Documenting Sea Change

Ocean Data Technologies, Sciences, and Governance

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■ **ABSTRACT:** This review examines social science and practitioner literature regarding the relationship between ocean sciences big data projects and ocean governance. I contend that three overarching approaches to the study of the development of ocean sciences big data techne (the arts of data creation, management, and sharing) and data technologies can be discerned. The first approach traces histories of ocean sciences data technologies, highlighting the significant role of governments in their development. The second approach is comprised of an oceanic contribution to the study of ontological politics. The third takes a human-social centered approach, examining the networks of people and practices responsible for creating and maintaining ocean sciences big data infrastructure. The three approaches make possible a comparative reflection on the entangled ethical strands at work in the literature.

■ **KEYWORDS:** big data, data portals, ethics, geospatial data, ocean sciences, ocean governance, techne, technologies

We are in the midst of a reconfiguration of approaches to ocean governance. Existing governance philosophies and practices are being reconfigured through an intimate dance with climate change anxieties, with changing ocean conditions (ocean warming, ocean acidification, sea level rise), and with visions of new capitalist potentialities—wind and wave energy development, deep-sea mining, and polar sea routes that have been but recurring, evanescent, ice-encrusted dreams since the 1800s. Scientific data, data technologies, geospatial visualization technologies, and the people who are responsible for oceanic scientific data infrastructure play a central role in these changing governance practices. The three-way relationship *between* ocean scientific data technologies and data—in all of their iterations ranging from collecting observations and measurements to hardware and software innovations for observing, managing, storing, and sharing information, informatics, and analytical products—*and* ocean sciences *and* governance is open-ended, iterative, and potentially transformational. To make sense of this transformation, I have organized the literature on ocean scientific data techne (the arts of data creation, management, and sharing) and technologies into three broad and distinct categories.

For most of US history, ocean governance has been organized by sectors, where each sector is managed largely in isolation from the others. By the end of World War II, fresh legal efforts had emerged at the national and international levels to coordinate the governance of human activities in the ocean across all use sectors (and where possible, across jurisdictions), culminating, for example, in the 1982 United Nations Convention on the Law of the Sea. Recently, large

marine ecosystems have become the conceptual vehicle around which new forms of planning and management are coalescing. Marine spatial planning has emerged as a keystone practice for realigning governance practices to fit large marine ecosystems. Ocean sciences, and their many data sets, models, and maps, are central to this undertaking. For this review, ocean sciences is a broad umbrella term for a range of distinct disciplinary and interdisciplinary research in which oceans and their human and nonhuman communities serve as objects of study, including geophysical and oceanographic sciences, biological sciences, social sciences, and data sciences (see also Baker et al. 2005). Why take such a broad approach to ocean sciences? Because all of the various informational and knowledge components must, ideally, be made to work as an integrated whole that reflects the ocean as an integrated system, if these sciences are to be useful to the emerging expressions of ocean governance.

Contemporary ocean data scientists create and maintain shared mediums of digital communication and representational practices used by other ocean sciences practitioners and researchers and governing entities, who also maintain their own repertoires of communicative and representational practices. The ocean as a whole system, and large marine ecosystems as smaller albeit not small components of oceans, is vast compared to any specific jurisdiction. The ocean's vastness is mainly understood by Western scientists and policy makers through measuring, monitoring, modeling, and geospatial visualizing technologies. Militaries and governing bureaucracies have long created and used rigorously defined, produced, and theoretically framed data as a way to capture and manage various forms of vastness such as territories and populations (Foucault 2007; Hull 2012; Mitchell 2002; Scott 1998). Therefore, ocean scientific data technologies and *techne* form their own currents in an ever circulating, expanding, and sometimes transformative sea of big data and big data infrastructures.

In this article, I first survey pertinent histories and government documents pertaining to the relationship between ocean sciences (and proto-sciences), ocean governance, and ocean scientific data technologies, with a focus on the United States. This literature examines the development of ocean scientific data technologies through narratives about inventions and scientific change. Science and technology scholars, historians, and practitioners focus on the social contexts and people who have pioneered and refined marine data *techne* and technologies. Pertinent government reports and executive orders, on the other hand, explicitly work to instantiate future directions that progress will take, often including an historical account to provide context. In documenting these refinements and inventions over time, this literature illuminates the keystone role of governments in building marine science data infrastructures.

Next, I examine the critical social science-humanities oceanic turn that focuses on ocean sciences data technologies through the lens of ontological politics, interrogating the relationship between humans and nonhumans, including oceans and their biophysical systems, ocean inhabitants, and human data technologies. These authors contribute to a broader critical examination of ontological politics that treats the co-constructed relations between humans and nonhumans as open-ended processes, and aims to foster transformative ethical reflection on the implications of relationality.

Finally, I examine the plentiful cache of literature about ocean scientific data technologies, infrastructures, and *techne*. Focusing on relational socialities from an explicitly human-centered perspective, social scientists and scientific practitioners investigate the networks of human relationships and representational practices that make data sets, algorithms, and technologies possible. Since late 2013, I have been conducting ethnographic field research among oceans data technologists, and my insights in this review essay are drawn from my field research. All three of these approaches in some way or another focus on the *techne* and technologies of ocean data sciences, albeit from often quite different perspectives and with different emphases.

