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Methodological and Ideological Options

# Ecosystem accounting for marine protected areas: A proposed framework

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ABSTRACT

Many policy initiatives and scientific studies promote the use of economic accounting as a statistical basis for end-users and policy-makers' evaluation of the distributive and allocative effects of environmental and economic policies. This can help in assessing the costs and the benefits of taxes and subsidies, public expenditures for environment protections, payment schemes for ecosystem services, or the construction of "green" gross product indicators. This paper develops an ecosystem-economic accounting framework to test some practical issues associated with the building of disaggregated accounts for single institutional units. Specifically, we focus on marine protected areas due to their direct relationship with ecosystems flows and for the latter's strong contribution to the former's productive and consumptive activities. The accounting framework aligns with the SEEA-EEA and it allows a straightforward integration of the MPA accounting records into regional and national Supply-and-Use tables aimed at performing input-output analysis. Moreover, it serves as a tool for the management of protected areas.

## 1. Introduction

Over the last two decades, increased environmental pressures, greater public awareness, and the new concept of sustainable growth have compelled international bodies to develop environmental economic accounts and indicators aimed to explicitly define the interactions between the environment and economic activity (e.g. the EU COM (94) 670 final Directions for the EU on Environmental Indicators and Green National Accounting; the System of Environmental Economic Accounting—SEEA and SEEA Central Framework, published by the United Nations in 1993 and 2014; the ESEA, released by Eurostat in 2003, 2008, 2014 and 2019). Environmental economic accounting involves realizing a conceptual framework to systematically describe the connections among the flows and stocks of natural resources and the socio-economic system in a specific area and time period. Further, it also includes an estimation of the circular flows of corresponding monetary costs and benefits. This framework forms a statistical basis and data source for end-users' and policy-makers' evaluations: on a supranational scale, the resulting data can be used not only to monitor progress toward sustainable development goals or a circular economy and efficient resources, but also facilitate the construction of "green" gross product indicators. At the national and local levels, these can be used to assess the distributive and allocative effects of competing environmental and economic policies, existing regulations, examine the costs and the benefits of environmental taxes and subsidies, determine the optimal amounts of public expenditures for environmental protections, and define payment schemes for ecosystem services.

Currently, interest in ecosystem accounting has increased, as this is an environmental economic accounting field that observes the environment from the ecosystem's perspective and uses ecosystem services (ES)[1] to integrate the ecological and economic disciplines (Costanza et al., 2017). In 2014, the United Nations' statistical unit developed and released its System of Environmental Economic Accounting—Experimental Ecosystem Accounting (SEEA-EEA) which included definitions and recommendations for national ecosystem accounting, as aligned with its System of National Accounts (SNA). However, the guidelines' fluid nature has prevented them from becoming standard, and the United Nations has emphasized the need to experiment with their implementation.

This paper responds to the SEEA-EEA, by aiming to design and implement ecosystem-flow accounts for a single economic unit. Moreover, we are unaware of any attempt to test ecosystem accounts at such a level of disaggregation, but we believe that, once standardized, these can form a foundation for local —and eventually, national—ecosystem accounts. Specifically, we consider marine protected areas (MPAs), as they represent a noteworthy case due to the public nature of

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[1] The definition of ecosystem services is controversial. However, in this paper, we embrace the SEEA-EEA definition, that is "the contribution of the ecosystems to benefits used in economic and other human activities" (United Nations et al., 2014).

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their activities, their close connection with ecosystems and the strong contribution that the ecosystems they manage provide to local productive and consumptive activities. This focus on MPAs is also motivated by our participation in a project regarding environmental accounting in marine protected areas, which involved environmental accounting for Italian MPAs; this allowed us to provide realistic numerical figures as examples of the proposed conventions.

The accounting framework and our relative compilation rules contribute to current literature in two respects: on the one hand, our set of accounting tables form a management tool for MPAs with ecological, economic and financial information recorded in a standard, intuitive manner. Moreover, this allows us to readily evaluate alternative management policies; assess the effectiveness, efficiency and sustainability of existing protection policies; and monitor how the management objectives are achieved in marine conservation. On the other hand, the structure of the accounting tables and conventions employed are respectively conceived and set to permit a straightforward integration between MPAs' accounting records and national and regional accounts. This is particularly convenient as it ensures coherence between aggregated and disaggregated accounts; further it allows us to identify how the ecosystems activity contributes to value creation and the production of income among disaggregated, individual economic units.

We define a set of three tables that measure ecosystem flows, ecosystem pressure flows and financial flows in economic terms. Subsequently, we illustrate practical issues connected to the accounting and valuation process and complement our theoretical explanation with a numerical example.

Our approach has two distinctive traits. First, we avoid duplicate counts when ecosystem flow records are integrated into national accounts by explicitly distinguishing between the ES that contribute to SNA benefits, such as the goods and services produced within SNA boundaries, and the ES that contribute to non-SNA benefits, such as benefits that do not derive from economic production processes within the SNA. Alternatively, we allocate ES to the relevant economic units, with a particular regard to distinguishing between services of a private nature, such as the provisioning of food, from those of a public nature, such as regulation. It is ideal to discuss ES recipients in detail for at least two reasons: it allows for a straightforward integration of the MPA's accounting records into regional or national supply-use tables (SUT) and it offers the possibility of building disaggregated indicators.

We offer insights on how the approach proposed can be generalised beyond a specific case study by providing an example regarding how to integrate MPA accounts into a national SUT table.

The remainder of this paper proceeds as follows: Section 2 provides an overview of recent developments in environmental and ecosystem accounting. Section 3 describes the premises behind our approach. Sections 4 and 5 illustrate our accounting tables and indicators, respectively. Section 6 shows the interlinkages between ecosystem flows accounts and a national SUT table and, finally, Section 7 concludes.

## 2. Literature review

Economic and environmental accounting have evolved independently and with limited exchanges until the 1990s; following the United Nations Conference on Environment and Development (1992), the Agenda 21 action plan called for the integration of these accounting fields to monitor the transition toward environmentally, socially and economically sustainable development. This was not a straightforward task due to the two disciplines' different measurement units and accounting conventions. Specifically, environmental accounting principles and classifications were not yet as standardized as economic accounting, but various conventions existed as a result of uncoordinated ad hoc statistics produced for independent environmental programs.

