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Principles for transformative ocean governance

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With a focus on oceans, we collaborated across ecological, social and legal disciplines to respond to the United Nations call for transformation in the '2030 Agenda for Sustainable Development'. We developed a set of 13 principles that strategically and critically connect transformative ocean research to transformative ocean governance (complementing the UN Decade for Ocean Science). We used a rigorous, iterative and transparent consensus-building approach to define the principles, which can interact in supporting, neutral or sometimes conflicting ways. We recommend that the principles could be applied as a comprehensive set and discuss how to learn from their interactions, particularly those that reveal hidden tensions. The principles can bring and keep together partnerships for innovative ocean action. This action must respond to the many calls to reform current ocean-use practices which are based on economic growth models that have perpetuated inequities and fuelled conflict and environmental decline.

In response to declining ocean health and increasing pressures on ocean resources[1,2], the 2022 United Nations (UN) Ocean Conference recognized the need for transformative change to 'halt and reverse the decline in the health of the ocean's ecosystems and biodiversity and to protecting and restoring its resilience and ecological integrity'[3]. This call echoes the '2030 Agenda for Sustainable Development'[4], the Kunming-Montreal Global Biodiversity Framework 2021–2030[5], as well as the Intergovernmental Panel on Climate Change and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), who called for 'transformative systemic change'[6] and 'transformative governance'[7], respectively.

Within the scientific literature there is also support for this call for transformation[8–12] and integrated and ecosystem-based, science-based, model-based and other knowledge-based approaches to ocean

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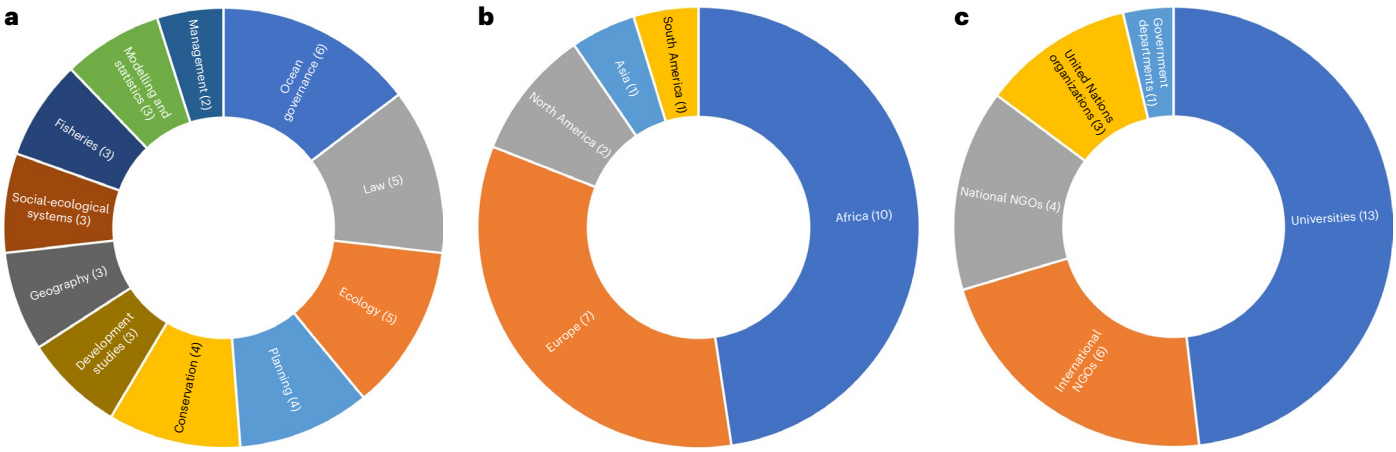

Fig. 1 | Metrics of author diversity. a, Disciplinary diversity (number of authors that work in a discipline—note that some authors work in more than one discipline). **b**, Geographic diversity (number of authors per continent). **c**, Institutional diversity (the number of different institutions in which authors have worked on ocean governance).

governance[13–17] are recommended to address multiple pressures[8,18–20] exacerbated by the adverse impacts of climate change[21–23]. Despite these calls, immense challenges to sustainable ocean use persist[4], earlier calls for a new planetary deal[24] remain unanswered and effective, holistic principles for transformative ocean governance have not yet been elaborated[25,26], although priorities for sustainable ocean economies[27,28] and social equity in ocean governance[29] have been articulated. There are also questions regarding not just equity but justice and whether global initiatives are the answer to transformative change[30].

According to IPBES, transformation implies a 'fundamental, system-wide change that includes consideration of technological, economic and social factors, including in terms of paradigms, goals or values'. In response, the Implementation Plan of the UN Decade of Ocean Science for Sustainable Development[31] calls for 'transformative science', as so-called inclusive science that spans the marine and social sciences, is codesigned and coproduced in partnership with a variety of stakeholders and knowledge holders (including Indigenous knowledge holders), uses Agenda 2030 as a framework for priorities and emphasizes solutions for governance[32]. We deepen this understanding that transformative ocean research is needed to support transformative ocean governance, if we wish to reform current ocean-use practices based primarily on economic growth models that have perpetuated inequities and fuelled conflict and environmental decline (oneoceanhub.org/publications/policy-brief). We rely on the definition of transformative governance proposed by biodiversity governance scholars as 'the formal and informal (public and private) rules, rule-making systems and actor networks at all levels of human society that enable transformative change'[33] towards environmental sustainability and environmental justice[34].

Building on earlier efforts that argue that transformative governance will require integrative, inclusive, adaptive and pluralist approaches that better address both the indirect and direct drivers undermining sustainability[33,35], including through transdisciplinary research and knowledge coproduction[17], we propose 13 principles, which, if applied as a comprehensive set, could support the implementation of current ocean governance policies in more transformative ways and also support more transformative future policies and practices.

Guiding principles are widely used in the international environmental governance realm, for example, principles for ecosystem-based management[36,37] and responsible fisheries[38] and increasingly at the intersection of human rights and the environment[39], including socially responsible seafood[40,41] and small-scale fisheries[42], the United Nations Guiding Principles on Business and Human Rights[43] and the Ten Principles of the UN Global Compact[44]. Transdisciplinary research projects have also recently developed principles[45,46]. Many of these principles emerged in areas of relevance to ocean governance.

Drawing from these, we used a rigorous, iterative, transparent and quantitative consensus-building approach to evaluate and synthesize this breadth of knowledge on the basis of a dialogue across ecological, social and legal sciences, as well as on the basis of our own diverse and complementary experiences. As a result, we developed a comprehensive set of 13 principles that strategically and critically connect transformative ocean research to transformative ocean governance, as a basis for developing and nurturing the 'partnerships' for 'scaling up ocean action based on science and innovation' for Sustainable Development Goal (SDG) 14 (Life Below Water), called for at the 2022 UN Ocean Conference. The principles can first be used to identify blind spots and hidden tensions in collective transformative ocean research endeavours, helping to see these tensions as areas for learning. The principles can then be used to 'navigate' these tensions, while keeping together diverse groups (diverse researchers, diverse human rights-holders and other stakeholders) as they navigate different positions of power regarding these tensions, in an iterative learning process (a partnership for innovation).

