

Review

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Social innovation that connects people to coasts in the Anthropocene

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Abstract

Post-industrial society is driving global environmental change, which is a challenge for all generations, current and future. The Anthropocene is the geological epoch in which humans dominate and it is rooted in the past, present, and future. Future sustainability is building on the momentum of the fundamental importance of studying human dynamics and governance of coupled social and ecological systems. In the Anthropocene, social innovation may play a critical role in achieving new pathways to sustainability. This conventional narrative review uses a qualitative analysis anchored in the Grounded Theory Method and a systematic collection and analysis of papers to identify broad types of social innovations. Scientific journal articles published since 2018 were prioritised for inclusion. The six types of social innovation proposed are (a) authentic engagement; (b) artful and engaging communication; (c) urging and compelling change; (d) governance for social-ecological systems; (e) anticipation in governance; and (f) lived experiences and values. The six innovations proposed in this paper can be embedded within, and form part of, social action using a science–society compact for the sustainable development of coasts in the Anthropocene.

Impact statement

This paper reflects on the need for sustainability of the coasts in the Anthropocene. It considers the increasing need for science to engage with society to achieve sustainable coastal futures. In the human-dominated system of the future, fact, or scientific evidence alone is not sufficient for society to adapt and transform towards higher degrees of sustainability. We propose that there are interventions and actions at the science–society interface that are needed to enable such higher degrees of sustainability. The paper identifies six social innovations knowable through the scientific literature that have the potential to substantially increase the ability of society to transform to coastal sustainability. These six social innovations are also critical for enabling the achievement of the UN Sustainable Development Goals. The six innovations proposed in this paper can be bound together with social action and interest in a new science–society compact for sustainable coasts in the Anthropocene.

Introduction

Post-industrial society has had a profound impact on the state of the planet, and living with global environmental change is a challenge for all generations, current and future. In an astoundingly short period of two centuries, human activities have caused the climate to change. This change is resulting in impacts from both slow onset changes and extreme events across the Earth system (see, e.g., Steffen et al., 2018; Folke et al., 2021). A new geological epoch was started, referred to as the Anthropocene, in which humans dominate the natural system. The Anthropocene is rooted in both the past and the present, but the concept of thresholds and tipping points (Rockström et al., 2009; Nash et al., 2017; McLaughlin, 2018; Turner et al., 2020), in a changing climate, makes this geological epoch more a matter of trajectories of change, and the state of the future (Bai et al., 2016). The world is changing faster than people recall, have lived, or are willing to accept. Science tells of major change to be expected, with dire warnings of impacts on human well-being (IPCC reports, media reporting on UNFCCC CoP, etc.). Where, in the past, we may have heard stories of the “good old days”, the stories we are now likely to tell are framed by the uncertainty of the future and the well-being of future generations.

Recent scientific literature reflects on the meaning and relevance of the future (of humanity) for virtually all aspects of human existence as part of social-ecological systems (also known as coupled human-natural systems and complex adaptive systems) (Hulme, 2020; Wyborn et al.,

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2020; Folke et al., 2021). In a sense, the contemporary desire for societal transformation towards sustainability is explicitly about the future of humanity. This has become a scientific currency with which to purchase leverage for change at a systemic scale (e.g., IPCC reports, and IPBES knowledge products). The UN Sustainable Development Goals (SDGs) are a product of Anthropocene-related thinking and an expression of the aspiration to collectively achieve desirable sustainable futures. Future sustainability (e.g., as expressed by the achievement of the SDGs by 2030) is increasingly understood to be possible only through human dynamics and governance of social-ecological systems (Biermann et al., 2016; Lindkvist et al., 2022).

This emphasis on futures is also relevant and important to oceans and coasts in the Anthropocene. Even without additional climate change impacts, coastal areas are highly dynamic bio-physical systems (at the land–ocean–atmosphere interface) that are constantly being reshaped by natural forces and human activities (Neumann et al., 2015; Newton et al., 2016; He and Silliman, 2019; Kopp et al., 2019). Coasts offer access to resources, both on land and in the ocean, attract people, human settlement, and economic and recreational activities while also being disproportionately affected by climate change (Barnard et al., 2021; Defeo and Elliott, 2021; IPCC, 2022). The importance of coasts and oceans is evidenced by the articulation of the SDGs (Neumann et al., 2017; Haas et al., 2021) and the UN Decade of Ocean Science, among other efforts.

The voice of science on the possible future states of the planet has become prominent, and with science – data, information, and knowledge – it is also possible to create a relationship (a story) between people and the state of the future coast. This relationship between people and place requires intangible elements such as trust, agreement, and values (Lacey et al., 2017; Pulkkinen et al., 2022), essential components of connection, and creates an incubator for social innovation. Social innovation is any action by individuals, organisations, and networks to generate novel solutions that contribute to changing behaviour across numerous perspectives, across markets and public sectors, and to enhancing bottom-up responsible inventiveness (Olsson et al., 2017; Soma et al., 2018). It has been suggested that within the context of the Anthropocene, social innovations may play a critical role in achieving new pathways to sustainability (Olsson et al., 2017).

The objective of this review paper was to *identify types of social innovation that are fundamental for establishing and maintaining the connection between people and the coast, which could result in achieving higher degrees of sustainability, now and in the future*. We identify social innovations by assessing recent literature on a broad range of topics including transdisciplinary knowledge co-production, human dynamics related to science–society interactions, anthropology, governance systems and legislation. We also propose that social innovations are essential for achieving the SDGs. We suggest a scheme of types of social innovation and how they relate to the SDGs. While we recognise that the impacts of social innovation can be both positive and negative, we focus on its positive impacts. We conclude by proposing that social innovation become part of a new social mandate or science–society compact for achieving coastal sustainability.

Methods

We use a qualitative analysis anchored in the Grounded Theory Method (Glaser and Strauss, 2017) to identify broad types of social

innovation from the literature. The steps of Grounded Theory include research design, data collection, data ordering, data analysis, and literature comparison. Data (concepts and theory in scientific literature) were collected using purposive sampling that allowed us to inductively identify social innovations. The social innovations that were included were knowable through scientific literature. The outcome of the methodology is presented as a conventional narrative review.

Literature was identified by (1) date range, and by (2) keywords and phrases from bibliographic databases including Scopus and Web of Science. Articles published from 2018 to June 2022 and listed in bibliographic databases were prioritised for inclusion (82% of the 113 references used in this paper). Very recently published literature was prioritised to demonstrate the rapidly increasing emphasis on social innovation to enable sustainability. We also used discretionary search methods such as reference list checking. We did not undertake a systematic review, and search terms (e.g., coast*; OR ocean*; OR marine; AND future; sustainability, climate change, social-ecological) were used as an initial filter to find other papers and branches of inquiry and interest in a snowball sampling approach, which is suitable for the exploratory approach taken here. Grey literature was not considered.

Publications included in the review for the elements identified, for example, legislation, climate change and coasts, are considered indicative of trends in the scientific literature (inclusive of natural and social sciences). Our approach assumes a connection between the coastal land, ocean, and atmosphere as a complex coastal social-ecological system, which provides cross-disciplinary insight into complex environmental problems (Refugio-Coronado et al., 2021). Thus, we included papers that have either a coastal or ocean focus, or both. In some instances, papers from other domains, for example, climate change, or not explicitly related to the coast or ocean were also included if they were deemed to indicate a particularly important and relevant trend.

Social innovation for sustainability

The social innovations identified here are not suggested to be discreet from one another and the overlap between them is expected and a positive trait. They can enable a positive relationship between people and the coast, and create conditions that may enable positive transformation towards sustainability. The six types of social innovation are (a) authentic engagement; (b) artful and engaging communication; (c) urging and compelling change; (d) governance for social-ecological systems; (e) anticipation in governance; (f) and, lived experiences and values. We provide some examples of social innovations with a positive impact on the sustainability of Anthropocene coasts in Table 1.

