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Putting the 'socio' in socio-ecological: Strengthening Great Barrier Reef adaptive management through evolving and elevating the role of social sciences

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ABSTRACT

The Great Barrier Reef (the Reef) is a globally significant socio-ecological system, where human wellbeing is deeply intertwined with ecological health. An adaptive management approach underpins, and shapes coordinated management of the Reef, in the face of spatial, temporal, and stakeholder diversity combined with rapidly changing climatic conditions. Social science, specifically human dimensions research, is essential for effective adaptive management of this marine environment. To examine how human dimensions research is currently applied in Reef adaptive management, and to identify barriers and enablers to its effective integration, we conducted semi-structured interviews with 30 Reef managers and social science practitioners. Overall, findings reveal increasing value placed on human dimensions research but also an uncertainty surrounding its application and significance beyond supporting biophysical science. We recommend that understanding the current challenges and the future opportunities for human dimensions to be a key player in management decision making, can be understood through a systems lens. Specifically, we suggest that shifting Reef adaptive management, from a rigid, solution-oriented hard systems approach to a more flexible, soft systems style has the potential to enable human dimensions research to move beyond contextual support for biophysical information to meaningful contributions shaping management processes and outcomes. We demonstrate the benefits of soft systems thinking for enhancing the influence of human dimensions research in environmental decision-making and adaptive management by linking empirical insights with governance literature. We conclude with recommendations to further support this transition, aiming to strengthen the resilience and inclusivity of Reef management in the face of accelerating environmental pressures.

1. Introduction

The World-Heritage listed Great Barrier Reef (Reef or the Reef hereon), located off the east coast of Northern Australia is beautiful, vast, and unique [1]. The Reef contributes nine billion dollars to the Australian economy [2] and is a key part of the spiritual and cultural identity of local First Nations Peoples [1]. Despite investment of over \$5

billion by the Australian and Queensland Governments and various stakeholders between 2014 and 2030 (Australian Government [3]), the most recent Outlook Report [4] and Scientific Consensus Statement for the Reef [5] highlight the continued need for urgent and accelerated action to address threats from climate change and poor water quality from terrestrial run-off.

The ecological issues facing the Reef are not unique. Marine socio-

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ecological systems (referred to as systems from here on) around the world are suffering from the cumulative impacts of unsustainable fishing practices, higher ocean temperatures, rising sea levels, ocean acidification, decreasing oxygen levels, algal blooms, melting ice and changing ocean currents [6]. Marine systems are considered ‘complex, uncertain and adaptive’, requiring flexible and iterative management approaches that can respond to feedback and change over time [7–12]. Adaptive management has historically been the preferred approach for managing complex systems. Adaptive management is best suited for conditions where there is high uncertainty, dynamic interactions and multiple actors, enabling ‘learning by doing’ and empowering stakeholders to test, revise, and improve strategies in response to ecological and institutional feedback [13–15]. While the importance of including the social sciences into the processes of adaptive conservation and environmental management is increasingly recognised in the literature [11,16–19] the level of integration has been less than ideal [13,14,20,21]. For example, social science is often not integrated from the beginning of adaptive management decision making processes. Investment in social science tends to occur at the end, to fulfil the need to provide context to biophysical information, or fulfill obligations of ‘stakeholder engagement or consultation’ [22–24]. Given the complexity of trade-offs within marine systems such as the Reef, and the growing consideration of novel reef restoration and adaptation technological interventions in the face of intensifying environmental pressures [25,26], the question about the role and position of social science for adaptive management of the Reef urgently needs to be revisited and refined.

This paper presents the results of an examination into the application and extent that social science is currently integrated into the management of the Reef. Because social science encompasses many disciplines (see Bennett et al. [27] we focus specifically on human dimensions research. That is, research that focusses on the social, cultural and economic benefits derived by people from the Reef and people’s connection to the Reef, as per the definition in the Australian Government’s Reef 2050 Plan [28]. We conclude with a reflective analysis of the evolving role of human dimensions research in Reef management and how this could be improved. The paper is set out as follows. In the next section we provide a brief discussion of soft and hard systems thinking as the theoretical framework against which the current and future application of human dimensions research for the Reef can be viewed. Section three focusses on the current role of Reef human dimensions research, providing a brief overview of the extent and achievements from investment in this space for Reef management to date. This is followed by the methods and key findings of our investigation and is concluded with an extended discussion of the extent to which Reef adaptive management approaches are transitioning to enable more effective integration of human dimensions research consistent with a soft systems approach. We also explore future opportunities for human dimensions research. Whilst this paper is focussed on the challenges and experiences of integrating human dimensions research into Reef management, we note that these challenges are not unique to the Reef and also occur in the management of wetlands [29], coastal systems [30], fisheries [24,31], agricultural systems [32] and other socio-ecological systems such as Australia’s Murray Darling Basin [33].

2. Theoretical framework - hard and soft systems thinking

Systems thinking is the framing of a problem across interconnected systems (e.g. social, economic, cultural) where the inter-relations between components of a system are recognised and explored together rather than in isolation of one another [34]. Systems thinking helps identify and address problems in dynamic, interconnected environments and is considered a necessary foundation for responding to complex sustainability challenges [35]. Systems thinking encompasses a range of methodologies, broadly categorised into ‘hard’ and ‘soft’ systems approaches (see Checkland [36]).

Hard systems thinking as a management approach is used to make decisions based on the technical aspects of a system based on operational, analytical and engineering methodologies. However, hard systems approaches are limiting in some circumstances due to their inability to handle significant complexity, to cope with a plurality of different belief and values, and to deal with issues of politics and power [37]. By viewing problems as situations that are socially constructed and thereby require a social solution, a soft systems approach offers potential advantages when dealing with complex problems where ecological and social dimensions are deeply intertwined and cannot be meaningfully separated.

2.1. Hard and soft systems

Within systems thinking, hard systems are viewed as external to the observer and can be examined and modified from this external perspective. In hard systems thinking, the world is seen as systemic, meaning it can be objectively modelled and optimised, where information is collected and applied to resolve the problem at hand. Jackson [38] argues that hard systems analysis is very similar to the steps in adaptive management especially when (i) the problem is well-defined; (ii) the goals are agreed upon by stakeholders; (iii) the system can be objectively analysed and mathematically modelled; and (iv) identified solutions can be modelled, tested and implemented. The advantage of a hard systems approach to managing a problem is that it facilitates precision and predictability. The disadvantage is that social, political and cultural dimensions to a problem are not as well incorporated in the problem definition or assessing pathways forward [36,38].

