Mapping the global values of recreation in coastal ecosystems: results from a meta-analysis

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Abstract

The values of the recreational services provided by coastal ecosystems are examined through a meta-analysis of an expanded database of value estimates. This study provides a substantially new contribution in relation to previous meta-analyses in its use of GIS techniques for the characterization of the valued ecosystems, the determination of the spatial variables of the meta-regression model and their application to value transfer. Furthermore, a series of explanatory variables including site accessibility, anthropogenic pressure, level of human development and richness in biodiversity are introduced for the first time in a meta-analysis of coastal recreation and are found to substantially influence values. The meta-analytical value transfer function is applied to produce the first global map of the economic value of the recreational services provided by coastal ecosystems.

1. Introduction

Marine and coastal areas host ecosystems that are among world's most valuable and rich in biodiversity. Besides their ecological value, coastal ecosystems deliver a series of goods and services that are of benefit to humans. These include cultural values that support tourism and recreational activities such as beach leisure (Bin et al. 2005; Freeman III 1995), wildlife watching (Loomis et al. 2000), diving (Depondt & Green 2006), bathing (Georgiou et al. 1998) recreational fishing and boating (Freeman III 1995). Market failures induced by the public good character of many of the mentioned goods and services or from ill-defined property rights result in many of the benefits delivered by coastal and marine ecosystems being overlooked in the policy-making process.

The number of published primary valuation studies focusing on the cultural values of marine and coastal ecosystems is rapidly growing. At the state of the art, however, only few studies endeavored to develop an analytical framework for identifying the determinants of values and forecasting how values may be affected by stressors such as climate change and habitat disappearance. Among the previous efforts in such direction count two meta-analyses (Brander et al. 2007; Liu & Stern 2008) which are focused, however, on a specific subset of ecosystem types (i.e., coral reefs) or valuation methods (i.e., contingent valuation method). Furthermore, both metaregressions rely on a relatively small sample of primary studies and value observations.

This study expands on previous research studies along several lines. First, the main goal of the study is to develop a meta-analytical value transfer function and apply it to draw a global map of the current economic value of the non-market recreational services provided by coastal ecosystems. Second, we employ Geographic Information Systems (GIS) to provide a geographically sound characterization of the extent and location of the valued ecosystem sites. This is a substantial improvement with respect to previous global meta-analyses of ecosystem values which generally rely on the location of the geometric centre of the ecosystem and on its areal extension for the characterization of the valued sites (see for instance (Brander et al. 2006; Ghermandi et al. 2008). Third, we employ a GIS analytical framework also in the characterization of the context variables of the meta-analytical model, which expand previous models to include geo-referenced information on variables such as richness in biodiversity, anthropogenic pressure, site accessibility, and level of human development near the valued site. Such variables are selected in order to get a better and more economically oriented explanation for observed differences in ecosystem valuations. Finally, the econometric estimates discussed in this paper have been drawn from a very extensive data set of valuation studies and value observations that includes 153 studies and 758 distinct observations of the cultural values of coastal and estuarine ecosystems. Although only part of the studies contained all the information required for the meta-analytical model and for the GIS characterization of the valued sites, the final dataset used in the meta-regression (196 observations from 57 studies) is larger than any that has been pulled together previously.

2. Materials and methods

2.1 The database of coastal valuation studies

The analysis presented in this paper relies on a comprehensive data set of valuations of the cultural services of coastal and estuarine ecosystems. More than 320 primary valuation studies were retrieved from online databases, libraries and through direct contact with authors and investigated. Online valuation databases such as EVRI (http://www.ecri.ca), EconPapers (http://econpapers.repec.org), Envalue (http://www.environment.nsw.gov.au/envalue) and Consvalmap (http://www.consvalmap.org) constituted the main source of primary valuation studies or references to relevant papers. The investigation was not limited to the analysis of publications in the official scientific literature, but also explored “grey literature” (such as reports for both public and private institutions, consultancy studies, and unpublished working papers). Only primary valuations were considered and care was taken not to include more than once in the data set estimates that were published in multiple papers.

For the present study, a subset of 57 independent studies from the whole dataset was selected which contained all the necessary information for the GIS characterization of the valued sites and the explanatory variables of the meta-analytical model. The total number of usable observations is 196. The average number of observations per study is 3.4 and the maximum number of observations per study is 15. The number of studies and observations is the largest in a meta-analysis of coastal and marine ecosystem values (Brander et al. 2007; Liu & Stern 2008).

Valued ecosystems in the data set are located in 22 countries (see Table 1). The largest number of observations is from the USA (77 observations). A relative large number of observations is from France (18 observations), Australia (14 observations) and Sweden (13 observations). The geographic distribution of the valued ecosystems is illustrated in Figure 1.

The majority of the observations (n=80) are located at temperate latitudes comprised between 30 and 45 degrees of latitude in the Northern hemisphere. A large number of observations are located in the Northern hemisphere but closer to the Equator (n=44) or at higher latitudes (n=57 between 45 and 60 degrees of latitude). Only 15 observations are for ecosystems located in the Southern hemisphere.