At the beginning of the 1990s, the United Nations worked with other supra-national bodies and scientific experts to reorganize existing environmental statistics and design an integrated environmental and economic accounting system based on the SNA. The SEEA—which was published in 1993 and evolved to become SEEA CF in 2013—represents a first attempt in this direction, as a handbook that defines statistical standards and a common information framework for national environmental economic accounting. It is based on a system of satellite accounts that complement the SNA to incorporate interactions between the economy and the environment, and the changes in environmental resources. The integration between economic and environmental disciplines is pursued through classifications and definitions consistent with the SNA and through the conversion of flows and stock data from physical to monetary terms. The comparison between physical and monetary data is made through "hybrid" account formats or through indicators.

In parallel with the definition of a standard framework for environmental economic accounting, an increasing demand for statistics on ecosystems degradation and the loss of biodiversity (Millennium Ecosystem Assessment, 2005; the economics and ecosystems and biodiversity—TEEB, 2010; United Kingdom national ecosystem assessment—UKNEA, 2011) led to the development of the ecosystem approach and ecosystem accounting. The latter provides a different, complementary way of integrating economic and environmental/ecological disciplines as it evaluates the environment from the ecosystem's perspective of and explicitly connects the flows of services they produce to human activity. Many economic and ecological papers have attempted to estimate ecosystems' stock and services; these have recommended various possible approaches to economically valuate these ecosystems (Atkinson et al., 2012; Barbier, 2007; Ferraro et al., 2012) and have proposed possible variations to the existent economic accounting structures to integrate ecosystems and their services (Bateman et al., 2011; Edens and Hein, 2013).

In 2014, the United Nations published the SEEA-EEA, an initial step toward a statistical standard framework for ecosystem accounting. This handbook defines and classified ES, conventions on how to measure them in physical terms, and approaches to their monetary evaluation. Attempts have been made since its publication to draft ecosystem accounting for specific ES and specific local areas (e.g. Busch et al., 2012; Obst et al., 2016; Remme et al., 2014; Suwarno et al., 2016; Wealth Accounting and the Valuation of Ecosystem Services—WAVES, 2012) or on a continental scale (La Notte et al., 2017) based on the SEEA-EEA's guidelines. Moreover, several academic papers explored some of the challenges that limit the proper integration of ecosystem assets and services into a national accounting system which the United Nations' publication did not address. Specifically, they addressed the following: classification challenges connected with the definition of ES and their complete inventory (Edens and Hein, 2013; Obst et al., 2016; Remme et al., 2014); methodological challenges in ecosystems' biophysical assessment and measurement of ecosystems (Vallecillo et al., 2019); challenges to current valuation methods (Caparrós et al., 2017; Droste and Bartkowski, 2017; La Notte et al., 2019; Obst et al., 2016); challenges to indicators used to properly measure ecosystem's degradation (Ovando et al., 2016); and implementation challenges (Bordt, 2018; Dvarskas, 2018).

This paper focuses on implementation challenges. As Dvarskas (2018) discussed, three main hindrances still exist to applying the SEEA-EEA's accounting framework. Firstly, there is a lack of consolidated environmental/economic datasets and time-series. Secondly, it is unclear as to how to define and select spatial accounting units. Third, no indications exist regarding how to compile ecosystem accounting schemes at a local level or for single institutional units/sectors in a way consistent with national accounting tables. Our analysis primarily contributes to the latter point.

Therefore, we join a still limited but growing strand of ecosystem accounting literature that focuses on marine and coastal ES. Lai et al. (2018) illustrated how Finnish ES indicators—produced nationally as a part of the European "Mapping and Assessment of the Ecosystems and their Services" initiative—can be exploited to create ecosystem accounts for water-related and fish-provisioning ecosystem services. In a case study on the Gulf of Saint-Malo, Martin et al. (2018) used an ad hoc survey to estimate the value of cultural marine ES, which provided insights on the relationship between cultural and recreational services. Further, Dvarskas (2018) developed a pilot application of the SEEA-EEA to Long Island coastal bays in physical terms by proposing new indicators of ecosystems' condition and ES. Our work differs from these studies, as we present a theoretical framework for the ecosystem accounting of a single economic unit as a logical connection between disaggregated and national accounting systems.

## 3. Premises of the accounting framework

Merely by observing their financial statements, MPAs seemingly create values matching the expenses they sustain for conservation activities, or similarly, the revenues they obtain through government funds and self-financing. Rather, MPAs generate much greater value as they contribute to produce the benefits that the community enjoys—both individually and collectively— in their surroundings.[2] Ecosystem accounting aims to measure the entire value the MPA produces to elicit the contribution of the environment to human activities.

The main premise behind the structure of the proposed accounts involves a natural sector composed of a set of different ecosystems, which acts as the "producer" of all ES and as the "consumer" of all environmental pressures (Peskin, 1976). The natural sector is particularly productive in some areas due to the presence of specific types of ecosystems and their favourable conditions. Therefore, these areas are "protected" by governments through the establishment of MPAs, which are entitled to conduct conservation activities and establish rules to limit the depreciation of natural assets and maintain non-diminishing services.

This paper follows the SEEA-SEEA's terminology to define the spatial area that the MPA manages as a reference ecosystem accounting unit (EAU) which contains a range of different ecosystem types that generate a certain quantity of ES flows in each period. Our framework ensures the ecosystem's capacity[3] through the MPA's conservation activities. Hence, we hypothesize for accounting purposes that the existence of ES in a specific territorial area is entirely due to the presence of the MPA.

This study focuses on how to record and measure accounting flows— such as ecosystem flows, ecosystem pressure flows, and financial flows—in economic terms. As anticipated in the Introduction, we separately consider ES connected to SNA benefits and non-SNA benefits. The former can be either private and be enjoyed by economic units of production (i.e. the provisioning service of fish exploited by professional fishermen) and by economic units of consumption (i.e. recreational service of scuba diving), or public and be enjoyed collectively (i.e. intellectual services from scientific research). The latter, instead, have generally only a public nature (i.e. regulating service of sequestrating $CO_2$). Fig. 1 summarizes these concepts.

