One Ecosystem 9: e129751
doi: 10.3897/oneeco.9.e129751

OPEN ACCESS

Research Article

Ecosystem Accounting for Marine-Based Tourism provided by *Posidonia oceanica* in Italy

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Academic editor: Joachim Maes

Received: 14 Jun 2024 | Accepted: 23 Jul 2024 | Published: 02 Sep 2024

Citation: Bartolini A, Di Gennaro* V, Reas V, Mascolo RA, La Notte A, Capriolo A, Ferrini S (2024) Ecosystem Accounting for Marine-Based Tourism provided by *Posidonia oceanica* in Italy. One Ecosystem 9: e129751. https://doi.org/10.3897/oneeco.9.e129751

Abstract

This work presents the first ecosystem accounts for Marine-Based Tourism (MBT) in Italy. We develop a methodological approach to connect biophysical and economic information required to fill ecosystem accounting supply and use tables. Coherent with the System of Environmental Economic Accounting – Ecosystem Accounting (SEEA EA) framework, this approach starts by estimating the extent and the condition of marine ecosystems, showing the urgency in improving the availability, organisation and accessibility of biophysical data. This work provides valuable insights into understanding MBT from an ecosystem accounting perspective. We focus on the *Posidonia oceanica* and its role in the MBT sector in Italy, providing a physical quantification of such contribution and converting this flow into monetary terms. Our findings show that such habitat significantly contributes to the tourism sector, resulting in exchange values of MBT of €6 million in 2019 and €3.7 million in 2021.

Keywords

Posidonia oceanica, ecosystem services, tourism, ecosystem accounting, supply and use tables

Introduction

The development of the System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA, United Nations et al. 2021) promotes empirical applications to understand the contribution of the environment to the economy and human activities. Marine ecosystems contribute to the so-called Marine-Based Tourism (MBT), which represents a form of tourism, based on enjoying recreational opportunities related to the marine and coastal environment.

Despite the link between ecosystem quality and tourism demand being well-recognised, the contribution of marine and coastal ecosystems to the tourism sector is complex and challenging to isolate for accounting purposes. However, the predominant interest in the Blue Economy and the Biodiversity COP15 commitments should prioritise this analysis. This paper addresses this urgency by proposing the first ecosystem service account for MBT in Italy.

In 2019, the EU Blue Economy Observatory reported that the MBT sector generated a Gross Value Added (GVA) of €81.5 billion (European Commission et al. 2023). Nature Conservancy's Mapping Ocean Wealth (2017) shows that coral reefs worldwide contribute significantly to global tourism, generating 70 million trips annually and a substantial economic value of $36 billion each year, of which $19 billion stems from direct "on-reef" tourism activities (e.g. diving, glass-bottom boating, wildlife observation within the reef). MBT significantly influences also local economies (Visintin et al. 2022, Gupta et al. 2023), which are encouraged to promote activities, based on the marine environment, such as whale watching, recreational fishing and diving (O'Connor et al. 2009; Cisneros-Montemayor et al. 2020; Gonzáles-Mantilla et al. 2022).

The availability, quality and accessibility of natural resources have recently gained a significant role in the choice of tourist destinations and activities (Otrachshenko and Bosello 2017). Marine recreation opportunities are intricately linked to the presence of ecosystems, such as coralligenous habitats (Spalding et al. 2017, Tonin 2018), seagrass habitats (Zunino et al. 2020) and specific coastline features, such as rocky reefs (Cardoso-Andrade et al. 2021). At the same time, marine ecosystems' deterioration negatively affects both tourist arrivals, i.e. the number of customers who checked in at a country's accommodation during a given period (ISTAT 2024, https://noi-italia.istat.it/) and the length of stay with consequent economic losses (Bigano et al. 2007, Onofri and Nunes 2013).

Therefore, understanding the impact and dependency of MBT on marine and coastal ecosystems is crucial policy decision information and the SEEA EA represents an accounting framework that can facilitate this process.

The paper contributes to account for the relationship between marine ecosystems and socio-economic data to identify the role of *Posidonia Oceanica* in the tourism demand in Italian coastal areas. We provide the first MBT ecosystem account in biophysical and monetary terms to emphasise the urgency for collecting, organising and improving the mapping and monitoring of marine ecosystems. The paper is structured as follows: **Previous works** summarises previous works aimed at identifying the economic contribution of ecosystems to the tourism sector and introduces MBT in an accounting context. **Data collection and methods** explains the method and data used referring to: i) identification, quantification and mapping of *P. Oceanica*; ii) quantification of the biophysical flow of the service provided; iii) conversion of the flow into monetary terms. The empirical results are described in **Results** section, while **Concluding remarks** concludes.