Authentic engagement

Authentic engagement to achieve coastal sustainability is an openness to engage among, and broaden the participation of, people, organisations, government, business sectors and multiple scientific disciplines. It is as much a mindset as it is an approach. The nature of the engagement breaks down power differences, aims to establish trust and acknowledges the value of different knowledge types, among others. For example, *transdisciplinarity* is appropriate for a society that is aiming to transform to higher degrees of sustainability (e.g., McKinley et al., 2021), as is the constellation of “co”-concepts (–design, –creation, –production,

Table 1. Examples of social innovations that facilitate the connection of people to the coast to achieve higher degrees of sustainability

Examples of social innovations with positive impact
Authentic engagement • Extensive and deliberate stakeholder engagement embedded in the scientific process (Kopp et al., 2019). • Citizen science methodologies coupled with transdisciplinarity (Agnew et al., 2022). • Negotiation of knowledge (Celliers et al., 2021). • Knowledge diversity and integration of values (Dam Lam et al., 2019; Stori et al., 2019).
Artful and engaging communication • Ocean futures and science fiction prototyping of scenarios (Merrie et al., 2018). • Story-based approaches (Vollstedt et al., 2021). • Evolution of art-science collaboration (Paterson et al., 2020; Strand et al., 2022).
Urging and compelling change • Evolving land–ocean interactions to incorporate the nature of coastal social-ecological systems (Schlüter et al., 2020; Van Assche et al., 2020). • Sector-specific policies and legislation (Galdies et al., 2020); or, spatially explicit interdisciplinarity (Reiblich et al., 2019). • Moral suasion, peer pressure or nudging (Vince and Hardesty, 2018), especially where legislation is less effective (da Costa et al., 2020).
Governance for social-ecological systems • Cohesive land–ocean governance systems, e.g., social-ecological systems approach, ecosystem-based management (EBM), integrated management, Integrated Coastal Management (ICM), Marine Spatial Planning (MSP), participatory co-management, and the precautionary approach (Stephenson et al. (2021) • Alignment of governance actors across institutional scales and sectors to account for interdependencies among coastal system elements as well as SDGs (Singh et al., 2021). • Policy integration in coastal governance (Harvey and Clarke, 2019; Van Assche et al., 2020). • Inseparability of coastal and ocean communities (Werle et al., 2018).
Anticipation in governance • Higher degrees of engagement and to develop shared and common understandings, practices, or visions about the future (Planque et al., 2019). • Stakeholder engagement, alternative futures modelling frameworks (Lipiec et al., 2018). • Structured collaborative conversations (Lund, 2021).
Lived experiences and values • Providing theoretical and ethnographic insights (Aswani et al., 2018; Gerkenmeier et al., 2018; Aswani, 2020). • Transdisciplinary development and community-led projects (Tsatsaros et al., 2021). • Enabling local environmental stewardship (Bennett et al., 2018). • Localising SDGs by linking to local experiences, priorities and understandings of well-being (Sterling et al., 2020). • High levels of personal connection may help managers to enhance public support for protecting climate-sensitive systems (Goldberg et al., 2016).

etc.) that are linked to a transdisciplinary approach (Norström et al., 2020; Chambers et al., 2022). It also aims to change the way research is done within society, by breaking down disciplinary “comfort zones” between natural sciences and humanities, as well as among sectors of society (Guillotreau et al., 2020). Authentic engagement creates active, even rightful, roles for society in knowledge production (Albagli and Iwama, 2022), and increases the likelihood for sustainability transitions to be equitable and just (Bennett et al., 2019).

Artful and engaging communication

There is no one-size-fits-all solution for communicating the outcome of science and making people part of the conversation on solutions for sustainability (Bentz et al., 2021). Visualising the three-dimensionality of the coast (both wet and dry) requires a combination of cultural local knowledge, artistic science and scientifically inspired art. Furthermore, this multidimensionality of the coast is highly dynamic in the short- and longer term. For example, art-based approaches routed in the social-cultural contexts can activate the human imagination and promote collaboration across disciplines (Galafassi et al., 2018; Tosca et al., 2021). Story-telling, narratives, and dialogues deepen learning, reduce ambiguity, and focus on hybridity, sense-making and the potential for transdisciplinary research to generate shared meaning and foster agency (Galafassi et al., 2018; Kelly et al., 2020; Vanderlinden et al., 2020). The use of, for example, narrative scenarios may function as accessible communication tools that

aim to foster anticipatory governance capacity (Spijkers et al., 2021).

Urging and compelling change

Behavioural change may be compelled through the institutionalisation of policy, legislation, and regulations. Humans function better if their actions are bounded (Kotzé and French, 2021), and enforceable (legal) boundaries set limits that are meant to achieve, maintain and/or return us to what is perceived to be a desired condition or critical service. Governance systems with institutionalised boundaries must be able to provide guarantees to secure such services (Jentoft, 2007). Legal and institutional structures can fundamentally shape the adaptive governance of environmental resources at multiple ecological and societal scales (DeCaro et al., 2017). Second, the role of social media and social learning, and moral and ethical suasion (i.e., the ability to persuade) of people, organisations and institutions, are opportunities for socially driven solutions for changing behaviour. They may be of particular relevance where the benefits of the use of legislation are less clear, or where the wielders of ethical suasion hold little practical power other than to influence situations in a positive or negative direction through persuasiveness (see, e.g., Bos et al., 2020).

Governance for social-ecological systems

Social innovations in governance include the role of authentic engagement and communication as described above. It implies a

higher degree of engagement and demands processes of co-creation and implementation of improved, comprehensive, and integrated management plans, enhancement of decision-making processes, and better anticipation and consideration of ambiguity and uncertainty (Haas *et al.*, 2021). The potential for social innovation includes the design of governance systems that combines poly-centric, multi-level, networked governance systems (Partelow *et al.*, 2020) with authentic engagement. It reconceptualises coastal management “units” that reflect social-ecological units, that is, across the land–ocean interface (see Harvey and Clarke, 2019), as opposed to purely administrative units.

Anticipation in governance

Purposeful and practical anticipation, and the expertise to do so, has become an indispensable core ingredient of contemporary attempts to govern complex problems (Aykut *et al.*, 2019). For example, anticipatory climate governance is understood to mean the evolution of steering mechanisms in the present to adapt to and/or shape uncertain climate futures (Vervoort and Gupta, 2018). This means drawing on conceptions of the future and considering implications for the present (Muiderman *et al.*, 2020). Anticipating future changes in coastal-ocean systems is a substantial challenge for coastal governance, but also essential in the context of accelerating global change. Adaptive management mechanisms such as integrated coastal management (ICM) and ecosystem-based management (EBM) are both approaches that accommodate the dynamic nature of a system. The question arises whether or not, given the role of politics and bureaucracy, the policy implementation cycle of these mechanisms can keep pace with the trajectory of change (Colenbrander and Bavinck, 2017; Edwards, 2021). The optimisation of adaptive management approaches to make multiple and dynamic adjustments is already ongoing (e.g., Haasnoot *et al.*, 2013).