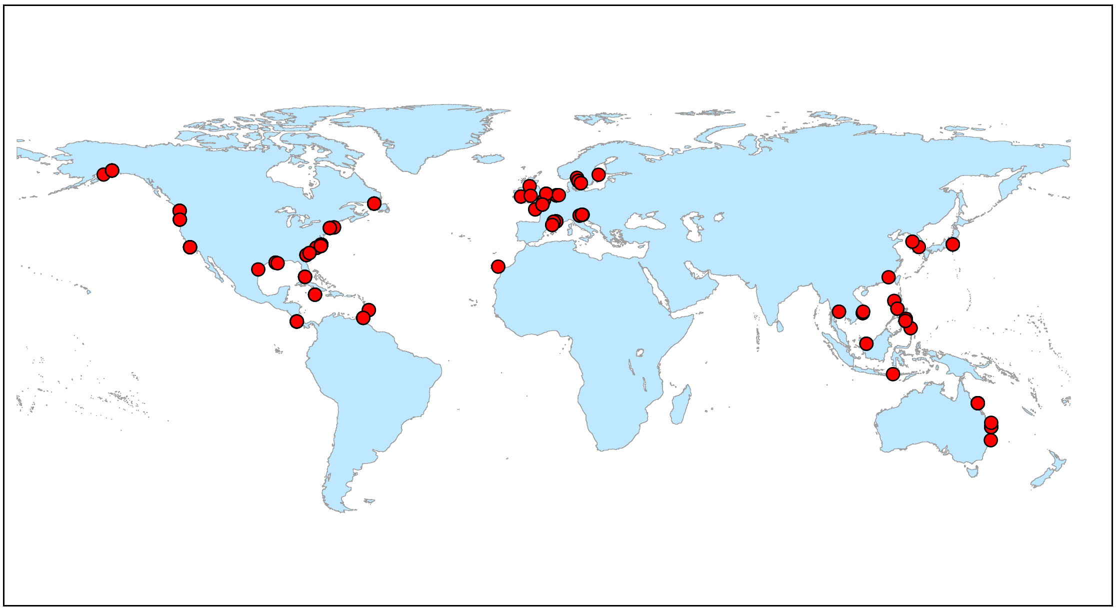

Figure 1. Centerpoints of the valued coastal ecosystems in the meta-regression

A large number of valuation studies focused on recreation, protection from erosion, and reduction of tourists congestion in sandy beaches (n=59). A relatively large number of observations is also available for conservation of biodiversity hotspots and recreation in coral reefs areas (n=26). In total, 11 observations are available for mangrove ecosystems. A significant fraction of the total observations focused on marine and coastal protected areas (n=80).

The largest valued ecosystems in the data set in terms of length of coastline are the coastline comprised between the Prince William Sound and the Kodiak Island in Alaska (Hausman et al. 1995) and the Great Barrier Reef in Australia (Carr & Mendelsohn 2003). Smaller sites are also represented, with 58 observations derived for sites of 50 km or less of total length.

Due to the focus on non-market values, the valuation methods included in the data set are either revealed or stated preference methods. Among the former, contingent valuation method provided the larges number of observations (n=61), but choice experiment is also represented (n=5). The observations that were obtained with the travel cost method are 101. Finally, 29 values were estimated with the contingent behavior method, which combines both revealed and stated preference methods.

2.2 Setting up the analytical framework for the meta-regression

2.2.1 Standardization of values

To allow for a comparison between values that have been calculated in different years and expressed in different currencies and metrics it was necessary to standardize them to a common metric and currency. For the meta-regression model presented in the following sections, values were standardized to 2003 US$ per hectare per year.

The original estimates from the valuation studies are typically reported in the metric of willingness to pay (WTP) or consumer surplus (CS) per person per year (or per household per year). These estimates were aggregated using the areal extension of the valued ecosystem (as derived from the GIS analysis) and the aggregation population (as derived from the primary study) as multiplicative factors. It is underlined here that the authors make no assumption on the extent of the aggregation population but rather use the total number of recreationists for each site as reported in the primary studies. Studies that fail to report the size of the aggregation population are not further considered in the analysis.

Following Ghermandi et al. (2008), values referring to years other than 2003 were deflated using appropriate factors from the Millennium Development Indicators (World Bank 2006) and differences in purchase power among the countries were accounted for by the Purchase Power Parity index provided by the Penn World Table (Heston et al. 2006).

2.2.2 Geographic characterization of the valued sites

Most of the investigated studies provide some information on the geographical location of the valued coastal ecosystems but fail to report on their extent (e.g., length of coastline, areal extent). Since both types of information are crucial for the calculation of the aggregated values and for the characterization of the contextual variables in the meta-analysis, particular care was taken to calculate with high precision the geographical location and extent of the valued sites.

For this purpose, a GIS analysis was performed. For each valued site where sufficient geographic contextualization is available in the primary studies, a line feature in a shapefile of coastline is created in ESRI® ArcGIS (see Figure 2). The length of coastline for each valued site is then calculated directly as the length of the line feature in the shapefile. The areal extent of the ecosystems is calculated considering a swath of 3 km landwards from the shapefile.

Besides the mentioned advantages, the described procedure has a further important advantage with respect to the procedures that are usually implemented in meta-analyses insofar as it allows to calculate the areal extension of the valued sites in a consistent way across all sites. The estimates derived from the GIS analysis are in fact not sensitive to the different assumptions and rounding offs made by the authors of the primary studies in reporting the length of coastline investigated or the breadth of the swath of land that is considered in their analysis.

