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Review Article

Marine and Coastal Cultural Ecosystem Services: knowledge gaps and research priorities

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Abstract

Cultural ecosystem services (CES) reflect peoples' physical and cognitive interactions with nature and are increasingly recognised for providing non-material benefits to human societies. Whereas coasts, seas, and oceans sustain a great proportion of the human population, CES provided by these ecosystems have remained largely unexplored. Therefore, our aims were (1) to analyse the state of research on marine and coastal CES, (2) to identify knowledge gaps, and (3) to identify research priorities and pinpoint the move forward. To accomplish these objectives, we did a systematic review of the scientific literature and synthesised a subset of 72 peer-reviewed publications. Results show that research on marine and coastal CES is scarce compared to other ecosystem service categories. It is primarily focused on local and regional sociocultural or economic assessments of coastal ecosystems from Western Europe and North America. Such research bias narrows the understanding of social-ecological interactions to a western cultural setting, undermining the role of other worldviews in the understanding of a wide range of interactions between cultural practices and ecosystems worldwide. Additionally, we have identified clusters of co-occurring drivers of change affecting marine and coastal habitats and their CES. Our systematic review highlights knowledge gaps in: (1) the lack of integrated valuation assessments; (2) linking the contribution of CES benefits to human wellbeing; (3) assessing more subjective and intangible CES classes; (4) identifying the role of open-ocean and deep-sea areas in providing CES; and (5) understanding the role of non-natural capital in the co-production of marine and coastal CES. Research priorities should be aimed at filling these knowledge gaps. Overcoming such challenges can result in increased appreciation of marine and coastal CES, and more balanced decision-supporting mechanisms that will ultimately contribute to more sustainable interactions between humans and marine ecosystems.

Keywords

Human wellbeing; non-material benefits; integrated valuation; value pluralism; drivers of change; co-production; synergies; trade-offs; social-ecological systems; systematic review; global assessment.

Introduction

The interactions between humans and nature promote cultural practices that shape and are shaped by ecosystems (Norgaard 1994, Berkes and Folke 1998, Berkes 2011). Cultural practices reflect physical and cognitive interactions between humans and nature, enabling non-material benefits provided by ecosystem structures, processes and functions through the development of, e.g., identities, capabilities and experiences (Chan et al. 2012a, Chan et al. 2012b, Garcia Rodrigues 2015, Fish et al. 2016). The interplay between cultural practices and the environment has been conceptualised as cultural ecosystem services (**CES**) (Fish et al. 2016). CES are defined as the "ecosystems' contribution to the non-material benefits (...) that arise from human-ecosystem relationships" (Chan et al. 2011), and contribute to individual and collective human wellbeing (Plieninger et al. 2013, Russell et al. 2013, Breslow et al. 2016). CES are often directly experienced and intuitively appreciated (Plieninger et al. 2013, Daniel et al. 2012, Schaich et al. 2010), frequently they are the most valued ecosystem services by stakeholders (Palomo et al. 2011, Plieninger et al. 2012, Fletcher et al. 2014, Oleson et al. 2015, Pleasant et al. 2014), and are subject to increasing demand and dependence (Guo et al. 2010). They are included in the main ecosystem services typologies (Millennium Ecosystem Assessment 2005, TEEB 2010, Haines-Young and Potschin 2013). Nonetheless, ecosystem services research has been focusing primarily on provisioning and regulating services (Fish et al. 2016, Rodríguez et al. 2006, Milcu et al. 2013), while the role of CES for enhancing the sustainability of human interactions with nature has remained largely unexplored (Daniel et al. 2012, Liquete et al. 2013, Milcu et al. 2013).

Research targeted specifically at CES has been focusing mostly on the economic valuation of nature-based recreation, tourism, and landscape or seascape scenic beauty (Milcu et al. 2013). These CES classes are more amenable to monetary metrics, are seemingly easier to quantify, and often generate high revenues in the global economy (Costanza et al. 1997, Groot et al. 2012). On the other hand, there is insufficient knowledge on CES related to spiritual interactions, inspirational experiences, cultural identity, sense of place, bequest and existence values (Milcu et al. 2013). These services generate non-material benefits that are usually not subject to market exchange and thus are not amenable to monetary quantification (Chan et al. 2012a, Chan et al. 2012b). To be valued, these services require integrated valuation approaches (Martinez-Alier 2002, O'Neill and Spash 2000, Gómez-Baggethun and Barton 2013, Dendoncker et al. 2013) that consider not only intrinsic and instrumental values, but also relational values (Chan et al. 2016) underling individuals' kin and stewardship relationships with nature (Chapin et al. 2010). Such approaches require value pluralism (Martinez-Alier 2002, O'Neill and Spash 2000) in the form of integrated sociocultural, ecological and economic values, and diverse knowledge systems (Berkes et al. 2000, Tengö et al. 2014, Sutherland et al. 2013).

Humans have been living by and interacting with coastlines and oceans for millennia (Erlandson and Fitzpatrick 2006). Currently, one-third of the world human population lives in coastal areas and three-quarters of all large cities are located on the coast (Brown et al. 2006, Creel 2003). Yet, although CES are included in ecosystem service typologies specific for marine ecosystems (Beaumont et al. 2007, Böhnke-Henrichs et al. 2013, Liquete et al. 2013), CES research remains mostly focused on land-based assessments (Liquete et al. 2013, Palumbi et al. 2009). There is limited information about CES provided by marine and coastal habitats and ecosystems, creating knowledge gaps about the importance that people assign to these areas (Martin et al. 2016). Understanding physical and cognitive interactions between people and marine and coastal ecosystems is fundamental in a context where a high dependence on these areas is reflected in unsustainable practices that generate anthropogenic drivers. Such drivers are related to food production, climate change, and coastal development, and negatively affect CES and marine biodiversity (Rocha et al. 2014, Worm 2006, Halpern et al. 2008). Determining the non-material benefits provided by marine and coastal ecosystems to human wellbeing, and the importance that people assign to coasts, seas and oceans, can help devise strategies that promote sustainable social-ecological interactions.

To address the current poor understanding of CES provided by coasts, seas and oceans, we present a systematic review of peer-reviewed scientific literature on marine and coastal CES. Our aims are (1) to analyse the current state of research on marine and coastal CES; (2) to identify knowledge gaps; and (3) to identify research priorities and pinpoint the way forward. To accomplish these objectives, we identified the methodologies described in the literature to quantify, value and map marine and coastal CES; the synergies and trade-offs found within CES, between CES and other ecosystem service categories, and between CES and human-related activities; the links between drivers of change, habitats and CES; and the geographical distribution of empirical studies.

Methods

Literature search strategy

We searched for publications in the main scientific literature databases, namely Scopus, ISI Web of Knowledge, ScienceDirect, JSTOR, Blackwell Synergy, and Ingenta Connect. To identify relevant publications, we used the search string "*(marine OR coast* OR sea OR ocean) AND ("cultural ecosystem service*" OR "cultural service*")*" on article title, abstract or keywords, or only on abstracts, depending on the searching options available on the bibliographic databases. Searches included all articles published until our cut-off date of 21 March 2016.

