Earth System Governance 12 (2022) 100140

Contents lists available at ScienceDirect

Earth System Governance

journal homepage: www.sciencedirect.com/journal/earth-system-governance

Architecture, agency and ocean data science initiatives: Data-driven transformation of oceans governance

Lauren Drakopulos [a,*], Elizabeth Havice [b], Lisa Campbell [c]

[a] Department of Global Development, Cornell University, USA
[b] Department of Geography, University of North Carolina at Chapel Hill, USA
[c] Rachel Carson Distinguished Professor, Nicholas School of the Environment, Duke University, USA

ARTICLE INFO

Keywords:
Ocean data science initiatives
Oceans governance
Architecture
Agency

ABSTRACT

The oceans are regarded as both relatively under-governed and understudied, especially at the global and regional scales. By mobilizing data with the express goal of improving oceans governance, ocean data science initiatives (ODSIs) are positioned to play a critical role in addressing and perhaps collapsing these gaps and to provide the "science we need for the ocean we want." We argue that ODSIs are now critical oceans governance actors, to be examined as such. To this end, we have compiled a catalog of more than 150 global and regional ODSIs. Through a textual analysis of websites and public communications of a subset of these, we have created metadata about their practices. We examine ODSIs from the lens of three elements of Earth Systems Governance: normative frames, architecture and agency. ODSIs emerge from and evolve through, a range of institutional frameworks both inside and outside of formal policy forums, however, they are also transforming those frameworks through norms, institutions and practices which shape how data is valued, collected, organized, analyzed, and acted upon. As a result, ODSIs and their data products are not just mobilized by actors seeking to influence governance but are creating novel forms of agency and have become significant ocean governance actors in and of themselves. Thus, ODSIs both expand and blur the boundaries of architecture and agency. We conclude by considering how we might better understand ODSIs as governance actors through Earth Systems Governance, their role in shaping architecture and agency in governance relations and, in turn, the implications of integrating data and technology in an Earth Systems Governance framework.

1. Introduction

The United Nations Decade of Ocean Science for Sustainable Development (2021–2030) (from here: Ocean Decade) aims to generate 'the science we need for the ocean we want' (United Nations, 2020). Specifically, this coordinated effort aims to leverage a 'once in a lifetime' opportunity to mobilize the scientific community, policymakers, industry and civil society around a common research and technological innovation agenda to 'improve the management of ocean and coastal resources.' More generally, the Ocean Decade is an illustration of growing interest and attention to the role of data and Ocean Data Science Initiatives (ODSIs) in oceans governance. This paper aims to turn attention to ODSIs—such as the Ocean Decade— as actors within dynamic oceans governance at regional and global scales and, in turn, to provide insights into how an Earth Systems Governance (ESG) analytical approach might integrate data and technology into explorations of governance relations. We define an ODSI as an initiative that mobilizes (often geospatial and temporal) data and/or novel data sources about the oceans with an express goal of informing or improving conditions in the oceans. ODSIs' work centers on various elements of technology, such as remote sensing, satellite telemetry, environmental sensor and observation networks that collect data, cloud computing for data storage, dashboards and other digital platforms for data sharing, or advanced computing and modeling techniques that enable data analysis. ODSIs may be involved in one or more stages of the data 'lifecycle,' such as methods of data collection or generation; platforms and infrastructures

* Corresponding author.
E-mail address: Laurendrak@cornell.edu (L. Drakopulos).

https://doi.org/10.1016/j.esg.2022.100140
Received 25 November 2021; Received in revised form 30 March 2022; Accepted 4 April 2022
Available online 13 May 2022

for storing, managing and distributing data; analytical techniques and tools to "make sense" of data for management purposes, or as hubs that catalyze data networks. While data is central to an ODSI's purpose, an ODSI might not 'own' any data at all but instead work to facilitate data sharing or other uses or forms of communication about data. Although ODSIs might handle large amounts of data, these datasets are not always 'Big.'[1] ODSIs come in many forms and have a range of attributes. They are poised to play an important role in advancing policy through the data they produce, manage, analyze and circulate (Pendleton et al., 2020; Visbeck 2018, von Schuckmann et al., 2020). To date, ODSIs are new actors that are emerging as important but understudied, sites of oceans governance transformation and thus a timely subject of study for ESG scholarship.

In recent years, ESG scholarship has turned attention to non-state actors, such as intergovernmental institutions, and non-traditional actors, such as transnational networks, to examine how they shape principles, institutions and actions involved in governance. We contribute to this area of study by contextualizing ODSIs within the ESG framework, asking how are ODSIs shaping oceans governance? We aim to examine and describe how ODSIs are emerging as governance actors, and the implications of these new actors for oceans and environmental governance more broadly. More than a social-scientific critique of the use of data and technology among ODSIs, this paper analyzes the science-governance interface to answer conceptual questions about the future of oceans governance. We move beyond 'celebration' or 'critique' of initiatives to think about the links between techno-scientific and political components of data, ODSIs and oceans governance (see Lave et al., 2014; Lave et al., 2018). In short, we are interested in exploring what ODSIs are, and what they are doing, or might do, in the shifting dynamics of oceans governance.

The specificities of oceans offer a unique lens for examining global governance relations and the role of scientific data and the organizations mobilizing it for policy and management purposes. Oceans are vast, varied, complex, fluid, and multi-dimensional.[2] Although oceans cover 70% of the planet, they are difficult for humans to 'see' beyond their two-dimensional surfaces, where both surficial and underwater environments are "hostile to and remote from [human] habitation." (Campbell et al., 2016, 518). These features have made oceans ill-suited to traditional tools of governing via territorialization and spatial control (e.g., cadaster, fencing, bounding, etc.) (Acton et al., 2019; Peters et al., 2018; Rankin 2016; Steinberg and Peters 2015), the hallmarks of the state-based global oceans governance architecture set out under the United Nations Convention on the Law of the Sea (UNCLOS). It is difficult to determine who owns mobile 'things' in the oceans such as fish, currents and plastic, and who has the rights or obligations to govern them as they move through areas beyond national jurisdiction (the high seas), sovereign national waters of multiple states, and for resources like fish, into global markets.

As a result of mismatches between ocean materiality and historical and geopolitical governance tools, oceans are regarded as relatively 'under-governed', especially at global and regional scales (e.g., Crespo et al., 2019; IUCN, 2021; Pew, 2016). Although not a 'blank slate', or 'Wild West' as sometimes described (c.f. Vandergeest 2018), oceans, in comparison with terrestrial spaces, have absent, partial, overlapping, and incomplete policy and governance processes (Steinberg, 2001). Therefore, oceans governance is changing rapidly. There is renewed interest in strengthening oceans governance and expanding its spatial coverage in response to a broadly decried 'oceans crisis' (e.g. overfishing, pollution, acidification, and climate change). State and non-state actors are developing new policies and tools to claim ocean areas for resource extraction and to create 'blue economy' conservation and economic development options (Dodds, 2010; Silver and Campbell 2018). Critically for our purposes, science and technology are understood to be central to governance, determining what and how to govern and lending legitimacy to actors seeking influence (Boesch 1999; Haas 1989; Jasanoff 1996, 2004; Miller 2001; Mol 2006).