Lived experiences (and values)

There is a critical role for individuals and communities in achieving local coastal sustainability (Westoby and McNamara, 2019; McNamara *et al.*, 2020; Westoby *et al.*, 2020). Cultural and life experiences encourage greater engagement of individuals and communities (and understanding asymmetries within, to avoid potential conflicts) with issues of sustainability (Brown *et al.*, 2019). Collective values, shaped by lived experiences, underpin human actions and constitute leverage points for sustainability transformations (Abson *et al.*, 2017). We understand that user needs, desires and actions hinge on value propositions formed by specific socio-cultural, climatic, spatial and bio-ecological contexts. As such, science-based interventions, for example, the development of climate services, require this contextual understanding to influence, alter and change behaviours (Martinez *et al.*, 2022). In most cultures and value systems, the coast is a recognisable entity that is a physical, aesthetic, emotional, and even religious construct, which needs to be considered in scientific approaches that aim at achieving local coastal sustainability (Gillgren *et al.*, 2018). Littoral societies account for such intertwined characteristics.

Achieving global goals, transformation, and sustainable coastal futures

In this paper, we refer to a combination of emerging or existing social innovations in the Anthropocene that could support efforts

to achieve sustainability. None of the social innovations identified here is particularly novel when considered in isolation. For example, there are four decades of published research on local knowledge, ecology, and “storytelling” (Johannes, 1978; Galafassi *et al.*, 2018). It has also been shown that formalised legislation often does not sufficiently recognise local forms of governance in coastal areas including customary marine tenure (right to use marine space), local management strategies and local territoriality (Schwarz *et al.*, 2020; Katikiro *et al.*, 2021). Scientific research has shown that formal management has failed because it has ignored local and informal forms of governance. Similarly, EBM that also considers human and social systems has been demonstrated as a useful approach to managing intact and connected natural systems faced with climate change (Fernandino *et al.*, 2018; Alexander *et al.*, 2019).

However, the overlap between and the use of multiple social innovations offer exciting opportunities. If considered collectively, they can create a connection between people and the coast. This relationship potentially creates the mechanisms and methods to agree on the alternative, shared, negotiated visions for achieving goals of sustainability. The social innovations weave sectors of society together, including science, and in doing so, make it possible for transformation towards greater degrees of sustainability. The mere existence of science and scientific understanding of the changing planetary system is proving to be an insufficient enabler for a societal transformation to sustainability. That is why we seek novel and broader views on social innovations and sustainability, combined with the sciences, to transform society and achieve environmental and social sustainability (Horcea-Milcu *et al.*, 2020; McKinley *et al.*, 2020; Folke *et al.*, 2021).

The science-inspired social innovations also respond to two contemporary challenges to science and “evidence” guiding decision-making for (coastal) sustainability. First, there is a need for science to inform a human-dominated system. This system is under pressure from climate change and rampant resource extraction, and people tend to be more willing and able to engage with science, not as a dominant force, but as an equal alongside other sources of information (Vanderlinden *et al.*, 2020; Serrao-Neumann *et al.*, 2021; Vogel and O’Brien, 2021). The knowledge needs of society are becoming more complex and more dynamic (Mach *et al.*, 2020; Pasquier *et al.*, 2020), and “facts” are no longer enough (Hulme, 2020). Second, there is growing anti-science activism that portrays scientists and science as being “other”, and apart from society and its interests (Hockfield, 2018; Holt, 2018; Hotez, 2021). Science needs to win the hearts and minds of people by using social innovations to connect them with solutions to the challenges they are facing.

Social innovation and the sustainable development goals

We are aware, through science outputs, for example, IPCC reports, of the accelerating rate of change in the earth’s system. If we are to achieve higher degrees of sustainability and meet the SDGs, we must have equally assertive and effective decision- and policy-making. The six types of social innovations are not presented as edifices of truth, complete and comprehensive, or rooted in the absolute. Depending on the context, the social innovations described can stand alone, or can also be inseparable. Complex coastal ecosystems are inhabited by a multilayer mosaic of people, communities, and multi-level government, with unique and often conflicting lived experiences. For some, a coast is a place of business and wealth, and for others a home and a connection to some form of



Figure 1. Characters of social innovation that connect people to Anthropocene coasts to achieve higher degrees of sustainability as defined by the United Nations Sustainable Development Goals (SDGs).

cultural or spiritual reality. The groups and individuals of the social mosaic of the coast are differently motivated, perceive risk differently, and are exposed to multiple but different hazards. This mosaic of social and ecological patterns (a social-ecological system) calls for a deeper understanding of how knowing about the system (science, experience, etc.) can result in actions that sustain its functioning.

Social innovations that authentically engage different coastal users cannot be achieved unless we understand how to talk to each other. How do we communicate value, and present scientific outputs so they can be similarly understood while acknowledging different perspectives and ways of knowing? Only once we engage with the appropriate level of trust and dispersion of power can we design governing systems for complex coastal systems. However, such governing systems cannot be designed for contemporary environmental, financial, and social conditions, but the rate of change in the earth system also demands that our designs for governance and management must now consider an inevitable future state. This raises questions about how to deal with formal and legally entrenched boundaries of actions. What social innovations are required to maintain order and critical services, and how do we establish new societal practices that keep up with the rate of system change?

In terms of the global ambitions for sustainability, the six types of social innovations have the potential to directly contribute to at least seven of the 17 SDGs (Figure 1), although their relevance and potential contribution are not restricted to these. Authentic engagement is most immediately relevant to the Goals related to equality

and partnerships (SDGs 5: gender equality, 10: reduced inequalities, and 17: partnership for goals), which have meaningful, equitable participation at their core, but potentially contribute to several other goals, notably those involving (collective) governance and institution-building, which are enhanced by authentic, well-planned engagement (e.g., Reed et al., 2018; Bennett et al., 2019).

Artful and engaging communication is of relevance to galvanising collective action and mobilising societal actors as well as developing science–society compacts (SDGs 13: climate action, and 17: partnership for goals), as it serves to bridge different relevant knowledge systems and triggers motivations to achieve greater sustainability (e.g., Paterson et al., 2020). There is also a case to be made for a narrative that incorporates a greater connection between land, ocean, and climate, as well as the institutions and partnerships (between science and society) that embed social innovations in actions (SDG 17) (Obura, 2020).

Urging and compelling change, including by moral suasion, directly relates to goals with strong moral and ethical dimensions (such as SDGs 5: 10, and 16: peace, justice and strong institutions) and contributes to the forging of strong partnerships based on common interests (SDG 17). However, it also contributes to meeting Goals requiring collective action and drastic changes in behaviour, such as sustainable consumption and production (SDGs 12) (e.g., Ostrom, 2010). Governance tailored to interconnected, social-ecological systems across the land–ocean interface enhances the sustainability of coastal terrestrial and marine systems and cities (SDGs 11: sustainable cities and communities, 14: life below water, and 15: life on land) (Singh et al., 2021).

Similarly, anticipation in governance contributes to finding shared and common visions about alternative future states of climate resilience and sustainable coastal social-ecological systems including urban areas (SDGs 11, 13, 14, and 15) (e.g., Vervoort and Gupta, 2018; Levin *et al.*, 2021; Rölfer *et al.*, 2022). Finally, lived experiences and values – similar to authentic engagement – creates the conditions for justice and equity among societal actors, including intersectional approaches to inequalities, for example, by including actors from different cultural backgrounds, gender, and ages (SDGs 5, 10, and 11) (e.g., Staffa *et al.*, 2022). The goals of equity (SDG 10: reduced inequalities), justice (SDG 16) and gender equality (SDG 5) are frequently invoked in one or more of the six types of social innovations, highlighting the intersectionality across all social innovations.