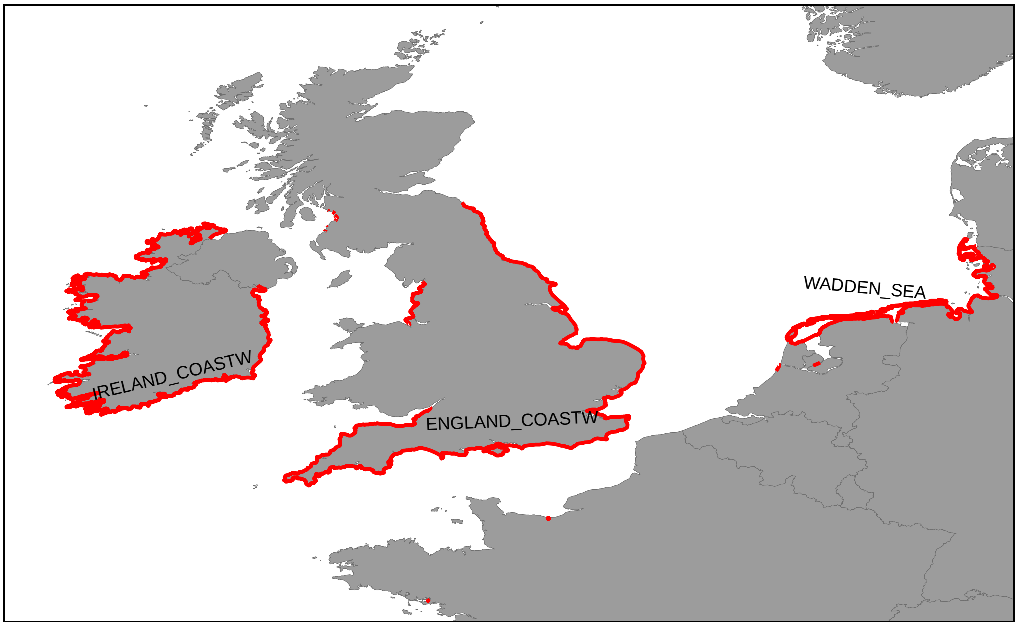

Figure 2. Shapefiles of valued sites located in several European countries

2.2.3 Meta-regression model specification

A semi-logarithmic model specification is assumed both for the regression values. The model is specified as follows:

$$\ln(y_i) = a + b_S X_{Si} + b_W X_{Wi} + b_C X_{Ci} + u_i \qquad (1)$$

where $\ln(y_i)$ is the natural logarithm of the endogenous variable (US$ / ha year); the subscript i is an index for the value observations; a is a constant term; b_S, b_W and b_C are vectors containing the coefficients of the explanatory variables X_S (study characteristics), X_W (site characteristics), and X_S (context characteristics); u is an error term that is assumed to be well-behaved. In the meta-regression the value observations are assumed to be independent.

In the semi-logarithmic model the coefficients measure the constant proportional or relative change in the dependent variable for a given absolute change in the value of the explanatory variable. For the explanatory variables expressed as logarithms, the coefficients represent elasticities, that is, the percentage change in the dependent variable given a one-percentage change in the explanatory variable.

2.2.4 Explanatory variables

The explanatory variables of the value function are chosen based on the experience gathered in previous meta-analyses of ecosystem values and in order to reflect the expectations on the main drivers of values as derived from economic theory. The exogenous model variables are classified into three principle categories: study characteristics, site characteristics, and context characteristics. Table 1 summarizes the explanatory variables of the model, which are discussed more in detail in the following sections.

Table 1. Explanatory variables of the meta-regression model

Group	Variable	Units and measurement	Mean (SD)	*N*
Study (X_S)	Stated preference	Binary (range: 0 or 1)	0.34 (0.47)	66
	Contingent behaviour	Binary (range: 0 or 1)	0.15 (0.36)	29
	Revealed preference	Omitted category	0.52 (0.50)	101
	Compensating variation	Binary (range: 0 or 1)	0.27 (0.44)	52
	Equivalent variation	Binary (range: 0 or 1)	0.15 (0.36)	29
	Consumer surplus	Omitted category	0.59 (0.49)	115
	Year of publication	Years since first valuation (1974)	22.8 (6.71)	196
Site (X_w)	Local	Binary (range: 0 or 1)	0.62 (0.49)	122
	Regional	Binary (range: 0 or 1)	0.24 (0.43)	48
	(Inter)national	Omitted category	0.13 (0.34)	26
	Latitude (absolute value)	Degrees of latitude	35.5 (15.0)	196
	Protected area (WDPA)[a]	Binary (range: 0 or 1)	0.41 (0.49)	80
	Beach	Binary (range: 0 or 1)	0.30 (0.46)	59
	Reef	Binary (range: 0 or 1)	0.13 (0.34)	26
	Mangrove	Binary (range: 0 or 1)	0.06 (0.23)	11
	Other coastal ecosystem	Omitted category	0.51 (0.50)	100
	Recreational fishing	Binary (range: 0 or 1)	0.45 (0.50)	88
	Non-consumptive recreation	Binary (range: 0 or 1)	0.84 (0.37)	165
	Mean sea surface temperature	Natural log of °C	2.81 (0.60)	196
Context (X_C)	GDP per capita [b]	Natural log of 2003 dollars (PPP)	10.1 (0.74)	196
	Population density [c,d]	Natural log of inhabitants	4.63 (1.58)	196
	Anthropogenic pressure [c,e]	Natural log of nutrients concentration (ton/km^2/year)	0.91 (2.10)	196
	Biodiversity [c,f]	Shannon index	4.63 (1.13)	196
	Accessibility [g]	Natural log of hours travel time to nearest major city	4.54 (0.99)	196
	Low human development [c,h]	Binary (range: 0 or 1)	0.63 (0.48)	123
	Medium human development [c,h]	Binary (range: 0 or 1)	0.05 (0.21)	9
	High human development [c,h]	Omitted category	0.33 (0.47)	64