Process of principle development

The process for developing our principles started at an international conference in South Africa in January 2020 to explore Transformed and Transformative Ocean Governance (TOG conference), which brought together diverse researchers from the Algoa Bay Community of Practice[47] and the One Ocean Hub (https://oneoceanhub.org/) and researchers involved in other projects from different regions. The conference aimed to provide an initial forum to engage with the latest developments impacting on ocean governance from developmental, ecosystem-based and human-rights-based approaches, before starting to reflect and give direction on what transformative ocean governance means and requires. Participants were invited to speak on the transformation imperative, legal frameworks and international and domestic politics of ocean governance; developmental approaches including inclusive and equitable development, the blue economy and SDG 14; as well as ecosystem-based and human rights-based approaches including marine planning, ocean health, social justice and the role of civil society in governance. Participants were selected on the basis of disciplinary, geographic and institutional diversity (Fig. 1) and their collective range, depth and diversity

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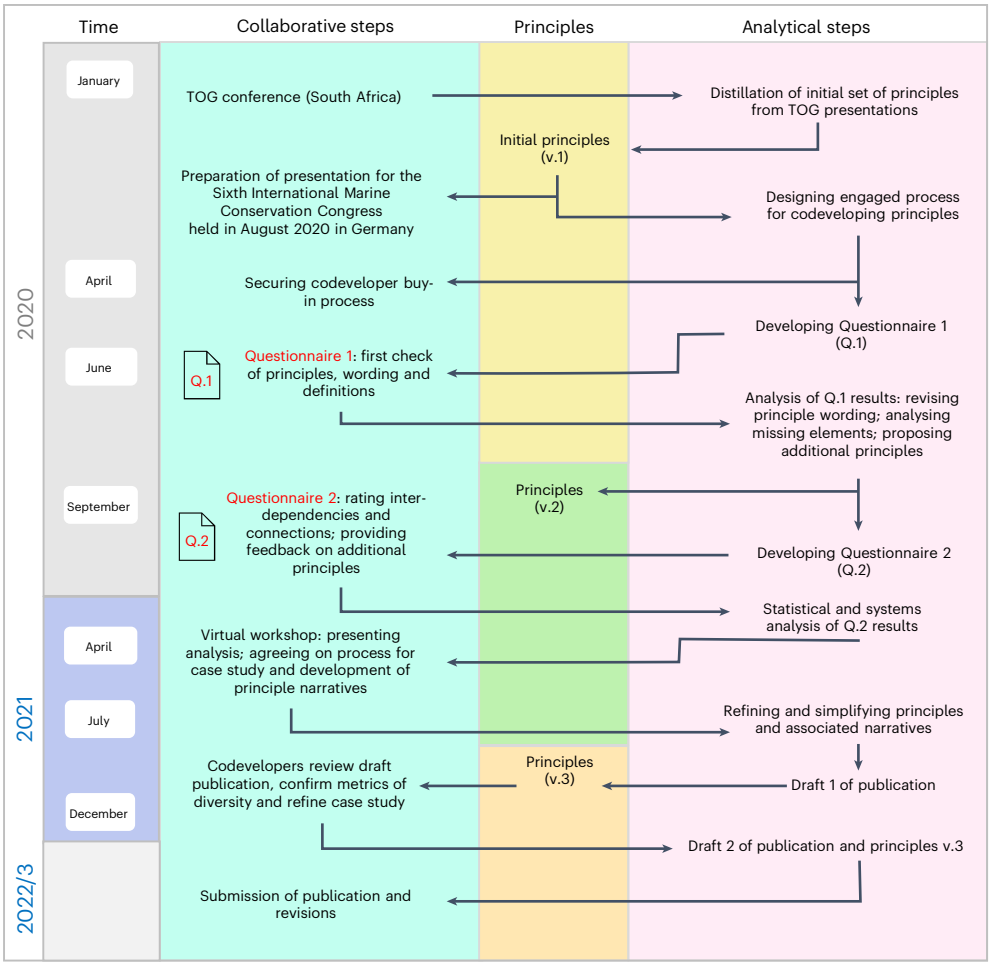

Fig. 2 | Iterative process of principle development. Illustrating the interplay between collaboration and analysis out of which the increasingly refined set of principles emerged.

of experience gained from working in and influencing, the ocean governance realm. Together, the 21 authors represented here (the participants) have a total of 440 years of experience gained by working in over 30 countries.

Although wide-ranging, the principles we developed reflect the participants involved in producing them and we acknowledge that different participants may have developed different principles. This does not, however, mean that the principles here lack validity or usefulness. It rather follows an awareness that who we are, is not separated from the knowledge we produce and that such an awareness strengthens research through an alertness to the way it is shaped, its potentials and its limitations[48]. Our principles are hence ours but have been carefully configured through a rigorous, iterative and transparent consensus-building approach so that they may also be more widely applicable.

The iterative and transparent process of principle development is summarized in Fig. 2. Details are provided in the Methods.

Thirteen principles for transformative ocean governance

Table 1 presents the 13 principles that are proposed here as encompassing the range and scope that might transform ocean governance, with a brief narrative for each principle. Full narratives, which capture the complexity and rich discussions during the formulation of the principles, are provided in Supplementary Note 1. To emphasize that the principles should be applied as a comprehensive set, and that no principle is considered more or most important, they are not numbered. Supplementary Note 2 describes the antitheses of these principles and helps to frame them in a continuum with a business-as-usual approach at one end (the antithesis) and a transformative approach at the other (the principle).

Relationships among the principles

Although the relationships among principles are mostly supporting or enabling, there is potential for tensions between them, similar to the 'trade-offs' identified in an analysis of the interactions between the SDGs[49,50]. However, these tensions provide indications of blind spots that can unveil areas of learning for transformation, which is why the 13 principles should be applied as a comprehensive set, so that none can dominate or control the outcome and synergies between the principles can be productive rather than counterproductive.

A social network analysis of the relationships between principles is provided in Fig. 3. Figure 3a shows which principles were selected by ≥85% of the authors as having supporting or enabling relationships between them. In this analysis, every principle was selected by a minimum of 25% of the authors as having a supporting relationship with another principle but to enable visualization of the most frequently selected relationships only, a threshold of 85% was chosen for display (the arrows show where 85% or more of authors selected a supporting or enabling relationship between two principles). The direction of the arrows shows the direction of the supporting relationship and points towards the principle being supported. For example, social-ecological

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Table 1 | Thirteen principles for transformative ocean governance

