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An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain

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A R T I C L E I N F O

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A B S T R A C T

A spatial value transfer analysis was performed to generate baseline estimates of the value of ecosystem services in the coastal zone of Catalonia, Spain. The study used the best available conceptual frameworks, data sources, and analytical techniques to generate non-market monetary value estimates that can be used to identify scarce ecosystem services among competing coastal uses. The approach focused on natural and seminatural, terrestrial and marine systems, which provide essential services that are not considered in current economic markets. Results show that in 2004 a substantial economic value of $3,195 million USD/yr was delivered to local citizens by surrounding ecosystems. In a spatially explicit manner, the approach illustrates the contribution made by natural environmental systems to the well being of communities in the coastal zone of Catalonia. It is hoped that this study will highlight the need to consider these coastal systems in future management strategies to ensure their proper maintenance and conservation.

1. Introduction

If sustainably managed and protected, ecosystems offer benefits to current and future generations. The concept of ecosystem services, which is defined as the flow of benefits from nature to people, offers a framework in which to promote this vision [1].

Traditionally, benefits from the use of natural resources have not been fully incorporated into coastal zone management. Ecologically productive and multifunctional ecosystems continue to be converted into simple, single functional land use/land cover zones (*e.g.* croplands, urban developments, artificial hardening of the shoreline). The result is a biotic homogenization of the coastal environment [2]. One reason why the benefits obtained from these areas is still underestimated is the difficulty in expressing their indirect use value or the importance of their ecological functions in monetary terms. Since most of the economic value of coastal and marine environments lies outside the markets, failure to provide an analogous economic indicator for ecosystem services is potentially more detrimental for coastal and ocean economies than for others.

Ecosystem valuation is the process of assessing the contribution of ecosystem services in achieving a particular goal. Traditionally, this goal is efficient allocation, but other goals are possible [3]. The basic aim of valuation is to determine the preference of the user: how much better or worse off they would consider themselves to be as a result of changes in the supply of certain ecosystem goods and services. By expressing these preferences and relating them to measures of human well-being, valuation aims to make natural capital comparable with other sectors of the economy (*e.g.* built capital) for appraising investments, planning activities, developing policies, or making decisions about land and resource use.

In this study a spatial value transfer assessment was conducted to generate baseline estimates of ecosystem service values (ESVs) that are not part of existing economic markets in the coastal zone of Catalonia, Spain. The value transfer method constitutes the application of values and other data from the original study site to the present policy site [4]. Due to the increasing sophistication and number of empirical economic valuation studies in the scientific literature, value transfer has become a useful method for assessing ESV when primary data collection is not feasible due to budget and time constraints [5]. This is particularly relevant when resources are negligible (zero value) because they have simply been ignored in the existing markets.

Traditionally, most of the attention on the value transfer approach has been focused on the economic theory behind value

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transfer, while the inherently spatial nature of ESV is largely avoided [6]. Consequently, few practical applications of the methodology exist. Thus, although economists realize the importance of considering the spatial and ecological context of sites in conducting value transfer, it is important to develop ecosystem and landscape classifications for this specific purpose [7].

The key underlying assumption of international value transfer methods is that the economic value of ecosystem goods or services at the study site can be determined with sufficient accuracy by analyzing existing valuation studies at other sites [8]. Despite the known limitations, such as the context sensitivity of value estimates (biophysical and socioeconomic) and of coastal and marine service coverage [9], accuracy clearly improves when the information is more detailed and larger data sets are available [6,10]. Therefore, the quality of primary studies will determine the quality and applicability of the value transfer study.

The purpose of valuation at the regional scale is more similar to national accounting than to estimating exchange values. Moreover, treating the economic value of ecosystem services as zero is sometimes referred to as the "business as usual" alternative (although it is not really an alternative), which has resulted in much more error than value transfer itself has [11].

From the perspective of ecological economics, the assessment of ESV is considered a powerful tool for placing ecosystems on the agenda of integrated coastal zone management (ICZM) [12]. Olsen et al. [13] argue that the fundamental challenge of coastal management is governance and not technology transfer or refined scientific knowledge. This article seeks to contribute to the governance of the Catalan coast by clearly identifying the value of the benefits obtained from ecosystems, the coastal features that provide them, how this value is distributed, and how it impacts the current administrative units used in the coastal zone of Catalonia. This information is expected to help decision makers avoid systematic biases and inefficiencies in coastal management processes.

The objective of this study was to develop a comprehensive spatial value transfer assessment of the non-market economic benefits provided by natural and seminatural systems along the coastal zone of Catalonia, Spain. By developing a valuation system, the aim was to generate value estimates that can be used to identify scarce ecosystem services related to competing coastal uses such as coastal development and nature conservation.

2. The Catalan coast

Catalonia is located along the northeastern Spanish Mediterranean coast. It is one of the richest and most rapidly developing regions in Spain. It occupies an area of 32,105 km^2 and about 44% of its population (3 million in 2004) lives in just 7% (70 municipalities) of the territory [14]. The coastline is 699 km long and comprises a variety of temperate coastal systems, of which 270 km are beaches. The coast has a NE–SW orientation and has considerable geo and biodiversity, represented in its cliffs, rocky coasts, sandy beaches, low coastlands, estuaries, and river deltas, such as the Ebro delta. The seagrass species *Posidonia oceanica* constitutes one of the most productive environments in the Mediterranean Sea and is particularly relevant in this study. It hosts a diverse assembly of ecosystem goods and services that directly affect the well being of coastal communities. Although there have been previous efforts to develop a framework of ICZM in Catalonia, the ESV has not yet been estimated to the knowledge of the authors at the time of preparing this manuscript.

Fig. 1 shows the 12 coastal *comarcas* (administrative units) included in the three provinces of the Catalan coast. The Mediterranean climate has helped create the current structure of the area, which is dominated by typical coastal activities such as tourism, commerce, agriculture and – more recently – residential development. Industrial and commercial activities are strongly associated with the metropolitan areas of Barcelona (Central) and Tarragona (South) but are less significant along the rest of the coast, where other economic activities (mainly tourism) are dominant [15].

The Spanish coast is not only a complex area from the demographic, economic and biophysical points of view, but also because of the way it is regulated. There are three main administrative levels in terms of institutions and legislation relevant to coastal zone management: the central government of the Spanish State, the Autonomous Government of Catalonia (*Generalitat*), and the Municipalities. Within those levels, the Catalan coast is governed through two main legal instruments: the Spanish National Coastal Act of 1988 that represents the jurisdictional framework through which coastal zones are organized, and the Statute of the Autonomous Community of Catalonia that sets out the limited competencies of the *Generalitat* with respect to the Catalan coast and its marine environment. Although in general the Spanish government manages most activities related to the marine public domain (as set out in the Coastal Act), some of the activities that influence the structure and dynamics of the shoreline are managed by the local municipalities (mainly seasonal services such as upkeep and cleaning of beaches, *e.g.* [16]), and river basin authorities. These two political instruments were reinforced by the adoption in 2002 of the European Parliament and Council Recommendation concerning the implementation of Integrated Coastal Zone Management in Europe (COM/00/545), origin in 2004 of the ICZM Strategic Plan for the Catalan coast. See Barragán [17] for a review on coastal zone management in Spain.