Scientific knowledge has long been seen as important to oceans governance; however, it has also been constrained, and oceans are typified not only by a 'governance gap', but also by a 'knowledge gap'.[3] The material properties of oceans present challenges to their study, and historically ocean science has been dependent on laborious and expensive ship-based research (Lehman 2018; Squire 2021; Webster 2018). Furthermore, only 0.04%–4% of total research dollars worldwide goes to ocean science (UNESCO, 2017). But this is also changing: remote sensing, global positioning systems, and satellite tracking illuminate ocean spaces, processes, and species from above, whereas remote and autonomous underwater vehicles do so from below (Campbell et al., 2016; Lehman, 2018). ODSIs are capturing, analyzing and sharing novel data that provide insights into the oceans' physical, chemical, ecological and biological materiality (e.g. Boustany et al., 2002; Halpin et al., 2006; Sayre et al., 2017), as well as human 'impacts' (e.g. Halpin et al., 2006; Kroodsma et al., 2018). The data revolution in ocean science and monitoring is fueled by NASA-type satellite and remote sensing hardware, and increasingly by new actors and activities, e.g., international NGOs building nature-data digital commons for the high seas, private startups releasing smaller satellites and gathering data at higher resolution and lower cost than previously possible, and 'hackathons' organized to develop novel ways of analyzing new datasets. As a result, diffuse data collection and analysis are now a part of the suite of oceans data sources, creating openings for broadening and changing participation in governance (Fawcett et al., 2022). In short, scientific knowledge and actors are now centrally positioned to influence the future of oceans governance. This is particularly the case at regional and global scales where governance is unsettled and in-the-making.

Efforts to close oceans governance and knowledge gaps are now coinciding. For instance, in describing the rationale for the UN Decade of Ocean Science, Visbeck (2018, 1) argues that the vast volume of oceans is "neither fully observed, nor adequately understood," and that this understanding is critical to ocean governance. ODSIs analyze data and make products that reveal the otherwise hidden, fluid, and lively nature of the oceans, making them visible in time and space. Thus, policy and governance innovations are supported by 'new productions of ocean space informed by growing global practices of information-gathering, geocoding, and synthesizing via networks of scientific and political actors' (Boucquey et al., 2019, 484). Efforts to close knowledge and governance gaps are not just coinciding but are mutually constituted.

We next overview our framework for conceptualizing environmental governance, particularly in relation to relevant concerns within science and technology studies and critical data studies specifically. We then summarize our novel methodological approach and dataset and introduce our subset of ODSIs, highlighting key attributes of their organizational structure and operations. In section four we examine ODSIs from the lens of three elements of ESG: normative frames, architecture and agency. We draw from empirical data to identify two central normative frames that ODSIs mobilize and circulate about data and its role in addressing oceans governance issues. Our analysis highlights how ODSIs are emerging as governance actors through the ways they mobilize data in infrastructures (architecture) and collaboration (agency). We conclude by considering how we might better understand ODSIs as

[1] Big data are typified by their tendency to be generated in large volumes, comprehensive in coverage, often collected and made available in real-time, and diverse in variety (Kitchin, 2014). Big data are differentiated from other kinds of data not only in how they are generated (rather than collected), but by what can be done with them, how, and to what ends.

[2] Some argue that there are four (or more) ocean dimensions including time to account for rapidly changing conditions (e.g., Childs 2020).

[3] For an in-depth discussion of ocean knowledge gaps see Palacios-Abrantes et al., (2019).

governance actors through Earth Systems Governance, their role in shaping architecture and agency in governance relations and, in turn, the implications of integrating data and technology in an Earth Systems Governance framework.

2. Addressing knowledge and governance gaps with new data technologies

The conceptual advancement of this paper is to link ESG literature's interests in the norms, architecture and agency in environmental governance, with critical data studies' interests in how data are mobilized in the world. We use the term "governance" to describe shifting relationships of power and authority evolving around environmental decision-making (Bridge and Perreault, 2009; Dingwerth and Pattberg, 2006). Governance is broader than policymaking, which can be defined most simply as a plan of action to achieve specified ends through tools such as rules, regulations, and principles that specify what is to be done and by whom. In particular, ESG scholars interested in "governance" have explored how, particularly since the 1980s advance of neoliberal reforms, governance norms have come to be characterized by the expansion of power and authority beyond the state to a variety of non-state actors, and the blurring of frames such as public and private sectors or scales of decision-making (e.g. local, national or global) (Campbell et al., 2016, Lemos and Agrawal, 2006). By engaging three focal elements of ESG scholars, normative framings, architecture and agency, we explore how these elements are specifically formulated by ODSIs as they mobilize data in the context of global and regional oceans governance. Norms are accepted principles or standards for how the world works. Normative frames can set standards, make claims, be regulatory, or visionary, describing idealized futures. Norms are shaped by actors, interests and contexts and through their formation, stabilization and contestation, influence governance architectures. In an ESG framing, architecture encompasses the institutions, principles, and frameworks that shape environmental decisions (Biermann et al., 2009, p. 31). Agency refers to environmental actors' capacity to act, as well as the relationships and power constellations that form around action. This includes examining who acts on behalf of whom, in what ways and in what forums, through what processes, and to what end (Burch et al., 2019). Our approach enhances understanding of ESG in an era in which data and technologies are beginning to take new roles in governance dynamics.

Critical data studies offers openings for examining how data science initiatives specifically are situated within broader governance processes. The field offers that 'data' are never raw (i.e., preexisting and only in need of being found and applied to solve environmental issues) (Gitelman 2013) but are instead "situated, contingent, relational, and framed and are used contextually to try and achieve certain aims and goals" (Kitchin, 2014; pg. 6). Data are practiced—or brought into being and made relevant—through the work of collecting, archiving, searching, sharing, and analyzing (Nost and Goldstein, 2021). These practices can include abstraction, contextualization, categorization, discourse and other forms of meaning-making that make data legible to policy and environmental decision-making (Blair 2019, Vurdubakis and Rajão, 2020). Data are governed insofar as norms and values about how they are accessed, stewarded, and applied are developed and shared. That is, the rules that structure data governance emerge through social, historical, political and economic conditions (Drakopulos, 2022; Nost and Goldstein, 2021). We look to social processes of data practice and governance to understand how ODSIs are imbricated with environmental politics.

As datasets are growing in type, size, number and speed, ODSIs contribute technical and institutional infrastructure in oceans governance, including databases and computational tools for analysis. We intentionally define ODSIs as organizations that attend to one or more stages of the data 'lifecycle,' such as methods of data collection or generation; platforms and infrastructures for storing, managing and distributing data; analytical techniques and tools to "make sense" of data for management purposes, or as hubs that catalyze data networks, to make this architecture visible and explore its work in oceans governance. Indeed, to focus on data alone ignores the ever-growing suite of data science initiatives used to generate, manage, share, analyze, and interpret environmental data (Havice et al., 2022). The processes that enable both large and 'Big' datasets to be formatted, standardized, searchable, interoperable, and well documented through metadata (i.e. the work of assembling datasets in data infrastructures) are contingent on theoretical, methodological and practical (e.g. funding) assumptions and constraints (Devictor and Bensaude-Vincent 2016, Leonelli, 2020). Moreover, the imagined potential of data science initiatives to enhance understanding of environmental dynamics across scales looms large, particularly in the context of oceans where material properties create physical barriers to scientific observation (Lehman, 2018) as well as to policy and governance practices (Campbell et al., 2016).

As ODSIs harness and advance data and technology, they have become embedded in environmental decision-making processes. Despite their proliferation, technology and data (and the organizations that create, share and apply them) have remained relatively understudied in environmental governance (Bakker and Ritts, 2018) and oceans governance in particular (Toonen and Bush, 2018). It is here that we see an opportunity for broadening our understanding of architecture and agency in the era of data and new data technologies, and in turn, the implications for governance. How might attention to frameworks and institutions apply in the context of data infrastructure and with what relevance for governance if those frameworks structure environmental decision-making?

