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Perspective

Co-benefits reveal the true value of blue ecosystems

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SUMMARY

Blue carbon ecosystems provide a nature-based solution to climate change due to high rates of carbon sequestration. Green finance mechanisms are crucial tools to enable the conservation and restoration of these ecosystems. Only considering carbon provides an incomplete argument for investment, and the case for blue carbon ecosystems can be greatly improved by including multiple co-benefits (e.g., pollutant breakdown). A rapid evidence assessment of the monetary value of blue carbon ecosystems' co-benefits was undertaken. The inclusion of co-benefits resulted in the monetary value of saltmarsh increasing by an order of magnitude, the value of seagrass increasing 50 times, and the value of oyster beds and kelp increasing by more than two orders of magnitude. The inclusion of co-benefits significantly increases the overall value and has significant potential to influence financing of blue carbon ecosystems. The findings highlight key data gaps and six key recommendations for future research.

INTRODUCTION

There is currently a global interest in developing carbon projects to contribute to climate change mitigation and for countries and companies to achieve their net zero emissions. For instance, the UK is legally committed to reaching net zero emissions of greenhouse gases (GHGs) by 2050, with an interim commitment to a 78% reduction from 1990 levels by 2035.[1] The protection and restoration of coastal ecosystems that sequester carbon (termed "blue carbon ecosystems") has been highlighted as a key natural climate solution.[2] Blue carbon ecosystems have attracted substantial interest because of their high rates of carbon sequestration and storage. However, these habitats have experienced extensive historical loss and continue to be threatened.[3] Green finance is proposed as a crucial mechanism to enable the conservation and restoration of these habitats and thus maximize their potential benefits. Although there is no agreed definition for "blue finance," it can be considered as a subset of green finance and refers to financial contributions from public, private, and non-profit sectors[4] aimed at achieving environmental benefits and supporting sustainable development in marine and freshwater ecosystems.[5] Blue finance mechanisms include a variety of instruments, including blue bonds, investment funds, credits, and payments for ecosystem services (ESs).[6] Blue finance enables conservation and restoration by funding direct interventions, such as project development, land purchase, and planting, and indirect interventions, such as reducing stressors of blue ecosystems.[7,8] Further, there is a growing recognition of the necessity to integrate the climate and biodiversity policy agendas at global and national scales.[9] The conservation and restoration of blue carbon ecosystems has the potential to address both these agendas. For instance, investors might be willing to make a greater investment for multiple benefits.[10]

Despite interest from the private and public sectors, thousands of scientific studies on blue carbon ecosystems, and the continued loss of these ecosystems worldwide, few blue carbon projects are actively receiving blue finance.[11] Blue finance remains nascent, though it is anticipated to become mainstream once specific constraints are overcome.[3] Constraints include issues around land tenure, uncertainty in carbon accounting and permanence, poor or nascent understanding of how to incorporate biodiversity values within blue finance mechanisms, poor understanding or negligible definition of different beneficiaries, uncertainty regarding green investment routes, and complex, unsupportive, or non-existent regulatory frameworks.[1,3,12,13] An additional core constraint is poor project cost-benefit ratios (e.g., expensive, high transaction costs, and minimal returns).[1] To address this constraint, there is increasing interest in assessing the wider benefits that these blue carbon ecosystems provide. In addition to their carbon sequestration and storage value, blue ecosystems provide important ESs (known as "co-benefits"), such as coastal flood risk management, biodiversity, and tourism, among others.[14,15] Some studies have focused ES valuation on specific blue ecosystems (e.g., kelp[16] and saltmarsh[17]) or for specific ESs (e.g., water quality regulation and carbon sequestration[18] and flood risk reduction[19]). There has been much debate on how to maximize co-benefits for carbon storage,[9] and the value of co-benefits is proposed to be much greater than the value of carbon sequestration, so monetization of co-benefits has the potential to improve the viability of