Ecosystem accounting envisages not only flow accounts, but also accounts on the extension, condition, and yearly capacity of producing services of the stock. Our flow tables do not record the ecosystem asset's patrimonial value, they instead include the value of its "depreciation" in terms of the replacement cost that the MPA bears to preserve the asset and the relative flow of ES in each period (or the value of the annual funds the MPA receives for ordinary maintenance).[4] Nevertheless, ES accounts alone are insufficient to observe whether the stock has declined or the stock-flow relationship has changed, but should be complemented with ecosystem asset accounts.[5]

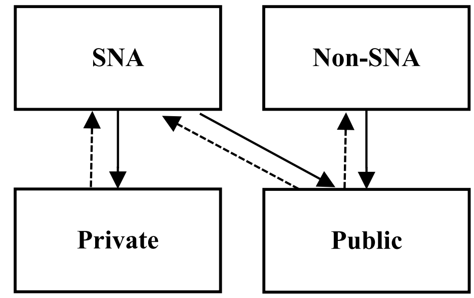


**Fig. 1.** The relationships between SNA/non-SNA benefits and private and public services.
(Source: The authors' elaboration.)

Table 1 presents a complete list of all the ES that can be associated with an MPA activity (United Nations et al., 2014). They belong to the three Common International Classification of Ecosystem Services (CICES) classes of provisioning, regulating, and cultural services. For each ES, the table details the group, classification code and associated benefits, as well as the nature of the ES (i.e. private and public) and the type (i.e. SNA and Non-SNA).

The SEEA-EEA accounting rules recommend recording ES at their market exchange value in line with the SNA, thus excluding any consumer surplus. However, there is an ongoing debate in the scientific literature on the appropriateness of the use of exchange values as compared to welfare values, and a widely supported position is that exchange values cannot reflect all the benefits generated by the environment to human beings, especially in the cultural services case. We share these concerns, which we believe are particularly reasonable when accounting is used to support local management decisions aimed at protecting ecosystems in the short run. Even though in this paper we follow the prevailing valuation conventions and align with the SEEA-EEA to facilitate the reader in the comprehension of a new set of ecosystem accounting tables for MPAs, we believe that framework proposed here would greatly benefit from the inclusion of an additional accounting table showing ES in welfare values, in line with the Complementary Accounts Network (CAN) approach recently proposed by Turner et al. (2019). The resulting set of accounts, in fact, would represent a comprehensive statistical base and would provide an exhaustive assessment tool for analyses in both an accounting and/or a

[2] These MPAs contribute to benefits that involve a wider population than the local one, such as benefits derived from regulating services. However, we do not discuss this matter in the context of this paper and limit the accounting discussion to the area managed by the MPA.

[3] We attribute to the concept of ecosystem capacity the meaning provided by the SEEA-EEA (i.e. the ability of a given ecosystem asset to sustainably generate a set of ecosystem services into the future). However, this definition leaves room to different interpretations, see La Notte et al. (2019).

[4] However, it should be noted that ministerial funds for MPAs in Italy are currently assigned based on their historical value and not on real financing needs. Therefore, the availability of yearly asset accounts' data should be exploited to define the criteria by which public conservation funds are allocated, as this narrows the gap between financial and physical accounts.

[5] Ecosystem assets accounts are not regarded in this article as they pertain to ecological accounting and should be measured in biophysical terms. Nevertheless, comparing biophysical and economic accounts is crucial for sustainability analysis. While high values of ES produced by the MPA are positive from an economic standpoint as they lead to an increase in wellbeing, they could be associated with either a good management or overexploitation: if the ES balances are not matched against accounts based on the condition of the ecological asset, it is not possible to assess whether the ES is high-valued because of an unsustainable increase in human fruition. Therefore, further research is needed to assess the interlinkage between ecological and economic approaches to ecosystem accounting and the availability of yearly data on asset accounts should be further exploited in order to define criteria by which allocate public conservation funds, narrowing the gap between financial and physical accounts.

**Table 1**
List of ecosystem services and associated bevfits relevant for MPAs.
(Source: The authors' elaboration.)

| Ecosystem Service | Group | CICES v5.1 | Benefits | Nature | Type |
|---|---|---|---|---|---|
| Provisioning | Cultivated aquatic plants for nutrition, materials or energy | 1.1.2 | Plants and algae from in-situ aquaculture | Private | SNA |
| | Raised aquatic animals for nutrition, materials or energy | 1.1.4 | Animals from in-situ aquaculture | Private | SNA |
| | Wild aquatic plants for nutrition, materials or energy | 1.1.5 | Wild plants and algae and their outputs | Private | SNA |
| | Wild aquatic animals for nutrition, materials or energy | 1.1.6 | Wild animals and their outputs | Private | SNA |
| | Genetic material from plants, algae or fungi | 1.2.1 | Genetic materials from all biota | Private | SNA |
| | | | | Public | Non-SNA |
| Regulation and maintenance | Mediation of wastes or toxic substances of anthropogenic origin by living processes | 2.1.1 | Bio-remediation by micro-organisms, algae, plants, and animals | Public | Non-SNA |
| | Mediation of nuisances of anthropogenic origin | 2.1.2 | Mediation of smell/noise/visual impacts | Public | Non-SNA |
| | Regulation of baseline flows and extreme events | 2.2.1 | Stabilisation and control of erosion rates, Buffering and attenuation of mass flows, Hydrological cycle and water flow maintenance and flood protection | Public | Non-SNA |
| | Lifecycle maintenance, habitat and gene pool protection | 2.2.2 | Maintaining nursery populations and habitats | Public | Non-SNA |
| | Water conditions | 2.2.5 | Chemical condition of salt waters | Public | Non-SNA |
| | Atmospheric composition and conditions | 2.2.6 | Global climate regulation by reduction of greenhouse gas concentrations | Public | Non-SNA |
| Cultural | Physical and experiential interactions with natural environment | 3.1.1 | Experiential use of plants, animals and seascapes in different environmental settings, Physical use of seascapes in different environmental settings | Private<br>Public | SNA<br>Non-SNA |
| | Intellectual and representative interactions with natural environment | 3.1.2 | Scientific, Educational, Heritage and cultural, Aesthetic | Public | Non-SNA |
| | Spiritual, symbolic and other interactions with natural environment | 3.21 | Symbolic, religious, entertainment | Private<br>Public | SNA<br>Non-SNA |
| | Other biotic characteristics that have a non-use value | 3.2.2 | Existence, bequest | Public | Non-SNA |

managing scope.

