Paradox incentive structures and rules governing sharing of coastal and marine data in Kenya and Tanzania: Lessons for the Western Indian Ocean

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Abstract
Comprehensive and timely data-sharing is essential for effective ocean governance. This institutional analysis investigates pervasive data-sharing barriers in Kenya and Tanzania, using a collective action perspective. Existing data-sharing rules and regulations are examined in respect to boundaries, contextuality and incentive structures, compliance and settlement mechanisms, and integration across scales. Findings show that current institutional configurations create insufficient or incoherent incentives, simultaneously reducing and reproducing sharing barriers. Regional harmonisation efforts and strategically aligned data-sharing institutions are still underdeveloped. This article discusses proposals to increase capacities and incentives for data-sharing, as well as the limitations of the chosen analytical framework. The debate is extended to aspects beyond institutional issues, i.e., structural data-sharing barriers or ethical concerns. Key recommendations include the establishment of more compelling incentives structures for data-sharing, increased funding of capacity-building and sharing infrastructure, and further awareness creation on the importance of data-sharing.

Keywords: data-sharing, ocean governance, collective action, institutional design, knowledge commons

Introduction
Coastal and oceanic ecosystems in the Western Indian Ocean (WIO) region sustain millions of lives and are characterised by their abundant biodiversity, which renders them immensely valuable in socio-economic and ecological terms (UNEP, 2015a). At the same time, they face various pressures related to anthropogenic activities and climate change (Diop et al., 2016; Hollander et al., 2020). Decision-makers are challenged with mitigating these pressures while settling space-use conflicts and considering the interests and needs of a diverse range of stakeholders. Local and national coastal management strategies also need to be harmonised to meet transboundary conservation goals in the region (UNEP, 2020). To this end, sustainability-oriented decision-making and integrated
coastal area management would greatly benefit from accurate, up-to-date, and comprehensive marine biodiversity data (Pendleton et al., 2020; UNEP, 2020; Satterthwaite et al., 2021). However, the amount of available biodiversity data as well as processing and interpretation capacities are limited in East Africa and the larger WIO region (UNEP, 2015a). Effective data-sharing among researchers, policy-makers, and stakeholders is thus critically important. Efforts to make more data available and develop common sharing strategies are undertaken at various levels of operation, including data-sharing policies, regulations, and voluntary initiatives within and among state agencies, research institutes, and environmental organisations (UNEP, 2020). Despite these endeavours, further barriers to data-sharing persist and urgently need to be addressed by scientists, decision-makers, and environmental managers (Pendleton et al., 2019; Satterthwaite et al., 2021).

This article aims to examine prevailing institutional barriers to data-sharing, building on findings of a qualitative exploratory study which was conducted to investigate data-sharing practices in coastal East Africa (Schwindenhammer, 2020). Data-sharing is a complex activity and involves various forms of information exchange among actors, within or across different sectors, i.e., research, politics, industry, and civil society. Findings from the exploratory study suggest that considerably different and even contrasting normative views of what data-sharing should entail and how it should be organised exist. This, despite a common understanding of its importance in general. Effective, equitable, and harmonised sharing practices in East Africa and the larger WIO region are yet to be further developed and refined (Ibid., Schwindenhammer et al., 2021). This analysis focuses on rules regulating data-handling practices in academia and research, and ways in which the current institutional design might prevent or complicate data-sharing. Implications of data-sharing for marine ecosystems sustainability and regional ocean governance are discussed. A collective action theory perspective (Ostrom, 1990) is used to investigate these issues and propose options for more productive exchange at the nexus of science, policy, and management. With this analysis, the authors intend to contribute to existing data-sharing recommendations for decision-makers and scientists in the WIO region (UNESCO-IOC, 2019; Schwindenhammer et al., 2021). This article mainly focuses on data-handling practices in science and academia, while remaining conscious that these may differ in interaction with other sectors.

Background on data-sharing in the WIO region

Data and information concerning the state of key species and ecosystems in coastal and marine environments of the WIO region are important to inform decision-making (UNEP, 2020; Satterthwaite et al., 2021). As such, the sharing of scientific products (data, information) with policy-makers is essential for ocean governance. Generally, many researchers are motivated to share their findings, e.g., to expedite scientific advancements, for collaborative purposes, to inform and educate, to increase the impact of their work, to generate funding, or to advance their career (Schmidt et al., 2016; Figueiredo, 2017; Schwindenhammer, 2020). Such collaboration is vital to enhance research in data-poor countries, which have limited capacities to collect, process, and analyse data (Hollander et al., 2020). Local researchers and practitioners with long-standing experience are well aware of blind spots and limiting factors for data-sharing in the WIO region. During expert workshops1, they have underlined the need for more uniform data collection and handling approaches, increased fostering of sharing skills and capacities, and taxonomy training for non-academics working with marine biodiversity data (Schwindenhammer et al., 2021). Furthermore, numerous initiatives exist to provide data and increase information flows. For example, the Nairobi Convention’s Coral Reef Task Force (CRTF), which consists of two nodes of the Global Coral Reef Monitoring Network (GCRMN), has successfully compiled complementary ecological data from multiple contributors into consolidated datasets (Obura et al., 2017; Gudka et al., 2018). These datasets have been pivotal to recent regional reef status reporting (Ibid.) and other analyses (Obura et al., 2021). Another important regional initiative is the Clearinghouse Mechanism2 introduced by the UNEP Nairobi Convention, which aims to provide a regional data reference centre, facilitating data-sharing for Contracting Parties and their stakeholders in the WIO region.