3. Methods

To support our analysis of ODSIs as oceans governance actors, we compiled a catalog of more than 150 global and regional ODSIs and coded metadata about each (Drakopulos et al., 2022). Empirically, we limited our data set to ODSIs directed at knowing oceans at global and regional scales. New data technologies have the potential to be influential at these scales where they can enhance and sometimes dramatically change existing ways of knowing, and frequently provide the first opportunity to know and visualize ocean spaces and resources. Furthermore, global and regional scale oceans policy and governance processes are presently evolving and proliferating, often to act on growing knowledge of transboundary challenges in oceans (Campbell et al., 2016).

To populate our catalog, we began with a purposive sample of ODSIs based on the research team's prior knowledge of and participation in global and regional ODSIs. This sample allowed us to pilot and refine our metadata catalog approach. We then used a combination of keyword searches on Google using search terms such as 'ocean data' 'marine data' and 'fisheries data'. Adopting a snowball sampling method, we reviewed the websites of ODSIs that came up in our initial search to find references to additional ODSIs. To determine if an entity was an ODSI, we reviewed web pages for information on purpose, goals, objectives, mission, values (usually in tabs labeled 'About' 'Goals' or 'Objectives') and we looked for links to 'data' or 'data products.' Entities were selected for our catalog based on two criteria: 1) their stated purpose, goals, objectives, mission, values indicated a commitment to advancing ocean science and data and 2) they focused on regional or global scales. Although many ODSIs' main purpose is to curate and share ocean datasets, our definition of ODSIs and criteria for selection for the catalog also included ODSIs that advanced ocean science and data at regional or global scales through methods other than collecting or sharing data (see below for examples). We selected and categorized ODSIs according to three broad focal areas in global and regional oceans governance: fisheries extraction, biodiversity conservation, and basic ocean science development.

For a subset of 30 ODSIs, we created metadata about their policy and governance stances and practices based on a textual analysis of their

websites and public communications.[4] We chose these data sources because they provide a snapshot of how ODSIs summarize and represent their work, in their own words, for wide, public audiences. Although in some cases websites might not be regularly updated, they are ODSIs' primary public-facing communications tool. Our sample of 30 ODSIs captures heterogeneity within the broader dataset and illustrates the different organizational features of ODSIs, while also being small enough to conduct meaningful textual analysis (Cope 2010). ODSIs, as defined in the introduction, share a common approach of engaging data and/or new data technologies to mobilize them to inform and/or improve conditions in the ocean. However, ODSIs demonstrated heterogeneity in many ways such as their issue areas of focus, organizational structure and funding mechanisms, and primary interface type and technological infrastructure among others. Because all types of ODSIs are playing a role in oceans governance, we avoided defining an archetypal ODSI or identifying exemplar ODSIs among our dataset. Doing so enables us, through our analysis, to capture the range of narratives about who has agency or who should act and how and explore how ODSIs are influencing architecture and agency at play in science and governance.

Analysis of this metadata serves as the basis for the findings that we relate in the following sections. We developed metadata fields to help us explore and describe the breadth of ocean data science initiatives and to characterize the governance actors enrolled through ocean data science. Metadata were organized under broad categories that address dimensions of ODSIs' architecture as well as the processes through which they gain, grant and exercise agency. These include organizational governance (e.g. type of organization, founding data and funding type), world-making strategies (e.g. mission, problem framing) and data infrastructure (e.g. data accessibility, tools for analysis). By analyzing the metadata, we advance our understanding of who and what ODSIs are, how they work and what they do. We examine how ODSIs frame governance problems and solutions and their role, and the role of data and technology more broadly, in relation to governance concerns.

3.1. Key attributes of the ODSI subset

Our subset of 30 ODSIs was almost equally distributed across our three focal areas (Table 1). We selected for this distribution to reflect the heterogeneity we observed in the larger dataset both within and across focal areas. We categorized ODSIs as one of five primary interface types: Repository/Data Portal; Decision-Support Tool; Research Hub; Analytic/Data Science Service Provider; and Data Analysis Tool. The majority of ODSIs in our subset were either data repositories or decision support tools (Table 1). In terms of organizational structure, approximately 10 ODSIs operate as nonprofits/non-governmental organizations, eight are affiliated with national governments or intergovernmental partnerships, six are international state-sponsored projects operating independent of a state, four are university-based research centers and two are corporate entities. ODSIs target a variety of audiences including the research sector, government, the public, philanthropic/nonprofit audiences, and/or commercial industry.

A review of metadata shows that the ODSIs in our subset are responding to what they perceive as policy failures and ocean governance gaps. They aim to address one or more social-environmental issues which can be broadly categorized through five issue areas: threats to habitat and biodiversity; overexploitation/overfishing and/or Illegal Unreported and Unregulated fishing (IUU); climate change; pollution; and blue growth. Within these issue categories, ODSIs frequently identified human activity such as IUU fishing, shipping and maritime commerce and coastal development, as key drivers of social-environmental issues in the oceans, although some aim to address climate and/or ocean change without identifying a specific driver or cause. Few ODSIs made

[4] Additional research examines the full dataset.

Table 1
Summary of case study ODSIs.

ODSI	Organziational Structure	Type of Interface
Basic Science		
SeaVision - US Navy	Government/Military	Decision Support Tool
Earth Observing System Data and Information System (EOSDIS)	Government/Military	Repository/Data Portal
Copernicus	Intergovernmental	Repository/Data Portal
UNESCO IODE Ocean Data Portal	Intergovernmental	Repository/Data Portal
International Seabed Authority DeepData Database	Intergovernmental	Repository/Data Portal; Decision-Support Tool
Odinafrica	International State-sponsored Research Body	Decision Support Tool
Argo	International State-sponsored Research Body	Repository/Data Portal
Ocean Biodiversity Information System	International State-sponsored Research Body	Repository/Data Portal
Partnership for Observation of the Global Ocean	International State-sponsored Research Body	Research Hub; Decision-Support Tool
Ocean Health Index	Non-profit/NGO	Decision Support Tool
Ocean Observation Initiative	University-based Research Center	Repository/Data Portal
Biodiversity Conservation		
Deep-Ocean Stewardship Initiative	International State-sponsored Research Body	Decision-Support Tool
Global Ocean Biodiversity Initiative	International State-sponsored Research Body	Research Hub; Decision-Support Tool
Our Shared Seas	Non-profit/NGO	Decision Support Tool
FishBase	Non-profit/NGO	Repository/Data Portal
Marine Protection Atlas	Non-profit/NGO	Repository/Data Portal
ReefBase	Non-profit/NGO	Repository/Data Portal
State of the world's sea turtles	Non-profit/NGO	Repository/Data Portal; Data Analysis Tool
Ocean Tracking Network	University-based Research Center	Data Science Service
Migratory Connectivity in the Ocean	University-based Research Center	Data Analysis Tool
Fisheries Extraction		
Lloyds List Intelligence (seasearcher)	Corporate	Data Science Service; Decision-Support Tool
Traseable	Corporate	Decision Support Tool
Fish-I Africa	Intergovernmental	Decision-Support Tool
CCAMLR Data	Intergovernmental	Repository/Data Portal
Pacific Islands Forum Fisheries Agency Regional Fisheries Surveillance Center	Intergovernmental	Repository/Data Portal; Decision-Support Tool
Ocean Disclosure Project	Non-profit/NGO	Data Science Service; Decision-Support Tool
EDF Fisheries Solution Center	Non-profit/NGO	Decision-Support Tool
Pew Charitable Trust 'Eyes on the Sea'	Non-profit/NGO	Decision-Support Tool; Data Science Service
Global Fishing Watch	Non-profit/NGO	Repository/Data Portal; Data Analysis Tool
Sea Around US	University-based Research Center	Repository/Data Portal

Type of Intereface Defined Repository/data portal: primarily a raw data source.
Decision support tool: intent to support audience decision-making, rather than a general tool and data set that visualize aspects of the ocean. Might include data and some analytical component that synthesizes data.
Analytic/data science service provider: data analysis and synthesis hub. They make data digestible and understandable for audiences. Very little if any raw data will be available.
Analysis tool/app for web or desktop: tools or suite of tools intended for the audience to use to analyze ocean data, however they may not actually provide much raw data. Does not actually analyze the data and produce data products.
Research Hub: primarily a catalyst for research and collaboration.

explicit policy recommendations, despite a general sentiment that current policies were inadequate to address pressing ocean issues. Those that did make recommendations for specific policy changes advocated for existing policy tools (e.g. marine protected areas or ecosystem-based management) rather than proposing new policy instruments and avenues.