Previous works

Given the broad set of benefits gained from marine ecosystems, such as fish and biomass as provisioning ecosystem services (ES), carbon storage and sequestration and coastal protection as regulating ES and recreational opportunities as cultural ES, literature related to the economic Monetary valuation of such services is very diversified. However, previous works that focus on the contribution of ecosystems to the economy are limited. Furthermore, it is worth noting that MBT refers primarily to tourism flows and differs from daily recreation activities. Although this distinction is crucial for ecosystem accounting (see Vallecillo et al. (2019), Zulian and La Notte (2022)), this clarification is often missing in previous papers.

Most of the previous studies focus on specific marine activities, such as whale watching (O'Connor et al. 2009), recreational fishing (Cisneros-Montemayor et al. 2020), shark watching (Gallagher and Hammerschlag 2011) and diving (Rodrigues et al. 2016, Chimienti et al. 2017, Gonzales-Mantilla et al. 2022). Studies that investigate the impacts of MBT activities on the economy (O'Connor et al. 2009, Cisneros-Montemayor et al. 2020) rely upon Input-Output (IO) or Social Accounting Matrix (SAM) coupled with tourist expenditure surveys to estimate value-added impacts (Chidakel et al. 2021), but without analysing the role of marine ecosystems.

Other studies assess marine cultural services, such as aesthetic and seascape value and underwater cultural heritage sites (Manglis et al. 2020). However, none of these previous studies is suitable for ecosystem accounting purposes where the main aim is to attribute the marine contribution to tourism flows.

Fewer papers clarify their intention to contribute to ecosystem accounts, considering mainly daily recreation activities of terrestrial ecosystems (Fitch et al. 2022, Zulian and La

Notte 2022) or specific marine ecosystems. Fitch et al. (2022) investigated the contribution of national parks and coastal areas to tourism expenditure in the UK, finding that the contribution of natural capital in 2017 was equivalent to 0.4% of the UK GDP. Zulian and La Notte (2022) have used an INCA-based methodology (the Integrated System for Natural Capital Accounts project launched by the European Commission in 2015) to analyse the contribution of nature to tourism in four Italian regions. The study focuses on the role of terrestrial ecosystems (settlements, cropland, woodland and forest, wetland), including the broad category of water (related to sea and freshwaters), to attract tourists. Their results show that 56.69% (246 million) of the overnight stays were motivated by nature-based tourism. Our approach expands these previous studies to assess the MBT motivated by the presence of the *P. oceanica* seagrass ecosystem in Italian regions.

Data collection and methods

P. oceanica is an endemic Mediterranean seagrass recognised for its ecological importance and the ecosystem services it provides (Catucci and Scardi 2020). It plays a crucial role in biodiversity conservation, sediment stabilisation and carbon sequestration and serves as a habitat and food source for various marine organisms (Bidak et al. 2021). The assessment of *P. oceanica* is prioritised over other species due to its status as a keystone species within its habitat, its sensitivity to environmental changes and its function as a biological indicator of the health of marine ecosystems (Tursi et al. 2021, Mutlu et al. 2024). *P. oceanica* is also used as a "biological quality element" for monitoring activities of marine species and habitats of Directives 92/43/EC "Habitats" and 2009/147/EC "Birds" provided for by the DM 11/2/2015 implementing of Article 11 of Legislative Decree 190/2010 (Marine Strategy). Furthermore, the economic Monetary valuation of ecosystem services provided by *P. oceanica* highlights its significant contribution to human well-being, further justifying the focus on this species (Campagne et al. 2015). In summary, assessing and monitoring *P. oceanica* is imperative to provide information for conservation efforts and ensure the sustainability of Mediterranean marine ecosystems.

This work focuses on assessing the Marine-Based Tourism (MBT) ecosystem service provided by *P. oceanica*. Our approach involves three primary steps, as illustrated in Fig. 1. The first is determining the extent and condition of *P. oceanica*. It follows the biophysical quantification of the ES flow and the conversion of this flow into monetary terms. The second one involves the biophysical quantification of the ecosystem service, while the third consists of converting the physical flow into monetary terms.

Biophysical quantification of *Posidonia oceanica* extent and condition

The first step, consistent with the SEEA EA, aims to determine the extent and condition of the Italian *P. oceanica* meadows. Despite the importance of this ecosystem, data on *P. oceanica* meadows in Italy are notably scarce, outdated or completely absent. Therefore, the first step is to statistically reconstruct a reliable dataset from the available data illustrated in Table 1.