1 Workshops took place in the context of the NeDiT project, led by the Institute of Marine Sciences at the University of Dar es Salaam (IMS) and the Leibniz Centre for Tropical Marine Research (ZMT). The international partnership project aims to create a collaborative network of researchers using innovative digital technologies to inform marine resource management.

2 Available at https://www.nairobiconvention.org/clearinghouse/

3 The Nairobi Convention is an intergovernmental partnership between states, private sector, and civil society.
Theoretical Framework

Governing the commons

Resources can be conceptualised as different kinds of goods, e.g., public and accessible to everyone, or private and only accessible to few (Ostrom and Ostrom, 1977; Ostrom, 1990). When natural resources are shared by one or several groups, dilemmas of appropriation and provision are bound to occur. This is particularly true for **common-pool-resources**, which are freely accessible and at the same time highly subtractable, i.e., using the resource or extracting units from it will leave less for others. **Commons** are resource systems which may include several types of goods and are used by more than one individual or entity (Ibid.). For many years, commons researchers proposed that self-interested individuals were incapable of achieving collective benefits as a group, i.e., using it sustainably. This rather fatalistic assumption, most famously described by Hardin’s *Tragedy of the Commons* (1968), has long served as a rationale to prescribe approaches for the governance of natural resources, i.e., through state and market instruments (Gordon, 1954; Olson, 1971; Demsetz, 1974). However, empirical findings have repeatedly indicated that communities are capable of aligning individual and group interests with regards to the use of shared resources (Ostrom, 1990; Gautam and Shivakoti, 2005; Cox et al., 2010). **Collective action theory** aims to understand how such communities cooperate through self-organisation, and why some succeed in overcoming commons dilemmas whereas others do not. One of the most prominent scholars in this field, Elinor Ostrom, has identified social and ecological variables which influence self-organisation for community-based resource governance (Ostrom, 1990; McGinnis and Ostrom, 1992; Hess and Ostrom, 2007).

Data as a shared resource

Although collective action concepts generally describe dilemmas of natural resource use, for example fish stocks or forests, they may also apply to **knowledge commons** (Hess and Ostrom, 2007, p. 4). Knowledge can be understood as ‘intelligible ideas, information, and data’ and implies varying degrees of accessibility and possibilities for appropriation (Ibid., p. 8). Publicly available scientific data and information, which are analysed holistically across geographical and disciplinary borders, could potentially bear great societal benefits (Figueiredo, 2017). Advocates of the open science movement emphasise the increased transparency, quality, and impact that could be achieved, and stress the societal obligations of science (Elliott and Resnik, 2019; Krishna, 2020). In an ideal world, one may be inclined to envision scientific data as public goods, which are freely accessible and non-subtractable (i.e., one individual’s use of data does not reduce the value to others using the same resource). Conversely, data are often understood as a common-pool resources which are rivalled in use and may be affected by collective issues such as freeriding, congestion, overuse, and conflict (Hess and Ostrom, 2007). Knowledge commons face issues such as ‘commodification or enclosure, pollution and degradation, and nonsustainability’, similarly to natural resources (Hess and Ostrom, 2007, p. 5; Krishna, 2020). Technological advancement throughout the last decades has rendered data a highly complex resource, creating new possibilities for sharing and collaboration, while simultaneously increasing the (perceived) risk of abuse and stealing (Hess and Ostrom, 2007, p. 14). In social environments characterised by high rivalry, i.e., competition for innovation and publications, incentives to withhold data often outweigh those for sharing. Cooperation may further be impeded by a lack of recognition and due credit, fear of data misuse, or additional efforts associated with sharing (Schmidt et al., 2016, Figueiredo, 2017; Chawinga and Zinn, 2019). Researchers who have invested personal and financial resources into data collection and analysis may find themselves in a dilemma of wanting to share their findings while also collecting the rewards of their hard work (Ibid.). Even if they decide to share data, further issues may arise due to the incompatibility of different datasets that were collected under a variety of methodologies, equipment, time scales, details, or insufficient data quality (Schmidt et al., 2016). When researchers lack the time and capacity to use the findings to their full extent, some data may remain unused on private servers or repositories. Such ‘data loss’ may also occur with digitally stored information on short-lived webpages and databases (Waters, 2007) or because of the lack of metadata describing these datasets (Chawinga and Zinn, 2019; Schwindenhammer et al., 2021). Scholars have stressed the importance of preventing data loss and enclosure (Heller, 1998; Boyle, 2007; Krishna, 2020), as it may leave scarce scientific resources underused. This is particularly problematic in the context of coastal and ocean governance, in which knowledge is both scarce and urgently needed to address complex and pressing social and environmental challenges (UNEP, 2020; Satterthwaite et al., 2021). Efforts are currently in place to mitigate against losing datasets by making global databases more robust to accept all data types and formats, e.g., the Ocean Biogeographic Information System (OBIS) (De
Pooter et al., 2017) and the World Register of Marine Species (WoRMS) (Vandepitte et al., 2018). Given this state of data-sharing, investigating underlying institutional structures may help to better understand barriers to data-sharing and how to overcome them (Hess and Ostrom, 2007; UNESCO-IOC, 2017).