In sum, ODSIs have emerged to address a range of issue areas in the oceans, they have a wide range of organizational structures, and have developed a range of interfaces for data organization and access. This summary suggests that ODSIs are now present as actors in oceans governance, our analytical categories below enable us to further explore some of the ways that they are acting in and shaping oceans governance.

4. ODSIs as governance actors

We analyzed our metadata to explore the ways that ODSIs engage with/shape three dimensions of environmental governance: through normative framings about data and technology, through their data infrastructure (architecture), and by building and coordinating collaboration networks (agency). In what follows, we review each of these, drawing linkages with concepts and concerns in ESG that we have outlined in the literature review above to explore how ODSIs are imagining and shaping oceans governance.

4.1. Normative framings of data and technology

> To counter global issues and ensure the sustainable use of marine resources, data-driven research, conservation and ocean management are key. – OBIS (Ocean Biogeographic Information System)

This section explores how ODSIs narratively position themselves in environmental governance through the normative frames they produce and circulate about data and technology. Language profoundly shapes how people come to understand the world and act on that understanding, in other words, language shapes politics. Thus, environmental discourses are instrumental in setting the agenda in governance and how that agenda is realized through policy (Hajer and Versteeg, 2005). We draw from our analysis of our metadata on organizational mission, vision and theory of change to explore the discursive contexts through which ODSIs frame data and technology and their role in addressing oceans governance issues. A review of our subset reveals that ODSIs share a foundational assumption that data renders the oceans, and the activity therein, visible to policy. This is epitomized in the following quote from the ODSI *Partnership for Observation of the Global Ocean's* website: "we cannot manage what we cannot measure!" (https://pogo-ocean.org). Claims such as these were common – though not universal – across our subset, and they suggest that more comprehensive data and widespread monitoring will render the oceans, and perceived ocean challenges, visible and measurable. This coupling of data and visibility drives two normative frames that ODSIs mobilize and circulate about data: 1) that there is not enough data about ocean attributes and ecological and social challenges in them and 2) that data creates, and is essential for, transparency in a range of forms (e.g., decision making and monitoring of processes in the oceans).

Building from the normative framing that there is not enough data about ocean attributes and ecological and social challenges in them, many ODSIs are addressing this problem by scaling up datasets to make them comprehensive in geographic scope and temporal extent. Scaling up becomes a central aim of ODSIs, as demonstrated by taglines such as: "The Marine Protection Atlas is building a comprehensive global database of marine protection to identify, monitor, and advocate for fully and highly protected areas" (https://mpatlas.org). The Ocean Tracking Network states that "We're not just tracking animals—we're tracking oceans" and that their "global receiver infrastructure comprehensively examines the local-to-global movements of tagged marine animals "(https://oceantrackingnetwork.org). Framings such as these suggest that large datasets provide create a 'complete' picture of global environmental challenges in the oceans.

Transparency, and the need for it, also emerged as a common normative framing, particularly for ODSIs focused on fisheries extraction. These ODSIs framed data as a necessary tool to create *transparency*. They promote widespread technology-based industry monitoring measures that they claim will make industry practices visible or transparent, transforming the global fishing industry, and its oversight and governance, in the process. These ODSIs offer expertise and high-tech data analysis services, often in the form of satellite monitoring or other tools that allow users to track activities in real-time. The benefits, they claim, extend to enforcement authorities who will have a more complete picture of fishing, and to the business sector to whom they offer bespoke decision-support tools and data products that are promised to improve industry efficiency. Some ODSIs in this arena position transparency as a tool to create market-based incentives that will motivate more environmentally sound fishing practices. For example, firms can demonstrate a 'commitment to transparency' by sharing data or participating in an ODSI's transparency project; benefits might compound when doing so has the potential to provide access to markets, create new value for their products, and create opportunities for collaboration across the industry. This is illustrated in ODSI *Traseable* which states, "we are reimagining how technology can be applied to address the provenance and traceability of our fisheries and agriculture products entering the global market … We are pioneers in the use of blockchain technology for traceability that can foster greater transparency" (https://www.traseable.com).

In sum, ODSIs are not only gathering, organizing and making data available, they are also producing and circulating normative understandings about data and their role in identifying and at times 'solving' certain challenges in the oceans. Most broadly, ODSIs take as a starting point that data renders the ocean visible and is thus essential for better policy and governance. This starting point is linked with two common normative frames about data: that there is not enough, and that data's value is the measurability and transparency they create. As such, ODSIs positions themselves as governance actors by creating, curating, stewarding and distributing ocean data *as well as* normative understandings about the role of data and technology in oceans policy and governance.

4.2. Architecture through data infrastructure

> Our vision is to make NASA's free and open Earth science data interactive, interoperable, and accessible for research and societal benefit both today and tomorrow. – NASA Earth Observing System Data and Information System (EOSDIS) Ocean Data

> While the amount of data continues to grow exponentially, efforts to synthesize and provide access to information on migratory connectivity for management and policy has lagged behind. –Migratory Connectivity in the Ocean (MICO)

ODSIs envision data access and infrastructure—amassing data sets, organizing the information, and making it accessible to audiences—as

critical for improved oceans policy. They see – and position – themselves as playing a central role in developing this scientific infrastructure. Some ODSIs see limited access to already existing data and information as a key challenge to applying that data for policy. They address these gaps by developing and offering elaborate data infrastructures that serve as a central access point for data. In other words, like ESG's attention to governance architecture as the frameworks and institutions that shape environmental decisions, ODSIs understand data infrastructure and qualities that make data more accessible as constitutive of the technical and scientific practices and products that support decision-making. For example, the ODSI *Ocean Biodiversity Information System* aims "To build and maintain a global alliance that collaborates with scientific communities to facilitate free and open access to, and application of, biodiversity and biogeographic data and information on marine life" (https://obis.org/about/). By creating data infrastructure, ODSIs aim to improve how data is stored and shared. Equally important, ODSIs also see and develop infrastructure as means to support open and transparent data science. In this context (and in distinction from the usage of transparency in section 4.2), "transparent" means establishing data standards and provenance to increase interoperability between datasets and improve data usability.

Despite a shared goal of improving data accessibility, our analysis reveals heterogeneity in the values and practices ODSIs deploy around data infrastructure (Table 2). We created metadata typologies to classify how ODSIs framed their **values** about data availability and how they made data available **in practice** (*Data Ethos* and *Data Availability* respectively). Whereas *Data Ethos* speaks to the ideologies, values and beliefs they promote about the accessibility of scientific data more broadly, *Data Availability* indicates practices ODSIs have instated for users to access data. Our typologies for *Data Ethos* and *Data Availability* are described in Table 2.

