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Research article

# Expert views on the governance of marine sedimentary carbon for climate change mitigation

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ABSTRACT

With growing interest in ocean-based climate solutions, attention is increasingly turning to the role of marine sedimentary carbon (SC) as a potential contributor to climate change mitigation. Substantial organic carbon stocks and burial processes operate across continental shelf sediments, yet the governance of this resource remains at an early and conceptually fragmented stage. This study examines the prospects for governing SC as a climate-mitigating natural resource through 20 semi-structured interviews with experts in blue carbon, marine governance, fisheries governance, economics, and policy. The findings reveal significant challenges relating to the definition and conceptual boundaries of the SC system; persistent scientific uncertainties in measuring stocks, flows, and anthropogenic impacts; and tensions concerning valuation, accounting, and the viability of economic instruments. These issues intersect with an already crowded institutional landscape and low public visibility of SC. Interviewees emphasised the need for pragmatic integration of SC considerations into existing governance frameworks rather than the creation of new institutions, supported by monitoring approaches capable of informing decisions under uncertainty. While economic instruments were viewed as limited in the near term, experts highlighted opportunities to align SC governance with broader marine management objectives, including biodiversity protection and transboundary cooperation. The study concludes that advancing SC governance will require improved empirical understanding of human impacts, clearer operational definitions, and enhanced public and stakeholder engagement to build legitimacy around potential interventions. These insights provide an initial foundation for designing governance frameworks for an emerging marine carbon resource with significant, yet uncertain, climate mitigation potential.

## 1. Introduction/background

Inputs of organic carbon from marine (e.g., primary production) and terrestrial sources (including river run-off and coastal vegetation) undergo transport and transformation via various biological processes within the marine water column before deposition on the seabed – a process known as the biological carbon pump (Honjo et al., 2008, 2014; Volk and Hoffert, 1985). A fraction is subsequently buried for centuries to millennia in sediments of the seabed. Globally, seabed sediments are estimated to contain up to ~2300 Gt of organic carbon within the top 1m (Atwood et al., 2020) with an additional 126-350 million tonnes (Mt) per year of particulate organic carbon (POC) added to this stock (Keil, 2017; Tegler et al., 2024). Seabed sediments therefore represent a significant global store of organic carbon and can be considered a carbon sink, thus providing an important potential contribution to mitigating climate change. This natural process of carbon sequestration and storage in the marine environment, henceforth referred to as the *Sedimentary Carbon* (SC) system, is relevant for climate change (CC) mitigation strategies as a potential Nature Based Solution, through both protection of the marine sediment stocks from human activities that might degrade it (emission avoidance) and the potential facilitation and extension of the processes that increase or maintain the stock and accumulation or burial (emission savings).

These considerations reflect wider debates around the role of blue carbon (BC) in climate mitigation. Blue carbon refers to coastal and marine ecosystems that store significant stocks of carbon and are amenable to management (IPCC et al., 2021; 2022). Historically, this has referred to vegetated coastal habitats such as mangrove forests,

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saltmarshes, and seagrass meadows (Nellemann et al., 2009) which are 'actionable' blue carbon habitats (Howard et al., 2023; Lovelock and Duarte, 2019; Luisetti et al., 2023), due primarily to their meeting the criteria as actionable in climate mitigation policy and are currently recognized for their climate mitigation value by the IPCC for inclusion in GHG accounting guidelines. However, discussion on the inclusion of other habitats and systems (known as 'emerging') centres on their assessment on several criteria.

These criteria centre on four main aspects: 1) Scale – the ecosystem captures greenhouse gases to a degree considered significant; 2) Long-term storage – that the carbon be stored for at least decadal timescales, or longer; 3) Anthropogenic influence – that there be a significant human influence on the ecosystem's ability to sequester and store carbon; and 4) Manageable – that the ecosystem be amenable to management interventions to enhance or protect sequestration and storage (Lovelock and Duarte, 2019; Macreadie et al., 2019). These criteria are relatively easily applied to conventional coastal BC (saltmarsh, seagrass, mangrove). But unlike conventional BC ecosystems, which capture atmospheric $CO_2$ through vegetative processes and store it locally within underlying sediments, marine SC consists of carbon in the water column that is subsequently transported and deposited in marine sediments. This distinction reflects a shift from spatially fixed, biologically mediated systems to more diffuse, geophysically driven (as well as biologically mediated) processes. Attempts have been made to explore whether the criteria can be applied to these more diffuse and wholly submerged systems such as macroalgal forests (Pessarrodona et al., 2023) and SC (Avelar et al., 2017; Christianson et al., 2022; Howard et al., 2023) in addition to conventional BC. SC, intertidal ecosystems, and kelp forests are considered "emerging" with the possibility of their inclusion in the blue carbon definition depending on how amenable they are to management interventions (Cifuentes-Jara et al., 2023; Lovelock and Duarte, 2019).

For the SC system specifically, understanding is too limited regarding the extent of the anthropogenic influence on the SC system, and the impact of such actions, for SC to be considered BC. The question is whether such influences could be managed in a way that enables SC to make a significant contribution to climate change mitigation. Another aspect of this is that fixation of $CO_2$ in marine habitats is regarded by some as not acting on long enough timescales or with enough efficiency to directly offset greenhouse gas emissions (Allen et al., 2025; Cullenward et al., 2023; Johannessen and Christian, 2023). Instead, there are strong arguments to suggest that conservation and protection of stocks – alongside the processes that feed them – could help offset *historic* emissions while helping to maintain the functions of the marine ecosystems that act to sequester $CO_2$ (Allen et al., 2025; Gao et al., 2022; Matthews et al., 2022).

It is the widespread perturbation of seabed sediments by human action that represents the major potential anthropogenic influence on SC (Epstein et al., 2025; Graves et al., 2022; Korpinen et al., 2013). Potential actions that could affect seabed sediments include: bottom contact fishing, dredging (for both mineral or aggregate extraction and maintenance or construction e.g., capital projects or shipping lane access), marine energy development, coastal development and construction, and the laying of pipelines and cables. Bottom contact fishing is widely regarded as the main anthropogenic influence in terms of extent (up to 80% of some continental shelf zones are affected by bottom contact fishing every year) (Eigaard et al., 2017; Epstein et al., 2022, 2025; Khedri et al., 2025), with an estimated 55-60% of stored $CO_2$ disturbed into the water column from bottom trawling fisheries making its way into the atmosphere within 9 years (Atwood et al., 2024), although these estimates are highly uncertain. Any further development of SC as a form of blue carbon needs to include these potential disruptions, particularly bottom contact fishing, as these activities will potentially affect the carbon content of the sediments (both addition and subtraction) and therefore form the focus of management interventions.

The rise and use of blue carbon as a concept has aided in the inclusion of marine habitats in nationally determined contributions (NDCs) and the declaration of annual carbon budgets as part of the obligations of each national signatory to the United Nations Convention on Climate Change (UNFCCC) (Martin et al., 2016; UNFCCC, 1992). Under the UNFCCC, each member state must declare their NDC – an annual audit of the total anthropogenic emissions, minus removals by any carbon sinks – in order to monitor action on climate change.