Literature selection criteria

We established four criteria to include publications in our quantitative synthesis. Namely, the publication had (1) to conceptualise, map, quantify and/or value CES; (2) to assess marine or coastal ecosystems; (3) to be peer-reviewed; and (4) to be written in the English language. We limited the scope of our analysis to publications using the concept of ecosystem services because this concept is increasingly employed in the understanding, management and governance of natural environments (Hansen et al. 2015). Despite persistent critique, it has several strong features, such as revealing and structuring human benefits from nature; creating objects that can be assessed regarding trade-offs and synergies occurring in social-ecological interactions; supporting biodiversity conservation; reconnecting society with natural environments; and linking natural, social sciences, and humanities (Schröter et al. 2014).

Literature review process

Our systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (Moher 2009). The PRISMA provides a checklist of items (Suppl. material 1) that is reported to enhance the transparency and robustness of the review process. Following the PRISMA, we divided the systematic review in four phases (Fig. 1). First, we identified 206 potentially relevant records. Among these, we obtained 187 publications from bibliographic databases, and identified further 19 potentially relevant publications in these articles' reference lists. Second, after removing duplicated entries, we screened titles and abstracts of 120 publications that resulted in the rejection of 23 publications because they did not meet one or more of our inclusion criteria. Third, we read through full-texts to examine whether publications were eligible for our final quantitative synthesis. At this phase, we assessed 97 publications of which 25 failed to meet our inclusion criteria. Finally, we carried out a quantitative synthesis of 72 publications.

We undertook a second round of reviews of a random 25% sample of the initial 120 publications to validate their eligibility for the quantitative synthesis (Pita et al. 2011). Twelve of the co-authors read through the full-texts of the sampled publications and confirmed the decisions made in the first round of reviews, except for two disagreements. The co-authors involved in the first and second rounds of reviews of these two publications deliberated over the eligibility of the studies to be included in the quantitative synthesis and arrived at a common decision. The number of eligible publications of the first round of reviews did not change. Conducting two rounds of reviews enhanced the validity and robustness of the entire review process.

Before starting the data collection, we carried out a 'calibration' exercise to attain a uniform data collection procedure among co-authors. This consisted of reviewing a randomly selected publication that had been previously identified for quantitative synthesis. Each co-author assessed this publication individually and subsequently the results were compared against each other. The outcome of the exercise resulted in our template for the data collection process.

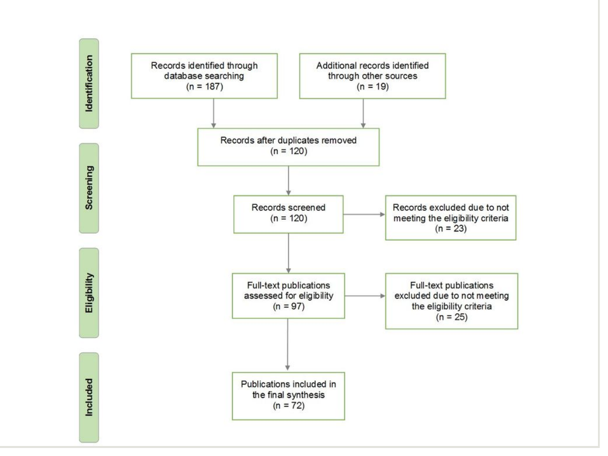

Figure 1.

Literature review flow diagram. The literature review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) (Moher 2009).

Data collection

The systematic review data included 20 variables and their corresponding response categories (Table 1). Data variables included CES classes assessed; quantification, valuation, and/or mapping methodologies; synergies and trade-offs identified; links between habitats, CES, and human wellbeing; countries of case studies; drivers of change affecting ecosystems and their CES; and others.

Table 1.

Data variables and corresponding **categories** used to collect data in the systematic literature review.

Data variables	Categories
CES categories	e.g., recreation and leisure; cultural heritage and identity
CES classification	e.g., MA; TEEB; CICES
Type of methodology	e.g., quantitative; qualitative; mixed
Methodology for CES quantification	e.g., questionnaire; interview; expert opinion
Methodology for CES valuation	e.g., contingent valuation; deliberative valuation; Q-methodology
Methodology for CES mapping	e.g., participatory mapping; InVEST; GIS
Indicator(s) for CES quantification, valuation, and/or mapping	e.g., spiritual, sacred and/or religious – no. religious facilities/area; aesthetic – extent kelp beds (ha)
Type of paper	e.g., empirical; review

Type of data	e.g., primary; secondary
Country of case study	e.g., Portugal; Argentina; Madagascar
Scale of study	e.g., local (0 - 999 km^2); regional (1,000 - 99,999 km^2); national (100,000 - 999,999 km^2, or country size)
Habitat type	e.g., mangrove; coral reef; seagrass meadow
Synergies within CES, or between CES and other ecosystem service categories	e.g., cultural heritage and identity – recreation and leisure; scientific – existence; social relations – food provisioning
Trade-offs within CES, or between CES and other ecosystem service categories	e.g., aquaculture – aesthetic; shipping – recreation and leisure; energy provisioning – aesthetic
Drivers of change affecting CES	e.g., climate change; invasive species; ocean acidification
Does the study link CES to human wellbeing?	yes; no
Indicator(s) to measure human wellbeing	e.g., social relations – no. citizen's initiatives; health – average no. sick days/person/year
Does the study relates ecosystem integrity (or state) with CES?	yes; no
Relationships between ecosystem integrity (or state) and CES	e.g., biodiversity – aesthetic (positive effect); exergy capture – recreation and leisure (negative effect)
Discipline of authors	e.g., ecology, economics, sociology

Data analysis

We used descriptive statistics to calculate the number of publications assessing CES classes, classifications used, type of publication, spatial scale, type of assessment, and whether publications assessed relationships between human wellbeing, ecological integrity (Müller 2005) and CES. We have searched for authors' main discipline(s) in their institutional and personal webpages to know the most prevalent disciplines in marine and coastal CES research and to know whether research teams were interdisciplinary. Additionally, we compared the number of publications assessing marine and coastal ecosystem service categories, i.e., provisioning, regulating and cultural, with the number of publications only assessing marine and coastal CES. To this purpose, we compiled data from Scopus between 1995 and 2015, which we obtained using a similar search string as the one described before, but excluding the search term 'cultural'. We did not screen these records because this analysis did not intend to be exhaustive, but instead served as an indicator for comparison between the assessment in the literature of marine and coastal CES and other ecosystem service categories.

To compare assessments, we adapted the CES classes found in the literature (Millennium Ecosystem Assessment 2005, TEEB 2010, Beaumont et al. 2007, Böhnke-Henrichs et al. 2013, Liquete et al. 2013, UK National Ecosystem Assessment 2011) to the Common International Classification for Ecosystem Services (CICES) (Haines-Young and Potschin 2013). CICES is arguably the most comprehensive and adaptable ecosystem services typology available to date (Turkelboom et al. 2013). However, we modified this typology and expanded it to cover the diversity of CES found in the literature (Suppl. material 2). Specifically, we added recreation and leisure; cultural heritage and identity; spiritual, sacred and/or religious services; inspiration for culture, art and design; sense of place; social relations; and services of humans to ecosystems – a new class proposed by Comberti et al. (2015). A few CES did not fit well into any of the previous or the CICES classes, and thus we classified them under the CICES group level (instead of class level as above) of ‘intellectual and representative interactions’.