As anticipated, this paper also proposes an accounting table dedicated to the economic estimation of the annual flows of pressures due to anthropic activities. The concept of pressures coincides with the one used in the DPSIR framework (i.e. anthropogenic factors —such as emissions, waste, or non-sustainable behaviours—that impact the stock of ecosystems in a certain timespan) and is closely linked to the notion of ecosystem's biophysical degradation.[6] The measurement of ecosystem pressures is not only interesting in itself, but also because it allows us to evaluate the level of sustainability of the various consumptive activities carried out in the MPA.

## 4. Structure and description of the accounts

The accounting framework proposed in this paper is composed of three accounting tables, all measured in monetary terms:

- an ES accounting table (Module 1)
- a human pressures accounting table (Module 2)
- a financial flows accounting table (Module 3)

We simplify the comprehension of this framework by populating our tables with numerical data. The presented figures are hypothetical but realistic as they are inspired to those for one of the Italian MPAs collected in the authors' Environmental Accounting in Marine Protected Areas project. We do not present a specific case study as the relevant information is not fully disclosed, and the case study is just intended to exemplify the common issues on accounting and valuation process.

### 4.1. ES accounting table (Module 1)

*Module 1* records the value of the ES produced within the MPA in a defined accounting period (year). The rows represent the selected ES and columns the recipients. In particular, we distinguish between recipients of SNA benefits and non-SNA benefits. It is noteworthy that the categories of ES and fruition activities to consider vary according to the protected area under investigation. In Table 2, we record only part of the flows indicated in Table 1, specifically, those that allow us to provide a realistic representation of an MPA and for which we were able to gather data and information.

The conventions we used for this valuation parallel those proposed by the SEEA-EEA; below, we detail these according to the various categories of ES identified and with specific reference to the MPA considered.

A) Provisioning services in MPAs

The provisioning services in MPAs are primarily represented by harvested fish and shellfish and the exchange value of the corresponding annual benefit is given by the quantity of fish and shellfish caught during the year multiplied by the relative market price, differentiating between species as appropriate. Consistently with the SEEA-EEA, the exchange value of provisioning ES is obtained by deducting the cost of human input (labour, produced assets, and intermediate consumption) from the monetary value of the associated benefits. In the case of professional fishing, these costs are represented by the opportunity cost of labor, the boat and gear's annual cost, and the annual expenses for intermediate goods, such as fuel, bait, boat insurance and provisions (Table 3). The total opportunity cost of labour is calculated as the region's average wage rate in manufacturing multiplied by the number of fishing boats. The total cost of produced assets is given by

[6] Ecosystem degradation is defined as the decline in an ecosystem asset over an accounting period due to economic and other human activity (United Nations et al., 2014).

**Table 2**
*Module 1*: ES in euro.
(Source: The authors' elaboration.)

| | | SNA | | | | | Non - SNA | Total ES per Type |
|---|---|---|---|---|---|---|---|---|
| Ecosystem Service | | Professional Fishing | Bathing Establishment | Scuba Diving Centres | Private Consumption | Public Consumption | Public Consumption | |
| Provisioning | Wild aquatic animals for nutrition | 5,513.91 | | | 4,497.59 | | | 10,011.50 |
| Regulating and maintenance | Atmospheric composition and conditions | | | | | | 9,868.72 | 9,868.72 |
| Cultural | Physical and experiential | | 16,223.90 | 66,880.35 | 88,358.26 | | | 171,462.51 |
| | Intellectual interactions | | | | | 141,143.45 | | 141,143.45 |
| Total services per recipient | | 5,513.91 | 16,223.90 | 66,880.35 | 92,855.85 | 141,143.45 | 9,868.72 | 332,486.18 |

**Table 3**
Professional fishing provisioning services.
(Source: The authors' elaboration.)

| Total value of harvested fish | € 28,403.91 |
|---|---|
| Number of boats | 7 |
| Average cost of labor | € 2457.00 |
| Average cost of capital | € 319.80 |
| Average cost of intermediate inputs | € 493.20 |
| Estimated ES annual value | € 5513.91 |

the price index of capital, or the average boat replacement cost[7] multiplied by the sum of the interbank interest rate and the depreciation rate, multiplied by the number of boats. Finally, miscellaneous annual costs are calculated by the sum of the average cost of the single items.[8]

A smaller part of provisioning services in an MPA is represented by the fish caught through recreational fishing. This is self-consumed but, nonetheless, enters the SNA production boundary. Activities such as recreational fishing draw from multiple ES and pose complex problems regarding both the proper allocation of accounting items and the estimation of the related figures.

From the point of view of the single beneficiary, the services enjoyed during the recreational fishing activity are both of a provisioning nature (nutrition) and of a cultural nature (referred to a leisure and recreation purpose). Therefore, the value of the recreational activity for the fisherman is the sum of these two components, and each of them must be attributed to a single ES.

In terms of estimates, the € 4497.59 in Table 2 refers exclusively to the benefits associated with the provisioning service. Computations are shown in the next section C) of this paragraph, together with those concerning the benefits of cultural services related to recreational fishing.

B) Regulating services

Regulating services contribute to the production of both SNA benefits, such as stabilisation and erosion control and habitat and nursery, and non-SNA benefits, such as climate regulation. A lack of shared conventions makes it difficult to estimate this type of ES. Vassallo et al. (2013) proposed a donor side approach to the valuation of regulating services based on the concept of emergy. However, the emergy approach is unsuitable here as the SEEA-EEA follows a user—side logic, such that ES only exist if they are enjoyed by human being. Following the SNA's recommendations to account for public goods at their marginal cost (European Commission et al., 2009); further, regulating services have commonly been estimated using avoided-damage cost methods, such as carbon sequestration and social cost of carbon.

In the case of MPA, carbon sequestration services are produced by marine vegetation. Specifically, the value of the service provided by algae though carbon storage can be estimated in terms of the ton of avoided $CO_2$ emissions. In particular, one needs to measure for each type algae the relative surface and storage capacity, and then convert this value in monetary terms using the social cost of carbon.[9] Although literature has widely proposed alternative approaches at measuring the social cost of carbon—as noted in, for example, the review provided by Wang et al. (2019), the estimates proposed in Table 4 refer to those produced by the United States' Interagency Working Group on the Social Cost of Carbon (2016) with a 3% social discount rate.[10]

C) Cultural services in MPAs

Cultural services can either have a private or a public nature.