Soft systems accept that observers are within (not external to) the social-ecological system and that ‘problems’ are socially constructed and framed. As a result, ‘problems’ often lack consensus and the way forward requires the consideration of multiple perspectives where no single person or agency is a leading expert. Goals may extend beyond finding a narrowly defined ‘solution to a pre-defined problem’ to include shared problem framing and incorporate objectives with system change and legacy goals such as facilitating learning and improvement through structured inquiry. Voulvoulis et al. [39] note that in the context of soft systems thinking, learning is not just the acquisition of knowledge but also increased familiarity with a breadth of perspectives, frames and worldviews.

Checkland [36] and Cundill et al. [14] state that soft systems are characterised in four ways: i) decisions have social elements and people attempt to make purposeful action that is meaningful to them; ii) many interpretations of a goal or purpose are possible and these originate from a [socially based] world view; iii) a challenge is viewed as a situation that many people see as problematic rather than a problem that requires a solution; and iv) management actions take place when people agree on a course of action that is desirable and feasible given their individual histories, relationships, culture and aspirations. The soft systems approach frames the management solution(s) within a social framework rather than external to it.

It is important to note that we are not arguing for the complete replacement of hard with soft systems thinking. Both have roles. However, the management and governance of the Reef as a system — the processes by which problems are defined, priorities are set, decisions are made and evaluated — is inherently suited to a soft systems approach. This is because, it involves multiple actors with differing values, contested goals, and socially constructed understandings of what the ‘problem’ is. A soft systems approach does not diminish the role of biophysical science nor the need for hard system approaches were appropriate; rather, it provides a framework for integrating all the sciences — biophysical and social — in ways that reflect the full complexity of the socio-ecological system being managed.

3. Human dimensions research in the Reef and the current study

Fundamental to how systems-thinking approaches shape Reef management is the distribution of investment across scientific domains. Historically, resources and funding streams have been directed predominantly toward the biophysical sciences [40] reflecting a long-standing preference for hard-systems approaches [41]. This orientation has also influenced the types of human dimensions research that have gained traction in Reef management, favouring positivist, quantitatively oriented work that fits within existing monitoring and reporting frameworks, rather than approaches that engage with the complexity of values, perspectives, and power relations.

Although human dimensions research remains a relatively small proportion of overall Reef investment and has often been embedded within an ecological focus, funding for this work has increased over the past two decades. As a result, human dimensions research now contributes to governance, community engagement, Indigenous knowledge systems, economic valuation, and behavioural change initiatives that support resilience and adaptive management. Recent initiatives, such as the Reef 2050 Plan [28] and the Reef Integrated Monitoring and Reporting Program (RIMReP), further signal growing recognition of the value of human dimensions research within the Reef governance landscape.

Despite this progress, the role of human dimensions research in Reef management continues to be largely supportive of biophysical science, with limited integration into core adaptive management processes (Foxwell-Norton, [23]). This paper addresses this gap by examining how human dimensions research is currently used in Reef adaptive management and identifying the factors that enable or constrain its effective integration. Drawing on interviews with Reef managers and social science practitioners, our findings highlight the opportunity to adopt an overarching soft systems framing for adaptive management, under which both hard and soft systems approaches and sciences are brought together to provide a pathway for human dimensions research to move beyond peripheral support to a more central role in adaptive management – one that supports more meaningful contributions to decision-making, codesign and equitable outcomes.

4. Methods

4.1. Participants and recruitment

Semi-structured interviews were conducted with three key groups: i) Reef management personnel across regional (catchment), state (Queensland) and federal (national) government levels; ii) non-government end-users of social sciences, including organisations involved in Reef Regional Report Cards (also referred to as Report Cards or Regional Report Cards in this paper) and other not-for-profit entities; and iii) researchers (including both social and biophysical scientists) who collaborate on Reef management projects. Interviewees were identified by the authors through the authors professional networks and snowball sampling [42]. Interviewees were invited to participate in the research through an email introducing the study and with information about the types of questions that would be asked. The interview protocol was approved by the CSIRO human ethics committee (approval 116/24). In total 48 potential interviewees were approached and 30 agreed to be interviewed. Representation of interviewees across decision making and research organisations are described in Table 1.

4.2. Data collection

Thirty interviews were conducted on Microsoft Teams between July and November 2024. Most interviews were held with two interviewers and one interviewee. In a few instances, multiple people were interviewed together when they were from the same organisation and worked together. Interviews lasted between 30 and 50 min and were

Table 1

Representation of interviewees

Level ^a	Proportion of participants
End-user – government	53%
End user – Non-government ^b	20%
Social science affiliated (referred to as researcher)	20%
Research but not affiliated with social science (noted as non-social science researcher)	7%

^a For this study, GBR management encompasses individuals directly involved in reef management decision-making processes, whether in informative roles (collecting and delivering information to senior managers), consultative roles (providing advice and connecting information to management), or decisive roles (determining policies, actions and programs for reef resilience implementation)

^b The Reef Regional Report Cards <https://www.reefplan.qld.gov.au/tracking-progress/reef-report-card>, delivered by ‘partnerships’ representing major regions of the GBR catchment, provide regional scale monitoring and evaluation that contributes to evaluation of progress towards the objectives of the Reef 2050 Plan. These reporting frameworks are to an extent region-specific, but have a range of overlapping indicators, including those encompassing human dimension components.

digitally recorded and transcribed with Microsoft Teams. Informed consent to participate in the study was received orally from all research participants at the start of the interviews.

Semi structured interviews followed three key components (Table 2). Component 1 established the participant's background and their understanding of HDSS. Component 2 explored the interviewees perceived usefulness of human dimensions research, including current approaches, examples of application, and challenges encountered. Component 3 focused on future perspectives and how human dimensions research could better address current and future information needs for Reef management. While the interview protocol as described in Table 2 provided a consistent structure, questions were adapted to reflect the different perspectives of end-users and producers of social science.

4.3. Data coding and analysis

For the 30 interviews, the files were first cleaned and de-identified to ensure the cohesiveness of the transcript and the privacy of the interviewees. Following the methodology presented by Braun and Clarke [43], a manual deductive thematic analysis was applied to the data corpus. A deductive thematic approach is based on extracting main themes, e.g. codes, by reading all the transcripts and highlighting recurring patterns. This approach was considered appropriate because

Table 2

Core interview questions.