Principle		Brief narrative
Transformative ocean governance...		
	... maintains and restores biological diversity, which is key for resilient ocean ecosystems.	Keywords: Biological diversity Biological diversity includes ecosystem, species and genetic diversity, all of which play an important role in the structure, functioning and productivity of ecosystems. Sustaining rich biodiversity fuels resilient and productive marine ecosystems, which provide the ecosystem services that underpin healthy societies. Biologically diverse ecosystems are also more resilient to changes and fluctuations in social-ecological systems and buffer society against adverse impacts.
	... upholds human rights approaches, which are essential for human well-being.	Keywords: Human rights States and other duty-bearers undertaking any activity in the marine environment must ensure that no foreseeable infringements of human rights may arise from their actions. Prior assessments of possible sociocultural and environmental impacts of projects or policies should be conducted before implementation begins. Meaningful public participation is a primary key to success.
	... adopts social-ecological systems approaches.	Keywords: Social-ecological systems Social-ecological systems describe the complex interlinkages between the social and environmental components of systems. For ocean governance to be effective, it needs to understand and embrace this complexity. This will promote and enable adaptation to unforeseen events or changes in the system.
	... integrates cross-sectoral policies to achieve social and ecological connectivity.	Keywords: Policy integration Given the interconnected nature of ocean systems, it is imperative that policies are integrative across governance, knowledge and stakeholder siloes, incorporating the coordination of governance and information exchange across international boundaries and land–sea boundaries, with the overall aim of achieving social and ecological connectivity.
	... uses simple, robust and diverse metrics of social-ecological systems status.	Keywords: Metrics The use of metrics to support ocean governance provides the opportunity to gauge and report on the state of a system, measure change and trigger an action. Environmental and socioeconomic metrics, if properly used, can support accountability, effective reporting and learning, as well as evidence-based decision-making and scenario planning.
	... requires inclusive and transparent IOM processes.	Keywords: Integrated ocean management (IOM) Oceans are dynamic and connected environments and current sectoral instruments and organizations are failing to halt a decline in ocean health and ecosystem service delivery. An integrated approach to management, that conserves species, resources and manages human activities for optimal use, is required. To transform ocean governance, IOM approaches should also be ecosystem-based, adaptive, inclusive and transparent.
	... coordinates engagement between ocean businesses and other diverse ocean stakeholders.	Keywords: Business engagement Coordinated and transparent engagement with ocean stakeholders, including private and corporate sectors, is essential to address the interlinked and cumulative impacts of businesses on the ocean and society and to promote net positive outcomes for both. Guiding principles for responsible businesses and platforms for business engagement do already exist, although more work is needed to connect them to ocean governance policies and laws.

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Table 1 (continued) | Thirteen principles for transformative ocean governance

Principle		Brief narrative
	... encourages diverse incentives to promote and enable sustainable ocean-use practices.	Keywords: Diverse incentives The use of rigorously designed, functionally integrated and effective diverse incentives, ranging from command-and-control (top-down), participative (bottom-up), economic (markets and economies), knowledge (collective learning) and interpretative (awareness-raising), can help ensure that sectors are managed and governed in ways that are appropriate to each sector and to the broader system.
	... promotes sustainable and inclusive technological and other innovation.	Keywords: Technology Technological innovation can support transformative ocean governance in many ways. For the transformative potential to materialize, technological innovation needs to account for multiple dimensions of sustainability, equity issues (access, availability and know-how) and be codeveloped with end users and affected stakeholders. It is equally important to consider other sources and forms of innovation than technology, such as social, cultural and economic innovation.
	... leverages international mechanisms that support inclusive decision-making for sustainable development.	Keywords: International mechanisms Leveraging international mechanisms can be critical to support local-level and national-level environmental commitments (for example the SDGs) as well as to secure human rights, particularly when national and local governments are lagging behind in implementing their international obligations on marine biodiversity, the protection of the marine environment and human rights.
	... advocates for dynamic, inclusive and adaptive approaches to governance.	Keywords: Governance approaches Given the inherent complexity in, and dynamic nature of, marine social-ecological systems, governance requires dynamic approaches that can respond to shifts in these systems. Governance also requires the respectful integration and inclusion of Indigenous and local knowledge and the ability to adapt to the status of ecosystems and the nonlinear reactions from both human and non-human pressures on these systems.
	... requires appropriate responses to existing and potential power dynamics.	Keywords: Power dynamics Transformative ocean governance will require action to address persistent and wicked marine governance problems that have impeded governance innovation. These problems are often derived from complex, sometimes unacknowledged, power dynamics. Power issues related to path dependency, bounded rationality or vested interests have been identified as barriers that have hitherto inhibited the implementation of the required transformative approaches to ocean governance.
	... requires urgent action across governance levels.	Keywords: Urgent action The value of a blue or ocean economy has become an integral part of the sustainable development discussion and thus gained substantial political weight. In addition to political weight, the demand for ocean resources and services has increased. The cumulative impacts on the ocean have amplified and the rapid deterioration of ocean health and the well-being of millions dependent on it now signals that urgent action is required for the timely and effective implementation of SDG14.

systems (SES) is an important supporting and enabling principle with many linkages. It supports five principles and is supported by eight (even at the high threshold of 85%).

As expected, principles can also have potentially conflicting or constraining relationships, which create tensions (Fig. 3b). Owing to the smaller number of conflicting relationships identified, a lower threshold of 25% or more of authors selecting such a relationship was used to achieve a similar density of connecting lines as for Fig. 3a (but note that, as for Fig. 3a, most principles would have connecting arrows in the figure if no threshold was applied). The arrow shows the direction of the conflicting relationship. If one considers only the relationships above the threshold of 25%, urgent action is a key conflicting or constraining principle; it can be constrained by five principles and can itself constrain three. In interpreting these data, it is important, however, to consider temporal scales. For example, in the short term, biological diversity and human rights can potentially constrain one another but not necessarily in the longer term. Conflicts and constraints would also be substantially modified and reduced in the reformed world envisaged by, for example, the 2030 Agenda for Sustainable Development, in which poverty and hunger are ended, peaceful, just and inclusive societies are built and the other goals achieved to promote a sustainable future for all.