Embedding social innovation

The combination of social innovations identified from the scientific literature relates strongly to transformation and sustainability. However, a missing element or action is needed to embed science-derived or -inspired social innovation as part of societal processes to achieve sustainability. Scientists and the sectors and actors within society have mutual responsibilities as part of a transdisciplinary approach to achieve higher degrees of sustainability. Much has been written about Mode 2 engagement between science and society (Funtowicz and Ravetz, 1993), and the responsibilities of scientists to engage with society (Gallopín *et al.*, 2008). Equally so, societal actors are also responsible for engaging differently, more broadly, with science and each other, and taking responsibility to integrate science as part of societal processes (e.g., governance, knowledge co-production). Actors within science and society should agree on these roles and responsibilities, who acts and when, or how responsibilities are shared. This is not intended to perpetuate a polarised view of science and society, but rather an agreement and commitment to actions.

One example of such an agreement was previously coined as a *science–society contract* to achieve targets for sustainability (Lubchenco, 1998). There are benefits to a more structured and equal relationship between science and society, for example, a *science–society compact* (avoiding the possible adversarial connotation of legal contracts). Such a structured relationship can create conditions for sciences to support the transformation of society towards sustainable future coasts. The example of a science–society compact may be a tool with which to govern a fundamental shift from an anthropocentric to a more eco-centric and regenerative social contract, acknowledging society as part of a coupled social-ecological system (Huntjens, 2021).

Embedding the roles and contributions of science and social innovation in such a deliberative mechanism for engagement may create a social mandate to enable behaviour changes through ownership. This may render the often hard evidenced-based decisions on sustainability (e.g., managed retreat, lifestyle change) bearable in the long term and provide the basis for future climate action (Howarth *et al.*, 2020), particularly for coastal sustainability.

A science–society compact may help to define the use of all the elements described in this paper to achieve higher degrees of sustainability and the SDGs. We maintain that achieving the SDGs does not become possible until we connect science to society, and through data, information and knowledge connect society with the environment, including the coast. These connections need to be forged under conditions of contested politics, everyday foundations of action, constant change, increasing degrees of urgency, and

flexibility and appetite for social innovation such as we never needed previously (Nightingale *et al.*, 2019).

Conclusion

Recent literature is replete with references to the future, various states of the future, and the agency needed to achieve desirable visions of such futures. We already know that compared to inland systems, coastal areas will be disproportionately more affected by global change and human activities, as we approach the middle of the twenty-first century. Social innovation's role in achieving higher degrees of sustainability is recognised, and the academic literature is reporting on a growing need for eco-centric and regenerative social action. The role of social innovations is inescapably part of human intentions to achieve higher degrees of sustainability, especially for coasts in the Anthropocene.

The six types of social innovation cannot be considered in isolation from one another, from the global efforts to understand and govern Earth systems, or the local actions to manage and live with global change impacts. We suggest a much higher degree of organising social innovations is needed. This also means exploring how they collectively enable human action based on diverse knowledge types. Knowing about social innovation is not enough, and there is a need and opportunity to embed such innovations within society using a science–society compact. Finally, in summarising the six types of social innovations, it is important to note that there are conceivably many additional types of social innovations that may support or enable a trajectory towards sustainable coastal futures. Education, awareness, and literacy are just some elements that can still be added (Westley *et al.*, 2011; Kelly *et al.*, 2021; Stephenson *et al.*, 2021).

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Competing interest. The authors declare none.

References

- Abson DJ, Fischer J, Leventon J, Newig J, Schomerus T, Vilsmaier U, von Wehrden H, Abernethy P, Ives CD, Jäger NW and Lang DJ (2017) Leverage points for sustainability transformation. *Ambio* 46(1), 30–39. <https://doi.org/10.1007/s13280-016-0800-y>.
- Agnew S, Kopke K, Power O-P, Troya MDC and Dozier A (2022) Transdisciplinary research: Can citizen science support effective decision-making for coastal infrastructure management? *Frontiers in Marine Science* 9. <https://doi.org/10.3389/fmars.2022.809284>.
- Albagli S and Iwama AY (2022) Citizen science and the right to research: Building local knowledge of climate change impacts. *Humanities and Social*