Component 1 Context and experience of human dimensions	Can you share a bit of an overview of your role within your organisation and how it relates to the management of the Reef? How familiar are you with the human dimension of the Great Barrier Reef? What do you understand as the human dimension of the Great Barrier Reef?
Component 2. Utility and experience	How important do you think understanding the human dimension of the Reef is? Where do you go to find out about the latest in human dimensions research for the Great Barrier Reef? Have you ever used or applied information related to the human dimension of the Great Barrier Reef and do you have some examples? Was anything challenging about the use of the information?
Component 3. Pathways to change	Do you have any recommendations or needs for how the information could be more useful or accessible? Is there any information, related to the human dimension research, that you wish you had?

the aim was to decipher understanding, applications, gaps and needs for the use of human dimensions research and monitoring at all levels of decision-making and research. The iterative process was achieved using the qualitative data analysis software, Nvivo. The protocol, described earlier in the Data Collection section, was used as a basis for the coding themes to ensure consistency and rigor in the understanding of each concept. At multiple stages, the research team reflected on the data, discussed themes and categories and checked the codes to ensure the reliability and validity of the results.

In total, five broader themes (main codes) were developed based on the protocol. These were: 'familiarity and understanding of human dimensions social science, 'importance of human dimensions social science, 'examples of use [in decision making]', 'factors that currently enable or challenge its use [to progress usability and to ensure fit for purpose for future needs?'. Challenges and enablers were examined for both current use and future needs to improve how can it inform and shape Reef management decisions and adaptive management cycles. These categories were coded for both social science creators and users.

5. Results

Results from interviews are discussed first as familiarity, use and opinions of importance of social science before a focus on factors that influence its use in Reef management. Square brackets [] are used to indicate editorial insertions or clarifications within a quote, while ellipses ... signify omitted material that is not essential to the meaning of the excerpt. The affiliation of the quote, consistent with Table 1, is also noted.

5.1. Familiarity and importance of human dimensions research

More than half of participants described low familiarity with human dimensions research as it has been applied within the Reef context. In many cases, this group was comprised of individuals with disciplinary training in biophysical sciences and included several government end-users. Of the smaller number of participants who indicated familiarity with human dimensions research most were social scientists or individuals whose roles specifically focused on the human dimensions of Reef management". Even within those participants reporting familiarity, many reported that the breadth and diversity of human dimensions research made it difficult to keep up with. As stated by one manager: "[I am] very aware of the body of work that represents human dimensions research in the reef, but also therefore very aware that [it's] huge and multifaceted ... I can't hope to be across all of it" [ID7, End user - government].

For most participants, human dimensions research was seen as important. The challenge of managing the Reef was recognised as a "people problem" and information about people was an important consideration to deliver "well thought out management". As stated by one government end user: "One of the key things about managing protected areas, whether they be the Great Barrier Reef or any [protected area], is predominantly managing people's interaction with that protected area" [ID01, End user - government]. One government participant described human dimensions as foundational to all management activities: "to me, the human dimensions is really everything that we do, because it's all about how we shape people's behaviour right from the top levels of governance decision making through to the landholder, making decisions about how to run [the] farm" [ID07, End user - government].

5.2. Perceptions about use of human dimensions research

Many participants reported observing a groundswell of support for, and interest in, what human dimensions research could provide to Reef management: "I think it's definitely improved ... really accelerated - the weight of effort and investment that goes into human dimensions research, the way it's treated" [ID7, state government]. For those with

experience using human dimensions research in decision making, the most frequently cited types of uses related to informing program design or communication strategies, and monitoring and evaluation. For example:

"[we are embarking on] strategic ways into improving engagement and...leveraging information of what we know about each other, what's different between us and the science sceptics and what's the same..." [ID21, researcher].

Several participants emphasised that human dimension data "tells a really good story" [ID15, End user - non-government] and provides powerful narratives that resonate with audiences in ways that biophysical data cannot. For example: "a big part of our role in regional report cards is communicating monitoring results back to the community. But also using it to inform our communication strategy" [ID20, End user - non-government]. Similarly, a state government participant described using "a human-focused lens to tell the story about why we're doing what we need to do for the reef in order to make it understandable, to have a sensible narrative that people can get behind, and to try and motivate uptake and interest" [ID07, End user - non-government].

Some participants articulated how human dimensions research have informed high-level policy and planning processes. Those that expressed this sentiment tended to be direct end users of the related information. For example:

"...we're gathering all this data, we're doing all this analysis, we're learning all this stuff, and then we're taking [it] and we're embedding it into the way we design programs and projects." [ID8, End user - government]

Some participants noted a more recent transition in monitoring practices from use of purely biophysical data towards incorporating human dimensions data such as monitoring "the social and cultural values and perceptions of our waterways". For example, one NGO participant described:

"When I first planned the M&E (monitoring and evaluation) framework and reporting, it was all very ... 'these are the management practices we did, ... this is the water quality improvement the projector says we've changed now' and that was it ... now in our final evaluation, it's about 70% the social side" [ID15, End user - non-government].

This shift was also noted by government participants, who acknowledged "*the integration of human information, social information into the Reef report card, for example*" [ID7, End user - government] and "*a very gradual kind of increase in prominence and recognition of importance*" [ID21, End user - government]. Similarly, researchers also reported "moving towards long term resilience benchmarking in NRM (natural resource management) bodies.... So that type of social science, it's directly influencing strategy and delivery and is very powerful" [ID25, researcher].

A small number of participants highlighted how human dimensions research has already been integrated within policy and planning. Examples of influence included informing the development and revision of specific policy instruments, such as the most recent Water Quality Improvement Plan review, or the revision of the Reef 2050 plan:

"I think all the work we're doing on the water quality improvement plan review and new direction has its basis in a better understanding of the humans... And so, I think a lot of the human dimensions work has really fed well into that" [ID04, End user - government].

"with the midterm review of that [2050] plan ... we needed to better embrace the important role of social science...So for me a big thing was about recognising the importance of [the] human dimensions ... in strategic policy" [ID13, End user- government].

One participant identified scenario planning as a particularly

valuable application of human dimensions research, because it facilitated the incorporation of futures thinking into policy and planning. For example, human dimensions research facilitated exploring questions such as, "...what does the community of 2050 look like? And how do they value the reef or what's going to change in that time" [ID10, End user - government]. Only a few participants, predominantly researchers, recognised the potential role for social science in informing decision-making processes and to "provide useful information to drive adaptive management". For example: "It's mostly around decision science so how do you inform effective decisions once you've done the science? How do you interpret it to inform the best decisions?" [ID14, researcher].