**Institutional design for collective action**

Collective action, such as preventing the deterioration of common-pool resources, relies on trust and reciprocity among members of a community or group (Ostrom, 1990). Social interactions are organised by institutions, commonly understood rules which shape responsibilities, procedures, and payoffs for individuals (Ibid.), helping them to reduce uncertainty in social environments (North, 1990). Formal rules are officially documented and enforceable, sometimes legally binding, for example laws, contracts, or directives. Informal rules are based on social norms and interpersonal agreements, usually imposed through social repercussions, e.g., affecting an individual’s reputation, access to certain social spheres, or collaboration opportunities (Ostrom, 1990). In the context of data-sharing, institutions provide incentives and disincentives for individuals or entities to make their data available to others. From a multitude of empirical studies, Ostrom and her colleagues identified eight design principles for ‘robust, long-enduring’ institutions (Hess and Ostrom, 2007, p. 7). These principles may help explain under which conditions trust and reciprocity can be built and maintained for the sustainable use of common-pool resources. Such collective action is also relevant in the context of data-sharing. Data in shared knowledge systems often involve different usage rights and opportunities for access for various user groups, which requires appropriate institutional arrangements to foster its equitable, efficient, and sustainable use (Ibid., p. 6). This is particularly relevant in the WIO region, where decision-makers from ten countries draw on their collective marine biodiversity knowledge to govern shared ecosystems. In the following sections, Ostrom’s design principles will serve as a point of reference to assess select institutional arrangements for data-sharing in

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<tr>
<th>Principle</th>
<th>Meaning for Data Sharing</th>
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<tr>
<td>1. Clearly defined boundaries: Individuals or entities who have rights to withdraw units from the resource must be clearly defined, as must the boundaries of the resource itself.</td>
<td>Clear definition of who may access and/or use specific sets of data, as well as the extent to which these data may be used, modified, and/or shared.</td>
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<td>2. Context-specific rules: Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labour, materials, and/or money.</td>
<td>Rules affecting the distribution of costs and duties in data-sharing arrangements are closely related to the distribution of benefits and rights. These rules are tailored to the situational conditions, i.e., type of data or capacities of involved parties.</td>
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<td>3. Collective-choice arrangements: Most individuals affected by operational rules can participate in modifying operational rules.</td>
<td>Those involved may participate in creating and/or revising rules of data-sharing arrangements.</td>
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<td>4. Monitoring of compliance: Monitors, who actively audit resource conditions and participant behaviour, are accountable to the participants or are the participants.</td>
<td>Those monitoring data-sharing activities are accountable to other members of data-sharing arrangements or are members themselves.</td>
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<td>5. Graduated sanctions: Participants who violate operational rules are likely to experience assessed graduated sanctions (depending on the seriousness and context of the offense) from other participants, by officials accountable to these participants, or by both.</td>
<td>Those who violate rules of data-sharing arrangements face sanctions which are proportional to severity and context (e.g., repetition) of the offense. These sanctions are carried out by other members or monitors of the violated data-sharing arrangement.</td>
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<td>6. Conflict-resolution mechanisms: Participants and their officials have rapid access to low-cost, local arenas to resolve conflict among participants or between participants and officials.</td>
<td>Spaces and procedures exist to easily resolve conflicts related to data-sharing arrangements, i.e., among members or between members and external officials.</td>
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<td>7. Minimal recognition of rights to organise: The rights of participants to devise their own institutions are not challenged by external governmental authorities.</td>
<td>Involved parties can create and enforce their own rules for data-sharing arrangements without interference from government authorities.</td>
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<td>8. Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organised in multiple layers of nested enterprises.</td>
<td>Rules, monitoring, sanctions, and governance activities related to data-sharing arrangements need to harmonise and complement each other among user groups and across scale.</td>
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Kenya and Tanzania and to identify potential areas for improvement. Table 1 contains an overview of the eight design principles, their definitions, as well as their meaning in the context of data-sharing.