While the differences between these typologies and sub-categories may seem subtle, the nuances are important for understanding the emerging architectures of data-driven ESG in the oceans. They show differences in ODSIs' theories of change and specifically the role of data and data science in governance insofar as their theories of change functionally determine what ODSIs prioritize, how data can and should be enrolled in decision-making and by whom. Some of these differences emerge around the topical focus of an ODSI (Table 3). ODSIs focused on biodiversity conservation and basic science tended to promote a data ethos of *Open* or *Free* data, whereas ODSIs often focused on fisheries extraction tended to adopt a *Private Data* ethos. This is likely in part due to the proprietary nature of fisheries data and that it is in many cases intrinsically linked with industry, as will be discussed in the next section.[5] ODSIs that are handling fisheries data might be upholding privacy restrictions that are already in place because of the data source and/or are required by national or international regulations. For all ODSIs, those with an *Open Data* ethos tended to also provide open and unrestricted data access. Conversely, those that promote *Free Data* (i.e., an ideology that does not specifically promote open and unrestricted access to scientific data) tended to also have more data access restrictions such as requiring users to create an account, request data, or to only make data available to specific users. While in some cases the accessibility of a particular dataset may be determined by the data source external to the ODSI, in many instances the ODSI is the primary authority determining access standards. The only ODSIs that enacted Paywalls for data were those that also promoted a *Private Data* ethos.

Table 2
Types of data ethos and data availability.

Data Ethos	- ideologies, values and beliefs about data accessibility
Open	ODSIs promote making data easily accessible to wide audiences and promote standards or expectations for data provenance, access permissions, and other specifications that promote transparency in science
Free	*ODSIs promote an ethos of making data freely available, though they do not advocate for or specify standards around data governance (e.g. what if any permissions or access steps) or provenance.*
Private	ODSIs emphasize private or proprietary data and advocate for its use by select or otherwise privileged stakeholders e.g., intended for commercial users or private interests
Data Availability	**- practices instated for users to access data**
Open	downloaded without permission or an account
Open with account or request	freely available data requiring intermediary steps
User dependent	data that is considered public but has additional layers of access restricted to partners or specialized audiences
Partnership-based	to access that is restricted to only formal ODSI partners
Paywall	access for a fee
View Only	classified data or data products that were not available for download e.g., packaged as a complete or final product

> In addition to accessibility, ODSIs view data handling, analysis and interpretation as important architectures that they can develop to make data legible to policy. Many use data to synthesize and summarize key ocean issues for users, as illustrated in the quote below from the *Ocean Health Index*:
>
> The Index allows us to combine different types of data and values to compare how well each country— and the world as a whole— is achieving a portfolio of key goals. Evaluating the performance of the entire portfolio provides more information than evaluating each goal separately. Historically, information about livelihoods, water quality, biodiversity, food production and other subjects have been considered separately. The Index analyzes them together so people can see how they interact and how we are doing overall in a comparable fashion. The Index allows countries to compare their progress to one another and to the global average in a way not possible with current ocean assessment tools.

In other cases, ODSIs frame the access and infrastructure as central to creating data products that are meaningful for change in conditions on or in the oceans. For example, ODSI *Global Fishing Watch* uses machine learning tools to manipulate proprietary datasets that track ocean-going vessels to create new data on presumed fishing activity, which they make publicly available. In this vision, by providing data access and infrastructure, change will naturally unfold. They claim that:

> By creating and publicly sharing map visualizations, data and analysis tools, we enable scientific research and drive a transformation in how we manage our ocean. By making our data and visualization tools freely available, we're enabling scientific understanding and insights that will lead to change on the water.

By creating both data ethos and data availability structures, ODSIs are becoming key purveyors of the architectures of oceans governance. The analysis of these infrastructures presented here illustrates that there are multiple approaches to organizing and making oceans data available, and as ODSIs develop these data infrastructures, they are (intentionally or unintentionally) writing the rules of how data is organized and accessed and by whom. By structuring data availability and their broader data ethos, ODSIs create architectures for who has the agency to mobilize data and therefore act with and on it. Data infrastructure therefore can be understood as a new kind of governance architecture, which by design, shapes agency, as we explore in the following section.

[5] A notable exception is ODSI GFW which promotes a *Free* data ethos and User Dependent availability with the express goal of making corporate activity visible and thus monitorable.

Table 3
ODSIs by focal area, data ethos and availability.

ODSI	Data Ethos	Data Availability
Biodiversity Conservation and Basic Science		
Marine Protection Atlas	Free	Under Construction
Argo	Free	Open
ReefBase	Free	Open With Account
Migratory Connectivity in the Ocean	Free	Open With Account
State of the world's sea turtles	Free	Open With Request
Odinafrica	Free	Source- Dependent
Our Shared Seas	Free	User-Dependent
Ocean Biodiversity Information System	Open	Open
UNESCO IODE Ocean Data Portal	Open	Open
Ocean Tracking Network	Open	Open
Earth Observing System Data and Information System	Open	Open With Account
Copernicus	Open	Open With Account
Ocean Observation Initiative	Open	User Dependent
Ocean Health Index	Open	View Only
FIshBase	Open	View Only
Global Ocean Biodiversity Initiative	Private	Partnership Based
SeaVision - US Navy	Private	Partnership Based
Deep-Ocean Stewardship Initiative	Private	User Dependent
International Seabed Authority DeepData Database	Private/Free	User Dependent
Partnership for Observation of the Global Ocean	Unspecified	User Dependent
Fisheries Extraction		
Global Fishing Watch	Free	User Dependent
Environmental Defense Fund Fisheries Solution Center	Open	Open
Ocean Disclosure Project	Open	Open
Sea Around US	Open	Open
Fish-I Africa	Private	Partnership Based
Pacific Islands Forum Fisheries Agency Regional Fisheries Surveillance Center	Private	Partnership Based
Lloyds List Intelligence (seasearcher)	Private	Paywall
Traseable	Private	Paywall
CCAMLR Data	Private	User Dependent
Pew Charitable Trust 'Eyes on the Sea'	Unspecified	Partnership Based

4.3. Agency through collaboration

> The ocean is too vast, too interconnected and its impacts too widespread for any one nation let alone one organization to embark on this task alone. One simple message is clear: international cooperation is essential. – Partnership for Observation of the Global Ocean

A second way that ODSIs mobilize data is by creating research networks and capacity building that are organized around data. Agency, or an environmental actors' capacity to act, and the relationships that form around environmental actions and decisions, are a chief concern of ESG. A core feature of ODSIs is that they function as a nexus for research collaboration, and frequently frame collaboration and networks as essential to addressing ocean governance issues, particularly at vast regional and global scales. ODSIs aim to achieve this by facilitating collaboration among diverse global stakeholders and institutions, and by integrating datasets, fields and disciplines. Many ODSIs launch to create platforms and networks where partners and researchers share data, costs, best practices, expertise and other resources.[6] ODSIs commonly frame cooperation as key for building relationships and trust. While biodiversity conservation and basic science collaborations primarily focus on data sharing, in some cases, fisheries extraction ODSIs leveraged data and technology partnerships to directly inform or enhance existing regulatory enforcement, strengthen states' regulatory and enforcement capacity and create peer pressure amongst partnering institutions to enforce policy and industry to comply with regulations.

Part of the "actionability" promise of large and evermore comprehensive data is its scalability—it can grow and multiply quickly and data infrastructures are increasingly built to accommodate the rapid expansion of both datasets and data users (Kitchin 2014). ODSIs are tapping into and creating new interpretations of scalability, including scaling-up partnerships, which contribute to creating a data-informed understanding or vision of policy problems and solutions. ODSIs commonly develop and initiate global- and regional-scale collaborations that enable and are made possible by, the scalability of new data technologies. For example, *Ocean Tracking Network* has created a "global network" of researchers and the *State of the World's Sea Turtles* is bringing together "turtle researchers from across the globe" to promote "common global standards for data." ODSIs link their work scaling-up through global networks to scaling-up solutions to problems in the oceans for example by creating 'global ocean knowledge' (*Copernicus)* and helping to measure 'global progress' towards conservation goals (*MPAtlas)*.