Taken together, the three categories make possible a comparative reflection on the different ethical strands within the study of ocean sciences big data projects.

Building Evidentiary Oceans

This first category of literature examines the development of ocean data technologies and is written by science and technology scholars, historians, practitioners, policy makers, and legal scholars. Science and technology studies highlight the ways in which empirically observed oceans often challenge human expectations and thwart initial aims, necessitating more data collection and improved data collecting technologies. Histories recount the building of technologies and institutions. Government documents, by contrast, aim to direct and shape progress, even when they include historical accounts. A key feature of the literature here is its documentation of the role of governments in the development of ocean sciences and ocean data technologies, and the resonances between capitalist development and government support. Militaries and their concerns have been at the heart of the development of ocean sciences and data technologies, as have government concerns with lucrative resources, including commercial fisheries stocks, minerals and energy extraction, and shipping and communications corridors. While the aims of different governments may supplant each other, the overall emphasis on developing and deploying ocean sciences data technologies has not waned. US ocean sciences and the development of data technologies have long been intertwined with international efforts (Hamblin 2005).

Early eighteenth- and nineteenth-century European efforts, and later Euro-American efforts to territorialize oceans and develop ocean-centric capitalist enterprises, were intimately related to systematic efforts to map the ocean floor. A vibrant science and technology studies literature highlights the ways in which necessity, government assignments, and capitalist development gave rise to an expanding constellation of technological innovations. As a part of managing their Arctic explorations in the early to mid-1800s, admiralty-sponsored vessels sounded depths, kept logs, and used these metrics to make maps, many of which were found wanting shortly thereafter (Millar 2013). By the 1850s, changed goals and practices for mapping ocean floors emerged, including borrowing and applying terrestrial methodologies (Humboldt's isolines) to improve survey transects, which gave rise to new instruments, including echo sounders, which then reconfigured the object of knowledge by forcing attention to the role of volume, temperature, and salinity in measuring practices (Höhler 2003). The impetus to map the ocean floor was both scientific and commercial, including the desire to lay cables (Millar 2013: 78; Rozwadowski 2001). Philip Steinberg (1999a, 2001, 2011, 2018) argues that discursive representations of the ocean, including maps and mapping projects, evince geopolitical and capitalist economic consequences, and that while the ocean is a geospatial site that challenges territoriality, states repeatedly work to territorialize ocean space. Jacob Hamblin (2005), on the other hand, argues that while states take a territorializing approach to ocean sciences research, many ocean scientists have seen the transnational relationships of a scientific community sharing scientific research interests as more important than nation-state boundaries, leading to tensions between scientists and government funders.

Navies were and remain key contributors to the development of ocean sciences (Kraska 2015), as, to a lesser extent, have been US-government-driven international development, foreign policy, and international cooperation efforts. During and after World War II, the federal government and Navy bolstered ocean sciences development (Hamblin 2005) through the US Office of Naval Research (ONR), founded in 1946, and, after 1950, through the National Science Foundation, which also fostered the early National Sea Grant College Program created in 1966

and assumed an even larger supporting role once the 1970 Mansfield Amendment greatly curtailed Department of Defense research funding (Knauss 2000; see also Conway 2006: 129). The ONR helped found oceanographic research centers at eight universities, and contributed to the Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution, in particular funding marine geophysical research (Hamblin 2005: 24–25, 40–41, 58; Knauss 2000: 3–4), although from the perspective of international cooperation, marine fisheries research was also important (Hamblin 2005: 28). In contrast to Knauss’s institutional recounting of Navy funding as aiming to increase basic science knowledge, Hamblin (2005: 33–42) asserts that while post-war Navy funding did support basic science research, Navy investment was largely part of an overarching defense-oriented strategy.

Navy investment, Knauss argues, led to the “multiship, multi-investigator, multi-institutional programs” (2000: 6) makeup of the ocean research agendas at the ONR, and later the National Science Foundation, allowing for the construction of a dispersed fleet of ocean research vessels and projects, as opposed to creating a centralized (top-down) center of research, and lent to maintaining scientific rigor (3–7; see also Hamblin 2005) by sharing expenses across projects (7–8; see also Toye 2000: 99). This went a long way toward defining “the practice of oceanography” including a shared culture (8). On the flip side, Hamblin (2005: 50–57) highlights the tensions between military secrecy and scientists’ desires for data sharing, as, for example, in Ronald Doel and colleagues’ (2006) account of the creation of comprehensive, physiographic seafloor landform maps by Bruce Heezen and Marie Tharp, at the Lamont Geological Observatory, Columbia University—work that used defense department funds, Bell Labs funds and data, and succeeded despite military security regarding depth data.