Despite this narrative about increasing interest and use of human dimensions research, many participants expressed concern that this type of research is not valued "in the way that they value environmental science" and was "still relegated to a relatively small part of [science for management]". As stated by one government end-user:

"I think if I look across the full remit of all the data and monitoring that goes on in the reef... I'm not convinced we're turning that into management action" [ID10, End user – government].

One researcher pointed to a fundamental challenge that exists in the application of social science research in adaptive management which resonates with our argument about the challenge of adaptive management applied in a hard systems framing:

"the social sciences struggle because the first thing nearly all social scientists will say is that we need to consider the power relationships here. And that means you've got to actually genuinely start looking at sharing power in the way that you make decisions. And starting to build genuine partnerships to do things. That's where things get really messy because many decision makers will want to ignore that particular piece of very sound social advice ... that will tend to marginalise the social sciences back to providing technically recognisable widgets rather than genuine advice about absolutely changing power relationships so we get better outcomes" [ID25, researcher]

Whilst framed as a challenge about power relationships, this quote reflects that while adaptive management occurs through a hard systems approach that does not commence with all voices able to be heard (power sharing), social science will continue to produce technically recognisable widgets, that are on the side, tend to not be transferable across time and space, and require translation, rather than genuine advice.

5.3. Factors that influence the use of human dimensions research

In this section we examine factors that positively and negatively influence the use and impact of human dimensions research in Reef management decisions.

5.3.1. Compatibility with management processes

Some participants linked challenges with the use of human dimensions research to fundamental incompatibilities between human related data and existing management or reporting frameworks. One researcher outlined multiple aspects of this challenge, explaining that "I think there's a real gap in thinking about how to take good quality [social] science and actually turn it into something practical that can be used" [ID28, researcher]. Some of these challenges relate to temporal and spatial elements of the information. For example, "It's very difficult to get information in the manner that you need it in order to make timely decisions...it's very hard if you're making decisions on old information and things have changed quickly" [ID11, End user – government]. Regarding the spatial scale, participants noted that "resolution of a lot of social science data is not suitable for place-based questions and decision making...but you actually need a dual layer of human dimensions data to capture users and non-use appreciators – place-based data is critical"

[ID19, End-user – non-government].

5.3.2. Compatibility with different knowledge systems

Most of the discussion about compatibility with different knowledge systems focused on challenges integrating human dimensions research within reporting systems founded on biophysical sciences and associated data. This feedback came almost exclusively from end-users, from non-government participants and seemingly due to a perception that the outputs are narrative based and fundamentally different from "hard" biophysical science data. For example, "Definitely when we talk about the social dimension, it has to be done in a narrative...I think it actually makes for a great story, perhaps not for a report and definitely not for a ... dashboard" [ID15, End user – non-government]. This paradigmatic mismatch creates practical obstacles, as another participant noted, in relation to what information is included in reports: "our process would be to do an evaluation and rationale process for how an indicator represents...socioecological system health. And we just don't have enough there in that process to be able to select a [social] indicator to start processing some of this data through that indicator to put into the report card" [ID19, End user – non-government]. However, many participants spoke to strategies to better integrate social science and biophysical data: "[we] collect human dimensions data in a spatial platform and store it in a spatial representation so that we can integrate it and overlay it with environmental data" [ID19, End user – non-government].

5.3.3. Language and jargon

Communication of human dimensions research results was regularly commented on as a challenge for application in management decision making. Multiple participants identified fundamental difficulties stemming from disciplinary differences in language and conceptual frameworks. Social science terminology was perceived as particularly challenging for both natural scientists and managers: "I have to look up what half these words mean that you're throwing at me because this is completely left field language to what me, as a biophysical scientist is accustomed to" [ID13, End user – government] and "we always knew that human dimensions are really important, but a lot of the scientists that work in the regional report cards are hard scientists and not social scientists and plus social science is a totally different language and we don't have the knowledge and expertise to either collect that information in the right way or to interpret it" [ID20, End user – non government].

Given the 'language barriers', participants consistently identified the importance of improving "accessibility and digestibility of content" [ID30] and enabling "people from different backgrounds or disciplines to talk the same language" [ID12]. Participants highlighted the importance of translation, providing guidance on "how to interpret that information and how to share it back in a way that recognises how complex it is. But to make it simple enough that people go, oh, I get it" [ID16, End user – non-government]. There was some discussion about where the responsibility for effective translation lay. While many emphasised the need for communication using shared language, others recognised that investment in human dimensions research should incorporate necessary translation activities: "you also need the investment in the translational work, which we're not properly investing in and I frequently feel that there's this expectation that we can just keep doing the translational work for decision makers for free" [ID17, End-user – non government].

5.3.4. Access and availability

Participants described challenges when accessing and applying information: "I don't know what's available to me, and how it would be useful and where to find it, and how to incorporate it" [ID9, End user – government]. And "I would love to [use social science] more to be honest, but it is difficult to know and access what data is out there" [ID23, End user – government]. Participants called for "more awareness about where it is, how we can access it, and how we can interconnect with that information" [ID2, End user – government]. Others expressed a

need to better understand the information that sits behind the data "I want to understand the information that's being chosen to go into that model" [ID13, End user – government].

5.3.5. Closing the gap between data collection and actionable insights

A central challenge identified by participants was translating human dimensions research findings into actionable insights for management. Decision-makers consistently highlighted a critical "so what?" gap - struggling to understand what research findings mean for their specific management contexts and what concrete actions should follow. For example, "...What does that mean if people say that they perceive this certain thing, whatever it is, or they value tourism. So what? How does that relate to our basin [and its management]?" [ID19, End user – non-government]. Similarly, "we sometimes struggle with how we can use all of this information that comes out of this work to protect the reef and do what it can for the resilience of the social-ecological system as a whole" [ID11, End user –government].

In the theme of translation, participants identified synthesis documents and consolidated outputs as essential tools for bridging this research-practice gap, helping to distil complex findings into accessible, decision-relevant guidance.

"... individual pieces of research are helpful at the right scale, but at the policy and strategy scale, synthesis is important" [ID7, End user –government].

"It'd be great to think about how these [social science] programs are shared. Is there scope to do a snapshot that celebrates the work and makes ... it easier for people to tap into" [ID16, End user – non-government].

One government participant emphasised the need for "explicit clear advice" rather than "general trend data" [ID3, End user - government]. However, another participant noted the potential trade-offs related to producing highly synthesised outputs: "Because then you're always just skating over the surface, and a lot of science is intricate and has depth and the depth matters" [ID9, End user –government].