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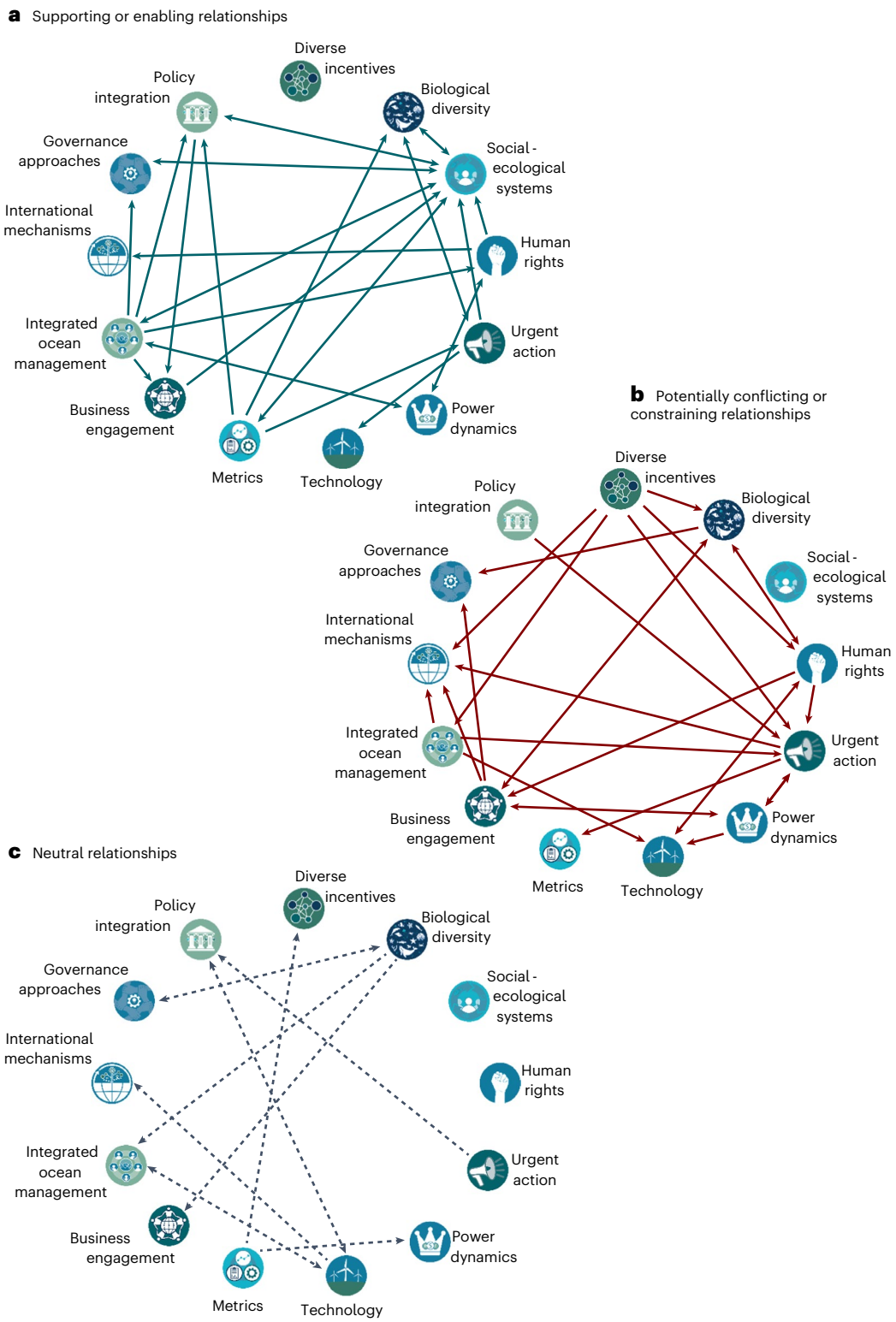

Fig. 3 | Relationships between principles. A social network analysis of the relationships between principles and the direction of the relationship. For example, the technology principle is supported by the urgent action principle in Fig. 3a. Note that the absence of arrows between any two principles does not indicate the lack of a relationship because arrows are displayed for the strongest relationships only. **a**, Supporting or enabling relationships. **b**, Potentially conflicting or constraining relationships. **c**, Neutral relationships.

It is also possible for neutral relationships to exist between principles (Fig. 3c). Here, a threshold of 40% or more of authors selecting this relationship was used. At this threshold, social-ecological systems and human rights do not have any neutral relationships with the other principles but biological diversity and technology have the most neutral relationships in both directions.

The value of this network analysis is not only that it identifies and quantifies the nature of relationships between principles, through

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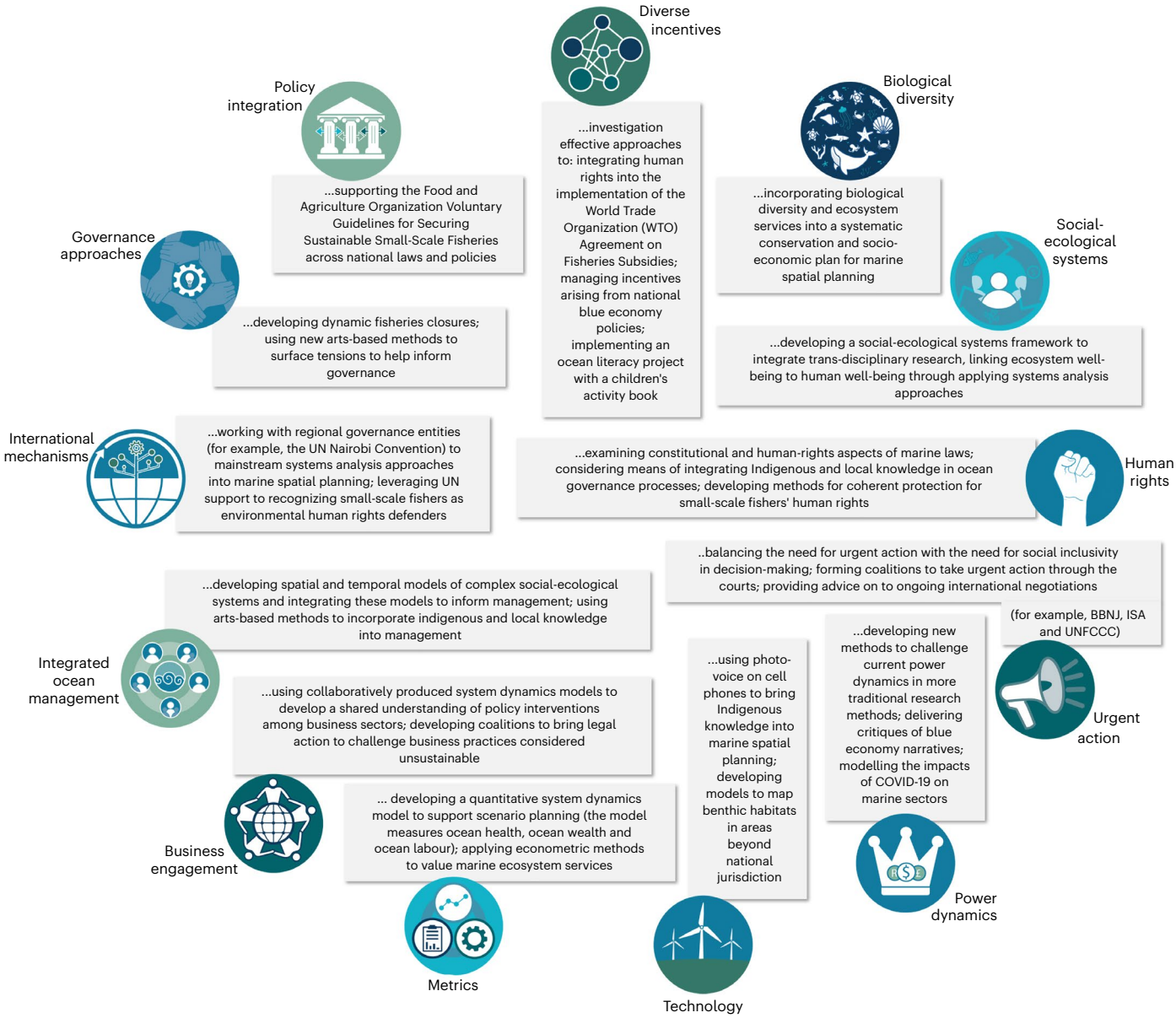

Fig. 4 | A summary of how the 13 principles map onto the ABP-OOH family of research projects. Details of these research projects are provided in Supplementary Note 3. BBNJ, Marine Biodiversity of Areas Beyond National Jurisdiction; ISA, International Seabed Authority; UNFCCC, United Nations Framework Convention on Climate Change.

the lenses of the participating authors, but that it highlights potential conflicting and constraining relationships that can create tensions. In addition to trying to reduce these conflicts and tensions (for example, the development of offset policies such as carbon credits[51] or financing sustainable economies[20]), we suggest that these tensions are explored as areas of learning for transformative change.