After the war, the federal government took more direct interest in controlling domestic territorial seas, which had been largely in the purview of states, passing the Submerged Lands Act in 1953, with energy resources, fisheries, and navigation being central concerns (Quast and Martell 2008: 68–70; Reed 2008: 20–23; Reed 2015: 22–25). In 1959, the Federal Council for Science and Technology created the Interagency Committee on Oceanography, which in turn created a National Oceanographic Program, charged with considering “special problems important in advancing oceanography” (Reeve 2000: 88). The earliest efforts to create ocean sciences data infrastructure include the computerized ocean data repository created when Scripps put computers on its research vessels and linked those back to identical computers at the land-side facilities in the 1960s, the creation of the Geological Data Center in 1970, also at Scripps, and the creation of the National Geophysical Data Center at NOAA in the early 1970s (McNutt 2000: 55–56).

During the 1960s and 1970s, a sea change in US oceans governance occurred when conservation concerns were firmly situated alongside concerns about commercial extraction (fishing, mining, etc.), transportation, communication, and military efforts. Several significant national environmental laws¹ also emphasized linkages between ocean governance, ocean sciences data, and oceanic territorial claims. Arguing for building more national marine science capacity, the Commission on Marine Science, Engineering and Resources report (1969)—the Stratton Commission Report—is generally held to be the most significant document linking ocean sciences and governance from this moment (USCOP 2004: 50–51). Numerous efforts to use space technologies to measure ocean conditions led to a plethora of data and a need to develop data management systems (Conway 2006). Later, the Clinton (1993–2000), Bush (2001–2008), and Obama (2009–2016) presidential administrations expanded national emphasis on linking ocean conservation efforts, ocean sciences, and data technological innovations.

Geospatial data forms a key component of ocean sciences data, and thus ocean-specific geospatial applications dovetail with terrestrial technological applications. The Federal Geographic

Data Committee's historical time line formally situates its origins in Theodore Roosevelt's 1840 Geographic Board, and in Woodrow Wilson's 1919–1942 Board of Surveys and Maps. Once disbanded, the tasks were placed under the Office of Management and Budget in 1953, which continues to direct federal agencies regarding geospatial data through Circular A-16 and its exhibits and amendments (OMB 2002, 2010). In 1983, an OMB memo sought to coordinate cartographic data across agencies. In 1990, the Federal Geographic Data Committee was established, and the Geospatial Clearing House Network was established in 1992 (FGDC 2020). President Clinton supported a wide range of government and private applications and uses of geospatial data (Executive Order 12906) and ocean protection (Executive Order 13158).

The Oceans Act of 2000 (PL 106–526), passed near the end of the Clinton administration, created the US Commission on Ocean Policy to assess federal policies and practices regarding the national oceans. Their report (USCOP 2004), along with the Pew Oceans Commission's (2003) report, argued for the creation of an overarching authoritative federal agency and for making scientific principles the basis of federal marine management policies and practices. The Bush (Executive Order 13366) and Obama (Executive Order 13547) administrations took their direction from the 2004 report. Obama's Interagency Ocean Policy Task Force (2010) report concretized the idea of using coordinated marine spatial planning based on large marine ecosystem principles. Ocean sciences and ocean sciences data infrastructure were central to the ensuing governance efforts, leading to the creation and enhancement of ocean data infrastructure across regions and at the federal level, and is included on the federal open data clearinghouse data.gov (2020). The Trump administration shifted emphasis more fully in the direction of developing economic opportunities in oceans but has maintained a strong emphasis on data (Executive Order 13840). A data technologist pointed out to me that although many corporations (e.g., Google, Esri) have also become key players in the ocean sciences data world, they rely on public data, especially observational data, generated by and served through government agencies and government-funded institutions, such as the Integrated Ocean Observing System, in order to build their corporate data products (e.g., interactive maps) and services.

The literature reviewed here invokes narratives of scientific invention and often progress, whether recounted historically or set out in future-oriented directives. One of the most important contributions of this literature is its documentation of the significant role of the US government's financial, scientific, institutional, and technological involvement in the development of ocean sciences data, data technologies, data infrastructure, and techne.

Immersive Ontological Politics

This section's literature explores ocean data technologies through ontological politics, a theoretical framing that accounts for sociality as a process comprised of any combination of humans, human technologies, nonhuman ocean inhabitants, and, in this case, physical ocean systems (currents, ice floes, etc.), all occupying agential roles. Analyses of ontological politics aim to account for relationality and contingency in co-constructed, human-nonhuman socialities, explicitly drawing attention to the ethical implications of these relational processes. Many of these authors draw attention to contrasts between oceanic contexts and terrestrial contexts, asserting that oceans are more revealing of the workings of ontological politics.

Two general categories of ocean science technologies are considered in this literature: (a) observational technologies, and (b) interpretive technologies that organize and make sense of the scads of observations gathered regarding ocean environments. This second category includes but is not limited to data sets and their organizational structures, computer algorithms,

geospatial visualizing technologies including maps, story mapping (often coupled with digital videos), scorecards, interactive map viewing technologies, and curated portals. Curated data portals have generated their own literature, which I will discuss later, along with the politics of representation. Observational and interpretive technologies are often used seamlessly in conjunction with each other, and making that happen is a significant goal for ocean data technologists, in part because their positioning within various organizations requires them to be results-oriented.