Notes: [a] Based on World Database on Protected Areas, 2009 edition (www.wdpa.org); [b] Evaluated at country level; [c] Within 20 km distance from the valued site; [d] CIESIN, Gridded Population of the World, v.2 (sedac.ciesin.columbia.edu/plue/gpw); [e] Source: Halpern et al. (2008); [f] Source: Ocean Biogeographic Information System, OBIS (www.iobis.org); [g] Source: European Commission, Global Accessibility Maps (bioval.jrc.ec.europa.eu/products/gam/); [h] Source: GLOBIO project (www.globio.info).

2.2.4.1 *Study characteristics*

The study characteristics that are accounted for in the meta-analytical value function are valuation method used in the primary study, type of welfare measure elicited, and year of the data used in the primary study.

Valuation methods are classified into two categories according to the distinction between stated and revealed preference methods. Observations derived with stated preference method include contingent valuation, choice experiment, and contingent behaviour estimates. Revealed preference (i.e., travel cost method) is the valuation method of reference in the meta-regression.

The type of welfare measure elicited in the primary valuation study is accounted for in the model by a dummy variable which account for whether the observation reflects (i) a total consumer surplus estimate, or (ii) the WTP to achieve an increase (forego a decrease) in the level of provision of a specific ecosystem service as compensating variation (equivalent variation).

The year of the data used in the primary valuation study is included in the meta-regression model as the number of year elapsed since 1974, i.e., the year to which the data used in the oldest valuation study in the data set pertain. The most recent data in the data set pertain to the year 2008.

2.2.4.2 Site characteristics

The site characteristics that are accounted for in the meta-analytical value function are: the size and importance of the valued site, the absolute value of the latitude at which the site is located, whether the valued site is a protected area, the type of ecosystem, the type of ecosystem service provided, and the sea surface temperature at or in proximity of the valued site.

The size and importance of the valued site is captured by a series of binary variables which identify whether the valued site is of local, regional or national/international importance. Such variables are meant to capture for instance the different types of recreational experience and attractiveness to non-domestic tourists. A binary variable is included to distinguish values estimated for coastal and marine protected areas identified in the World Database on Protected Areas (www.wdpa.org).

Four ecosystem types are included in the analysis. Three binary variables are included to characterize sandy beaches, coral reefs, and mangroves, while a fourth category accounting for other kinds of coastline (e.g., lagoons and coastal marshes) and mixed coastal types is used as the reference category in the analysis.

Two main types of recreational activities are considered: recreational fishing and non-consumptive recreation. Since the two services are not mutually exclusive, i.e., one value observation may reflect a combination of the two services, no reference category is defined for ecosystem services in the analysis. For this reason, the observations reported in Table 1 for the variables identifying the type of service provided do not add up to 196. This is due to the fact that individual observations may pertain to two or more levels.

2.2.4.3 Context characteristics

The context characteristics accounted for in the meta-regression model are: real GDP per capita (World Bank 2006), population density (sedac.ciesin.columbia.edu/plue/gpw) , biodiversity richness (www.iobis.org) , anthropogenic pressure (Halpern et al. 2008), level of human development (www.globio.info), and accessibility of the valued site (bioval.jrc.ec.europa.eu/products/gam/). With exception of real GDP per capita, which is evaluated at country level, all other context variables were assessed using GIS techniques within a distance of 20 km from the valued site.

For the evaluation of the context variables, buffer zones where created in ESRI® ArcGIS, which identify all the points on the map located within a distance of 20 km or less from the shapefile of the valued sites (see Figure 3). The values of the context variables were then calculated as the average value within the buffer zone, with the exception of the human development variables which were calculated based on which category the majority of pixels falls into.

The spatial analysis implemented here for the evaluation of the context variables represents a significant improvement to the techniques that were previously used in similar studies. Two meta-analyses of wetland values (Brander et al. 2006; Ghermandi et al. 2008) used a radius of 50 km around the geographical center point of the valued ecosystem as buffer area for the calculation of the value of the context variables. Applying such method to the present study would provide a reasonable good approximation of the geographical context in small sites such as Aiguamolls and Thau in Figure 3, but would fail to capture the geographic extension of the valued areas in larger sites such as the Camargue (Figure 3), the coast of England, the coast of Ireland, and the Wadden Sea (Figure 2).