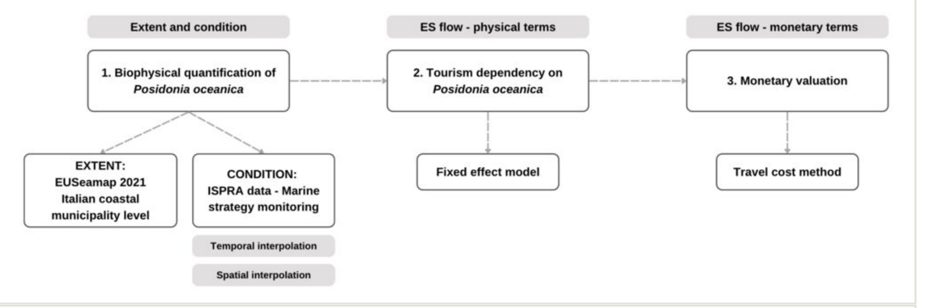

Figure 1.

Steps to assess the marine-based tourism ES provided by the *P. oceanica*.

Table 1.

Scope of datasets used in the analysis

Dataset	**Available at**	**Scope**
EUSeamap 2021	https://emodnet.ec.europa.eu/en/seabed-habitats	Extent of Italian *P. oceanica* meadows.
Italian administrative boundaries	https://www.istat.it/it/archivio/222527	Administrative boundaries of Italian municipalities
Monitoring data under the Marine Strategy Framework Directive	http://www.db-strategiamarina.isprambiente.it/app/#/datiMonitoraggio20182023	Density of the meadows in the sampled area

To derive the extent of meadows, we refer to EUSeamap 2021 (Vasquez 2021, accessed in July 2023) and use QGIS software to extract meadows that meet the following criteria simultaneously: i) the 2007-2011 EUNIS code was “A5.535: [Posidonia] beds”; ii) the 2019 EUNIS code was “MB252: Biocenosis of [Posidonia oceanica]”; iii) the substrate type was “[Posidonia oceanica] meadows” and iv) they were located within Italian administrative boundaries. EUSeaMap is a comprehensive predictive seabed habitat map developed through the EMODnet Seabed Habitats project, which involves biologists and seabed habitat mapping experts. The project aims to map and predict seabed habitats, enhancing marine spatial planning and conservation efforts. Seabed habitat maps are available to inspect on the project website (https://emodnet.ec.europa.eu/geoviewer/), allowing the download of map shapefiles.

Subsequently, *P. oceanica* meadows are linked to each Italian coastal municipality to facilitate the connection between the biophysical and monetary Monetary valuation steps. We use biophysical monitoring data from ISPRA (https://strategiamarina.isprambiente.it/sic-sistema-informativo-centralizzato/), collected under the Marine Strategy Framework Directive to assess the condition of the habitat. The dataset includes information about the density, i.e. the number of *P. oceanica* shoots/m^2, which can be considered a proxy indicator of the health status of *P. oceanica* (Montefalcone 2009) within the sampled sites across different time ranges (1999-2011 and 2018-2021). In each municipality, we can have null, one or multiple observations of *P. oceanica* density over time. In the latter case, we aggregate the information and compute the average density at the municipality level. However, density data are unavailable for all years or for municipalities where *P. oceanica* is present. To address this limitation, as IDEEA Group (2020) suggests, we apply two types of interpolation: temporal and spatial. These techniques produce estimates of average *P. oceanica* density in each coastal municipality for all relevant years. Fig. 2 provides an overview of the steps taken to estimate the extent and condition of the *P. oceanica* ecosystem.

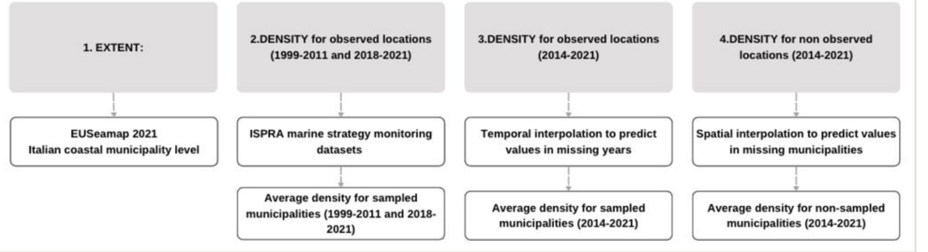

Figure 2.

Steps to assess the extent and condition of *P. oceanica* Italian meadows, dataset used and applied methodologies.

First, a fixed-effect ordinary least squares model using available yearly observations and a spatial identifier (geo) generated using the geohashTools package (https://www.rdocumentation.org/packages/geohash/versions/0.3.0) permits capturing site-specific characteristics. Predicted density values for missing years are then generated using the estimated coefficients.

For spatial interpolation, we run a second model regressing the density (observed or predicted) on the year, latitude, longitude and concentrations of phosphorus and nitrogen (proxies for anthropogenic pressure on marine ecosystems, aggregated from Grizzetti et al. (2021). Coefficients from this model are used to predict density in municipalities that are not monitored, resulting in observed or predicted values, based on the interpolation type. Through these temporal and spatial regressions, we establish the condition of *P. oceanica* in each municipality.