Methodology
Data collection and previous analysis
An exploratory, qualitative study was conducted for the purpose of a Master thesis in the context of the NeDiT\(^4\) project (Schwindenhammer, 2020). In November and December 2019, thirteen interviews were conducted in Kenya (Mombasa and Nairobi) as well as Zanzibar, Tanzania. Interview partners were chosen through a combination of criterion and snowball sampling (Patton, 2002), mostly involving partners of the NeDiT project network. Professional involvement with marine biodiversity data, such as using, providing, or producing it, was the main selection criterion. Potential interview partners were either approached in person or contacted via email before arranging conversations. Data were collected through semi-structured interviews, using the ‘romantic conception of interviewing’ (Roulston, 2010). This interview method served to build trust and rapport between researcher and participant, encouraging a high degree of openness and self-revelation by the latter. A semi-structured interview guide granted flexibility and conversational flow while covering all topics of interest (Patton, 2002) and allowed participants to express ideas in their own words (Flick, 2015). Interview questions were informed by previous experiences of the NeDiT project, as well as Ostrom’s institutional design principles and assumptions (1990), contributing to six research objectives. These objectives were to: 1) understand the current situation of actors who produce, process, analyse, or use marine biodiversity data; 2) identify motives for sharing marine biodiversity data in different formats; 3) identify existing formal and informal rules related to the handling and sharing of marine biodiversity data and analysing the mediating role they play; 4) explore patterns of interactions between involved actors and investigate the mediating role of social norms and trust; 5) determine the willingness and capacities of involved actors to share marine biodiversity data among each other and with others in different formats; and 6) to explore which new rules and norms could be established to increase collaboration among actors (Schwindenhammer, 2020). Prior to beginning the interview, participants were informed about the procedure, the purpose of the study, and about their rights to withdraw from the interview at any time. They were advised to sign the consent form and asked permission to record the conversation on a private mobile phone. Afterwards, interviews lasted between 34 and 96 minutes. Recordings were complemented by extensive notes taken during the interview, which were reviewed and annotated with further personal impressions after each session (Patton, 2002).

After the completion of field interviews, a two-fold qualitative text analysis was conducted to identify common themes around data-sharing. Interview recordings were transcribed as post-scripts, which included a detailed account in the form of paraphrased statements while remaining close to a participant’s choice of language and expressions. Whereas parts of little relevance to the research topic were shortened or omitted, particularly relevant or interesting statements were transcribed as full citations, based on the judgment of the researcher. In another step, paragraphs within these post-scripts were re-ordered by topic to facilitate coding. A free version of the qualitative data analysis software f\textsuperscript{4}analyse\(^8\) (Evers, 2018) was employed for two rounds of coding, using a combination of deductive and inductive coding. For the first round, an initial coding frame was developed according to the interview guide and findings from the Belmont Forum Open Data Survey (Schmidt et al., 2016). The initial coding frame was tested using a line-by-line method and subsequently revised to include additional categories and three in-vivo codes which emerged from the second round of inductive coding. The final coding frame included five main categories which encompassed statements related to: 1) motivation for sharing; 2) descriptions of what makes shared data valuable; 3) accounts of how data are shared; 4) institutions and rules; and 5) conditions which may impede data-sharing. In addition to the content analysis, a comparison of institutional contexts was conducted, using a different framework\(^6\) which is beyond the scope of this paper. The main purpose of this additional analysis was to understand how varying institutional configurations in seemingly similar contexts could produce vastly different outcomes regarding data-sharing.

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\(^{1}\) More project information available at https://www.leibniz-zmt.de/en/research/research-projects/nedit.html

\(^{3}\) Version 1.0.0-beta.26 FREE for Windows, available at https://www.audiotranskription.de/english/f4-analyse

\(^{4}\) The framework used was the Institutional Analysis Development (IAD Framework). More detailed information about the study may be requested from the corresponding author.
Present article
Aggregated findings of the study were systematically re-examined according to Ostrom’s eight institutional design principles (1990), which were thematically grouped into four clusters, i.e., ‘boundaries’, ‘congruence of context, costs, and benefits’, ‘compliance and settlements’, and ‘integration across scales’. Specifically, operational rules, which organise daily activities around resource appropriation and provision, their monitoring, as well as the enforcement of sanctions, were investigated (Hess and Ostrom, 2007).

Findings
An abundance of operational rules affects scientific data-sharing practices in Kenya and Tanzania. This section relates these rules in view of Ostrom’s institutional design principles (1990). In each cluster, the interpretation of these principles in the context of data-sharing is elaborated prior to specifying examples from the study.

Boundaries
This first cluster includes findings related to principle 1 (see Table 1), which is understood as the necessity to define explicit boundaries in operational data-sharing rules. Appropriation rules indicate individuals or groups who may access certain datasets and specify ways in which these data may be used, modified, or shared with others. Whereas some datasets may be freely available to anyone, e.g., in open access formats, others may be reserved for users of a certain professional background, employees or affiliates of an institute, agency, or organisation, or for individuals involved in a project. Moreover, financial boundaries restrict data access via subscriptions or one-off payments. Limitations for data use include restrictions for specific purposes, determine the level of aggregation which may be accessed and modified (i.e., primary or compiled data), or state the appropriate form of acknowledgement given to data collectors and owners. Sustainable data use implicates sensible information-handling, with boundaries in place to protect original ideas or vulnerable species from exploitation.