- Sciences Communications* 9(1), 39. <https://doi.org/10.1057/s41599-022-01040-8>.
- Alexander KA, Hobday AJ, Cvitanovic C, Ogier E, Nash KL, Cottrell RS, Fleming A, Fudge M, Fulton EA, Frusher S, Kelly R, MacLeod CK, Pecl GT, van Putten I, Vince J and Watson RA (2019) Progress in integrating natural and social science in marine ecosystem-based management research. *Marine and Freshwater Research* 70(1), 71–83. <https://doi.org/10.1071/mfr17248>.
- Aswani S (2020) New directions in maritime and fisheries anthropology. *American Anthropologist* 122(3), 473–486. <https://doi.org/10.1111/aman.13380>.
- Aswani S, Lemahieu A and Sauer WHH (2018) Global trends of local ecological knowledge and future implications. *PLoS One* 13(4), e0195440. <https://doi.org/10.1371/journal.pone.0195440>.
- Aykut S, Demortain D and Benboudiz B (2019) The politics of anticipatory expertise: Plurality and contestation of futures knowledge in governance—Introduction to the special issue. *Science & Technology Studies* 32(4), 2–12. <https://doi.org/10.23987/sts.87369>.
- Bai X, van der Leeuw S, O'Brien K, Berkhout F, Biermann F, Brondizio ES, Cudennec C, Dearing J, Duraiaappah A, Glaser M, Revkin A, Steffen W and Syvitski J (2016) Plausible and desirable futures in the Anthropocene: A new research agenda. *Global Environmental Change* 39, 351–362. <https://doi.org/10.1016/j.gloenvcha.2015.09.017>.
- Barnard PL, Dugan JE, Page HM, Wood NJ, Hart JAF, Cayan DR, Erikson LH, Hubbard DM, Myers MR, Melack JM and Iacobellis SF (2021) Multiple climate change-driven tipping points for coastal systems. *Scientific Reports* 11(1), 15560. <https://doi.org/10.1038/s41598-021-94942-7>.
- Bennett NJ, Blythe J, Cisneros-Montemayor AM, Singh GG and Sumaila UR (2019) Just transformations to sustainability. *Sustainability* 11(14), 3881. <https://doi.org/10.3390/su11143881>.
- Bennett NJ, Whitty TS, Finkbeiner E, Pittman J, Bassett H, Gelcich S and Allison EH (2018) Environmental stewardship: A conceptual review and analytical framework. *Environmental Management* 61(4), 597–614. <https://doi.org/10.1007/s00267-017-0993-2>.
- Bentz J, do Carmo L, Schafenacker N, Schirok J and Corso SD (2021) Creative, embodied practices, and the potentialities for sustainability transformations. *Sustainability Science* 17(2), 687–699. <https://doi.org/10.1007/s11625-021-01000-2>.
- Biermann F, Bai X, Bondre N, Broadgate W, Arthur Chen C-T, Dube OP, Erisman JW, Glaser M, van der Hel S, Lemos MC, Seitzinger S and Seto KC (2016) Down to earth: Contextualizing the Anthropocene. *Global Environmental Change* 39, 341–350. <https://doi.org/10.1016/j.gloenvcha.2015.11.004>.
- Bos B, Drupp MA, Meya JN and Quaas MF (2020) Moral suasion and the private provision of public goods: Evidence from the COVID-19 pandemic. *Environmental and Resource Economics* 76, 1117–1138. <https://doi.org/10.1007/s10640-020-00477-2>.
- Brown K, Adger WN, Devine-Wright P, Anderies JM, Barr S, Bousquet F, Butler C, Evans L, Marshall N and Quinn T (2019) Empathy, place and identity interactions for sustainability. *Global Environmental Change* 56, 11–17.
- Celliers L, Scott D, Ngcoya M and Taljaard S (2021) Negotiation of knowledge for coastal management? Reflections from a transdisciplinary experiment in South Africa. *Humanities and Social Sciences Communications* 8(1), 207. <https://doi.org/10.1057/s41599-021-00887-7>.
- Chambers JM, Wyborn C, Klenk NL, Ryan M, Serban A, Bennett NJ, Brennan R, Charli-Joseph L, Fernández-Giménez ME, Galvin KA, Goldstein BE, Haller T, Hill R, Munera C, Nel JL, Österblom H, Reid RS, Riechers M, Spierenburg M, Tengö M, Bennett E, Brandeis A, Chatterton P, Cockburn JJ, Cvitanovic C, Dumrongrojwattana P, Paz Durán A, Gerber J-D, Green JMH, Gruby R, Guerrero AM, Horcea-Milcu A-I, Montana J, Steyaert P, Zaehring JG, Bednarek AT, Curran K, Fada SJ, Hutton J, Leimona B, Pickering T and Rondeau R (2022) Co-productive agility and four collaborative pathways to sustainability transformations. *Global Environmental Change* 72, 102422. <https://doi.org/10.1016/j.gloenvcha.2021.102422>.
- Colenbrander D and Bavinck M (2017) Exploring the role of bureaucracy in the production of coastal risks, City of Cape Town, South Africa. *Ocean & Coastal Management* 150, 35–50. <https://doi.org/10.1016/j.ocecoaman.2016.11.012>.
- da Costa JP, Mouneyrac C, Costa M, Duarte AC and Rocha-Santos T (2020) The role of legislation, regulatory initiatives and guidelines on the control of plastic pollution. *Frontiers in Environmental Science* 8. <https://doi.org/10.3389/fenvs.2020.00104>.
- Dam Lam R, Gasparatos A, Chakraborty S, Rivera H and Stanley T (2019) Multiple values and knowledge integration in indigenous coastal and marine social-ecological systems research: A systematic review. *Ecosystem Services* 37, 100910. <https://doi.org/10.1016/j.ecoser.2019.100910>.
- DeCaro DA, Chaffin BC, Schlager E, Garmestani AS and Ruhl JB (2017) Legal and institutional foundations of adaptive environmental governance. *Ecology and Society* 22(1), 1–32. <https://doi.org/10.5751/ES-09036-220132>.
- Defeo O and Elliott M (2021) The 'triple whammy' of coasts under threat—Why we should be worried! *Marine Pollution Bulletin* 163, 111832. <https://doi.org/10.1016/j.marpolbul.2020.111832>.
- Edwards N (2021) Politics of the coastal professional. *Ocean & Coastal Management* 202, 105419. <https://doi.org/10.1016/j.ocecoaman.2020.105419>.
- Fernandino G, Elliff CI and Silva IR (2018) Ecosystem-based management of coastal zones in face of climate change impacts: Challenges and inequalities. *Journal of Environmental Management* 215, 32–39. <https://doi.org/10.1016/j.jenvman.2018.03.034>.
- Folke C, Polasky S, Rockström J, Galaz V, Westley F, Lamont M, Scheffer M, Osterblom H, Carpenter SR, Chapin FS, 3rd, Seto KC, Weber EU, Crona BI, Daily GC, Dasgupta P, Gaffney O, Gordon LJ, Hoff H, Levin SA, Lubchenco J, Steffen W and Walker BH (2021) Our future in the Anthropocene biosphere. *Ambio* 50(4), 834–869. <https://doi.org/10.1007/s13280-021-01544-8>.
- Funtowicz SO and Ravetz JR (1993) Science for the post-normal age. *Futures* 25(7), 739–755. [https://doi.org/10.1016/0016-3287\(93\)90022-1](https://doi.org/10.1016/0016-3287(93)90022-1).
- Galafassi D, Daw TM, Thyresson M, Rosendo S, Chaigneau T, Bandeira S, Munyi L, Gabriellsson I and Brown K (2018) Stories in social-ecological knowledge cocreation. *Ecology and Society* 23(1), 23. <https://doi.org/10.5751/es-09932-230123>.
- Galafassi D, Tàbara JD, Heras M, Iles A, Locke KA and Milkoreit M (2018) Restoring our senses, restoring the earth. Fostering imaginative capacities through the arts for envisioning climate transformations. *Elementa: Science of the Anthropocene* 6, 69. <https://doi.org/10.1525/elementa.330>.
- Galdies C, Bellerby R, Canu D, Chen W, Garcia-Luque E, Gašparović B, Godrijan J, Lawlor PJ, Maes F, Malej A, Panagiotaras D, Romera BM, Raymond CE, Rochette J, Solidoro C, Stojanov R, Tiller R, Torres de Noronha I, Uścińowicz G, Nataša V, Walsh C and Guerra R (2020) European policies and legislation targeting ocean acidification in European waters—Current state. *Marine Policy* 118, 103947. <https://doi.org/10.1016/j.marpol.2020.103947>.
- Gallopín GC, Funtowicz S, O'Connor M and Ravetz J (2008) Science for the twenty-first century: From social contract to the scientific core. *International Social Science Journal* 53(168), 219–229. <https://doi.org/10.1111/1468-2451.00311>.
- Gerkenmeier B, Ratter BMW, Vollmer M and Walsh C (2018) Managing coastal risks at the Wadden Sea: A societal perspective. *Disaster Prevention and Management* 27(1), 15–27. <https://doi.org/10.1108/dpm-04-2017-0074>.
- Gillgren C, Støttrup JG, Schumacher J and Dinesen GE (2018) Working together: Collaborative decision making for sustainable integrated coastal management (ICM). *Journal of Coastal Conservation* 23(5), 959–968. <https://doi.org/10.1007/s11852-018-0631-z>.
- Glaser BG and Strauss AL (2017) *The Discovery of Grounded Theory*. New York: Routledge. <https://doi.org/10.4324/9780203793206>.
- Goldberg J, Marshall N, Birtles A, Case P, Bohensky E, Curnock M, Gooch M, Parry-Husbands H, Pert P, Tobin R, Villani C and Visperas B (2016) Climate change, the great barrier reef and the response of Australians. *Palgrave Communications* 2(1), 15046. <https://doi.org/10.1057/palcomms.2015.46>.
- Guillotreau P, Trouillet B, Mahévas S and Pardo S (2020) Addressing trans-disciplinary and participation issues to cope with rapid changes shifting marine social ecological systems. *Marine Policy* 117, 103929. <https://doi.org/10.1016/j.marpol.2020.103929>.
- Haas B, Mackay M, Novaglio C, Fullbrook L, Murunga M, Sbrocchi C, McDonald J, McCormack PC, Alexander K, Fudge M, Goldsworthy L,