This obligation has spurred enquiry into accounting the carbon stored in the seabed within the Exclusive Economic Zone (EEZ) of the U. K., alongside the wider Northwest European Sea shelf, concluding an estimated 80-110 Mt particulate organic carbon in the upper 0.1 m of English waters and up to 524 Mt in the wider UK EEZ (Burrows et al., 2024; Parker et al., 2022). Additionally, there is an estimated 520–1600 Tmol of carbon stored in the upper 0.1 m of seabed sediments on the Northwest European Shelf (Legge et al., 2020).

A recurrent problem is how to measure and quantify the *flows* of carbon in the offshore marine environment (as contrasted with the *stock* found buried in sediments), which account for the organic carbon while in the states of fixation, transportation, deposition and burial i.e., the various states in which it proceeds before being stored in sediments for the long term (i.e., tens to hundreds of years, if not millennia). In order for SC to be considered blue carbon and a viable method of climate change mitigation, the SC system (the combined stocks and flows of marine organic carbon and the processes that give rise to them e.g., primary production) and the carbon contained therein must be considered a natural resource of a kind i.e., the stored carbon (and associated flow of organic carbon accumulation and burial within the seabed) represents a resource that helps to mitigate climate emissions (Luisetti et al., 2020; Macreadie et al., 2019, 2019, 2019).

SC's flows, however, are challenging to quantify and attribute to a specific origin, which makes it difficult to assign the carbon stock (i.e., the natural resource) to a nation state (or states) when calculating NDCs due to uncertainty as to where the carbon originated (Graves et al., 2022; Macreadie et al., 2019). Luisetti et al. (2020) have argued that these carbon flows are migratory and transboundary (in contrast to the stationary stocks within the seabed), meaning that a degree of the system is shared across national marine borders, rendering SC a common pool resource with attendant repercussions centring on the need for at least a minimum degree of shared international governance and management, which can be supported by natural capital accounting. It has been argued therefore, that there is a need for collaborative international governance frameworks for SC resources across borders (Christianson et al., 2022; Howard et al., 2023; Luisetti et al., 2020). The aim of the research presented in this paper is to explore the hypothetical governance of the SC system as a form of BC and for the purpose of CC mitigation given that there are no existing forms of SC governance.

This paper is structured as follows. In section 2, the interview method and process of thematic analysis are described. In section 3, the interview data are explored in the form of seven themes, with attendant discussion. Section 4 finishes with a conclusion of the study and its findings.

## 2. Methods

### 2.1. Study approach and aims

To understand SC's governance challenges, experts in five areas of expertise relevant and pertinent to the subject of SC governance were invited to take part in the study to discuss foundational and exploratory questions for SC governance. The five areas were 1) blue carbon, 2) fisheries governance, 3) marine governance in general, 4) environmental economics, and 5) policy. Each participant was allocated to one of the areas of expertise by the researcher during the participant selection process, based on their work. To prioritise a depth of understanding, semi-structured interviews were chosen with a qualitative analysis to best understand the in-depth knowledge of the chosen participants and

how such knowledge could relate to the emerging topic of SC governance (Biggs et al., 2021; Clark et al., 2021; Cundill and Fabricius, 2010; de Vos et al., 2019; Newing, 2011). Given the emergent nature of marine sedimentary carbon as a governance issue and the limited availability of quantitative data, this qualitative approach is appropriate for generating empirically grounded insights into expert perspectives. Following Graham et al. (2003) and Hatfield-Dodds et al. (2007), governance here is defined as an *organisational structure which describes the relationships between the relevant actors and the distribution of responsibilities, remits, and decision-making power between those actors, regarding an overarching aim or purpose*. The aims and outcomes of the research therefore were held in relation to this definition, informing both the interview protocol and the findings.

### 2.2. Participant selection and recruitment

Interviewees were selected through purposive sampling (Clark et al., 2021) to ensure relevant expertise across the five areas (blue carbon, marine governance, fisheries governance, economics, and policy). Additional details on the selection characteristics and assessment criteria used to identify suitable experts are provided in Supplementary Material A.

A systematic search for participants was conducted using five approaches, 1) An assessment of the expertise based on authorship of relevant publications, identified from an attendant (unpublished) literature review; 2) A search of members of Blue Carbon organisations, such as *The Scottish Blue Carbon Forum* and *The Blue Carbon Initiative*; 3) A literature search for authors of prominent publications in the listed fields of interest, dated to within the ten years preceding the study (and separate to the literature review mentioned in approach 1); 4) conversations with networks on experts working in the relevant fields in government positions; 5) and – at a later stage-snowball sampling (Parker et al., 2019) was utilised once interviewing had begun. This resulted in the identification of eighty-seven potential candidates for further assessment, with at least ten in each chosen field of expertise.

To determine which of the potential candidates to contact first, each potential was ranked using a systematically devised coding system allocating a numerical value for each of the participant characteristics. A score was allocated subjectively by the lead researcher (with follow-up verification from the research team), following an assessment of the participants' experiences, job roles, any work conducted for government or policy work, publications etc. The thirty highest scoring candidates were placed in a primary grouping, with the next thirty in a secondary group of back-up candidates. Thirty-nine candidates were contacted to request interview, leading to the interviews of twenty experts (51.3% positive response rate), with most drawn from the primary group of candidates. See Table 1 for a list of the participants by their designated number and their main field of expertise.

As stated, the participants were selected using a purposive sampling strategy to capture informed perspectives on the governance of marine SC. As such, the sample reflects a greater proportion of experts in marine governance and BC, consistent with the study's primary focus, while still incorporating insights from adjacent fields such as economics and policy. This approach prioritises depth of domain-specific expertise over disciplinary balance and is not intended to be statistically representative. The sample is very slightly geographically weighted towards Europe, reflecting both the distribution of respondents and the researcher's location. While no explicit exclusions were made, participation was contingent on response. Accordingly, the findings should not be interpreted as globally representative, but rather as reflecting regionally situated expert perspectives.

### 2.3. Interviews

The semi-structured interviews were undertaken in March-May 2021. Interviews were conducted online and one-to-one at a time of the interviewee's choosing. Participants were provided with an information sheet about the study and consent form. Interviews were audio recorded and transcribed, lasting from 30 min to 1 h. Interviewees were pseudonymised as P(participant) followed by the number in order of when they were interviewed e.g., P1, P2 etc. This study was given ethics approval by the University of East Anglia ethics committee. The interview protocol (see Supplementary Material B) was the same for each participant and covered three areas of enquiry reflective of the research aims: policy and utilisation of SC, questions surrounding governance actors, and a third category exploring more general aspects of governance. Interviewees were asked their initial thoughts on the concept of SC as a form of CC mitigation with follow ups as to how it relates to their field of expertise, what policies could be devised for SC, what institutions would be needed and attendant institutional responsibilities, and the issues and challenges that would face a realised SC policy. Data collection proceeded until thematic saturation was reached (20 participants), defined as the point at which no new themes emerged from additional interviews (Guest et al., 2006).