Participants of the study consider boundaries established in formal sharing rules important to prevent conflict, reduce ambiguity, and create a sense of control over the data. Yet, boundaries around shared data often appear unclear and non-transparent in practice, especially in the case of openly accessible databases or repositories. In such open formats, data contributors may anticipate loss of control and authority over their data, not knowing who can access them and how they are used. Concerns about data misuse, i.e., use and reproduction without permission, for unintended purposes, or without acknowledgement, may prevent researchers from sharing data to open platforms. Alternatively, sharing information about data, e.g., via metadata declarations or data papers, enables contributors to establish more explicit boundaries and maintain transparency. This form of sharing is popular among contributors and data users alike, as it creates data visibility while retaining control over access and use. Direct sharing of datasets, i.e., from one person or entity to another, also allows for an unambiguous communication of boundaries through verbal or written agreements. Overly strict boundaries, on the other hand, may also constitute data-sharing barriers. Some individuals may struggle with legal constraints on data-sharing, e.g., restrictive contracts which prevent sharing or use beyond the scope of specific projects. In the WIO region, a substantial amount of data is dispersed across specialised databases of government departments, research institutes, or organisations, only accessible to employees and affiliates. Moreover, sensitive data may be confined within national borders, e.g., data containing genetic information.

Congruence of context, costs, and benefits
This cluster reports on findings with respect to design principles 2, 3, and 7 (see Table 1). Appropriation rules are suitable in the context of application, e.g., considering the appropriate extent of data accessibility, the intended group of users and their capacity to adhere to given rules, as well as local culture and customs. Moreover, provision rules assigning costs and duties in data-sharing arrangements are closely aligned with the distribution of benefits and rights, promoting rule adherence from a cost-benefit perspective and conveying equity. For example, those investing time and financial resources into the collection, treatment, or provision of data profit from their findings or receive credit when these data are used by others. Equity is promoted by applying sharing rules to everyone while considering variations according to individual needs and abilities. If possible, affected users and contributors are involved in the creation or modification of operational rules. They may possess profound information and experience to devise effective and context-specific rules, contrary to externally imposed statutes which may neglect local conditions.

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7 Searchable metadata documents, which describe a particular dataset or a group of datasets and may be published in peer-reviewed journal articles.
Furthermore, locally devised data-sharing rules may be more potent in the absence of interference from external authorities, i.e., governments.

In the study cases, scientific data-handling is often regulated by rules created in local contexts, e.g., through internal policies or directives of research institutes, organisations, or journals. For instance, researchers are frequently required to contribute data declarations or entire datasets to internal repositories of their affiliated institute upon completion of a project. These operational rules are generally appropriate for affected employees and affiliates, matching their capacities to comply and securing sensitive information. Incentives for sharing are created by making it a prerequisite for research licenses, field-work permissions, project funding, or publishing. In some situations, general data-sharing rules require some flexibility on an individual basis, e.g., for projects involving longitudinal data collection. In absence of guaranteed data protection and credit for data contributors, individuals may perceive risks and burdens of sharing as larger than its benefits, especially in highly competitive research environments. This may reduce their willingness to share data unless attribution or authorship is strictly enforced.

Creating context-specific provision and appropriation rules is often a challenge for open access databases, which have a broad user base and mostly rely on voluntary contributions. Instead, some global databases provide additional sharing incentives, such as the DOI service\(^8\) offered by the Flanders Marine Institute (VLIZ) which hosts the World Register of Marine Species (WoRMS), African Register of Marine Species (AfReMaS) and the Ocean Biodiversity Information System (OBIS) databases. This service enables researchers to formally publish their data, so they can be traced and cited. For projects or bilateral agreements, contracts are commonly used to establish formal data-sharing rules, e.g., creating a memorandum of understanding about when, how, and with whom data collected within a funded project should be shared. Projects involving multiple partners may employ initiative-specific data-sharing agreements with each data owner to facilitate sharing, as was the case for the Nairobi Convention’s CRTF ecological data compilation (Obura et al., 2017; Gudka et al., 2018). Assigning data coordination and management responsibilities to a trusted non-governmental intermediary in the region sustains perceived impartiality and fairness in such large projects. Rules are also commonly established informally, i.e., through interpersonal verbal agreements. Due to direct and clear communication among involved parties, contracts and informal agreements often result in high contextuality and a fair distribution of benefits. Incentives to share data are high to avoid legal or social repercussions.

**Compliance and settlements**

This cluster includes findings regarding principles 4, 5, and 6 (see Table 1). Compliance with operational data-sharing rules is monitored to identify and address rule violations. Ideally, compliance monitors belong to the group affected by these rules or are in some way accountable to its members, rather than uninvolved external authorities. Known and observable monitors are more likely to establish rapport with the people they oversee, fostering trust and cooperation. Moreover, monitors who benefit from sustainable data-handling practices have additional incentives to ensure rule compliance. Sanctions for violations of operational data-sharing rules are fair and enforceable, which means they are proportional to the severity and context of the offense, avoiding excessively harsh or unreasonable punishments. Disciplinary measures include the limitation or withdrawal of permissions, e.g., to publish, conduct field-work, or access repositories. Consequences could also be of a financial nature, i.e., fines or retraction of funding. Finally, spaces and procedures exist to resolve conflicts around data-sharing at low costs.