Tourism dependency on *P. oceanica* - ecosystem service flow in physical terms

The second phase involves the assessment of tourism flow in physical terms, i.e. the number of arrivals directly dependent on the *P. oceanica* ecosystem. Our goal is to assess factors motivating MBT by analysing the annual national arrivals in each Italian coastal municipality and isolating the contribution of *P. oceanica* to this flow. To achieve this, we systematically collect and organise a comprehensive dataset encompassing biophysical, cultural and socioeconomic characteristics of each Italian coastal municipality. The dataset includes a set of variables summarised, together with the description and source of information, in Table 2. For each year, we consider the number of arrivals by Italian tourists. We also include variables, such as the presence of marine protected areas, the number of seaside resorts, clubs, hotels, campsites, bed and breakfasts and other accommodation facilities, the blue flag status of beaches, the presence of diving centres, the length of the coastline and the density of *P. oceanica* derived from the first phase of this analysis. We also consider marine and terrestrial areas included in the Natura 2000 network, differentiating between marine sites, areas which are only partially related to marine-based activities and terrestrial areas located in coastal municipalities.

Table 2.

Variables included in the models.

Variable	**Description**	**Source**
Arrivals_*it*	Number of tourist arrivals in each coastal municipality	http://dati.istat.it/
MPA_*it*	Dummy: whether a marine protected area is present within the municipality	https://www.mase.gov.it/pagina/aree-marine-istituite
Density_*it*	Predicted density of *P. oceanica* (shoots/m^2)	Predicted or observed (Section *Biophysical quantification of P.oceanica extent and condition*
Blue Flag_*it*	Number of blue flag status beaches	http://www.bandierablu.org
Beach resorts_*i*	Number of beach resorts	www.spiagge.it
Diving_*i*	Dummy: whether at least one diving centre is present within the municipality	PADI, Google maps
Hotels_*it*	Number of hotels	http://dati.istat.it/
Camping_*it*	Number of camping sites	
Apartments_*it*	Number of apartments to rent	
Clubs_*it*	Number of clubs	
B&B_*it*	Number of bed and breakfast	
Other_*it*	Number of other types of accommodation	
Coast km (/1000)_*i*	Kilometres of coast	https://www.istat.it/it/archivio/137341
Marine_n2000_*i*	Hectares of marine areas included in the Natura2000 network. These areas include seabeds, reefs, islands and beaches of ecological significance	https://www.mase.gov.it/pagina/rete-natura-2000
Related_n2000_*i*	Hectares of marine-related areas, such as salt marshes, lagoons, marshes and near-shore pine forests, included in the Natura2000 network	

Variable	Description	Source
Terrestrial_n2000_*i*	Hectares of terrestrial areas included in the Natura2000 network, including, for example, forests and mountains	
Note: The Table also provides a brief description of the variables and sources. The subscript *i* indicates the municipality, while the subscript *t* indicates whether the variable varies over time.		

We are interested in isolating the effect of *P. oceanica* on the number of arrivals while controlling for other tourist attractions. Therefore, we built a model to investigate how the explanatory variables outlined in Table 2 influence the number of arrivals in coastal municipalities. To address potential endogeneity issues arising from some variables (e.g. the numbers of accommodation affected by tourist flows), we use lagged variables (Anderson and Hsiao 1981), which also allow us to account for the influence of past information on current tourists' decisions (Morley 1998). We use a log-linear specification, resulting in the model described by the following equation:

$$ln(y_{it}) = \beta_1 MPA_i + \beta_2 P.Density_{it} + \beta_3 Diving_i + \beta_4 Resorts_i + \beta_5 BlueFlag_{i,t} + \beta_6 Coast_i + \beta_7 Clubs_{i,t-1} + \beta_8 Hotels_{i,t-1} + \beta_9 Camp_{i,t-1} + \beta_{10} B\&B_{i,t-1} + \beta_{11} Rent_{i,t-1} + \beta_{12} Other_{i,t-1} + \beta_{13} Marine2000_i + \beta_{14} M.Related2000_i + \beta_{15} Terrestrial2000_i + \varepsilon_i$$

(1)

Equation (1) is structured to isolate the contribution of *P. oceanica* to the tourism flow. We apply standard ordinary least squares pooled and fixed effect models to account for individual heterogeneity tested on the data. Given the log-linear specification, an increase of one unit of the regressor X is associated with a variation of $100 \times \beta_X \%$ in the number of arrivals. Therefore, the estimated density coefficient β_X is used to measure the proportion of visits attributable to the *P. oceanica* ecosystem, thereby assessing the ecosystem service flow in physical terms.