**Table 1**
Interview participants by number,primary field of expertise and position/occupation.

| Participant Number | Field of Expertise | Position/Occupation |
|---|---|---|
| 1 | Economics | Academic (Professor) |
| 2 | Policy | Government Researcher |
| 3 | Policy | Government Policy Advisor |
| 4 | Marine Governance | Academic (Professor) |
| 5 | Blue Carbon | Academic (Professor) |
| 6 | Marine Governance | Academic (Professor) |
| 7 | Blue Carbon | Senior Associate (NGO) |
| 8 | Economics | Policy Director (Think Tank) |
| 9 | Blue Carbon | Academic (Adjunct Professor) |
| 10 | Marine Governance | Academic (Lecturer) |
| 11 | Marine Governance | Academic (Professor) |
| 12 | Economics | Academic (Adjunct Professor) |
| 13 | Blue Carbon | Academic (Professor) |
| 14 | Fisheries Governance | Academic (Professor)/Editor |
| 15 | Policy | Government Policy Advisor |
| 16 | Fisheries Governance | Director - Intergovernmental Organisation |
| 17 | Fisheries Governance | Academic (Professor) |
| 18 | Marine Governance | Principal Advisor (Public Sector) |
| 19 | Blue Carbon | Strategic Lead (NGO) |
| 20 | Marine Governance | Academic (Assistant Professor) |

### 2.4. Analysis

The interviews were transcribed and analysed via a thematic analysis. Nowell et al. describe thematic analysis as "a method for identifying, analyzing, organizing, describing, and reporting themes found within a data set" (Nowell et al., 2017, pp.2). Themes, or "super-ordinate structures", are coherent categories into which textual data are organised following a process of textual coding (Langdridge and Hagger-Johnson, 2013). Themes therefore act to correlate and sort the data where there are similarities, while making clear any discrepancies, leading to a coherent and rigorous interpretation of the data set. Thematic analysis was chosen because it enables the organisation of a large amount of textual data into discreet and informative categories. By creating themes, the data could be understood and interpreted in relation to the research aim. For details of the codes and their descriptions, see Table 2. For a break-down of the themes and which codes informed them, see Table 3.

Coding was conducted by one researcher, so to enhance analytical rigor coding was conducted iteratively with repeated engagement with the data, allowing for refinement of codes and themes over multiple rounds of analysis. Analytical decisions were continuously checked

**Table 2**
The codes of analysis, their descriptions, and examples from the data.

| Code | Description | Example from the data |
|---|---|---|
| Accounting | Points pertaining to carbon accounting | *"In many countries the government requires that cost benefit analysis is conducted not because the cost benefit analysis is going to be used to charge someone, but just because we want to know on net is this a good policy or bad policy. So, in that case, this kind of carbon accounting should be included in those cost benefit analyses with all the uncertainty that goes with it."* (Participant (P)12) |
| Additionality | How/whether SC contributes to carbon storage and CC mitigation in a meaningful way | *"So that latter part makes it trickier to think of as a carbon offset opportunity, because you really have to say, well, if we did not do X, then this carbon would be released, and it's very difficult showing that kind of additionality."* (P12) |
| Alternative Uses | Points concerning different ways SC could be utilised outside of economic instruments and accounting e.g., geoengineering | *"If it is that bottom trawling is releasing this carbon into the atmosphere, then you'd have to include some type of carbon calculation and valuation to your bottom trawling effort. I always stated we manage fisheries in terms of maximum sustainable yield. Well, maybe we should manage it in terms of maximum sustainable yield plus carbon, so MSY + C, right?"* (P19) |
| Conception | How SC should be conceived as a natural resource at the conceptual level | *"If you define it as a resource and relate it to activities, then you can try to find out: what are the consequences of this carbon resource? What are the negative effects? How to regulate them? And you can only do that when you define it as a resource in connection to an activity."* (P10) |
| Data | Points made regarding monitoring and measuring the SC system for governance purposes, esp. regarding a lack of data and required measurements | *"It is not at all easy to estimate sedimentation. Even experimentally, there's lots of people putting traps all over the ocean to try to estimate sedimentation. But it's very patchy and it's difficult to estimate."* (P16) |
| Economic Instruments | Points pertaining to the possibility of economic instruments for SC | *"So there's definitely potential for using those mechanisms* [economic instruments]. *And there's financial tools, but I feel at the moment that the uncertainty around them is really too high."* (P1) |
| Integration | Co-benefits and governance/management collaboration between jurisdictions | *"Thing that we love about blue carbon is not the carbon. The carbon is just the button you press, it's the proxy for all those other co-benefits around it: biodiversity, adaptation. All of those sorts of things."* (P9) |
| New Institutions | Points made regarding the need, or lack thereof, for new institution(s)) | *"It could be a way of managing it is if you have the regional seas. So regional agreements on the management of these other resources. Yeah, that would be the way to follow. You don't want to set up something new."* (P19) |
| Politics | Points pertaining to political aspects e.g., decision-makers, public buy-in etc. | *"Then there are questions to do with getting cooperation between governments. So, if it's a common pool resource and if it's something which straddles different states, that requires agreement and standards across states."* (P17) |
| Publics | Points made pertaining to publics and the extent of their involvement in SC | *"I think what's common is it's hard to address any issue where the public is the stakeholder, within governance."* (P2) |
| Responsibilities | Institutional responsibilities, what would need to be done and by whom | *"it's about being clear, having this evidence and having impartial ways of working or an entire body that [is] given jurisdiction over this without favouring individual countries or even, to a certain extent, acknowledging that countries have these borders"* (P3) |
| Scale | The conceptualised geographic and political scale of SC as a resource e.g., local, national etc. | "*It's hard to represent the public and government even at a national scale, probably even at a local scale, to be honest, but the higher up the scale you get, the harder and harder it is to represent the public.*" (P2) |
| Value | Points made on the different ways to conceive SC's value and its importance | *"They have discrete properties and value is a very subjective attribute and certain activities get greater value because they can be reduced more readily to dollar values, whereas things like amenity, are just difficult to quantify."* (P17) |

against the dataset to ensure consistency and grounding in participants' accounts. As a sole coder analysis, reflexive awareness was maintained throughout the analysis to minimise subjective bias.

At most points of analysis, the data were analysed inductively i.e., interviewees' words were coded from their first-person perspective, allowing for the creation of novel insights, as opposed to deductively i.e., through a preconceived set of categories or set theory (Watts, 2014). The analysis however was conducted iteratively with a first stage inductive analysis of each transcript following an initial read-through (Watts, 2014). At this stage the data were coded descriptively based on the topics and opinions addressed within the data. This was proceeded by a second more in depth inductive analysis in which the descriptive codes were sorted into themes. As is common with thematic analysis, there is overlap, with some codes contributing to more than one theme (see Table 2). Overlap between codes and themes reflects the interconnected nature of governance challenges, where single issues (e.g., economic instruments) intersect with institutional and political dimensions. Themes were developed through a process of constant comparison, whereby codes were grouped based on conceptual similarity, frequency, and relevance to the research aims. Candidate themes were reviewed and refined to ensure internal coherence and clear distinction between themes. Themes were retained where they captured a recurring and analytically significant pattern across multiple interviews, rather than isolated viewpoints. In the final stage, themes were interpreted deductively in relation to existing literature, enabling the identification of alignments, divergences, and emergent conceptual contributions (see Fig. 1 for a break-down of the coding process). Seven themes (see Table 3) emerged from the analysis of the interview data: Definition, Disruption, Governance Integration and Co-Benefits, Carbon Accounting, Economic Instruments, Institutions, and Politics.