Participants in this study generally perceive a high adherence to data-sharing rules. Ample accountability exists among people who directly interact and can observe each other’s behaviour, e.g., colleagues and project partners. As data-sharing is often required prior to obtaining funding or permissions, monitoring automatically becomes a by-product of approval processes, and rules are easily enforced. Executives in research institutes have a strong interest to ensure that all scientific data are shared into their respective repository, particularly those serving a double-function as National Oceanographic Data Centres (NODCs). However, in absence of formalised rules, comprehensive monitoring and successful enforcement of data-sharing is less likely. Moreover, in settings in which data contributors and users seldom interact or stay anonymous, e.g., open access databases, individuals may attempt to avoid accountability. Monitoring through strong peer review systems

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may complement formal rules and create additional incentives to share, especially in competitive professional environments. For instance, the peer review screening by the WIO Journal of Marine Science (WIOJMS) enables regional reviewers acquainted with current research activities to detect plagiarised ideas or data. Disputes around data-sharing may emerge between or among individuals, organisations, or authorities. Breaching of contracts is usually followed by established protocols to settle conflicts, whereas disciplinary boards may conciliate violations of internal directives and codes of conduct. Data are often shared informally, rendering conflict resolution dependent on the personal relationship of involved parties. Although these arrangements often involve a high degree of accountability and are easily monitored, they are unsuitable to serve as reliable long-term understandings and lack standardised procedures to deal with disagreements, e.g., when relationships or conditions change.

Integration across scales
This cluster involves aspects related to the principle 8 (see Table 1), which translates to the need for data-sharing rules, monitoring, sanctions, and governance activities to harmonise and complement each other among user groups and across scale. Like puzzle pieces, different rules and regulations between individuals, organisations, authorities, and regional coordination bodies interlock and engage in the bigger picture of the data-sharing institutional landscape.

Operational data-sharing rules in the WIO region are often influenced by higher-level institutions such as national laws, e.g., decrees which require reporting of scientific data to government authorities or regulate data-sharing across borders. In Kenya, for instance, guidelines for data-sharing are provided by the National Commission for Science, Technology and Innovation (NACOSTI), which manages research activities in the country. Moreover, international data-sharing standards and obligations may prompt the creation of operational rules, e.g., through mandates of the Nairobi Convention (UNEP, 2015b), the Convention of Biological Diversity (Secretariat of the CBD, 2010, 2012, 2020) or the United Nations (UNESCO-IOC, 2014, 2019; United Nations, 2015). Norms for data-sharing in research and academia are further shaped by international frameworks, such as the ‘Findable, Accessible, Interoperable, and Reusable’ (FAIR) principles (Wilkinson et al., 2016) or the ‘CARE’ principles for indigenous data sources9. Overall, various influences and interests have resulted in the large number and diversity of data-sharing rules and regulations in the region. Sometimes, these rules are inconsistent or even contradict each other. For instance, NACOSTI obliges researchers to report data collected in Kenya to the respective affiliation institute, including full datasets, metadata forms, research articles, or dissertations. NACOSTI further prohibits the sharing of certain findings across national borders. At the same time, these researchers may be bound to different sharing policies at their workplace or must uphold contract agreements with project donors and partners. Such legal constraints especially affect international and inter-organisational projects which conduct research on transboundary ecosystems.

Moreover, international or regional attempts to harmonise data-sharing often fall short of integrating across scale. A regional data-sharing protocol by the Nairobi Convention, for instance, would rely on voluntary commitments of signatory states. However, it may be incompatible with existing protocols in some of these states. Further, a considerable amount of research data never reaches national repositories, e.g., due to inconsistent sharing rules in institutes and organisations, or because of a shortage of data collection capacities.

Discussion
This investigation guided by Ostrom’s design principles (1990) sheds light on the intricate web of social norms and formal rules for data-sharing in Kenya and Tanzania, as well as the institutional barriers which persist.

Paradoxes and payoffs
In their current constellation, institutional arrangements create incentives both for and against sharing, simultaneously reducing and creating data flow barriers. Given the pressing demand for scientific data, devising rules that are fair, realistic, and effective seems to constitute a delicate balance between creating incentives for voluntary sharing while also employing compulsory means. Although similar principles of institutional design may be applied, organising collective action for the sustainable use of shared data fundamentally differs from sharing natural resource commons. For instance, defining appropriate boundaries of access and use is often more difficult for a

9 Global Indigenous Data Alliance, available at https://www.gida-global.org/care
dataset than for physical places, such as lakes or forests. Whereas data may be collected and processed in a specific place and by a closed group of people, boundaries become increasingly intangible as such data are shared and further handled in digital spaces. This is apparent in the difficulty to establish context-appropriate and enforceable sharing rules in large open access databases, which store data from a variety of places and contributors and have a broad, sometimes anonymous, user base. Although open sharing practices are often encouraged to reduce bureaucractic and accelerate research processes, highly contextual rules may actually produce additional administrative burdens, e.g., when specific contracts are needed for each alternative use of the same datasets.