To analyse the relationships between drivers of change, habitats and CES, we created matrices linking drivers to habitats, and habitats to CES. Each matrix cell contained the sum of the number of links identified by the empirical studies of our database. We created a third matrix linking drivers to CES by multiplying the two previous matrices. We then applied hierarchical clustering on the Euclidean distance between the rows and columns of the matrices to group drivers affecting CES (Rocha et al. 2014), according to the number of links found in the literature review. For this analysis, we used the *heatmap.2* function from *gplots* package (Warnes et al. 2016) of R version 3.2.2 (R Core Team 2015).

Synergies and trade-offs (Howe et al. 2014) were also a focus in our systematic review. We examined whether publications specified synergies and/or trade-offs within CES, or between CES and other ecosystem service categories, or between CES and human-related activities. Moreover, we investigated whether publications linked explicitly the benefits of supplied CES to human wellbeing, and whether they specified changes in wellbeing or proposed wellbeing indicators (Breslow et al. 2016). In a similar way, we analysed whether publications related CES to the ecological integrity or state of marine and coastal ecosystems, and whether they indicated positive or negative effects of ecological integrity variables on CES (Müller 2005, Kandziora et al. 2013).

Finally, we mapped the geographical location of case studies found in the literature (n=60), using QGIS (Quantum GIS Development Team 2016). Besides location, the maps also depict the number, spatial scale and type of assessments per country, the CES classes evaluated, and the habitats assessed.

Results

The number of publications about marine and coastal ecosystem services is growing exponentially, increasing from 20 papers in 2005 – the year the Millennium Ecosystem Assessment (MA) was published – to 373 publications in 2015 (Fig. 2). Before 2005, the annual number of publications using the concept of ecosystem services was limited, indicating that this field of research started to gain traction after the publication of the MA. Nonetheless, marine ecosystem service assessments are skewed towards provisioning and regulating services. Publications assessing CES represent just a tiny fraction of the entire body of marine and coastal ecosystem services research. Similarly, the number of publications about marine and coastal CES is slightly increasing, from 3 publications in 2008 to 16 in 2015 (Fig. 2). Prior to 2008, publications on this topic are almost non-existent.

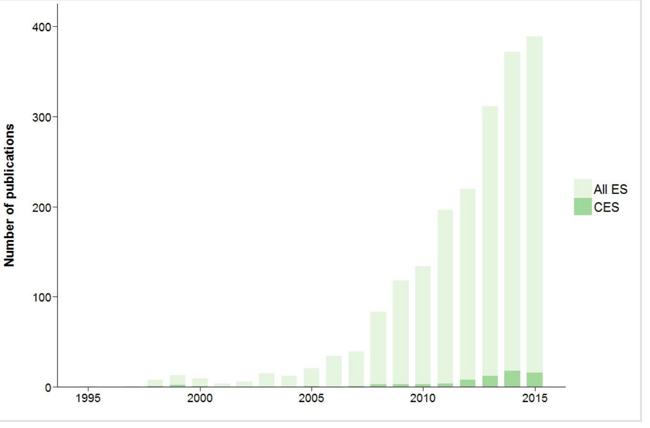

Figure 2.

Number of publications about marine and coastal ecosystem services. The figure compares the number of publications on all marine and coastal ecosystem services categories (All ES), i.e., provisioning, regulating and cultural, and the number of publications only about marine and coastal CES, between 1995 and 2015.

Literature synthesis

Our literature synthesis includes 72 publications (Suppl. material 3) where the most assessed marine and coastal CES classes were recreation and leisure (60), aesthetic services (44), and cultural heritage and identity (39) (Fig. 3). Bequest (10), symbolic (2), and services to ecosystems (1) were the least represented CES classes. On average, four CES classes were assessed per publication, but 12 studies assessed just one class.

The 72 publications synthesised include 46 empirical studies, 19 literature reviews and 4 conceptual papers (Fig. 4a). Three publications are literature reviews but present new case studies (Everard et al. 2010, Jordan et al. 2012, Satterfield et al. 2013), thus we classified them as both review and empirical papers. To classify CES in all conceptual, empirical and review papers, authors mostly used the MA classification (46) (Fig. 4b), followed by adapted, combined or new classifications (13) (Chan et al. 2012a, Chan et al. 2012b, Beaumont et al. 2007, Böhnke-Henrichs et al. 2013, Liquete et al. 2013, Kandziora et al. 2013, Farber et al. 2006, Groot 2011, Loomis and Paterson 2014, Fletcher et al. 2014, Papathanasopoulou et al. 2015, Comberti et al. 2015, Chung et al. 2015). Several publications did not specify any classification (12), and one publication (Jobstvogt et al. 2014) used the UK National Ecosystem Assessment classification. Remarkably, no publications used the CICES alone (Haines-Young and Potschin 2013), although it was adapted and combined with other classifications in two publications (Papathanasopoulou et al. 2015, Chung et al. 2015). Among the 46 empirical publications, there were 60 case studies with a diverse range of spatial scales (Fig. 4c). Regional assessments (22) are the most common in the literature, followed by local (14) and national (8) studies. Three studies combined different spatial scales. We found one continental (Everard et al. 2010) and one global study for one CES class (Coscieme 2015).

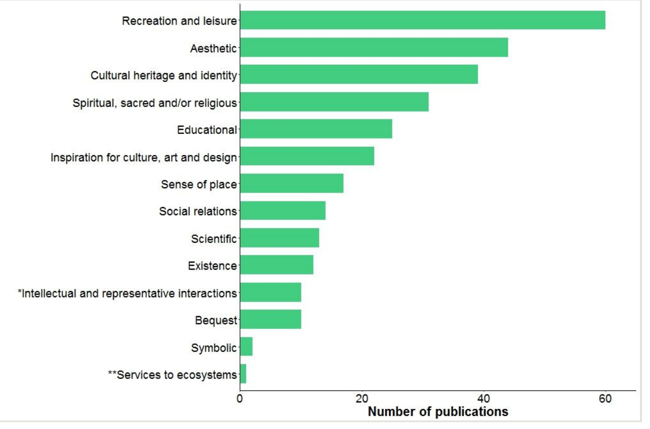

Figure 3.

Number of publications assessing each marine and coastal CES class. **Intellectual and representative interaction*s is a CICES group that we used to classify CES that did not fit into any class (Suppl. material 2). ***Services to ecosystem*s is a new CES class proposed by Comberti et al. (2015).

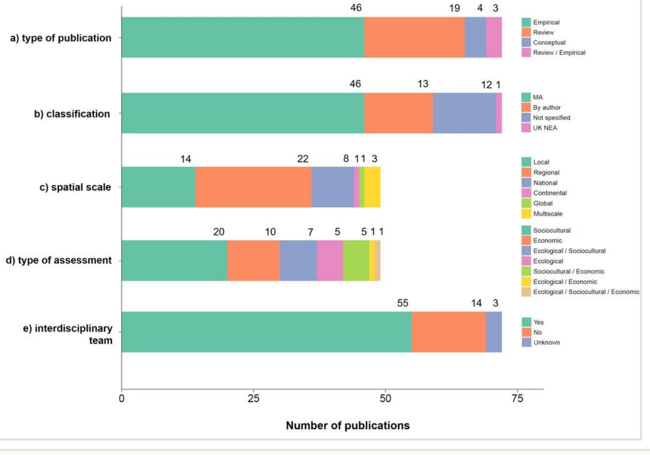

Figure 4.

Overview of literature review data variables. Data variables include: (a) type of publication (n=72); (b) classification (n=72); (c) spatial scale of empirical studies (n=49); (d) type of assessment of empirical studies (n=49); (e) interdisciplinary team (n=72).