**Table 3**
Code book detailing how the codes of analysis are linked to the derived themes.

| Theme | Related Codes |
|---|---|
| 1. Definition | • Conception<br>• Scale<br>• Value<br>• Data |
| 2. Disruption | • Additionality<br>• Alternative Uses<br>• Accounting |
| 3. Governance Integration and Co-Benefits | • Conception<br>• Integration<br>• Alternative Uses<br>• Politics<br>• Value<br>• Responsibilities |
| 4. Carbon Accounting | • Accounting<br>• Economic Instruments<br>• Additionality<br>• Data<br>• Scale<br>• Value |
| 5. Economic Instruments | • Economic Instruments<br>• Accounting<br>• Value<br>• Data<br>• Additionality<br>• Scale |
| 6. Institutions | • New institutions<br>• Conception<br>• Integration<br>• Responsibilities<br>• Data |
| 7. Politics | • Integration<br>• Politics<br>• Publics<br>• Responsibilities<br>• Scale |

Where appropriate, in the findings (section 3 below), indicative counts are provided to give a sense of the distribution of perspectives across participants. While variation in perspectives was observed, these did not align in any clear or systematic way with expert group categories. As such, no strong patterns of divergence between expert groups were identified.

### 2.5. Limitations

This study is subject to a number of limitations. The purposive sample, including a concentration of participants from BC and marine governance backgrounds (and slight focus towards Europe), reflects a focus on depth of domain-specific expertise and contextually grounded perspectives, and shapes the extent to which the findings can be considered broadly representative. In addition, the use of a qualitative, interview-based approach enables an in-depth exploration of expert understandings, though the results reflect perspectives rather than quantitatively generalisable patterns. Coding was conducted by a single researcher, which introduces the potential for interpretive bias, although this was mitigated through an iterative approach and close engagement with the data. As such, the findings should be understood as exploratory and indicative rather than definitive. At the same time, this approach provides a necessary foundation for future research, which could build on these insights through more diverse sampling and the integration of complementary methods as the evidence base surrounding marine SC develops.

## 3. Results and discussion

Seven themes were derived from the interview data (see Table 3). Across themes, participants consistently emphasised that progress in SC governance is constrained by (i) unresolved questions about what constitutes the relevant SC system and resource unit for management, (ii) uncertainty regarding the scale and mechanisms of anthropogenic disruption, and (iii) the resulting difficulties for accounting, valuation, and instrument choice. These challenges intersect with a crowded institutional landscape and the relatively low visibility of SC in public and political discourse. This section presents the seven themes, while discussing their challenges and implications for governance and needs for future research. See Table 4 for a summary of the main results and discussion.

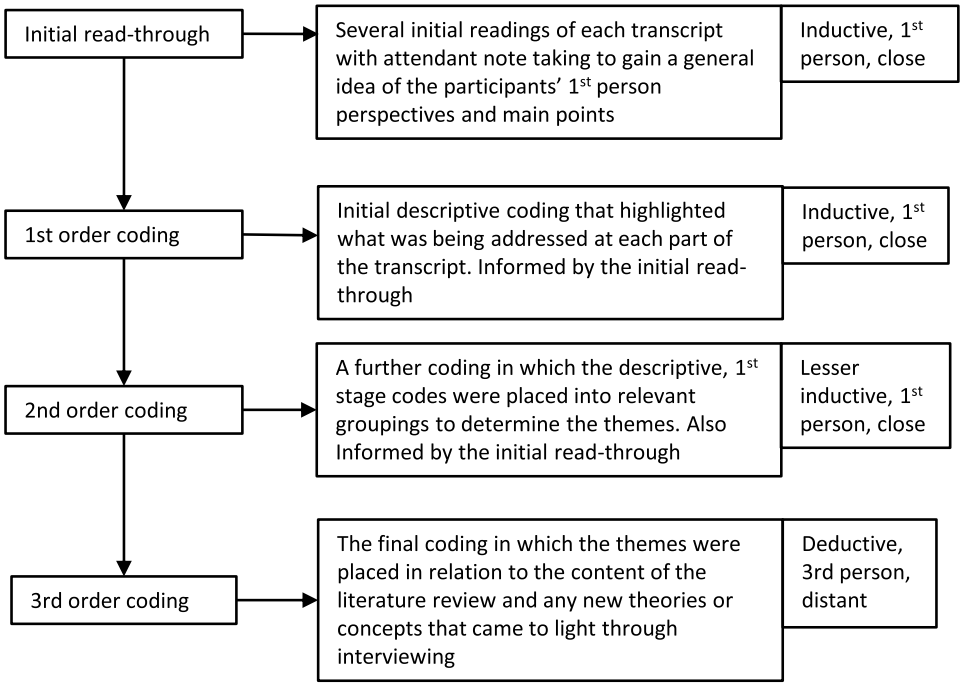


**Fig. 1.** Interview analysis, coding process.

**Table 4**
– Summary of results and discussion by theme.

| Theme | Key Insights | Implications for Governance |
|---|---|---|
| Definition | SC remains conceptually unsettled: participants differed on what constitutes the SC system, its boundaries, and how (or whether) it maps onto "blue carbon". These definitional choices matter because they determine what can be measured, valued, and governed. | Start with pragmatic definitions (boundaries and "resource units") that support monitoring and regulation. Transboundary dynamics and potential "negative fish stock" incentives point to burden-sharing and legitimacy measures (e.g., compensation or co-benefit framing). |
| Disruption | Views diverged on whether SC is governable for mitigation at all, given uncertainty about the scale and mechanisms of anthropogenic disturbance. Even proponents emphasised that disruption evidence is the key constraint on policy design and justification. | Focus near-term governance on regulating activities (e.g., bottom-contact fishing) and use risk-based, evidence-proportionate decisions rather than exhaustive quantification. Treat any "blue carbon" designation as a strategic enabler, not a prerequisite. |
| Governance Integration and Co-Benefits | Participants favoured integrating SC into existing marine governance, often via co-benefits (especially biodiversity and seabed integrity). However, integration risks SC being deprioritised unless responsibilities and implementation strategies are made explicit. | Embed SC where it strengthens existing mandates (e.g., seabed integrity/ biodiversity), not as a stand-alone mitigation goal. Prevent dilution through clear ownership, indicators, and cross-jurisdiction coordination. |
| Accounting | Accounting SC is challenging due to uncertain stocks/ flows, attribution across dynamic and transboundary systems, and questions of permanence and verification. Participants also highlighted that accounting choices can embed particular values and governance risks. | Be explicit about accounting purpose and audience (UNFCCC, SEEA-EA, corporate), since standards and risks differ. Add safeguards to protect plural values and avoid accounting driving premature monetisation/ commodification. |
| Economic Instruments | Most participants were sceptical about market-based instruments for SC in the near term, citing measurement/ accounting uncertainty, leakage and greenwashing risks, and contested views about monetisation and "neoliberal" approaches. | Prioritise regulatory/planning measures over offsets until uncertainties fall. If economic mechanisms are used, apply strict conditions (conservative baselines, leakage controls, distributional safeguards, anti-greenwashing rules). |
| Institutions | Participants saw the institutional landscape as crowded and fragmented, with no clear locus of responsibility for SC. Most opposed creating new bodies, favouring integration – provided monitoring, enforcement, and conflict-resolution functions are covered. | Coordinate across existing bodies with clear roles for monitoring, compliance, and conflict resolution. Make integration workable by ensuring adequate capacity and shared cross-jurisdiction standards and data. |
| Politics | Participants emphasised low public visibility ("just mud"), competing sectoral interests, and the need for political buy-in to enable more effective management and trade-offs (e.g., restrictions on bottom-contact fishing). They also raised risks of greenwashing and inequity in transboundary settings. | Build legitimacy through clear framing (seabed health + climate co-benefits), early engagement on trade-offs, and transparent communication of uncertainty. Any future finance/coordination should include procedural fairness and protections against capture. |