The dispersion of scientific information across specialised databases is another example of such bureaucractic hindrances, as outsiders need to obtain permissions for data access and use. Whereas these boundaries may seem reasonable from an organisational perspective, they can impede essential collaborations and efficient data-reporting to national or regional regulatory bodies. A payoff between contextualised boundaries and streamlining of information seems inevitable if regional and international conservation goals are to be effectively supported. Informal sharing based on trust and personal relationships is frequently used to circumvent data accessibility issues and plays an important, yet ambiguous role. On one hand, these unofficial sharing pathways may serve as a foundation to develop formal agreements and build long-term professional relationships. At the same time, they can reduce transparency and awareness of existing data, reproducing the exact issues which data-sharing aims to reduce, i.e., research redundancy and information gaps. Furthermore, agreements bound to personal relationships are vulnerable to change and may even result in ownership conflicts. Thus, depending on the context, informal rules can both strengthen and undermine formal institutions.

Moreover, the incongruence of time horizons in science and governance poses another contradiction. Research and publishing are lengthy processes and scientific data may only become available after several years, whereas the information is needed immediately. Requiring data-sharing within shorter time frames would often be unattainable, as stages of data collection or processing may still be incomplete or because of inadequate personal capacities. Furthermore, premature sharing may contradict other obligations researchers have, e.g., with donors or project partners. Due to these discrepancies, research findings might become significantly delayed and cannot be used to inform policy and management decisions in a timely manner.

**Perspectives for ocean governance**

To facilitate regional ocean governance, i.e., achieving the Sustainable Development Goals (United Nations, 2015), the Aichi Biodiversity targets (Secretariat of the CBD, 2010), and milestones defined in the UN Decade for Ocean Science (UNESCO-IOC, 2019), data-sharing is imperative. Otherwise, the measurement of relevant indicators and mobilisation of the necessary political and financial capital to implement decisions is unattainable. In the WIO region, numerous approaches to counter the issues outlined above are starting to develop or already exist, albeit inconsistently. For instance, the growing use of metadata declarations, both for obligatory and voluntary sharing, is highly promising. Sharing metadata can constitute a valuable compromise, increasing the visibility of scientific data and transparency of their origin, while contributors retain control over access and use. This could be an especially fruitful option to encourage sharing to open access databases or from ongoing research projects.

Publishing and funding bodies possess considerable levers to shape and enforce data-sharing rules, and thus play a central role in fostering metadata availability (Chawinga and Zinn, 2019; Schwindenhammer et al., 2021). Targeted policy adjustments could grant greater legal authority to NODCs and increase their capacity to act as intermediaries for the implementation of data-sharing mandates. Additionally, the inclusion of feedback mechanisms, e.g., tracing access and purpose of use, could further reduce fears of data misuse and increase voluntary sharing (Pendleton et al., 2019; Chawinga and Zinn, 2019). Sharing could further be encouraged with a simplified publishing process, i.e., promoting data papers and attributing them the same significance as traditional research articles (Chawinga and Zinn, 2019; Schwindenhammer et al., 2021).

Providing traceable and citable DOIs for datasets is another auspicious approach to reward frequent and swift data-sharing, especially for time-sensitive research needed to inform indicator-based conservation strategies (Pendleton et al., 2019; Chawinga and Zinn, 2019). Such data citations further ensure that the data cannot be manipulated and anyone claiming them as their originators can be confirmed.
by the citations. Authorship crediting mechanisms in journals could further be adapted to better acknowledge the contributions of individual authors in large collaborations, contrary to the current focus on first and last authors (Li et al., 2021; Devriendt et al., 2022). Moreover, attention should be paid to create equitable, collaborative, and inclusive environments in diverse research teams, as a cordial work climate may positively impact data-sharing practices (Settles et al., 2019). Currently, some researchers in the region have embraced collaborations for publishing global papers or regional assessments. Shared skills from these experiences spur the creation of new networks and can ultimately attract more funding as a wider group of donors and collaborators become involved. This is particularly relevant in instances in which no historical precedence for data-sharing policies exists and uncertainty about the benefits of sharing prevails.

Leonelli et al. (2018) stress the need to sensitise global data-sharing efforts to diverse research environments, pointing out global differences in access to digital infrastructure and highlighting the distinct challenges, concerns, and goals of African researchers. They further criticise the unequal power relations in global standards of scientific rigour and data quality, which are usually determined by countries with privileged access to technical and financial resources (Ibid.). Contextual considerations may increase the accessibility of international data-sharing spaces for researchers from low-resourced environments. To this end, donors and funding bodies could consider more flexible financing options, e.g., in the form of micro-funding for routine research activities (Rappert, 2017). Researchers should receive comprehensive data-sharing training, ideally early in their career (Chawinga and Zinn, 2019; Tanhua et al., 2019; Schwindenhammer et al., 2021). Chawinga and Zinn (2019) propose that researchers are educated to spend equal efforts toward data management as to research publications. Some scholars caution against imprudent data-sharing or absolute interpretations of openness (Leonelli et al., 2018). Instead, they underscore the need to provide researchers with data-sharing tools that enable them to include a variety of considerations and make ethical, safe choices (Levin and Leonelli, 2017; Leonelli et al., 2018). Examples for African-led initiatives prioritising ethical and adequate data-sharing include the African Open Science Platform (Boulton et al., 2018) or H3Africa and H3BioNet (Leonelli et al., 2018).