The methodologies used by empirical studies to quantify, value and/or map marine and coastal CES are heterogeneous (Suppl. material 4). Regarding the type of assessment (Fig. 4d), sociocultural assessments were the most applied type to evaluate CES in marine ecosystems. Twenty empirical studies assessed CES by applying sociocultural assessment methods such as perceptions surveys, Q-methodology, and participatory mapping. Ten publications used economic assessment methods such as contingent valuation, choice experiments, and benefit transfer. Only five publications applied ecological assessment methods such as habitat frequency analysis and ecological surveys. The remaining nine publications used mixed methods, applying sociocultural, economic, and/or ecological methods. Among these publications, only one conducted an integrated assessment by applying the three assessment types (Outeiro et al. 2015a).

Most publications (55) were authored by an interdisciplinary research team (Fig. 4e), i.e., more than one discipline was represented. Most of the authors of the publications included in our synthesis are ecologists (Fig. 5). Economics and biology are, respectively, the second and third-most represented disciplines and, besides economists, only a few social scientists and humanities' experts participated in these publications.

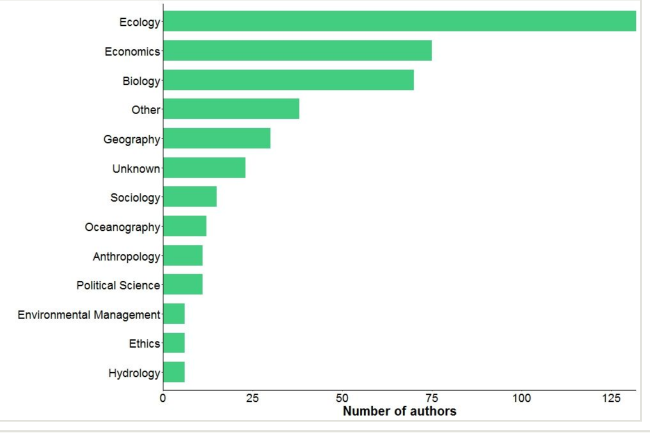

Figure 5.

Number of authors per main discipline(s). All publications' authors are included.

We evaluated whether publications assessed how marine and coastal CES affect human wellbeing and how these services depend on the ecological integrity of ecosystems. Among the 72 publications synthesised, 41 linked CES and human wellbeing in their text. Yet none measured the contributions of CES to human wellbeing, and only two publications – a review (Liquete et al. 2013) and a conceptual paper (Loomis and Paterson 2014) – presented indicators to measure human wellbeing. The links between ecological integrity and CES were referred to in 25 papers. Most of these publications (16) highlighted the positive effect of marine biodiversity in the supply of 28 CES. Some examples presented were the bequest and existence values that people derive from a diverse marine life (Beaumont et al. 2008), the larger number of recreational activities and higher aesthetic quality of more diverse and conservation-dominated coastal areas (Chung et al. 2015), and the level of marine biodiversity as a determining factor of diving locations (Ruiz-Frau et al. 2013). Eight publications mentioned the importance of habitat heterogeneity for CES provision, such as the dynamic spatial extent of sea-ice that provides a place for instruction and mentoring for Arctic communities and possibilities for tourism activities (Eicken et al.

2009), and the variety of deep-sea habitats such as hydrothermal vents and trenches that provide opportunities for education and scientific discovery (Thurber et al. 2014). One publication denoted the importance of natural/environmental flow regimes in an estuary for the provisioning of recreation and leisure and aesthetic amenities (Davis and Kidd 2012). On the other hand, one publication reported the negative effect of ctenophore and jellyfish blooms on the supply of recreation and leisure and aesthetic services (Baulcomb et al. 2015). Another publication denoted the negative effect of dune systems on the generation of cultural heritage and identity, and spiritual, sacred and/or religious services (Everard et al. 2010).

Synergies, trade-offs, and bundles of marine and coastal CES

CES are often generated synergistically within bundles or sets of ecosystem services or, in some cases, other services are provided at the expense of CES, generating trade-offs (Fig. 6). Our literature synthesis revealed that synergies are common among marine and coastal CES bundles. For example, areas with conditions for recreation and leisure are often valuable due to their aesthetic and cultural heritage and identity qualities (e.g., Chan et al. (2012b), Comberti et al. (2015), Chung et al. (2015), Jobstvogt et al. (2014), Gee and Burkhard (2010)). Likewise, areas with scenic beauty often provide inspiration and opportunities for education, holding significant existence values (e.g., Fletcher et al. (2014), Outeiro et al. (2015a), de Oliveira and Berkes (2014), Hashimoto et al. (2014), Martínez-Pastur et al. (2015)). Synergies with other ecosystem service categories are also identified in the literature, namely cultural heritage and identity, and the creation of social relations that often occur together with seafood provisioning ecosystem services (Fletcher et al. 2014).

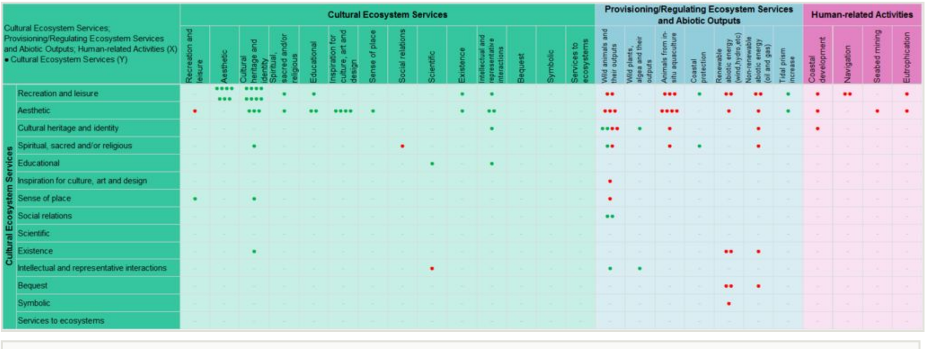

Figure 6.

Synergies and trade-offs of marine and coastal CES. The figure shows synergies and trade-offs within CES, between CES and provisioning/regulating ecosystem services and abiotic outputs, and between CES and human-related activities. Abiotic outputs refer to those ecosystem elements that provide benefits to humans but are not generated by biotic processes (e.g., minerals, wind, waves). One **green dot** represents a **synergy**, and one **red dot** a **trade-off**, as identified in the literature.

Trade-offs are more common between CES and other ecosystem service categories, and human-related activities, than within CES themselves. For instance, aquaculture and commercial fishing areas often provide seafood at the expense of aesthetic, and recreation and leisure opportunities (Chan et al. 2012b, Chung et al. 2015, Outeiro and Villasante 2013, Ruiz-Frau et al. 2013, Thurber et al. 2014, Outeiro et al. 2015b). Renewable and non-renewable energy production areas affect the supply of CES such as existence and bequest values, aesthetic amenities, symbolic, spiritual, sacred and/or religious experiences, cultural heritage and identity, and recreation and leisure (Papathanasopoulou et al. 2015, Gee and Burkhard 2010, Burkhard and Gee 2012). Similarly, human-related activities such as seabed mining, eutrophication, coastal development, and navigation, affect negatively the provision of CES by marine and coastal areas (Fletcher et al. 2014, Jobstvogt et al. 2014, Thurber et al. 2014, Rönnbäck et al. 2007, Tengberg et al. 2012).

