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Article *in* Ecosystem Services · December 2024

DOI: 10.1016/j.ecoser.2024.101673

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Wood, K.A., Jupe, L.L., Aguiar, F.C., Collins, A.M., Davidson, S.J., Freeman, W., Kirkpatrick, L., Lobato-de Magalhães, T., McKinley, E., Nuno, A., Pagès, J.F., Petruzella, A., Pritchard, D., Reeves, J.P., Thomaz, S.M., Thornton, S.A., Yamashita, H. & Newth, J.L. (2024). A global systematic review of the cultural ecosystem services provided by wetlands. Ecosystem Services, 70, 101673.

Final published article available at: https://doi.org/10.1016/j.ecoser.2024.101673

A global systematic review of the cultural ecosystem services provided by wetlands

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Abstract

Wetlands make a disproportionately large contribution to global biodiversity and provide critical ecosystem services for humanity. Yet, our understanding of the cultural ecosystem services (CES) provided by wetlands remains limited, with benefits often only recognised at local scales. To address this knowledge gap, we conducted a global systematic review of wetland CES. Our synthesis addressed key questions related to the provision of CES by different types of wetlands, their economic value, their co-occurrence and associations with other ecosystem services, threats to the provision of CES by wetlands, as well as the availability and use of CES information. Based on 861 published papers (1968–2022) in 17 languages, we found evidence of CES provided by wetlands in 175 countries and territories, highlighting that wetlands are globally important for the provision of CES. Recreation/tourism was the most frequently reported CES (40%), with cultural identity/heritage (16%) and education/learning/knowledge (13%) also well-represented. In contrast, examples of sense of place (4%) and bequest (4%) were least frequent. Our synthesis of published estimates yielded a mean of £57262 ha^{-1} yr^{-1} for the cultural benefits of wetlands; however, this mean should be interpreted with caution given that we documented a very wide range of estimates for each CES type of <£1–£1065205 ha^{-1} yr^{-1}. Threats to wetland CES were documented in 45% of papers, and included wetland destruction, pollution, and climate change. The probability that a CES paper would be available open access, and the probability that a published paper featured at least one author affiliated with the country where the study was conducted, both varied significantly among continents and publication years. Conservation outcomes related to CES featured in 13% of papers, whilst 10% made policy/management recommendations. Our study highlights the links between wetlands and human culture, emphasising their importance in motivating future wetland creation and restoration.

Keywords: Aquatic ecosystems; Cultural benefits; Ecosystem goods; Evidence synthesis; Water; Wetland threats

1. Introduction

Wetlands are among the Earth's most threatened ecosystems, with estimates indicating that 21–87% of all wetlands (*sensu* Ramsar Convention on Wetlands, 1971) globally have been destroyed between 1700 AD and the present (Davidson, 2014; Darrah et al., 2019; Fluet-Chouinard et al., 2023). These losses have been widespread and pervasive, affecting every continent where wetlands occur (Čížková et al., 2013; Davidson, 2014; Kingsford et al., 2016; Hu et al., 2017). Coastal wetlands, including seagrass beds, salt marshes, mangroves, and coral reefs, lost >50% of their area during the 20th century alone (Li et al., 2021), whilst freshwater wetlands, such as lakes, rivers, and marshes, have also been affected (Vörösmarty et al., 2010; Reid et al., 2019). The key drivers of global wetland loss include conversion of wetlands for agricultural and other uses, water abstraction, flow regulation, eutrophication, pollution, aquaculture, invasive species and climate change (Davidson, 2014; Reid et al., 2019). Among remaining wetlands, these factors have caused widespread habitat degradation that has impacted the structure and functioning of wetland ecosystems (Nilsson et al., 2005; Jiang et al., 2015; Nguyen et al., 2016; Zhang et al., 2017).

The pervasive destruction and degradation of wetland ecosystems have led scientists to consider what has been lost (Ramsar Convention on Wetlands, 2018; Davies et al., 2020). Wetlands make a disproportionately large contribution to global biodiversity; freshwaters alone contain approximately 6% of all described species, including one-third of vertebrate species, despite accounting for only 0.8% of the Earth's surface (Dudgeon et al., 2006; Reid et al., 2019; WWF, 2022). For example, coastal wetland ecosystems are also known for their high biodiversity and unique species assemblages (Li et al., 2018), and for their contribution to fisheries and biodiversity in coastal areas (Manson et al., 2005). The loss and degradation of wetlands threaten this biodiversity (Gibbs, 2000); a recent report concluded that amongst 6,617 freshwater populations of 1,398 species of mammals, birds, amphibians, reptiles, and fishes monitored between 1970 and 2018, the average change in abundance was a reduction of 83% (WWF, 2022).

In addition to their high biodiversity value, wetlands also provide a wide range of ecosystem services that benefit people (Maltby and Acreman, 2011; Mitsch et al., 2015; Xu et al., 2020; Vári et al., 2022; Brander et al., 2024). A previous study has shown that more than 50% of the human population lives within 3 km of a freshwater body (Kummu et al. 2011) and 40% within 100 km of the coast (Maul and Duedall 2021), which are also likely to be impacted by wetland loss and degradation. Davidson et al. (2019) estimated that the annual value of ecosystem services provided by wetlands globally is approximately Int$47.4 trillion, although such economic valuations of nature are not universally accepted (e.g., Victor, 2020). Wetland ecosystem services include provisioning services such as the supply of fresh water and food for human use (Ayeni et al., 2019), regulating services such as flood control and water purification (Pattison-Williams et al., 2018), and supporting services such as the cycling of water and nutrients (Fennessy et al., 2008). In addition, a fourth class of ecosystem services, termed ‘cultural ecosystem services’ (CES), has received less attention from researchers and decision-makers relative to provisioning, regulating, and supporting ecosystem services (Chan et al., 2012; Hirons et al., 2016).

The Millennium Ecosystem Assessment (2005) defined CES as the “*benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences*”. Over time the range of recognised types of CES has grown from the original cultural and recreation categories of Costanza et al. (1997), and now includes benefits such as aesthetic values, sense of place, cultural heritage, spiritual and religious values, as well as recreation and tourism (Milcu et al., 2013). As CES are highly recognized and perceived by people, these services may be among the most directly important for mental and physical health and wellbeing (Daniel et al., 2012; Russell et al., 2013; Pröbstl-Haider, 2015). Evidence supports the importance of CES in human physical and mental wellbeing (Riis et al., 2020; Reeves et al., 2021; Ruiz et al., 2021), as well as the role of CES in fostering connectedness to nature and pro-environmental behaviours among people (Zhang et al., 2023).

Despite the evidence of benefits, a comprehensive understanding of the range of CES provided by wetland ecosystems has, to date, eluded researchers. The limited attention received by CES compared to other ecosystem services likely reflects the intangibility of some CES types, their subjective nature, and the difficulty of quantifying their value in monetary terms (Daniel et al., 2012; Hirons et al., 2016; Ghermandi and Sinclair, 2024). Furthermore, it is unclear whether the currently available published literature represents a balanced picture of global wetlands and CES, or rather a knowledge base which is highly biased towards certain geographic areas, certain types of wetland, or specific types of CES that are more amenable to study.

Improved knowledge of the evidence for the CES provided by wetlands is required to truly understand how wetlands benefit people and contribute to human health and wellbeing, and furthermore how the loss and degradation of wetlands impact on the provision of ecosystem services and the people who use them. Addressing this knowledge gap is especially vital given the historic and ongoing destruction of wetlands. A lack of understanding of CES may also precipitate or exacerbate conflicts between people (Redpath et al., 2015), for instance between wetland conservationists and local people for whom the use of wetland resources is culturally important. Further, our relatively poor understanding of CES represents a lost opportunity to engage people and build support for conservation and restoration efforts (Chan et al., 2016). Indeed, Pedersen et al. (2019) argued that greater awareness of the high levels of CES provision by wetlands could offer a powerful motivation for the creation, restoration and improved management of wetlands. Recognition of the cultural value of sites can lead to greater protection, benefitting both people and biodiversity (Zannini et al., 2021). Payment for Ecosystem Service (PES) schemes, although somewhat controversial (Yan et al., 2022), have been highlighted as a potential mechanism for funding large-scale wetland creation and restoration projects, although the lack of knowledge and valuation of CES often limits their inclusion within such schemes (Canning et al., 2021).

Although the importance of the cultural benefits of wetlands is increasingly recognised (Chan et al., 2016), we are not aware of any previous attempts to examine the accessibility of such information to practitioners and policy-makers. Many practitioners and policy-makers lack access to articles that are behind a paywall; where papers are available ‘open access’ with no requirement for readers to make such payments, this can increase the availability of information (Alston, 2019), although it is important to recognise that certain open access practices can place prohibitive costs on authors (Wood et al., 2021; Mekonnen et al., 2022). Another important way in which information on CES can be disseminated is the involvement of local researchers in the authorship of CES papers, who may act as focal points for the dissemination of knowledge into their communities. The involvement of local researchers also helps to develop scientific capacity (Reidpath and Allotey, 2019) and can help to incorporate different knowledge systems, to the benefit of decision-making (Wheeler and Root-Bernstein, 2020). However, it is recognised that international researchers may not always credit local researchers with co-authorship on papers, undertaking ‘parachute science’ (de Vos and Schwarz, 2022). Such inequitable research and authorship practices limit opportunities for engagement and the dissemination of knowledge (Brittain et al., 2020; de Vos and Schwarz, 2022). Yet, it is currently unknown how much of the published literature on wetland CES is open access and freely available to practitioners and policy-makers, or how widespread parachute science might be in the wetland CES literature.

We are similarly unaware of any attempts to quantify the applied use of information on wetland CES in primary studies. Although CES are perceived as motivators for the conservation or restoration of wetlands (Pedersen et al., 2019), to date there have been no attempts to quantify the specific conservation or restoration benefits associated with CES. Similarly, there have been no attempts to quantify how CES research papers might be attempting to inform practice and policy through the inclusion of applied recommendations. Studies that offer recommendations for practice or policy are typically better integrated with stakeholders compared to studies that lack such recommendations (Guerrero et al., 2018).

While there have been earlier reviews of CES (e.g., Milcu et al., 2013), to date none has specifically addressed wetland ecosystems. In this study we use a systematic review approach (*sensu* Koricheva and Gurevitch, 2013) to synthesise the available global knowledge on the CES associated with wetlands to address the following key questions:

(i) What are the CES provided by different types of wetlands, and when and where have these been documented?

(ii) What is the economic value of the cultural benefits of wetlands?

(iii) Which CES co-occur, and which CES co-occur with other types of ecosystem services?

(iv) What are the potential threats to the provision of CES by wetlands?

(v) How have open access and authorship practices, which affect the availability of CES information to practitioners and policy-makers, varied over time and amongst global regions?

(vi) What conservation outcomes and applied recommendations are found within the literature on CES in wetlands?

2. Methods

2.1 Systematic review protocols

To improve the transparency of the methodology and findings of our study, we used the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA; Page et al., 2021) flow diagram (**Supplementary information 1**) and checklist (**Supplementary information 2**).

2.1.1 Literature search protocol

As relevant information is known to be widely dispersed across different literatures, including ecosystem services, cultural landscapes, recreation, psychology, and health and wellbeing (Hirons et al., 2016), we conducted our literature reviews using multiple search tools. We sought relevant literature in *Web of Science Core Collection* (https://clarivate.com/webofsciencegroup/solutions/web-of-science/), *Scopus* (https://www.scopus.com/), *PubMed* (https://pubmed.ncbi.nlm.nih.gov/), and *EBSCO Host* (https://search.ebscohost.com/Login.aspx), as these are known to be valuable sources of published information on CES (e.g., Cheng et al., 2019). In each of these four tools, we used a search string based on a set of terms associated with CES, combined with a set of terms associated with wetlands, and the Boolean operators "OR" and "AND". In addition, the symbol "*" was used as a suffix for terms where multiple different endings of that term were likely to exist in the literature (e.g., the term "inspir*" was used to capture multiple similar terms such as "inspire", "inspired", "inspiring", "inspiration", and "inspirational"). The CES terms were informed by the categories used by the Millennium Ecosystem Assessment (2005) and Common International Classification of Ecosystem Services (CICES; Haines-Young and Potschin, 2018), whilst the wetland terms were based on the Ramsar Convention's definition of wetlands, and included all aquatic ecosystems "*whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*" (Ramsar Convention on Wetlands, 1971). The following search string was used to explore each of the four search tools:

"cultural ecosystem service*" OR recreation OR leisure OR ecotourism OR bequest OR "cultural identity" OR spirit* OR sacred OR symboli* OR "sense of place" OR aesthetic OR educat* OR heritage OR inspir* OR “nature* contribution to people” OR identity OR “non-material benefit*”

AND

wetland* OR “blue space*” OR lagoon* OR “seagrass*” OR “rocky shore*” OR “coral reef*” OR estuar* OR marsh* OR swamp* OR lake* OR pond* OR river* OR bog* OR canal* OR reservoir* OR mangrove* OR peat* OR “geographically isolated wetlands” OR “temporary wetlands” OR floodplain* OR riparian.

Searches were conducted on 13th April 2022. We included articles in any language in our search, to reduce the risk of bias (Konno et al., 2020). To avoid the risk of ‘double-counting’ information, our review was restricted to peer-reviewed primary articles only, and did not include either grey literature or secondary articles such as reviews and syntheses; grey literature articles may have been subsequently published, sometimes in a markedly amended form which makes duplicated information hard to detect, whilst including secondary articles would have resulted in duplication of information that was also present in the original primary studies.

2.1.2 Literature screening protocol

Our literature screening protocol involved screening all papers found in our search, to assess their relevance against our criteria for inclusion in our study. Our inclusion criteria stated that, for a paper to be included in our final dataset, that paper should report evidence of one or more CES, as defined by CICES criteria (Haines-Young and Potschin, 2018), within at least one wetland habitat, as defined by the Ramsar definition of wetlands (Ramsar Convention on Wetlands, 1971). There were three stages of screening, with papers evaluated by their (i) title, (ii) abstract, and (iii) full text. At each stage, any papers that were deemed not to meet our inclusion criteria were not considered further. Each paper was screened by one of two individuals, with an assessment conducted to evaluate the degree of concordance among these two individuals; in this assessment both individuals screened the same batch of 2396 papers (which represented 25% of our total literature, as recommended by Côte et al., 2013) independently by title, as this was the stage of screening for which the least information is available and hence the greatest degree of judgement must be used. The results were compared by calculating the value of Cohen's Kappa, which adjusts the proportion of papers for which the two individuals agreed by the amount of congruence that would be expected by chance, and produces a score of between 0 and 1 (Cohen, 1960). Our value of Cohen's Kappa was calculated using the kappa.test function in the *fsmb* package (Nakazawa, 2022) in R (R Core Team, 2022). For our subset of 2396 papers, we achieved a kappa score of 0.74, indicating "*substantial agreement*" (*sensu* Landis and Koch, 1977), and exceeding the minimum of 0.60 recommended for such assessments (Côte et al., 2013). Therefore, our findings were unlikely to have been biased by differences between the individuals conducting the assessment.

2.1.3 Data extraction protocol

For each paper retained for inclusion during our screening process, we noted the full citation details of each paper (author names, year of publication, article title, and journal name) and extracted the following information:

(1) *Language*. We recorded the language that the paper was written in.

(2) *Type(s) of CES reported*. We assessed the following eight categories of CES, based on those listed by the Millennium Ecosystem Assessment (2005) and CICES (Haines-Young and Potschin, 2018): (i) aesthetic value: people show appreciation for the beauty or aesthetic value of aspects of ecosystems; (ii) bequest, intrinsic, and existence: people value ecosystems for their inherent qualities, motivating protection/conservation for current and future generations; (iii) cultural identity and heritage: features within the environment influence the ways in which people view themselves, and remind people of their collective and individual roots; (iv) education, learning and knowledge: the components and processes of ecosystems provide opportunities for formal and informal learning and the development of systems of knowledge; (v) inspiration: ecosystems provide inspiration for culture, including art, folklore, architecture, and advertising; (vi) recreation and tourism: people may choose to spend part of their leisure time on activities within a particular ecosystem; (vii) sense of place: aspects of ecosystems can help to develop a strong connection between people and a particular location; (viii) spiritual and religious values: people may attach spiritual or religious value to ecosystems or their components. Where recreation was reported as a wetland CES, we recorded any specific activities that the study documented.

(3) *Wetland type*. We recorded the type(s) of wetland in which the study was conducted. Based on the Ramsar definition and categorisation of wetlands (Ramsar Convention on Wetlands, 2012), wetlands were assigned to one of six distinct types: (i) marine (coastal wetlands including coastal lagoons, rocky shores, and coral reefs); (ii) estuarine (including deltas, tidal marshes, and mangroves); (iii) lacustrine (i.e. lakes and associated wetlands; (iv) riverine (i.e. rivers, streams and their associated wetlands); (v) palustrine (such as inland marshes, swamps and bogs);

(vi) human-made wetlands (including reservoirs, canals, fish/shrimp ponds, farm ponds, irrigated agricultural land, salt pans, gravel pits and sewage farms).

(4) *Economic valuation*. For any papers which reported assessments of the economic value of one or more CES, we recorded the estimated value, the currency, year(s) of valuation, the type(s) of CES valued, as well as the spatial extent (ha) of the wetland and the numbers of people associated with the valuation (e.g. number of paying visitors). For studies that reported multiple economic valuations, estimates for different sites were extracted separately, whilst multiple estimates for the same site were averaged to avoid biasing the dataset towards studies with high degrees of temporal replication. To facilitate comparisons across different studies, we first converted all values into GBR sterling £ using the Bank of England's published interest rates between sterling and the original currency (for the time of data collection, or the year of publication if the former was not available). Next, we adjusted all of the values for inflation, using the Bank of England's inflation calculator. Thus, all estimates were converted into GBR sterling adjusted to its March 2023 value. Where relevant information was obtained, we reported values ha^{-1} yr^{-1}, in common with previous syntheses of ecosystem services (e.g., de Groot et al., 2012). As ecosystem services are fundamentally about value to people, however, we also reported values $user^{-1}$ yr^{-1} and ha^{-1} $user^{-1}$ yr^{-1}, where such information was available.

(5) *Other ecosystem services*. We recorded the identity of any other types of ecosystem services (e.g., provisioning, regulation/maintenance, supporting) that were also reported in the study, which could indicate an association or synergy between CES and other types of ecosystem services.

(6) *Threats*. From each paper, we recorded the identity of any threats to the focal wetland or its provision of CES. Based on the categories used in the International Union for Conservation of Nature's Red List of Threatened Species (IUCN, 2022), threats were classified as: (i) residential & commercial development; (ii) agriculture & aquaculture; (iii) energy production & mining; (iv) transportation & service corridors; (v) biological resource use; (vi) human intrusions & disturbance; (vii) natural system modifications; (viii) invasive & other problematic species, genes & diseases; (ix) pollution; (x) geological events; (xi) climate change & severe weather; (xii) other options; (xiii) wetland loss or degradation due to unspecified cause(s).

(7) *Location*. We noted the continent and country/countries in which the study was conducted.

(8) *Open access*. We recorded whether the paper was published open access.

(9) *Authorship*. We noted whether the paper featured at least one author associated with the country (based on their institutional affiliations) where the study was conducted.

(10) *Applied information*. We noted whether the paper recorded any (i) conservation or restoration benefits or (ii) applied recommendations related to CES. Based on the information that was extracted from the papers, the conservation/restoration benefits were subsequently grouped into one of the six major categories that were identified: (i) habitat creation/restoration; (ii) site protection; (iii) increased conservation governance, i.e. where participants in a wetland-based recreational activity form a group to manage the wetland; (iv) educational activities; (v) actions to limit or reduce environmental impacts; and (vi) other benefits. The applied recommendations were assigned to one of ten categories: (i) improve resources/infrastructure for CES; (ii)

manage conflicts between stakeholders; (iii) improve wetland site management; (iv) conduct conservation/restoration work; (v) integrate CES into decision-making/policy; (vi) better protect wetland site; (vii) improve wetland site monitoring; (viii) improve education/awareness; (ix) involve local community; and (x) other recommendations.

2.2 Statistical analyses

We used generalised linear models with binomial error structures to assess the spatial and temporal variability in two response variables: (i) the probability that a CES paper would be available open access, and (ii) the probability that a published paper featured at least one author affiliated with the country where the study was conducted. Spatial variability was modelled as the continent where the study was conducted (Africa, Asia, Central America, Europe, North America, Oceania, and South America), whilst temporal variability was modelled as the year of publication for each study. A paper that reported multiple CES was included as a single data point in our analyses. For the authorship analysis, papers that reported CES from multiple countries contributed multiple data points. For each response variable we ran a total of five models, comprising all combinations of additive and two-way interactive effects of publication year and continent, as well as the null model.

All models were fitted using the *lme4* and *MuMIn* packages (Bartoń, 2012; Bates et al., 2015) in R version 4.2.2 (R Core Team, 2022). We explored the use of mixed effects models, including a categorical study identity variable as a random effect to account for some non-independence among studies conducted in more than one country; however, these models would not converge and so could not be considered further. Moreover, as <4% of papers reported data from more than one country, we considered that this issue was unlikely to materially affect our results. Model assumptions, including checks for collinearity, were performed using the *performance* package (Lüdecke et al., 2021). For each response variable, all candidate models were compared using second-order Akaike's Information Criteria (AIC_c), with any model with an AIC_c value of within 2.0 of the lowest AIC_c was considered to have received substantial support in the data (Burnham et al., 2011). The explanatory power of each model was quantified using Nagelkerke's R^2, via the *DescTools* package (Signorell, 2020). Tukey's HSD *post-hoc* differences between continents (accounting for multiple comparisons) were determined using the *emmeans* package (Lenth et al., 2019).

3. Results

3.1 Literature search, screening and data extraction

Our literature searches identified a total of 9581 primary journal articles. The subsequent screening protocols reduced the total to 861 articles (published between 1968–2022; **Figure 1**), from which we extracted data on the CES provided by wetlands (**Supplementary information 1**). The 861 papers were written in 17 different languages, with English accounting for 84% (**Supplementary information 3**).

3.2 Cultural ecosystem services in wetlands

3.2.1 CES provision by wetlands

Amongst the 861 relevant papers identified in our review, we identified 2654 instances of CES provided by a wetland (**Table 1**). Recreation/tourism was the most frequently reported type of CES (40%), with cultural identity/heritage (16%) and education/ learning/knowledge (13%) also well-represented in the literature (**Table 1**). In contrast, sense of place (4%) and bequest (4%) were least frequently reported.

A total of 63 recreational activities in wetlands were reported, among which fishing (reported in 53% of papers that listed recreational activities), boating (51%), observing nature (30%), and swimming (29%), were documented most frequently (**Figure 2**). Of the 2654 identified examples of wetland CES, riverine (31%) and lacustrine (23%) types were the most prevalent, whilst marine (12%) and palustrine (8%) types were the least common (**Table 1**). Human-made wetlands accounted for 10% of the reported examples of CES (**Table 1**).

From our extracted data we identified evidence of CES provided by wetlands in 175 countries and territories (**Figure 4**), with examples for each CES type found for all continents (**Figure 5**). However, there was a dearth of studies from northern Africa, the Arctic, and parts of Asia (**Figure 4**). Global study effort was not evenly distributed, with the USA (n=177) and China (n=64) being the most frequently mentioned countries in the studies identified by our review, whilst Europe, North America and Asia were the most represented continents (**Figure 5**). The USA was the most-frequently mentioned country for (i) aesthetic value; (ii) bequest, intrinsic, and existence values; (iii) cultural identity and heritage; (iv) inspiration; (v) recreation and tourism; and (vi) sense of place (**Figure 4**). In addition, the USA and China were tied for the most frequent reports of education. In contrast, however, India was the country that was most-frequently reported for spirituality/religious CES (**Figure 4**).

3.2.2 Economic values of CES provided by wetlands

We synthesised estimates of per area or per user valuations of the economic benefits associated with different types of CES (**Table 2**). The range for the estimates of wetland CES values was substantial, and the number of estimates found in the literature for recreation/tourism was much higher than the ones found for bequest/intrinsic/existence, education/learning/knowledge, inspiration or spiritual/religious CES (**Table 2**). We did not find per area or per user valuations for aesthetic value, cultural identity/heritage, and sense of place. The mean ± SD economic value associated with wetland CES ranged from £0.26 ha^{-1} yr^{-1} for inspiration to £41093 ha^{-1} yr^{-1} for recreation/tourism (**Table 2**). Recreation/tourism similarly had the highest associated mean annual value per user, at £163 $user^{-1}$ yr^{-1} (**Table 2**). Finally, the highest mean annual value for a hectare of wetland per user was associated with spiritual/religious value, at £1.13 ha^{-1} $user^{-1}$ yr^{-1}, although this was based on a single study (**Table 2**). Summing the mean values for the CES types for which data was obtained yielded estimates of £57262 ha^{-1} yr^{-1}, £218 $user^{-1}$ yr^{-1}, and £0.60 ha^{-1} $user^{-1}$ yr^{-1}, for the cultural benefits of wetlands to people.

3.2.3 Wetland CES co-occurrence

In total, 408 of the 861 papers (47%) reported multiple CES types provided by the same wetland. The most frequent associations were between spiritual/religious and inspiration (20%), spiritual/religious and cultural identity/heritage (18%), sense of place and inspiration (18%), and recreation/tourism and aesthetic value (18%)

(**Figure 3**).We found that 211 of the 861 relevant CES papers also reported provisioning, regulating, or supporting ecosystem services (**Supplementary information 4**). A total of 201 papers documented 272 instances of 6 distinct provisioning services, of which fresh water (listed in 48% of papers that reported other types of ecosystem service), food (32%), and energy (11%) were the most frequently identified. Regulating services were recorded in 62 papers, with 73 instances of 6 distinct services; the most documented were flood control/storm protection (20%) and pollution attenuation (4%). Finally, 9 papers included information on supporting services, with 11 instances of 2 distinct services: soil formation (3%) and nutrient cycling (1%).

3.2.4 Threats to CES provision by wetlands

Threats to wetland ecosystems and their provision of CES were documented in 45% of the 861 relevant papers. These papers reported a total of 1025 threats (**Table 3**). Among them, pollution was the most commonly reported threat across all types of wetlands (comprising 34% of reported threats), followed by climate change and severe weather in five out of the six types of wetlands (16%), and by residential and commercial development, which ranked third in frequency (12%) (**Table 3**).

3.2.5 Accessibility of wetland CES information

We found that 58% of the 861 papers had some level of open access availability. Among our candidate models, the probability that a paper would be available open access was best explained by additive effects of publication year and continent, which accounted for 95% of the total Akaike weights (**Table 4**). No other candidate models had AIC_c values within 2.0 of this best-supported model (**Table 4**). The probability that a paper would be available open access increased over time (**Table 5; Figure 6a**) and differed between continents. The mean probabilities were highest for South America (0.840, 95% CI = 0.689–0.926) and were lowest for Oceania (0.476, 95% CI = 0.339–0.616) (**Table 6**). *Post-hoc* testing indicated that the probability that a paper would be available open access was greater for studies conducted within South America compared with Asia, Europe, North America, and Oceania (**Table 7**); however, no other statistically significant differences were detected.

Among the 861 papers, there were 1079 studies of wetland CES in named countries and territories; 26% of these featured no authors affiliated with the country where the study was conducted (**Figure 6b**; **Figure 7**). Our model selection process indicated that the probability that a published paper featured at least one author affiliated with the country where the study was conducted was best explained by an interaction between publication year and continent, which accounted for 100% of the total Akaike weights (**Table 4; Table 5**). None of the other candidate models had AIC_c values within 2.0 of this best-supported model (**Table 4**). The mean probabilities were highest for studies conducted in South America (0.959, 95% CI = 0.774–0.994) and North America (0.898, 95% CI = 0.842–0.936), and were lowest in Africa (0.380, 95% CI = 0.287–0.484) and Central America (0.345, 95% CI = 0.225–0.488) (**Table 6**). The probability that a published paper featured at least one author affiliated with the country where the study was conducted showed the steepest declines over time for studies from Central America, South America, and Oceania, with more marginal declines in those of Africa and North America, whilst studies conducted in Asia and

Europe showed a slight increase (**Figure 6b**). *Post-hoc* testing indicated that the probability that a published paper featured at least one author affiliated with the country where the study was conducted was lower for papers conducted within either Africa or Central America when compared with those from Asia, Europe, North America, Oceania, and South America (**Table 7**). In addition, studies carried out in North America were more likely than those from Europe to feature at least one author affiliated with the country (**Table 7**). No further statistically significant differences were detected.

3.2.6 Applied use of wetland CES information

Overall, 113 papers (13%) listed a total of 125 distinct conservation or restoration benefits associated with the provision of CES. Wetland site protection was the most-frequently specified benefit, accounting for 41% of the total (**Figure 8a**). Asia and Europe accounted for the largest shares of the 113 papers, each accounting for 26% (Figure 8a); 24% of the studies were conducted in North America, whilst the other continents accounted for between 2–8% each.

In total, 89 of the 861 papers (10%) made a total of 161 applied recommendations related to policy and management associated with CES. The most reported type of recommendation was to improve the resources and infrastructure for CES, which accounted for 19% of the total (**Figure 8b**). A comparison among continents indicated that studies conducted in Asia accounted for the largest share (34%) of the 89 papers, followed by Europe (21%), Africa (17%), and North America (12%), whilst the remaining continents accounted for between 2–8% each (Figure 8b).

4. Discussion

4.1 CES provision by wetlands

Our systematic review demonstrates that there is rapidly growing evidence that all types of wetlands provide a diverse array of cultural benefits to people. The reported benefits were not limited to any particular region or continent, but rather were globally widespread; the 2654 examples of CES identified from the 861 relevant papers in our study were drawn from 175 different countries and territories, which attests to the global relevance of wetlands in the delivery of CES.

Examples of all eight of the CES categories that we considered in this study were found in each of the different types of wetlands, demonstrating that cultural benefits are not restricted to any one type of wetland. Moreover, our findings illustrated that cultural benefits can be gained from both natural and human-made wetlands. Amongst the natural ecosystems, riverine wetlands featured the highest number of CES studies, which may reflect the widespread nature of rivers in the globe as well as with the diverse types of wetlands associated with them (Verhoeven, 2014; Grill et al., 2019). The benefits of human-made water bodies such as reservoirs for recreational activities such as boating, fishing and swimming have long been recognised (e.g., James, 1970; Waelti, 1970); however, our results show that these artificial blue spaces can also provide a much wider range of services, including cultural identity and heritage associated with historic canals (Burd, 2016) or agricultural reservoirs (Vafadari, 2013), the value of constructed wetlands in education programmes (Nesmith et al., 2016), and the potential of small human-made water bodies as places where people may petition deities associated with water (Peña, 2015).

Recreation/tourism was the most frequently studied cultural benefit, with the steepest temporal increase in the number of publications in the last decade, and with more studies than any other CES type. An earlier review of CES (Milcu et al., 2013) also found that recreation/tourism accounted for the greatest number of publications. Milcu et al. (2013) associated these results with the relative ease of evaluating this ecosystem service and cautioned that such an approach may widen the disparity between what can be assessed and what holds significance for individuals.

Although we found evidence that wetlands provide a diverse range of cultural benefits globally, our data show clearly that for each type of CES there were biases in study effort towards certain countries and regions, in common with previous studies of CES and associated topics (e.g. Ghermandi and Sinclair, 2019; Xu et al., 2020). Studies conducted in the USA and China were numerous for each type of CES, indicating the relatively high levels of study effort associated with those countries. In contrast, our study indicated a notable absence of studies from parts of the world including northern Africa, parts of the Arctic (e.g., Greenland, Iceland), and certain countries within Asia (e.g., Laos, Pakistan, Yemen). The absence of studies in those areas suggests a need for targeted studies to assess existing cultural benefits of wetlands in these parts of the world.

4.2 Economic values of CES provided by wetlands

Our work builds on the findings of previous studies that highlighted the economic benefits of CES provided by wetlands (e.g., de Groot et al., 2012; Clarkson et al., 2013; Davidson et al., 2019; Ghermandi and Sinclair, 2024). Taken together, the five CES types for which we obtained economic values yield a mean value of £57262 ha^{-1} yr^{-1} for the cultural benefits of wetlands. This value is considerably higher than the values for wetlands which typically have been reported previously; for example, de Groot et al. (2012) reported a mean economic value for wetlands (based on the five wetland categories reported in that study: coral reefs, coastal ecosystems, coastal wetlands, inland wetlands, fresh water rivers/lakes) of USD$23540 ha^{-1} yr^{-1} in 2007, equivalent to £18761 ha^{-1} yr^{-1} in 2023; these values were recently updated by Brander et al. (2024) to Int$18764 ha^{-1} yr^{-1} in 2020, equivalent to £16901 ha^{-1} yr^{-1} in 2023. Similarly, the estimates reported by Ghermandi and Sinclair (2024) show a mean value of CES for coastal wetlands (based on data for coral reefs, sandy shores, mangroves, estuaries and coastal marshes) of Int$5448 ha^{-1} yr^{-1} in 2020, equivalent to £5492 ha^{-1} yr^{-1} in 2023. The reasons for the differences between the findings of our study, and those of previous studies, are not due to differences in the range of CES categories included in the assessments. Our assessment, along with those of de Groot et al. (2012), Brander et al. (2024), and Ghermandi and Sinclair (2024), each incorporated data for 5–6 types of CES. However, our estimates for certain CES categories were notably higher than those reported in previous assessments, which reflects the valuations made in the original sources. For example, we estimated the economic value of religious/spiritual services from wetlands as >£8800 ha^{-1} yr^{-1}, based on the findings of Maharana et al. (2000); in contrast, de Groot et al. (2012) and Brander et al. (2024) estimated this CES as £18 and £97 ha^{-1} yr^{-1}, respectively, whilst Ghermandi and Sinclair (2024) did not include this category in their valuation. It should be noted that our estimate of the economic value of religious/spiritual services, as well as that of Brander et al. (2024), were each based on only a single available study, highlighting the considerable uncertainty and the need for further estimates.

In comparison to wetlands, Brander et al. (2024) documented values associated with the CES of tropical forests (Int$5841 ha^{-1} yr^{-1} in 2020), temperate forests Int$2138 ha^{-1} yr^{-1} in 2020, and grasslands (Int$3008 ha^{-1} yr^{-1} in 2020) that were respectively equivalent to £5261 ha^{-1} yr^{-1}, £1926 ha^{-1} yr^{-1}, and £2709 ha^{-1} yr^{-1} in our 2023 valuation year. Our results provide further evidence, therefore, that the economic value of wetland CES exceeds those of terrestrial ecosystems (Brander et al. 2024).

We found that recreation/tourism ranked consistently among the most economically valuable CES for wetlands, in common with previous studies, including de Groot et al. (2012), Brander et al. (2024), and Ghermandi and Sinclair (2024). With the exception of recreation/tourism, our mean estimates of economic value are based on relatively few studies, and much greater study effort would be required to refine the mean estimates of the economic benefits of these CES types. Moreover, for those CES types for which multiple studies had estimated the economic benefits, we found high-levels of variance in those estimates. Our review identified some studies which indicated that the economic value associated with the aesthetic value of wetlands could be estimated (e.g., Kulshreshtha and Gillies,1993; Hanson et al., 2002); but we did not include them in our summary of wetland CES economic values because their units could not be converted to values per area or per user. Our synthesis indicates that at least some types of cultural benefits from wetlands can have measurable economic value, and illustrates the attempts of previous research to provide economic valuations of different types of cultural benefits. However, given that the economic valuations synthesised in our study reflect a wide range of valuation methodologies, wetland types, sample sizes, and study locations, we urge the reader to interpret the mean economic estimates with caution. Furthermore, it is important to recognise that neoclassical economic approaches to valuing the environment and its benefits to people are not universally accepted; for example, ecosystem service economic valuations have been criticised by some authors for its anthropocentric focus on the instrumental value of nature to people, its tendency to commodify complex social-ecological systems (Matulis, 2014; Victor, 2020). Future attempts to value wetlands should therefore also investigate non-monetary techniques further, as well as approaches that incorporate diverse values and worldviews, including the intrinsic value of wetlands themselves (Davies et al., 2020).

4.3 Wetland CES co-occurrence

It was clear from our findings that many wetlands provide multiple different types of cultural benefits simultaneously. The 47% of studies that reported the co-occurrence of multiple types of cultural benefits is likely a marked underestimate of the true associations between different types of CES, because many studies only set out to investigate single types of CES in isolation. Although cultural benefits are frequently divided into discrete categories to enable tractable assessments, in reality there can be considerable overlap between such categories. Religious pilgrimages to sacred wetland sites illustrate how religious benefits and tourism can intersect, for example (Verschuuren, 2018). The provision of education resources such as information boards at recreation and tourism sites (Spalding and Parrett, 2019) similarly highlights the overlap between education/knowledge/learning and recreational tourism. Furthermore, we found a variety of other ecosystem services in publications about CES, with fresh water and flood control/storm protection identified as the most frequent for provisioning and regulation services, respectively. The high frequency of these ecosystem services may be explained by the predominance of riverine wetlands in our survey, since rivers are among the most important sources of drinking water and their wetlands are also associated with flood protection (Bullock and Acreman, 2003; Opperman et al., 2018).

4.4 Threats to CES provision by wetlands

Our review uncovered examples of wetland CES provision impacted by all 13 of the threat categories that we included in our assessment. Our finding that pollution, climatic change, and urban development are key threats to the provision of cultural benefits by wetlands, accords with the evidence provided by previous research (e.g. Xu et al., 2020). For example, Mucioki et al. (2021) reported that more extreme weather patterns due to climate change have made it more difficult for the Karuk, Yurok, and Klamath Tribes in parts of California and Oregon to harvest culturally important aquatic and riparian plants such as wocus (*Nuphar polysepala*) and sandbar willow (*Salix exigua*), as plant growth seasons have become less predictable. Similarly, reduced ice cover due to climate change has restricted the ability of communities to undertake religious ceremonies on frozen lakes (Knoll et al., 2019). Moreover, the losses of CES due to wetland destruction and degradation are not felt equally within societies, with recent evidence showing that the most disadvantaged and vulnerable are often impacted most (Adhya and Banerjee, 2022).

Currently, the relationships between CES provision and wetland ecosystem health are not well understood. Future research should seek to understand whether CES provision is eroded gradually as wetlands are degraded, or whether tipping points can be identified, beyond which CES provision collapses. Such information would benefit wetland conservation and management for example by helping to set restoration targets linked to CES provision.

4.5 Accessibility of wetland CES information

We found evidence of a general temporal trend towards a greater availability of information on wetland CES, with studies from each continent showing an increased propensity to be published open access over time. This increase reflects the rapid growth of open access publishing in the last decade (Piwowar et al., 2018). However, global inequalities in the availability of information remain, with papers on wetland CES in countries within Oceania and Asia still less likely to be available open access. According to our data, however, South American countries are exceptions, since they have the highest probability that a paper was published open access. The possible explanation is that Latin America has the Scielo database, which is a publicly funded initiative with c.1,700 journals to promote OA science (Bulock, 2019). Open access publication can increase availability of information, especially for practitioners and policy-makers who may lack access to paywalled articles (Alston, 2019). However, the financial costs associated with some models of open access publication are a barrier for those who lack the required funding, such as authors from outside of the global north and non-academic researchers (Wood et al., 2021; Mekonnen et al., 2022). It is crucial, therefore, that the move towards greater open access publication of CES benefits does not disadvantage authors without access to open access funding, which could reinforce the existing geographic bias of available information towards richer countries in the global north.

The cultural benefits of wetlands have been studied widely across the world, and yet local researchers have not always been included as co-authors on those studies. We found evidence that 26% of the studies identified in our review contained no co-authors from the country in which the study was conducted, which is symptomatic of parachute science (de Vos and Schwarz, 2022). The level of inclusion of in-country authors was particularly low in countries within Africa. Whilst in some regions (e.g., Europe) practices appear to be improving, our analyses documented concerning trends towards lower inclusion of in-country authors in some parts of the world, such as Central America, Oceania, and South America. CES researchers need to ensure that local partners are credited for their involvement, and moreover that information on the cultural benefits of wetlands is disseminated to local practitioners and policy-makers, to ensure that such evidence helps to inform wetland action and decision-making.

4.6 Applied use of wetland CES information

Whilst only a minority of papers reported information on conservation outcomes (13%) or applied recommendations (10%), these papers nonetheless illustrate the potential value of CES information for management actions and policy. Yet, our results illustrated considerable geographic biases in the likelihood of wetland CES papers reporting either conservation actions or applied recommendations; in particular, we found that Central America, Oceania, and South America were all under-represented in the available literature. It should be noted, however, that our approach cannot distinguish between studies that did not report conservation outcomes because the authors did not include them, and studies for which there genuinely were no conservation outcomes. Therefore, our data likely represent a minimum level and serve to illustrate the types of conservation outcomes reported in the wetland CES literature. A greater consideration of culture into decision-making could benefit wetland conservation by helping us to understand the complex relationships between people, culture and nature (Hinson et al., 2022).

Among the papers which reported conservation outcomes we found examples that illustrate the role that culture can play in the conservation protections afforded to wetland sites. One such case can be found in the riverside forests of Togo, where local communities afford greater respect and protection to sacred riparian areas than for the government’s protected areas, which is reflected in greater degradation of the latter sites (Kokou et al., 2008). The cultural significance of wetlands can lead to communities imposing restrictions on the activities that may be undertaken; for example, among the Akan people, the River Tano in Ghana is revered as a deity and fishing within the river is prohibited as the fish are considered to be the children of the river (Sarfo-Mensah et al., 2014). Despite their importance, there is a risk that spiritual/religious values, which can be challenging to measure, may be overlooked in decision-making processes (Verschuuren, 2018).

The widespread incidences of pollution and degradation at wetlands identified in our review demonstrate that cultural importance does not, by itself, guarantee protection from environmental damage. Moreover, some CES such as recreation/tourism can cause impacts on protected wetland areas (Schvab et al., 2022). The need for greater legal protection of wetland sites was among the most frequently made applied recommendations identified in our review, although to be effective these must be locally relevant (Kokou et al., 2008). There is also the need to understand variation in power and values between different stakeholders, as those who value a wetland for its cultural importance may not always have the power to make environmental management decisions.

4.7 Limitations

It is important to consider limitations associated with our systematic review. We limited our searches to peer-reviewed primary literature only, and hence some useful wetland CES examples from the grey literature will have been excluded. However, in our view we have no reason to expect that the types of CES, types of wetlands, or the geographic origin of the excluded grey literature examples would have been markedly different to those of the published literature, and so the key conclusions of our review are unlikely to have been affected substantially. Previous research has recognised that reviews which consider only papers written in English typically represent a biased sample of the global literature on a topic (Konno et al., 2020). To reduce such bias and to obtain a representative global sample of the literature on wetland CES, we included papers written in all languages. However, as we conducted our searches in English, it is likely that there was still some residual bias in our results. Finally, we recognise that the ecosystem services paradigm that we used in this review is one of many different ways of conceptualising human-environment relationships, and so our review may have excluded literature which used other approaches or frameworks, including nature's contributions to people, biocultural approaches to conservation, more-than-human geographies, kincentric ecologies, and other Indigenous approaches and ways of knowing (Diaz et al., 2018; Dean et al., 2021). Integrating insights from these other disciplines with those of ecosystem services approaches may also produce further useful insights into the cultural values associated with wetlands.

5. Conclusions

Our review has shown the important links that exist between wetlands and different aspects of human culture. It has also revealed that our view of wetland CES is affected by substantial geographical biases and inequalities exist in study effort, research practices, and the availability of CES information to practitioners and policy-makers. In particular, without research that addresses wetland CES in historically under-studied regions such as northern Africa, we will not achieve a truly global assessment of wetland CES. Our work identifying these knowledge gaps and biases in the current literature will be only the first step towards addressing them.

By highlighting the diverse range of cultural benefits that wetlands provide to people across the world, our study helps to "*raise awareness of the benefits of wetlands*", as advocated by a recent synthesis of the parlous state of the world's wetlands (Ramsar Convention on Wetlands, 2018). The loss and degradation of wetlands, due to the threats identified in our review and in previous research (e.g. Ramsar Convention on Wetlands, 2018), compromise the provision of cultural benefits to people. Even where the wetland itself is not destroyed, wider environmental changes may still impact on the provision of CES. Globally, there are increasing efforts to conserve, create and restore wetland ecosystems in response to the losses and ongoing threats (Guan et al., 2019; Yamashita, 2021). Such efforts are increasingly linked to the need to protect and restore ecosystem services, although the focus to date has been on provisioning and regulating services (e.g. Mason et al., 2023). The findings of our systematic review demonstrate the diverse range of cultural benefits that are likely to be gained from global efforts to conserve, create and restore wetlands. An improved understanding of CES, diverse values, and relationships which people have to wetlands, will facilitate efforts to engage people and build support for much-needed conservation and restoration efforts (Chan et al., 2016), and will offer a powerful motivation for the creation, restoration and improved management of wetlands (Pedersen et al., 2019). Moreover, the diverse links between wetlands and culture identified in our study make clear the need for wetland conservation and restoration to be a priority concern, not just of the policy and decision-making sectors that are charged with water and environmental management, but also those responsible for cultural heritage, education, recreation, tourism, and Indigenous affairs.

Acknowledgements

Thanks to Professor Rudolf de Groot, the handling editor, and an anonymous reviewer for their valuable feedback which helped us to improve our manuscript. FCA was supported by CEF, a research unit funded by FCT, Portugal (UIDB/00239/2020). AP acknowledges the support received from Rhodes University Postdoctoral Research Fellowship 2023. LK received funding from the UKRI Economic and Social Research Council and support from the UK Environment Agency. AN acknowledges the support of the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement SocioEcoFrontiers No. 843865. We thank Jacqui Coakham and her team for creating the graphical abstract.

Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

Data availability

The data files and the analytical code used in our study are available via the following *figshare* repository: https://figshare.com/s/5a62801cb1f9a1cfd862

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Tables

Table 1: The numbers of unique reports within our 861 papers of the provision of different types of CES by each type of wetland.

CES type	All wetlands	Marine	Estuarine	Lacustrine	Riverine	Palustrine	Human-made
Aesthetic value	307	41	21	76	116	27	26
Bequest/intrinsic/existence	106	12	12	29	39	9	5
Cultural identity/heritage	423	51	32	97	167	28	48
Education/learning/knowledge	335	32	129	50	66	30	28
Inspiration	132	11	9	43	50	12	7
Recreation/tourism	1069	147	195	217	283	83	144
Sense of place	104	11	11	34	36	8	4
Spiritual/religious	178	14	10	76	57	11	10
All CES types	2654	319	419	622	814	208	272

Table 2: A summary of the estimated economic value associated with the different types of cultural benefits provided by wetlands, based on the relevant papers identified by our review.

	Annual value per area (£ ha-1 yr-1)				**Annual value per user (£ user-1 yr-1)**				**Annual value of 1ha per user (£ ha-1 user-1 yr-1)**			
CES type	**n**	**Mean**	**SD**	**Range**	**n**	**Mean**	**SD**	**Range**	**n**	**Mean**	**SD**	**Range**
Aesthetic value	0	-	-	-	0	-	-	-	0	-	-	-
Bequest/Intrinsic/Existence	3	4888.08	6243.76	326.44-13716.45	4	50.80	78.15	2.78-186.11	3	0.24	0.35	0.0005-0.73
Cultural identity/heritage	0	-	-	-	0	-	-	-	0	-	-	-
Education/learning/knowledge	1	2459.57	-	-	0	-	-	-	0	-	-	-
Inspiration	1	0.26	-	-	0	-	-	-	0	-	-	-
Recreation/Tourism	39	41093.48	170183.96	1.15-1065205.07	90	162.51	414.03	0.22-3547.65	34	0.44	1.71	0.00002-10.11
Sense of place	0	-	-	-	0	-	-	-	0	-	-	-
Spiritual/religious	1	8820.73	-	-	1	4.29	-	-	1	1.13	-	-

Table 3: The numbers of studies which reported each type of threat for each type of wetland.

Threat categories	Marine wetlands	Estuarine wetlands	Lacustrine wetlands	Riverine wetlands	Palustrine wetlands	Human-made wetlands	Total
Residential and commercial development	17	20	27	43	6	12	125
Agriculture and aquaculture	3	7	11	11	6	5	43
Energy production and mining	3	2	2	7	0	1	15
Transportation and service corridors	9	3	0	0	0	1	13
Biological resource use	29	14	5	9	5	3	65
Human intrusions and disturbance	17	12	23	24	2	12	90
Natural system modifications	1	1	2	22	2	1	29
Invasive and other problematic species, genes and diseases	6	9	9	8	5	2	39
Pollution	60	45	73	114	16	40	348
Geological events	1	3	1	2	0	0	7
Climate change and severe weather	22	21	30	58	8	24	163
Other threats	4	10	17	19	3	8	61
Wetland loss or degradation for unspecified reasons	5	4	5	7	4	2	27

Table 4: Comparisons of our candidate models of (i) the probability that a published paper was available open access (P_{OA}) and (ii) the probability that a published paper featured at least one author affiliated with the country where the study was conducted (P_{Author}).

Response variable	Explanatory variables	D.F.	AIC_c	ΔAIC_c	Relative Likelihood	Akaike weights	Evidence ratio	Nagelkerke's R^2
P_{OA}	Continent+Year	8	1106.21	0.00	1.00	0.95	1.0	0.158
	Continent*Year	14	1112.59	6.33	0.04	0.04	23.6	0.166
	Year	2	1114.76	8.55	0.01	0.01	71.8	0.128
	Continent	7	1170.27	64.06	0.00	0.00	8.1×10^{13}	0.066
	null	1	1201.10	94.89	0.00	0.00	4.0×10^{20}	0.000
P_{Author}	Continent*Year	14	1067.67	0.00	1.00	1.00	1.0	0.249
	Continent+Year	8	1083.93	16.26	0.00	0.00	3394.8	0.216
	Continent	7	1085.21	17.54	0.00	0.00	6441.4	0.212
	Year	2	1226.31	158.64	0.00	0.00	2.8×10^{34}	0.024
	null	1	1242.31	174.64	0.00	0.00	8.4×10^{37}	0.000

Table 5: A summary of the parameter estimates associated with our best-supported model of (i) the probability that a published paper was available open access (P_{OA}) and (ii) the probability that a published paper featured at least one author affiliated with the country where the study was conducted (P_{Author}).

Response variable	Parameter	Estimate	S.E.	Z value	P value
P_{OA}	Intercept	-112.900	14.970	-7.55	<0.001
	Continent: Asia	-0.720	0.348	-2.07	0.039
	Continent: Central America	-0.196	0.510	-0.38	0.701
	Continent: Europe	-0.484	0.356	-1.36	0.174
	Continent: North America	-0.593	0.361	-1.64	0.101
	Continent: Oceania	-0.959	0.436	-2.20	0.028
	Continent: South America	0.797	0.546	1.46	0.144
	Publication year	0.057	0.007	7.61	<0.001
P_{Author}	Intercept	5.067	37.421	0.14	0.892
	Continent: Asia	-16.010	57.821	-0.28	0.782
	Continent: Central America	217.635	84.811	2.57	0.010
	Continent: Europe	-36.038	44.872	-0.80	0.422
	Continent: North America	69.195	54.210	1.28	0.202
	Continent: Oceania	157.616	88.024	1.79	0.073
	Continent: South America	599.240	250.414	2.39	0.017
	Publication year	-0.003	0.019	-0.15	0.882
	Continent: Asia * Publication year	0.009	0.029	0.31	0.757
	Continent: Central America * Publication year	-0.108	0.042	-2.57	0.010
	Continent: Europe * Publication year	0.019	0.022	0.84	0.401
	Continent: North America * Publication year	-0.033	0.027	-1.23	0.220
	Continent: Oceania * Publication year	-0.078	0.044	-1.78	0.076
	Continent: South America * Publication year	-0.296	0.124	-2.39	0.017

Table 6: The estimated marginal means, standard errors, as well as the lower and upper 95% confidence limit values of the continent-specific probabilities that (i) a published paper was available open access (P_{OA}) and (ii) a published paper featured at least one author affiliated with the country where the study was conducted (P_{Author}). All values were estimated from our best-supported models (see Table 4); values for P_{Author} refer to 2011.

Response variable	**Continent**	**Mean**	**S.E.**	**Lower 95% CL**	**Upper 95% CL**
P_{OA}	Africa	0.703	0.068	0.556	0.817
	Asia	0.535	0.032	0.472	0.598
	Central America	0.661	0.088	0.474	0.808
	Europe	0.593	0.036	0.521	0.661
	North America	0.567	0.038	0.491	0.640
	Oceania	0.476	0.073	0.339	0.616
	South America	0.840	0.059	0.689	0.926
P_{Author}	Africa	0.380	0.051	0.287	0.484
	Asia	0.802	0.027	0.743	0.850
	Central America	0.345	0.069	0.225	0.488
	Europe	0.751	0.027	0.695	0.799
	North America	0.898	0.024	0.842	0.936
	Oceania	0.753	0.060	0.620	0.851
	South America	0.959	0.038	0.774	0.994

Table 7: Tukey's HSD *post-hoc* differences between the continent-specific estimated marginal means of the continent-specific probabilities that (i) a published paper was available open access (P_{OA}) and (ii) a published paper featured at least one author affiliated with the country where the study was conducted (P_{Author}). Statistically significant contrasts are indicated in bold.

Response variable	Contrast	Odds ratio	S.E.	Z value	P value
P_{OA}	Africa : Asia	2.05	0.71	2.07	0.372
	Africa : Central America	1.22	0.62	0.38	1.000
	Africa : Europe	1.62	0.58	1.36	0.824
	Africa : North America	1.81	0.65	1.64	0.655
	Africa : Oceania	2.61	1.14	2.20	0.295
	Africa : South America	0.45	0.25	-1.46	0.768
	Asia : Central America	0.59	0.25	-1.26	0.870
	Asia : Europe	0.79	0.16	-1.20	0.896
	Asia : North America	0.88	0.19	-0.59	0.997
	Asia : Oceania	1.27	0.41	0.75	0.989
	Asia : South America	**0.22**	**0.10**	**-3.33**	**0.016**
	Central America : Europe	1.34	0.56	0.69	0.993
	Central America : North America	1.49	0.63	0.94	0.965
	Central America : Oceania	2.14	1.05	1.56	0.708
	Central America : South America	0.37	0.22	-1.68	0.629
	Europe : North America	1.12	0.24	0.50	0.999
	Europe : Oceania	1.61	0.53	1.45	0.775
	Europe : South America	**0.28**	**0.13**	**-2.76**	**0.084**
	North America : Oceania	1.44	0.48	1.11	0.926
	North America : South America	**0.25**	**0.12**	**-2.95**	**0.049**
	Oceania : South America	**0.17**	**0.09**	**-3.33**	**0.015**
P_{Author}	**Africa : Asia**	**0.15**	**0.04**	**-6.83**	**<0.001**
	Africa : Central America	1.17	0.43	0.42	1.000
	Africa : Europe	**0.20**	**0.05**	**-6.14**	**<0.001**
	Africa : North America	**0.07**	**0.02**	**-7.90**	**<0.001**
	Africa : Oceania	**0.20**	**0.08**	**-4.15**	**<0.001**
	Africa : South America	**0.03**	**0.03**	**-3.63**	**0.005**
	Asia : Central America	**7.71**	**2.69**	**5.86**	**<0.001**
	Asia : Europe	1.35	0.30	1.33	0.839
	Asia : North America	0.46	0.14	-2.50	0.159
	Asia : Oceania	1.33	0.48	0.78	0.987
	Asia : South America	0.17	0.17	-1.76	0.573
	Central America : Europe	**0.17**	**0.06**	**-5.21**	**<0.001**
	Central America : North America	**0.06**	**0.02**	**-7.07**	**<0.001**
	Central America : Oceania	**0.17**	**0.08**	**-3.99**	**0.001**
	Central America : South America	**0.02**	**0.02**	**-3.70**	**0.004**
	Europe : North America	**0.34**	**0.10**	**-3.64**	**0.005**

Europe : Oceania	0.99	0.35	-0.04	1.000
Europe : South America	0.13	0.13	-2.07	0.369
North America : Oceania	2.89	1.19	2.58	0.133
North America : South America	0.38	0.38	-0.96	0.962
Oceania : South America	0.13	0.13	-1.98	0.430

Figures

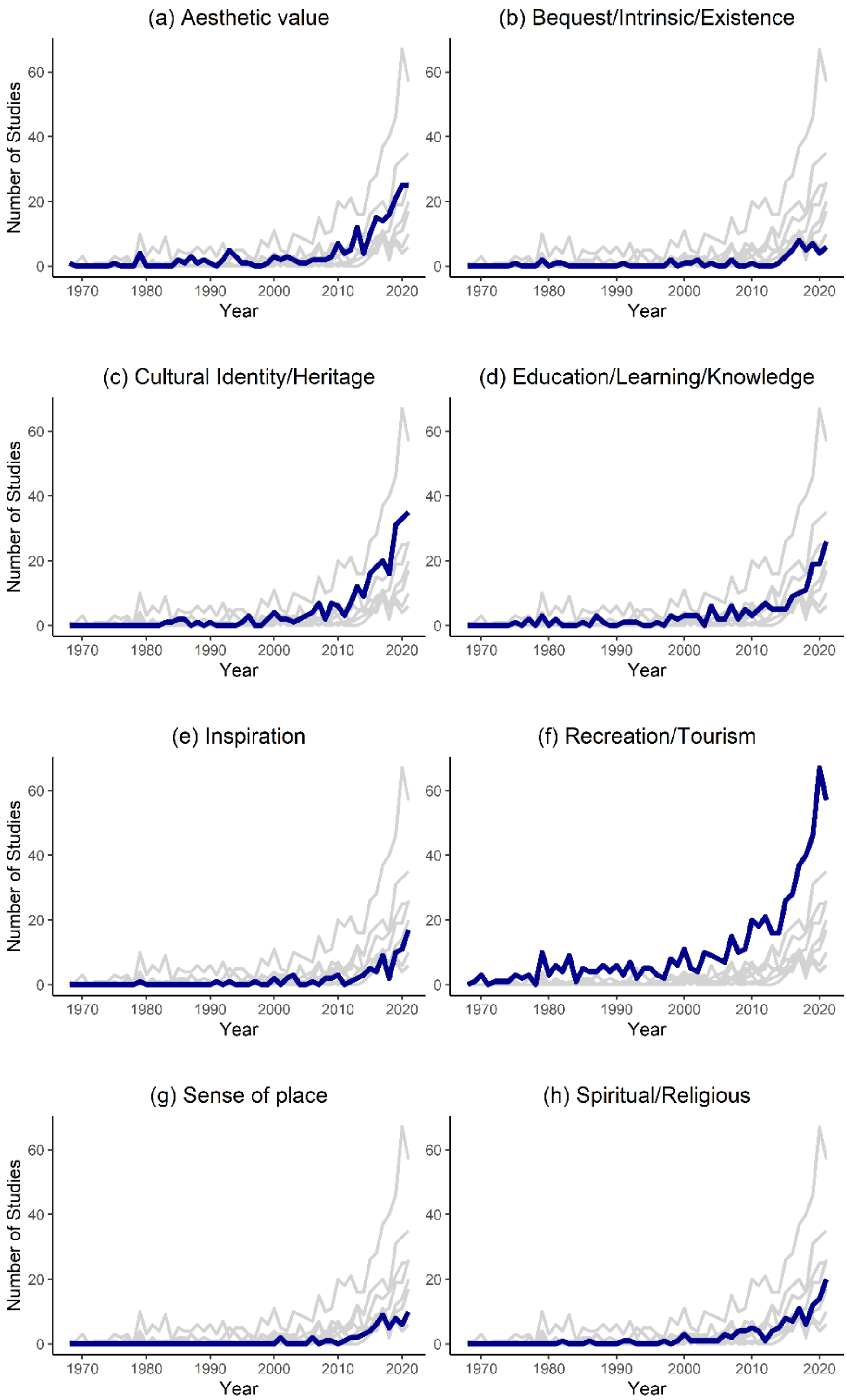


Figure 1: The temporal trends in the numbers of published studies that reported each type of CES provided by wetlands.

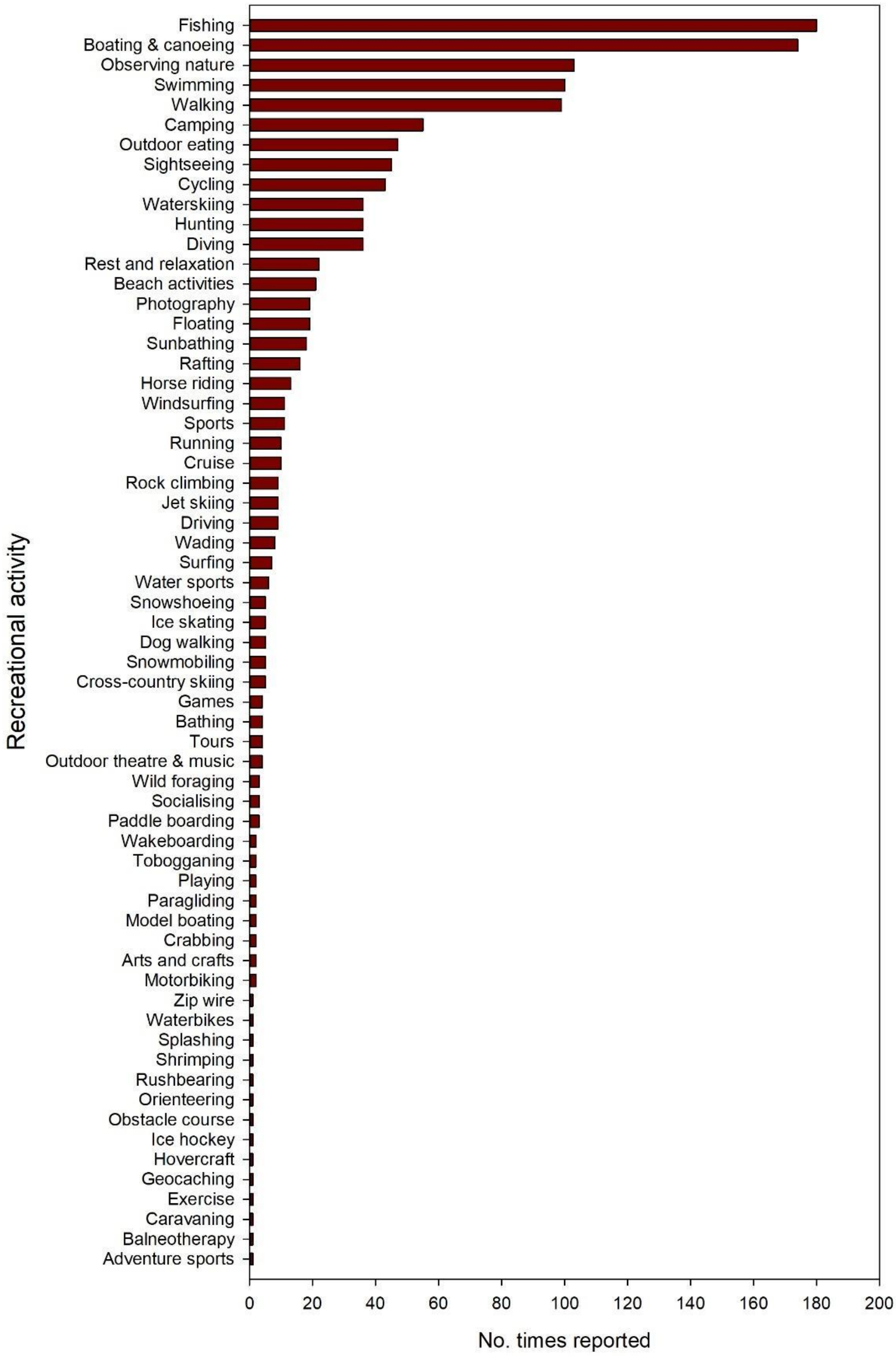


Figure 2: The numbers of studies which reported each type of recreational activity carried out in wetlands.

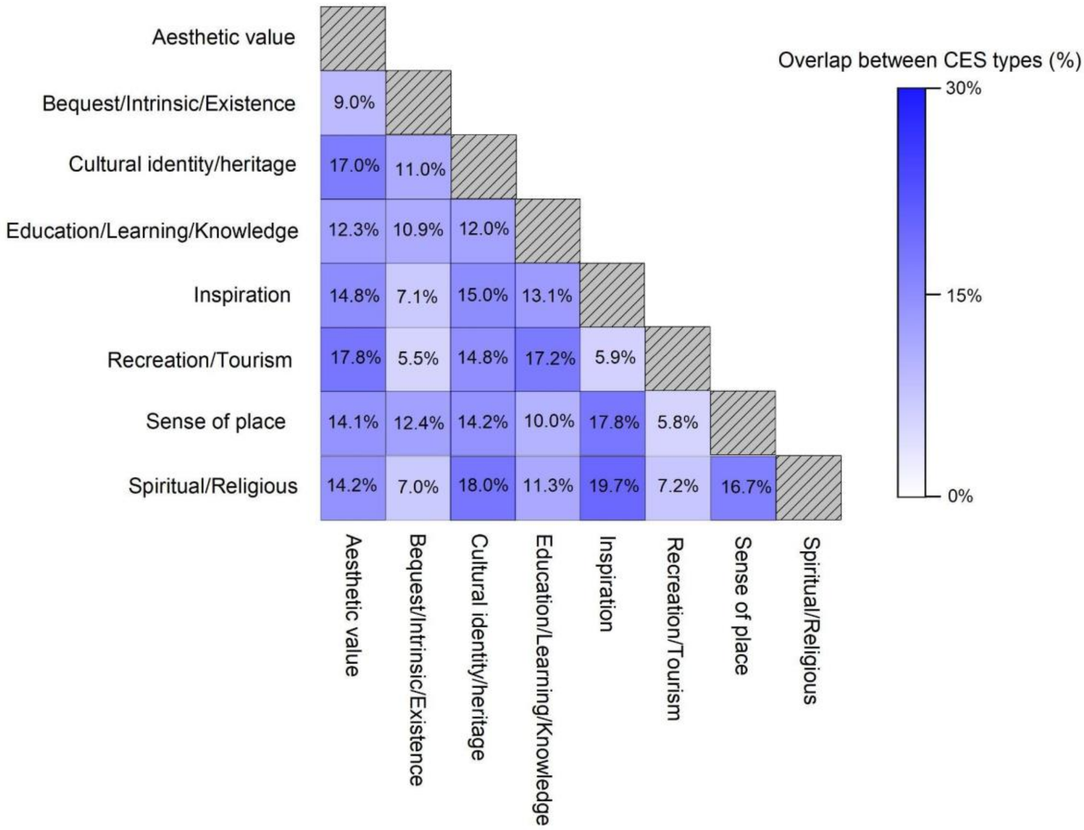


Figure 3: The associations between pairs of CES, expressed as the percentage of times that a pair of CES co-occurred within the total number of reports of those CES types.