Our review of our subset illustrates that ODSI partnerships take many forms and are organized around the scaling of not only ecological data sources but also the scaling of political and economic processes. This is particularly evident for ODSIs focused on fisheries extraction. These organizations leverage existing reporting requirements born of state-based regulatory frameworks and the political economy of the global fishing industry to aggregate global catch data generated from multiple sources (*The Sea Around Us*) and establish transnational partnerships to monitor fishing activity as a global phenomenon (*Global Fishing Watch*). Other fisheries extraction ODSIs draw on relationships established through global supply chains to promote transparency and data sharing across sectors (*Ocean Disclosure Project*). As such, ODSIs focused on fisheries extraction build new global-scale networks across governance actors that center on data and technology.

ODSIs build partnerships in several ways and for a variety of reasons. We categorize partnering practices as generally oriented around three

[6] Note that in our metadata we developed a typology of 'Interface type' in which we identify ODSIs whose primary function was Research Hub. However, our findings suggest a broader trend amongst all ODSIs of idealizing partnership and collaboration, including among those whose primary function was categorized as another interface type.

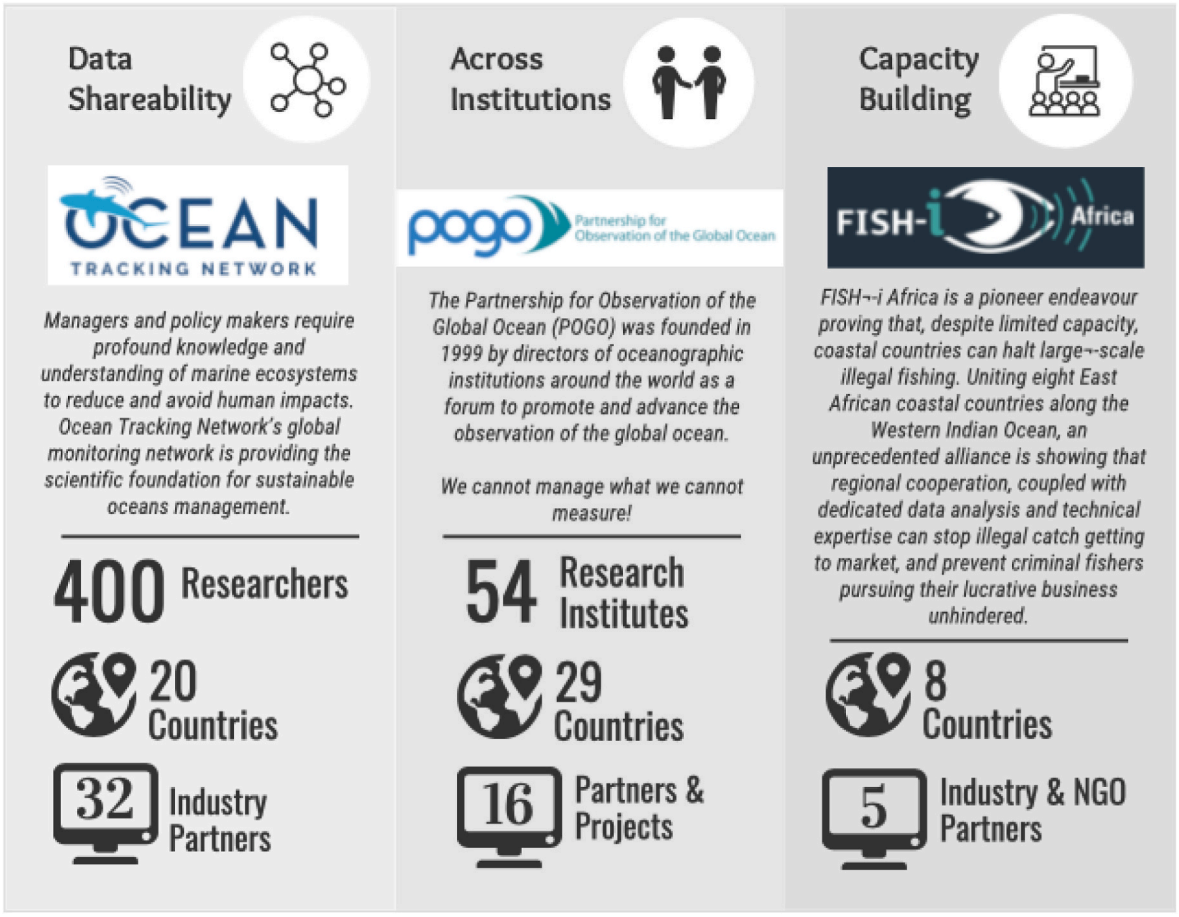

Fig. 1. Examples of three approaches to partnership.

objectives: *facilitate data sharing*, *connect institutions* and *build capacity*. These categories are differentiated primarily by the scale and central aim of collaboration. Examples from our subset illustrate the three different approaches to partnership (Fig. 1). ODSIs that develop partnerships to *facilitate data sharing* (i.e. data standards and interoperability and accessibility) to make it easier to share and collaborate. They emphasize partnering at the level of individual researchers and see their role as enabling researchers to more efficiently share data. For example, the *Ocean Tracking Network* boasts linking 400 researchers through their work. In addition to facilitating partnerships between individual researchers, some ODSIs are building networks to *connect institutions* through ODSIs' organizational structure and governance. These ODSIs focus attention on the scale of research institutions and organizations to develop data collection projects. The *Partnership for Observation of the Global Ocean* highlights that they engage 54 research institutions (rather than documenting individual researchers) through 16 projects (and project partners). Finally, some ODSIs set out to *build capacity* for their members, users and affiliated entities, through their datasets and infrastructure and they leverage data products and services, and connections with other institutions, to build legitimacy for their members/users. In this approach, ODSIs often engage at the country level (usually countries or institutions claimed to be under-resourced). In our example, *Fish-I Africa* the ODSI engages far fewer partners than the other two examples – just eight countries – which could indicate that capacity building is a resource-intensive approach to partnership that emphasizes quality of relationships over quantity.

ODSIs are mobilizing and creating networks of scientists and knowledge brokers. In doing so, they create new forms of participation and new networks of stakeholders – key attributes of agency in the ESG literature – in oceans governance. Although ODSIs frame participation as occurring through technical practices around data and technology, the networks and relationships built around data and technology are new mechanisms of participation in governance. These hold potential to structure agency and are becoming a form of architecture through frameworks that formalize stakeholder relationships around data. These collaboration frameworks are creating new constellations of environmental actors and integrating state and non-state actors into governance relations via relationships around data and technology.

5. Conclusion

The Ocean Decade and the rapid growth and proliferation of ODSIs signals a pivotal moment in which efforts to close ocean knowledge gaps and governance gaps are co-constituting one another. Our analysis offers the ESG elements of normative framing, architecture and agency, as entry points for examining this co-constitution and for situating data and technology – and the organizations that are creating, managing and coordinating its use – in the study of oceans governance. Through our analysis we highlight three key ways that ODSIs are emerging as governance actors: through the normative framing they advance about the role of data and new data technologies in creating and addressing governance problems, through the data infrastructure that they design and develop, and through the partnerships and collaborative networks they build around data. In turn, our analysis shows that examining ODSIs offers openings for understanding the relationship of these ESG framings to the emerging 'data revolution' that is relevant for oceans governance and environmental governance more broadly.