The above mentioned instruments play a role in the practical implementation of new emergent European Union policy (*e.g.* Integrated Maritime Policy for the European Union, Blue Paper – COM/2007/574), legislation (*e.g.* Marine Strategy Framework Directive - 2008/56/EC), and regional sea scale policy as the recent Protocol on Integrated Coastal Zone Management in the Mediterranean recently launched in 2009 (EU/34/2009), the first ever legally binding instrument on ICZM in the Mediterranean Sea. The framework developed in this paper is intended to provide a unified conceptual basis for the valuation of ecological services as scientific-support to decision making in these new European Union policy developments.

3. Methodology

The methodological approach was divided into three parts: (i) the estimation of the non-market monetary value of ecosystem services provided by the Catalan coastal zone, (ii) the analysis of the annual ESV flow using relevant coastal management units, and (iii) comparisons and future recommendations. The study focused only on terrestrial and marine goods and services that are not represented in economic markets; marketed goods, such as commercial offshore fisheries (>50 m depth), aquaculture, and agriculture were not considered in this study. Hereafter, non-market ecosystem goods and services will be referred to as ecosystem services.

3.1. Spatial value transfer analysis

The ESV analysis was based on a unit value transfer approach. Its implementation follows the method proposed by Troy and Wilson [6] for estimating and geographically mapping the monetary ESV. It consists of six core steps: (1) selecting the ecosystem services to be valuated, (2) defining the study area, (3) establishing a typology to classify land use/land covers that can then be used to predict significant differences in the value and flow of the ecosystem

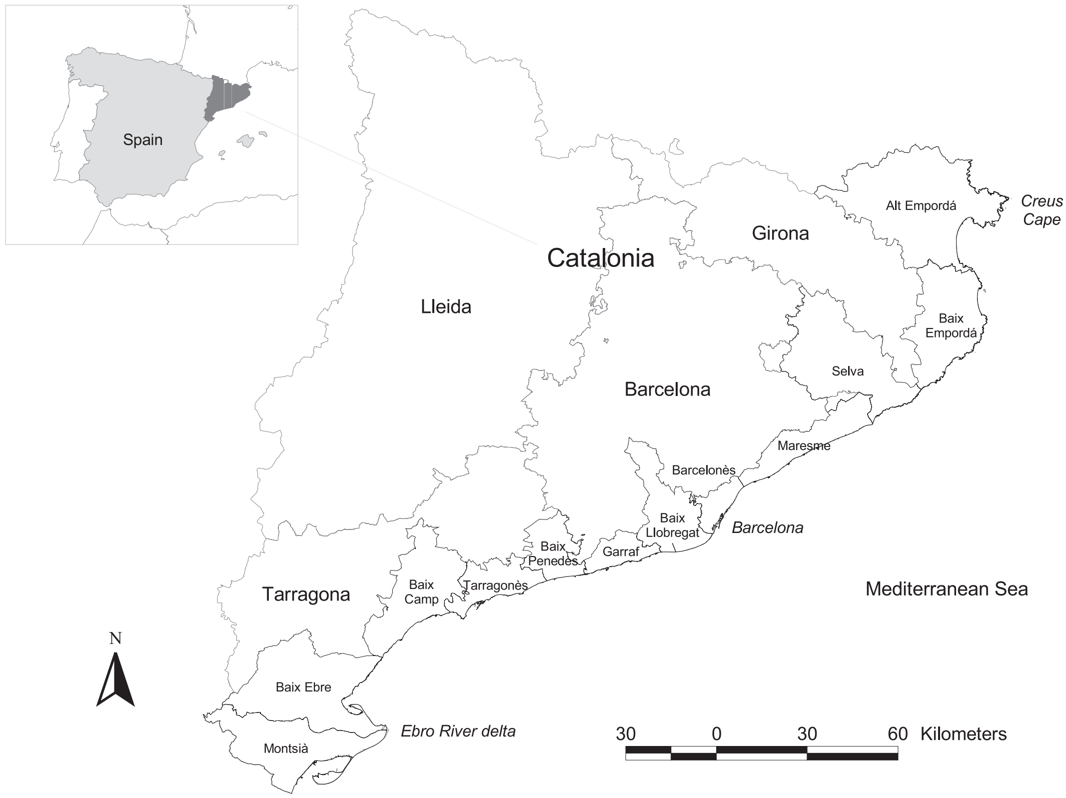

Fig. 1. Geographical extent of the provinces and coastal *comarcas* of Catalonia.

services selected, (4) meta analysis of previous valuation literature to identify available land use/land cover types, (5) estimating the value of ecosystem services per area unit, and (6) calculating the ESV annual flow, based on land use/land cover and mapping.

3.1.1. *Selection of ecosystem services*

The first step of the valuation involved identifying relevant ecosystem services. The study reviewed several typologies for ecosystem services that had been developed for application in biodiversity conservation, integral environmental assessments, and the economic valuation of ecosystem services [18–25]. However, in developing a typology for ecosystem services, it is important to take into account the specific objectives of the assessment, data availability, the quality of the peer reviewed literature, and existing cartography. This step is therefore closely related to steps 3 and 4 described above.

3.1.2. *Study area definition*

To assess the value of ecosystem services provided by the terrestrial area of the coastal zone, the *comarca* administrative level was selected. By dividing the area into *comarcas* rather than individual municipalities, the area was conveniently categorized into historical clusters of municipalities, each with coherent natural and socioeconomic characteristics. In fact, *comarcas* are official administrative units used in Spain for which socioeconomic data is publicly available. To clarify the defined marine division of the coastal zone, a 50 m isobathic line was selected. This area has commonly been referred to as the most productive marine environment in Catalonia, due its proximity to inputs from land sources, the processes that occur in the photic zone, and the high diversity of submerged habitats. We therefore expected that the most relevant coastal marine processes occurred in this area. In Catalonia, this large area includes approximately 80% of the continental shelf and offshore environment [26]. Commercial and industrial fisheries in Catalonia operate at depths greater than 50 m. Only self-sustaining fisheries were considered in our analysis. The definition of the coastal zone used in our assessment comprises the 12 terrestrial *comarcas* (Fig. 1) and the marine area up to the 50 m depth isobath. The total area of the coastal zone is 922,892 ha.

3.1.3. *Land and marine cover typology definition*

Land and marine cover incorporates aspects of biophysical land and marine cover types and land uses. The typology used primarily refers to land cover rather than use, and to terrestrial rather than aquatic and/or marine environments. The typology was determined by the available digital cartography for land use/land cover types, and the vegetation communities and habitats present in the area. The resulting typology used in this study covers Catalan habitats [27], the Catalan Sea bathymetry [28], and the seagrass bed vector layers [29]. The final cartographic scale of habitat spatial layer was 1:50,000 and was compiled from aerial orthophotos at a scale of 1:25,000 between 1998 and 2003. The layer includes more than 600 natural, seminatural, and artificial habitat types for the entire autonomous community of Catalonia, and was based on the CORINE Biotopes Manual of the European Union [30]. The bathymetry layer was used to select a strip of the continental shelf and the seagrass bed layer with a depth of ≤50 m. The seagrass communities within this strip (mainly composed of *P. oceanica* meadows) were then mapped.