Limitations and further considerations

This paper highlights a few examples of data-sharing issues in the WIO region. However, these findings are not necessarily representative or generalisable for the entire region, as the empirical basis is a small qualitative sample from selected locations in Kenya and Tanzania (Schwindenhammer, 2020). Another limitation may have been the exclusive use of collective action as a theoretical perspective, as it only encompasses institutional aspects of data-sharing issues. Recalling the FAIR principles (Wilkinson et al., 2016), sharing rules and directives often address data findability and accessibility, while omitting dimensions of interoperability and reusability. Comprehensive harmonisation of data-sharing efforts across scales thus exceeds the coordination of rules and should also consider structural barriers. Such obstacles include, for instance, inadequate quality, comprehensibility, or applicability of data shared for decision-making (Fisher et al., 2010; Tanhua et al., 2019; Schwindenhammer et al., 2021); or navigation issues for other researchers wanting to use shared data (Pendleton et al., 2019). Tanhua et al. (2019) suggest building interoperable data management systems based on existing structures, i.e., databases and open sharing infrastructures. A practical example for this is the European Marine Observation and Data Network (EMODnet)\(^ \text{10} \) effort, which provides access to European marine data from local, national, regional, and international repositories (Ibid.). Additional efforts to increase the robustness of global databases, i.e., compatibility with all data types and formats, are currently in place to mitigate against losing datasets, e.g., in OBIS (De Pooter et al., 2017), WoRMS (Vandepitte et al., 2018), and AfReMaS (Odido et al., 2022).

Others propose a combination of technical and cultural solutions, drawing from various sectors to address sharing barriers (Pendleton et al., 2019). This could be in the form of ‘ocean data combinatory machines’, i.e., technology platforms which draw lessons from commercial online marketplaces to bring together data, researchers, and users (Ibid., p. 6). Data management systems should be built in anticipation of an increased volume of data in the near future, e.g., due to technological advances and facilitated data capture through sensors (Tanhua et al., 2019). Close collaborations with sensor manufacturers could result in direct communication of metadata according to standards and conventions of the respective research community (Ibid.). Additionally, several scholars suggest incorporating

user experience-testing when developing digital data-sharing infrastructure (Hermes et al., 2019; Tan-hua et al., 2019; Volentine et al., 2021).

Furthermore, a holistic reassessment of research priorities may be needed to avoid a mismatch of research efforts and conservation needs (Fisher et al., 2010), or a lack of research data use in policy-making (Agges-tama and Mangalagiu, 2020). Such insights could be yielded from a focus on the co-production of knowledge and expertise (Wyborn et al., 2019). Participatory methods, i.e., collaborative or transdisciplinary research designs, could highlight the perspectives of all relevant stakeholders, create more equitable data collection processes, and produce actionable data for decision-making (Berkes et al., 2000; Cinner et al., 2009; Glass and Newig, 2019; Norström et al., 2020). Lastly, a substantial amount of financial capital is necessary to build and maintain data-sharing capacity-building and infrastructure. This should be considered when allocating financial priorities in projects, as well as in organisational, national, or international budgets (Leonelli et al., 2018; Chawinga and Zinn, 2019; Schwindenhammer et al., 2021).

Conclusion
This article intends to contribute to a more profound understanding of institutional data-sharing barriers in the WIO region and their implications for regional ocean governance. For this purpose, a collective action theory lens was applied, using Elinor Ostrom’s institutional design principles (Ostrom, 1990) as an analytical framework to review existing data-sharing-rules and how they interact. Data-sharing is commonly believed to be a matter of ethical obligation, fairness, and proper scientific conduct. However, this social norm does not always translate into the routines of people who work with marine biodiversity data. Current institutional configurations often create insufficient or incoherent incentives for sharing. In absence of clear, enforceable, and fair rules, competitive professional contexts tend to promote non-collaborative data-handling practices. Existing initiatives to harmonise data-sharing practices in the region still have little directly measurable effects on more effective coordination, as links to strategically align data-sharing institutions across governance levels are still underdeveloped. Overall, three key messages emerged from the findings of this paper. Firstly, more compelling incentives for individual and organisational data-sharing must be established. A transformation of the reward system in scientific professional circles could tie benefits and career advancement to timely and transparent sharing, e.g., promoting data papers or DOIs for datasets. Measures to make project funding or publishing contingent on data-sharing have also proven successful in encouraging open data practices. Secondly, capacity-building and infrastructure for data-sharing should be considered more prominently when allocating fiscal budgets for projects, institutes and organisations, or constituencies. Thirdly, further awareness creation on the importance of data-sharing among researchers, publishers, and funding bodies is essential. A sharing culture should be nourished in all research environments, with lessons learned from successful regional collaboration examples.

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