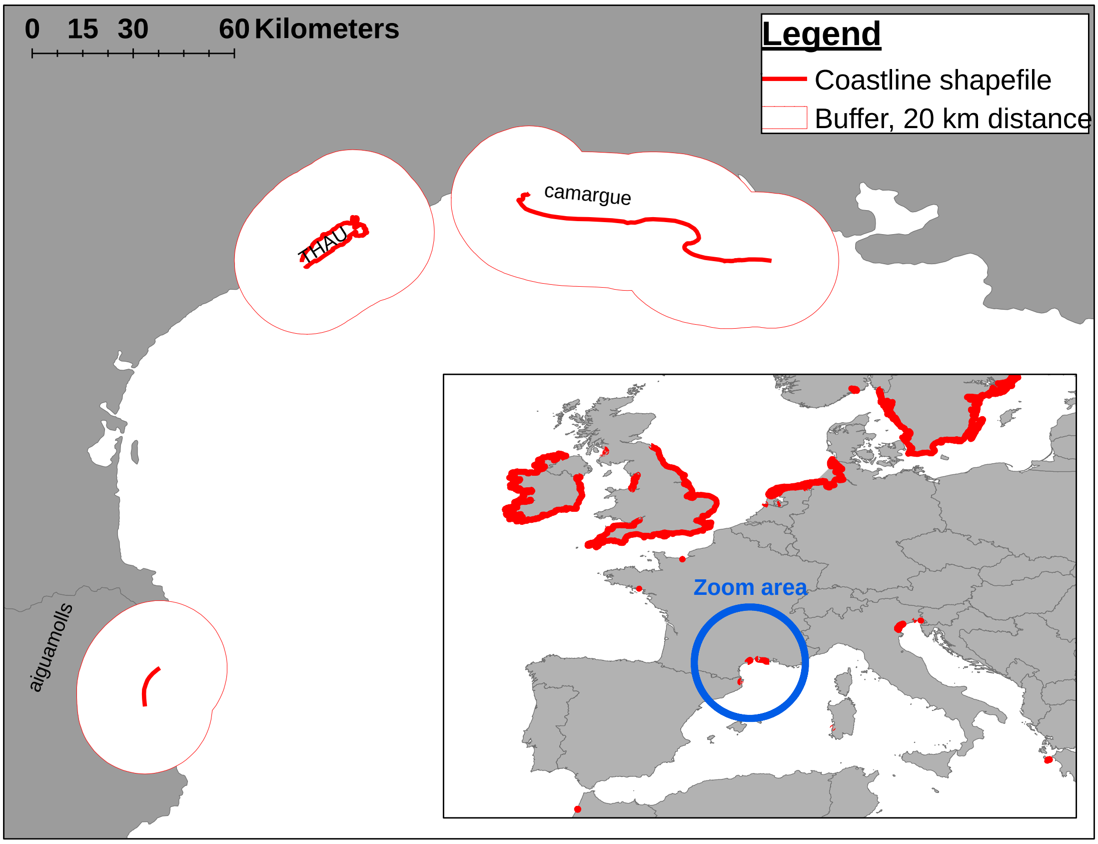

Figure 3. Buffer zones for the evaluation of the context variables in three Mediterranean sites.

2.3 The procedure for meta-analytical value transfer and GIS-based scaling up of values

The method used in this study to draw the global map of current recreational values of coastal ecosystems makes use of value transfer techniques consisting in two steps:

(i) calibrating the meta-regression function based on all available data on actual values from the study sites. This step is necessary to estimate the value of the coefficients a, b_s, b_w and b_c in equation (1);

(ii) applying the calibrated meta-regression function to all the coastal areas where no primary valuation is available, i.e., the policy sites. In order to do so, the value of the explanatory variables X_s, X_w and X_c presented in Table 1 must be known in all policy sites, i.e., in all coastal locations of the map.

The value transfer procedure consists thus in plugging in the policy site data in the calibrated meta-analytical regression model. It should be noted that the proposed value transfer process estimates values for individual grid cells which represent coastal areas in the final map. Coastal grid cells are thus the units of analysis in the value transfer exercise and therefore spatial variables need to be defined at this level.

To achieve this goal, all the eight layers representing geo-referenced site- or context-specific variables of the equation (i.e., mean sea surface temperature, GDP per capita, population density, anthropogenic pressure, biodiversity, accessibility, human development, and absolute value of latitude) were prepared in ArcGIS so that their projection, spatial resolution and extension would be consistent. The layers were re-projected in the geographic coordinate system WGS1984 and converted to raster layers with a cell dimension of 0.5 degrees.

The values of the non-spatial variables in the regression were assumed in the calculation as follows:

- for methodological variables and ecosystem services, the sample mean was taken as a constant value in the value transfer function:
- due to the resolution of the final map, the geographical extent was assumed to correspond to that of regional studies (i.e., the value of the binary variable "regional" is set to be equal to one);
- also due to the resolution of the final map, it was not possible to distinguish between beach and coral reef sites; the two dummies were thus assumed equal to zero in the transfer function;
- the reference year for the value transfer is 2009.

Once the grid cells in the different layers containing the geo-referenced information are perfectly overlapping and the value of the non-spatial variables has been determined, the meta-regression function can be evaluated in each cell by using map algebra.