To private cultural services belong all services connected with recreational interaction with the environment. In an MPA, these are associated to recreational activities in the scope of the SNA production boundary, such as bathing, scuba diving, recreational fishing and boating.

In general terms, the monetary value of recreational ES can be derived as the difference between the monetary value of the relative recreational benefit and the cost of human contribution to its production. Thus, the exchange value of these ES is represented by the product between their monetary value and their quantity, measured as the number of individuals enjoying the recreational activity.

When the recreational benefit is marketed, the value of ES accrues the supplier of the activity. In this case, the price of ES can be derived as the difference between the market price of the benefit (the price of the recreational activity) and the cost of the other inputs (capital, labour, intermediate goods) used in its production. However, unfortunately, data relative to the cost of inputs are often unavailable as they are not

[7] We follow Asche et al., 2009and calculate the replacement cost of as one-third of the market value of the boat.

[8] In this specific example, in lack of more detailed data, we only considered the replacement cost of the boat for what concerns produced assets and the cost of fuel for what concerns the intermediate input. In particular, for what concerns the latter, we calculated the average cost of fuel multiplying the its annual price for the annual kilometres covered in a year by the fishermen fleet.

[9] This approach is equivalent to measuring the marginal damage cost of carbon.

[10] There are other private regulating services that are provided by marine vegetation and produced within the MPA. As their value come typically from ecological analysis that were not carried out during the project, we considered sequestration a sufficient example of regulating services. However, the SEEA-EEA guidelines provide indications on how these could be valued. For example, sedimentation and erosion-control services could be estimated using the "cost of treatment" method, which estimates the cost of repairing damages that would occur without the service; nursery and habitat services could be estimated as a proportion of the value of commercial fish species within a certain habitat, calculated based on such methods as a visual census.

**Table 4**
Sequestration services.
(Source: The authors' elaboration.)

| | |
|---|---|
| Total ton of $CO_2$ sequestered per year | t 267.3 |
| Social cost of carbon | €/t$CO_2$ 36,92 |
| Value of $CO_2$ sequestered per year/estimated ES annual value | € 9868.72 |

explicitly included in the financial statements of the suppliers of the recreational activity.

When recreational services are not marketed and when it is not possible to derive an ES market price equivalent from a surrogate market, the price of the ES can be estimated using valuation methods based on the concept of WTP. However, it should be noted that, in this case, the estimate does not represent an exchange value as it includes a consumer surplus.

An alternative approach that we propose is to use, as a proxy for the ES monetary value, the price of the annual authorization required for privately carrying out the recreational activity, when available. This, indeed, represents a price that is determined by the intersection of the MPA supply and the individuals demand for a certain quantity of ES.

To public cultural services belong all services connected with the intellectual and educational activities carried out by the MPA. No standardized approach to their valuation yet exists, as public cultural services should consider all the positive externalities associated with scientific progress and increased knowledge is particularly problematic. In accordance with conventions for public in the SNA, one possible approach involves pricing intellectual services at their cost, as we describe in more detail below.

There are other types of cultural services that can be considered: spiritual and symbolic, and existence and bequest. These cultural services are generally of a public nature too but are typically site-specific, such as a particular specie of flora or fauna or landscape. Bequest and existence-based cultural services are particularly noteworthy as they represent the non-use and non-market value of ecosystem flows in line with the theory of total economic value (Plottu and Plottu, 2007). As such, they are in principle excluded from SNA boundaries. However, it is unquestionable that the total value of the ecosystem flows produced within the MPA should include non-use cultural services that are valuable from the point of view of societal wellbeing. In some cases, non-use values can be deduced from the values of marketed goods or services. For example, payments to associations that protect biodiversity and endangered species can be considered as a *proxy* of the individual WTP for environmental conservation. However, further research is needed regarding the best way to consistently price them within an exchange-value logic.

In the remainder of this section, we provide compilation rules to estimate the exchange value of different types of cultural ES that characterize the considered MPA, by type of activity.

*Bathing*

In line with what outlined above, the monetary value of ES (i.e. physical use of seascape) is obtained as the difference between the price of the benefit (i.e. the bathing activity) and the cost of human contribution.

For private beaches, the price of the admission ticket or the price of the bathing equipment can be used as a proxy of the price of the benefit. For public beaches, instead, one could either estimate users' WTP or use the equivalent price of the admission ticket to private beaches. For what concerns the cost of human contribution, this is in both cases negligible as there are not specific produced inputs needed to carry out the activity. Thus, the price of the benefit matches the price of the ES.

In Table 5 we report the annual value of the ES referred to the bathing activity of the MPA considered.

*Scuba diving*

Scuba diving in the MPA is allowed for private individuals and licensed diving centers. Even though information on the average price per dive is available (i.e. the price of the benefit), data on the input cost incurred by diving centres to provide the recreational activity are not disclosed. Thus, we use as a proxy for the price of the ES (i.e. physical interaction with seascape flora and fauna) the price of the annual license fee paid by private divers. As license prices differ between residents and non-residents, we use this information to increase the ES estimates' accuracy-.

In Table 6, we present the annual value of ES for the MPA considered.

*Recreational fishing*

As already noted above, for recreational fishing the total benefits enjoyed by the single user is given by the sum of the provisioning benefit (i.e. harvested fish) and the recreational benefit (i.e. physical experience of seascape). However, a single set of human input costs is necessary to produce both benefits. Thus, to estimate the value of the services, we calculate the total benefit as the sum of the single benefits, subtract the cost of human contribution and then impute the difference to each ES according to its relative share on the total benefit.

In particular, provisioning benefits are obtained using data of fish catches and market prices, differentiated for species; recreational benefits are based on an average WTP estimated from contingent choice interviews to recreational fishermen in the MPA; human inputs include the same items considered for professional fishing excluding the opportunity cost of labour.

Table 7 shows the various steps followed for the estimation of the exchange value of provisioning and cultural services connected with recreational fishing for the MPA considered.