Relationships between drivers of change, habitats, and CES

Most CES were assessed in the coastal zone (119), coastal and marine areas (40) and only a few in the open-ocean (12) (Table 2). These results correspond to publications that did not specify the habitat under assessment. For the empirical studies that specified the habitat, we identified that CES are mainly assessed in coastal lagoons and in intertidal areas. Subtidal areas are represented mostly by assessments in tropical coral reefs and seagrass meadows. Excluding coastal lagoons, transitional waters are among the least studied areas. Reflecting the importance of non-natural capital in the co-production of ecosystem services, a few marine and coastal CES were assessed in artificial habitats, i.e., human-made structures.

Table 2.

Number of marine and coastal CES assessed per ecosystem or habitat. All case studies are included (n=60). **CES classes** in the table are represented by the following letters: (A) Recreation and leisure; (B) Aesthetic; (C) Spiritual, sacred and/or religious; (D) Cultural heritage and identity; (E) Educational; (F) Inspiration for culture, art and design; (G) Sense of place; (H) Social relations; (I) Scientific; (J) Existence; (K) Intellectual and representative interactions; (L) Bequest; (M) Services to ecosystems.

Ecosystem/Habitat		**Cultural Ecosystem Services**													**TOTAL**
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	
General	**Coastal zone**	27	16	12	15	13	7	6	4	11	3	2	1	2	119
	Coastal and marine	10	7	6	6	2	3	3	1	0	0	0	2	0	40
	Open-ocean	3	2	1	1	1	1	0	0	1	2	0	0	0	12
Intertidal	**Beach**	8	4	4	4	3	4	2	3	2	2	2	0	0	38
	Dune	6	5	5	4	4	3	2	3	1	2	0	0	0	35
	Mudflat	5	3	4	4	4	2	3	3	0	1	0	0	0	29

	Saltmarsh	5	2	2	2	2	1	2	1	1	3	0	0	0	21
	Mangrove	2	2	2	2	2	1	1	2	1	1	0	1	0	17
	Coastal wetland	6	5	0	2	2	1	1	0	1	0	0	0	0	18
	Hard substrata	2	2	2	2	2	0	0	0	0	0	0	0	0	10
	Unconsolidated sediment	1	1	1	1	1	0	0	0	1	1	0	0	0	7
Subtidal	**Tropical coral reef**	1	1	5	1	1	1	0	6	1	1	4	1	0	23
	Seagrass meadow	4	4	3	3	3	1	0	1	1	2	0	0	0	22
	Macro-algal bed	2	2	1	1	1	0	0	0	1	2	0	0	0	10
	Oyster reef	1	1	1	1	1	0	0	0	1	1	0	0	0	7
	Cold-water coral reef	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Transitional waters	**Lagoon**	10	8	7	7	7	7	7	0	0	1	9	0	0	63
	Estuary	6	5	0	0	0	1	0	0	0	1	0	0	0	13
	Fjord	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Artificial	**Human-made structure**	5	3	3	2	2	0	2	0	0	0	0	0	0	17

Our literature synthesis revealed that economic drivers negatively affect the provision of practically all CES classes (Fig. 7). Several publications listed this type of drivers in a general and aggregate manner, but others specified the type of economic drivers affecting CES, namely economic growth, damming, tourism, land reclamation, to name a few. Also, two main clusters of drivers primarily affect a set of CES composed by recreation and leisure, aesthetic amenities, cultural heritage and identity, spiritual, sacred and/or religious experiences, and educational services. The main cluster of drivers includes depopulation, aging of local community, human perception of environmental threat (public opinion about areas potentially under environmental threat such as pollution, toxins, debris, etc.), urbanization, industrial fishing, and sociopolitical and economic drivers. A second cluster of drivers affects primarily the same set of CES plus the group 'intellectual and representative interactions'. This cluster is composed by traditional activities abandonment, local communities' isolation, identity loss, invasive species, habitat degradation, and biodiversity loss. A common characteristic in the composition of these two clusters is a set of economic, demographic, sociocultural and ecological drivers that together negatively affect marine and coastal CES.

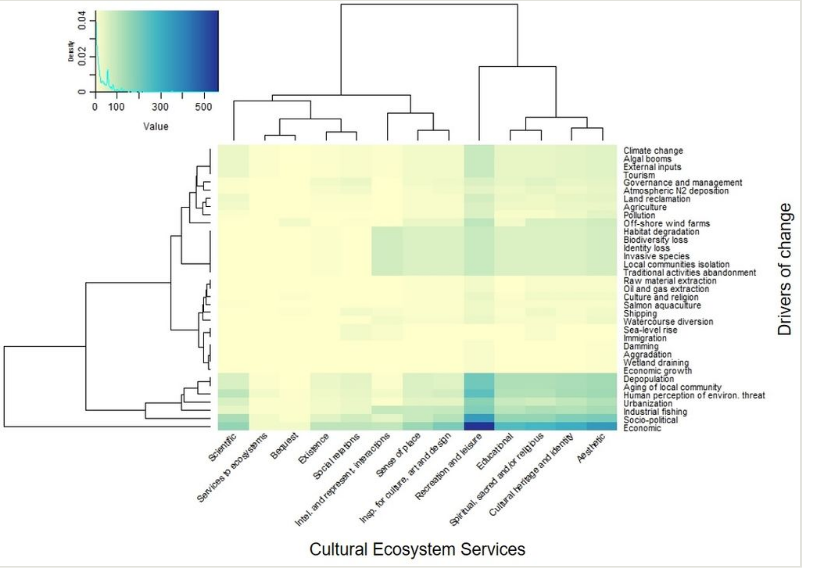

Figure 7.

Drivers of change affecting marine and coastal CES classes. Dendograms represent similar drivers grouped by hierarchical clustering on the Euclidean distance between the rows and columns of the matrix, according to the number of links found in the literature review.

Geographical distribution of case studies

The global spatial distribution of case studies assessing marine and coastal CES is markedly skewed (Fig. 8). Most marine and coastal CES were assessed in the Global North, mainly on the coasts of Western Europe, USA, Canada, Australia, Japan, and South Korea. Consequently, the Global South is underrepresented, with only a few studies in South America, Madagascar, and China (the Global North/South Divide groups countries according to their socioeconomic, political, and historical characteristics, thus southern hemisphere countries such as Australia and New Zealand belong to the Global North, while some northern hemisphere countries such as China and India belong to the Global South). Remarkably, no marine and coastal CES were assessed in any country of the African continent so far, at least in publications of our systematic review. The countries where most case studies were carried out are the UK (8), USA (7), Canada (6), and Germany (4). One cross-national assessment was undertaken for the coasts of the countries surrounding the Baltic Sea. But in most of these countries, no individual CES studies have been published. Unsurprisingly, for the countries with more case studies there has been reported a wider range of assessment types to evaluate more CES classes in a more diverse set of habitats. Nonetheless, countries with only one case study such as Brazil, France, Portugal, and Singapore assessed more than seven CES classes in each study.