- Boschetti F, Dutton I, Dutra L, McGee J, Rousseau Y, Spain E, Stephenson R, Vince J, Wilcox C and Haward M (2022) The future of ocean governance. *Reviews in Fish Biology and Fisheries* 32, 253–270. <https://doi.org/10.1007/s11160-020-09631-x>.
- Haasnoot M, Kwakkel JH, Walker WE and ter Maat J (2013) Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change* 23(2), 485–498. <https://doi.org/10.1016/j.gloenvcha.2012.12.006>.
- Harvey N and Clarke B (2019) 21st century reform in Australian coastal policy and legislation. *Marine Policy* 103, 27–32. <https://doi.org/10.1016/j.marpol.2019.02.016>.
- He Q and Silliman BR (2019) Climate change, human impacts, and coastal ecosystems in the Anthropocene. *Current Biology* 29(19), R1021–R1035. <https://doi.org/10.1016/j.cub.2019.08.042>.
- Hockfield S (2018) Our science, our society. *Science* 359(6375), 499. <https://doi.org/10.1126/science.aat0957>.
- Holt R (2018) A tale of two cultures. *Science* 359(6374), 371. <https://doi.org/10.1126/science.aat0588>.
- Horcea-Milcu A-I, Martín-López B, Lam DPM and Lang DJ (2020) Research pathways to foster transformation: Linking sustainability science and social-ecological systems research. *Ecology and Society* 25(1). <https://doi.org/10.5751/es-11332-250113>.
- Hotez PJ (2021) Anti-science kills: From soviet embrace of pseudoscience to accelerated attacks on US biomedicine. *PLoS Biology* 19(1), e3001068. <https://doi.org/10.1371/journal.pbio.3001068>.
- Howarth C, Bryant P, Corner A, Fankhauser S, Gouldson A, Whitmarsh L and Willis R (2020) Building a social mandate for climate action: Lessons from COVID-19. *Environmental and Resource Economics volume* 76, 1107–1115. <https://doi.org/10.1007/s10640-020-00446-9>.
- Hulme M (2020) One earth, many futures, no destination. *One Earth* 2(4), 309–311. <https://doi.org/10.1016/j.oneear.2020.03.005>.
- Huntjens P (2021) *Towards a Natural Social Contract*. Cham: Springer. <https://doi.org/10.1007/978-3-030-67130-3>.
- IPCC (2022) *WG II: Summary for Policymakers (Climate Change 2021: Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Issue)*. C. U. Press.
- Jentoft S (2007) Limits of governability: Institutional implications for fisheries and coastal governance. *Marine Policy* 31(4), 360–370. <https://doi.org/10.1016/j.marpol.2006.11.003>.
- Johannes RE (1978) Traditional marine conservation methods in Oceania and their demise. *Annual Review of Ecology and Systematics* 9(1), 349–364. <https://doi.org/10.1146/annurev.es.09.110178.002025>.
- Katikiro RE, Kweka OL, Minja R, Namkesa F and Ponte S (2021) Stakeholder engagement and conservation outcomes in marine protected areas: Lessons from the Mnazi Bay-Ruvuma estuary Marine Park (MBREMP) in Tanzania. *Ocean & Coastal Management* 202, 105502. <https://doi.org/10.1016/j.ocecoaman.2020.105502>.
- Kelly R, Evans K, Alexander K, Bettiol S, Corney S, Cullen-Knox C, Cvitanovic C, de Salas K, Emad GR, Fullbrook L, Garcia C, Ison S, Ling S, Macleod C, Meyer A, Murray L, Murunga M, Nash KL, Norris K, Oellermann M, Scott J, Stark JS, Wood G and Pecl GT (2021) Connecting to the oceans: Supporting ocean literacy and public engagement. *Reviews in Fish Biology and Fisheries* 32, 123–143. <https://doi.org/10.1007/s11160-020-09625-9>.
- Kelly R, Nettlefold J, Mossop D, Bettiol S, Corney S, Cullen-Knox C, Fleming A, Leith P, Melbourne-Thomas J, Ogier E, van Putten I and Pecl GT (2020) Let's talk about climate change: Developing effective conversations between scientists and communities. *One Earth* 3(4), 415–419. <https://doi.org/10.1016/j.oneear.2020.09.009>.
- Kopp RE, Gilmore EA, Little CM, Lorenzo-Trueba J, Ramenzoni VC and Sweet WV (2019) Usable science for managing the risks of sea-level rise. *Earths Future* 7(12), 1235–1269. <https://doi.org/10.1029/2018EF001145>.
- Kotzé LJ and French D (2021) Chapter 1: Staying within the planets safe operating space? Law and the planetary boundaries. In French D and Kotzé LJ (eds), *Research Handbook on Law, Governance and Planetary Boundaries*. Cheltenham, UK: Edward Elgar Publishing. <https://doi.org/10.4337/9781789902747.00007>.
- Lacey J, Howden M, Cvitanovic C and Colvin RM (2017) Understanding and managing trust at the climate science–policy interface. *Nature Climate Change* 8(1), 22–28. <https://doi.org/10.1038/s41558-017-0010-z>.
- Levin SA, Anderies JM, Adger N, Barrett S, Bennett EM, Cardenas JC, Carpenter SR, Crepin AS, Ehrlich P, Fischer J, Folke C, Kautsky N, Kling C, Nyborg K, Polasky S, Scheffer M, Segerson K, Shogren J, van den Bergh J, Walker B, Weber EU, & Wilen J (2021) Governance in the face of extreme events: Lessons from evolutionary processes for structuring interventions, and the need to go beyond. *Ecosystems* 25, 697–711. <https://doi.org/10.1007/s10021-021-00680-2>.
- Lindkvist E, Pellowe KE, Alexander SM, Drury O, Neill E, Finkbeiner EM, Girón-Nava A, González-Mon B, Johnson AF, Pittman J, Schill C, Wijermans N, Bodin Ö, Gelcich S and Glaser M (2022) Untangling social–ecological interactions: A methods portfolio approach to tackling contemporary sustainability challenges in fisheries. *Fish and Fisheries* 23, 1202–1220. <https://doi.org/10.1111/faf.12678>.
- Lipiec E, Ruggiero P, Mills A, Serafin KA, Bolte J, Corcoran P, Stevenson J, Zanco C and Lach D (2018) Mapping out climate change: Assessing how coastal communities adapt using alternative future scenarios. *Journal of Coastal Research* 34(5), 1196–1208. <https://doi.org/10.2112/jcoastres-d-17-00115.1>.
- Lubchenco J (1998) Entering the century of the environment: A new social contract for science. *Science* 279(5350), 491–497. <https://doi.org/10.1126/science.279.5350.491>.
- Lund D (2021) Navigating slow-onset risks through foresight and flexibility in Fiji: Emerging recommendations for the planned relocation of climate-vulnerable communities. *Current Opinion in Environmental Sustainability* 50, 12–20. <https://doi.org/10.1016/j.cosust.2020.12.004>.
- Mach KJ, Lemos MC, Meadow AM, Wyborn C, Klenk N, Arnott JC, Ardoin NM, Fieseler C, Moss RH, Nichols L, Stults M, Vaughan C and Wong-Parodi G (2020) Actionable knowledge and the art of engagement. *Current Opinion in Environmental Sustainability* 42, 30–37. <https://doi.org/10.1016/j.cosust.2020.01.002>.
- Martinez G, Celliers L, Collard M, de Jong F, Huang-Lachmann J-T, Manez Costa M, Rubio-Martin A, Ozier-Lafontaine H, Garcia Prats A, Stelljes N, Swart R, Wimmermann T, Llarío F and Pulido-Velazquez M (2022) Societal local and regional resiliency spurred by contextualized climate services: The role of culture in co-production. *Climate Services* 26, 100300. <https://doi.org/10.1016/j.cliser.2022.100300>.
- McKinley E, Acott T and Yates KL (2020) Marine social sciences: Looking towards a sustainable future. *Environmental Science & Policy* 108, 85–92. <https://doi.org/10.1016/j.envsci.2020.03.015>.
- McKinley E, Crowe PR, Stori F, Ballinger R, Brew TC, Blacklaw-Jones L, Cameron-Smith A, Crowley S, Cocco C, O'Mahony C, McNally B, Power P and Foley K (2021) 'Going digital' - lessons for future coastal community engagement and climate change adaptation. *Ocean & Coastal Management* 208, 105629. <https://doi.org/10.1016/j.ocecoaman.2021.105629>.
- McLaughlin JF (2018) Safe operating space for humanity at a regional scale. *Ecology and Society* 23(2), 43. <https://doi.org/10.5751/es-10171-230243>.
- McNamara KE, Clissold R, Westoby R, Piggott-McKellar AE, Kumar R, Clarke T, Namoumou F, Areki F, Joseph E, Warrick O and Nunn PD (2020) An assessment of community-based adaptation initiatives in the Pacific Islands. *Nature Climate Change* 10(7), 628–639. <https://doi.org/10.1038/s41558-020-0813-1>.
- Merrie A, Keys P, Metian M and Österblom H (2018) Radical Ocean futures-scenario development using science fiction prototyping. *Futures* 95, 22–32. <https://doi.org/10.1016/j.futures.2017.09.005>.
- Muiderman K, Gupta A, Vervoort J and Biermann F (2020) Four approaches to anticipatory climate governance: Different conceptions of the future and implications for the present. *WIREs Climate Change* 11(6), e673. <https://doi.org/10.1002/wcc.673>.
- Nash KL, Cvitanovic C, Fulton EA, Halpern BS, Milner-Gulland EJ, Watson RA and Blanchard JL (2017) Planetary boundaries for a blue planet. *Nature Ecology & Evolution* 1(11), 1625–1634. <https://doi.org/10.1038/s41559-017-0319-z>.
- Neumann B, Ott K and Kenchington R (2017) Strong sustainability in coastal areas: A conceptual interpretation of SDG 14. *Sustainability Science* 12(6), 1019–1035. <https://doi.org/10.1007/s11625-017-0472-y>.