3. Results

3.1 Econometric results of the meta-regression

The results obtained with the best-fit meta-analytical model and using ordinary least squares (OLS) are presented in Table 2. Various alternative model specifications including different combinations of variables were tested but several variables from

Table 1 were dropped from the final regression model since they were not statistically significant or were substantially correlated with other explanatory variables.

Table 2. Results of the meta-regression model of recreational values

Variable	Coefficient		Standard error
Constant	-12.120	***	3.993
Stated preference	-1.188	***	0.283
Contingent behaviour	-1.063	***	0.366
Year of publication	0.146	***	0.020
Local	2.827	***	0.535
Regional	2.576	***	0.469
Latitude (absolute value)	0.035	***	0.012
Beach	1.973	***	0.397
Reef	2.080	***	0.466
Recreational fishing	1.455	***	0.344
Non-consumptive recreation	2.042	***	0.487
GDP per capita	0.726	***	0.257
Population density	0.352	**	0.175
Anthropogenic pressure	-0.180	**	0.069
Biodiversity	0.456	***	0.143
Accessibility	-0.816	**	0.291
Low human development	2.508	***	0.375
Medium human development	1.300	**	0.622
Nr. of observations	196		
R-square	0.74		
Adjusted R-square	0.72		

Note: OLS estimates. Significance is indicated with *** and ** for 1% and 5% statistical significance levels respectively.

A series of diagnostic tests were performed in order to investigate the robustness of the results presented in Table 2. The analysis of residuals indicates that they are distributed between a maximum value of 2.939 and a minimum of –3.656 with mean –0.001±1.015. The Shapiro-Wilk test (p-level = 0.126) does not reject the assumption of normal distribution of the residuals. The null hypothesis of homogenous variance of the residuals cannot be rejected by means of Breusch-Pagan test (Prob. > χ^2 = 0.498) and visual inspection of the distribution of the residuals does not reveal evidence of heteroskedasticity in the distribution of residuals. Since, however, White's test (p-level = 0.000) indicates heteroskedasticity, we re-estimated the standard errors in Table 1 with the Huber-White estimators, which are more robust to the failure to meet assumptions concerning normality and homoskedasticity of the residuals. Sign and significance of the coefficients in Table 1 is not affected with exception of the significance of "GDP per capita" which becomes significant at the 5% level. The presence of multicollinearity between predictor variables was investigated by means of the variance inflation factor (VIF). The maximum value of VIF is 7.24. The fact that all the values of VIF are lower than 10 suggests that multicollinearity is not an issue of particular concern in the analysis. With respect to model specification, the link test for model specification (p-value of _hatsq = 0.145) does not indicate specification errors. The regression specification error test for omitted variables (Prob > F = 0.056), however, rejects the hypothesis that the model has no omitted variables.

The estimated coefficients of the explanatory variables reported in Table 2 are all statistically significant and reflect a priori expectations. The values estimated with stated preferences methods and with the contingent behaviour method are statistically lower than those obtained with the travel cost method. The coefficient on the variable identifying the year of the data used in the primary studies indicates that values tend to increase in recent years, which is consistent with the large increase in the number of visitors to coastal recreation resorts that many locations have experienced over the past decades in various regions of the world.

For what concerns site-specific variables, coastal ecosystems of local and regional importance have higher values per hectare per year than larger sites of national and international significance. Such observation is consistent with the decreasing returns of scale of marginal values that was observed in previous meta-analyses (Brander et al. 2006; Ghermandi et al. 2008). Values tend to increase with the distance from the Equator. Among ecosystem types, coral reefs and sandy beaches provide the highest recreational values. Non-consumptive recreational activities (e.g., beach leisure, diving, and swimming) are more highly valued than recreational fishing.

Among context-specific variables, the coefficients of “GDP per capita” and “population density” are positive and suggest the presence of an inelastic income effect and that proximity to the market of potential visitors results in higher recreational values. A high level of anthropogenic pressure – as identified by a high concentration of nutrients in the coastal waters – and reduced accessibility – i.e., a long travel time from the nearest major city – both have a negative impact on the recreational values. On the contrary, high biodiversity richness and a low level of human development both result in high values.

The explanatory variable of the model (R-square = 0.74; Adj. R-square = 0.72) is high, particularly for a meta-analysis with a broad scope such as the present one.

Nelson & Kennedy (2008) found that the median adjusted R-square of the 140 meta-analyses they surveyed was equal to 0.44.

3.2 The map of recreational values of coastal ecosystems

Figure 4 presents the global map of recreational values obtained with the value transfer and scaling up procedure described in Section 2.3.