*Intellectual and educational activities*

Public cultural services can be valuated at their marginal cost. In the case of an MPA, intellectual services are represented by the scientific research on flora and fauna conducted within the borders of the MPA.

**Table 5**
Bathers cultural services.
(Source: The authors' elaboration.)

| | Admission ticket/ price of ES | Number of bathers | ES annual value |
|---|---|---|---|
| Bathers in public beaches | € 1.73 | 45,390 | € 78,524.70 |
| Bathers in bathing establishments | | 9378 | € 16,223.90 |

**Table 6**
Scuba-divers cultural services.
(Source: The authors' elaboration.)

| | Authorization fee/ES price | ES annual value |
|---|---|---|
| Private divers | € 45–75 | € 5336.00 |
| Divers with scuba centres | | € 66,880.35 |

**Table 7**
Recreational fishing cultural and provisioning services.
(Source: The authors' elaboration.)

| | |
|---|---|
| Provisioning benefit (total value of harvested fish) | € 13,654.40 |
| Cultural benefit | € 6985.00 |
| Annual WTP of recreational fishermen | € 55.00 |
| Number of recreational fishermen | 127 |
| **Total benefit of recreational fishing** | € 20,639.40 |
| Average cost of capital | € 3840.70 |
| Average cost of intermediate inputs | € 10,000.33 |
| **Total cost of human contribution** | € 13,841.03 |
| Total ES value of recreational fishing | € 6798.37 |
| Share provisioning benefit to total benefit | % 66.10 |
| Share cultural benefit to total benefit | % 32.30 |
| **Provisioning services of recreational fishing** | € 4497.59 |
| **Cultural services of recreational fishing** | € 2300.78 |

**Table 8**
Scientific and educational intellectual services.
(Source: The authors' elaboration.)

| | ES annual value |
|---|---|
| Research funds | € 77,000.00 |
| Educational activities | € 64,143.45 |

Although their value in physical terms can be estimated by the number of scientific publications produced in a year, the relative economic value is more challenging to estimate. As MPA research is generally funded by European programs, the amount of funds for research projects received in a particular year can be used as a proxy for intellectual services. Nonetheless, we anticipate this value to be overestimated as research funds also pay for intellectual human effort. Regarding educational services, the MPA considered conducts several educational activities for both adults and children, such as snorkelling guided tours. The value of the corresponding ES can be approximated by the cost of this activity for the MPA, excluding personnel and miscellaneous costs.

Table 8 report the annual value of ES for the MPA considered. The values reported are included in the financial accounts table (Table 10). In particular, research funds are part of the funds from other sponsor used for specific project, and educational activities are included in other expenditure.

### 4.2. Human pressures accounting table (Module 2)

During fruition, economic units may generate pressures that impact the ecosystem assets leading to their degradation, and consequently, to decreased annual flows of ES. These pressures occur in the form of residuals, such as carbon emissions and waste, or in the form of unsustainable behaviours. Further, these can have direct (e.g. destroying the seabed with anchors) or deferred impacts (e.g. carbon emissions) on assets. In this section, the term pressures is borrowed from the DPSIR[11] (Drivers-Pressures-State-Impact-Response) framework, adopted by the European Environmental Agency and by Eurostat to organize environmental statistics and indicators (EEA, 1995; Jesinghaus, 1999) and increasingly used to support management decisions in the context of marine environments (for a comprehensive review see Patrício et al., 2016). Indeed, the SEEA-EEA guidelines make no reference to pressures[12] and to their measurement in relation to ES, but focus on the importance of measuring ecosystem degradation in biophysical terms, of directly attributing it to one or more economic units, and of valuating it (with an explicit acknowledgment of the complexity of the latter two tasks).

As we regard human pressures as annual flows of ecosystem degradation, we believe their estimation could complement the biophysical measurement of asset degradation. Thus, we propose *Module 2*, in which we estimate a value for the annual human pressures on ecosystems.

As MPAs' management regulates fruition by prohibiting unsustainable behaviours, we assume that the human pressures produced during fruition and conservation activities (such as surveillance and maintenance) are limited to their residuals.[13]

The accounting table is organized to allow a direct juxtaposition with *Module 1* and facilitate comparisons (Table 9): pressures are reported in terms of negative regulating services, as the residuals are ultimately $CO_2$ emissions. The monetary value is derived as the social cost of carbon for the damages from emissions; the producing of waste; and the consumption of resources, such as water and electricity.

### 4.3. Financial flows accounting table (Module 3)

This module records MPAs' financial inflows and outflows as reported annually in its financial statements and reorganized to convey useful information to MPA managers and policy-makers. The proposed reclassification aims to establish a more understandable connection between the financial flows and the MPA's operations, both internal and external.

*Module 3* illustrates the financial benefits generated and received by the MPA and how they are employed for different types of institutional activities (Table 10). Financing sources are disaggregated to explicitly define the revenues obtained from government funds; European projects funds[14]; and specific fruition activities, such as licensing, as Table 11 illustrates. Expenditures are categorized as either current, such as in the maintenance and surveillance of mooring fields; capital, such as those used to purchase of durable goods and unscheduled maintenance operations; for specific projects, such as the provision of services and temporary personnel; and other expenditure, such as administrative personnel and consumables.

## 5. Efficiency and sustainability indicators

The previously described flow accounts' structure enables us to derive several financial indicators that are commonly reported with MPA financial statements. In particular, this section focuses on two types of economic indicators that in our view could be of particular interest for policy-makers and at the MPA level: efficiency indicators and sustainability indicators.

### 5.1. Efficiency indicators

A first general measure of efficiency refers to the MPA's institutional activity and measures the rate of return of investments in ES (RORIES), defined by the following ratio:

$$RORIES = \frac{Total\ ES}{(Public\,funding + self - financing)}$$

If we take the denominator as a measure of the resources invested in the MPA's conservation actions, the ratio can be interpreted as the return—in terms of ES flow—of each euro invested in conservation activities. In other terms, the ES flow is compared to the financial flow deriving from public funding and self-financing. We can interpret its value as a measure of efficiency, so the greater the indicator, the more efficient the MPA's conservation activities.[15] RORIES does not have clear cut-off values and must be interpreted as a general efficiency measure paying attention to its variations over time. Having said that, RORIES higher than 1 show that the conservation activity is so efficient that 1 euros of financial inflows generate a return of more than 1 euro in terms of total ES.