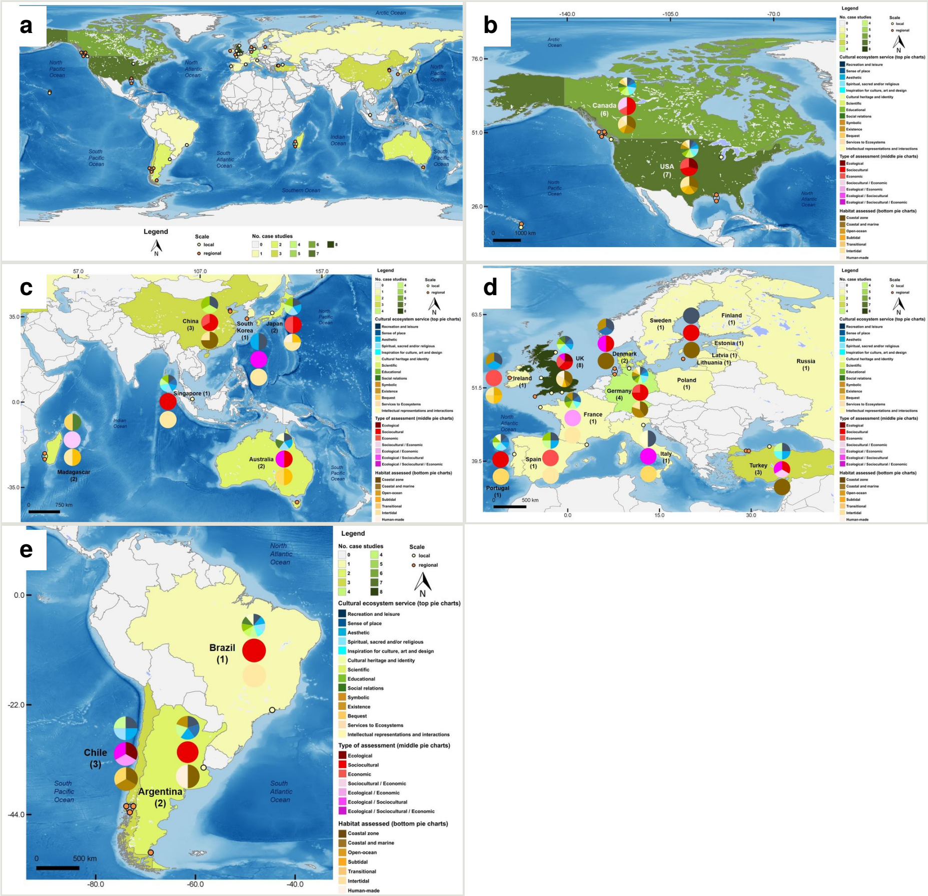

Figure 8.

Geographical location of marine and coastal CES assessments. All case studies are included (n=60) and are divided by location: (a) World (overview); (b) North America; (c) Asia and Oceania; (d) Europe; and (e) South America. The maps depict the number of case studies per country (number under the name of the country), their spatial scale, marine and coastal CES classes assessed (top pie charts), type of assessments (middle pie charts), and type of habitats assessed (bottom pie charts). Assessments at the national or larger spatial scales are not represented in the figure. Dots connected with a black circle represent assessments undertaken in the same location. We used vector map data from Natural Earth, and raster map data from the General Bathymetric Chart of the Oceans (GEBCO).

a: World (overview)

b: North America

c: Asia and Oceania

d: Europe

e: South America

Discussion

Research on marine and coastal CES is slowly gaining traction in the scientific literature. It is generating heterogeneous and interdisciplinary assessments, focused on a diverse range of habitats, spatial scales, and drivers of change. These findings from our systematic literature review complement the results of other review about marine and coastal CES (Martin et al. 2016) by presenting additional insights gathered through a wider coverage of the scientific literature. In this article, we present and discuss complementary results about CES classes (Fig. 3), ecosystems and habitats (Table 2), and methodologies and indicators used to quantify, value and map marine and coastal CES (Suppl. material 4). Additionally, we introduce new topics such as type of marine and coastal CES assessments (Fig. 4d); synergies and trade-offs within CES, or between CES and other ecosystem service categories or human-related activities (Fig. 6); drivers of change affecting marine and coastal CES (Fig. 7); spatial location of assessments (Fig. 8); and relationships between marine and coastal CES and human wellbeing, and links with ecological integrity.

Considerable knowledge gaps remain when comparing marine and coastal CES research with research done on provisioning and regulating ecosystem services (Fish et al. 2016, Rodríguez et al. 2006, Milcu et al. 2013), or in land-based ecosystems (Liquete et al. 2013, Palumbi et al. 2009). The main knowledge gaps that persist within marine and coastal CES research are related to: a lack of integrated valuation approaches; poor understanding of the contribution of CES benefits (e.g., identities, experiences, capabilities) to human wellbeing; poor knowledge about more intangible and incommensurable CES classes; lack of information on the role of ecosystems not prone to physical interactions by humans, such as open-ocean or deep-sea areas, to provide CES; and insufficient understanding on the role of non-natural capital (e.g., human, social, manufactured) in the co-production of marine and coastal CES (Palomo et al. 2016, Reyers et al. 2013). Geographically, the distribution of case studies is markedly uneven, undermining the worldview plurality necessary in CES research (Díaz et al. 2015). Next, we elaborate on these knowledge gaps and identify priorities to move forward marine and coastal CES research.

Diverse perspectives on marine and coastal CES research

CES contribute to the multiple dimensions of societal and individual wellbeing with myriad benefits such as health, knowledge, inspiration, spirituality, tranquillity, and discovery, among others (Plieninger et al. 2013, Russell et al. 2013). To capture the diversity and complexity of human wellbeing and what provides it, multiple values of marine ecosystem services need to be considered (Martinez-Alier 2002, O'Neill and Spash 2000, Max-Neef et al. 1992). Sociocultural, ecological, and economic values are all crucial to understand the importance, meaning, and worth of CES benefits to human societies. Hence, they need to be considered together to support environmental management and decision-making (Gómez-Baggethun and Barton 2013, Dendoncker et al. 2013, Martín-López et al. 2012, Martín-López et al. 2014). Most assessments of marine and coastal CES in our literature synthesis have a single valuation perspective, either sociocultural, economic, or ecological

(Suppl. material 4 and Fig. 4d). And sociocultural valuation is the most used valuation perspective. These findings are in line with previous reviews showing that CES assessments tend to take a sociocultural valuation perspective (Scholte et al. 2015) and mainly assess the social benefits provided by CES (Schmidt et al. 2016), although CES can also be associated with economic and ecological values. Among the 72 publications synthesised in our study, only nine combined more than one valuation type, and just one considered the three broad value types (Outeiro et al. 2015a). A future challenge for marine and coastal CES research is to engage more often in integrated valuation assessments that ensure value pluralism which, in the best case, would be elicited through participatory processes (Palomo et al. 2011, Oteros-Rozas et al. 2015). To capture the complexity inherent to integrated valuation assessments there is a need for interdisciplinary research teams. Indeed, as observed in our literature synthesis, most publications were authored by interdisciplinary research teams mostly composed by ecologists and economists. Having interdisciplinary research teams that include experts not only on ecology and economics, but also on other social sciences and humanities, is crucial to tackle complex integrated valuation assessments. Moreover, marine and coastal CES assessments can potentially be more relevant if they go beyond intrinsic and instrumental values, and focus also on relational values (Chan et al. 2016) that are behind peoples' kin and stewardship relationships with nature (Chapin et al. 2010). Such integrated valuation assessments can be part of, e.g., ecosystem-based management and marine spatial planning approaches (Lillebø et al. 2017), and thus inform policies that address the sustainability challenges we face today (Haberl et al. 2009).