Supplementary Figs. 1–4 provide additional results from the social network analysis, including the percentage of authors who identified a supporting or enabling relationship between principles and eigenvector centralities for all three types of relationships. These relationships are further explored in a case study below.

Applying the principles in a case study

Here, we examine and test the 13 principles in two ways: first, we map them onto a case study that over half of the authors have been directly involved in and, second, we reflect as a group on the interactions between principles in the case study as described in Fig. 3. The study began in 2017 in Algoa Bay, South Africa, with a national government research grant aimed at connecting researchers across disciplines to 'provide evidence-based solutions to societal challenges'. The study soon expanded to include a family of related and collaboratively developed multidisciplinary projects, for example, CICLICO (Cities and Climate Change in Coastal Western Indian Ocean) funded by the Western Indian Ocean Marine Science Association, MARISCO (Marine Research and Innovation for a Sustainable management of Coasts and Oceans) funded by the Belmont Forum and a regional marine spatial planning (MSP) strategic framework for the Western Indian Ocean[52] funded by the UN Environment Programme. In 2019, the family of Algoa Bay projects (ABP) joined the One Ocean Hub (OOH), an international programme of 'fair research partnerships for sustainable development' among the Global North-South, funded by United Kingdom Official Development Assistance. The aim of the ABP is a 'healthy ocean for all', focusing on MSP informed by systems thinking and integration of different knowledge systems. The OOH mission is 'transformative

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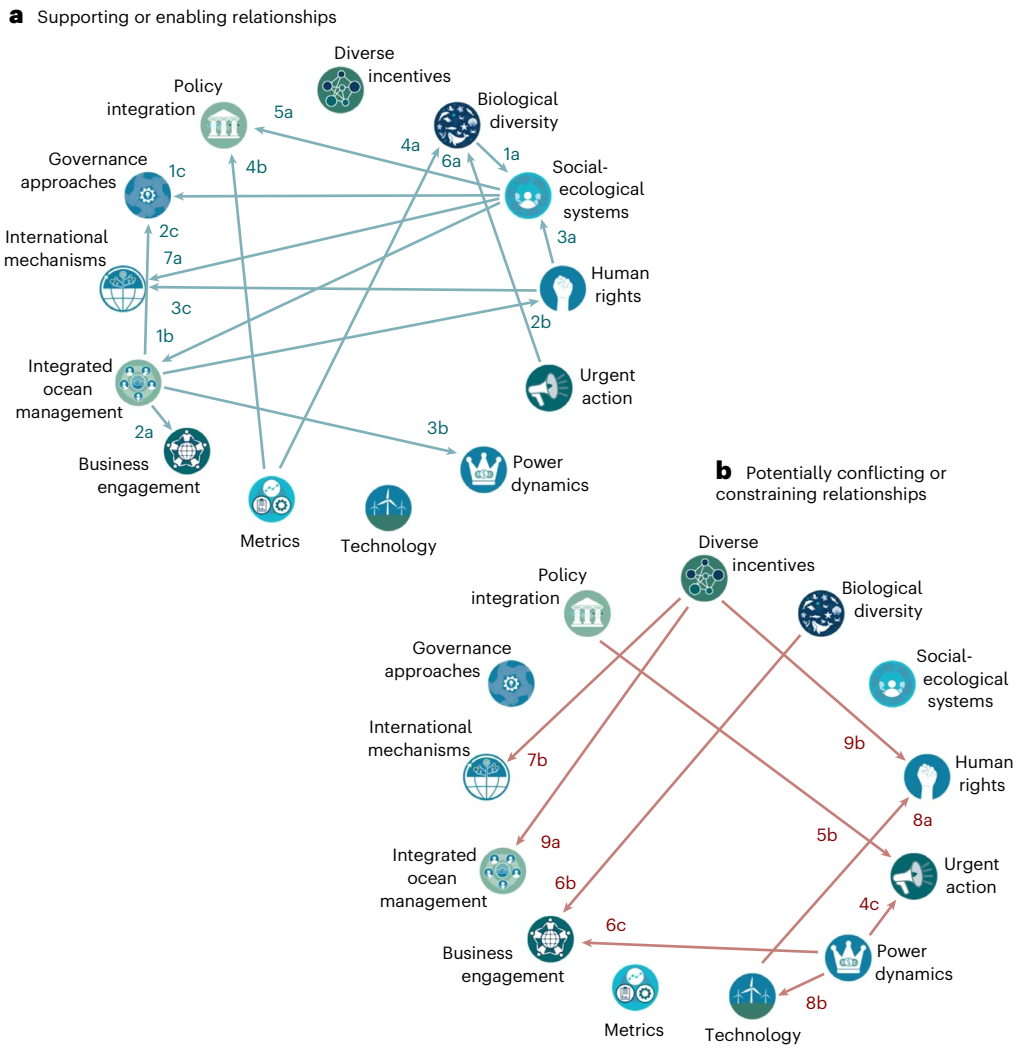

Fig. 5 | Examples of interactions between principles in the ABP-OOH family of research projects and the direction of the interaction. Interactions are numbered and described in the text. Further details of these interactions are provided in Supplementary Note 4. **a**, Supporting or enabling relationships. **b**, Potentially conflicting or constraining relationships.

ocean research for inclusive and integrated governance'. Together, the ABP-OOH projects have brought together researchers from the biophysical sciences (including deep-sea and fisheries science), the social sciences (including anthropology and the arts), ecological and resource economics and law (national and international law on environment, human rights and the sea), with the joint aim of helping to inform stakeholders and governments on what transformative governance entails and what can be achieved through it.

A summary of how the 13 principles can be mapped onto the ABP-OOH case study is provided in Fig. 4 (Supplementary Note 3 provides greater detail). The case study (with all its subcomponent projects) did not begin with the 13 principles as an overarching roadmap, so it was interesting and reassuring to learn that all 13 principles had been considered in at least one of these subcomponents. The challenge and opportunity for future transformative research is to apply the 13 principles simultaneously in project formulation, with a view to identifying hidden tensions and blind spots at the initial stages and in an iterative way throughout implementation and then to adjust the terms and approaches of the emerging and evolving partnership.