One of the challenges of this study was to link our selected ecosystem services to the compiled layer of land and marine cover types in the geographic information system (GIS). A large amount of precision is required to accurately estimate an ESV in a narrow coastal zone such as that of Catalonia. To achieve this, we used a vector layer model in the GIS. The analysis of spatial aggregation was conducted at the habitat level to increase the possibility of visualizing the exact location of ecologically important elements in the coastal zone.

3.1.4. Literature review

According to Brouwer [31], the accuracy of an ESV estimate is determined by the quality of the reference studies used. Peer reviewed empirical studies from similar biophysical and socioeconomic contexts are preferred over any other source of data [8]. According to Farber et al., data should also be evaluated based on its transferability across the different types of ecosystem services, the type of land and marine cover assessed in the studies, and the valuation methods used [24]. If no appropriate studies are available, data from non-peer reviewed material and meta analyses should be evaluated. If none of the above options are applicable, new empirical studies should be commissioned. By increasing the number of publications used in a value transfer analysis we can eliminate gaps in value data for certain ecosystem services, which then increases the number of estimates that can be used in the analysis. This helps to detect any potential inaccuracy in estimates.

In this study a set of criteria was developed for selecting studies from the literature, which would then be added to the ESV database for the Catalan coast. Firstly, the scientific literature included in the analysis was divided into two types: empirical analyses (Type I), and meta analyses of peer reviewed and non-peer reviewed studies (Type II). Empirical analyses included peer reviewed journals and book chapters that used conventional economic valuation methods and were restricted to preference based valuations (*e.g.* travel costs, hedonic pricing, contingent valuation). The meta analyses of peer reviewed and non-peer reviewed studies included material that used conventional and non-conventional economic methods, and any preference based and non-preference based valuations (*e.g.* factor income, avoided and replacement costs). In addition, other criteria were used to select transferable estimates: (i) studies with results that could be readily translated into spatial equivalencies (*e.g.* dollars per hectare); (ii) studies that focused on socioeconomic and biophysical regions that were similar to Catalonia, mostly Western Europe and North America; and (iii) studies that focused primarily on non-consumptive resource use and ecosystem services (*i.e.* non-market value).

3.1.5. Estimation of the value of ecosystem services per unit area

A database and an accounting system were created with information of values of ecosystem services. All ESV were standardized to the average 2004 United States dollar (USD) equivalents per hectare and per year to provide a consistent basis for comparison. Values were standardized using the annual Consumer Price Index variation for Catalonia [32] and when required, the Euro was converted into USD using the fixed exchange rate defined in 1994 by the Bank of Spain ($1 USD = 133.94 Peseta, and 166.38 Peseta = 1 Euro) [33]. Each value represents the standardized average value for ecosystem services associated with a unique land or marine cover type. As is recommended in the literature, all results presented represent the statistical mean of individual estimates for each ESV [19,34,35].

3.1.6. Calculation of ESV annual flow and value mapping

The calculation of the value of annual flow followed the recommendations of Bateman et al. [7] for the application of GIS to environmental economics. The value of annual flow for a given land or marine cover unit (polygon in the GIS) was calculated by adding the individual ecosystem service value by the area. These spatially explicit results represent the annual value flow provided by an ecosystem service. The annual value flow is calculated as:

$$V(\mathrm{ES}_i) = \sum_{k=1}^{n} A(\mathrm{LU}_i)\cdot V(\mathrm{ES}_{ki})$$

where $V(\mathrm{ES}_i)$ is the flow value expressed in currency amount per year units, $A(\mathrm{LU}_i)$ is the area of land or marine cover type (i), and $V(\mathrm{ES}_{ki})$ is the annual value per unit area of ecosystem service type (k) (expressed in currency amount per unit area and per year) generated by each land and marine cover type (i) [6].

In the GIS environment, the ESV flow contribution of each land and marine cover type was estimated using the spatial value transfer function described above. Flow estimates were then mapped across the Catalan coastal zone showing the value of the annual flow of services provided by each polygon. Analyses and maps were produced with the GIS software Arcview™ v3.2 (Environmental Systems Research Institute) using the original cartographic scale of the habitat spatial layer in Catalonia of 1:50,000 [27].

3.2. Analysis of ESV flow based on relevant coastal management units

To ensure the availability of the ecosystem services, their use should be limited to levels that are sustainable from both a social and an ecological perspective. To be able to inform coastal managers about the importance of ecosystem service conservation, the annual flow value was spatially summarized using the coastal *comarcas* as relevant management units. In this study, we used the Homogeneous Environmental Management Units for the Catalan coast, based on *comarca*, which were proposed by Brenner et al. [36] to evaluate the relationship between the annual flow of ESV and the social and ecological characteristics of the coastal zone. Due to the characteristics of ESV, hierarchical aggregations had to be performed to summarize data at high and aggregated units before they could be mapped at their original minimum mapping unit (*i.e.* precise vector or grid cell position and boundary).

3.3. Comparisons and future recommendations

Results of the spatial transfer analysis were compared with other studies and analyzed with the aim of making suggestions for improvement in the present study. The following section offers coastal zone managers information on how to implement future developments using spatial value transfer analysis.

4. Results and discussion

4.1. Non-market value of ecosystem services

Several authors have proposed different typologies for ecosystem services. The present study has adopted that developed by Costanza et al. [19] for standardization and comparability purposes. Since its publication in 1997, several authors have used this classification and/or adapted it to their needs. The study uses a set of 14 non-consumptive services provided by natural and seminatural coastal ecosystems: (1) atmospheric gas and climate regulation, (2) disturbance regulation, (3) freshwater regulation, (4) freshwater supply, (5) erosion control, (6) soil formation, (7) nutrient regulation/cycling, (8) waste treatment, (9) pollination, (10) biological control, (11) habitat/refugia, (12) genetic resources, (13) aesthetic and recreation, and (14) cultural and spiritual services. Costanza et al. [19] provide examples of ecosystem functions and services of each of the services selected.

The accurate definition of the study area was critical since even on highly valued land and marine cover types, small boundary adjustments could have large impacts on ESV estimates (*e.g.*

seagrass beds). For example, the ESV estimates were significantly affected by the inclusion of land and marine cover types from the continuum between the terrestrial and marine portions of the coastal zone. In terms of management, this approach should provide the advantage of incorporating the key social, economic, political and cultural dimensions of the human subsystem into the coastal system value assessment. The study area represented 22.8% of the total terrestrial surface area in Catalonia and 21.5% of its entire continental shelf.

The typology for land and marine cover, shown in Table 1, was specifically developed for the purpose of calculating the ESV and the flow of ESV in a spatially explicit manner. Land and marine cover types were divided into two main domains, the coastal and marine domain, and the terrestrial domain. The coastal and marine domain includes the true marine continental shelf and seagrass beds, the oceanic influenced beaches, dunes, and saltwater wetlands. This domain occupies 22.2% of the area valuated. The terrestrial domain constitutes 77.8% of the total area valuated and includes the vegetated communities, freshwater flows and bodies, and the more artificial and urban related land covers. Most land and marine cover types included in the assessment represent subsequent hierarchical aggregations of habitats that were eventually clustered. This was done based on functional affinities and the availability of value data for the development of the appropriate typology needed for valuation. For example, beach or dune land covers include two systems present at the transition of the coastal zone, which maintain the structure and function of the shoreline. Some categories were developed using secondary data sources in combination with the habitat layer: *e.g.* layers for rivers, lakes, and priority wetlands were used to develop the freshwater layers for open freshwater systems, freshwater wetlands, and riparian buffers. Although urban, barren, burned forest and mining grounds are included in Table 1 for area accounting purposes, they were not valuated. This was either because they were not expected to provide services or because their value had not been found in the reviewed literature.