Observational technologies are the cornerstone of ocean sciences (Lehman 2018). Several of the contributions to this approach capitalize on a very fine-grained experiential methodology regarding observational technologies. Charles Goodwin and Stefan Helmreich, who have conducted ethnographic field research aboard expensively outfitted ocean research vessels, emphasize the experiential dimension to human and nonhuman socialities during the processes of data gathering. Goodwin (1995), whose work predates the emphasis on ontology, describes process-based relational knowledge creation practices between people and their machines, many of whom (the people) inhabit very different subject positions as they engage in collaborative research. Helmreich (2007, 2009) foregrounds ontological politics anchored not in sighted observations but in sounds as a way to disrupt our given notions about oceans (see also Höhler 2002). In each of these cases, uncovering communicative interactions and relationality is a central concern for the authors. However, translation as an analytical apparatus comes to be seen as inadequate for this analytical task, because communication itself transforms the communicating parties. Thus, transduction (a mutual change in states of being brought about through interactive communicative relations) emerges as a superior conceptual explanation (Helmreich 2011, 2016; Jue 2014; Kitchin and Dodge 2007).

Melody Jue (2014) focuses on the construction of ocean mapping interfaces, including that found on ATLAS in Silico, an interactive educational project. She is critical of using transduction as an unexamined conceptual apparatus: “It is not only a matter of transduction, but also a matter of erasure of the bodies of microbes, whose genetic materials have been ‘liquefied’ by the process of sequencing, thus artificially creating a new abstract space and place for contemplation and play with information re-embodied in randomly generated ‘shape grammars’” (2014: 254–255). The data displayed as graphic images of microscopic sea creatures on the floor-to-ceiling screens of ATLAS in Silico are meant to be immersive and transformative for the human users. However, Jue emphasizes, for the displayed microbes, the changed state of being (transduction) meant becoming silicon memes of themselves—a point that allows Jue to sustain her argument that data-driven virtual experiences mislead their human participants.

A focus on ontological politics requires an immersive repositioning of the researcher in relation to the object of study—an immersive repositioning meant to challenge our understandings of oceans and ourselves (Helmreich 2011, 2016; Jue 2014; Lehman 2016; Steinberg 2013; Steinberg and Peters 2015). Helmreich (2011, 2016) and Jue (2014) reposition the reader and analyst in the flow of seawater, challenging deeply entrenched cultural notions. Seawater, Helmreich argues, refuses to docilely assume either subject position in the culturally invented culture-nature divide: “Water oscillates between natural and cultural substance, its putative materiality masking the fact that fluidity is a rhetorical effect of how we think about ‘nature’ and ‘culture’ in the first place” (2011: 132). Helmreich then traces that rhetorical fluidity through the changing socially ascribed meanings of seas and seawater as it moves through various domains of anthropological, geographical, and marine research. Resonating with Steinberg’s work, Helmreich argues we should think about *how* the sea is used in different analytical contexts.

Other researchers push for a more profound ontological repositioning. Steinberg (2013) urges geographers to critically engage with oceans from the perspective of the ocean as opposed

to the perspective of the land, to use the discursive framing of Lagrangian fluid mechanics so as to meaningfully engage with volume (see also Steinberg and Peters 2015: 257–260). Philip Steinberg and Kimberley Peters agree that terrestrial environments evince volume, but they point out: “the volume of the sea shifts very differently” and is always in motion, and its liquid “materiality has itself been discursively placed within (and outside) terrestrial ontologies” (2015: 254, 257), including in ways conducive to capitalist expansion. Jessica Lehman (2016) situates the ontological shift in the perspective of ocean systems as planetary-scale objects of governance that actively engender potentialities and risks, challenging our received scientific notions about differences between life and nonlife (for a practitioner case that illustrates Lehman’s point, see Anderson et al. 2019). Jue (2014) turns the immersive approach inside out, interrogating practices of representing data as being metaphorically like oceans. She challenges us to animate seawater—animate in the sense of giving seawater its actual living properties at multiple scales, as opposed to its computer animated (think Google Ocean) properties and their close ties to terrestrial environments, including sedimented layers of maps, lacking volume and lacking liveliness. Data and oceans, she argues, are not metaphorically commensurate, because while oceans team with life, data is dead and static even when reanimated in interactive maps.