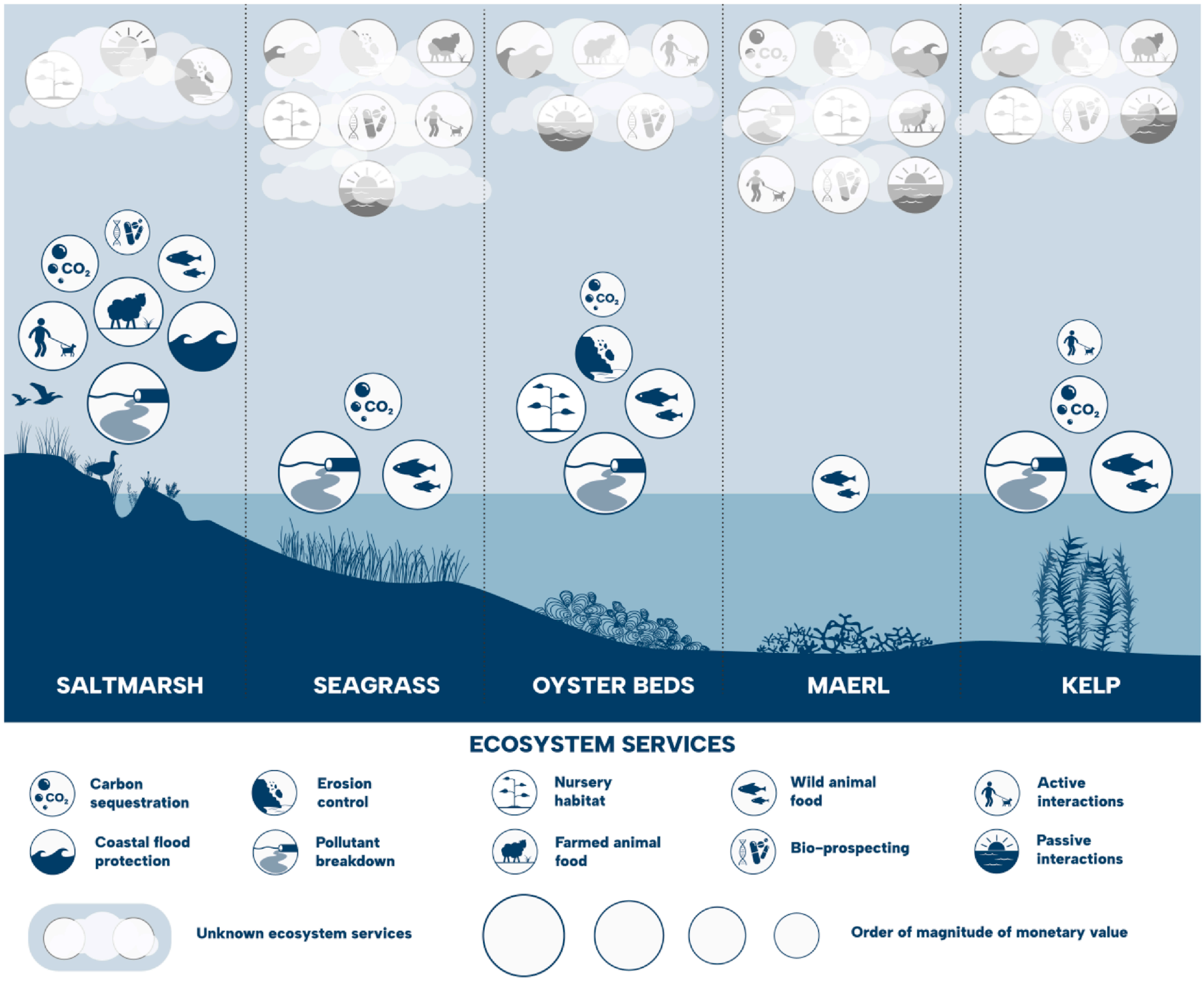

Figure 1. Summary of available ES monetary values and evidence gaps for blue ecosystems

projects.[1] Thus, there is an urgent need to improve our valuation and accounting of blue carbon ecosystems' co-benefits. This study provides the first comprehensive review of ES values for an array of blue ecosystems (Figure 1).

This study aims to review and value the co-benefits provided by blue carbon ecosystems, using the UK as an exemplar, and then apply these to a case study. The co-benefits included in this study are based on available values for ESs and thus might not represent all ESs provided by a blue ecosystem. The discussion section reflects on high-value co-benefits, value gaps, issues with value transfer and valuation approaches, the importance of assessing the condition of the ecosystem, and stacking or bundling co-benefits and makes recommendations for areas of future research.