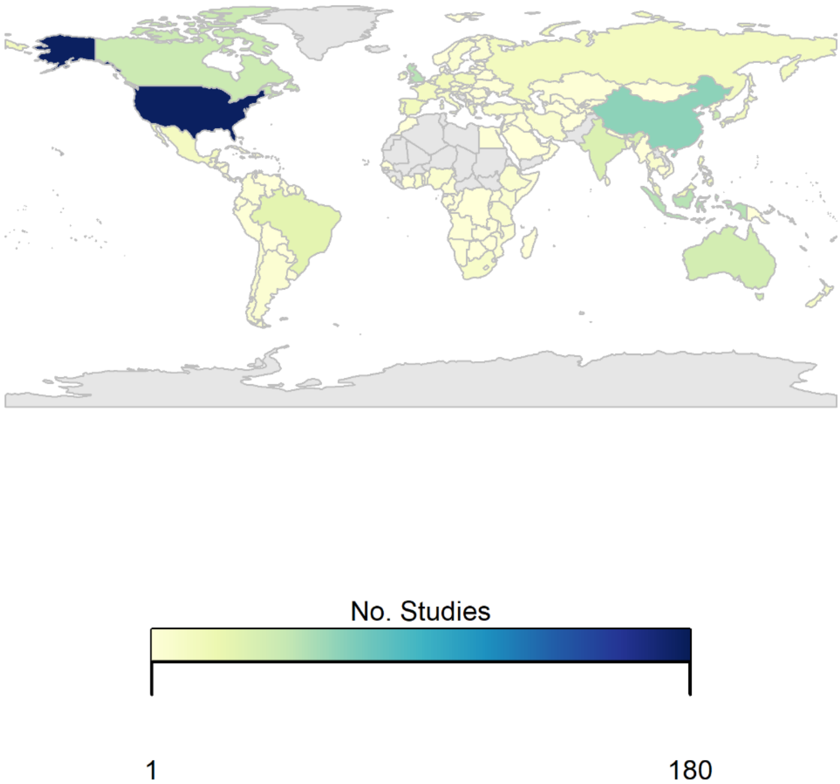


Figure 4: The numbers of studies that reported at least one type of CES associated with wetlands in each country, illustrating relative global study effort. Grey = no data.

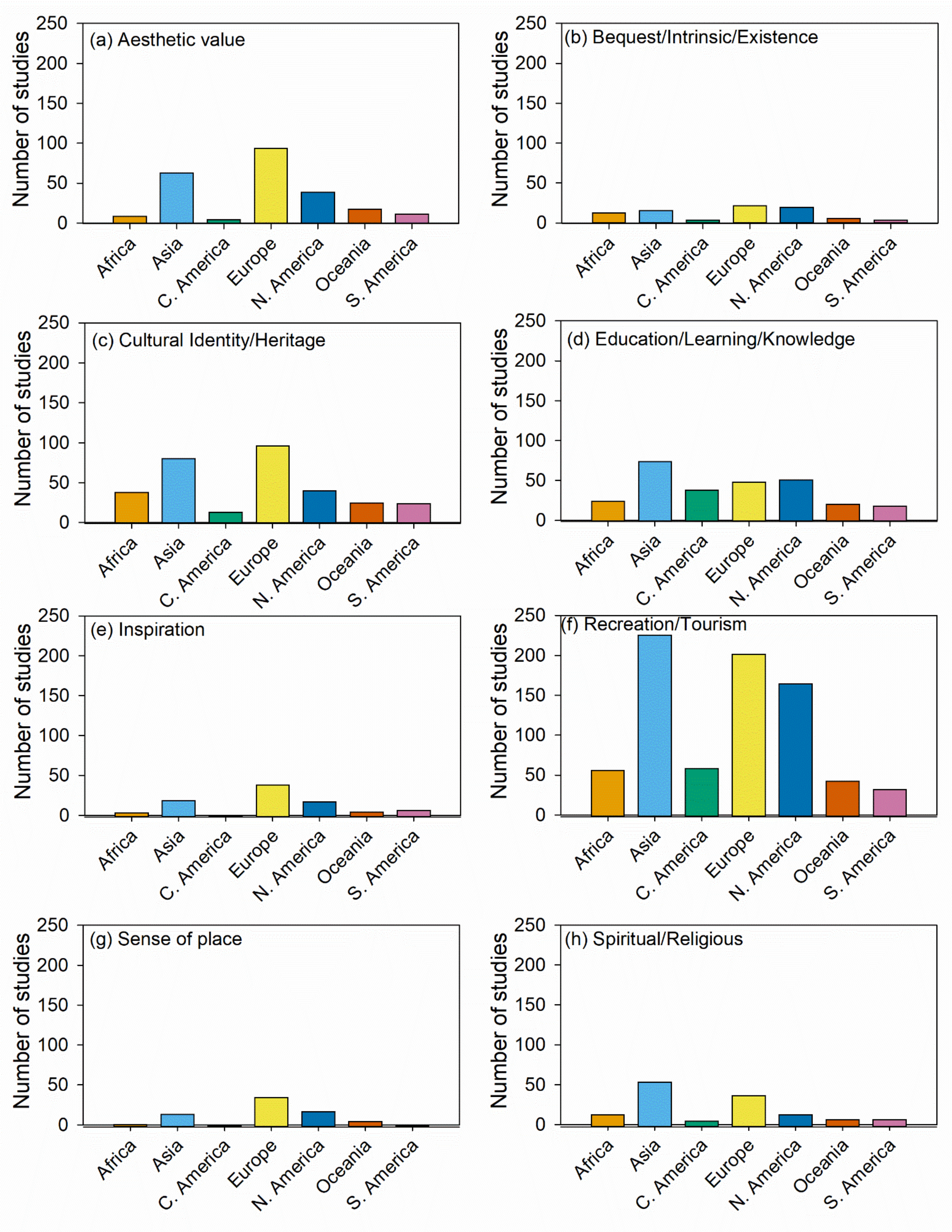


Figure 5: The numbers of studies that reported each type of CES associated with wetlands on each continent, illustrating relative global study effort.

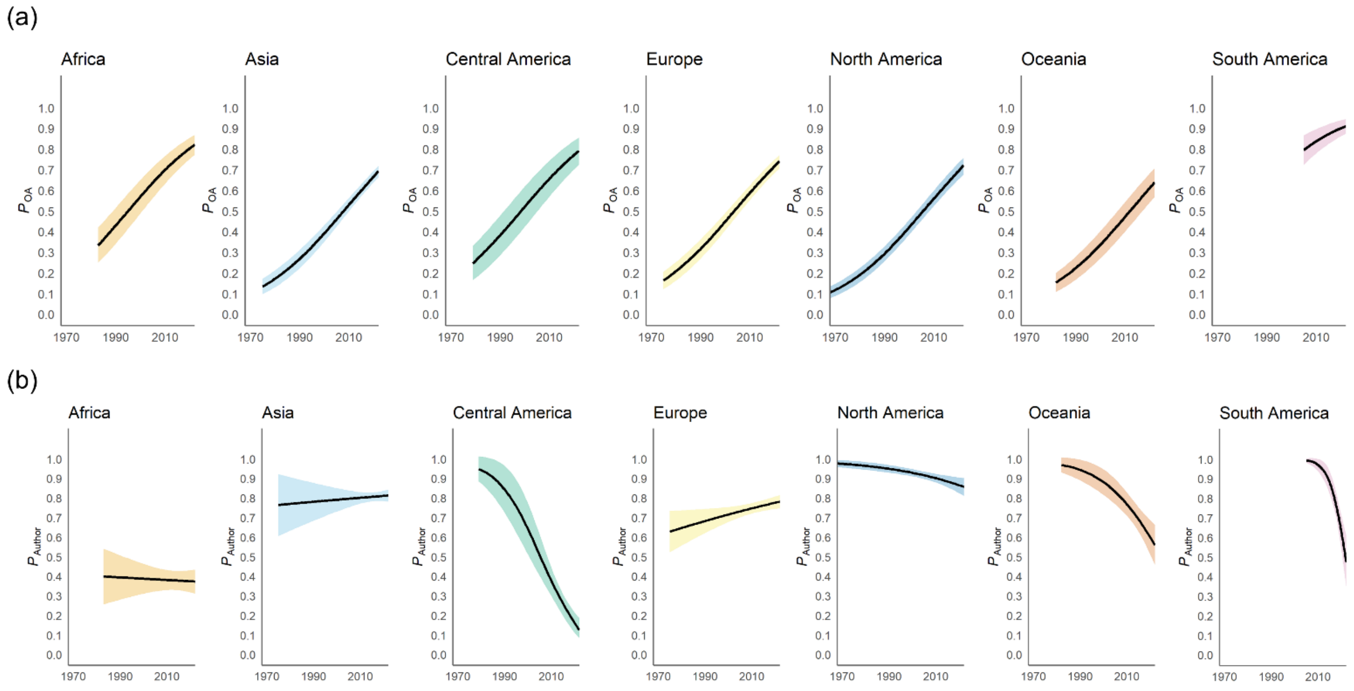


Figure 6: The temporal trends in the mean (± 95% CI) probability that a published wetland CES paper would (a) be available open access (P_{OA}), and (b) have had at least one author affiliated with the country where the study was conducted (P_{Author}), for studies conducted in each continent.

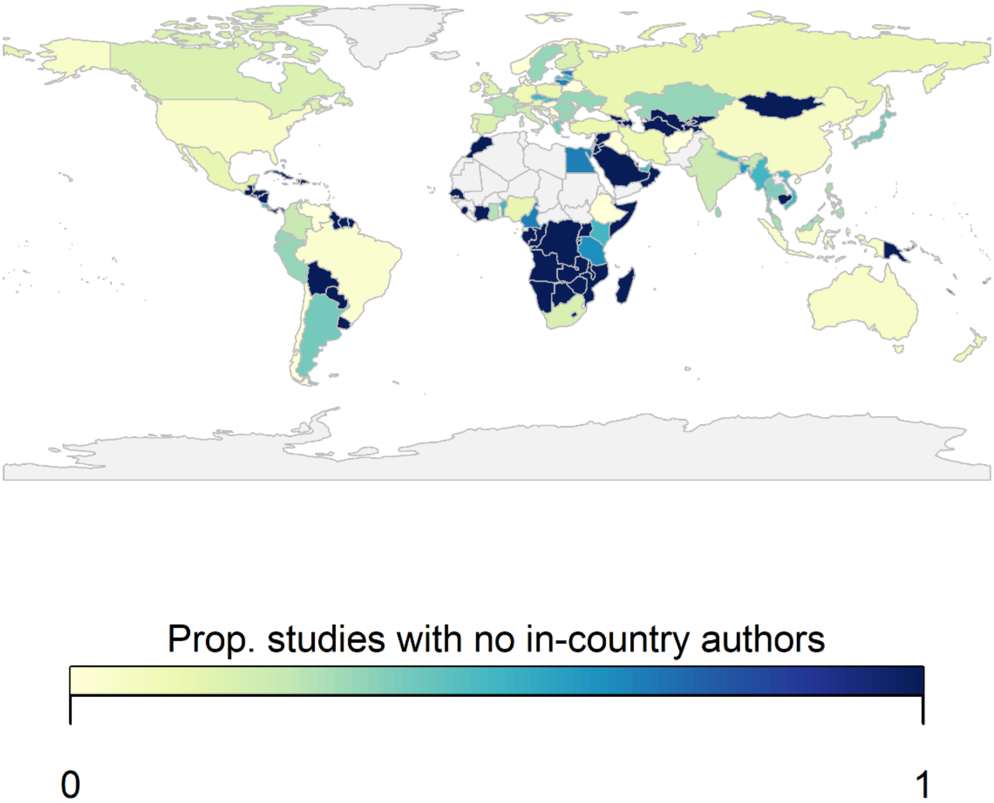


Figure 7: The proportions of studies conducted in each country that featured no authors from that country. Grey = no data.