Digital geospatial visualization tools, including interactive map viewers, are lynchpin technologies in ocean sciences, seamlessly weaving together practices of observation and interpretation. Geography has produced a rich and nuanced literature critically examining maps, mapping, and mappers. Rather than recapping that well-rehearsed literature, I briefly summarize Rob Kitchin and Martin Dodge (2007), who review the main critiques that geographers have made of maps and mapping, and then suggest a fresh approach anchored in a politics of ontology. Kitchin and Dodge argue that critical interrogations of maps and mapping projects largely fall into two categories, neither of which they completely reject, but which, they assert, do not go far enough. The first category of critique is that maps are ideological representations and embody the ideologies and assumptions of their makers. The second category of critique is that maps are not simply reflections but rather produce their own reality effects. They argue that neither of these critiques challenges commonly held ontological assumptions about maps as fixed, stable objects. Kitchen and Dodge then suggest all maps are social practices, both in their making and in their remaking throughout all of their uses, and as such, no map is ever finished, fixed, or completely stable. Mapping, which is not limited to cartographers in this train of thought, is always a contingent practice, always in process. They further suggest that maps as processes take shape not through translation but rather through transduction processes that creatively reconfigure the system of map, user, uses, and meanings. Interactive mapping tools, which have rapidly spread through the ocean sciences data and ocean governance worlds, perfectly illustrate Kitchin and Dodge’s argument.

Several authors have taken up Kitchin and Dodge’s suggestions to help explain the social effects of instability introduced by fluid ontological states. For example, Philip Steinberg and Berit Kristofferson explore the tensions over official Canadian and Norwegian geopolitical territorial maps representing the scientifically mapped edge of sea ice, which is the basis for claims on the Arctic Ocean. They argue the tension becomes acute because most people concerned with the geopolitical Arctic, excepting the Inuit who have lived there since time immemorial, experience the Arctic only through maps (2017: 630). The authors demonstrate how the behavior of ice in warmer oceans confounds the ontological assumption that maps and ice edges are stable, static, legally authoritative objects, even as ice also confounds scientific measurement. Legal scholars also fully recognize the “ambulatory” (the term used in legal circles) nature of ocean geophysical features (and mobile fisheries stocks) and have used several US laws, courts, and international conventions to address ambulation under various conditions (Reed 2008,

2015). Extrapolating from these points, I suggest that an often expressed desire by policy makers to technologists for both descriptive and predictive products can be seen as another effort to ontologically stabilize the conditions under which regulators and policy makers must govern.

Interactive maps have also become an analytical focal point. Interactive maps allow users to turn off and on map layers generated from data sets, to use scalability (zoom) functions, and to show temporal change through animation. Noëlle Boucquey et al. (2019: 491–493) observe that using interactive marine maps in one US regional public marine spatial planning process had political consequences. They argue that interactive marine map practices can (a) temporally collapse distinct events, and (b) (a point echoed by Jue 2014) flatten the scaler effect of ocean depth, pushing separate layers of activities together. Tracing the way oceans are animated through several interactive mapping platforms, Jue (2014) concludes that the human, user-centered aspect of digital ocean mapping systems misleads, because the immersed user dominates the system as vastly different scales are made commensurate, unlike immersion in the physical ocean. Scaling techniques, Jue argues, obviate the possibility of critiquing the way in which humans actually live in our largely ocean world.

These social sciences / humanities scholars reveal the political ethical regimes at work in the technologies and their applications by illuminating the extant terrestrial ontological reasoning about the ocean, which is embedded in the oceanic observational and mapping technologies. Their efforts are particularly ambitious given that they are working in cultural settings in which terrestrially grounded ontological reasoning is hegemonic and aligns with the interests of dominant subject positions.

Oceanic Networking

The largest body of social science literature addressing ocean sciences data techne and technologies investigates the human-social networks that create, maintain, enhance, and occasionally abandon ocean sciences data technology projects. Social-human networks are integral to the creation and operation of data-sharing projects (Baker et al. 2005; Conway 2006; Lehman 2016; Longley-Wood 2016; Millerand et al. 2012; Strain et al. 2006: 438–439; Sullivan 2019). Big data studies often overlook the significant role of the human networks in big data projects, a role that Neal Stephenson (1995) effectively illustrates in his science-fiction novel *The Diamond Age*. Three general approaches can be found in this category of literature: (a) texts emphasizing human sociality and the social relations of the human networks responsible for creating and maintaining data networks, (b) texts emphasizing practices and politics of representation, and (c) texts addressing applied technical issues, which I only briefly address in the course of covering the first two.

Fluctuating networks of people create data networks that reach beyond technical and scientific work teams to include data providers, data users such as governing agents and their constituencies, and data systems financial supporters, which, as I suggested earlier, are very often government entities. Knowledge about the ocean, technological platforms, and techne is shared and reconfigured; challenges are considered; ideas are floated through conferences, publications, conversations, social/intellectual get-togethers, blogs, gray literature, and memory devices, which leave what Geoffrey Bowker (2005) describes as memory traces. Echoing authors in the previous section, Karen Baker and Geoffrey Bowker (2007) urge starting one's analysis from the position that these e-science and cyber-infrastructures are fundamentally ongoing processes (see also Baker et al. 2005; Boucquey et al. 2016). Social hierarchies can be reconfigured through collaborative undertakings within work teams as they develop new techne and

technologies (Baker and Bowker 2007; Lehman 2018; Millerand et al. 2012). New constellations of relationships between data producers and a whole range of ever-proliferating data managers and users have emerged (Boucquey et al. 2016: 6–9; Conway 2006: 150; Lehman 2016). Ontological approaches and human-social-centered approaches build on a plethora of social science and humanities efforts to foreground and incorporate contingency, messy excesses, and fluidity as key aspects of all human socialities.