5.3.6. Integration and embedding

Interviewees identified a range of approaches to support or enable the improved use of human dimensions research for Reef management. For example, many participants highlighted the importance of collaboration and effective partnerships between researchers and decision makers and that the need for collaboration was: "... a real willingness of people on both sides to achieve something that is meaningful, not just to tick a box and get the project done" [ID12, End user –government]. Co-design processes were identified as particularly effective for fostering collaboration but needed clear objectives to be successful: "I think a process of co-design is really useful, but it requires the participants being able to come to the table and clearly articulate...what's needed" [ID30, End user - government].

There are already examples of successful integration and embeddedness with dedicated knowledge brokers focussing on translation. For example: "What we ended up doing was putting in a dedicated research translation person that was appointed between 3 organisations... as a result, support for this research has grown and grown" [ID14, non-social science researcher]. Having genuine partnerships was also highlighted as an element to achieve integration "I want [to see] a genuine partnership and relationship so that you can govern the issues that you need to manage well and that type of partnership needs to be evidence based and strongly driven by science and shared knowledge as well" [ID25, researcher].

5.3.7. Futures thinking

Participants emphasised the critical importance of incorporating futures thinking into social science to ensure Reef management remains relevant and effective over time. Several participants highlighted the

need for more forward-looking approaches that move beyond current monitoring frameworks to anticipate future challenges and opportunities. This approach was also acknowledged as having potential to resolve spatial and temporal challenges of information and policy decisions.

Participants stressed that effective social science requires clear articulation of future management priorities and how human dimensions research can inform these goals. As one researcher suggested, the ideal approach is bringing "scientists and managers [together] in the same room workshopping priorities going forward and figuring out what's the best way to get there" [ID29, Research]. This approach to priority setting was seen as essential, with government representative noting that "it's about the objective setting. So, if we're clear on the objective and we know what we want to get out of it then we can monitor it and see whether we're making an improvement or not" [ID10, End-user government].

However, participants also acknowledged institutional barriers that complicate futures-oriented planning. Government participants recognised the challenge of articulating "burning questions at the top of the pile" to help researchers "design the initiatives in the programmes, the data collection processes and the reporting outputs that meet those needs" [ID30, End user - government]. Essentially, there was some concern that the gaps between research and policy could undermine the effectiveness of forward-looking social science approaches.

6. Discussion and conclusion

Our findings indicate that while participants widely recognised Reef management as fundamentally a 'people problem', familiarity with human dimensions research varied considerably, with many, including both government and non-government end-users, reporting limited awareness and feelings of 'uncertainty'. Even then, respondents who did engage with human dimensions research applied it to communication, stakeholder engagement, and monitoring and evaluation, with fewer examples of integration into strategic planning or decision-making processes. Several barriers to integration were identified. These were incompatibilities between outputs and existing reporting frameworks designed for quantitative biophysical data; disciplinary differences in language and terminology; fragmented and inaccessible research outputs; and a gap in translating findings into actionable, management insights. Despite these challenges, some respondents identified enabling factors to the use of human dimensions research. These included recognising the value of narrative and storytelling for influencing change and the potential for embedded, co-designed research partnerships between social scientists and reef managers. However, these findings also reveal a fundamental tension: while social science is valued in principle, its integration reflects a hard systems approach - functioning as support within largely biophysically defined frameworks rather than shaping how problems are defined and decisions are made. It was promising, however, to hear that co-designed, embedded partnerships were identified as a pathway forward, suggesting a desire for soft systems approaches that position social science leading the adaptive management cycle.

In this paper, we argue that prevailing 'hard systems' orientations contribute to the ongoing underutilisation of human dimensions research for Reef management. And, when guided by a hard systems approach, social, political and cultural dimensions of the problem remain external to the problem framing and the spectrum of solutions considered. In a hard systems approach social science remains relegated to providing the narrative to accompany biophysical data with calls by biophysical scientists and decision makers for science translation (left side of Fig. 1). Nonetheless, our findings do suggest a growing appetite for, and the beginnings of, a transition toward a 'soft systems' paradigm for adaptive management of the Reef. For example, the 2024 Great Barrier Reef Outlook Report leads with discussion on the human dimensions of the Reef and commits to this rhetoric by presenting all

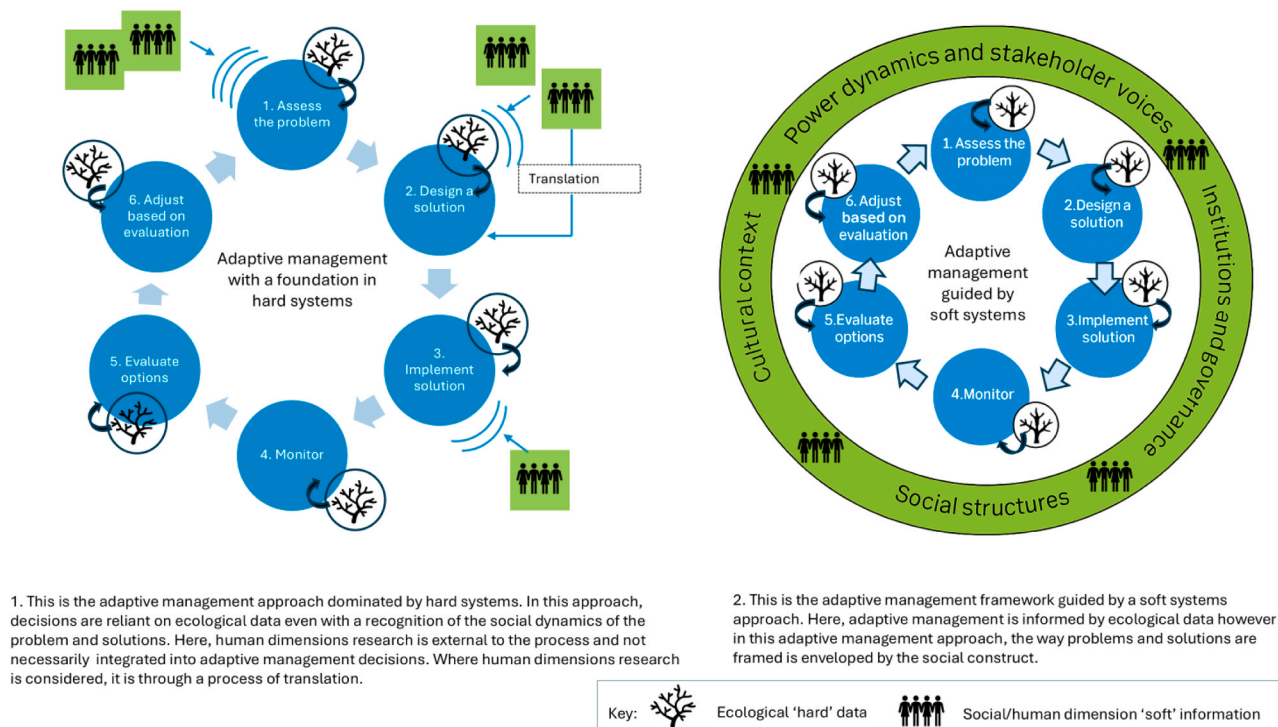


Fig. 1. A visual depiction of adaptive management based on hard systems compared with one based on soft systems.