Monetary valuation - ecosystem service flow in monetary terms

In the third step, we convert the physical flow into monetary terms. To do so, we apply one of the methodologies approved by the SEEA EA for the Monetary valuation of recreational ecosystem services, i.e. the travel expenditures method. We have data on arrivals in each coastal municipality. However, we lack information on the origin of tourists. To overcome this issue, we leverage tourism industry statistics (https://www326.regione.toscana.it/prodext/Turismo_matrice/) to collect data on national tourist flows across Italian regions and use this information to assign origins to our arrivals. Further details can be found in the supplementary materials (Suppl. material 1).

We compute the travel cost (TC) from each coastal municipality i to each Italian province j as follows:

$$TC_{(i-j)} = \frac{2 \times dist_{(i-j)} \times c}{2}$$
(2)

where $dist_{(i-j)}$ represents the route distance in kilometres between the coastal municipality i, with $(i = 1, ...583)$ and centroid of the province j, with $j = (1, ..., 110)$. Distances were computed using the ORS tools plugin in the QGIS software (http://www.qgis.org). The multiplication by 2 accounts for the round-trip distance, while c is the cost per kilometre*[1]. The resulting travel cost is then divided by 2, assuming that individuals travel and share costs, at least with one other person (Capriolo et al. 2020). The travel cost is then used as a proxy for the price to be applied to the *P. oceanica* ecosystem-dependent arrivals, quantified through the method described in the previous section.

Results

In this section, we present the key outcomes of each stage in our analysis: i) the assessment of *P. oceanica* extent and condition, ii) the estimates from models used to identify the portion of the tourism flow attributable to the *P. oceanica* ecosystem and iii) the conversion of this flow into monetary terms. Additionally, we present the supply and use tables (SUT) for the MBT ecosystem service provided by *P. oceanica* in Italy in both physical and monetary terms for 2019 and 2021. We selected these two years because: i) they are the most recent and ii) they are the only two years in which we have all the available information (i.e. population and tourism statistics).

Extent and condition of *P. oceanica*

Table 3 shows the extent and condition of *P. oceanica* meadows in Marsala Municipality, located in Sicily, as an example. The extension of meadows has been aggregated at the municipality level and density has been estimated by the temporal and spatial interpolation described in *Biophysical quantification of Posidonia oceanica extent and condition* section. Models' estimates are available in the supplementary material (Suppl. material 1).

Table 3.

Extent and condition (density) of *P. oceanica* Italian meadows for the Marsala Municipality.

Municipality	ISTAT code	Extent (m^2)	Year	Observed density (shoots/m^2)	Predicted density (shoots/m^2)
Marsala	81011	80152829.64	2014	-	269.848 [165.459, 372.707]
			2015	-	265.031 [160.519, 369.025]

Municipality	**ISTAT code**	**Extent (m^2)**	**Year**	**Observed density (shoots/m^2)**	**Predicted density (shoots/m^2)**
			2016	-	260.213 [155.403, 364.398]
			2017	-	255.396 [150.439, 359.361]
			2018	361.6	361.6
			2019	-	245.760 [139.391, 350.555]
			2020	-	240.942 [134.509, 346.508]
			2021	84	84

Note: 95% confidence intervals for the predicted values are estimated via 10000 Monte Carlo simulations and reported in brackets.

Fig. 3 and Fig. 4 show the density maps of *P. oceanica* meadows in the same area in 2019 and 2021, respectively. The maps show the decreasing trend of the *P. oceanica* density estimated from the models.

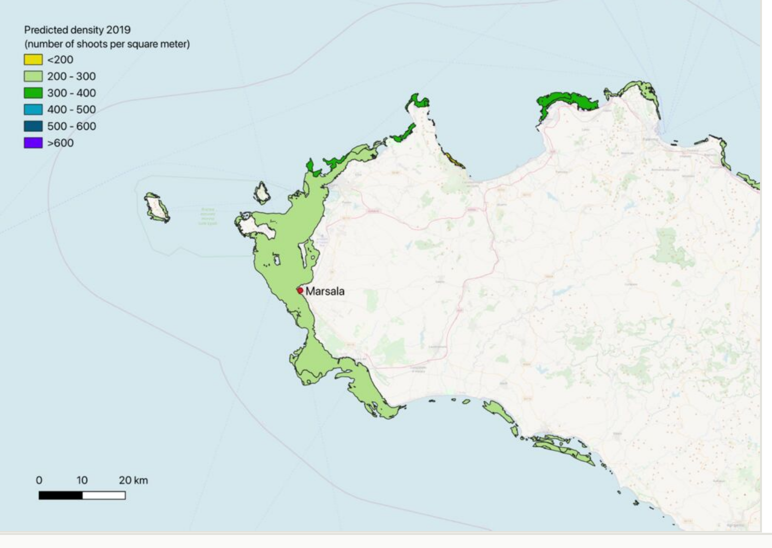

Figure 3.