CO-BENEFITS VALUATION REVIEW

The full methodology for this study is detailed in supplemental methods. Looking at UK-based sources, saltmarsh had the highest number of monetary values for the largest range of ESs (Table 1; see source data in supplemental information summary table). Seagrass had the second-highest number of values, but these were clumped across four ES, leaving 15 ES without values available, which is the highest number of all the ecosystems. Oyster beds, maerl, and kelp also lacked monetary values for many ES and relied more heavily on non-UK sources of information.

Depending on the valuation method, ES values were obtained in two general formats: GBP (British Pound Sterling) per person (or household) (per year) or GBP per hectare (per year). GBP per-person (or household) values (see supplemental information S3): there are 33 UK values from eight sources covering five co-benefits, plus values for all ESs in aggregate, all provisioning services in aggregate, and "unspecified interactions." There are also 12 non-UK values in GBP per household format from one source. Transferring these GBP per-person (or household) values to case study sites is complex, as the values have been

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Table 1. Co-benefit monetary values available from UK and non-UK sources for blue carbon ecosystems (non-UK values in parentheses)

#	Ecosystem service	Saltmarsh	Seagrass	Oyster beds	Kelp	Maerl	Values
1	Carbon sequestration	15	6	5	1	–	27
2	Coastal flood protection	19	–	(4)	–	–	19 (4)
3	Erosion control	–	–	(1)	–	–	(1)
4	Pollutant breakdown	10	10	10	2	–	32
5	Nursery habitat	5	–	(5)	–	–	5 (5)
6	Farmed animal food	1	–	–	–	–	1
7	Farmed plant food[a]	3	–	–	–	–	3
8	Wild animal food	1	1 (3)	(7)	(3)	1 (1)	3 (14)
9	Wild plant food	–	–	–	–	–	0
10	Materials	–	–	–	–	–	0
11	Bioprospecting	1	–	–	–	–	1
12	Passive interactions	–	–	–	–	–	0
13	Active interactions	1	2	1	3	–	7
14	Aesthetic experiences	2	–	–	–	–	2
15	Education or research	2	–	–	–	–	2
UK (non-UK) values		60 (0)	19 (3)	16 (17)	6 (3)	1 (1)	102 (24)

[a]Farmed plant food is a net loss from saltmarsh restoration.

derived based on specific scenario attributes and socio-demographic characteristics of study sites. On the same basis, it is also challenging to compare these values. However, these GBP per person (or household) do provide values for some ESs that are not covered by the UK-based per hectare values, highlighting that these ESs can be valued in monetary terms (i.e., "nursery habitat," "aesthetic experiences," and "education" for saltmarsh and "active interactions" for seagrass and oyster beds). These values can be useful to understand the distribution of benefits (to human well being) across all relevant actors, to avoid "losers" or to know how much to compensate them (e.g., such as ES offsets). They may also contribute toward the development of new finance mechanisms or payment schemes that require an individual payment (e.g., entrance fee rate for protected blue carbon ecosystems). Finally, these values are useful to assess the feasibility of goods being considered for a new market and policy scenarios being considered for different locations.[20]

GBP per hectare per year values

Table 2 provides the descriptive statistics for the GBP per hectare per year values for blue carbon ecosystems. There are 86 UK values from 15 sources covering eight ESs. There are also 12 non-UK-based per hectare values from six sources covering three ESs. These values are more comprehensive than the per-person or household values, plus they are more transferable to other sites as they are linked to ecosystem size, not specific scenarios of socio-demographics. Note that Table 2 evidences some variation in units of valuation, particularly GBP per hectare and GBP per hectare per year. Values in GBP per hectare (non-annual) covered varied periods of several years and, due to the valuation method and policy solution employed, cannot be converted into a per year value.

The blue carbon ecosystem values were generated from eight different valuation methods (Table 3). There is a clear trend of using mainly one method for estimating the monetary value of each ES.