biophysical monitoring results in a socio-ecological construct, rather than the other way around; [44]. Further, others note arrangements of multi-layered governance in the Reef, facilitating and adapting to feedback [45], understanding this and capturing growth in this space is now supported following the development of monitoring toolkits to track trends in governance health [46]. More recently, and broader than the Reef, Sbrcchi et al. [20] led the first dedicated social science white paper in a series informing the National Marine Science Committee new national decadal plan 2025-2035 and Steins et al. [24] call to the international community to make the practice of situating marine science advice within social, cultural, economic and political realities, the business as usual approach. These papers identify many of the same challenges surfaced by our Reef specific research and highlight a similar future pathway for facilitating greater leadership from social science in marine systems management.

So how can the conduct and integration of human dimensions research into Reef management specifically, or the management of complex systems through better integration of soft and hard systems approaches more broadly, be advanced? Based on the interviews and the reviewed literature, we suggest the following next steps.

- i) **Redefine what is meant by 'human dimensions' in the Reef context.** The current framing of human dimensions - people's connections to and benefits derived from the Reef - reinforces the position of social science as a descriptive input and supports the continued view that social science provides the 'technically recognisable widgets' into adaptive management driven by a biophysical paradigm. We propose a change to the definition of human dimensions into the Reef 2050 Plan. We propose the definition: human dimensions of Reef management encompass the complex, dynamic, and reciprocal relationships between people and the Great Barrier Reef, recognising people as both a component of an integrated socio-ecological system and managers of that system, shaping both decisions and outcomes. Changing this definition in the Reef Plan, the centrepiece for all Reef research, would signal a shift from the view that the Reef is a biophysical problem to solve to recognising the many voices that

have value when considering the challenges faced by the Reef and recognising that adaptively managing the Reef is a socially constructed 'situation' open to insight from biophysical and social science.

- ii) **Make explicit the values and ethical judgements embedded in how Reef problems and 'good' outcomes are defined.** While Reef plans and strategies increasingly adopt socio-ecological language, problems are still largely framed as biophysical, carrying implicit and rarely surfaced assumptions about what counts as a healthy or successful Reef and whose interests are reflected. Government lead agencies (e.g., the Reef Authority and DCCEEW) can require these value judgements to be stated openly in framing documents and decision processes. As Partelow et al. [47] note, ethical considerations must be made explicit rather than assumed and may "require us to expand our notion of what constitutes 'right' and 'good' based on a grounded understanding of local ethics".
- iii) **Government invest in trialling, monitoring, improving and engaging in long term place-based, integrated and co-designed approaches** to Reef adaptive management, where managers, researchers (both social and biophysical), and communities jointly frame problems and design responses. Not only will this approach distribute power across all stakeholders in decision-making but will also improve the availability of data, overcome institutional barriers to forming solutions and reduce the need for science translation. When research is embedded in local context from the outset, the persistent barriers of jargon, silos, institutions and mismatched scales are addressed by design rather than retrofit.
- iv) **Invest in futures thinking when framing challenges and understanding the spectrum of solutions for Reef management.** This will align human dimensions research with marine conservation in a global context (see United Nations Environment Program [48] enabling improved alignment between spatial and temporal data for forecasting needs. Futures thinking would also aid the integration of hard and soft systems to build capacity and facilitate a national and integrated transdisciplinary dialogue to

support addressing socio-ecological challenges. This is also put forward by Lentz et al. [49] in relation to coastal systems and climate change and in the National Marine Science Strategy white paper released by Sbrocchi et al. [20].

- v) **Government prioritise monitoring and improving the adaptive management system itself** [46] recognising that improvement and learning within soft systems occurs through structured and social science-led inquiry.

Collectively, these recommendations will begin to address the systemic barriers faced by human dimensions research identified in our findings. Specifically, a transdisciplinary approach to problem framing, combined with embedded research, has the potential to address the persistent question of "so what?" faced by human dimensions approaches. When social scientists and managers jointly define challenges and explore solutions, relevance is built in rather than retrofitted. Additionally, sharing power in decision-making will help overcome a historical legacy of relegating the social sciences to narrative and communication roles, instead positioning them to shape how problems are understood and decisions are made. These shifts would move Reef management away from attempting to fit social science into frameworks designed for biophysical data (left side of Fig. 1) toward approaches that treat social and ecological dimensions as interconnected from the outset (right side of Fig. 1). This is not merely a methodological refinement requiring slight tweaks in the way management is done; it is a necessary reorientation to recognise and manage the Great Barrier Reef as a socio-ecological system. Management approaches that fail to recognise this, and fail to foreground the social sciences, will continue to fall short. Our recommendation to shift to a soft systems approach offers a more realistic foundation for adaptive management precisely because it reflects what the Reef actually is: a socio-ecological system in which people are both a component of the system and managers of it - simultaneously shaped by the Reef and shaping decisions and outcomes for the Reef.

CRedit authorship contribution statement

Anthea Coggan: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tracy Shultz:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michelle Dyer:** Writing – review & editing, Methodology, Investigation, Formal analysis, Conceptualization. **Smantha Stone-Jovicich:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation. **Maxine Newlands:** Writing – review & editing, Writing – original draft, Validation, Formal analysis. **Clemence Belgnaoui:** Writing – original draft, Investigation, Formal analysis, Data curation. **Angela Dean:** Writing – review & editing, Writing – original draft, Validation, Formal analysis, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Microsoft CoPilot for assistance in generating Fig. 1. The author(s) reviewed and edited the output as needed and take full responsibility for the content of the published article.

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Data availability

The authors do not have permission to share data.