Predicted density of *P. oceanica* meadows in the Municipality of Marsala in 2019.

Ecosystem service flow in physical terms

Table 4 presents the results of the models detailed in *Tourism dependency on P. oceanica* section. As expected, marine protected areas positively impact the number of tourist arrivals in the pooled and fixed effect models. In the pooled model, we observe a positive impact of the Blue Flag status, along with notable influences from factors such as the abundance of accommodation and entertainment options, bathing establishments and the length of the coastline. Additionally, amongst the Natura2000 network areas, only land areas appear to influence arrivals significantly. As for the Fixed Effect (FE) model, the significance of certain variables shifts. Notably, the Blue Flag status and the number of apartments and other types of accommodation lose significance, while the number of B&Bs seems to impact tourist arrivals negatively. However, the positive and statistically significant relationship between the dependent variable and the quality status of *P. oceanica* remains consistent in both models.

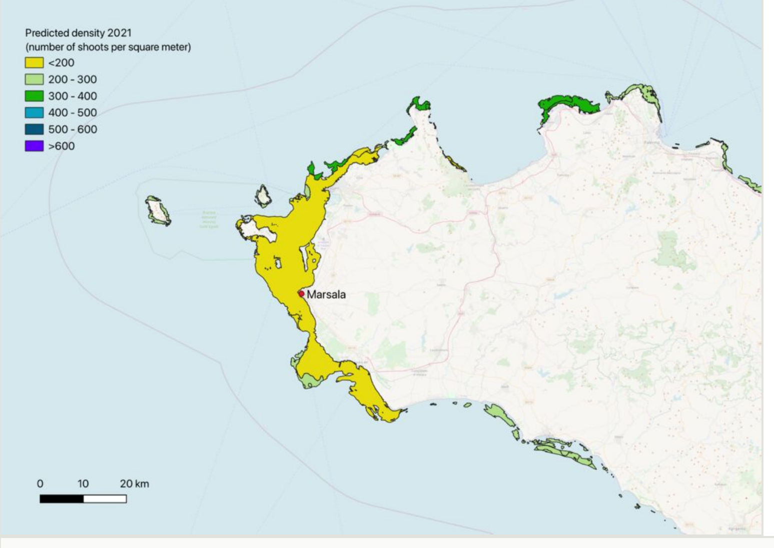

Figure 4.

Predicted density of *P. oceanica* meadows in the municipality of Marsala in 2021.

Table 4.

Pooled and fixed effect models' estimates (n = 3901).

Dependent variable: number of tourist arrivals	Pooled model estimates	Fixed Effect model estimates
Variables		
Marine Protected Area (indicator)	0.576*** (0.068)	0.791*** (0.138)
Density (shoots/m^2)	0.001*** (0.0001)	0.002*** (0.001)
Number of Blue Flag beaches - lagged	0.079*** (0.013)	0.008 (0.012)
Diving (indicator)	0.718*** (0.041)	-

Dependent variable: number of tourist arrivals	Pooled model estimates	Fixed Effect model estimates
Number of beach resorts	0.027*** (0.002)	-
Coast length (km)	0.005*** (0.001)	-
Number of clubs	0.020*** (0.007)	-
Number of hotels - lagged	0.048*** (0.005)	0.095*** (0.023)
Number of camp sites - lagged	0.044*** (0.003)	0.006* (0.003)
Number of apartments to rent - lagged	0.025*** (0.003)	-0.003 (0.002)
Number of B&B - lagged	0.007*** (0.001)	-0.007*** (0.001)
Number of other types of accommodation - lagged	0.007*** (0.001)	-0.001 (0.001)
Marine areas Natura2000 (ha)	-0.002 (0.001)	-
Marine-related areas Natura2000 (ha)	0.0001 (0.001)	-
Terrestrial areas Natura2000 (ha)	0.004*** (0.001)	-
Constant	-0.648*** (0.033)	-
R2	0.524	0.953
Adjusted R2	0.522	0.944
*p < 0.1; **p < 0.05; ***p < 0.01		
Note: The first column includes variables described in Table 2, which impact the number of tourist arrivals in the two models reported in columns 2 and 3. Models in columns 2 and 3 differ in including municipalities' fixed effects, as described in *Tourism dependency on P. oceanica* section. Fixed effects for municipalities are omitted for brevity. Standard errors are reported in brackets.		

Considering the FE model's superior fit to our data, we leverage its results to identify the portion of arrivals attributable to the *P. oceanica* ecosystem. The log-linear model indicates that a one-unit increase in *P. oceanica* density corresponds to a 0.2% variation in the number of arrivals. Therefore, we apply this percentage to attribute arrivals to the presence of *P. oceanica*. The total arrivals for 2019 and 2021, along with those entirely attributed to *P. oceanica*, are presented at a regional level in Table 5. The analysis focuses on all Italian coastal municipalities, attributing arrivals only to the coastal municipalities where *P. oceanica* meadows are present.

