quality and supports the overall ecological performance of the basin. • Maintenance of nursery habitats and gene-pool protection The colonised LBU surface provides refuge spaces, settlement points and low-disturbance microhabitats essential for juveniles. These nursery conditions help maintain or increase the survival of early life stages of fish, crustaceans and invertebrates. In ecosystems affected by habitat fragmentation and scarcity of natural hard substrate, such as many Mediterranean ports, LBUs help restore ecological functions that would otherwise remain impaired. • Pest and disease control By diversifying species composition and restoring trophic interactions, LBUs enhance natural biological controls. Balanced communities can regulate opportunistic species, biofouling dominance

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	and pathogen proliferation. This regulation mitigates risks associated with degraded ecosystems—such as blooms of nuisance organisms or species imbalances that cascade across the ecosystem.
Cultural Ecosystem Services	• Physical and experiential interactions The biodiversity increased by LBUs enhances recreational experiences such as diving, snorkelling, underwater routes or educational visits. Ports and coastal areas adopting LBUs benefit from healthier waters and more visually appealing underwater environments, which strengthens their social and recreational value. • Intellectual and representative interactions LBUs create accessible environments for scientific observation, underwater monitoring, photographic documentation, and environmental education. They serve as demonstration sites where citizens and stakeholders can perceive the tangible outcomes of restoration actions—an important element in EFFECTIVE's emphasis on community engagement and communication of ecosystem benefits.

Discussion and Conclusion

Discussion

Economic and Social Importance

The contribution of MPAs to socio-economic systems around them is not trivial. MPAs, in particular, the Medes Island MPA play a key role in its contribution to the regional economy, the wellbeing and livelihood of coastal communities, and the maintenance of a cultural significance though traditional diets or historical seascapes, among others.

Assessing the socio-economic consequences of MPAs is a challenging endeavour. First, we need to identify both, the socio-economic pressures (footprint) affecting these environments, as well as the socio-economic consequences, drivers, and causal chains (dependences), that derive from a healthy MPA condition (its structure and functions). By understanding such pressures and dependences and applying a correct management to all these relationships, other socio-economic features, and its cascade effects, will be benefiting from that.

At EFFECTIVE, we have been using the D(a)PSWR(m) accounting framework to deal with all these relationships. The types of human activities taking place within, and in areas adjacent to the MPA, were identified and their pressures assessed in a workshop celebrated in July's 2025 (L'Estartit; Girona-Spain). We assessed these pressures based on the perception (expert group assessment) of human activities on the 11 Good Environmental Status (GEnS) descriptors that were formulated through in the Marine Strategy Framework Directive. A panel of 40 natural scientists from different disciplines and backgrounds, all of them connected with different aspects of GEnS, were consulted to describe their perceptions on the pressures of identified activities on the MPA. After results were obtained and to simplify the given information in the average, quantitative data of an employed Likert scale (1 to 4) into four possible qualitative pressures: a) no pressure – light grey (1-1.40); b) low pressure – light

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yellow (1.5-2,49); c) medium pressure – orange (2.5-3.49); and d) high pressure – red (3.5-4). Final results, expressed in Figure xx, demonstrated which are the most stressful human activities on the MPAs. These pressures can modify the states of such areas contributing to the degradation of the benefits the areas give to people, its ecosystem services.

Based on the importance of the pressures included in this matrix, this report deems important to define mitigation actions as to revert the trends and include advisory services from experts (probably the same group of experts as of July's 2025, workshop in Estartit). Therewith, future research could address the improvement of ecosystem services by targeting more precisely the pressures affecting each (See Box: Potential regeneration actions at the end of the document).

Observed tendencies in the way MPAs are challenged against their main ultimate objectives makes that there is an emerging global interest in accounting for ocean ecosystem services as to better protect MPAs and natural assets in general. With this research, as highlighted in the introduction we are aligning different steps from 2024 until 2027 to offer a transparent and complete ES valuation accounting framework for North-western Mediterranean ocean ecosystems.