The Solent case study: Value transfer

To understand the potential influence of these co-benefit values, we undertook a value transfer. The Solent forms the largest estuarine system of the south coast of the UK. It includes key harbors such as Portsmouth and the Isle of Wight. Currently, 1.5 million people live in the cities of Portsmouth and Southampton and surrounding areas. The Rivers Trust map of the Environment Agency's Saltmarsh Extent & Zonation shows a saltmarsh extent of 1,319 and 3,838 ha of potential saltmarsh restoration[21] (see maps in Section S4). The Solent has 698 ha of good-to-moderate condition seagrass,[21] and the Rivers Trust map reports 6,628 ha of potential seagrass restoration. Contrastingly, there are 2,839 ha of native oyster beds (*Ostrea edulis*) in bad condition,[21] but the 2022 restoration potential map proposes 1,764 ha for oyster restoration. Potts et al.[22] report 121 ha of kelp and seaweed. Finally, there is no maerl present in the Solent. The Solent has been the focus of several important nature-based solution restoration initiatives (e.g., the Solent Seascape project https://solentseascape.com/), which aim to find ways to create and restore the condition of nationally important blue ecosystems.[23,24] The Partnership for South Hampshire manages a list of nutrient mitigation schemes in the Solent, with nineteen sites listed as of April 2025 (https://www.push.gov.uk/work/mitigation-schemes-available-to-developers/).

For all ecosystems, it was evident that co-benefit values are substantially higher than carbon values alone (Table 4). The "pollutant breakdown" value had a substantial effect on the value of each ecosystem. This ES also had the highest standard

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Table 2. ES values for blue carbon ecosystems in GBP per hectare

			Saltmarsh				Seagrass				Kelp				Oyster beds				Maerl	
Ecosystem service	Value origin	Units	Mi	Ma	Me	μ	Mi	Ma	Me	M	Mi	Ma	Me	μ	Mi	Ma	Me	μ	Me	μ
Carbon sequestration	UK	GBP/ha/yr	52	1,132	219	315	34	145	79	79	N/A	N/A	225	225	−46	72	35	25	N/A	N/A
Coastal flood protection	UK	GBP/ha/yr	384	4,176	1,103	1,692	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		GBP/ha	98,500	11,820,000	591,000	3,526,000	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Erosion control	non-UK	GBP/ha/yr	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	742	742	N/A	N/A
Pollutant breakdown	UK	GBP/ha/yr	3,245	133,000	22,980	54,190	−14,687	64,328	24,662	26,265	88,294	100,624	94,459	94,459	17	214,000	14,990	41,714	N/A	N/A
Nursery habitat	non-UK	GBP/ha/yr	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,555	3,555	N/A	N/A
Farmed animal food	UK	GBP/ha	N/A	N/A	2,955	2,955	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wild animal food	UK	GBP/ha/yr	N/A	N/A	277	277	N/A	N/A	3,979	3,979	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	237	237
	non-UK		N/A	N/A	N/A	N/A	42	2,107	384	844	16,839	58,933	31,828	35,867	759	14,722	1,466	5,649	493	493
Farmed plant food	UK	GBP/ha/yr	−251	−23	−112	−129	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bioprospecting	UK	GBP/ha/yr	N/A	N/A	27	27	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Active interactions	UK	GBP/ha/yr	N/A	N/A	971	971	N/A	N/A	N/A	N/A	N/A	N/A	49	49	N/A	N/A	N/A	N/A	N/A	N/A
Unspecified interactions	UK	GBP/ha/yr	N/A	N/A	1,474	1,474	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
All categories	UK	GBP/ha	30	25,377	33	5,102	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mix of ESs	UK	GBP/ha/yr	N/A	N/A	240	240	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		GBP/ha	34	37	36	36	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

k, thousand; Mi, minimum; Ma, maximum; Me, median; μ, average; negative values indicate a net loss of the service/nutrient from the habitat; N/A, columns where no data are available; unspecified interactions, unclear interactions, either passive or active or both; mix of ESs, an array of aggregated but not comprehensive set of ESs; all categories, covers provisioning, regulating, and cultural ESs.