Diverse worldviews and knowledge systems are necessary to understand the worldwide range of interactions between cultural practices and the natural environment, i.e., CES (Norgaard 1994, Fish et al. 2016, Berkes et al. 2000). Yet the geographical distribution of marine and coastal CES case studies is skewed. Assessments in our literature synthesis were mostly conducted in the Global North, with only a few assessments undertaken in the Global South (Fig. 8), and even fewer incorporating indigenous and local knowledge (Oleson et al. 2015, Comberti et al. 2015, Outeiro et al. 2015a, Butler et al. 2012, Sousa et al. 2013). Thus, there is mainly a Western European and North American (Canada and USA) perspective on the non-material contributions of natural systems to human societies. Such bias narrows the understanding of social-ecological interactions to a particular cultural setting, undermining the role of other worldviews in the understanding of the full spectrum of interactions between cultural practices and ecosystems worldwide. Examples of alternative worldviews are *Sumak Kawsay* from indigenous traditions of South America (Gudynas 2011), *Ubuntu* from Sub-Saharan countries (Shumba 2011), or *Ecological Swaraj* from grassroot communities in India (Kothari 2014).

Synergies, trade-offs, and bundles of marine and coastal CES

Our literature synthesis indicates that synergies are common among marine and coastal CES (Fig. 6). This suggests that CES often occur in bundles (Raudsepp-Hearne et al. 2010), and that often people cannot clearly separate the benefits provided by one CES class from another (Plieninger et al. 2013). Synergies with other ecosystem service categories are also identified in the literature, namely cultural heritage and identity, and the creation of social relations that often co-occur with seafood provision (Fletcher et al. 2014). Our results suggest that trade-offs are more common between CES and other ecosystem service categories, and human-related activities, than within CES. Provisioning ecosystem services related to commercial fisheries, aquaculture, and abiotic outputs such as renewable and non-renewable energy production are identified as occurring at the expense of marine and coastal CES. These trade-offs are noticeable when such activities compete for space with maritime recreational uses and when they are perceived to degrade seascapes. In fact, the use of maritime space for aquaculture and energy production implies building and assembling infrastructure that can alter the perceived visual, peaceful and remoteness qualities of seascapes, from natural to more industrial environments. Artificial elements in seascapes are likely to proliferate in the future given that the world human population is expected to increase to 11.2 billion people by 2100 (United Nations 2015), and so will the demand for seafood and energy.

Our literature synthesis also highlights that marine and coastal CES classes are not assessed by equal numbers of studies (Fig. 3). More tangible and commensurable CES classes such as recreation and leisure, and aesthetic services, receive comparatively more attention in the literature than more subjective and intangible CES such as existence, bequest, and symbolic services. One reason for this bias could be related with the high economic importance of recreation and leisure (mainly related to tourism) and aesthetic services, to the global economy (Costanza et al. 1997, Groot et al. 2012), stimulating more research and valuation assessments in these CES classes. In addition, the higher level of complexity inherent to more intangible CES classes, coupled with a fuzzy distinction between services, benefits and values associated to e.g., existence and bequest values, could also hinder more research on the topic. Moreover, it is challenging to define the ecosystem unit to which societies and individuals assign value (Gee and Burkhard 2010). This might indicate the limits of the CES concept and the notion of discrete services. Nonetheless, when spatial scales and system boundaries are well-defined, it is easier to relate CES with particular ecosystems and spatial properties (Plieninger et al. 2013). On the other hand, intangible CES such as spiritual and inspirational services are not usually associated with a specific landscape or seascape attribute (Brown 2004). It remains poorly understood what the effects of marine ecosystem change are on these intangible CES, and thus to what extent relevant stakeholders are affected by such changes. Consequently, ecosystem service assessments provide incomplete information to decision-makers, underlying a need to acknowledge this issue in CES research.

Another way to approach the difficulties in assessing CES is by explicitly linking their benefits to the multiple dimensions of human wellbeing (Plieninger et al. 2013, Klain and Chan 2012, Busch et al. 2011, Bryce et al. 2016, Daw et al. 2016). This is an underdeveloped research topic within marine and coastal CES. Connections between CES and human wellbeing are often mentioned in the literature, but they are hardly measured, and indicators are lacking. Similarly, conditions for the supply of marine and coastal CES remains largely unexplored, although a few publications from our literature synthesis highlight the positive effect of marine biodiversity and uninterrupted view out to seascapes in CES provision (Butler et al. 2012, Busch et al. 2011, Gee and Burkhard 2010, Ruiz-Frau et al. 2013, Fletcher et al. 2014).

The biophysical side of CES

Coastal areas and their seascapes constitute the physical limit for most of the world population to interact with marine systems. They are among the most populated areas on the planet (Brown et al. 2006), which makes them highly relevant for CES assessments. Beaches, intertidal mudflats, and dunes are well-assessed coastal areas as regards their economic importance in providing opportunities for recreation and leisure (Garcia Rodrigues 2015, Everard et al. 2010, de Oliveira and Berkes 2014). Other coastal habitats such as estuaries, fjords, reefs, seagrass meadows, mangroves, and wetlands are poorly assessed, particularly regarding those CES that arise from cognitive interactions with the environment such as spiritual, sacred and/or religious experiences, inspiration for culture, art, and design, sense of place, existence and bequest values, and symbolic services. Practical aspects such as accessibility or proximity to the study area and the expertise of authors may explain this lack of assessments (Liquete et al. 2013). Another possible reason is that experts who could assess these CES are critical to the concept of ecosystem services, refusing to measure or place value on the benefits from nature (Silvertown 2015).

Open-ocean and deep-sea habitats are inaccessible to the great majority of the world population and could be understood as irrelevant for CES research. Yet a few assessments exist for the open-ocean (e.g., Graham et al. (2014)) indicating that CES are not generated solely by human interaction with physical space and its natural processes, but also by people’s mental space with its symbolic and interpretative interactions, formed by perceptions, emotions, attitudes, values and understandings of a given natural setting (Chan et al. 2012a, Chan et al. 2012b, Fish et al. 2016, Gee and Burkhard 2010, Kumar and Kumar 2008). In this sense, even if one has never visited or interacted with open-ocean or deep-sea habitats, such areas could be valuable and meaningful to people – having existence and/or bequest value – generating CES benefits to wellbeing such as inspiration, knowledge, or spirituality through photographs, books, documentaries, paintings, exhibitions, or even scientific publications. Knowing the extent and contents of these marine ecosystem depictions in the media, cinema, literature, and music (Coscieme 2015), can provide insights about the importance that the wider public assign to those ecosystems (Jobstvogt et al. 2014b, Börger et al. 2014). This notion points out to the difference between the presence of marine and coastal CES, i.e., their availability, and their valuation by different people at different times, depending on the perceived benefits they provide. This raises important questions about the relative value assessment of CES, namely on which CES are valuable to whom and why. CES are not static entities meaning that their availability and importance to society and individuals change over time. These are relevant knowledge gaps that still need to be addressed in future CES research. Overcoming such knowledge gaps has the potential to help framing conservation policies aimed at the largest ecosystems on the planet, i.e., open-ocean and deep-sea areas.