Our analysis shows that ODSIs, blur the boundaries between architecture and agency and that this work is in part enabled by the normative frames ODSIs mobilize and circulate about data and specifically the

ways data render the ocean visible to policy. Bridging ESG with the lens of critical data studies helps to offer nuance to not only the technical but also the political, work of these normative frames. These frames contribute to setting the agenda for ocean governance, and the work and roles of ODSIs therein. Data and technology are framed as essential for seeing and knowing oceans, justifying the need for ODSIs as actors that harness data and technology. ODSIs emerge from and evolve through governance architecture both inside and outside of formal policy bodies (e.g, the Ocean Decade), which are becoming ever-more dependent on larger, more comprehensive and 'big' datasets. Yet, by creating data infrastructure, ODSIs are also a form of architecture shaping policy decisions through the ways that they organize, analyze and share ocean data. Although many ODSIs see data infrastructure as enabling access to data, ODSIs are far from unified in their approaches to making data accessible. Instead, ODSIs enact a heterogeneous set of visions and practices for making their data accessible which, in turn, has profound implications for agency. ODSIs and their data products are mobilized by actors seeking to influence governance, linking ODSIs implicitly with agency and governance practices. However, ODSIs also create novel forms of agency by providing the data infrastructure and architecture that shape which actors have agency to mobilize data and therefore act with and on it.

Our findings raise several questions for the field of Earth Systems Governance. Collectively, these findings situate data and new data technologies in the Earth Systems Governance frame by providing ways to think about ODSIs as governance actors and the multiple kinds of influences they have in Earth Systems Governance. ODSIs push ESG thinking on the interplay between architecture and agency, and how data and technology are transforming governance relations through the melding of these elements. As critical data studies scholarship reminds us, data is never 'raw' but is instead always 'cooked' through social, and thus political, practices that are embedded in broader historical, economic and political processes. Understanding architecture and agency in the context of the Ocean Decade demands careful attention to the data practices and data governance standards that ODSIs deploy. By attending to these diverse modes of practicing and governing ocean data, we begin to see their intersections with environmental politics and governance.

Our focus on the role of data and technology in the context of *oceans* governance, in particular, demonstrates how the specificities of the oceans add nuance and complexity to how ESG might understand architecture and agency. Normative frames that couple data with visibility are responding to historic challenges of knowing the oceans. The ability of data and technology to render previously unseen ocean spaces and phenomena visible is much of their appeal. Likewise, the ability to track and visualize mobile ocean things is thought to hold promise for developing better tools for governing those objects. Here we see the potential for ESG to think more deeply about architecture and agency in the context of the oceans. Specifically, ESG should consider how architecture is evolving to govern the unruly spaces of the ocean, particularly as they transcend global and regional scales, and how this is enabled by technological tools of mediation.

Our analysis highlights a critical opening for ESG to engage the current oceans data and technology moment. Though there are many areas of potential future research, we will highlight just a few here. First, we see an opportunity, and need, for scholarship that expands research on ODSIs through a wide variety of methodological approaches ranging from in-depth case studies that employ qualitative research methods to large-scale network analyses. Likewise, future research could both utilize and build on our dataset to develop analyses comparing ODSIs within and across metadata categories. Second, through this research we show the potential for ODSIs to set the ocean governance agenda, directing attention to those ocean issues that are captured by current data collection and measurement regimes. However, future research should explore the possibilities of over-reliance on data and technologies for addressing ocean governance issues. Specifically, we see important questions about the potential for data and technology to make visible, or obscure, social, political and economic drivers and outcomes of ocean crisis. Finally, while the focus of this study has been on governance, there is much work to be done to understand ODSIs at the science-policy interface. The heterogeneous nature of ODSIs and their approaches to data governance suggests a complex politics around access and applications of data. Bringing these politics to the fore is critical if the Ocean Decade is to advance a more equitable ocean future and avoid reproducing and/or magnifying existing inequalities and power relations. With the momentum of the Ocean Decade building, ODSIs are well-poised to continue to shape the future of oceans governance for decades to come. The role of data in the Ocean Decade demands attention to the ways that architecture and agency are changing in the face of a knowledge revolution enabled by technology. This is essential for understanding the intersection and co-production of governance and knowledge.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This material is based upon work supported by the National Science Foundation, Geography and Spatial Sciences Division, Award# 2026345. The authors would like to thank two anonymous reviewers and the editors for their feedback on the manuscript and the journal's editorial and administrative staff for their work moving the manuscript through to publication. They would also like to acknowledge Katie Crisp and Anna Zurita Poses for their outstanding work on data collection.

References

Acton, L., Campbell, L.M., Cleary, J., Gray, N.J., Halpin, P.N., 2019. What is the Sargasso Sea? The problem of fixing space in a fluid ocean. Polit. Geogr. 68, 86–100.

Bakker, K., Ritts, M., 2018. Smart Earth: a meta-review and implications for environmental governance. Global Environ. Change 52, 201–211.

Biermann, F., Betsill, M.M., Gupta, J., Kanie, N., Lebel, L., Liverman, D., Schroeder, H., Siebenhüner, B., 2009. Earth system governance project: people, places, and the planet: science and implementation plan of the Earth System Governance Project. Bonn: IHDP: the earth system governance project. Earth System Governance Project Report No. 1, IHDP Report No. 20. http://www.earthsystemgovernance.org/sites/default/files/publications/files/Earth-System-Governance_Science-Plan.pdf.

Blair, J., 2019. Tracking penguins, sensing petroleum: "Data gaps" and the politics of marine ecology in the South Atlantic. Environ. Plann.: Nature and Space. https://doi.org/10.1177/2514848619882938.

Boesch, D.F., 1999. The role of science in ocean governance. Ecol. Econ. 31 (2), 189–198.

Boucquey, N., Martin, K.S., Fairbanks, L., Campbell, L.M., Wise, S., 2019. Ocean data portals: performing a new infrastructure for ocean governance. Environ. Plann. Soc. Space 37 (3), 484–503.

Boustany, A.M., Davis, S.F., Pyle, P., Anderson, S.D., Le Boeuf, B.J., Block, B.A., 2002. Expanded niche for white sharks. Nature 415 (6867), 35–36.

Bridge, F., Perreault, T., 2009. Environmental governance. In: Castree, N., Demeritt, D., Liverman, D.M., Rhoads, B. (Eds.), *A companion to environmental geography*. Oxford: Wiley-Blackwell, pp. 475–497.

Burch, S., Gupta, A., Inoue, C.Y., Kalfagianni, A., Persson, Å., Gerlak, A.K., et al., 2019. New directions in earth system governance research. Earth Syst. Govern. 1, 100006.

Campbell, L.M., Gray, N.J., Fairbanks, L., Silver, J.J., Gruby, R.L., Dubik, B.A., Basurto, X., 2016. Global oceans governance: new and emerging issues. Annu. Rev. Environ. Resour. 41, 517–543.

Childs, J., 2020. Extraction in four dimensions: time, space and the emerging geo (-) politics of deep-sea mining. Geopolitics 25 (1), 189–213.

Cope, M., 2010. Coding qualitative data. In: Gomez, B., Jones III, J.P. (Eds.), Qualitative Research Methods in Human Geography. Oxford University Press.

Crespo, G.O., Dunn, D.C., Gianni, M., Gjerde, K., Wright, G., Halpin, P.N., 2019. High-seas fish biodiversity is slipping through the governance net. Nat. Ecol. Evolu. 3, 1273–1276.

Devictor, V., Bensaude-Vincent, B., 2016. From ecological records to big data: the invention of global biodiversity. Hist. Philos. Life Sci. 38 (4), 1–23.

Dingwerth, K., Pattberg, P., 2006. Global governance as a perspective on world politics. Global Governance 12, 185–203.