### 3.1. Definition

Given the novelty of SC, defining exactly what SC is and how it should be conceptualised formed a dominant focus of reflection. Many interviewees found it difficult to offer a precise definition within the constraints of a 1-h interview and given the complexity and scale of the SC system. Instead, most insights referred to a holistic or ecosystems approach in which various aspects of carbon are entwined. For example, Participant (P)13 emphasised the important role that rivers play in contributing to shelf sea carbon as an example of the challenges associated with defining the physical boundary of an SC system, fundamental to any potential governance. With up to one third of Particulate Organic Carbon (POC) on continental shelf margins estimated to have a terrestrial origin (Cartapanis et al., 2018), these reflections by the interviewees highlight the difficulty in separating terrestrial and marine deposits and the potential for double counting carbon that has already been included in terrestrial accounts. To make SC governable in practice, a simplification of the complex physical system (the setting of its operational physical boundary) will be necessary to avoid including the full carbon migration pathway from land to seabed.

A small number of interviewees (3) indicated that alongside definition of the physical system is the need to define legal and regulatory boundaries. According to P17, the solution lies in following Ostrom by defining and separating resource "unit" from "system" (Ostrom, 1990). With comparable marine resources, the resource unit tends to be straight forward and clear e.g., fish can be understood in terms of species and quantified by catch weight or similar. By contrast, participants suggested that the SC "unit" would need to be defined in ways that are (i) closely tied to the underlying biophysical resource (i.e., not overly abstract), (ii) quantifiable in principle, and (iii) aligned with the chosen interpretation of SC's value. These criteria point to the practical challenge that a workable definition of SC must support measurement and regulation, not only scientific description. Five participants stated that natural resources contain different values – social, ecological, cultural etc. – which can often be ignored due to difficulty in measuring and including them in structures of management and governance. P6, P9, and P14 observed that these values are often superseded by economic values ascribed to the natural world, which tend to be relatively easier to quantify. Additionally, because value is socially constructed, SC will be socially embedded by necessity, meaning it will also be highly subjective. As such, concerted effort should be made to ensure social (and other values) are not superseded by economic values (i.e., that the dominance of economic values may negatively affect other categorisations).

Several interviewees contrasted how natural resources are normally seen as beneficial for economic development, with how a large SC stock could be seen as a burden to be shouldered rather than an asset to be utilised by any jurisdiction claiming ownership – as management of the stock will likely come at a cost, especially in relation to lost opportunity costs (e.g., a ban on bottom contact fishing would create economic costs to the given fishery and associated stakeholders). Following this argument, P14 was compelled to characterise SC as a "negative fish stock" i.e., a stock of natural resource that a host jurisdiction would rather *not* have ownership over, considering the attendant lost opportunity costs of its management.

The "negative fish stock" idea suggests that it will be challenging for SC to gain traction from decision makers, considering the potential conflict that could arise from restricting other uses of the marine space. This is similar to conflicts that may arise in forest governance when host jurisdictions make pro-conservation decisions at the expense of resource exploitation – such as expansions in mining or agriculture – or vice versa (de Area Leão Pereira et al., 2020). Three participants proposed that SC governance could benefit from learning from principles of programmes such as REDD+ (i.e. that if a host jurisdiction is to maintain an ecosystem as a universal public good in the interests of all humankind, it should be properly supported and compensated by all humankind for

doing so) and their implementation (such as the importance of directly involving local communities and balancing power relations between more and less powerful actors) (Corbera and Schroeder, 2011; Poudyal et al., 2018). The interviewees therefore highlight that an essential initial problem (also found in the literature (Luisetti et al., 2020)) for SC governance is one of ownership: the stock may lie within an EEZ of a host jurisdiction but, contrary to rainforests, the carbon flows constitutive of SC are generated across borders within the water column, migrating between jurisdictions. There is therefore a strong argument to regard SC as a common pool resource requiring shared ownership and responsibility for its management between neighbouring marine states.

**Governance implication:** Early SC governance is likely to depend on pragmatic, operational definitions (including boundaries and resource units) that are fit for monitoring and regulation, even if they simplify the full biophysical system. Given the transboundary nature of SC flows and the potential "negative fish stock" dynamic, governance designs may also need to include burden-sharing arrangements and legitimacy measures (e.g., compensation or co-benefit framing) to make protection politically feasible.

### 3.2. Disruption

How human actions "disrupt" the SC system – by both adding and/or subtracting carbon from the stock and/or altering the processes that sustain carbon accumulation and burial – was considered a major focus for many of the participants whose views, they maintained, were based on a limited understanding of the anthropogenic effect on SC storage (stock) and processes (flow). Consistent with the SC literature (Christianson et al., 2022; Graves et al., 2022; Howard et al., 2023), interviewees mentioned the lack of a sufficient understanding of the anthropogenic effect in what can be called the "disruption problem". A minority of participants (4) were highly sceptical that there was a sufficient enough anthropogenic effect on the SC system to warrant any SC governance in the first place; they believed that any human influence on the SC system will likely be relatively small, and therefore that any policy interventions to protect or extend SC will subsequently be ineffectual forms of CC mitigation. These four (P1, P5, P7 and P14) have expertise from BC, from Economics, and from Fisheries Governance, suggesting the sceptical view is not discipline based.

For those who thought otherwise, the emphasis lay on gaining a more empirical understanding of the effect and extent of any interventions. Given the centrality of the disruption problem to the participants' answers, their views suggest that gaining a fuller understanding of the anthropogenic effects and their extent should be considered a major priority, perhaps the top priority, of SC research going forward. This linked with sceptic P7's point, for example, that governance of a natural resource occurs where the human sphere meets the natural sphere; it is the human beings acting upon a resource that are governed, not the resource itself. It follows therefore, that without a fuller understanding of this, SC governance research cannot advance in a practical direction.