With regard to area, Table 1 shows the individual contribution of each land and marine cover type in the study area. Temperate forests and the continental shelf (≤50 m depth) are the largest systems represented. Medium to high human influence and resource use occur in the top five represented land and marine cover types (top two plus cropland, urban and grassland). The remaining land and marine cover types, represented in lesser amounts, are subject to relatively lower human influence (beaches, dunes, wetlands, running water, water bodies, and seagrass habitats). The difference between the surface area of the study area and of the valuated area is caused by the addition of the area of seagrass beds (8,568 ha). The seagrass beds are highly valued due to the services they provide such as waste processing, storm protection, and erosion control, which are not provided by the general shelf [1,37,38].

Estimates for non-market values found in the literature were added to a database to contribute to the valuation process. Due to time constraints in verifying the quality of the studies, gray literature such as technical reports, doctoral theses and government documents were not included in the database. Online search engines and scientific databases were queried to generate estimates for baseline ecosystem service values for the entire coastal zone. Most data were found by searching the ISI Web of Science [39] and the Environmental Valuation Reference Inventory™ [40].

The valuation database was integrated by 53 ESV from 188 individual estimates from a collection of 94 Type I and Type II studies that were included in the database (97.8% were empirical studies). All the literature used had been published during the period 1971–2004; the median was 1994, and 1996 was the year with the most publications. Most estimates were based on current willingness to pay (30.8%) or other preference approaches (71.8% for all preference based methods), which were limited by human preferences and the knowledge base.

Table 2 shows the baseline compiled for the value of ecosystem services and land and marine cover types in the Catalan coastal zone. The summary in the column on the far right shows considerable variability in the ESV provided by the different land and marine cover types. As expected, each cover type represents a unique aggregation of services, which was reported in the reviewed literature. Each individual ESV represents a mean value that can be derived from one or more estimates. In the database, 45.2% (24) of the 53 ecosystem service values were obtained from only one estimate; 5.6% (3) were obtained from averaging more than 10 estimates, and one value was obtained from 38 individual estimates (gas/climate regulation by forest).

There were several ecosystem services that seemed to be undervalued due to the limited availability and reliability of literature. Empty spaces in Table 2 represent data gaps in the literature and/or failure to fulfil the selection criteria. In the future, filling these data gaps by integrating gray literature (technical reports, doctoral theses, government documents, among others) in the analysis could lead to a higher total ESV. Data gaps are not unique to this study: several authors have reported difficulties in integrating value data from heterogeneous sources. Common difficulties in data standardization include accessibility to data (not always available online) and the quality of the validation process [9,41]. Consequently, the estimated figures should represent the minimum value since some of the services provided by certain areas are not accounted for.

On a per hectare basis, environmental systems providing the highest ESV were beaches and sand dunes, providing $104,146 USD/ha•yr. This result is due to their large contribution to disturbance control ($67,400 USD/ha•yr), and their aesthetic and recreation values ($36,687 USD/ha•yr). In fact, these systems represent the largest individual values in the assessment. Both freshwater wetlands ($28,585 USD/ha•yr) and seagrass beds ($24,228 USD/ha•yr) contribute significantly to total ESV. At the lower end of the value spectrum, croplands and grasslands account for just $2140 USD/ha•yr and $230 USD/ha•yr, respectively, the lowest ESV of the

Table 1
Valuated area by land and marine cover types in the coastal *comarcas* of Catalonia.

Domain	Land and marine cover	Area (ha)	Area (%)
Coastal and marine	Shelf (≤50 m)	191,484	20.6
	Seagrass bed	8,568	0.9
	Beach or dune	4,098	0.4
	Saltwater wetland	2,494	0.3
	Total	206,644	22.2
Terrestrial	Temperate forest	350,472	37.6
	Grassland	37,010	4.0
	Cropland	246,416	26.5
	Freshwater wetland	73	0.0
	Open freshwater	5,611	0.6
	Riparian buffer	2,558	0.3
	Urban greenspace[a]	1,848	0.2
	Urban[b]	71,589	7.7
	Barren	3,781	0.4
	Burned forest	2,778	0.3
	Mining ground	2,681	0.3
	Total	724,816	77.8
	Total	931,460	100

[a] Large urban parks and other green areas.
[b] Urban land cover type includes urban areas and other impervious zones.

Table 2
Non-market value of ecosystem services provided by each land and marine cover type along the Catalan coast (USD/ha•yr in 2004). Empty cells indicate lack of value data.

Domain	Land and marine cover	Gas/climate regulation	Disturbance regulation	Water regulation	Water supply	Erosion control	Soil formation	Nutrient cycling	Waste treatment	Pollination	Biological control	Habitat/ refugia	Genetic resources	Aesthetic and recreation	Cultural and spiritual	Total ESV (USD/ha•yr)
Coastal and marine	Shelf (≤50 m)				1,287			1,787			49				86	3,210
	Seagrass bed							24,228								24,228
	Beach or dune		67,400											36,687	59	104,146
	Saltwater wetland		766						13,376			497		64	445	15,147
Terrestrial	Temperate forest	133			403	122	12		109	400	5	2,281	20	301	2	3,789
	Grassland	7		5		37	7		109	32	30			2		230
	Cropland									20	30	2,053		37		2,140
	Freshwater wetland	331	9,037	7,378	3,815				2,071			279		3,474	2,199	28,585
	Open freshwater				1,011									880		1,890
	Riparian buffer		217		4,747									3,385	10	8,359
	Urban greenspace	830		15										5,266		6,111
	Urban/barren/burned/mining															0
	Total	1,301	77,420	7,398	11,263	159	19	26,015	15,664	452	114	5,110	20	50,098	2,802	197,835

assessment. These findings are relevant to the current analysis, which focuses on non-market values and excludes more traditional ecosystem services that agricultural landscapes deliver (food and raw materials).

Totals for the value of ecosystem services, shown at the bottom of Table 2 reveal considerable variability. Disturbance regulation is the most valuable ecosystem service ($77,420 USD/ha•yr), followed by aesthetic and recreation services ($50,098 USD/ha•yr). Soil formation and genetic resources are the two lowest valued ecosystem services ($20 USD/ha•yr).

The annual flow of ecosystem services delivered by each land and marine cover type was determined by multiplying the per hectare value in Table 2 by the area of each cover type (in hectares). Results summarized in Table 3 show that a substantial stream of services is delivered to citizens every year. It was estimated that ecosystem services contributed an annual value of $3,195.99 million USD/yr to the total natural capital of the Catalan coast.