- Neumann B, Vafeidis AT, Zimmermann J and Nicholls RJ (2015) Future coastal population growth and exposure to sea-level rise and coastal flooding—A global assessment. *PLoS One* 10(3), e0118571. <https://doi.org/10.1371/journal.pone.0118571>.
- Newton A, Harff J, You Z-J, Zhang H and Wolanski E (2016) Sustainability of future coasts and estuaries: A synthesis. *Estuarine, Coastal and Shelf Science* 183, 271–274. <https://doi.org/10.1016/j.ecss.2016.11.017>.
- Nightingale AJ, Eriksen S, Taylor M, Forsyth T, Pelling M, Newsham A, Boyd E, Brown K, Harvey B, Jones L, Bezner Kerr R, Mehta L, Naess LO, Ockwell D, Scoones I, Tanner T and Whitfield S (2019) Beyond technical fixes: Climate solutions and the great derangement. *Climate and Development* 12(4), 343–352. <https://doi.org/10.1080/17565529.2019.1624495>.
- Norström AV, Cvitanovic C, Löf MF, West S, Wyborn C, Balvanera P, Bednarek AT, Bennett EM, Biggs R, de Bremond A, Campbell BM, Canadell JG, Carpenter SR, Folke C, Fulton EA, Gaffney O, Gelcich S, Jouffray J-B, Leach M, Le Tissier M, Martín-López B, Louder E, Loutre M-F, Meadow AM, Nagendra H, Payne D, Peterson GD, Reyers B, Scholes R, Speranza CI, Spierenburg M, Stafford-Smith M, Tengö M, van der Hel S, van Putten I and Österblom H (2020) Principles for knowledge co-production in sustainability research. *Nature Sustainability* 3(3), 182–190. <https://doi.org/10.1038/s41893-019-0448-2>.
- Obura DO (2020) Getting to 2030—Scaling effort to ambition through a narrative model of the SDGs. *Marine Policy* 117, 103973. <https://doi.org/10.1016/j.marpol.2020.103973>.
- Olsson P, Moore M-L, Westley FR and McCarthy DDP (2017) The concept of the Anthropocene as a game-changer: A new context for social innovation and transformations to sustainability. *Ecology and Society* 22(2), 31. <https://doi.org/10.5751/es-09310-220231>.
- Ostrom E (2010) Analyzing collective action. *Agricultural Economics* 41, 155–166. <https://doi.org/10.1111/j.1574-0862.2010.00497.x>.
- Partelow S, Schlüter A, Armitage D, Bavinck M, Carlisle K, Gruby RL, Hornidge A-K, Le Tissier M, Pittman JB, Song AM, Sousa LP, Văidianu N and Van Assche K (2020) Environmental governance theories: A review and application to coastal systems. *Ecology and Society* 25(4). <https://doi.org/10.5751/es-12067-250419>.
- Pasquier U, Few R, Goulden MC, Hooton S, He Y and Hiscock KM (2020) We can't do it on our own!—Integrating stakeholder and scientific knowledge of future flood risk to inform climate change adaptation planning in a coastal region. *Environmental Science & Policy* 103, 50–57. <https://doi.org/10.1016/j.envsci.2019.10.016>.
- Paterson SK, Le Tissier M, Whyte H, Robinson LB, Thielking K, Ingram M and McCord J (2020) Examining the potential of art-science collaborations in the Anthropocene: A Case study of catching a wave. *Frontiers in Marine Science* 7. <https://doi.org/10.3389/fmars.2020.00340>.
- Planque B, Mullon C, Arneberg P, Eide A, Fromentin JM, Heymans JJ, Hoel AH, Niiranen S, Ottersen G, Sandø AB, Sommerkorn M, Thébaud O and Thorvik T (2019) A participatory scenario method to explore the future of marine social-ecological systems. *Fish and Fisheries* 20(3), 434–451. <https://doi.org/10.1111/faf.12356>.
- Pulkkinen K, Undorf S, Bender F, Wikman-Svahn P, Doblas-Reyes F, Flynn C, Hegerl GC, Jönsson A, Leung G-K, Roussos J, Shepherd TG and Thompson E (2022) The value of values in climate science. *Nature Climate Change* 12(1), 4–6. <https://doi.org/10.1038/s41558-021-01238-9>.
- Reed MS, Vella S, Challies E, de Vente J, Frewer L, Hohenwallner-Ries D, Huber T, Neumann RK, Oughton EA, Sidoli del Ceno J and van Delden H (2018) A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology* 26, S7–S17. <https://doi.org/10.1111/rec.12541>.
- Refugio-Coronado S, Lacasse K, Dalton T, Humphries A, Basu S, Uchida H and Uchida E (2021) Coastal and marine socio-ecological systems: A systematic review of the literature. *Frontiers in Marine Science* 8, 648006. <https://doi.org/10.3389/fmars.2021.648006>.
- Reiblich J, Hartge E, Wedding LM, Killian S and Verutes GM (2019) Bridging climate science, law, and policy to advance coastal adaptation planning. *Marine Policy* 104, 125–134. <https://doi.org/10.1016/j.marpol.2019.02.028>.
- Rockström J, Steffen W, Noone K, Persson A, Chapin FS, 3rd, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sorlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P and Foley JA (2009) A safe operating space for humanity. *Nature* 461(7263), 472–475. <https://doi.org/10.1038/461472a>.
- Rölfer L, Celliers L and Abson DJ (2022) Resilience and coastal governance: Knowledge and navigation between stability and transformation. *Ecology and Society* 27(2). <https://doi.org/10.5751/es-13244-270240>.
- Schlüter A, Van Assche K, Hornidge A-K and Văidianu N (2020) Land-sea interactions and coastal development: An evolutionary governance perspective. *Marine Policy* 112, 103801. <https://doi.org/10.1016/j.marpol.2019.103801>.
- Schwarz A-M, Gordon J and Ramofafia C (2020) Nudging statutory law to make space for customary processes and community-based fisheries management in Solomon Islands. *Maritime Studies* 19(4), 475–487. <https://doi.org/10.1007/s40152-020-00176-0>.
- Serrao-Neumann S, de Araújo Moreira F, Dalla Fontana M, Torres RR, Lapola DM, Nunes LH, Marengo JA and Di Giulio GM (2021) Advancing transdisciplinary adaptation research practice. *Nature Climate Change* 11(12), 1006–1008. <https://doi.org/10.1038/s41558-021-01221-4>.
- Singh GG, Cottrell RS, Eddy TD and Cisneros-Montemayor AM (2021) Governing the Land-Sea Interface to achieve sustainable coastal development. *Frontiers in Marine Science* 8. <https://doi.org/10.3389/fmars.2021.709947>.
- Soma K, van den Burg SWK, Hoefnagel EWJ, Stuiver M and van der Heide CM (2018) Social innovation—A future pathway for blue growth? *Marine Policy* 87, 363–370. <https://doi.org/10.1016/j.marpol.2017.10.008>.
- Spijkers J, Merrie A, Wabnitz CCC, Osborne M, Möbjörk M, Bodin Ö, Selig ER, Le Billon P, Hendrix CS, Singh GG, Keys PW and Morrison TH (2021) Exploring the future of fishery conflict through narrative scenarios. *One Earth* 4(3), 386–396. <https://doi.org/10.1016/j.oneear.2021.02.004>.
- Staffa RK, Riechers M and Martín-Lopez B (2022) A feminist ethos for caring knowledge production in transdisciplinary sustainability science. *Sustainability Science* 17(1), 45–63. <https://doi.org/10.1007/s11625-021-01064-0>.
- Steffen W, Rockström J, Richardson K, Lenton TM, Folke C, Liverman D, Summerhayes CP, Barnosky AD, Cornell SE, Crucifix M, Donges JF, Fetzer I, Lade SJ, Scheffer M, Winkelmann R and Schellnhuber HJ (2018) Trajectories of the earth system in the Anthropocene. *Proceedings of the National Academy of Sciences of the United States of America* 115(33), 8252–8259. <https://doi.org/10.1073/pnas.1810141115>.
- Stephenson RL, Hobday AJ, Allison EH, Armitage D, Brooks K, Bundy A, Cvitanovic C, Dickey-Collas M, de Miranda Grilli N, Gomez C, Jarre A, Kaikkonen L, Kelly R, López R, Muhl E-K, Pennino MG, Tam JC and van Putten I (2021) The quilt of Sustainable Ocean governance: Patterns for practitioners. *Frontiers in Marine Science* 8. <https://doi.org/10.3389/fmars.2021.630547>.
- Sterling EJ, Pascua P, Sigouin A, Gazit N, Mandle L, Betley E, Aini J, Albert S, Caillon S, Caselle JE, Cheng SH, Claudet J, Dacks R, Darling ES, Filardi C, Jupiter SD, Mawyer A, Mejia M, Morishige K, Nainoca W, Parks J, Tanguay J, Ticktin T, Vave R, Wase V, Wongbusarakum S and McCarter J (2020) Creating a space for place and multidimensional well-being: Lessons learned from localizing the SDGs. *Sustainability Science* 15(4), 1129–1147. <https://doi.org/10.1007/s11625-020-00822-w>.
- Stori FT, Peres CM, Turra A and Pressey RL (2019) Traditional ecological knowledge supports ecosystem-based management in disturbed coastal marine social-ecological systems. *Frontiers in Marine Science* 6, 571. <https://doi.org/10.3389/fmars.2019.00571>.
- Strand M, Rivers N and Snow B (2022) Reimagining ocean stewardship: Arts-based methods to 'hear' and 'see' indigenous and local knowledge in ocean management. *Frontiers in Marine Science* 9. <https://doi.org/10.3389/fmars.2022.886632>.
- Tosca MG, Galvin A, Gilbert I, Walls KL, Tyler GE and Nastan AM (2021) Reimagining futures. *Elementa: Science of the Anthropocene* 9(1), 00016. <https://doi.org/10.1525/elementa.2021.00016>.
- Tsatsaros JH, Bohnet IC, Brodie JE and Valentine P (2021) A transdisciplinary approach supports community-led water quality monitoring in river basins adjacent to the great barrier reef, Australia. *Marine Pollution Bulletin* 170, 112629. <https://doi.org/10.1016/j.marpolbul.2021.112629>.