In recent years, ocean sciences data technologists have spent considerable effort in finding ways to make ocean sciences data discoverable, accessible, available, and useable. Along with visualizing technologies, curated data portals have emerged as key and growing pieces of infrastructure linking scientific findings to governance practices. Thus, a substantial literature concerning ocean data portals by practitioners and by social scientists is accumulating.

All data portals are constructed, curated, and maintained for specific purposes. Data portals are curated virtual sites for accessing ocean sciences data, data products (maps), and data tools, and are some of the most important communicative practices in ocean sciences and governance. Data portals can house actual data (fisheries data sets, temperature data sets, acidification data sets), as well as links to other data sets, data portals, data products, and services housed elsewhere, by using metadata records and URLs to make data discoverable and available. Some data portals are exclusively dedicated to oceans, such as those associated with the federal/state/tribal regional ocean marine spatial planning and coordinating efforts, the Integrated Ocean Observing System, and the Ocean Biodiversity Information System, now a project of UNESCO's International Oceanographic Data and Information Exchange (IODE). Other data portals include some or another crucial oceanic topic under an umbrella covering ocean and terrestrial scientific environmental data, for example, the Long-Term Ecological Research Network (LTER), a repository designed to track specific ecosystems through time, including the southern portion of the California Current Large Marine Ecosystem. The LTER has been extensively studied by a collection of science and technology scholars, and represents one of the most documented cases of the development of a portal designed for ecological-environmental purposes. Ocean data portal catalogs can be roughly situated in a long line of oceanic archiving efforts that started with handwritten logs aboard ships. Neither archives (Daston 2012) nor data portals—a recent if exponentially changed iteration of an archive (Waterton 2010)—are unique to ocean sciences, but ocean governance and ocean science research have both contributed to and benefitted from data portal technologies found elsewhere.

Some of the key concerns addressed in the literature are establishing standards, geospatial semantics, machine languages, metadata (data about data), and interoperability (Fugazza et al. 2016; Wright, Cummins et al. 2011); curation processes and information management (Boucquey et al. 2016: 6–9; Karasti and Baker 2008; Karasti et al. 2006); improving functionality and innovating ways to discover disciplinary data and to bring data from different scientific disciplines and geographic locations into conversation (Baker and Chandler 2008; Baker et al. 2000; Signell et al. 2016; Strain et al. 2006; Weisberg et al. 2000; Zimmer et al. 2014); and resolving social-technical issues arising from efforts to create long-term, geographically dispersed data infrastructures for environmental sciences (Baker and Bowker 2007; Baker et al. 2005; Ribes and Finholt 2009). Keeping the available scientific data and databases relevant is a task left to data providers (scientists) and their institutions, although Baker and Bowker (2007) and Florence Millerand et al. (2012) examine how scientists and data scientists must work together in order for the LTER portal system to function over the long term.

While data technologists are concerned that data infrastructure systems function, critical social scientists and humanities scholars are more interested in the socialities of these systems. One important observation concerns how the development and deployment of new kinds of

ocean science data technologies reshape human socialities by creating particular kinds of collaborative cultures (Conway 2006; Knauss 2000: 7–8), opening new avenues for reconfiguring human social hierarchies (Conway 2006; Lehman 2018), and reconfiguring our conceptualizations of oceans (Höhler 2002; Jue 2014; Lehman 2016).

One analytical tack turns an ethnographic eye on how ocean scientists work together and communicate in interdisciplinary collaborative environments (Almklov 2008; Baker et al. 2005; Bowker 2000; De Bont 2009; Decker 2018; Edwards et al. 2011; Goodwin 1995; Helmreich 2007, 2009; Sullivan 2019; Turan 2003). Millerand et al. (2012), discussing the LTER, suggest that a data infrastructural system entails an invisible hierarchy of social status and control, and negotiation between levels (see also Boucquey et al. 2016: 6–9). In another vein of research, social science scholars interrogate how databases, languages, categories, maps, and algorithms encode and reproduce existing social relations, especially relations of hierarchy and power (Boucquey et al. 2016; Mackenzie 2015; Waterton 2010), and are cultural products with social histories and are embedded in social contexts (Andrejevic et al. 2015; Fairbanks et al. 2019: 128–130; Striplas 2015; Zimmerman 2008). Data technologies can help maintain and reinforce existing political economies (Gehl 2015; Leszczynski 2012). Big data projects are important research sites (for geography, see Ash et al. 2018; Steinberg 1999b; for anthropology, see Boellstorff and Maurer 2015). Other scholars examine the legal implications of portals, in particular their role in governing, and as such, how data portals are to be held accountable (Baker 2013), and how code and other digital technologies act as regulators in lieu of or in tandem with actual government regulators (Lessig 2006; Leszczynski 2012).