More than 97% of the total contribution to the flow of ecosystem services in the Catalan coastal study zone was provided by just two terrestrial cover types: forest and cropland. In contrast to the results reported on a per hectare basis, it appears that ecosystem services associated with temperate forests provide the largest flow (41.6%) due to their large representation in the total study surface area (37.6%). However, coastal and marine cover types provided 40.3% of the total flow value, despite only accounting for 22.2% of the total valuated area.

Land use/land cover types were also aggregated into only four categories: marine (shelf and seagrass), coastal (beach, dunes and saltwater wetlands), terrestrial (forest, grassland, cropland and urban greenspace) and aquatic (freshwater wetlands, open freshwater systems and riparian buffers). Coastal types showed the highest ESV flow to area ratio (18.1), compared with marine and aquatic (1.1), and terrestrial (0.8) types. This indicates that the ecosystem services provided by coastal cover types are more valuable per hectare than any other cover type in the study area.

It is important to note that if the services provided by the ecosystem in the Catalan coastal zone are in fact scarcer than assumed here, this study will have underestimated their value. Reductions in supply could have occurred as a result of land conversion and development. For example, during the period 1987–2000 Catalonia experienced a 12% increase in urbanized land compared with the national average of 30% [42]. Climate change could also adversely affect coastal ecosystems. Its precise impacts, however, are difficult to predict and for this reason were not considered in the present study.

As shown in the map in Fig. 2, there is a considerable degree of heterogeneity in the annual delivery of ESV in the coastal zone; differences are particularly apparent between the interior areas and those closer to the shoreline, as well as along the coast. This spatial heterogeneity reflects the underlying landscape pattern. For example, beaches, dunes, and saltwater wetlands occupy a small surface area concentrated along the coastline but they contribute significantly to the total flow of ecosystem services due to their high value per hectare. Similarly, value appears to be concentrated at the northern and southern ends of the study area, where there are large natural and seminatural environments (*i.e.* the Cap de Creus Park and the Ebro River delta, respectively) that have not been as exploited as much as other areas.

The contribution of ecosystem services to total ESV flow was also analyzed. Fig. 3 shows the variability between the different ecosystem services. Habitat contributed the most to the total flow of ESV (40.9%) in the area. The addition of the surface dimension to the analysis resulted in land and marine cover types with large areas having larger contributions to value (*e.g.* forest and cropland). However, larger areas do not necessarily provide more ecosystem services: beaches, dunes,

Table 3
Annual flow of non-market value of ecosystem services shown for each land and marine cover type in the Catalan coast (USD/yr in 2004).

Domain	Land and marine cover	Annual flow (USD/yr)	Annual flow (%)
Coastal and marine	Shelf (≤50 m)	614,637,663	19.2
	Seagrass bed	207,585,504	6.5
	Beach or dune	426,791,880	13.4
	Saltwater wetland	37,777,608	1.2
	Total	1,286,792,655	40.3
Terrestrial	Temperate forest	1,328,021,174	41.6
	Grassland	8,502,682	0.3
	Cropland	527,307,954	16.5
	Freshwater wetland	2,086,694	0.1
	Open freshwater	10,606,674	0.3
	Riparian buffer	21,383,563	0.7
	Urban greenspace	11,292,851	0.4
	Urban/barren/burned/mining	0	0.0
	Total	1,909,201,592	59.7
	Total	3,195,994,247	100

and seagrass beds, which are not very abundant compared with the other terrestrial cover types, contribute most to disturbance regulation and aesthetic and recreational services.

Limited by the availability of literature and the previously established criteria, this study does not provide value estimates for some of the most traditional functions of a coastal zone. Therefore, if included in future analyses, reliable estimates of waste treatment provided by wetlands, water regulation by river deltas, gas and climate regulation by the continental shelf, and the cultural and spiritual function of the coast in general will increase the value of the services provided by all of these ecosystems.

The value estimates calculated in the present study were compared with current market economic indicators to explore the contribution made to natural capital in the coastal zone of Catalonia. Results show that total ESV flow constitutes 2.8% of the gross domestic product (GDP) in the study area ($114,805.98 million USD in 2004 [43]). Furthermore, total ESV flow constitutes 4.3% of the available family income ($74,375.95 million USD in 2004 [44]). The relationship between ESV and income was significant. This is because income can be compared with the natural wealth provided by ecosystem services. Temperate forest systems accounted for the largest contribution to natural wealth with a natural capital equivalent to $11.57 USD per $1000 USD of GDP in 2004, while freshwater wetlands provided only $0.02 USD.

4.2. Value of ecosystem services at the comarca level

The spatial summary of monetary value using management units has been previously reported as being a useful tool for understanding the heterogeneous nature of the underlying processes involved in the provisions and use of ecosystem services [6,45]. This study summarizes the ESV using *comarcas*, which are discrete administrative units. They have been recognized as practical social and ecological planning systems of the coastal zone in Spain [46]. From a management perspective, we used the spatial regionalization of *comarcas* of the Catalan coast developed by Brenner et al. [36]. The regionalization provides four categories of Homogeneous Environmental Management Units (HEMU). The HEMU of the Catalan coast represent social and ecological systems

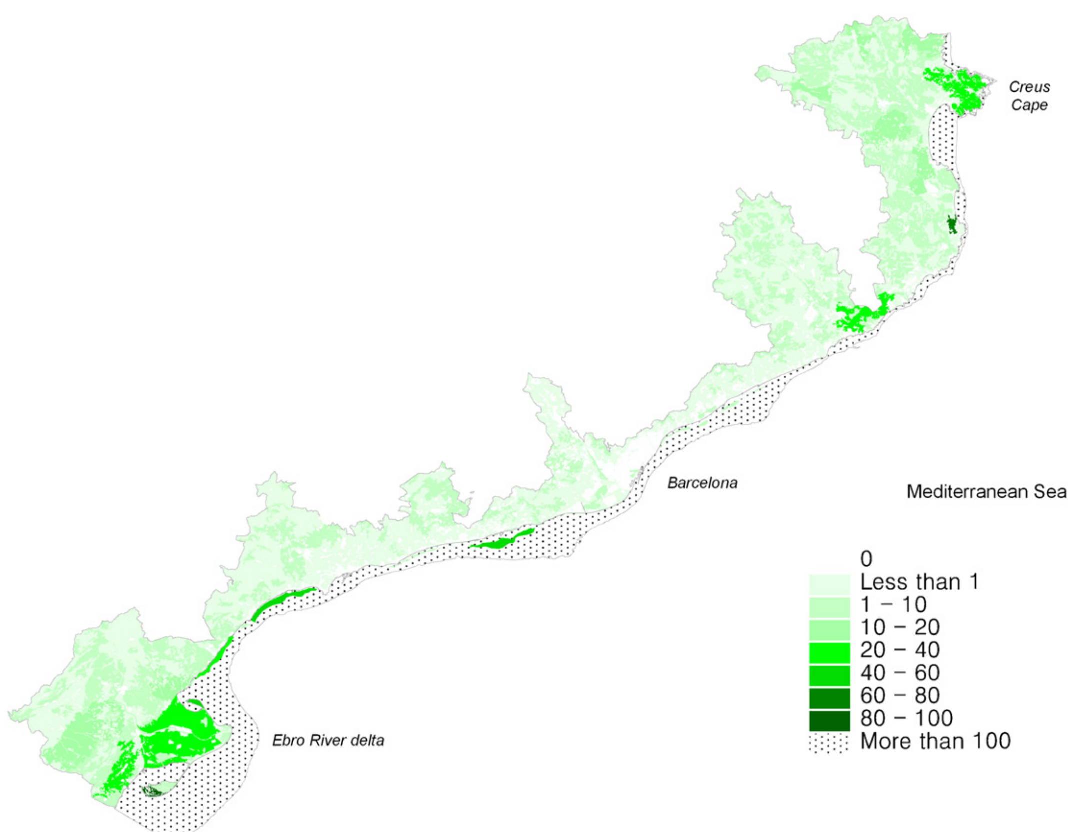

Fig. 2. Annual flow of non-market ecosystem service value in the coastal *comarcas* of Catalonia (million USD/yr in 2004).