References

- [1] Commonwealth of Australia. (2021). Reef 2050 Long-Term Sustainability Plan. Department of Agriculture, Water and the Environment. Retrieved from <http://www.gbrmpa.gov.au/our-work/reef-strategies/reef-2050>.
- [2] Deloitte Access Economics At what cost? Safeguarding the Great Barrier Reef's role in Australia's economy. Retrieved from Brisbane 2025.
- [3] Australian Government Department of Climate Change, Energy, the Environment and Water (2025). Our Investments. Retrieved from <https://www.dcccew.gov.au/parks-heritage/great-barrier-reef/protecting/our-investments>.
- [4] Great Barrier Reef Marine Park Authority (2024). Great Barrier Reef Outlook Report 2024.
- [5] J. Waterhouse M.-C. Pineda K. Sambrook M. Newlands L. McKenzie A. Davies M. Devlin Land-based impacts on Great Barrier Reef water quality and ecosystem condition 2022 Scientific Consensus Statement Summary 2022.
- [6] A.K. Spalding, E. McKinley, The State of Marine Social Science: Yesterday, Today, and into the Future, *Annu. Rev. Mar. Sci.* 17 (2025) 143–165, <https://doi.org/10.1146/annurev-marine-121422-015345>.
- [7] Cintron-Molero, G., Schaeffer-Novelli, Y., Abuchahla, G.M. d O., & Rovai, A.S. (2023). Coastal Zone Adaptive Management in the Context of Complex Adaptive Systems. In Y. Schaeffer-Novelli, G. M. D. Abuchahla, & G. Cintron-Molero (Eds.), *Brazilian Mangroves and Salt Marshes* (pp. 381–392).
- [8] L.X.C. Dutra, R.H. Bustamante, I. Sporne, I. van Putten, C.M. Dichmont, E. Ligtermoet, R.A. Deng, Organizational drivers that strengthen adaptive capacity in the coastal zone of Australia, *Ocean. & Coast. Manag.* 109 (2015) 64–76, <https://doi.org/10.1016/j.ocecoaman.2015.02.008>.
- [9] J. Fischer, T.A. Gardner, E.M. Bennett, P. Balvanera, R. Biggs, S. Carpenter, J. Tenhunen, Advancing sustainability through mainstreaming a social-ecological systems perspective, *Curr. Opin. Environ. Sustain.* 14 (2015) 144–149, <https://doi.org/10.1016/j.cosust.2015.06.002>.
- [10] M. Gooch, M. Curnock, A. Dale, J. Gibson, R. Hill, N. Marshall, K. Vella, Assessment and promotion of the Great Barrier Reef's Human Dimensions through collaboration, *Coast. Manag.* 45 (6) (2017) 519–537.
- [11] E. Khodaparast, F. Eshaghi, H. Darabi, H. Azadi, Bridging Social and Ecological Dynamics: A Comprehensive Scientometric Analysis of Social-Ecological Systems Research, *Int. J. Environ. Res.* 19 (4) (2025), <https://doi.org/10.1007/s41742-025-00802-x>.
- [12] K. Zoeller, G.C. Cumming, Towards an integrated framework for understanding social-ecological interactions: nature's contributions to people meets cultural ecosystem services, *Ecosyst. People* 20 (1) (2024).
- [13] L. Crase, B. Cooper, M. Burton, L. Baumgartner, N. Ning, Adaptive management: are important environmental concepts understood and valued by the public? *Australas. J. Environ. Manag.* 31 (3) (2024) 362–377.
- [14] G. Cundill, G.S. Cumming, D. Biggs, C. Fabricius, Soft Systems Thinking and Social Learning for Adaptive Management, *Conserv. Biol.* 26 (1) (2012) 13–20, <https://doi.org/10.1111/j.1523-1739.2011.01755.x>.
- [15] C.S. Holling, *Adaptive Environmental Assessment and Management*, John Wiley and Sons, London, 1978.
- [16] N.J. Bennett, R. Roth, Realizing the transformative potential of conservation through the social sciences, arts and humanities, *Biol. Conserv.* 229 (2019) A6–A8, <https://doi.org/10.1016/j.biocon.2018.07.023>.
- [17] R. Dacks, S. Yadav, A. Mawyer, Emerging human dimensions research in coastal and nearshore Oceania, *Conserv. Biol.* 39 (2) (2025) e14455, <https://doi.org/10.1111/cobi.14455>.
- [18] A.M. Guerrero, N.J. Bennett, K.A. Wilson, N. Carter, D. Gill, M. Mills, A. Nuno, Achieving the promise of integration in social-ecological research: a review and prospectus, *Ecol. Soc.* 23 (3) (2018), <https://doi.org/10.5751/es-10232-230338>.
- [19] K. Massarella, A. Nygren, R. Fletcher, B. Buscher, W.A. Kiwango, S. Komi, A. R. Percequillo, Transformation beyond conservation: how critical social science can contribute to a radical new agenda in biodiversity conservation, *Curr. Opin. Environ. Sustain.* 49 (2021) 79–87, <https://doi.org/10.1016/j.cosust.2021.03.005>.
- [20] C. Sbrocchi, E. Ogier, P. Fidelman, K. Barclay, A. Diedrich, M. Dyer, M. Voyer, Social Science for Meeting Australia's Ocean Goals. White Paper submitted for input to the 2025–2035, National Marine Science Plan, Hobart, 2025.
- [21] B. Williams, E. Brown, Adaptive management: From talk to real action, *Environ. Manag.* 53 (2014) 465–479.
- [22] J. Conallin, J. Campbell, L. Baumgartner, Using Strategic Adaptive Management to Facilitate Implementation of Environmental Flow Programs in Complex Social-Ecological Systems, *Environ. Manag.* 62 (2018) 955–967.
- [23] K. Foxwell-Norton, Environmental or Ecological Communication? Lessons (too late) from the Great Barrier Reef, *Environ. Commun.* (2025).
- [24] N.A. Steins, P.M. Clay, M. Ballesteros, D.J. Dankel, N. Furmanek, P. Ramírez-Monsalve, O. Thébaud, Breaking with business as usual to integrate human dimensions research in ICES science and advice, *Ices J. Mar. Sci.* 83 (8) (2026), <https://doi.org/10.1093/icesjms/fsag152>.