Interaction of principles in the case study

Although we recommend that the 13 principles presented here are applied as a comprehensive set, how they interact with one another will probably differ from case to case. This can manifest in different ways. First, a principle could support another principle under one condition but could be neutral towards, or even constrain, the realization of the same principle under different conditions. Second, the way in which a principle could support or constrain another principle could be desirable or undesirable, depending on whose perspective is taken. For example, a constraint that reduces the centralization of power is desirable from an overall system perspective, although it may be undesirable from the powerful stakeholder's perspective. These possible interactions suggest that the principles are neither absolute nor are they value-neutral or context independent. This is best illustrated by reflecting on how the 13 principles interact with one another in the ABP-OOH case study. These interactions are discussed in detail in Supplementary Note 4 but a selection of interactions is summarized below and in Fig. 5.

In interaction 1a (Fig. 5), a systematic conservation plan was developed to identify priority areas for biodiversity and nature-based activities in MSP[53]. This work is now incorporating socioeconomic data, including cultural data and the valuation of ecosystem services. Using an SES framework, the work is intended to contribute to environmental and social resilience to negative climate change impacts (illustrating biological diversity supporting SES).

Social-Ecological Systems approaches have also been an important part of the project. Others[54] developed an exploratory system

dynamics model to support MSP in Algoa Bay, showing how healthy marine ecosystems support multiple sectors. The associated collaborative dynamic modelling process provides a prototype for inclusive and transparent integrated ocean management (IOM) processes, to iteratively co-identify levers of change and to simulate the implications of different actions. The modelling process used a visual user interface for stakeholders to engage in scenario planning and to support decision-making (interaction 1b, SES approaches supporting inclusive and transparent IOM processes).

One of the tensions arising from this interaction is that these tools are focused on temporal changes but do not yet include a spatial approach. Different sectors use different methods (either temporal or spatial) to plan ocean use, thus arriving at different conclusions on fishing quotas and closed areas. The challenge is to combine temporal and spatial approaches for adaptive governance (to further develop SES approaches that support adaptive, dynamic and inclusive approaches to governance; interaction 1c).

The MSP process in Algoa Bay recognized the value of incorporating different knowledge systems and methodologies and including diverse knowledge holders. This contributes to 'cultural layers' in MSP, reflecting the SES framing of the overall MSP and opening the MSP process to other knowledge holders that are usually excluded (illustrating human rights approaches supporting SES; interaction 3a). Pathways were codeveloped with Indigenous and local knowledge holders, together with ocean governance role players and managers. One of the pathways calls for policy coherence, particularly between the MSP legislation and the National Heritage legislation. This reflects SES supporting integration of cross-sectoral policies (interaction 5a).

A further challenge in this modelling work is the respectful incorporation of cultural data with other quantitative and monetizable data, so as to provide appropriate protection for the human rights of vulnerable groups. The ABP is exploring how to integrate these cultural layers into models to ensure consideration of human rights issues (interaction 3b, IOM processes supporting appropriate responses to power dynamics). OOH research has also shown that some blue economy programmes have been negatively impacting cultural rights[55]. The OOH human rights-based research and innovations are supporting the development of global guidelines[42] and as a result of this work, the OOH has been invited to lead a global programme on transdisciplinarity for the UN Decade for Ocean Science (interaction 3c, human rights supporting international mechanisms).

In many countries, including South Africa, there is a lack of interdepartmental cooperation and cross-sectoral integration at a national level. For example, the MSP authorities in South Africa are based in the Department of Forestry, Fisheries and the Environment, rather than in an interdepartmental body that could facilitate cross-sectoral policies. This institutional reality raises the challenge of different temporal scales: the political system, where the power for cross-sectoral policy integration sits, is based on a short term (five-year time span), whereas biodiversity and human rights require a longer time-frame (illustrating how a lack of integration of cross-sectoral policies constrains taking urgent action, interaction 5b). This lack of integration, which results in narrow national economic growth prerogatives (which is not unique to South Africa) hinders both South Africa and its neighbouring countries in their ability to respond to (or benefit from or engage in) regional MSP plans, such as the one developed for the Western Indian Ocean under the United Nations Nairobi regional seas Convention[52] (illustrating how a lack of diversity in incentives can constrain international mechanisms, interaction 7b). The regional plan uses an SES framework and calls for the integration of policies to respond to regional challenges (such as unsustainable and illegal fishing, pollution and maritime security). Our area of learning is now to understand how progress at the regional level can influence the national level, given that South Africa is a party to the Nairobi Convention (interaction 7a, SES approaches supporting international mechanisms).

Transformative ocean research and governance also need to consider biodiversity in areas beyond national jurisdiction (ABNJs) but research in deep-sea ecosystems requires advanced technologies and expertise. OOH research has found multiple areas of inequity in deep-sea research and associated technologies and these inequities have legal implications from the perspective of the human right to science (illustrating how inequitable technological development and deployment can constrain human rights, interaction 8a). In response to this constraint, the OOH is providing urgent advice to international processes (such as the UN negotiations on a new instrument on biodiversity in ABNJ).

Whether under national or international jurisdiction, ocean governance involves diverse incentives and it is important to consider how these incentives functionally interact[56]. The narrow focus on one type of incentive (namely economic incentives) can erode the principles of inclusivity and transparency that are central to IOM and human rights. For instance, Operation Phakisa[57] in South Africa illustrates how sectoral growth priorities (with their associated economic incentives) are often considered to be of national importance and override local public opinions, thereby undermining inclusive and transparent IOM processes, illustrating how a lack of diversity in incentives can constrain IOM (interaction 9a) and human rights (interaction 9b). In response to this constraint, the OOH is exploring with international bodies how to shed light on the problematic nature of these incentives and the missed opportunities for realizing multiple SDGs through a more integrated and human-rights-based approach: for instance, the World Trade Organization Fisheries Subsidies Agreement could support the protection or undermine the human rights of small-scale fisheries.

Discussion

We have distilled a set of 13 principles, which resonate across ecological, social and legal sciences, to strategically and critically connect transformative ocean research to transformative ocean governance. They provide a basis for potentially developing and nurturing the 'partnerships' for 'scaling up ocean action based on science and innovation' for SDG 14, responding to the calls for action of the UN Ocean Decade and the 2022 UN Ocean Conference. We have tested the principles in the context of a case study (or 'real-world laboratory'[58]), which was aligned with the UN Ocean Decade vision for 'transformative ocean science' but has also provided opportunities to consider how to integrate codeveloped research at different stages and across different projects. Within the OOH, for instance, we have developed multiple projects that apply the principles to particular issues, such as the ocean–climate nexus, ocean plastics or fisheries subsidies at the stages of international law-making, financing and application on the ground.

It should be noted, however, that there is also ongoing resistance to some global forums and initiatives aimed at ocean governance, for example, the 2022 conference held by the World Forum of Fisher Peoples[59]. Some ocean peoples are (rightly) doubtful that the 'answer' to ocean governance can be found within such international theatres, where there are frequent drives for participation but often a lack of active listening and response to concerns of those who literally live with the sea. Indeed, transformation may lie beyond these very historically contingent and at times troubling institutions which oftentimes repeat injustices and inequalities of the past.