Additionally, RORIES can be disaggregated into the following two

[11] Atkins et al. (2011) incorporated the concept of ecosystem services in the DPSIR framework. Moreover, DPSIR evolved more recently into DPSI(W)R(M) that includes explicit reference to human welfare (W) and to the need of defining measures (M) for adequate human responses (see Elliott et al., 2017).

[12] It should be noted the environmental pressures are, instead, the focus of the SEEA-CF.

[13] We are aware that this represents a simplification, as many unsustainable behaviours may be hard to be detected by the MPA management. If data on the annual value of unstainable behaviours were available, these should be included in the accounting table, which was not our case.

[14] It should be noted that funds obtained from European projects could be reasonably ascribed to self-financing. Indeed, they are granted only on the basis of the research effort exerted by the MPA.

[15] It is to note that its interpretation must take into account that this ratio differs from return on investments traditionally used in financial accounting (e.g. return on assets) since it compares two kinds of flows (i.e. total ES and financial inflows) without using balance sheet data.

**Table 9**
*Module 2*: Human pressures on ecosystems, in euros.
(Source: The authors' elaboration.)

| | Users | Professional Fishing | Scuba Diving Centers | Bathing Establishments | MPA Conservation Activity | Total Pressures Sustained |
|---|---|---|---|---|---|---|
| Regulating and maintenance | -14,058.81 | -2,199.45 | -6,012.88 | -1,840.04 | -2,089.47 | |
| Total pressures produced by human activities | 14,058.81 | 2,199.45 | 6,012.88 | 1,840.04 | 2,089.47 | 26,193.65 |

**Table 10**
*Module 3:* Financial benefits in euro.
(Source: The authors' elaboration.)

| | Current Expenditure for Conservation Activities | Current Expenditure for Specific Projects | Capital Expenditure for Conservation Activities | Other Expenditure | Total amount financed |
|---|---|---|---|---|---|
| **Public funds** | | | | | **476,964.49** |
| National/regional government | 67,744.85 | 161,530.81 | 76,109.56 | 11,031.64 | 316,416.86 |
| Other sponsors | 1,713.65 | 135,592.18 | 16,258.67 | 6,983.13 | 160,547.63 |
| **Self-financing** | | | | | **202,328.14** |
| Recreational fishing | | | | 14,964.15 | 14,964.15 |
| Scuba-diving centers authorization | | | | 117,875.21 | 117,875.21 |
| Private scuba-diving authorization | | | | 7,474.58 | 7,474.58 |
| Mooring areas | | | | 35,501.49 | 35,501.49 |
| Other | | | | 26,512.72 | 26,512.72 |
| **Reserves** | | | | | **137,197.83** |
| Total financial expenditures | 69,458.50 | 297,122.99 | 92,368.23 | 352,680.89 | |
| Net financial balance | | | | | 4,859.84 |

**Table 11**
Efficiency indicators for the MPA considered.
(Source: The authors' elaboration.)

| | |
|---|---|
| RORIES | 0.49 |
| RORIES_SNA | 0.48 |
| RORIES_Non-SNA | 0.02 |

indicators:

$$RORIES_{SNA} = \frac{SNA\ ES}{(Public\ funding + self - financing)}$$

$$RORIES_{Non-SNA} = \frac{Non - SNA\ ES}{(Public\ funding + self - financing)}$$

These indicators reveal the efficiency of a conservation investment in terms of the SNA- and non-SNA-related services the ecosystem assets produce. Table 11 displays the RORIES indicators for the specific MPA analyzed in this study. This illustrative example should be interpreted considering that this study takes into account only some ES due to data availability issues, so the numerator is likely to be undervalued.

Observing RORIES-type indicators over time can indicate the possible trends in efficiency among conservation policies, especially when the denominator is adequately stable. Alternatively, comparisons between MPAs are not recommended, as indicators significantly depend on the asset's ecological quality—such as its composition, functions, configuration, landscape, and biodiversity—that can greatly differ among MPAs.

The previously noted efficiency indicators could be more usefully expressed in marginal terms as:

$$\frac{\Delta_{t_1-t_0}(\ Total\ ES)}{\Delta_{t_1-t_0}\ (Public\ funding + self - financing)}$$

where the numerator and denominator represent the variation in total ecosystem services and the variation of funding between two periods, respectively. This could be interpreted as the marginal rate of return (in terms of ES flow) of an increase of conservation funding from one period to another. However, marginal data on ES are rarely available.

### 5.2. Sustainability analysis and indicators

The MPA management activities aim to: (i) regulate fruition in protected areas and (ii) directly and actively intervene regarding the quality or quantity of the ecosystem asset. Although sustainability analyses need to be supported by asset accounts, the set of accounting tables described above can be used to conduct some preliminary sustainability assessments in terms of ecosystem flows.

From a weak sustainability standpoint, when setting the price of the annual authorization for carrying out a recreational/provisioning activity, the MPA management should use as a lower bound the annual monetary value of the pressures it generates. This ensures that the pressures produced are at least economically compensated. However, the MPA can increase the price using as a reference the value of the ES users have enjoyed during the year. In Table 12, we provide an example regarding recreational fishing. In this case, the MPA should set a price for the authorization that is at least equal to € 11.46, but it is justified to ask users to pay also for the amount of services they benefited (€ 53.95).

However, from a strong sustainability standpoint, the mere economic compensation for the pressures produced is not enough for considering a human activity as sustainable. Even though only a biophysical analysis can measure the impact that human activities have on

**Table 12**
Strong sustainability analysis.
(Source: The authors' elaboration.)

| | Total | Per user |
|---|---|---|
| A. Annual value of cultural and provisioning ES enjoyed | € 6798.37 | € 53.95 |
| B. Annual value of pressions produced | € 1444.04 | € 11.46 |
| A + B | € 8242.41 | € 65.41 |

natural capital and inform on the actual level of sustainability, a first indication can be drawn from the MPA flow accounts presented above. We define "Net ES" the difference between the value of ES flows produced and the value of pressures generated by human activities in a year. Since the pressures considered in this paper are only emissions, we can calculate this indicator just for regulating services:

$$Net\ ES_{Regulating} = ES_{Regulating} - Total\ pressures$$

If this margin is negative, we can conclude that the MPA's current status is unsustainable in the long-term. If this margin is positive, further ecological analyses are needed to assess the overall impact of emissions. In the MPA case provided in this paper, $Net\ ES_{Regulating}$ is negative (−16,324.93 €), thus the current situation appears to be not sustainable at least from a flow standpoint.