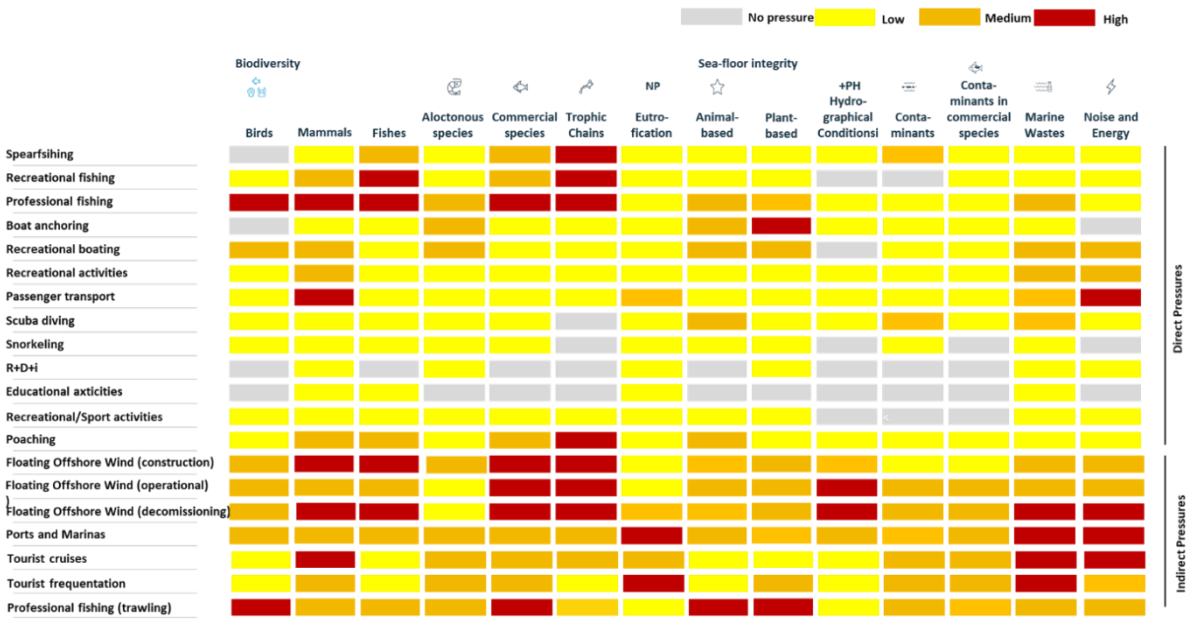

Figure 4. Expert judgment analysis of the direct and indirect pressures imposed by 20 human activities on the good environmental status (GEnS) of North-western Mediterranean MPAs. [Source: EFFECTIVE]

Next steps

Further research will be conducted in regard to polishing up the synergies across EFFECTIVE and OCEAN + projects. This collaboration among other benefits, will highly speed up the data acquisition for the regulatory and cultural ES, which are now missing, yet crucial for the next phase of EFFECTIVE; i.e, (D) D3.3 Natural capital assets evaluation report, to be conducted between January-May 2026. As said, it all will boost the development of accounting frameworks in Spain and the Mediterranean, to know the extent, status and value of natural capital assets and the services and benefits derived from MPAs.

Overall, EFFECTIVE will continue contributing to capture ocean value as to better protect it, by aligning with global ocean accounts frameworks to pave the way for the Mediterranean results.

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Sustainable Management and Policy Responses

Along the same lines, ocean governance should be transformed for the better so as to halt the previous challenges, and avoid surpassing the planetary tipping points. International and transboundary policies are a must, and should speak to one another. For instance:

- Marine Protected Areas regulations.
- Sustainable fisheries and aquaculture policies.
- International agreements (UNCLOS, CBD, SDG 14 "Life Below Water").
- Emerging regulatory tools for the blue economy, ecosystem-based management, nature-based solutions.

Lastly, with the polycrisis context and threats and challenges affecting us all, and especially marine life, it is timely and crucial to communicate results of interdisciplinary studies such as this one and create regenerative actions to help the Mediterranean sea thrive again.

Box: Potential regeneration actions

POTENTIAL REGENERATION ACTIONS

- Pressures at ports and marinas such as, invasive species, pollutants, pollutants on commercial fish species and marine trash are included in the LBUs accountability methodology that Ecoacsa is developing for Ocean Ecostructures as part of Effective's project as well. Future versions of the accountability methodology may include other pressures- at ports and marinas too- such as eutrophication and noise. Those developments will aid future regeneration actions, as it will be easier to track and target the pressures - in the hopes of enhancing the condition of the ecosystem, and thereby ameliorating the health of the ocean.

References

Berkes, F. & Folke, C. (1998). Linking social and ecological systems for resilience and sustainability. In: F. Berkes & C. Folke (Eds.), Linking social and ecological systems: management practices and social mechanisms for building resilience. pp:15-25. Cambridge University Press. Cambridge.

Boyd, J. & Banzhaf, S. (2007). "What are ecosystem services?". Ecological Economics, 63: 616-626.

Cooper, P. (2013). Socio-ecological accounting: DPSWR, a modified DPSIR framework, and its application to marine ecosystems. Ecological Economics 94: 106-115.

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This project has received funding from the European Union's Horizon Europe innovation programme under the Grant Agreement No. 101112752

Costanza, R., d'Arge, R., de Groot, R., Faber, S., Grass, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. &van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. Nature, 387:253–260.

Daily, G.C. (1997). Nature's Services. Island Press, Washington. 393 pp.

de Groot, R. (1992). Functions of nature: evaluation of nature in environmental planning, management and decision making. Netherlands: Wolters-Noordhoff. 315 pp.

de Groot, R., Wilson, M.A. & Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, 41: 393–408.

Elliott, M. and T.G. O'Higgins. (2020). From DPSIR the DAPSI (W) R (M) Emerges… a Butterfly 'protecting the natural stuff and delivering the human stuff'. In: Ecosystem-based management, ecosystem services and aquatic biodiversity: Theory, tools and applications, 61-86.

Ehrlich, P. & Ehrlich, A. (1981). Extinction: the causes and consequences of the dissapearence of species. New York. Random House.

Ehrlich, P., Ehrlich, A. & Holdren, J. (1977). Ecoscience: Population, resources, Environment. San Francisco. W.H. Freeman.

Gilbert A. J. & Janssen, R. (1998). Use of environmental functions to communicate the values of a mangrove ecosystem under different

Gómez-Baggethun, E. & Ruiz-Pérez, M. (2011). Economic valuation and the commodification of ecosystem services. Progress in Physical Geography, 35: 613-628.

Millennium Ecosystem Assessment (MEA). (2005). Ecosystems and Human Well-being Synthesis. Washington DC. Island Press.

Murillas-Maza, A., Prellezo R., Gomes, H., Ojea, E., Ayarza, H., León, R. & R. Sardá. (2024). Identificación y priorización de los servicios de los ecosistemas en las demarcaciones del Estado Español. Entregable Proyecto Aproximaciones científicas en la implementación de estrategias marinas: herramientas de gestion (PTI OCEANS+). MITECO. 89 pp.

Sardá, R. (2013). Ecosystem Services in the Mediterranean Sea: the need for an Economic and Business oriented approach. In: Mediterranean Sea. Ecosystems, Economic Importance and Environmental Threats. Novar Publ. New York. pp: 1-35.

Study on Critical Environmental Problems (SCEP). (1970). Man's Impact on the Global Environment. Cambridge, Mass. MIT Press.The Economics of Ecosystem and Biodiversity (TEEB). (2010). The economics of of ecosystem and biodiversity: ecological and economic foundations. UNEP TEEB Office.

Westman, W.E. (1977). How much are nature's services worth?. Science, 197: 960-964.

OCEANS+ - CSIC.

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This project has received funding from the European Union's Horizon Europe innovation programme under the Grant Agreement No. 101112752