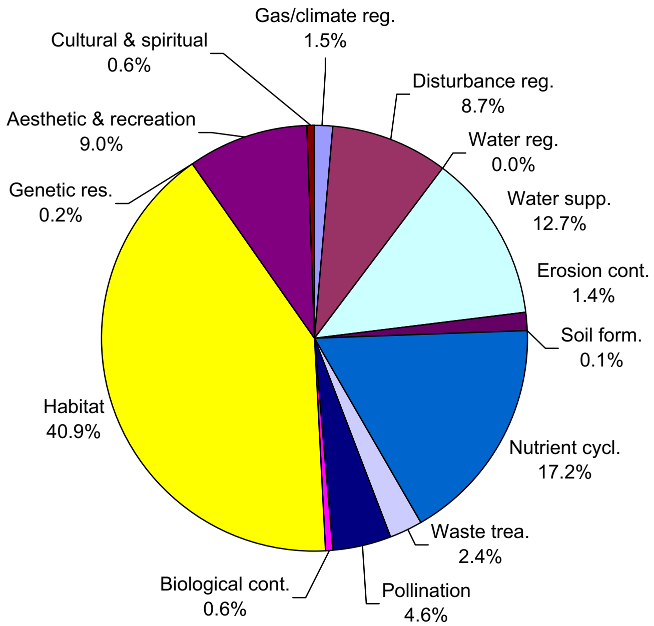

Fig. 3. Contribution to annual flow value based on ecosystem service type in the coastal *comarcas* of Catalonia.

that range from highly natural and less developed *comarcas* to less natural and highly developed *comarcas* [36,47].

Due to the previously observed impact of area in the spatial value transfer analysis the relationship between area and the ESV flow in the different *comarcas* was analyzed. Fig. 4 shows the results of this analysis, which are consistent with HEMU geography in that higher total values were found in larger and more natural *comarcas* such as in the northern and southern extremes of the study area. Montsià (16.5%) accounted for the larger absolute ESV flow followed by Alt Empordà and Baix Ebre. In contrast, Barcelonès, the region in which the administrative, political, and industrial capital is located (Barcelona), shows the smallest contribution to the delivery of services (1.2%). The Garraf is highly valuable due to the contribution of the Massís del Garraf natural protected area. As expected, the size of coastal management units has a large effect on the annual provision of ESV. This is not only true in terms of flow calculations (ESV is multiplied by the area to obtain the flow, so larger areas will provide larger values), but also because large *comarcas* are less populated and comprise more natural environments, resulting in a higher ecosystem service value. Consequently, the flow to area ratios of the Baix Empordà, Garaf, Baix Camp, Baix Ebre, and Montsià were higher than one. They therefore represent the largest relative contributions to the total annual ecosystem value on the Catalan coast.

The large impact on ESV observed for marine cover types (40.3%) was also seen at the *comarca* level in the analysis of the ESV flow along the Catalan coast. Although the original HEMU analysis did not integrate the marine portion of the *comarcas*, marine cover types were found to be major providers of ESV. For example, the Maresme constitutes an economic dominated HEMU, but has a very large marine portion (valuated shelf constitutes 35% of total) that provides a higher annual value (6.7%) than was expected from its HEMU category (terrestrial dimension). Although the structure and function of the marine environment are difficult to valuate, due to data availability and resolution, both terrestrial and marine areas of the coastal zone were found to be very influential in the analysis of the capacity of the coastal zone to provide services to citizens.

Fig. 5 illustrates the spatial distribution of the relative contribution of each *comarca* to the total ESV flow and to the main economic and demographic variables along the Catalan coast. The first aspect to be highlighted is that, in general, there is a clear inverse pattern between environmental and economic values. Highly economically developed *comarcas* (especially Barcelonès and Tarragonès) have very low ESV flow values, whereas the less developed *comarcas* correspond to regions that host large natural areas with well preserved ecosystems. Consequently, these less developed *comarcas* contribute considerably to the total ESV flow of Catalonia. As mentioned above, the largest contributions to ESV flow are concentrated in the northern and southern *comarcas*.

The economic indicators for Baix Penedès and Garraf do not seem to follow the general trend. Baix Penedès and Garraf have low values for economic indicators (*e.g.* the lowest GDP) but their contribution to the ESV flow is modest. This could be explained by their location; these areas have been (and are) popular for second homes and for recreational trips for residents of the Barcelona Metropolitan area. They support a relatively low permanent population but are subjected to high pressure. This situation was highlighted in the Maresme Strategic Development Plan, which warns about changes from natural to urban land use caused by the development of dormitory towns along its coast [48].

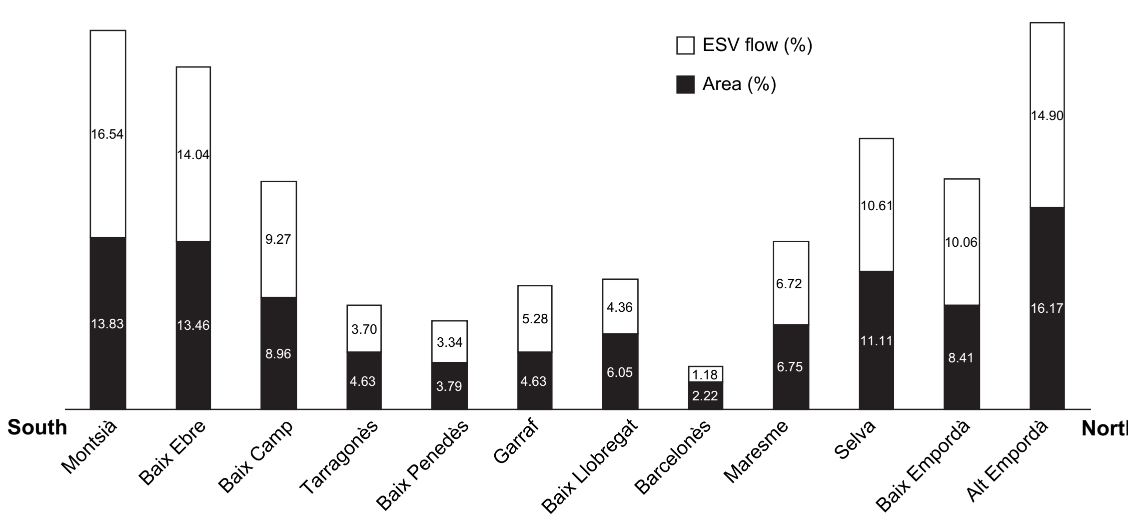

Fig. 4. Contribution of annual ESV flow and area within each *comarca* on the Catalan coast. Values indicate percentages of total.