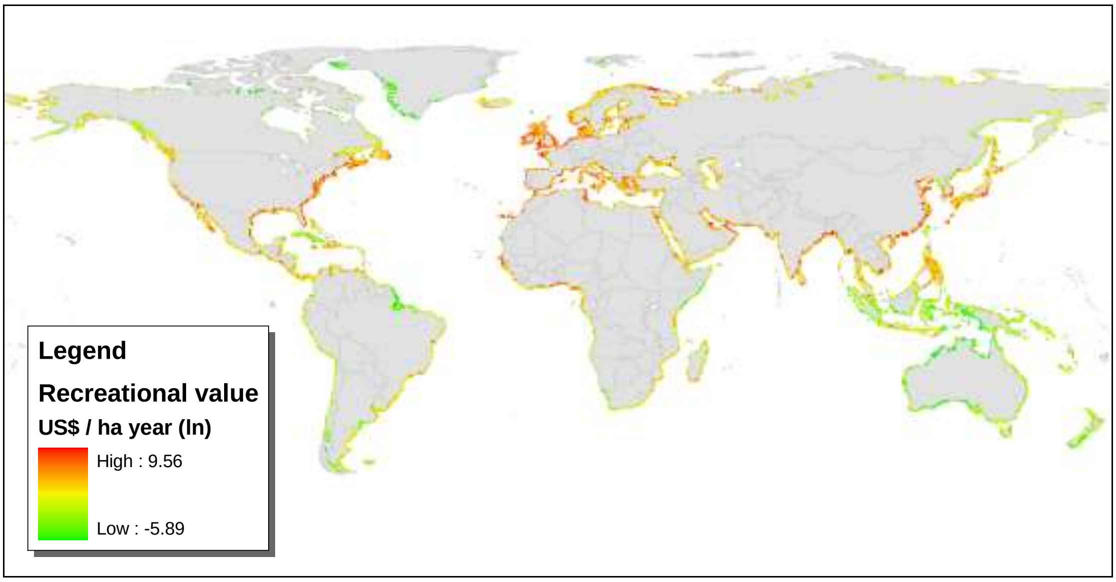

Figure 4. Global map of recreational values of coastal ecosystems

Since the color variance in the global map is restricted to a thin line along the coast and may be difficult to be perceived, Figure 5 presents a close up of the global map which illustrates the variation of recreational values predicted for the Eastern Coast of the US, Mexico and the Caribbean.

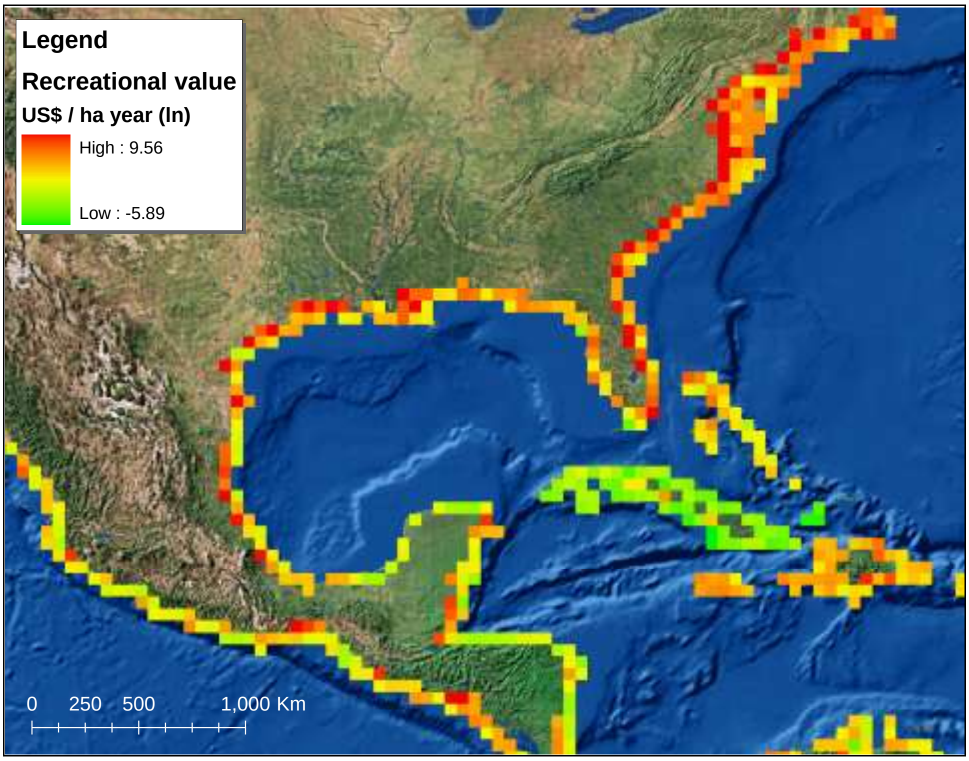

Figure 5. Estimated recreational values in the Eastern US, Mexico and Caribbean

The recreational values in the map are reported in logarithmic scale and range between 9.56 and -5.89. The model predicts in particular high values for the US (Eastern Coast, California and various areas along the Gulf of Mexico), most European countries (in the Mediterranean region and along most of the coast of England, Ireland, France, the Netherlands, Belgium and Denmark), and various parts of the Persian Gulf, India, China and Japan. Relatively low values are predicted in Indonesia, Australia, most of Sub-Saharan Africa, Cuba and (with some exceptions) most of South America. For various coastal grid cells, particularly at high latitudes along the coast of Canada and Russia, it was not possible to estimate a value since the value of one or more of the explanatory variables is not defined within the respective GIS layers.

All the spatial variables included in the model contribute to determine the distribution of values illustrated in Figure 4. Scarce accessibility and low population density along most of the coast of Australia and parts of the coast of South America (e.g., in Northern Brazil) contribute to the low values observed in those areas. On the contrary, high population densities in India and China positively influence values despite the negative impact of anthropogenic pressure in various areas. Similarly, high accessibility, population density and GDP per capita positively affect values in

Europe and the US despite high development and anthropogenic pressure in various regions.