Human-made structures such as waterfronts, harbours, and artificial reefs, were identified as CES-providing areas in our literature review (Ruiz-Frau et al. 2013, Faggi et al. 2013). However, it remains unclear what the ecosystem contribution to these services would be beyond the fact that an ecosystem or habitat has been transformed to carry these structures, while the previous natural habitat is not involved or it has a reduced capacity of delivering ecosystem services. This indicates that a common understanding of what constitutes an ecosystem service is still lacking. Nonetheless, artificial elements in association with the natural environment can facilitate interactions between people and ecosystems, enabling cognitive and physical benefits from CES. For example, one may need a boat and diving gear (non-natural capital) to access a coral reef (natural capital) for being able to enjoy (benefit) the beauty of the reef (CES). This highlights the role of social-ecological processes in the co-production of CES (Palomo et al. 2016, Reyers et al. 2013) by the joint contribution of natural and non-natural capital (e.g., social, human, manufactured).

Although ecosystems structures, processes and functions are needed to provide ecosystem services and their benefits (Haines-Young and Potschin 2009), they are also mediated by perceptions, values, institutions, and power relations among stakeholders, that can change ecosystems' state and integrity. Substituting natural capital with forms of non-natural capital usually imply trade-offs and equity issues (Palomo et al. 2016). For example, building a harbour in a sensitive coastal area may increase recreation and leisure for tourists who can afford renting boats, while lowering the benefits that the local population receive from ecosystem services such as mitigation of extreme events, lifecycle maintenance (habitat for fish larvae) for seafood provisioning, or recreation and leisure for those who do not own boats. In this sense, the notion of co-production increases the complexity of social-ecological interactions. Such notion needs to be further understood to inform environmental decision-making to address trade-offs and equity issues associated with the substitution of natural capital with forms of non-natural capital.

Drivers of change affecting marine and coastal CES

Marine and coastal CES are affected by combined sets of drivers of change including economic, demographic, sociocultural, climate change, and other ecological drivers (Fig. 7). By contributing to marine and coastal CES decline, such drivers negatively affect human wellbeing causing societal impacts. Some economic drivers play a particularly important role, namely land reclamation and habitat change in coastal wetlands for the purpose of economic growth (Chung et al. 2015), coastal infrastructure development (Tengberg et al. 2012, Hynes et al. 2012), urbanization (Faggi et al. 2013, Soy-Massoni et al. 2016, Thiagarajah et al. 2015), tourism (Wang et al. 2016), industrial fishing (Ruiz-Frau et al. 2013, Moberg and Folke 1999, Jobstvogt et al. 2014, Rocha et al. 2014), aquaculture (Outeiro and Villasante 2013), and maritime shipping (Jobstvogt et al. 2014). Demographic drivers also affect marine and coastal CES supply and are related with depopulation (Hashimoto et al. 2014), local communities' isolation (Sousa et al. 2013), and aging of local communities (Hashimoto et al. 2014). These demographic drivers erode cultural values through the loss of indigenous and local knowledge, and are linked to sociocultural drivers, namely traditional activities abandonment and identity loss. Lastly, but not least, we identified ecological drivers contributing to marine and coastal CES decline, namely biodiversity loss, habitat degradation, and the spread of invasive species (Sousa et al. 2013). To some extent, these drivers of change act synergistically upon marine ecosystems (Fig. 7) and can disrupt the supply of cultural and other ecosystem services (Rocha et al. 2014). Thus, environmental management strategies that target single drivers of change are likely to fail. Understanding the co-occurring nature of all drivers affecting ecosystems and the appropriate spatial and temporal scales for management are crucial to halt the decline of CES in marine and coastal areas (Rocha et al. 2014). Also, an important aspect to bear in mind is the intrinsic dynamic nature of both cultural practices and the marine environment, which might contribute to the production of new CES and their appreciation.

Concluding Remarks: moving forward

We have identified knowledge gaps and research priorities in the context of marine and coastal CES. Comparatively little research attention has been given to marine and coastal CES, which decreases their integration in environmental management plans (e.g., marine spatial planning) due to the biased perception that their importance is negligible compared to other ecosystem services. Generally, most marine and coastal CES classes are missing quantitative and qualitative assessments and therefore there is a need for testing and developing suitable methodologies and indicators to assess them.

To close knowledge gaps, research priorities should be directed at testing and developing integrated marine and coastal CES assessments, which require closer interactions with stakeholders to identify relevant CES, their plural sociocultural, ecological, and economic values, and how to mitigate conflicts and manage trade-offs inherent to decision-making. Incorporating indigenous and local knowledge in research and decision-supporting tools could be especially important to highlight the contribution of marine and coastal CES to the sustainability of social-ecological interactions, as such knowledge often holds practical answers to deal with sustainability problems. At the same time, the role of non-natural capital in the co-production of marine and coastal CES – including abiotic outputs from marine systems – also deserves careful attention in such assessments, as e.g., capabilities, access rights, or technology, may be required to co-produce CES and hence to access their benefits, with obvious environmental justice implications. Another crucial research priority to halt the decline of CES in marine and coastal areas resides in understanding the synergistic nature of drivers of change, and the appropriate scale for their management. Moreover, the areas of the Global South where marine and coastal CES assessments are missing seem to be those where a major effort should be carried out to fill knowledge gaps. Explicitly incorporating marine and coastal CES preservation, enhancement and restoration into the goals of international efforts for achieving sustainability could boost research on these so far neglected areas. Finally, there is a need for broader methodological studies with a wider set of expertise. This requires that scientists are incentivised to cross the disciplinary and cultural divide, incur the extra cost of learning to communicate, interact and research in a multidisciplinary and multicultural fashion.

We have highlighted the importance of considering marine and coastal CES for providing new knowledge to support global coastal and marine sustainability. Knowledge sharing plays a central role in the way we develop future sustainability and conservation action plans that are inclusive across disciplines and cultural settings, building on the importance of indigenous and local knowledge in its different forms of expression. Successfully closing the knowledge gaps in marine and coastal CES research will provide a more comprehensive picture of the interactions between humans and marine ecosystems, hopefully resulting in more balanced and just decision-making outcomes. CES are strong motivations for people to embrace sustainability, and hence their inclusion in environmental decision-supporting mechanisms can contribute to a more sustainable future for marine and coastal ecosystems.

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Author contributions

JGR and SV designed the study. All authors wrote the main manuscript text. JGR, SV, AJC, SRR, SR, PP, KMK, CP, PL, VAR, SSR, DK, LO, CA, LT, SS, ABH, MK, AIL, EMB, AB, and AM collected data by reviewing articles for the systematic literature review. JGR analysed the data and prepared all figures and tables.

Conflicts of interest

The authors declare no conflicts of interest.

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Supplementary materials

Suppl. material 1: PRISMA checklist

Authors: João Garcia Rodrigues
Data type: Table
Filename: Table S1.docx - Download file (20.18 kb)

Suppl. material 2: Correspondence between our classification and labels for marine and coastal CES as found in the literature

Authors: João Garcia Rodrigues
Data type: Table
Filename: Table S2.docx - Download file (16.59 kb)

Suppl. material 3: List of papers included in the literature synthesis

Authors: João Garcia Rodrigues
Data type: List
Filename: S3.docx - Download file (24.33 kb)

Suppl. material 4: Overview of the methods and indicators used to assess marine and coastal CES

Authors: João Garcia Rodrigues
Data type: Table
Filename: Table S4.docx - Download file (499.03 kb)