Ocean data portals span a range of geospatial configurations, and that too has generated literature about knowledge-sharing practices that challenge and are challenged by geopolitical territorial boundaries, even as the products themselves remain anchored in geopolitical territories. For example, the collection of digital coastal atlases collected under the auspices of the International Coastal Atlas Network (O’Dea et al. 2007), now part of the IODE (Glover et al. 2010), emerged out of “human connections” between researchers at Oregon State (a program originally fostered by the ONR), the Oregon Coastal Atlas (2020; Haddad et al. 2011), and the people behind the Marine Irish Digital Atlas (2020). In its turn, the IODE is emerging as one of a handful of significant globe-spanning ocean sciences data networks fostering transnational ocean sciences data sharing, and is exemplar of how ocean sciences data sharing practices complicate notions of geopolitically defined territoriality (for a similar observation regarding the Global Ocean Observing System, see Lehman 2016), even as data repositories and products, such as the coastal atlases, are built around more traditional notions of geopolitical territoriality. Kate Longley-Wood (2016: 5) points out that having portals at various scales (national, regional, and state-based) resonates with the concept of nested scales intrinsic to scientific ecosystem-based management principles.

The literature discussed thus far concerns the building of human-social networks. However, another concern is with the politics of representation, a politics mediated through narrative. Paul Dourish and Edgar Cruz underscore the critical role that narrative plays in making data into data: “the two are deeply mutually intertwined,” not least because narrative lends structure and sequencing to data, and “the stories that arise in these settings do not rely solely on the data. Elements of these stories are pre-figured . . . stories operate in terms that we recognize and that are culturally available to us” (2018: 2, 5, 7; see also Millerand et al. 2012). Boucquey et al. (2019) point out that metadata records, and not just finished story products, also act as influential narratives.

Three of the US regional ocean data portals, formed in order to support regional marine spatial planning exercises under the Obama administration, have catalogues that are curated

around a large marine ecosystem, and have generated geospatial data products, including geospatial map layers, story maps, and video narratives aiming to showcase their geospatial data catalogues and training materials. These portals aim to help governing bodies and their constituencies with their shared work (see Boucquey et al. 2019; Hallenbeck et al. 2015, 2016; Longley-Wood 2016; MidA RPB 2016: 17; Sullivan 2019). Recognizing that various genres of data products can support each other, technologists point to the necessity of building the search tools and products in collaboration with scientists and managers, and across disciplines, beginning in the initial planning stages so that communication and functionality run smoothly (Longley-Wood 2016: 7–9; Weisberg et al. 2000: 55, 57–58). Boucquey et al. (2016) observe that tensions engendered in the social sites where oceans are inscribed through data practices are intrinsically part of their ontological political makeup.

Indicator tools, known also as scorecards and report cards, are another form of narrative product growing in importance for ocean governance. Indicator tools use ocean sciences data sets to generate metric snapshots about specific ocean conditions, for example, ocean health, ocean acidification, or beach conditions. Indicators can be descriptive or evaluative in condensing and then re-presenting complex constellations of data sets. While several ocean indicators are already available,² including those produced by government agencies and NGOs, marine indicator tools have yet to receive analytical attention in the social science literature. However, a small critical anthropological literature has emerged regarding systems of indicators used as evaluative tools tied to other forms of evidence-based governing. One vein of critique concerns how indicators and indexes create their knowledge effects—that is, the ways in which the measurements, algorithms, categories, theoretical framings, political decisions, and underpinning assumptions that are used to create an indicator are made opaque once the indicator is produced (Merry 2011). Sally Engle Merry (2011: S84) asserts: “Indicators, particularly those that rely on ranks or numbers, convey an aura of objective truth and facilitate comparisons,” which obviates all the embedded decisions and relationships (see also Gray 2018: 268). Indicators are also criticized for the ways in which they extend the control of technical experts and audit cultures, and can discourage political discussion and reasoned debate (Conley 2011; Merry 2011; Turnhout et al. 2014).

Baker and Bowker point out that much of what is assembled in environmental data portals is actually of less interest to scientists: “It is third party [*sic*] users—planners, development agencies, policymakers, modelers working in other arenas like climate change—who are the beneficiaries of interoperability” (2007: 133). Managers and policy makers express desires for ocean sciences data findings to be processed into representations that make immediate sense of complex situations. Thus, oceans policy makers increasingly seek indicator tools, especially those that rank or evaluate the conditions assessed. For civil servants running participatory planning exercises, maps and scientific data play central roles. As such, the use of interactive mapping platforms has become common on oceans planning exercises (see discussions in Boucquey et al. 2016, 2019; Cravens 2016; Fairbanks et al. 2019). Noella Gray (2018), looking at emerging high seas conservation areas as human social coproduced territorial formations, highlights the hierarchical relations among human coproducers in which science acts as cultural capital, a situation, she suggests, that might be ameliorated by including technology sharing requirements. Boucquey et al. (2019), who engaged in multiyear ethnographic research with two east coast regional marine spatial planning efforts, argue (following Callon) that the portals themselves are agential in the planning processes.