Table 3. Type and number of valuation methods to determine each of the ES values (£GBP/ha only)

Ecosystem service	MAC	RC	MP	CBA	OC	AC	DC	CE	No. of methods
Carbon sequestration	25	–	–	–	–	–	–	–	1
Coastal flood protection	–	–	5	–	2	1	1	–	4
Erosion control	–	–	–	–	–	1	–	–	1
Pollutant breakdown	–	32	–	–	–	–	–	–	1
Nursery habitat	–	–	1	–	–	–	–	–	1
Farmed animal food	–	–	1	–	–	–	–	–	1
Wild animal food	–	–	13	–	–	–	–	–	1
Farmed plant food	–	–	2	1	–	–	–	–	2
Bioprospecting	–	–		1	–	–	–	–	1
Active interactions	–	–	3	–	–	–	–	–	1
Unspecified interactions	–	–	1	–	–	–	–	–	1
All categories	–	–	–	1	–	–	–	4	2
Mix of ESs	–	–	–	1	–	–	–	2	2
Total values	25	32	26	4	2	2	1	6	–

AC, avoided cost; CE, choice experiment; CBA, cost-benefit analysis; DC, damage cost; MAC, marginal abatement cost; MP, market price; OC, opportunity cost; RC, replacement cost.

deviation, which could potentially indicate an issue with the application or basis of the replacement cost method, which is generally used to value pollutant breakdown.

DISCUSSION AND RECOMMENDATIONS

Context-specific values: Condition of blue carbon ecosystems

Although most sources explored how ES values were affected by different attributes of beneficiaries, users, and payment methods, among others, few explored how the condition of blue ecosystems affected the values. Provision of ESs is dependent upon the condition of the ecosystem, with a poorer condition of habitat yielding fewer ESs.[21] The condition of blue ecosystems can be affected by diverse factors, such as hydrology, extreme weather, stage of growth, and anthropogenic activities (e.g., restoration and land use change[25]). Several sources make implicit assumptions regarding the value in different blue ecosystems. For instance, one study[26] presents attributes in a choice experiment, such as a 10% and 20% increase in water quality, but does not refer to specific habitat conditions. Other sources make a more direct attempt to value habitat condition. For instance, one study[27] explored different ranges of CO_2 sequestration by saltmarsh, and another study[19] assessed willingness to pay for converting grazed saltmarsh into low-intensity or no grazing. However, only two studies[18,21] estimated ES values for blue ecosystem creation or restoration to “good” and “high ecological status” in the UK. One non-UK study[28] estimated harvest values for “pristine” and “degraded” oyster beds. Omitting ecosystem condition is likely to increase the uncertainty in carbon estimates, but also of co-benefits. Other context-specific characteristics that might influence values but are not accounted for include vegetation species and geographic location attributes.[29–31]

Recommendation

Studies are needed to advance our understanding of how the provision of ESs from blue carbon ecosystems changes (positively or negatively) under different conditions or states, either naturally or anthropogenically driven.

Additional value of co-benefits

The results demonstrate that the inclusion of co-benefits significantly increases the overall monetary value of blue carbon ecosystems. In the Solent example, the value of saltmarsh increased by an order of magnitude when co-benefits were included. In the case of seagrass, the value is increased 50 times, and for oyster beds and kelp, the value is increased by more than two orders of magnitude. Still, all co-benefit values are an underestimate, as

Table 4. Median ES values in GBP1,000/year (2023) for current extent and potential restoration of blue ecosystems at the Solent

Ecosystem	Saltmarsh		Seagrass		Oyster beds		Kelp
Area (ha)	Current (1,319)	Potential (3,838)	Current (563)	Potential (6,628)	Current (2,839)	Potential (1,764)	Current (121)
Carbon value	289	841	44	524	99	62	27
Co-benefits value	33,299	96,894	16,125	189,833	58,918	36,608	15,287
Carbon + co-benefits value	33,588	97,735	16,169	190,356	59,017	36,670	15,314
Co-benefits value without pollutant breakdown	2,989	8,697	2,240	26,373	16,361	10,166	3,857
Carbon + co-benefits value without pollutant breakdown	3,278	9,537	2,285	26,896	16,461	10,228	3,884

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although the pollutant breakdown value has been removed due to quality concerns, this service is still expected to have a substantial value.[32,33] Finally, only 16%–36% of ESs were valued for blue carbon ecosystems. If a more holistic ES valuation was possible, the co-benefit value would therefore be expected to substantially increase, as there are substantial value gaps.