## 6. Discussion: from MPA accounts to national SUT tables

This paper proposes an approach that can be used to draft an economic and environmental accounting framework for MPAs. The structure we built provides a dual purpose: its accounting can be easily integrated into national accounts, and it also serves as a management tool for MPAs. This section focuses on the former objective by demonstrating how this integration could occur. In particular, we consider a national SUT table and explain how this can be populated using the records from the ecosystem accounting tables described in the previous sections.

The approach to integrate ES into national accounts involves the following steps: first, the provisioning and cultural services' value must be explicitly noted among the intermediate inputs, and the regulating services' value must be added to the final products. The remainder of this section provides an example of the transition from our MPA accounting schemes to the national SUT table. We employ the accounting convention proposed by Edens and Hein (2013) where the ecosystem is regarded as a new sector that produces resources—such as ES—that other sectors consume.

Table 13 illustrates a simplified version of our *Module 1* account, and Table 14 provides an example of a SUT table. The ecosystem sector produces provisioning, regulating, and cultural services, as displayed in the rows in Table 13 and in the second column of the supply table. The provisioning and cultural (SNA) services become intermediate inputs in producing harvested fish, and in the recreational activities consumed by the professional fishing and diving sectors, respectively (Tables 13 and 14), while regulating (non-SNA) services offer the final benefits to the community (see the "Households" column in Table 14).

## 7. Conclusions

National environmental-economic accounting is a field of study that has gained increasing attention, as it supports national decision-making in the pursuit of global targets in general, and sustainable development goals in particular. The latest advancements in this field involve the development of ecosystem accounting, in which ecological and economic data are integrated due to ES, a new concept. In spite of the SEEA-EEA—the United Nations' 2014 handbook synthesizing current knowledge on ecosystem accounting with a set of accounting conventions and structures—the topic must be further investigated to develop a standard framework.

This paper shifts the focus from the national perspective to the MPA as a single institutional unit in an attempt to design ecosystem accounts following the SEEA-EEA's recommendations. Moreover, the integration of single institutional units' financial statements into the national economic accounts is standardized within the SNA, but lack conventions regarding how their ecosystem accounting records should enter into national accounts.

The policy implication of MPA ecosystem accounting is manifold. First, we provide an accounting framework for MPAs that reflects the current ecosystem accounting norms and can be easily integrated into larger-scale accounts. Specifically, the integration of MPAs accounting items into a regional or national SUT tables would form a valuable source of data for performing input-output analyses for policy purposes and a powerful tool for estimating the impacts of environmental and economic policy interventions and the ripple effects throughout the various sectors of the economy. Second, we organize the accounts and define indicators so they can become an intuitive management tool for MPA managers. Third, the information provided can also be exploited by local governments to evaluate the impact of investments in conservation in generating income for the local economic activities in terms of the value of the ES the benefit from.

We pursue this accounting objective by designing three modules consisting of ES flow, environmental pressure, and financial accounts. In each, we disaggregated the records to explicitly define the economic unit involved, thus easing the transition toward national accounts. This approach also allows us to construct a series of mixed-type indicators (financial, economic, and ecological) that provide, among others, information on the return of investments in conservation while allowing for the evaluation of alternative conservation policies.

To better illustrate this approach, we provide an example of how the presented accounting schemes can be populated based on data from an Italian project on MPAs. We also outline the primary obstacles that must be addressed when attempting to fill these schemes, with an emphasis on the issues still under debate by both economic and ecological researchers.

Our illustrated approach can be easily replicated for rural protected areas once the provided ES and human activities present in the territory are identified. Moreover, we believe that a further step toward standard disaggregated ecosystem accounting would regard those sectors as closely linked to the environment in general, and to such sectors as the agricultural or energy sectors in particular. A similar approach could be employed to create ecosystem accounting schemes for these sectors and reorganize their financial statements. Once conventions for single institutional units are consolidated, these can then be aggregated at the sectorial level to form local and regional ecosystem accounts that could eventually merge into a single national account through a bottom-up approach.

There is room for further research on matters that were not closely investigated in our work. On the one hand, consistently with the SEEA-EEA, our framework is based on exchange values, but it could be expanded to include the associated economic values in order to investigate the relationship among welfare, economics and ecosystems. On the other hand, we consider exclusively ecosystem flows, but it could be worth complementing them with assets accounts to derive indicators of ecological sustainability and investigate the asset-flow relationship directly.

**Table 13**
Example of Module 1 for an MPA.
(Source: The authors' elaboration.)

| Ecosystem Services | Households | Professional fishing | Diving |
|---|---|---|---|
| Provisioning | | 5513.91 € | |
| Regulating | 9868.72 € | | |
| Cultural | | | 66,880.35 € |

## 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.

**Table 14**
Example of national SUT table, extended to include non-SNA values (values in euro).
(Source: The authors' elaboration.)

| | | Ecosystem | Professional fishing | Scuba-diving | Households | |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| SNA | Provisioning of fish | 5,513.91 | | | | 5,513.91 |
| | Harvested fish | | 28,403.91 | | | 28,403.91 |
| | Cultural | 66,880.35 | | | | 66,880.35 |
| | Recreational | | | 323,509.25[a] | | 323,509.25 |
| Non-SNA | Regulating | 9,868.72 | | | | 9,868.72 |
| **Use** | | | | | | |
| SNA | Provisioning of fish | | 5,513.91 | | | 5,513.91 |
| | Harvested fish | | | | 28,403.91 | 28,403.91 |
| | Cultural | | | 66,880.35 | | 66,880.35 |
| | Recreational | | | | 323,509.25 | 323,509.25 |
| Non-SNA | Regulating | | | | 9,868.72 | 9,868.72 |
| VA – SNA | | 72,394.26 | 22,890.00 | 256,880.35 | | 352,164.61 |
| VA – SNA and NON-SNA | | 82,262.98 | 22,890.00 | 256,880.35 | | 362,033.33 |

[a] This value is calculated as the price of the dive multiplied by the number of annual dives.

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