In taking a human-social-centered approach, the literature here highlights the often deeply entrenched hierarchies in human socialities, and the power relations operating among and

between different groups of people. The authors examine the human social practices that develop as the technologies are developed, and the human and technical challenges that arise when big data is used to address ocean systems that span multiple jurisdictions and large regions. These challenges include questions of establishing shared data standards so that data sets can be compared and combined, interoperability and metadata standards so that data can be shared, and creating representations of data for nonexperts, especially policy makers and their constituencies. This literature is especially useful for its insights into the techne, as the arts of data creation, management, and sharing are re-crafted and reimagined through knowledge-sharing practices.

Concluding Reflections

Juxtaposed, the three overarching approaches illuminate ocean science data techne, technologies, infrastructures, human networks, and social relations from three distinct intellectual orientations, those of history, ontological politics, and human-social-centered sociality. Although these are largely distinct categories of literature, several authors bring some aspects of the different approaches into fruitful conversation in a kind of analytical experimentation that is a feature of contemporary knowledge-sharing practices, even as specific texts and arguments align most closely with one or another of the three general approaches discussed. That human social groups shape and are shaped by their technologies is not a novel idea. Albeit from quite different analytical perspectives, all three general approaches take into account that human practices and sociality both shape and are shaped by technological endeavors. Each general category of literature also suggests an ethical stance or orientation toward the social-technological-ocean relationships found in big data projects.

Using narratives about scientific invention, the first body of literature describes the foundations and growth of an evidence-based system of ocean governance built on scientific research and data technologies, largely supported by government funding. Some of these narratives invoke intertwined notions of nation-building and progress, including economic and especially scientific progress. Others instead critically examine the territorial expansion of states and/or capitalist enterprises into oceans, or the tensions between nation-building efforts and efforts to build transnational scientific communities. Over time, the US federal government has made tax-funded ocean sciences data increasingly open and available, a governing practice that reached a zenith under the Obama administration, in the context of both innovative digital infrastructural development, and increased pressure for participatory forms of governance. This body of literature documents the government's pivotal role in the development of ocean sciences data and infrastructure. This approach lends itself to the ethical argument that technologies are tools, and tools and the hands that wield those tools are distinct and separate. In this line of ethical reasoning, the moral being to whom the hands belong exercises intention, purpose, and ethical choice, not the tools. In this line of reasoning, tools are not agential; hands are.

The authors using a framework of ontological politics foreground relationality, contingency, and process, in their efforts to open spaces for ethical reflection on scientific knowledge and governance practices. This group of authors challenges the notion that the tool, the hands that wield the tools, and the object of study or application are separate and distinct from each other. Rather, in this line of reasoning, tools, hands, and objects of study are relationally co-constructed. This literature is successful at critically illuminating the socially constructed nature of the deeply entrenched culture-nature divide, and the unexamined terrestrially grounded ontologi-

cal assumptions deployed in ocean sciences data and technologies. However, and while suggesting alternative ontological positioning, the many registers in which human social hierarchies and social relations of power operate are often pushed to the background. Goodwin, at the scale of the collaborative team, and Steinberg, at the scale of global geopolitical relations, are exceptions in which social hierarchy is foregrounded. As a cluster, these authors push us, as Dimitrios Papadopoulos (2011) so aptly puts it, to creatively imagine alternatives to the rigid binary between technocratic governance and pluralism.

The third more human-social-centered approach focuses primarily on human sociality, and human social relationships and their specific *modus operandi* in the context of scientific big data technologies, highlighting extant social hierarchies and inequalities, as well as potential challenges to these entrenched hierarchies. As a body, this literature provides perhaps the deepest insight into ocean data techne, because it closely follows the knowledge creation and knowledge-sharing practices of people engaged in building, sustaining, and refining ocean data infrastructure.

While each body of literature opens a window onto an important aspect of ocean sciences big data technology and infrastructure, when taken together these three bodies of literature offer a more nuanced picture of the entanglements of ocean sciences big data technologies, infrastructures, social networks, oceans, and governance practices. The role of US government support in gathering data and building data infrastructure, the role of nonhuman systems in human endeavors to govern oceans, and the role of human sociality in conceiving of knowledge projects and then acting on that knowledge are all intertwined. Each approach strikes different ethical chords with which to reflect upon some of our emerging, most pressing, multi-scalar challenges. We currently face regional and planetary changes that will bring problems with enduring material consequences, and that suggest we should be asking: How should oceans be governed and for whom amid increasingly fluid, unpredictable planetary systems? What are the implications of the imbricated relationship between science and governing? What are our responsibilities to a planet that some groups of people have exploited to the hilt, and to the people who have benefited least from that exploitation, even as they have also borne the brunt of the costs?

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NOTES

1. Oceanic examples include the 1972 Marine Protection, Research, and Sanctuaries Act (later the National Marine Sanctuaries Act 1992), the 1972 Coastal Zone Management Act, the 1972 Marine Mammal Protection Act, and the 1976 Magnuson-Stevens Fishery Conservation and Management Act.
2. Two examples are the Beach Report Card (2020), which is part of Heal the Bay's work, and the Ocean Health Index (2020). Thanks to Marisa Nixon and Tanya Haddad for pointing me to an impressive collection of online ocean indicator tools.

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