Recommendation

To ascertain the true value of blue carbon ecosystems, beyond carbon sequestration, the multiple benefits derived from blue carbon ecosystems need to be quantified and recognized as standard in blue carbon ecosystem projects.

Gaps in co-benefit values

Of the ESs provided by blue ecosystems,[15,16,34–40] almost half did not have any monetary values available. This gap is focused on wild plant food, materials, and a range of cultural services. This gap becomes even larger when we consider only "transferable" monetary values, with gaps across most ecosystems. The lack of monetary values for cultural services and the challenges to generate these values have been well documented elsewhere.[41] It is important to highlight that this does not signal that these ESs are of lower monetary value, but rather that these values have not or cannot be derived. In future co-benefit research, it is recommended that these ESs be assessed in more detail, and if monetary values still cannot be calculated, that they be included in decision-making through other means, e.g., using qualitative assessments.[42]

Saltmarsh ecosystems have the highest number of studies on ESs and monetary values of the blue carbon ecosystems studied. But it is important to note that not all of these were in a format that allows transferability. The key gaps for saltmarsh are erosion and nursery habitat. Oyster beds had the second-highest number of transferable ES values but only five, and the key gaps were flood protection, farmed animal food, bioprospecting, and interactions.

There is ample research and a good evidence base for the ESs provided by kelp,[43–45] and even more if aquaculture is considered. However, these were often focused on a limited number of ESs, and the key gaps were coastal flood protection, erosion control, nursery habitat, and bioprospecting.

There is extensive research and a well-established evidence base for the ESs provided by seagrass.[46] However, the number of seagrass ESs that had monetary values associated with them is low. This lack of monetary values is also documented elsewhere.[47,48] For example, a systematic literature review found that only 1.8% of publications on ESs of seagrass had economic values.[49] Finally, some studies mention ESs from maerl,[50–52] but only one study had monetary values. This can partly be explained by this ecosystem's very patchy distribution and often unexplored areas (https://www.marlin.ac.uk/species/detail/1284).

Recommendation

Although there are many studies on ESs from blue carbon ecosystems, research studies that fill the knowledge gaps in transferable ES values for each of the specific blue carbon ecosystems need to be prioritized.

Transfer of values

Previous studies have been liberal in transferring monetary valuations, but this is not always appropriate, as regions vary substantially depending on their species type, geographic, and socio-demographic situation. This is a challenge, as it is clearly not feasible, in terms of time or resources, to undertake a new valuation for each co-benefit at each site. This constraint in value transfer means that the dataset of robust values available is small. Nevertheless, value transfers are often the only option, and whenever they are undertaken, the potential for error should be made clearly transparent and minimized as far as possible following clear guidelines. In this review, we have considered the potential to transfer the values for each ecosystem type.

This issue has been raised particularly regarding seagrasses. For example,[46] "the transfer of estimates of economic value of services from one seagrass ecosystem to another system, genera, and bioregion must be used with caution, as the lack of such ecological or economic correspondence can lead to highly unreliable valuation estimates. Existing studies commonly focus on or include only a few services and often seagrasses in general or a specific species, not considering genera or several species. Unreliable estimates imply that the public, managers, and policymakers may be misled or confused, which may affect their decision-making processes. The considerable variation in seagrass ESs across genera and bioregions demands that regional and species-specific valuation studies assess the benefits of seagrass systems and the multitude of species they contain."

It is notable that there are studies that value seagrass ESs but that cannot be applied here due to focusing on species absent in the UK.[53,54] These studies do, however, provide evidence of monetary values for seagrass, and as such, similar species-specific studies should be undertaken in the UK.

Recommendation

Primary valuation of ESs in blue carbon ecosystems should be prioritized where feasible (to ensure data robustness and applicability), but if value transfers are employed, the potential for error should be made clearly transparent and minimized as far as possible following clear guidelines.

Robust valuation methods

In the case of pollutant breakdown, replacement costs were used, resulting in very high-value estimates. The validity of these values has been called into question, and new methods of valuation are currently underway, for example, in the UK Research and Innovation-funded Sea the Value project (https://pml.ac.uk/projects/Sea-the-Value/). If these co-benefit values are intended to be used for future green investment purposes, they will need to be developed to the same standard as the carbon values. Currently, for many of the co-benefits the values are highly variable, and a range of valuation methodologies are used to calculate these.