Dodds, K., 2010. Flag planting and finger pointing: The Law of the Sea, the Arctic and the political geographies of the outer continental shelf. Political Geo. 29 (2), 63–73. https://doi.org/10.1016/j.polgeo.2010.02.004.
Drakopulos, L., 2022. Privatizing the fisheries observer industry: Neoliberal science and policy in the US West Coast fisheries. Geoforum 131, 116–125.
Drakopulos, L., Havice, E., Crisp, K., Zurita Posas, A., Campbell, L.M., 2022. Catalog of Ocean Data Science Initiatives [Dataset]. Qualitative Data Repository, V1. https://doi.org/10.5064/F6ZQWQJS.
Fawcett, L., Havice, E., Zalik, A., 2022. Frontiers: ocean epistemologies - privatise, democratise, decolonise. In: Peters, K., Anderson, J., Davies, A., Steinberg, P. (Eds.), The Routledge Handbook of Ocean Space. Routledge.
Gitelman, L. (Ed.), 2013. Raw Data" Is an Oxymoron. MIT Press, Cambridge, MA.
Haas, P.M., 1989. Do regimes matter? Epistemic communities and Mediterranean pollution control. Int. Organ. 43 (3), 377–403.
Hajer, M., Versteeg, W., 2005. A decade of discourse analysis of environmental politics: achievements, challenges, perspectives. J. Environ. Pol. Plann. 7 (3), 175–184.
Halpin, P.N., Read, A.J., Best, B.D., Hyrenbach, K.D., Fujioka, E., Coyne, M.S., et al., 2006. OBIS-SEAMAP: developing a biogeographic research data commons for the ecological studies of marine mammals, seabirds, and sea turtles. Mar. Ecol. Prog. Ser. 316, 239–246.
Jasanoff, S., 2004. Ordering knowledge, ordering society. In: Jasanoff, S. (Ed.), States of Knowledge: the Co-production of Science and Social Order, pp. 13–45.
Havice, E., Campbell, L.M., Boustany, A., 2022. New data technologies and the politics of scale in environmental management: Tracking Atlanticbluefin tuna. Ann. Assoc. Am. Geogr. https://doi.org/10.1080/24694452.2022.2054766.
IUCN, 2021. The IUCN Red List of Threatened Species, Version 2021-3. IUCN. https://www.iucnredlist.org.
Jasanoff, S., 1996. Science and norms in global environmental regimes. In: Hampson, F. O., Reppy, J. (Eds.), Earthly Goods: Environmental Change and Social Justice. Cornell Univ. Press, Ithaca, NY, pp. 173–197.
Kitchin, R., 2014. Big Data, new epistemologies and paradigm shifts. Big data & society 1 (1), 2053951714528481.
Kroodsma, D.A., Mayorga, J., Hochberg, T., Miller, N.A., Boerder, K., Ferretti, F., et al., 2018. Tracking the global footprint of fisheries. Science 359 (6378), 904–908.
Lave, R., Biermann, C., Lane, S.N., 2018. Introducing critical physical geography. In: Lave, R., Biermann, C., Lane, S.N. (Eds.), The Palgrave handbook of critical physical geography. Palgrave Macmillan Cham, pp. 3–21.
Lave, R., Wilson, M.W., Barron, E.S., Biermann, C., Carey, M.A., Duvall, C.S., Johnson, L., Lane, K.M., McClintock, N., Munroe, D., Pain, R., Proctor, J., Rhoads, B.L., Robertson, M.M., Rossi, J., Sayre, N.F., Simon, G., Tadaki, M., Van Dyke, C., 2014. Intervention: Critical physical geography. The Canadian Geographer 58 (1), 1–10. https://doi.org/10.1111/cag.12061.
Lehman, J., 2018. From ships to robots: the social relations of sensing the world ocean. Soc. Stud. Sci. 48 (1), 57–79.
Lemos, M.C., Agrawal, A., 2006. Environmental governance. Annual Review of Environment and Resources 31, 297–325.
Leonelli, S., 2020. Scientific research and big data. Online at. https://plato.stanford.edu/entries/science-big-data/.
Miller, C., 2001. Hybrid management: boundary organizations, science policy, and environmental governance in the climate regime. Sci. Technol. Hum. Val. 26 (4), 478–500.
Mol, A.P., 2006. Environmental governance in the Information Age: the emergence of informational governance. Environ. Plann. C Govern. Pol. 24 (4), 497–514.
Nost, E., Goldstein, J.E., 2021. A political ecology of data. Environ. Plan. E: Nature and Space 5 (1), 3–17. https://doi.org/10.1177/25148486211043503.
Palacios-Abrantes, J., Cisneros-Montemayor, A.M., Cisneros-Mata, M.A., Rodríguez, L., Arreguín-Sánchez, F., Aguilar, V., et al., 2019. A metadata approach to evaluate the state of ocean knowledge: strengths, limitations, and application to Mexico. PLoS One 14 (6), e0216723. https://doi.org/10.1371/journal.pone.0216723.
Pendleton, L., Evans, K., Visbeck, M., 2020. Opinion: we need a global movement to transform ocean science for a better world. Proc. Natl. Acad. Sci. 117 (18), 9652–9655.
Peters, K., Steinberg, P., Stratford, E. (Eds.), 2018. Territory beyond terra. Rowman & Littlefield.
Pew, 2016. Netting billions: a global valuation of tuna.. Pew Charitable Trust.
Rankin, W., 2016. After the Map: Cartography, Navigation, and the Transformation of Territory in the Twentieth Century. University of Chicago Press.
Sayre, R.G., Wright, D.J., Breyer, S.P., Butler, K.A., Van Graafeiland, K., Costello, M.J., et al., 2017. A three-dimensional mapping of the ocean based on environmental data. Oceanography 30 (1), 90–103.
Silver, J.J., Campbell, L.M., 2018. Conservation, development and the blue frontier: the Republic of Seychelles' debt restructuring for marine conservation and climate adaptation program. Int. Soc. Sci. J. 68 (229–230), 241–256.
Steinberg, P.E., 2001. The social construction of the ocean, 78. Cambridge University Press.
Steinberg, P., Peters, K., 2015. Wet ontologies, fluid spaces: giving depth to volume through oceanic thinking. Environ. Plann. Soc. Space 33 (2), 247–264.
Squire, R., 2021. Undersea Geopolitics: Sealab, Science, and the Cold War. Rowman & Littlefield.
Toonen, H., Bush, S.R., 2018. The digital frontiers of fisheries governance: fish attraction devices, drones and satellites. J. Environ. Pol. Plann. 22 (1), 125–137. https://doi.org/10.1080/1523908X.2018.1461084.
UNESCO, 2017. Global Ocean Science Report—The current status of ocean science around the world,. UNESCO Publishing, Paris.
United Nations, 2020. The Science We Need for the Ocean We Want. The United Nations Decade of Ocean Science for Sustainable Development (2021-2030). Paris, 20 pp. (English). IOC Brochure 2020-4 (IOC/BRO/2020/4).
Vandergeest, P., 2018. Law and lawlessness in industrial fishing: frontiers in regulating labour relations in Asia. Int. Soc. Sci. J. 68 (229–230), 325–341.
Visbeck, M., 2018. Ocean science research is key for a sustainable future. Nat. Commun. 9 (1), 1–4.
von Schuckmann, K., Holland, E., Haugan, P., Thomson, P., 2020. ocean Science, data, and services for the UN 2030 sustainable development goals. Mar. Pol. 121, 104154.
Vurdubakis, T., Rajão, R., 2020. Envisioning Amazonia: geospatial technology, legality and the (dis)enchantments of infrastructure. Environ. Plann.: Nature and Space. https://doi.org/10.1177/2514848619899788.
Webster, D.G., 2018. Strengthening sustainability through data. Proc. Natl. Acad. Sci. 115 (44), 11118–11120.