To transform from the logarithmic scale to more straightforward values in US$/ha/year, one must take into consideration that taking logarithms is a nonlinear transformation and that therefore the expected value of a logarithm function is not the logarithm of the expected value. Assuming that the error term in equation (1) is normally distributed with mean value zero, one can calculate the expected value by adding an additional term in the argument of the exponential function as presented in equation (2):

$$E\{y_i | X_{1,\ldots,n}\} = \exp\left\{E\{\ln y_i | X_{1,\ldots,n}\} + \frac{1}{2}\sigma_v^{\,2}\right\} \qquad (2)$$

where E indicates the expected value, y_i and $X_{1,\ldots,n}$ are, respectively, the dependent and explanatory variables, and σ_v^2 is the variance of the error term.

Applying equation (2) to the meta-regression model discussed in this study, one finds that the estimated recreational values of coastal ecosystems range between 0 and 43,112 US$/ha/year.

4. Discussion and conclusions

In this study we presented an application of meta-analysis and value transfer in combination with GIS techniques for the assessment of the recreational values of coastal ecosystems. The results of the econometric analysis were used to draw a map of recreational values worldwide.

The proposed approach has several appealing features:

- Among value transfer methodologies, meta-analysis is generally indicated as the most suitable for studies with a broad scope of analysis and for scaling up values of ecosystem services at large geographical scales (Brander et al. 2008). On eof the reasons is that meta-analysis allows the value function to include greater range of variation in site, study and context characteristics (e.g., socio-economic and physical attributes, valuation method) that cannot be captured by a single primary study or a small number of studies. Furthermore, various studies have shown that meta-analytical value transfer results in more accurate estimates than other methodologies for value transfer (R. Rosenberger & Phipps n.d.; Engel 2002). Meta-analytical value transfer allows to assess values in each policy site independently and to scale up values with a “bottom-up” approach which is based on the aggregation of the values estimated at the level of the single sites. Other methods often rely on the determination of an average value which is assumed to be characteristic for a specific ecosystem service/type and is scaled up simply by multiplying such value by the total areal extent of the ecosystem of interest.

- Full integration of GIS-based analysis may bring several advantages to the accuracy of the exercise of transferring and scaling up ecosystem values due to the geographic nature of many of the variables involved. In this study, we used GIS analysis at three distinct levels: (1) for the characterization of the study sites by creating shapefiles of the valued ecosystems; (2) for the determination of the spatial variables involved in the analysis, both site-specific and context-specific; and (3) for the assessment of the values at the policy site level, where the unit of analysis in the value transfer exercise was the grid cell in the final map. Such use of GIS techniques constitutes a methodological advancement compared to previous meta-analyses (see for instance (Brander et al. 2006; Ghermandi et al. 2008). Although this should be subject to further testing, it seems reasonable to believe that the accurate geographical characterization of the study sites may have contributed to the high explanatory power that we found in our model as compared to other similar studies.

Despite the highlighted advantages of the proposed approach, there are several limitations to the present study that should be underlined and that will be object of further development:

- A rigorous analysis of the transfer errors arising from using the meta-analytical model for value transfer shall be included. Previous research has shown that such error can be potentially very large (Brander et al. 2008). A commonly used method to evaluate transfer errors is the n-1 data splitting technique. This consists in calibrating the meta-regression model omitting one of the value observations and subsequently applying the estimated model parameters to predict the value of the omitted observation, which is available from the primary studies.
- A further limitation of this study and most meta-analyses lies in the treatment of potential selection bias in the dataset of primary studies. A selection bias arises for

instance when ecosystems that are perceived more valuable a priori are more likely to be selected for valuation or when the probability of a study being published is correlated to the effect size measure (Hoehn 2006; Woodward & Wui 2001). Such biases may have relevant consequences in particular when the results of a meta-analysis are used for value transfer (Hoehn 2006; R.S. Rosenberger & Johnston 2009). In the case of coastal recreation values, it seems likely that sites with high perceived recreational values are more easily subject to investigation than sites with little or no recreation. Such potential bias may have important consequences on the value transfer estimates.

- Similar to the selection bias, there appears to be a clear geographic bias in the available valuation studies. These are mostly concentrated in North America and Europe with little or no information available on, for instance, the values of African and South American sites. In the next steps of the analysis, the gaps in the current valuation literature will be clearly identified and the conditions under which the estimates predicted with the value transfer technique are less confidently established will be identified and discussed.

Overall, the present study provides several original contributions to the valuation of the services provided by coastal ecosystems:

- In the frame of this study, the most comprehensive review of coastal non-market valuation studies on cultural values of coastal ecosystems was conducted and previous datasets were substantially enlarged;
- The contribution of a series of economically oriented context variables to the formation of the values of coastal ecosystems was explored. Such variables are site accessibility, anthropogenic pressure, level of human development in the surrounding of the valued sites, richness in biodiversity, governance, GDP per capita and population density near the valued ecosystem. All such values are found to be significantly correlated with recreational values;
- The first global map of the recreational values of coastal ecosystems was produced. Values are found to range between 0 and 43,112 US$/ha/year. The developed map and analytical framework may be a useful tool for the identification of priority areas for conservation or development and for the assessment of the potential impact of external stressors (such as for instance climatic changes) on the estimated values.

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