Recommendation

Standardization in the valuation methods and verification of the results will be required for each individual co-benefit to ensure that robust and decision-grade data is used in future schemes.

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Stacking or bundling co-benefits

Our results provide evidence for considering and accounting for as many co-benefits as possible when estimating the value of blue carbon ecosystems. First, it provides evidence of the extensive potential monetary value of these ecosystems. Second, accounting for co-benefit values has the potential to shift financial initiatives to become financially viable when the focus on only one benefit is not viable. Third, if a finance mechanism recognizes other co-benefits, this can allow for a premium to the price that can be obtained for blue carbon. This has already been seen in action. For example, Lou et al.[10] found that carbon credit projects providing the highest co-benefits got a price 30% higher than projects with the lowest co-benefits. Fourth, the premium obtained can incentivize project developers to develop "multiple benefit seascapes"[55] and/or larger restored areas and well-connected habitats.[56] This multi-benefit approach can avoid some issues linked to carbon-only initiatives, which have led to, e.g., monocultures and low biodiversity.

Despite the advantages of accounting for co-benefits in blue carbon initiatives, there is an ongoing debate about how best to do it. Two main approaches are discussed here: "bundling," which refers to packaging all the benefits together as one product, and "stacking," which entails packaging each benefit separately. Stacking is favored, as it may promote new restoration projects,[57] allows the costs of restoration to be borne by several buyers, and can increase revenue for project developers.[58] However, there are trade-offs, as stacking can require high technical capacity and be costly to measure several co-benefits.[59] Stacking risks double counting if co-benefits are accounted for in different standards, i.e., inflated ES provision and unaccounted ES losses due to limited understanding of ecological complexity.[55,60] Stacking could favor a market approach and buyers providing more saleable units and targeted purchases based on, e.g., geographic or ES interests. This approach can also favor sites where the blue carbon value is low but higher for, e.g., coastal protection or pollutant breakdown.

On the other hand, bundling is favored as it is lower cost (e.g., setup transaction costs[61]) and is considered less risky as it can bring better environmental outcomes for an ecosystem area as a whole.[60,62] Bundling could allow for more easily including context-specific benefits, e.g., evidenced in existing carbon projects (e.g., https://registry.verra.org/app/search/VCS/), that might not otherwise be financed. However, bundling can lead to decline of individual ESs, as these are not always positively correlated, e.g., carbon can be prioritized at the expense of biodiversity, leading to ecological imbalances or species decline,[59] and bundling will not increase revenue for project developers.[60]

Recommendation

Further research and pilot studies are needed to understand the (dis-)benefits of stacking and/or bundling ESs from blue ecosystems.

CONCLUSIONS

The co-benefits that can be obtained from blue carbon ecosystems are well documented; however, there are substantial gaps and challenges in their monetary valuation. This research provides a quantification of the monetary value of co-benefits of blue carbon ecosystems. The inclusion of co-benefits results in the monetary value of saltmarsh being increased by an order of magnitude, the value of seagrass being increased 50 times, and the value of oyster beds and kelp being increased by more than two orders of magnitude. Thus, making a clear case for both improving and including these co-benefit values for blue ecosystems. We recommend that research be undertaken to advance our understanding of how different conditions of blue ecosystems influence the provision of ESs and that the multiple benefits from blue ecosystems be quantified with primary or transferable values. Further, we recommend standardization in the valuation methods and verification of the results to ensure robust and decision-grade data is used, either in bundling or stacking of co-benefits. Through the advancement of values and methodology gaps, these findings are also providing a substantial step toward reducing the uncertainty of the value of co-benefits in blue ecosystem schemes.

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AUTHOR CONTRIBUTIONS

Conceptualization, O.R.R. and N.J.B.; methodology, O.R.R. and N.J.B.; validation O.R.R. and N.J.B.; formal analysis, D.K., N.J.B., and O.R.R.; investigation, D.K. and O.R.R.; data curation D.K. and O.R.R.; writing – original draft, O.R.R. and N.J.B.; writing – review & editing, O.R.R. and N.J.B.; visualization, O.R.R.; supervision, O.R.R. and N.J.B.; project administration, O.R.R.; funding acquisition, N.J.B. and O.R.R.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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