- [25] S. Lockie, H.A. Bartelet, B.W. Ritchie, C. Demeter, B. Taylor, L. Sie, Australians support multi-pronged action to build ecosystem resilience in the Great Barrier Reef, *Biol. Conserv.* 299 (2024) 110789.
- [26] G. Paxton, S. Lockie, V. Backhaus, Articulating futures: Community storylines and assisted ecosystem adaptation in the Great Barrier Reef, *Environ. Sci. & Policy* 162 (2024), <https://doi.org/10.1016/j.envsci.2024.103944>.
- [27] N.J. Bennett, R. Roth, S.C. Klain, K.M.A. Chan, D.A. Clark, G. Cullman, D. Verissimo, Mainstreaming the social sciences in conservation, *Conserv. Biol.* 31 (1) (2017) 56–66, <https://doi.org/10.1111/cobi.12788>.
- [28] Australian Government. (2021). Reef 2050 Long-Term Sustainability Plan 2021–25. Commonwealth Department of Agriculture, Water and Environment, Canberra. Canberra Retrieved from <https://www.awe.gov.au/parksheritage/great-barrier-reef/long-term-sustainability-plan>.
- [29] L. Diaz-Pinzon, L. Sierra, F. Trillas, J., M. Verd, The social-ecological system framework of urban wetlands: the role of collective management at local level, *Int. J. Commons* 18 (1) (2024) 649–669.
- [30] N. Ho, A review of coastal resources co-management in Southeast Asia, in: C. Baldwin, S. van Bommel (Eds.), *Rural Development for Sustainable Social-ecological Systems*, Springer Nature, Switzerland, 2023.
- [31] P.N. Dudley, T.L. Rogers, M.M. Morales, A.D. Stoltz, C.J. Sheridan, A.K. Beulke, M. H. Carr, A More Comprehensive Climate Vulnerability Assessment Framework for Fisheries Social-Ecological Systems, *Front. Mar. Sci.* 8 (2021) 2021, <https://doi.org/10.3389/fmars.2021.678099>.
- [32] S. Teixeira, R. Getting the priorities right: stakeholders' involvement for a holistic view of research and extension needs in the Australian and Brazilian dairy industry, in: C. Baldwin, S. van Bommel (Eds.), *Rural development for sustainable socio-ecological systems. Putting communities first.*, Springer Nature, Switzerland, 2023.
- [33] J. Alexandra, Evolving Governance and Contested Water Reforms in Australia's Murray Darling Basin, *Water* 10 (2) (2018), <https://doi.org/10.3390/w10020113>.
- [34] S.L. Mahajan, L. Glew, E. Rieder, G. Ahmadi, E. Darling, H.E. Fox, M. McKinnon, Systems thinking for planning and evaluating conservation interventions, *Conserv. Sci. Pract.* 1 (7) (2019), <https://doi.org/10.1111/csp2.44>.
- [35] J. Birkinshaw, T. Bansal, Why you need systems thinking now, *Harv. Bus. Rev.* (2025).
- [36] P. Checkland, Soft systems methodology: A thirty year retrospective, *Syst. Res. Behav. Sci.* 17 (2000) S11–S58, [https://doi.org/10.1002/1099-1743\(200011\)17:1+<::Aid-sres374>3.3.Co;2-f](https://doi.org/10.1002/1099-1743(200011)17:1+<::Aid-sres374>3.3.Co;2-f).
- [37] M.C. Jackson. *Systems Thinking: Creative Holism for Managers*, 1 ed., Wiley, 2003.
- [38] M. Jackson, *Hard Systems Thinking*, in: In.M. Jackson (Ed.), *Systems Methodology for the Management Sciences*, Springer Nature, 1991.
- [39] N. Voulvoulis, T. Giakoumis, C.A. Hunt, V. Kioupi, N. Petrou, I. Souliotis, W. binti Wan Rosely, Systems thinking as a paradigm shift for sustainability transformation, *Glob. Environ. Change* 75 (2022) (2022).
- [40] Great Barrier Reef Marine Park Authority Priority Monitoring Gaps Prospectus: Reef 2050 Integrated Monitoring and Reporting Program. Retrieved from Townsville 2021.
- [41] K. Moon, D. Blackman, A Guide to Understanding Social Science Research for Natural Scientists, *Conserv. Biol.* 28 (2014) 1167–1177.
- [42] P. Biernacki, D. Waldorf, Snowball sampling: Problems and techniques of chain referral sampling, *Sociol. Methods Res.* 10 (2) (1981) 141–163.
- [43] V. Braun, V. Clarke, Using thematic analysis in psychology, *Qual. Res. Psychol.* 3 (2) (2006) 77–101, <https://doi.org/10.1191/1478088706qp0630a>.
- [44] Great Barrier Reef Marine Park Authority, Great Barrier Reef Outlook Report, Reef Authority, Townsville, 2024.
- [45] L.S. Evans, N.C. Ban, M. Schoon, M. Nenadovic, Keeping the 'Great' in Great Barrier Reef: Large scale governance of the Great Barrier Reef Marine Park, *Int. J. Commons* 8 (2) (2014) 396–427.
- [46] K. Vella, A. Dale, M. Gooch, D. Calibeo, M. Limb, R. Eberhard, U. Baresi, Deep Deliberation to Enhance Analysis of Complex Governance Systems: Reflecting on the Great Barrier Reef Experience, *Sustainability* 17 (15) (2025), <https://doi.org/10.3390/su17156911>.
- [47] S. Partelow, A. Schlüter, N.C. Ban, S. Batterbury, M. Bavinck, N.J. Bennett, R. Bleischwitz, J. Blythe, T. Bogusz, A. Breckwoldt, J.E. Cinner, M. Glaser, H. Govan, R. Gruby, V. Hatje, A.-K. Hornidge, G.K. Hovelsrud, J.N. Kittinger, L. C. Kluger, S. Kochalski, A. Mawyer, E. McKinley, J. Olsen, J. Pittman, M. Riechers, M.-C. Riekhof, K.S. Manez, R.J. Shellok, R. Siriwardane-de Zoysa, N.A. Steins, K. Van Assche, S. Villasante, Five social science intervention areas for ocean sustainability initiatives, *npj Ocean Sustainability* 2 (1) (2023) 24, <https://doi.org/10.1038/s44183-023-00032-8>, <https://www.nature.com/articles/s44183-023-00032-8>.
- [48] United Nations Environment Program. (2024). Navigating New Horizons: A globalforesight report on planetary health and human wellbeing. Retrieved from Nairobi: URL: <https://www.unep.org/resources/global-foresight-report>.
- [49] E.E. Lentz, D.L. Passeri, S.L. Zeigler, K. White, T. Wahl, A.D. Stoltz, C.A. Buckel, Challenges and Opportunities for National-Scale Projections of Future Coastal Landscape Change, *Earths Future* 14 (4) (2026) e2024EF005833, <https://doi.org/10.1029/2024EF005833>.