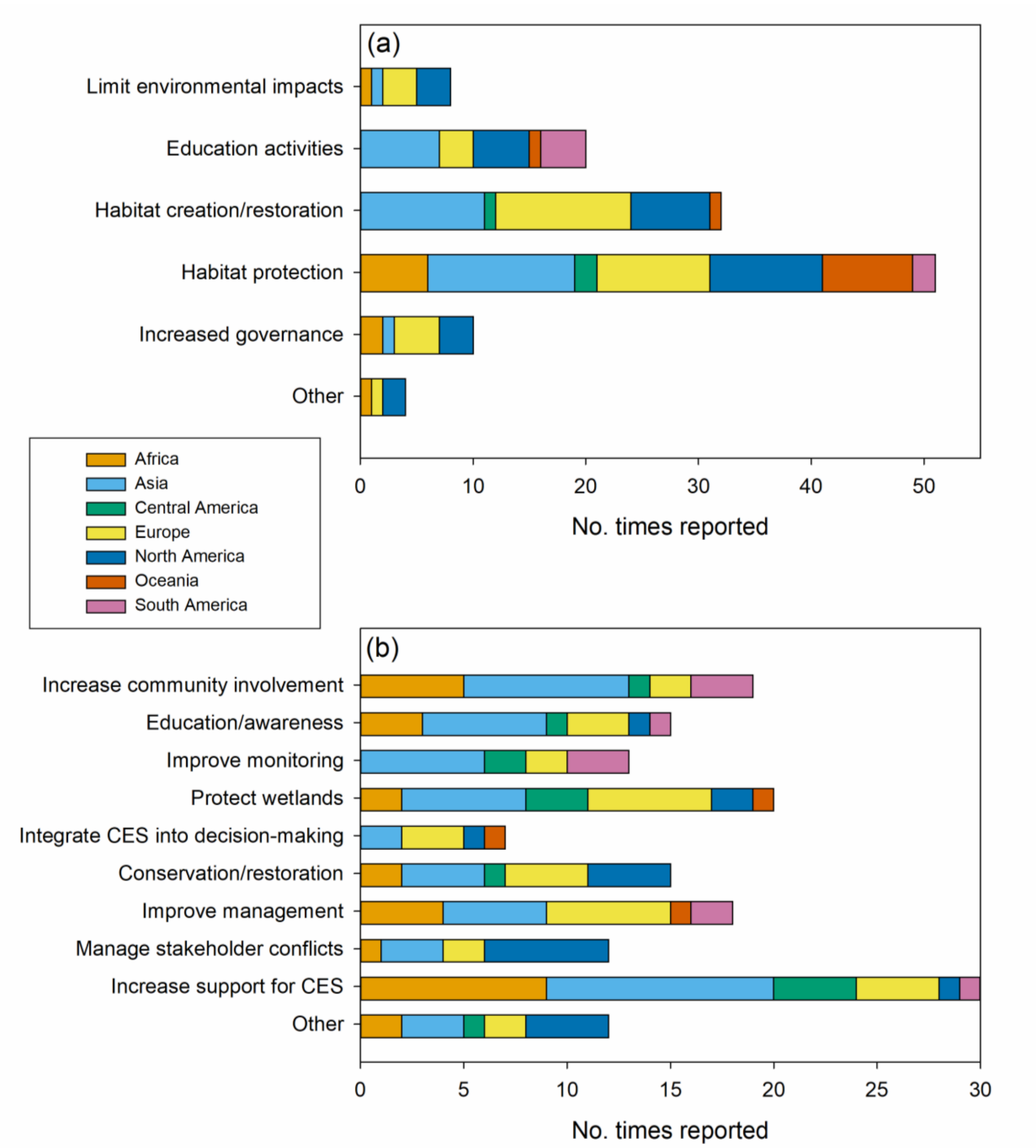
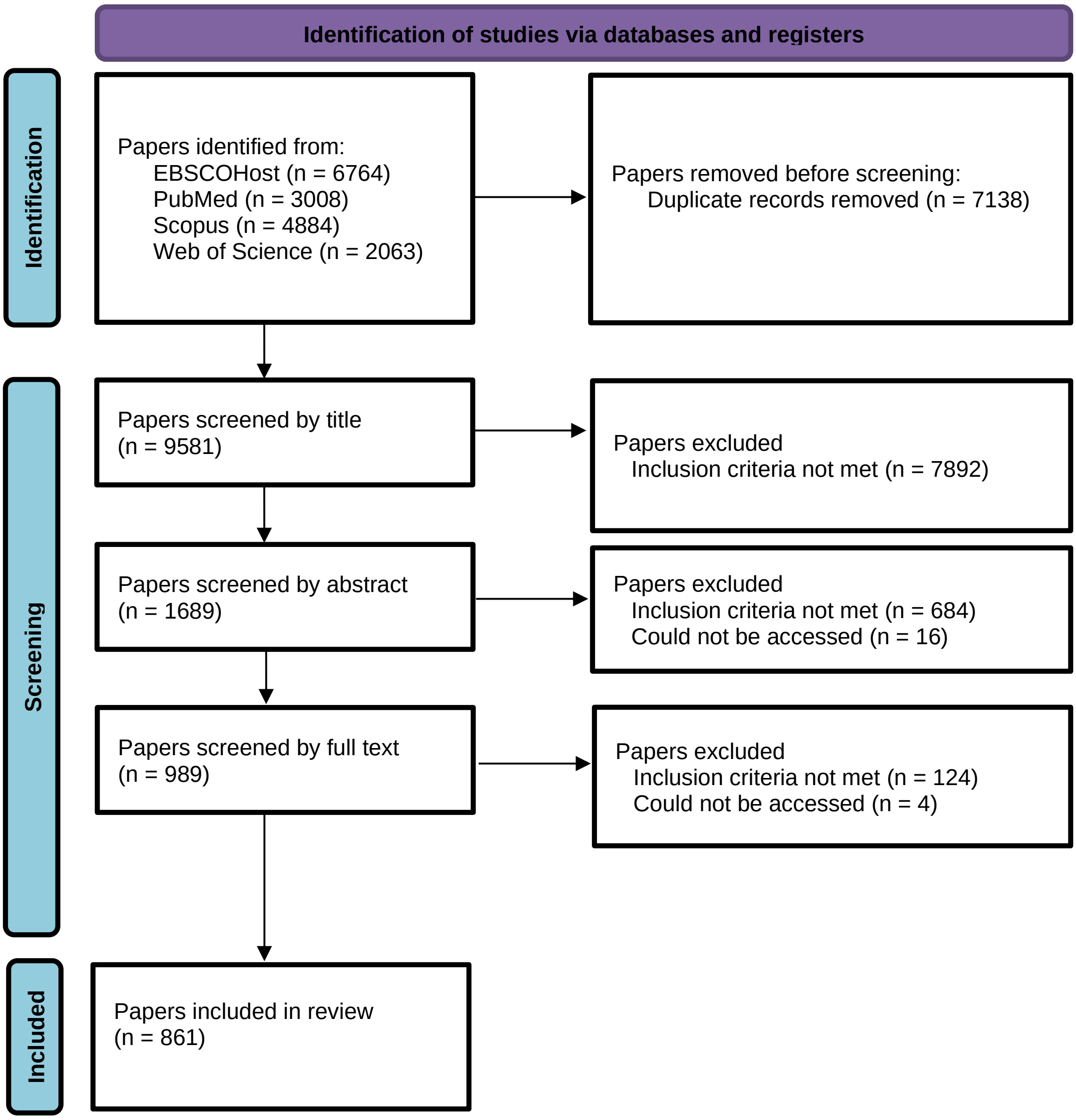


Figure 8: The numbers of studies for each continent that reported (a) conservation or restoration benefits associated with the provision of CES, and (b) applied recommendations.

Supplementary information

Supplementary information 1

The PRISMA 2020 flow diagram (Page et al., 2021) for our systematic reviews of the cultural ecosystem services provided by wetlands.



Supplementary information 2

The PRISMA checklist for our systematic review (Page *et al*. 2021).

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	*Paper title*
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	*See below*
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	*Section 1*
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	*Section 1*
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	*Section 2.1.2*
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	*Section 2.1.1*
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	*Section 2.1.1*
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	*Section 2.1.2*
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	*Section 2.1.3*
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	*Section 2.1.3*
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	*Section 2.1.3*
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	*Section 2.1.3*

Section and Topic	Item #	Checklist item	Location where item is reported
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	*Section 2.1.3*
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	*Section 2.1.2*
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	*Section 2.1.3*
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	*Section 2.1.3*
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	*Section 2.2*
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	*Section 2.2*
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	*n/a*
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	*n/a*
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	*n/a*
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	*Section 3.1; PRISMA Flow Diagram*
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	*Section 2.1.1; Section 4*
Study characteristics	17	Cite each included study and present its characteristics.	*Data on figshare*
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	*n/a*
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	*Table 3; Data on figshare*
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	*Section 4*
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	*Section 3.2*

Section and Topic	Item #	Checklist item	Location where item is reported
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	*n/a*
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	*n/a*
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	*Sections 2.1.1 & 2.1.2*
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	*n/a*
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	*Section 4*
	23b	Discuss any limitations of the evidence included in the review.	*Section 4*
	23c	Discuss any limitations of the review processes used.	*Section 4*
	23d	Discuss implications of the results for practice, policy, and future research.	*Section 4*
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	*n/a*
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	*Section 2.1*
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	*n/a*
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	*Section: Acknowledgements*
Competing interests	26	Declare any competing interests of review authors.	*Section: Declaration of Competing Interest*
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	*Data on figshare*

PRISMA 2020 for Abstracts Checklist

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	*Yes*
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	*Yes*
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	*Yes*
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	*In main text*
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	*In main text*
Synthesis of results	6	Specify the methods used to present and synthesise results.	*Yes*
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	*Yes*
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	*Yes*
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	*In main text*
Interpretation	10	Provide a general interpretation of the results and important implications.	*Yes*
OTHER			
Funding	11	Specify the primary source of funding for the review.	*n/a*
Registration	12	Provide the register name and registration number.	*n/a*

Supplementary information 3

The frequency of relevant papers identified by our review written in each language.

Language	No. Papers	%
Arabic	1	0.1
Chinese	20	2.3
English	723	84.0
Estonian	1	0.1
French	13	1.5
German	6	0.7
Indonesian	2	0.2
Japanese	4	0.5
Korean	36	4.2
Persian	1	0.1
Polish	6	0.7
Portuguese	18	2.1
Russian	7	0.8
Slovenian	1	0.1
Spanish	20	2.3
Swedish	1	0.1
Ukrainian	1	0.1

Supplementary information 4

A summary of the other types of ecosystem services that were also reported in the relevant CES studies, based on those listed by the Millennium Ecosystem Assessment (2005) and CICES v5.1 (Haines-Young and Potschin, 2018).

Ecosystem service type	Service	No. times reported
Provisioning	Energy	30
	Fertiliser	1
	Food	87
	Fresh water	131
	Materials	16
	Medicines	7
Regulation/Maintenance	Carbon storage	2
	Climate regulation	2
	Flood control/Storm protection	54
	Pollution attenuation	10
	Saline flushing	1
	Sediment regulation	3
Supporting	Nutrient cycling	3
	Soil formation	8