Table 5.

Number of tourist arrivals attributable to *P. oceanica* in the 15 Italian coastal regions.

	2019		**2021**	
Region	**Tourists 2019**	**Tourists *P. oceanica***	**Tourists 2021**	**Tourists *P. oceanica***
Veneto	3,932,631	0	3,345,937	0
Friuli Venezia Giulia	1,580,326	0	1,150,793	0
Liguria	4,487,686	8,235	3,298,128	6,039
Emilia Romagna	5,880,102	0	4,501,353	0
Toscana	4,139,479	5,571	3,277,868	4,345
Marche	1,650,344	0	1,453,046	0
Lazio	1,484,428	1,483	667,188	680
Abruzzo	1,010,516	0	845,462	0
Molise	77,931	0	67,606	0
Campania	5,188,135	9,040	2,603,583	4,496
Puglia	3,185,989	4,742	2,587,990	3,655
Basilicata	337,149	309	209,657	215
Calabria	1,419,590	1,950	900,763	1,332
Sicilia	4,633,723	7,910	2,810,895	4,812
Sardegna	3,205,567	6365	2,287,478	4,530
Total	42,213,596	45,604	30,007,747	30,104

Ecosystem service flow in monetary terms

We focus on the portion of the MBT ecosystem service that directly depends on *P. oceanica* and is enjoyed directly by tourists, who pay a price to "consume" it. We use the travel cost data from each Italian province (NUTS3) to each coastal municipality to proxythis price. This cost is then multiplied by the number of visits dependent on the presence of *P. oceanica*. Table 6 completes Table 5 with economic information. For 2019 and 2021 and each Italian region, the table reports the total estimated value of marine-based tourism provided by *P. oceanica*. This value is estimated according to the procedure outlined in *Monetary valuation* section and represents the share of tourists' travel expenditures attributable to *P. oceanica*. Table 6 also shows the per-arrival price estimated according to Equation 2 and subsequently averaged by region. Regions with zero values are those in which P. oceanicais not present and, consequently, the ecosystem service is not provided. Notably, while the average price in 2021 is higher than in 2019, the value generated in 2021 is lower. This discrepancy is due to the reduced number of tourist arrivals recorded in 2021. Finally, the last column of Table 6 shows the total extent of *P. oceanica* in each Italian region. At the national level, we obtained figures of €6.1 and €3.7 million for 2019 and 2021, respectively. Tables 7, 8, 9, 10 represent the supply and use tables (SUTs) in physical and monetary terms at the national level for the years 2019 and 2021.

Table 6.

Value and average price (€ 2022) of arrivals attributable to *P. oceanica* in the Italian regions.

	2019		**2021**		
Region	**Value (€)**	**Average price (€)**	**Value (€)**	**Average price (€)**	***P. oceanica* extent (km^2)**
Veneto	0		0		0
Friuli Venezia Giulia	0		0		0
Liguria	641,221	77.87	478,341	106.18	503
Emilia Romagna	0		0		0
Toscana	514,427	92.34	395,259	118.39	5889
Marche	0		0		0
Lazio	165,991	111.96	65,636	244.03	2257
Abruzzo	0		0		0
Molise	0		0		0
Campania	1,215,427	134.44	403,771	270.36	1469
Puglia	735,590	155.13	545,269	201.26	9743
Basilicata	42,234	136.78	24,866	196.54	73
Calabria	2,93,060	150.28	186,348	220.07	2242
Sicilia	1,443,006	182.42	879,521	299.87	8168
Sardegna	1,078,687	169.48	768,069	238.10	28112
Total	6,129,643		3,747,082		58460

Note: Values and prices are expressed in € 2022. They can be converted to € 2023 or made comparable by considering purchasing power parity (PPP) using the inflation rates and conversion factors available at https://wdi.worldbank.org/table/4.16.

Concluding remarks

This study represents the first Italian Marine-Based Tourism ecosystem account, offering insights into the complexity of assessing its physical and monetary flows. The interest in empirical applications and the development of ecosystem accounts under the SEEA EA framework is exponentially growing. Within this framework, we propose a methodological and empirical approach to estimate the role of marine ecosystems in the marine-based tourism sector. We show in three main steps how the employment of biophysical and socio-economic information in a statistical model allows us to: i) assess the contribution of the marine ecosystem to the tourism sector in physical and monetary terms and ii) fill the use and supply tables required in ecosystem accounting.

Table 7.

Physical Supply and Use Table in 2019.

		Economic sectors		Households	Government	Coast (*Posidonia oceanica*)
		Tourism	Other			
SUPPLY						
Cultural ES (Marine-based tourism)	**Number of arrivals**					**45,604**
USE						
Cultural ES (Marine-based tourism)	**Number of arrivals**	**45,604**				

Table 8.

Monetary Supply and Use Table in 2019.

	Unit of measure	Economic units				Coast (*Posidonia oceanica*)
		Economic sectors		Households	Government	
		Tourism	Other			
SUPPLY						
Cultural ES (Marine-based tourism)	€					**6,129,643**
USE						
Cultural ES (Marine-based tourism)	€	**6,129,643**				

Table 9.

Physical Supply and Use Table in 2021.

	Unit of measure	Economic units				Coast (*Posidonia oceanica*)
		Economic sectors		Households	Government	
		Tourism	Other			
SUPPLY						
Cultural ES (Marine-based tourism)	**Number of arrivals**					**30,104**
USE						
Cultural ES (Marine-based tourism)	**Number of arrivals**	**30,104**				

Table 10.

Monetary Supply and Use Table in 2021.

	Unit of measure	Economic units				Coast (*Posidonia oceanica*)
		Economic sectors		Households	Government	
		Tourism	Other			
SUPPLY						
Cultural ES (Marine-based tourism)	€					**3,747,082**
USE						
Cultural ES (Marine-based tourism)	€	**3,747,082**				

The proposed approach allows us to estimate the value of the contribution of MBT provided by *P. oceanica* to the tourism industry by using travel expenditure. We find that *P. oceanica* significantly contributes to the tourism sector, resulting in exchange values of MBT of €6 million in 2019 and €3.7 million in 2021.

Our findings contribute to a clearer understanding of MBT from an accounting perspective. Marine ecosystems, here proxied by *P. oceanica*, provide direct or indirect ecosystem services. In the MBT, this role is “indirect” because *P. oceanica* density is used as a proxy to determine the number of touristic arrivals due to the good quality of coastal habitats. However, the economic benefits are quite substantial and a loss of ecosystem extent and conditions can impact the tourism sector.

Despite the progress made in this analysis, there is still room for methodological and empirical improvements, mainly related to mapping marine ecosystems and data availability. Data availability particularly affects our biophysical assessment. While the temporal model works fine, the spatial model is subject to greater limitations, mainly due to the limited availability and fragmented nature of data on the condition of Italian marine ecosystems. A series of other variables could be included in the model to represent the anthropogenic pressure on the ecosystem. For example, including other variables on recreational boat anchorages, water turbidity and sediment quality might represent a significant opportunity to improve the model and, consequently, the accuracy of the estimates, which, however, already provide starting data for the development of the related accounting tables. In this context, we emphasise the urgent need for improved data availability. Collection, organisation, updating and accessibility are key to compiling accurate and complete accounts of marine ecosystems.

Nevertheless, this paper provides valuable insights for policy-makers to expand their options of actions related to the nature-based tourism sector. By carefully reading the information from the supply and use tables of ecosystem accounting, policy-makers can plan investments orientated towards monitoring, conservation or restoration of marine ecosystems considering the impact on the tourism industry and relying on a broader, more comprehensive set of information (e.g. their geographical area, physical and monetary accounts).

Acknowledgements

*Valentina di Gennaro worked on this study in the framework of the MARBEFES (MARine Biodiversity and Ecosystem Functioning leading to Ecosystem Services) project, funded by the European Union under the Horizon Europe Programme, “HORIZON-CL6-2021-BIODIV-01” Theme, Grant Agreement no. 101060937 [marbefes.eu]. The work of Alice Bartolini was co-founded by the European Union - FSE REACT-EU, NOP Research and Innovation 2014-2020.

Hosting institution

ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale (Institute for Environmental Protection and Research), within the context of the project "Servizio di elaborazione di dati e informazioni biofisiche finalizzare alla contabilizzazione dei servizi ecosistemici marini", resulting from the collaboration between ISPRA and the Department of Political and International Sciences of the University of Siena.

Author contributions

Alessio Capriolo and Silvia Ferrini planned and supervised the project. Silvia Ferrini and Alessandra La Notte designed the study. Alice Bartolini, Vittoria Reas and Valentina Di Gennaro collected data and conducted the analysis. All co-authors contributed to the writing of the article.

Conflicts of interest

The authors have declared that no competing interests exist.
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Supplementary material

Suppl. material 1: Ecosystem Accounting for Marine-Based Tourism provided by *Posidonia oceanica* in Italy - Supplementary materials doi

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Data type: Supplementary materials

Brief description: Biophysical model estimates, information on tourists' origins. This file helps to better understand the paper's results.

Download file (291.81 kb)

Endnotes

*1 Here, we assume a cost of 0.26 €/km, the minimum value used by Paletto et al. (2022) and based on Italian Automobile Club Tables (ACI), available at www.aci.it.