- Turner MG, Calder WJ, Cumming GS, Hughes TP, Jentsch A, LaDeau SL, Lenton TM, Shuman BN, Turetsky MR, Ratajczak Z, Williams JW, Williams AP and Carpenter SR (2020) Climate change, ecosystems and abrupt change: Science priorities. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 375(1794), 20190105. <https://doi.org/10.1098/rstb.2019.0105>.
- Van Assche K, Hornidge A-K, Schlüter A and Vaidianu N (2020) Governance and the coastal condition: Towards new modes of observation, adaptation and integration. *Marine Policy* 112, 103413. <https://doi.org/10.1016/j.marpol.2019.01.002>.
- Vanderlinden J-P, Baztan J, Chouinard O, Cordier M, Da Cunha C, Huctin J-M, Kane A, Kennedy G, Nikulkina I, Shadrin V, Surette C, Thiaw D and Thomson KT (2020) Meaning in the face of changing climate risks: Connecting agency, sensemaking and narratives of change through transdisciplinary research. *Climate Risk Management* 29, 100224. <https://doi.org/10.1016/j.crm.2020.100224>.
- Vervoort J and Gupta A (2018) Anticipating climate futures in a 1.5 °C era: The link between foresight and governance. *Current Opinion in Environmental Sustainability* 31, 104–111. <https://doi.org/10.1016/j.cosust.2018.01.004>.
- Vince J and Hardesty BD (2018) Governance solutions to the tragedy of the commons that marine plastics have become. *Frontiers in Marine Science* 5. <https://doi.org/10.3389/fmars.2018.00214>.
- Vogel C and O'Brien K (2021) Getting to the heart of transformation. *Sustainability Science* 17, 653–659. <https://doi.org/10.1007/s11625-021-01016-8>.
- Vollstedt B, Koerth J, Tsakiris M, Nieskens N and Vafeidis AT (2021) Co-production of climate services: A story map for future coastal flooding for the city of Flensburg. *Climate Services* 22, 100225. <https://doi.org/10.1016/j.ciser.2021.100225>.
- Werle D, Boudreau PR, Brooks MR, Butler MJA, Charles A, Coffen-Smout S, Griffiths D, McAllister I, McConnell ML, Porter I, Rolston SJ and Wells PG (2018) Synthesis looking ahead: Ocean governance challenges in the twenty-first century. In *International Ocean Institute-Canada* (ed.), *The Future of Ocean Governance and Capacity Development*. Canada: International Ocean Institute, pp. 533–542. https://doi.org/10.1163/9789004380271_094.
- Westley F, Olsson P, Folke C, Homer-Dixon T, Vredenburg H, Loorbach D, Thompson J, Nilsson M, Lambin E, Sendzimir J, Banerjee B, Galaz V and van der Leeuw S (2011) Tipping toward sustainability: Emerging pathways of transformation. *Ambio* 40(7), 762–780. <https://doi.org/10.1007/s13280-011-0186-9>.
- Westoby R and McNamara KE (2019) Fear, grief, hope and action. *Nature Climate Change* 9(7), 500–501. <https://doi.org/10.1038/s41558-019-0511-z>.
- Westoby R, McNamara KE, Kumar R and Nunn PD (2020) From community-based to locally led adaptation: Evidence from Vanuatu. *Ambio* 49(9), 1466–1473. <https://doi.org/10.1007/s13280-019-01294-8>.
- Wyborn C, Davila F, Pereira L, Lim M, Alvarez I, Henderson G, Luers A, Martinez Harms MJ, Maze K, Montana J, Ryan M, Sandbrook C, Shaw R and Woods E (2020) Imagining transformative biodiversity futures. *Nature Sustainability* 3(9), 670–672. <https://doi.org/10.1038/s41893-020-0587-5>.