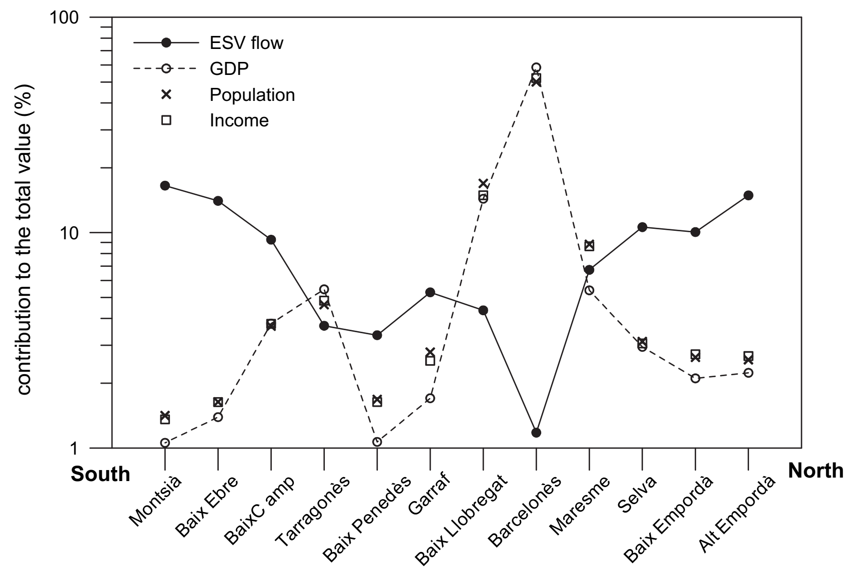

Fig. 5. Contribution to the total annual ESV flow, GDP, income and population within each *comarca* along the Catalan coast. *Y* axis in logarithmic scale.

The map in Fig. 6 shows the average value of non-market ecosystem services per hectare provided by all the terrestrial and marine cover types based on the HEMU system. Due to the inclusion of the value provided by marine cover types in the analysis, the resulting trends differed from those obtained by Brenner et al. who used the original HEMU classes [36]. For example, the value per hectare for the Garraf was greater than that for the Alt Empordà ($4,123 USD compared with $3,166 USD), considering that the Alt Empordà accounts for the second largest contribution to the ESV flow (14.9%). In this case, higher per hectare values represent highly valued ecosystem features (cover type) in a particular HEMU. With only 4.6% of the total area and a contribution of 5.3% to the total ESV flow, 52% of the valuated area of the Garraf constitutes its shelf ($\leq$50 m) and 17% is forest. Furthermore, it accounts for 25% of all seagrass beds on the Catalan coast. For consistency purposes, the map was created using the same method and number of classes of

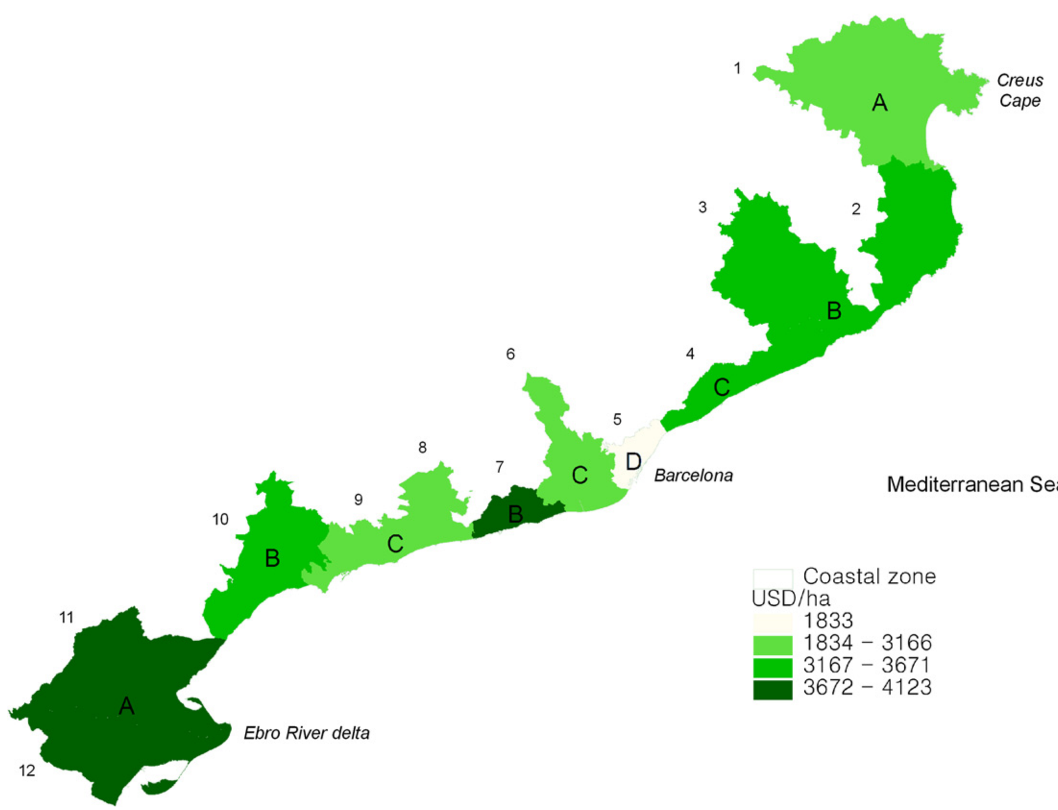

Fig. 6. Average ecosystem service value by HEMU of the coastal *comarcas* of Catalonia (USD/ha•yr in 2004). Letters in *comarcas* indicate HEMU class. Numbers indicate *comarcas*: (1) Alt Empordá, (2) Baix Empordá, (3) Selva, (4) Maresme, (5) Barcelonès, (6) Baix Llobregat, (7) Garraf, (8) Baix Penedés, (9) Tarragonès, (10) Baix Camp, (11) Baix Ebre, and (12) Montsià.

Table 4
Comparison of studies on the non-market valuation of ecosystem services. Data standardized for 2004.

	Area (ha × 10^6)	GDP (USD × 10^6)	Pop (pop × 10^6)	ES flow (USD/yr × 10^6)	GDP (%)	Mean ESV (USD/ha yr)	ES flow per capita
World[a]	51,625.0	44,384,871	6,464.0	42,410,000	95.6	822	6,560
Catalan coast	0.9	114,805	4.3	3,195	2.8	3,463	730
Scotland[b]	16.0	141,888	5.0	32,622	23.0	1,936	6,424

[a] World data from Costanza et al. [19] and other sources.
[b] Scotland data from Williams et al. [50] and other sources.

the original HEMU map (four classes using the Jenks optimization method [49]).