Indeed, the principles, applied as a whole here, helped identify blind spots and hidden tensions in interdisciplinary and transdisciplinary ocean research that unveil areas of learning for transformative ocean governance. We concur with other reflections arising from research codevelopment experiences on the importance of including attention to social and ecological systems[60], power dynamics[61] and learning from other knowledge holders[62]. We also acknowledge the great challenges in respectfully and genuinely codeveloping knowledge with Indigenous and local knowledge holders[60]. Our principles, however, are distinctive first because they integrate human rights as

a lens to support systems thinking and programmatic capacity building in ocean research and MSP, instead of focusing only on violations and redress. This allows us to reflect on sociocultural and ecological connections at the outset of planning processes (be they for research, ocean management or policy development) and pay due attention to historical and current environmental/blue justice issues[34]. Second, we consider it essential to integrate arts into transformative ocean research not only as a way to communicate our research findings 'in forms that are widely understood and trigger excitement' (as called for by the UN Ocean Decade). In addition, arts are a form of research itself, as well as a method that allows us to reveal and address power imbalances, including those that arise in knowledge cocreation[63] and contribute to application (or test the application) of the human rights-based approach to ocean research, governance and management. Notably, this has supported progress towards respectful engagement with Indigenous and local knowledge holders, as well as deeper understanding of the injustices they face and how they are linked to whole-of-society sustainability challenges. Third, we consider codesigned and codeveloped research with UN bodies and other global and regional governance actors as a way to develop governance insights across scales and co-identify opportunities for upscaling and cross-scalar governance uptake, which has been documented as a major challenge in knowledge coproduction[64]. Our case study provides early (and sometimes mutually supportive) areas of impact on ocean-related rules, rule-making systems and actor networks in different sectors at the national, regional and international level. Our innovations in this connection have been recognized through an invitation from the Intergovernmental Oceanographic Commission of UNESCO to the ABP-OOH researchers to lead a programme on transdisciplinary research during the UN Decade for Ocean Science.

Research aimed at transforming ocean governance may benefit from applying the 13 principles presented here and understanding the interactions among them, so that both the synergies and the inevitable tensions that arise when all 13 are applied as a comprehensive set can be identified and navigated, while keeping together diverse groups of researchers and other stakeholders who hold differing world views and positions of power. Learning, self-reflexivity and navigating differences are critical elements of transformation. So too are agency in a social network that engages with socio-ecological feedbacks and the role of power[65]. Applying the 13 principles as a whole thus helps keep together a partnership for transformative ocean action, by iteratively unveiling new challenging areas and new directions for ocean research to unlock system changes in ocean governance.

Methods

The iterative and transparent process of principle development is summarized in Fig. 2, which illustrates the interplay between collaboration and analysis, out of which the refined set of principles emerged. The first analytical step was the distillation of an initial set of principles drawing from the TOG conference presentations. The version 1 (v.1) set of principles was presented at the Sixth International Marine Conservation Congress in 2020, to expose them to a broader audience for feedback. Interest in increasing the scope and rigour of the final principles and their wording led to the design of an engaged process for codeveloping the principles, based on a modified Delphi method. The process involved two rounds of questionnaires, completed electronically, with virtual workshops and meetings held in between (the COVID pandemic prevented in-person meetings). Questionnaire 1 (Q.1) provided the TOG conference participants with the opportunity to review the distillation of the initial set of principles from the conference presentations. This review included validation and clarity of expression in the principles and addressed any duplications or omissions. The analysis of the Q.1 results led to revised wording for the principles and the proposal of three additional principles, which were summarized in principles v.2. The second questionnaire (Q.2) allowed the participants to rate the interdependencies and connections between the v.2 principles as well as provide feedback on the additional principles. The results of a social network analysis were presented in a virtual workshop, where it was agreed that fuller narratives for each principle were required and that a process was required to illustrate the principles 'in action'. The final analytical step involved refining and simplifying the principles and their narratives and inviting all participants to review the draft publication, which presents principles v.3.

Consensus on the principles was built using a modified Delphi method. Approaches for consensus building (often referred to as 'consensus methodologies') include consensus development conference, nominal group technique and the Delphi method[66,67]. The Delphi method was originally intended for developing consensus within small groups of experts but it has increasingly been applied in more open, inclusive and diverse forms, given that it is well suited to address 'complex and multi-layered problems that require the attention of multiple stakeholder groups'[68]. Our modified Delphi method included questionnaires and online workshops with reflection and discussion.

The modified Delphi method

The Delphi method is characterized by four key elements: (1) an expert panel; (2) multiple engagement rounds, with feedback between each round; (3) statistical analysis of group response; and (4) assured participant anonymity. The engagement rounds are typically undertaken via questionnaires, each followed by analysis and feedback to the group, which allows participants the space to 'reflect on this feedback and reconsider their opinions when responding to subsequent questionnaires'[68]. The benefit of the Delphi method is that it can be applied to expert groups with many participants from different geographical areas when it is neither practical nor cost-efficient to bring them together in person (which was additionally valuable during the Covid-19 pandemic). The disadvantages of the Delphi method include: (1) reliance on good questionnaire design; (2) biases with the initial selection of the 'expert' panel; (3) lack of generalizability or scientific validation of findings; (4) difficulties with coordinating large groups; and (5) the length of process, given the number of rounds required and the iterations in between the rounds[67,68].

The modified Delphi method applied in this study was designed to be more open, transparent and participatory than the traditional versions of Delphi. The overall goals of the approach remained that of 'understanding the various perspectives…, aggregation or synthesis of responses between rounds and iterative refining of views'[69]. At the centre of the process (Fig. 2) were two questionnaires. The design and format of these two questionnaires is described in detail in the main text and in the Supplementary Questionnaire. A third Delphi round could have allowed participants to incorporate feedback from Q.2 into their responses to a third questionnaire and would probably have led to further convergence of viewpoints. Aware of stakeholder fatigue and the negative returns of a drawn-out process[70], the lead authors deemed the two rounds of questionnaires (and associated feedback) to be sufficient to gain an understanding of the various perspectives and an iterative refinement of views (as per ref. 69).

Data collection and analysis

Feedback on the proposed principles was obtained from all authors using two questionnaires. The first was a Google form survey (represented by Q.1 in Fig. 2). Authors listed their background and experience, which was used to summarize the overall experience of the author group (reported in Fig. 1). A five-point Likert scale was used for authors to indicate their level of agreement with each principle and any concerns with the principle could be selected from a dropdown menu or mentioned in open-ended comments. Alternative wording could be proposed for each principle and new principles could be suggested. Bar plots of the Likert-scale agreement and the concerns were used to illustrate the trends in response and identify common concerns with

the principles. Chi-squared tests were used to investigate the relationship between the agreement rating and the concerns with the principle. A list of 13 revised and new principles were decided on by the core group and were then presented to the author group in Q.2.