The participants' emphasis on the "disruption problem" highlights this as one of the more contentious elements in relation to SC being classed officially as a form of BC (alongside conventional coastal ecosystems – as outlined earlier in this paper), because a clear and substantial anthropogenic effect is a requirement for a carbon stock to be considered BC (Crooks et al., 2018). This brings into question, however, the relevance of a BC designation for the governance of SC.

On one hand, recognising SC as blue carbon (BC) could make existing BC programmes and funding more accessible, and could allow SC governance to build on established BC processes and networks. It may also shape how policy actors interpret SC; framing it as BC could help some stakeholders accept and champion it as a mitigation-relevant resource. On the other hand, governance for climate mitigation could still proceed without a BC designation as SC differs materially from conventional BC systems in ways that may require distinct governance approaches, not least with respect to scale and transboundary dynamics. Although participants did not address this question directly, the findings highlight SC's novelty and the potential need for greater international cooperation, suggesting two broad positions: (a) if pursuing a BC designation for SC would materially facilitate SC governance and enable mitigation benefits, then it may be strategically valuable; (b) if designation proves difficult or inappropriate given SC's characteristics, it may be preferable to develop a bespoke governance approach independent of existing BC arrangements. Further research assessing whether (and how) BC designation affects the feasibility and effectiveness of SC governance could therefore be valuable.

**Governance implication:** In the near term, SC policy interventions will need to be designed around activities (e.g., bottom-contact fishing) and justified through risk-based, evidence-proportionate decision making rather than complete quantification of all stocks and flows. Where a BC designation is pursued, it should be treated as a strategic governance choice (to unlock pathways and resources) rather than a prerequisite for acting to reduce seabed disturbance.

### 3.3. Governance integration and co-benefits

Participants expressed a prevalent opinion that a resource such as SC, in the spirit of conventional blue carbon, would benefit from being considered alongside or in relation to the relevant governance of ecosystem services, widely referred to as the co-benefits approach (Mayrhofer and Gupta, 2016; Spencer et al., 2016). In particular, eight out of the twenty interviewees proposed that associating SC with conservation for biodiversity purposes – if co-benefits for both could be achieved – would likely strengthen SC's political position i.e., relevance to decision makers and publics. This suggestion is mirrored throughout the literature and contemporary positions on marine governance e.g., calls for combining and simplifying marine governance (Boyes and Elliott, 2014; Taljaard et al., 2019) by moving towards Integrated Coastal Zone Management (Ballinger et al., 2010; J. R. Clark, 1997; Gallagher, 2010), and Marine Spatial Planning (Collie et al., 2013; Douvere, 2008; Santos et al., 2019). These theories of resource management highlight that the different aspects of coastal and marine zones cannot be managed in isloation; that successful governance often depends directly on an effective application of an holistic approach.

This tradition of integration-is-best was also expressed between states, not just within them. A majority of the participants suggestioed that SC could be incorporated into existing international institutions and remits such as (in a European context at least) OSPAR or Regional Marine Fisheries Organisations. An integration of SC into existing international marine governance could act to strengthen SC as an ecosytem service/natural resource by benfitting from other already established governance of, say, fisheries or marine conservation. However, as P18 cautioned, such an approach could also dilute an SC governance's implementation if SC is ignored or reliquinshed behind other marine issues or resources that are percieved as higher priority. This speaks again to the strong potential to link SC governance with that of other concerns providing associated co-benefits and causes e.g., seabed conservation, especially in an international and transboundary context.

**Governance implication:** Integrating SC into existing marine governance will likely be most effective where SC objectives are explicitly linked to established mandates with clearer implementation strategies (e.g., seabed integrity and biodiversity), rather than introduced as a stand-alone mitigation goal. To avoid dilution, integration strategies may require clear ownership of responsibilities, explicit performance indicators, and coordination mechanisms across jurisdictions.

### 3.4. Carbon accounting

Within the literature, "carbon accounting" can refer to three distinct forms of accounting: 1) the UNFCCC carbon budget, 2) the accounting of carbon within national natural capital accounts that measure the extent, condition, supply, and value of natural resources (including carbon

stocks and flows), as laid out in the UN's System of Environmental Economic Accounting – Ecosystem Accounting (SEEA - EA), and 3) corporate carbon accounting used by organisations to calculate their contributions to greenhouse gas emissions i.e., their carbon footprint (He et al., 2022; Luisetti et al., 2020; UNFCCC, 1992; United NationsEuropean UnionFood and Agriculture Organization of the United Nation, 2024). Similarly, Schaltegger & Csutora (2012) identify three levels of institutional accounting: scientific, corporate and governmental, each with distinct goals and intentions, making the attendant point that the manner and purpose of any carbon accounting is determined by those using the tool for their specific purpose.

With these distinctions in mind, during the interviews, of their own accord (i.e., without prompting via the interview protocol), six participants mentioned carbon accounting, with most speaking about it in a "general" sense i.e., not specific to either UNFCCC carbon accounting or SEEA natural capital accounting, but in a way that could be interpreted as referring to both, or even to the carbon accounting compiled by corporates. In other words, most interviewees did not specify particular forms of carbon accounting when they referred to these. These participants echoed the general challenges facing carbon accounting that have been highlighted in the literature: 1) leakage and ensuring what is accounted equates to real and commensurate additions or reductions of emissions and levels of atmospheric carbon and natural carbon stocks (Brander et al., 2021); 2) insufficient personnel and expertise to produce the required accounts (Ascui and Lovell, 2012); and 3) problems relating to a lack of standardisation of methods and measurement between organisations and across different countries (Bowen and Wittneben, 2011; Hartmann et al., 2013).

Representing an ongoing concern among environmentalists and researchers (Costanza, 2024; Monbiot, 2018; Segoff, 2017), P14 highlighted that carbon accounting can represent the assertion of certain values and norms, not least that economic quantification can often, but not always, lead to the assigning of monetary values and a potential commodification. For P14, this can lead to issues surrounding the monetisation of natural resources, namely that alternative values can be ignored, and the natural resource can be overexploited causing environmental harm, as has been argued elsewhere (Monbiot, 2018; Segoff, 2017). P12 countered with the argument that natural capital accounts act as ledgers that allow governments to understand the efficacy of policy interventions as they relate to changes in the stocks and flows of natural resources and are therefore primarily tools of environmental monitoring. This juxtaposition reflects a wider tension in environmental governance between instrumental and normative orientations: whether accounting systems primarily function as neutral information infrastructure, or whether they actively shape governance priorities and behaviour. The divergence between P12 and P14 therefore illustrates the challenge of designing governance that satisfies demands for technical measurements that inform decision-making while avoiding the pitfalls of oversimplification, financialisation, or the privileging of economic value over other forms of worth. This tension appears recurrent across the interview data, highlighting that future SC governance will need to carefully balance information needs, political expectations, and the plurality of values associated with the marine environment.

**Governance implication:** Any attempt to formalise SC within accounting frameworks will need to be explicit about purpose and users (UNFCCC inventories, SEEA-EA accounts, or corporate claims), because each implies different standards and governance risks. Participants' concerns also suggest that SC accounting should be accompanied by safeguards that protect plural values and prevent accounting becoming a route to premature monetisation or commodification.

### 3.5. Economic instruments

When asked to discuss SC in the context of environmental economic instruments (i.e., policy interventions that harness market forces and incentives to add monetary value to ecosystems and ecosystem services for reasons such as CC mitigation and conservation (Ekpe, 2013; Helm, 2004)), thirteen (out of twenty) participants thought it would be highly problematic, centring on the difficulty to obtain detailed enough data in the context of SC to understand whether the instrument was having the commensurate effect on CC mitigation (i.e., reducing atmospheric $CO_2$) and the correct distribution of any benefits accrued. Additionally, as with accounting, there was a perceived lack of expertise and personnel required to undergo the complex measurements required to substantiate and evaluate the implementation of any instruments. For these reasons, participants 9, 13 and 17 expressed doubts that carbon offsetting would be viable for SC, adding that offsets have a tendency towards exacerbating CC by giving polluters licence to pollute and can lead to high levels of leakage.

The barriers participants identified for economic instruments mirror the challenges they identified for carbon accounting, especially in quantifying a complex transboundary resource in the large-scale marine environment. Given this difficulty, modelling was suggested as a practical way to understand the difficult-to-measure flows of carbon in the marine environment. The minority of participants (4) who commented on the feasibility of modelling were divided as to whether feasible models could be constructed utilising only a handful of key measures of the highly complex ecosystem functions that occur across the marine zone. For the sceptics, a further difficulty related to decision makers, who will likely demand more certainty than is likely to be obtained regarding the efficacy of policy interventions (such as economic instruments), especially if there are high financial or opportunity costs at stake. For the model-optimists, a belief that a general idea of whether an intervention is contributing to greater carbon storage than would have been otherwise is enough, and this can likely be obtained with a relatively small set of key data. This conflict highlights a deeper governance challenge: the need to balance scientific uncertainty with the practical imperative to act, recognising that future SC governance will depend not only on technical modelling capacity but also on political willingness to make decisions under persistent uncertainty.

Three participants (P6, P9, and P14) voiced apprehension concerning the political economy of economic instruments within the natural capital approach, arguing that it is "too neoliberal". For these participants, neoliberal norms – such as capital accumulation, an emphasis on the role of the private sector, profit maximisation, and financialisation (Harvey, 2005) – are dissonant with the actions required to address CC, with the idea expressed that issues of environmental degradation have largely been caused by capitalist overexploitation and so the approach of utilising such methods, of which economic instruments were characterised, represents an inherent contradiction. P9 anticipated that neoliberal approaches will likely lose popularity as their ineffectuality becomes clearer over time. Instead, direct management interventions (such as regulatory and legislative policies) will become more dominant (Stechemesser et al., 2024).

The critique of economic instruments as too neoliberal indicates a concern, voiced by other participants, that any management of SC by economic instruments (i.e., a financialisation of a particular kind) would reduce it to an economic resource detracting from its complexity. A concern was raised by two participants that using economic instruments could leave an SC policy open to greenwashing or having its CC mitigation overstated. Therefore these opinions reflect those in the wider conflict in environmentalism previously mentioned, between those who see the natural capital approach as a pragmatic translation of environmental issues into the language of international finance/companies/governments on one side and those, like the above mentioned participants, who see the natural capital approach as a harmful reduction that is doomed to fail in addressing the underlying issues (Monbiot, 2018; Read and Cato, 2014; Segoff, 2017).

**Governance implication:** In the near term, SC governance is likely to rely more on direct regulatory and planning measures than on offset-style instruments, unless and until monitoring and accounting uncertainties can be reduced to acceptable levels. Where economic

mechanisms are considered, participants' concerns indicate a need for strong governance conditions (e.g., conservative baselines, leakage controls, clear distributional safeguards, and anti-greenwashing rules) to maintain legitimacy.

### 3.6. Institutions

Participants generally stated that institutions involved in the governance of SC would have responsibilities similar to those inherent in governance of most natural resources: monitoring, enforcement, and stakeholder conflict mitigation. A responsibility to involve wider society and publics was also voiced, to ensure a listening process that would allow people to inform the development of any SC policies or interventions. Most interviewees argued that these kinds of institutional responsibilities be shared between jurisdictions where possible, underpinned by common pool resources thinking, as the social benefit (CC mitigation) is ultimately a public good for which all jurisdictions hold responsibility. The advantage of this would be to make consensus-building easier, help prevent gaming by aligning incentives, and facilitate shared monitoring (standardising measurements and sharing expertise), all regarded as essential given the complexity of monitoring SC. These points made by the participants are consistent with proposals in the literature on marine protected area management (Fox et al., 2012; Jentoft et al., 2007) which mirrors the participants' emphasis on the relevance and importance of monitoring (Addison et al., 2015; Gill et al., 2017; Perkins et al., 2021), enforcement (Causey, 1995; Monteiro et al., 2009), and stakeholder conflict (Bellanger et al., 2020; Gaebel et al., 2020). In other words, interviewees – similarly to the literature – argued that SC institution(s) could build a wealth of knowledge and insights from established practice.

Interviewees acknowledged that ecosystem monitoring is challenging and would be further complicated by SC's scale and the diversity of relevant inputs and influences. For monitoring, many of the same points regarding the challenges raised for carbon accounting (Section 3.4) were made e.g., lack of uniformity of measurements, lack of expertise etc. Enforcement would reflect the interventions devised e.g., bans on bottom contact fishing, say, would require additional fisheries enforcement to complement already established practice. The participants acknowledged that enforcement is notoriously challenging in marine zones, and this would need to be considered in relation to the effective implementation of instruments and how they are governed by key institutions (Pendleton et al., 2018).

A majority of interviewees (11) felt no new institutions should be devised to govern SC, at least not at first. It was considered, certainly in a Global North context, that there are enough institutions governing the marine space as is. Adding more would not be conducive to better or more efficient governance but would likely act to hamper existing governance by adding yet another voice and organisation to the table. Additionally, it would slow down any initial SC policy implementation due to the time and effort required to establish and operationalise such an institution. Instead, an integration into existing institutions should be pursued. Only a small number of participants (P10 and P11 – both experts in the broad category of marine governance) dissented from this view; they argued that this would be tested empirically – it will become clear whether a specialised institution is required as more is learned about the SC system, its potential, and any devised interventions. They also argued that a reluctance to say no to new institutions often stems from a reluctance to create more bureaucracy but any antipathy towards bureaucracy should not deter from using such approaches if they work.

The widespread no-new-institutions view of the majority of the participants aligns with established views that there are already too many governance institutions in the marine sphere, certainly in a European context at least (Boyes and Elliott, 2014, 2016). The participants holding such perspectives argued that important key actors should work together across similar responsibilities, acting to make more complex but effective an already complex system of remits and responsibilities. However, it was also mentioned that the call for institutional integration creates questions for SC going forward, centred on how SC, a quite unusual resource, can be integrated into existing institutional structures of governance and whether that would be feasible and effective.

**Governance implication:** A pragmatic starting point is likely to be coordination across existing bodies (e.g., fisheries management, marine conservation, and spatial planning) with clearly assigned responsibilities for monitoring, compliance, and conflict resolution. However, integration will only be workable if institutions are equipped with resourcing and enforcement capacity commensurate with the scale of SC, and if cross-jurisdictional mechanisms are established for shared standards and data.

### 3.7. Politics

The participants as a group were very interested in discussing political aspects they associated with the potential feasibility and success of an SC governance. They argued that for many publics, the SC system occurs out at sea, removed from people's lived experiences, and therefore does not hold a prominent position in the public imagination, if publics are even aware of the SC carbon system at all. Indeed, participants stressed that it may be understood as highly unappealing or inconsequential; in the words of P2: "this is just mud". The significance of this is that it suggests there will be a lack of buy-in and interest from decision makers who will too easily ignore SC in favour of other, more publicly relevant uses of the marine space or resources, or simply other issues and concerns that have more public and media attention. However, the profile of SC, its climate mitigation service provision and the potential impact of human activities is rapidly gaining political and governance traction. Within the UK there is recently published evidence needs statements from the UK Blue Carbon Evidence Partnership which highlights the need for evidence on seabed carbon and human impacts to support management decisions (UKBCEP, 2023). This is mirrored in other European countries and networks (Ni Longphuirt et al., 2025). Furthermore, regarding conflicting uses of the marine area, it was heavily stressed that this will present a major difficulty for SC e.g., a potential ban on bottom contact fishing to protect SC stocks would likely put SC in direct conflict with fishing interests. Four participants stated that having a high level of sympathy and buy-in from publics would help decision-makers have the confidence to consider making pro-SC (and therefore potentially pro CC mitigation) choices when such conflicts arise. This aligns with conclusions in Sections 3.4 and 3.5 that decision makers will require key information and evidence, through well conducted monitoring to support their decisions against competing interests while acknowledging that some decisions will have to be made without the full understanding provided by the fantasy of a fully perfected monitoring.

The participants' perspectives indicate that the issue of generating sufficient interest amongst actors that would support a SC-specific policy decision is an enduring issue for any concern that relies on political attention in a crowded field (Hart et al., 2015; Newig, 2004). The emphasis on including publics suggests that the expert participants think SC governance cannot and should not be a completely technocratic endeavour orchestrated by government officials far away from public fora. It raises pertinent questions for any SC policy: how relevant is public interest and support for decision makers to act on SC? And, how can interest among publics be cultivated when SC is so far away from people's lived experience? This brings to the fore the question of how to incorporate public views, if possible, into decision making when an issue is emergent. This question could be explored by following similar work on "upstream engagement", such as that found in the context of nanotechnology and geoengineering (Corner et al., 2012; Pidgeon et al., 2009).

Ancillary concern expressed by participants centred on the potential for SC to be abused, as has been observed in similar natural resource contexts. The first was the potential for greenwashing, described by P9

as "look over there" behaviour e.g., using SC to indicate that something was happening on CC while business-as-usual practices regarding heavily polluting industries continues elsewhere. This was associated by P9, and other interviewees, with a critique of offsetting practices in general and seen as too often used to prove action on CC that was ineffectual in practice (closely linked to the points made on economic instruments, see 3.5). The second concern was articulated by P20 who stressed that unequal power relations between different countries, especially between the global north and south, will lead to unequal use and discordant management and governance of SC. Despite the positive motivation of CC mitigation, mismanagement of SC has the potential to lead to the entrenchment of unequal and damaging power dynamics. Some interviewees observed this has been the case with some REDD + schemes in the Amazon with the rules and governance of the schemes dominated by those paying the most money rather than led by the host jurisdiction or local publics, with the benefits of offsetting coming at the cost of native and local communities (Corbera and Schroeder, 2011; Poudyal et al., 2018).

**Governance implication:** Building durable SC governance will likely require deliberate legitimacy strategies: clear public-facing framing (e.g., seabed health plus climate co-benefits), early stakeholder engagement around trade-offs, and transparent communication of uncertainty. In addition, transboundary and equity concerns indicate that any future SC finance or coordination arrangements should incorporate procedural fairness and protections against capture by powerful interests.

## 4. Conclusions

This study demonstrates that while marine sedimentary carbon (SC) is increasingly recognized for its potential contribution to climate mitigation, progress towards its effective governance remains constrained by unresolved conceptual and empirical questions. Participants emphasised that the first-order challenge is operational: agreeing pragmatic definitions of the SC "resource unit" and system boundaries that are fit for monitoring and regulation, even if they simplify complex biophysical dynamics. At the same time, limited understanding of the scale and mechanisms of anthropogenic disruption continues to complicate efforts to design and justify interventions, and to determine how SC should relate to (or remain distinct from) "blue carbon" framing. These uncertainties intersect with transboundary dynamics and contested values, shaping the feasibility and legitimacy of any emerging governance arrangements.

The findings suggest that near-term SC governance is most likely to be activity-focused and risk-based: regulating seabed-disturbing activities (notably bottom-contact fishing) using evidence-proportionate decision making rather than waiting for complete quantification of stocks and flows. Participants generally favoured working through existing marine governance mandates (e.g., seabed integrity and biodiversity) and institutions, but cautioned that integration can dilute SC unless responsibilities, indicators, and coordination mechanisms are made explicit and matched by adequate monitoring and enforcement capacity. Consistent with this, economic instruments and offset-style approaches are unlikely to be viable in the near term due to current measurement and accounting uncertainties; where economic mechanisms are considered, strong safeguards (e.g., conservation baselines, leakage controls, distributional protections, and anti-greenwashing provisions) would be needed to maintain credibility and legitimacy.

Future research should prioritise improving empirical understanding of human impacts on SC and testing how specific interventions (e.g., spatial measures or restrictions on bottom-contact fishing) perform in practice, including their distributional and sectoral consequences. Given SC's low public visibility, work is also needed on legitimacy-building strategies, including clear public-facing framing (e.g., seabed health with climate co-benefits), early stakeholder engagement around trade-offs, and transparent communication of uncertainty. Finally, further exploration of transboundary coordination and burden-sharing arrangements, (including the role of regional seas organisations) may also help clarify how SC can be managed as a transboundary environmental resource and avoid inequitable outcomes. Advancing these areas will be critical to determining whether SC can be mobilised as a meaningful component of climate mitigation and marine environmental management.

## CRediT authorship contribution statement

**Jack Smith:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Irene Lorenzoni:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing. **Ruth Parker:** Writing – review & editing. **Tiziana Luisetti:** Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Jack Smith reports financial support was provided by UK Research and Innovation Natural Environment Research Council. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2026.129947.

## Data availability

Data will be made available on request.

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