Comparisons are only possible between equivalent land and marine cover types and the only dependent variables in the analysis are mean ESV and ESV flow (normally driven by geographic specific human preferences). Thus, to accomplish accurate comparisons between sites, a common and objective definition of coastal zone land and marine cover type must be established in the future. Moreover, this study proposes the use of similar social and ecological systems to that of the HEMU in the analysis of ESV flow, since this approach enables users to integrate specific territorial characteristics into management strategies.

4.3. Comparisons and future recommendations

Table 4 shows a comparison between the results of our study and of two others, one global and one regional. A direct comparison between most of the categories provided was not possible due to differences in goods and services assessed, land and marine cover typologies, and spatial and temporal resolutions used. However, as Table 4 shows, the Catalan coastal assessment achieved a higher mean ESV than the global and regional areas ($3,463 USD/ha•yr compared with $822 USD/ha•yr and $1,936 USD/ha•yr, respectively).

Some of the differences found between the regional analyses for the ESV flow in Catalonia and Scotland can be explained by differences in the nature of the study areas. For example, the true marine portion assessed in Catalonia represented only 20.6% of the territory (continental shelf ≤50 m depth), whereas the same cover type represented more than half the total valuated surface area in Scotland [50]. A significant amount of the ESV flow in Scotland was achieved due to the large marine area included and also because the marine environments have larger associated ESV values. Nevertheless, the use of a larger cartographic scale for base data (land and marine cover type spatial layers) seems to be responsible for a higher mean ESV on the Catalan coast. This larger scale can more accurately determine and integrate highly valued land and marine cover types (*e.g.* saltwater wetlands, seagrass beds, freshwater rivers, water bodies, and wetlands).

The result for mean ESV in Catalonia was higher than that reported by Costanza et al. [19] for global mean ESV. This is mainly due to two important improvements in present study. Firstly, 10 years after the publication of the global value of the world's ecosystem services, the increased number of studies estimating value [51] and the increased number of available online databases [41] has improved the accuracy of the present study (94 peer reviewed studies, 97% of which were empirical studies). Costanza et al. [19] used over 100 studies (Type I and Type II) for all land and marine cover types including four that were not applicable to this study. Secondly, a detailed spatial and contextual resolution of the data available for the Catalan coast facilitated the present spatial transfer analysis (using a cartographic scale of 1:50,000 and more than 600 original vegetation/habitat types) compared with the global land and marine cover types used by Costanza et al. (1:500,000 or smaller cartographic scale and approximately 32 original categories) [19]. The increases in spatial and contextual resolutions and in the quality and availability of social, economic and political data, have permitted a viable estimation of ecosystem service values downscaled to the coastal zone. This should allow coastal managers to consider the required allocation of resources in CZM to then provide such services under a scenario of resource degradation.

The results presented here should be treated as conservative estimates of the total non-market ESV of the Catalan coast. The present estimate represents a minimum value, which according to Costanza et al. [19] is more likely to increase under the following conditions: (i) there are increased efforts to integrate a broader range of ecosystem service values; (ii) more realistic representations of ecosystem dynamics are incorporated; and (iii) ecosystem services become scarcer in the future (since markets are driven by complex supply and demand dynamics).

Some values, however, could also be overestimated. This is particularly likely when representative values are transferred from a few cases in which the estimated value is dependent on very specific conditions. A typical example could be the role of beaches in providing protection to the coastal zone. It is expected that this value would be high in areas subjected to very high energy marine climates, whereas in areas subjected to low energy marine climates it would be lower. It should also be considered that the value associated with the protection function will depend on the characteristics of the hinterland (*e.g.* if there is nothing of significant importance threatened by storms, the value of the protection function should be reduced, with increasing values as the characteristics of the territory, natural and/or artificial environments, increase in importance).

Although the initial estimate of $3,195.99 million USD/yr should be considered as a useful starting point for managing the benefits provided by coastal ecosystems, we suggest that additional developments from the social and natural sciences are required to improve future valuations in Catalonia and elsewhere. Some suggestions that would increase the accuracy of ESV estimation for ICZM are to (1) improve the quality and availability of ESV data in empirical peer reviewed literature; (2) develop land and marine cover typologies that are relevant to the coastal zone and can be used to test the biophysical similarity of the policy site and the study site; (3) develop site specific socioeconomic functions for value transfer analysis; (4) increase consistency in the use of ecosystem service terminology to better communicate the value of ecosystem services; (5) assess the biophysical capacity of ecosystems to deliver a healthy flow of services; (6) integrate the concept of ecological and economic scarcity of ecosystem services into new valuation methods; and (7) develop payment schemes for ecosystem services that integrate ESV into markets.

5. Conclusions

This study established a set of criteria to estimate the non-market ESV using a value transfer approach in a spatially explicit manner for the Catalan coast. The *comarca* was selected as the working administrative unit. Results indicate that an economic value of at least $3,195.99 million USD was delivered to citizens in 2004 by the Catalan coastal systems. If this is incorporated into estimates for the wealth of the Catalan coastal area and a new aggregated figure representing both the economic and natural wealth of the area is established, it would be the equivalent of each family receiving an additional 4.3% in available income every year. This implies that every year ecosystem services provide a substantial and indeed quantifiable contribution to the well being of coastal communities and should therefore be included in future management plans as essential coastal assets.

The spatial analysis revealed that coastal and marine areas provided 40.3% of the total annual flow of ESV, though they only accounted for 22.2% of the total surface area considered. From the existing environments, the beach and dune cover types provided the largest value on a per hectare basis ($104,146 USD/ha•yr), and disturbance regulation was the most valued ecosystem service ($77,420 USD/ha•yr). These results confirm the value of the regulation function of transitional land and marine ecosystems in the coastal zone, which help provide other benefits to citizens.

Consistent with the HEMU geography of the Catalan coast, the largest, least developed, and more natural *comarcas* (northern and southern areas) contribute most to the total value of the area. Again, consistent with the HEMU, the highly populated and developed area of Barcelonès contributed the least to ESV flow (1.2%). The combination of terrestrial and marine areas determined the total flow of services in the *comarca's* coastal zone. Consequently, it seems more than appropriate that both the terrestrial and marine coastal systems be considered in management strategies to ensure the proper maintenance of the services provided by these ecosystems, as outlined by the recent European Marine Strategy Framework Directive.

The spatial quantitative assessments of ecosystem service values carried out in this study highlight, geographically, the benefits on which citizens depend the most and therefore those ecosystems to which conservation efforts should be directed. The monitoring of changes in land and marine cover types along the coastal territory would allow management to estimate changes in ESV, which would thus provide a clear estimate of how the well being of the local communities would be affected. For example, if we had to pay for ecosystem services in Catalonia, or replace them, then an annual increment in GDP of at least 2.7% would be necessary (since the evaluated services are not currently captured in GDP). With regard to replacement, this would lead to a reduction in economic wealth since we would only be replacing existing services (without considering that many ecosystem services are irreplaceable).

This approach could be applied to similar environments and would enable users to assess the economic value of coastal ecosystem services in an explicit spatial framework, which would otherwise remain hidden or unappreciated. This would help managers to make (better) informed decisions about land and coastal management issues by considering their contribution to human well-being. Finally, as a social consequence, improving people's knowledge about the contribution of surrounding ecosystem services, particularly how they affect community well-being, would almost certainly increase the value people assign to ecosystems, and therefore increase their monetary value.

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