Questionnaire 2 was sent to the author group in an Excel document (Supplementary Questionnaire). Each new principle was rated on the same questions as had been presented in Q.1. For all 13 principles, the authors were asked to identify either a supporting/enabling, neutral or potentially conflicting or constraining relationship with each of the other 12 principles. The questions were asked in two directions: first, when that principle is held up and each other principle is applied and second when that principle is applied to all other principles being held up. Results were plotted using bar plots of the responses and ordered by the overall level of agreement with that principle. A network analysis[71] was used to identify the linkages between the principles for each of the three different types of relationships (supporting/enabling, neutral or potentially conflicting or constraining). This was used to illustrate which principles were related to one another and the direction of the relationship.

All analyses were conducted using R[72]. The network analysis was run using the igraph package[71].

Inclusion and ethics

The research reported here included 21 researchers (from five continents) throughout the research process, starting with funded attendance at the original TOG Conference in South Africa, then study design, survey participation, data analysis and ownership and ending with authorship of this publication. None of the original researchers was excluded from the process and all agreed to participate until manuscript submission. Roles and responsibilities were agreed amongst all authors at the start and were affirmed and checked at a number of online meetings during the research process. No human or animal ethics approvals were required, given that we worked as a team of 21 co-authors. The questionnaires we developed are open access and are provided in Supplementary Questionnaire. The answers of co-authors (to these questionnaires) have been kept anonymous.

Reporting summary

Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

This research reported here collected data from all 21 co-authors in the form of questionnaires. These questionnaires and the results are provided on an open-access data portal for permanent archive, namely the Algoa Bay project (algoabaydata.com). Questionnaire 1 is provided on https://algoabaydata.com/documents/344; and Questionnaire 2 is provided on https://algoabaydata.com/documents/343. Participant names are removed from responses.

Code availability

All the R software and packages used in the analysis are freely available online and are clearly described and referenced in the Methods. No custom codes were developed.

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Author contributions

P.V., B.S. and A.T.L. conceptualized the initial TOG conference. A.T.L., J.C.H., V.G., B.S. and H.T. designed the study. All authors (A.T.L., J.C.H., V.G., B.S., H.T., P.V., P.J.S.J., K.C., W.F., C.H., L.G., E.H.A., D.D., K.P., B.E., P.L., P.H., M.N.S., A.A., H.G. and E.M.) participated in the process to develop the principles and filled in the questionnaires. V.G. conducted the analyses with support from H.T., A.T.L. and J.C.H. J.C.H. led the case study and conceptualized all the figures. A.T.L., J.C.H. and E.M. drafted the manuscript with contributions from all authors.

Competing interests

The authors declare no competing interests.

Additional information

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Software and code

Policy information about availability of computer code

Data collection	Google Forms was used to collect data for questionnaire one, and a Microsoft Excel spreadsheet was used for questionnaire 2 (this spreadsheet is provided as supplementary material).
Data analysis	All the R software and packages used in the analysis are freely available online and are clearly described and referenced in the Methods section of the main manuscript. No custom codes were developed. References are: Csardi, G. & Nepusz, T. The igraph software package for complex network research. InterJournal, Complex Systems 1695. https://igraph.org (2006). Team, R. C. R.: A Language and Environment for Statistical Computing. Retrieved from https://www.R-project.org/ (2020).

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Questionnaire 1 is provided on https://algoabaydata.com/documents/344;
and Questionnaire 2 is provided on https://algoabaydata.com/documents/343.
Participant names are removed from responses.

Human research participants

Policy information about studies involving human research participants and Sex and Gender in Research.

Reporting on sex and gender	No additional human research participants were involved (other then the 21 co-authors).
Population characteristics	No additional human research participants were involved (other then the 21 co-authors).
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Ethics oversight	No additional human research participants were involved (other then the 21 co-authors).

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Study description	We used a mixed methods approach to collect and analyse questionnaire data. Qualitative and semi-quantitative data were collected with a modified Delphi approach to consensus building. This approach included two questionnaires. The first was conducted with Google Forms, where authors used a 5-point Likert scale to indicate their level of agreement with each principle, with space for open-ended comments. The second was conducted via a Microsoft Excel spreadsheet, where authors scored the relationships among the principles as supporting, neutral or constraining. Once data were generated, quantitative analyses included Bar plots (of the Likert-scale agreement) and Chi-squared tests (of the relationship between the agreement rating and any concerns with the principle). Word clouds identified high level themes among the principles. Finally, a quantitative network analysis identified the linkages between the principles and the direction of the relationships. All analyses were conducted using R software and packages (as cited in the Methods section).
Research sample	All 21 co-authors were selected initially to attend the founding conference in South Africa, and these authors were retained throughout the research process. We do thus not view the author pool as a sample, but rather as a fixed group, or full population (in statistical terms). Selection criteria for the author pool are provided in the manuscript, but in essence, authors were selected based on extensive experience across legal-social-environmental ocean governance domains, and present a diversity across disciplines, geography and institutions (see Figure 1 in the manuscript).
Sampling strategy	Given that we do not view our author pool as a sample, but rather as a 'population', we did not have a sampling strategy per se, other than to ensure that our author pool was drawn from diverse disciplines, geographies and institutions. The sampling procedure can thus best be described as one of convenience. Consequently, we did not consider saturation, other than the decision that we made to stop after two rounds of questionnaires (and not to complete a third round). Co-author (stakeholder) fatigue became evident after two rounds, and there was sufficient consensus on the principles at that point that a third round was deemed unnecessary (and may actually have had negative returns in the form of authors leaving the process).

Data collection	Our two questionnaires used Google Forms, and an Excel spreadsheet sent out on email (and uploaded to a shared cloud drive). Set time periods were given for questionnaire completion, and a core group of four authors handled the communications and analysis. Given that the authors of the manuscript are the study population (i.e., the participants are the researchers), no-one else was present or involved in data collection. No hypothesis was being tested, and all authors knew the objectives of the process. All responses were made available to all authors, except that the names of authors were removed from the responses (to protect the personal views of the authors).
Timing	Figure 2 in the manuscript describes the timing of the research process in detail. In summary, the founding conference was held in January 2020 (just before the COVID pandemic was announced globally). Questionnaire 1 was developed between January-May 2020, it was completed by co-authors in June and responses were analysed by the core team thereafter. Questionnaire 2 was developed and sent to co-authors in August-September 2020 and responses were analysed thereafter. Results were presented to co-authors at a virtual workshop in April 2021, whereafter a writing period allowed all co-authors to develop different sections of the written manuscript and contribute to the associated supplementary materials. The first draft publication was produced at the end of 2021, and January-September 2022 was used to refine the draft, develop the case study narratives, and finalise the artwork.
Data exclusions	No data were excluded from the analyses.
Non-participation	No participants dropped out or were excluded from the process. All original 21 co-authors remained in the research team until manuscript submission.
Randomization	Randomization was not applicable to our study design, because respondents for the study were participants/presenters at the TOG conference held in Port Elizabeth. Hence there was no random selection of a sample. Questionnaire 1: Questions needed to link together in terms of the principle, level of agreement, and alternative wording. Randomization using Google Forms was not appropriate for this. Questionnaire 2: The Excel spreadsheet provided a matrix of the principles applied against each of the other principles which could be answered in any order by the respondents and hence randomization was unnecessary.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☒	☐ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging