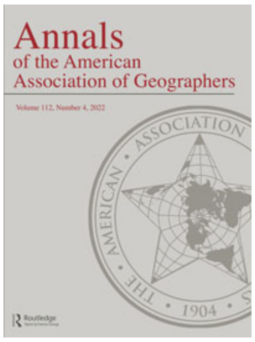

Annals of the American Association of Geographers

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/raag21

New Data Technologies and the Politics of Scale in Environmental Management: Tracking Atlantic Bluefin Tuna

Elizabeth Havice, Lisa Campbell & Andre Boustany

To cite this article: Elizabeth Havice, Lisa Campbell & Andre Boustany (2022): New Data Technologies and the Politics of Scale in Environmental Management: Tracking Atlantic Bluefin Tuna, Annals of the American Association of Geographers, DOI: 10.1080/24694452.2022.2054766

To link to this article: https://doi.org/10.1080/24694452.2022.2054766

Published online: 07 Jun 2022.

New Data Technologies and the Politics of Scale in Environmental Management: Tracking Atlantic Bluefin Tuna

Elizabeth Havice,* Lisa Campbell,† and Andre Boustany‡

*Department of Geography, University of North Carolina–Chapel Hill, USA
†Marine Affairs and Policy, Nicholas School of Environment, Duke University, USA
‡Monterey Bay Aquarium, USA, and Nicholas School of Environment, Duke University, USA

Knowledge and scientific practice have largely been backdrops to examinations of scale and rescaling processes, including studies of rescaling environmental management. The growing use of new data technologies in environmental management highlights the need to situate knowledge and scientific practice into the politics and production of scale. Reviewing sixty years of debate over spatial management of the highly migratory and Atlantic bluefin tuna, this piece illustrates the central, dynamic roles of knowledge and scientific practice in scalar transboundary management. Findings corroborate prior studies demonstrating that stakeholders mobilize knowledge (and uncertainty) to influence spatialized management. We examine whether such practices are transformed by new data technologies, a nomenclature we adopt as "more" than big data to encapsulate and parse methods of data collection or generation, the data themselves, and the analytical techniques and infrastructures developed to make sense of data for management purposes. We find that as new data technologies reveal objects in space and time, they reformulate and multiply—rather than resolve and circumscribe—scalar management possibilities. They mix with historic scientific and political practices and are never "complete." Beyond the bluefin case, findings point to the complications of turning to new data technologies—often uncritically celebrated for their potential to give clear, actionable data—to "solve" scalar dilemmas. Instead, they are positioned to become a new way of knowing the world: a new geo-epistemology that shapes experimentation and debate around the spatialized power relations determining control over contested spaces and the valuable resources within and moving through them. *Key Words: Atlantic bluefin tuna, environmental management, new data technologies, satellite telemetry, scale.*

Knowledge and scientific practice have largely been backdrops to examinations of scale and rescaling processes in geographic scholarship, including in studies of rescaling environmental management. The emergence of new data technologies, the seemingly complete portrait of "the real" they paint, and their growing use in environmental management highlight the need to reflectively situate knowledge and scientific practices into the politics and production of scale. In this article, we intentionally develop the term *new data technologies* rather than *big data*: The former encapsulates and parses methods of data collection and generation, the data themselves, and the platforms, analytical techniques, and infrastructures developed to make sense of them for management purposes. New data generated from remote sensing, satellite telemetry, environmental sensor and observation networks, among others, and interpreted with advanced computing capacity and modeling techniques are enhancing understanding of spatiotemporal environmental dynamics important for management.

The growing literature relating new data technologies to environmental concerns often presupposes that more comprehensive and higher resolution spatiotemporal data will reduce uncertainty and lead to "better" management (see, e.g., Runting et al. 2020). It is now well understood that science–policy relations, including those surrounding new data technologies (Gabrys 2016), are not technical, apolitical, and linear but coproduced (Goldman, Nadasdy, and Turner 2011). Yet this ideal of science influencing policy retains its hold on environmental management regimes and is intensified by the misconception that new technologies, particularly big data, can capture a domain, provide full resolution, and be interpreted by anyone who can understand a statistic

Annals of the American Association of Geographers, 0(0) 2022, pp. 1–21
Initial submission, May 2020; revised submissions, January and November 2021; final acceptance, January 2022
Published by Taylor & Francis, LLC.

or visualization (Kitchin 2014). Data in this view present "the real" and "speak for themselves."

Social science research on the role of new data technologies in environmental management is in its infancy, although interest is growing because new data hold potential to destabilize management regimes, alter the political economy of resource management, and raise new ethical concerns in environmental governance (Bakker and Ritts 2018). A 2020 special issue of *Environment and Planning E* attends to how new data technologies shape human–environment relations, including resource extraction, governance practices, the built environment, and legality in environmental management (see Nost and Goldstein [2022]). Such studies illustrate that states mediate transboundary disputes and control over resources and space in part through the use of the new technologies' knowledge and knowledge products (Goldstein 2020). They also show how new data technologies, as mechanisms, reproduce uneven power dynamics among states (Lehman 2016). New knowledge and new ways of collecting and analyzing data are affecting science management agendas and, in turn, reconfiguring socioecological relations (Drakopulos 2020).

Some work in this field explores how management bodies rely on data and data products to define politically acceptable spatial management possibilities, finding that, as they do this work, they also format and bring into being other objects such as environment and community (Boucquey et al. 2016; Fairbanks et al. 2019; Campbell et al. 2021). To date, however, there has been limited research on the relationship between new data technologies and the politics and production of scale in environmental management.[1] Here, we further link geographers' interests in knowledge, scale, and environmental management by exploring precisely that relationship and by asking this: How do new data technologies differ from earlier knowledges and scientific practices used in producing scale? What are their implications for the power relations determining control over and access to valuable resources and spaces?

We turn to the oceans, where fluid and mobile natures, and the difficulty of studying them, have long shaped management debate, including scalar debate (Campbell et al. 2016). Mobilities of all sorts (animals, vessels, currents) present challenges related to scale in oceans management because marine species and economic activities are hard to track over time and space and rarely abide jurisdictional boundaries (Peters and Squire 2019). These mobilities—and knowledges (or lack thereof) about them—shape the politics, scales, and politics of scale of managing and claiming oceanic spaces and resources.

As new data technologies expand knowledge of complex ocean systems and human impacts on them, there is a sense of urgency to "act" on their data for improved oceans management (Visbeck 2018). This often entails (re)defining "appropriate" scales of management that circumscribe the spaces and agents best situated to generate improvements (Havice, Campbell, and Braun 2018). In what follows, we examine international efforts to manage the highly migratory Atlantic bluefin tuna (ABT) over six decades, as data and analyses of the animal have become increasingly sophisticated. By situating new data technologies within the historical trajectory of the relationship between knowledge and scalar management practices, we have found that scientific knowledge is now a tool that stakeholders mobilize to achieve management goals and a site where scalar possibilities are created and negotiated. We argue that as new data technologies make the geographic knowledge underwriting environmental management more accurate, they also transform how control over resources and space is determined.

From here, we first ground our analysis conceptually through reviewing and bridging the fields of critical data studies and the politics and production of scale in environmental management. We then introduce our research methods and the ABT case study. Our analysis focuses on the evolving relationship between knowledge about ABT and the politics and production of scale in ABT management over three time periods, each associated with distinct knowledge and scientific advances. We conclude by reflecting on the significance of these findings for ABT management and for geographic understandings of how new data technologies stand to inform, shift, mediate and perhaps arbitrate the politics and production of scalar debate in environmental management.

New Data Technologies and the Politics and Production of Scale in Environmental Management

New data technologies can destabilize reality and simultaneously provide representations of the material world that suggest that the world can be known, mastered, changed, and controlled. They stake out new terrains and objects, methods of knowing, and definitions of life (boyd and Crawford 2012). They integrate multiple data sources (e.g., biophysical data and data about human activity) to provide models of environments in flux, as opposed to frozen points in time and space (Kitchin 2014). New techniques to analyze and digest data make it "actionable," or comprehensible for management. The results—large data sets, visualizations, model outputs, and the like—make "the environment" visible and reinvigorate long-challenged assumptions that science gives an impartial *view from nowhere* (Haraway 1988). This is particularly true in the oceans, where new visualizations transform a vast, blank space into one of biophysical complexity and ecological potential (Bax et al. 2016), human impact (Halpern et al. 2008), or extractive activity (Kroodsma et al. 2018), as seen from above and often at global or regional scales. As new data technologies reveal these processes, they create a need for different management tools or forms and spatialities of political action that more accurately reflect changing understandings of oceans and ocean resources (Havice, Campbell, and Braun 2018).

As state and nonstate environmental management bodies explore how to use new data technologies in projects such as real-time regulation, dynamic ecosystem-based management, and predictive management (Maxwell et al. 2015; Dunn et al. 2016; Bakker and Ritts 2018), they are often experimenting with and making decisions about scale in environmental management, particularly around vexing scalar mismatches. Lee (1993) concisely described mismatches and their ensuing problems: "When human responsibility does not match the spatial, temporal, or functional scale of natural phenomena, unstable use of resources is likely, and it will persist until the mismatch of scales is cured" (561; see also Cohen and Bakker 2014; Cohen and McCarthy 2015). "Curing" scalar mismatches implies identifying the right scales of action, which involves detailing evidence of the spatial extent of socioecological processes and negotiating these with bounded political jurisdictions dedicated to managing defined environmental concerns.

Yet, in practice, curing mismatches is constrained by uncertainty in both ecological sciences and the politics through which spatial objects are delineated and claimed (Swyngedouw 2004b). As a result, circumscribing species or ecosystems with actionable boundaries and accordingly rescaling management are contested efforts, even though rescaling often aims to depoliticize management by abiding with "natural" scales (Cohen and Bakker 2014). Furthermore, although resulting boundaries are coproduced outcomes of politics and science, once in place, they are often intractable (Reed and Bruyneel 2010). As suggested in a study of the Baltic Sea transboundary environmental management, "The spatiality of a particular environmental concern is neither a given nor simply a product of environmental-scientific methodology" (Larsen 2008). Rather, following (Swyngedouw 2004a), Larsen suggested that the creation of spatial management objects should be seen as a provisional outcome of the politics and production of scale.

Examinations of such mismatches build from rich geographic theorizing that positions the politics and production of scale as a dynamic process through which power relations become spatialized (for an oceans context, see Mansfield 2001). Through this lens, scale is produced via assemblages of sociospatial practice (Cox 1998), and scalar configurations reflect temporary standoffs in ongoing power struggles (Swyngedouw 1997a, 1997b). Human geographers have examined the social and cultural actors and processes enrolled in these temporary scalar practices, including globalization, the state, labor organization, and social reproduction (Marston 2000; Sayre 2015). Likewise, geographic subfields focused on environmental management have examined how scale is mobilized to define environmental problems and solutions and in struggles over resource control, especially states' efforts to transform management scales to strengthen authority over space and resources (Boyle 2002; Gruby and Campbell 2013; Neumann 2015). These subfields are attentive to how biophysical processes (e.g., the movement of highly migratory species) shape the politics and production of scale (Zimmerer 2000; Turner 2006; Valdivia, Himley, and Havice 2021).

Of keen interest is the question of *how* processes are rescaled. Sayre (2015) and others have pointed to the role knowledge plays in spatialized power relations and the politics and production of scale (see, e.g., Swyngedouw 2004b; Turner 2006; Cohen and Bakker 2014; Cohen and McCarthy 2015; Havice, Campbell, and Braun 2018). However, while work in political ecology has been attentive to the role of knowledge and metrics in rendering resources legible for management (Lave 2012; Robertson and Wainwright 2013), in studies of scale and rescaling, knowledge and scientific practice have largely remained as backdrops. When they are examined in relation to the politics and production of scale, they are often considered important because interest groups mobilize them to influence or define how power becomes spatialized. Geographic literature on marine resources and spaces offers openings for examining these links. For instance, in a seminal article on knowledge in New England fisheries management, St. Martin (2001) illustrated that sharp differences between government-led bioeconomic modeling and fishers' knowledge of fishing practices and marine environments yield distinct conceptions of the scale of problems and solutions. Likewise, Mansfield and Haas (2006) explored the intersection of knowledge and scale in endangered Stellar sea lion management, finding that stakeholder groups shift the scale at which problems are framed as a strategy to cope with scientific uncertainty about the population's decline. Both studies suggest that stakeholders employ scientific knowledges (or the lack thereof) in ways that presuppose the "right" scales of management and foreclose alternatives.

The growing use of new data technologies increases the need to reflectively situate knowledge and knowledge practices into the politics and production of scale. Rankin (2016) suggested that the changing, spatialized logic of new data technologies represents a shift in "geo-epistemology," or a way of knowing Earth that can reinforce, challenge, and reinvent existing spatialities of management and the power relations therein. Enhanced accuracy in renderings of "the environment" can decouple and offer openings for reformulating links between geographic legibility and political authority. Geographers with an interest in scale might conceive such changes as ushering in spatial shifts in geometries of power (Massey 1994) from a world of codified political boundaries to a world of actionable geographic knowledge that spans and transcends those boundaries.

New knowledge practices that have emerged with the data revolution are transforming practices of observing and representing the environment. In the process, they raise the possibility of altering interactions around which scale is debated and enacted, including in environmental management. Sayre (2005; following Rykiel 1998) argued that observations of size, space, and time become scales when they are divided into segments that can be used for measurement and political action. This holds for the arena of environmental management, as well. Campbell and Godfrey (2010) demonstrated as much in a study of how genetics has advanced understanding of highly migratory sea turtle populations. Their analysis showed that although distinct knowledges about sea turtles (haplotype, individual turtle, nesting population, regional population) can each be ecologically meaningful, selecting which scale to act on in management decisions (i.e., where, when, and how they should be managed, and by which states) reflects not only scientific "accuracy" but also politics and values. How might new data technologies that "better" reveal the spatiotemporal properties of the environment resolve, stabilize, or otherwise shape the politics of scale in environmental management bodies? How are environmental management's links to spatialized power relations of concern to geographic theorizing on scale?

This article focuses on the evolution of scientific knowledge about ABT movements and how that evolution has influenced the management of the highly migratory species over the past sixty years. In our case, the new data technology includes satellites for remote sensing; electronic tags; software, programming, and additional data sources (oceanographic and ecological) that scientists combine and analyze to track individual animals in time and space; visualizations of those tracks; population dynamics models that include the tracks alongside other data sources (e.g., advancements in genetics and otolith microchemistry for assigning stock of origin); and the associated computing power to handle large data sets and run associated models. Collectively, scientists develop these technologies to generate management advice. As new tools have brought ABT migrations into clearer view, results have garnered attention in management circles. This is in part because they delineate seemingly clear, actionable data about spatiotemporal attributes of animals, which purportedly can "resolve" scalar mismatches (and uncertainty about them) between the animal movements and spatial jurisdictions of management. Accompanying visualizations are often taken to be instantly understandable by scientists, policymakers, and advocacy groups (for examples, see the visuals later in this article). Several studies have highlighted instances in which tracking data

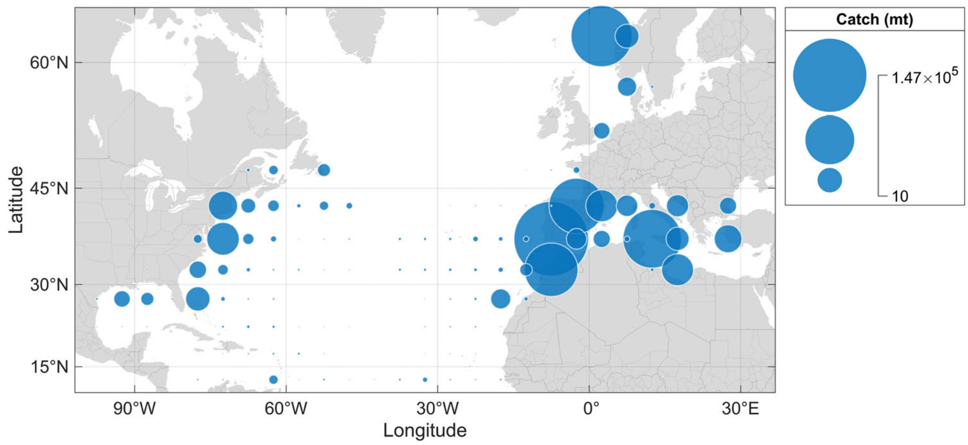

Figure 1. Total Atlantic bluefin tuna catch by volume (metric tons) located in 5° cells, 1950–2017. *Source:* Authors.

have been used in oceans management, including to inform scales and rescaling for highly migratory species (e.g., Jeffers and Godley 2016; Havice, Campbell, and Braun 2018; Hays et al. 2019). Few, however, have examined the relationship between evolving scientific knowledge and the politics and production of scale in environmental management, specifically. We turn to this now, where, in the case study of ABT, scientific efforts to know, place, and predict tuna in time and space are entangled with multistate political debate over management scales that determine how many tuna will be caught, where, and by whom.

Atlantic Bluefin Tuna and Fisheries

Atlantic bluefin tuna are an iconic, highly migratory species. ABT grow up to 10 feet in length and 1,500 pounds in weight, and they live as long as thirty-five years. Humans have hunted them for consumption and sale for thousands of years, but the modern era's capital-intensive fishing methods have depleted their populations (Longo and Clark 2012). In recent decades, ABT have gained international attention for the prices they capture at auction, their role in globalizing Japanese cuisine (Bestor 2000), and because of the stark challenges of achieving economic and conservation goals via the multilateral cooperation required to manage them. ABT move through national waters of multiple countries and the high seas with seasonal and other temporal patterns, resulting in typical scalar challenges of managing transboundary fisheries (see, e.g., Aqorau, Bell, and Kittinger 2018; Pinsky et al. 2018). The scalar mismatch in ABT management results from a distinction between (1) the spatial extent of fisheries and their management and (2) the spatial extent of bluefin stock(s) themselves. We review these two mismatched scalar objects.

Two distinct fisheries target ABT, concentrated on either side of the Atlantic (Figure 1). The Eastern fishery, located in the Eastern Atlantic and Mediterranean Sea, has existed for more than 4,000 years. In recent years, thirty-three countries' fleets have been active in the fishery, mostly coastal states and three distant-water fleets (Japan, Taiwan, and South Korea[2]). The Western fishery theoretically includes coastal states of North, South, and Central America and the Caribbean, but since the 1980s it has been dominated by the United States, Canada, and the Japanese distant-water fleet. The Eastern fishery is much larger in volume. Since the 1970s, Eastern catches have ranged from lows of roughly 12,900 metric tons per year to a high of more than 50,000 metric tons. In contrast, landings in the Western fishery peaked at nearly 20,000 metric tons in the 1960s. During the 1970s, landings averaged about 5,000 metric tons and have since declined to less than 3,000 metric tons (Sissenwine et al. 1998; Standing Committee on Research and Statistics [SCRS] 2017). The differences in the fisheries and their management are analyzed in what follows, but the points here are that they are of different sizes (in terms of both landings and number of countries participating) and spatially distinct. Only the Japanese fleet participates appreciably in both fisheries.[3]

Whereas ABT fisheries are spatially distinct, the definition of the *stock* and its spatial extent has been subject to much debate. There are two main ABT spawning areas, a larger one in the Mediterranean

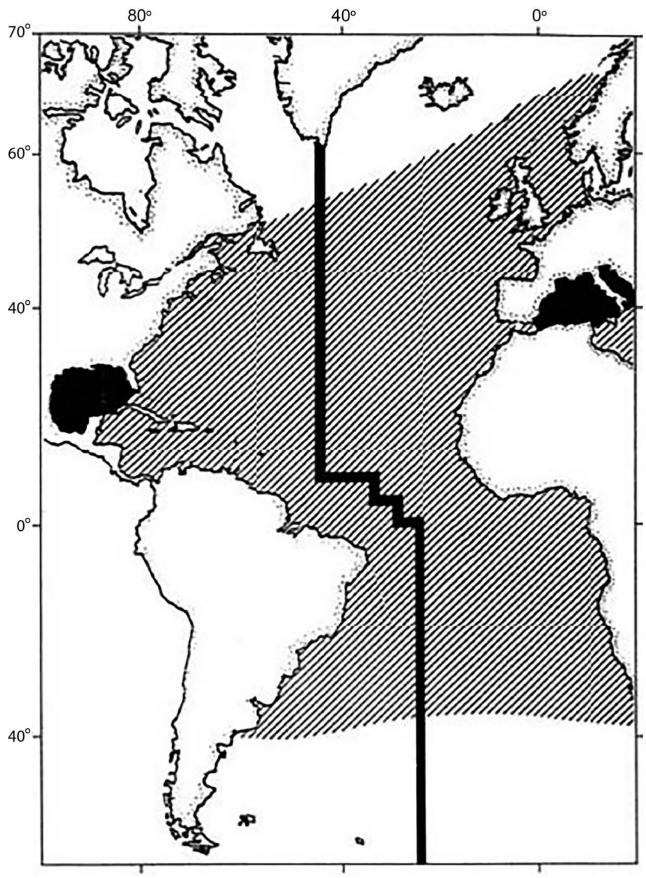

Figure 2. International Convention for the Conservation of Atlantic Tunas 45° line, Atlantic bluefin tuna range (hatched lines), and main spawning areas (solid black). *Source:* National Research Council (1994).

Sea (MED) and a smaller one in the Gulf of Mexico (GOM). Fishers and scientists, however, have long known that ABT move throughout the ocean (see Figure 2). In the early 1900s, hooks specific to a Mediterranean fishing technique were found in the mouths of tuna caught in the Western Atlantic. In the 1960s, tags inserted into animals on one side of the Atlantic were recovered on the other (Mather, Mason, and Jones 1995). However, the specifics of ABT movements in volume, time and space were not well known until recently. In short, the question of what ABT stock *is* has long been unsettled, and this has shaped management practices and interstate political wrangling, particularly around appropriate scales of management.

We distinguish between ABT *fisheries* as the activity of extracting ABT from the oceans for entry into the market and ABT *stock* as the population(s) of fish. Management is directed at the fisheries (licensing, quota, gear restrictions, etc.) to achieve agreed-upon goals for the health of the stock while deriving economic benefit from the fisheries. The distinction between ABT fisheries and stock and whether the spatial extent of fisheries management does, can, or should match that of ABT stock is at the core of scalar debate. Whether ABT are a single, oceanic-wide stock with two breeding grounds or distinct Eastern and Western Atlantic stocks with some mixing matters for how the fisheries are managed and which stakeholders can claim and benefit from ABT. Further, if there are two stocks that mix, the nature and extent of mixing in space and time also matter. Throughout history, stakeholders have relied, to varying degrees, on scientific knowledge to debate scalar possibilities for achieving management goals. At present, new data technologies figure centrally in these debates and their reformulation.

The International Convention for the Conservation of Atlantic Tunas (ICCAT), signed in 1966, is the overarching management authority for ABT. Despite the distinction between Western and Eastern fisheries, in the mid-1960s, fishing nations agreed to coordinate international management because they recognized that ABT are a highly migratory species distributed throughout the Atlantic. When ICCAT entered into force, given knowledge gaps about ABT movements, members decided to treat the fish as a single stock with two breeding grounds.

ICCAT's mandate is to conserve and manage tuna throughout their ranges in a manner that achieves maximum sustainable catch. Like most international agreements related to the environment, ICCAT is committed to making decisions based on "the best available scientific data." To facilitate this, ICCAT has a Standing Committee on Research and Statistics, comprising volunteer and government scientists and mandated to share data on ABT biology, ecology, and population dynamics and to use these data to develop ABT stock assessment models. Stock assessment modeling is a technique through which scientists make sense of biological, ecological, and fishing data to advise managers on meeting stated economic and conservation goals. The SCRS uses models to project outcomes (e.g., stock size and trajectory) and make management recommendations to ICCAT member states, including on the annual level of total allowable catch (TAC) for ABT fisheries. ICCAT member states are mandated to consider

SCRS recommendations in management decisions, including agreeing to a TAC for each fishery.

In 1996, when the multistate ICCAT framework was established, the extent and frequency of ABT movement throughout the Atlantic—and of "mixing" between fish spawning in the Gulf of Mexico and Mediterranean—was unknown. Related, scientists, managers, and fishers did not know how much, if at all, ABT mixing and movement influenced population dynamics, because without data on ABT movement and stock of origin, it was impossible to know whether each fishery caught only fish from its side of the ocean or also fish from the other side (and in what volumes). These knowledge gaps are now being filled by fine-grained and increasingly voluminous spatial–temporal data from electronic satellite tags, complemented by genetic and otolith microchemistry data that establish the breeding ground of origin of each fish (i.e., if it was born and spawns in the MED or GOM). As scientists disseminate findings that illuminate ABT movement, ICCAT members and individual states have come under pressure to make use of them in management tools and policy.

We examine the politics and production of scale in ABT management, exploring how they shift, are contested, and multiply as new data technologies reveal the spatial extent of ABT stock(s). Over three phases, detailed in what follows, assumptions about ABT are unsettled by epistemological advances: the new technologies move toward more "complete" spatial–temporal understanding of ABT biology and movement and, in turn, influence debate over the appropriate scales of management and the role of science in resolving that debate. These changes destabilize—but do not resolve—contentious ABT management that determines conservation and national allocation of quota to one of the most valuable fish on the planet. At stake is which countries have rights to extract fish from the ocean and in what volumes and locations and the extent to which countries have autonomy to claim and manage their fish or influence other countries' management practices.

Methods

Data informing this analysis were collected using a mixed-methods approach that included participant observation, semistructured interviews, and collection of documents, including e-mail communications. The first and third authors attended three meetings of the ICCAT SCRS, the body that provides scientific analysis and management recommendations to the larger ICCAT political forum. They also attended public outreach meetings facilitated by the U.S. National Marine Fisheries Service (NMFS) to observe how policymakers communicated findings and addressed stakeholders' concerns about ABT modeling and management advice. Data were used to document the process through which scientists made decisions about how to use new data to form management advice. The first author attended one ICCAT annual commission meeting and documented how scientific findings and management advice intersected (or not) with ABT management decision making. Individually and as a pair, the first and third authors conducted semistructured interviews with twenty-seven people involved in historical and contemporary ABT management, including government officials, scientists, and industry and environmental advocacy representatives. These methods were complemented with review of academic literature and white papers developed as a part of and in relation to ICCAT management, as well as exchanges on the SCRS e-mail listserv. Our interdisciplinary team has expertise in marine ecology, experience in ICCAT stock assessment modeling exercises, and expertise in geographic queries about scale in oceans management.

Results

1970 through the Early 1990s: Splitting the Stock, Splitting the Fisheries

In the early days of ICCAT, member states managed ABT as a single stock with two different spawning sites. Although the Eastern and Western fisheries were spatially distinct, they were assumed to be targeting the same stock. A single-stock definition of ABT supported Atlantic basin-wide management and meant that all ICCAT members had to reach consensus on any regulatory action, despite the fact that Western and Eastern fisheries operated on opposite sides of the ocean with a distinct gap in fishing effort (Figure 1).

By the 1970s, countries in the Western fishery, particularly the United States, noted a decline in the fish on "their" side of the ocean. High fishing pressure and uneven distribution of ABT biomass stood to make the Western fishery vulnerable to a decline, which would negatively affect fishers. Abundance of fish in the West was estimated to be ten times less than that in the East. Aiming to protect its fishery, in 1973 and 1974, the United States pressed ICCAT for immediate ABT conservation measures, including a 25 percent reduction in catch of large fish, a 50 percent reduction for smaller fish, and a minimum size limit. Eastern ICCAT nations, however, were unwilling to introduce fishing regulations that would limit their own booming fishery (Ruis 2011). The United States began to see the ocean-wide single-stock assumption as an impediment to Western management. Government scientists began to use conceptual modeling exercises to explore hypotheses about ABT stock structure that might enable the U.S. government to strengthen autonomy over management practices in its waters.

In the late 1970s, U.S. scientists at NMFS initiated modeling experiments to assess the effects of rescaling ABT management: they tested a single, basin-wide stock assessment hypothesis against a two-stock (with limited mixing) one. The latter, if accepted, would split the Eastern and Western stocks and thus the fisheries and fisheries management. When the United States shared their findings at the 1981 ICCAT SCRS meeting, they presented two scalar management possibilities. The first option—a basin-wide single-stock assessment—revealed severe ABT population decline across the Atlantic. Addressing this decline would require immediate fishing reductions in both the East and the West. The second option—a split stock assessment, built on an assumption of discrete Eastern and Western stocks with limited mixing—offered a different result: it showed that the Eastern fishery could maintain its extraction levels but the Western fishery would have to set catch levels as near to zero as possible to protect the now regionally defined Western stock.[4]

Following the SCRS meeting, the ICCAT Commission adopted the second option: a two-stock definition for ABT, one in the Eastern Atlantic with spawning in the Mediterranean and the other in the Western Atlantic with spawning in the Gulf of Mexico. The group agreed to rescale management, replacing a single area with a split area dividing the Atlantic into two by a line fixed at 45° longitude in the North Atlantic (Figure 2). Based on the available science, policymakers explicitly assumed that ABT mixing was not significant enough to alter the results of stock assessments conducted separately for a Western and Eastern Atlantic stock on each side of the 45° line (Brown and Parrack 1985). This line fixed the shift from a one- to two-stock definition, and the concomitant decisions created a new spatiality of interstate power relations: countries on either side of the 45° line gained autonomy to manage ABT fisheries independent of the interests of countries on the other side.

Although parties accepted the two-stock definition, they knew the line between stocks was arbitrary and that fish crossed it, though the volume and frequency of movements was unknown. Countries selected the 45° line to demarcate fishing effort, which generally fell on one side of that longitude, and management ambitions in the West versus the East. According to one government official involved, the dividing line was "a convenient fiction" that helped advance progress in management (ABT-S-12). Government scientists and industry representatives from the West described controversy over the decision; for instance, U.S. industries were concerned that "their" fish were crossing the line, only to be caught by the Eastern industry. However, with no concrete movement data, the decision to split the ocean into two fishery management areas, regardless of how accurately they mapped onto the biological areas of what were now assumed to be two stocks, was about political expediency. It gave the West the "freedom" to manage a fishery when management partners on the other side of the Atlantic did not share the political will to introduce fishing limits (ABT-S-12, ABT-S-14, ABT-S-17). During this time, the ICCAT SCRS developed and began to use a stock assessment model known as the two-box Virtual Population Analysis (VPA), which could be run discretely and provide distinct management advice for each side of the 45° line.

Once agreed upon, the 45° line began to structure scientific and management practices, setting the stage for the U.S., Canadian, and Japanese governments—the key fishing nations in the West—to implement dramatic reductions in Western Atlantic quota in the name of saving both the fishery and the stock. Using outputs from the stock assessment model run for their side of the ocean, in 1981, these countries agreed to limit catch by upwards of 65 percent, leaving only a small quota for scientific monitoring, which was allocated to the historically active fishing nations.[5] In 1983, the Western fishery's TAC was 2,660 metric tons, catch of small fish was tightly limited, and targeting ABT in the Gulf of Mexico spawning area was prohibited. These limits continued through 1991, when quotas were slashed an additional 10 percent for 1992 and 1993. Cuts were coupled with fines for exceeding quota and reporting programs to prevent illegal catch and trade.

The 45° line became a spatial management reality around which political relationships and identities developed. In international politics, the U.S. government established itself as a leader in fisheries science and management in the West and a model ICCAT member based on use of science in management and commitment to cutting TAC despite industry pressure to maintain the status quo. These actions distinguished the U.S. government from the Eastern countries, which had not implemented a quota; the Eastern fishery was essentially unmanaged (National Research Council 1994).

Resulting national politics were more contentious: U.S. actions created tense relations among the U.S. government, U.S. industry, and the burgeoning ocean conservation movement. During the 1980s, industry groups opposed NMFS's proposal for separate Eastern and Western stock assessments. Industry organized into the East Coast Tuna Association (later, the Atlantic Bluefin Tuna Association; Hoover 1983; Ruis 2011) and began to work with scientists to ground their lobbying in data on ABT abundance and movements (ABT-I-2, ABT-I-3). Simultaneously, –U.S.-based ABT environmental advocacy emerged. The nascent Ocean Wildlife Campaign, which included prominent ocean conservation organizations WWF, Wildlife Conservation Society (its ocean interests later split and formed the Ocean Conservancy), Center for Marine Conservation, and Pew Charitable Trusts, accepted the two-stock assumption, drew popular attention to the plight of Western stock, and urged NMFS to strengthen Western management (ABT-A-2; Safina 1993). The East–West management split at ICCAT meant that these political conflicts brewed within the United States, creating a Western, rather than basin-wide, politics characterized by deepening tensions and lack of trust among interest groups (ABT-G-1, 2, 3; ABT-I-1, 2, 3; ABT-A-2). However, concern was also growing that lack of scientific clarity on population biology—particularly stock structure and mixing—was hindering ICCAT members' ability to "accurately" manage ABT. Stakeholders in the Western fishery fueled these concerns, highlighting that despite the severe quota restrictions imposed in the West, recovery of the stock, and thus the fishery, was not forthcoming.

By 1993, independent modelers and the SCRS began to examine how sensitive the two-box VPA was to a range of hypotheses about the extent of mixing between the Western and Eastern stocks (Butterworth and Punt 1994; ICCAT 1994).[6] Findings suggested that if mixing assumptions were wrong, the model outputs were unlikely to approximate biological realities (i.e., stock size and health). Around the same time, a National Research Council (NRC) study concluded that mixing was likely significant for management. The NRC raised concern that though "political boundaries are commonly used in fisheries management, a stock defined in this way generally will not reflect biologically meaningful management units" (NRC 1994, 9). They recommended that new assessments include mixing of ABT stocks across the 45° line, and subsequent studies examined a range of hypotheses associated with the practice of two separate management units (Sissenwine et al. 1998). Shortly thereafter, the ICCAT Commission resolved that the SCRS should develop management options for ABT that account for the possible effects of mixing (Porch, Turner, and Powers 2001). In this moment, scientists and managers again called biological and political scales into question. They identified a need to bolster and act on knowledge about the potential impacts of movement to improve management tools and practices.

2000 through the Early 2010s: Epistemological Discovery and Scalar Shifts

As management attention turned to mixing and stock structure, limited data made it difficult for scientists to study how significant ABT movements were to the accuracy of stock assessment models. This began to change in the early 2000s, when electronic satellite tracking innovations created what many interview respondents called a "watershed moment." A 2001 paper showed that ABT tagged in the West moved across the 45° line to the East. These fish had not been assigned natal origin, so it was not possible to specify whether "Eastern" or

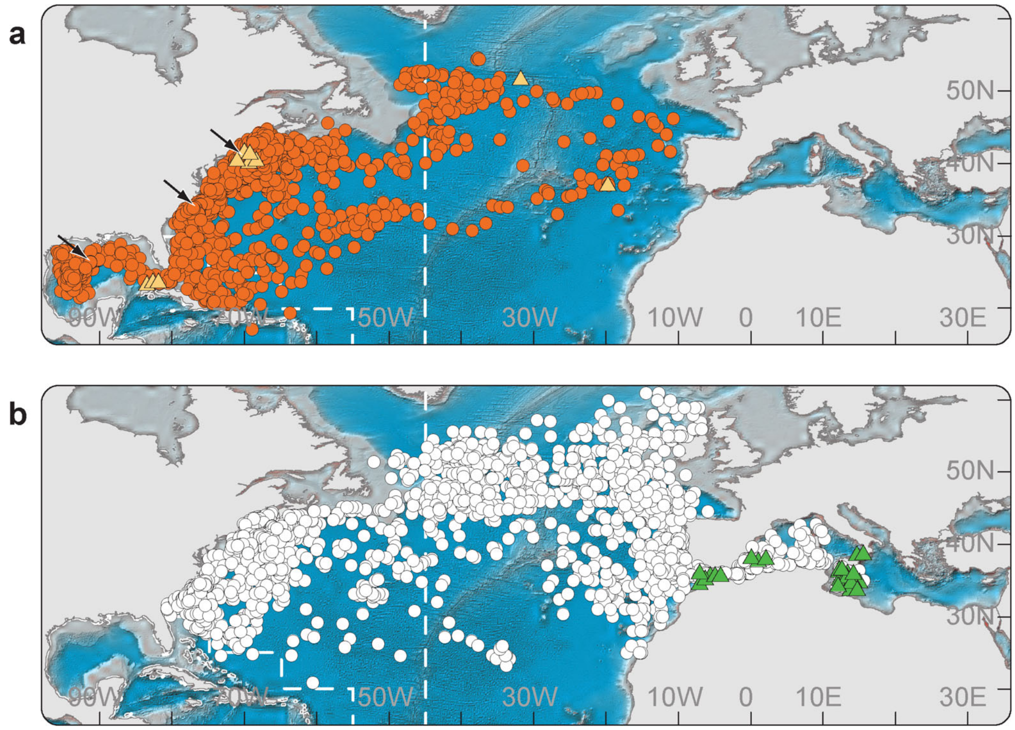

Figure 3. Tracking data showing Eastern- and Western-origin tagged fish present throughout the Atlantic. (A) Fish classified as Western breeders (ten archival tags, twenty-six PAT tags, 219 ± 27 cm CFL at release, median time at large 579 days). (B) Fish classified as potential eastern breeders (twenty-three archival tags, three PAT tags, 207 ± 17 cm CFL at release, median time at large 926 days). *Source:* Modified from Block et al. (2005). PAT = Pop-up Archival Tag; CFL = Curved Fork Length.

"Western" fish—or both—were making the trans-Atlantic migrations (Block et al. 2001). Block et al. (2005) built on these findings, revealing mixing and the stock of origin by assigning fish to either the Eastern or Western population based on whether they moved into the spawning ground in GOM or MED during the time they were tracked. Data visualizations located assigned fish at a moment in time in the ocean, "proving" the presence of Western fish in the East and Eastern fish in the West (Figure 3). Additional satellite tracks, such as a visualization of a single fish moving throughout the Atlantic over three years (Figure 4), illuminated a spatial extent of migrations over time. The representations enacted a seemingly clear picture of mixing and introduced a new spatiotemporal complication—movement—into the two-stock definition underwriting the politics and production of scale in ABT management.

These accessible data offered political fodder for stakeholders in the West to express concern that the vulnerable Western ABT stock could be affected by management practices in the East. Reflecting on the findings of the Block et al. (2001) study, one group said:

> The controversy over who owns the bluefin tuna is international because the species is distributed throughout the North Atlantic and is fished by many countries. Block et al.'s main finding—that Western Atlantic fish mix with their Eastern relatives far more than predicted by conventional tagging methods—will spark further debate over management of Atlantic bluefin. … [It] provides additional evidence for the interdependence of fisheries on both sides of the Atlantic, and the need to halt overfishing in the Eastern Atlantic [for the recovery of the Western stock]. (Magnuson, Safina, and Sissenwine 2001, 1268)

The U.S. ABT industry also used tracking science to inform its interventions into management debates. The industry raised funds to support additional tagging research, and when results revealed fish tagged in the West migrated into the Eastern side of the 45° line, industry invoked these findings as evidence of why the draconian management measures of the 1980s and 1990s failed to generate a recovery of Western stock. According to one respondent, "[With the tagging data] we came to an answer: Western fish were swimming across the line and being subject to uncontrolled fishing in the East" (ABT-I-2).

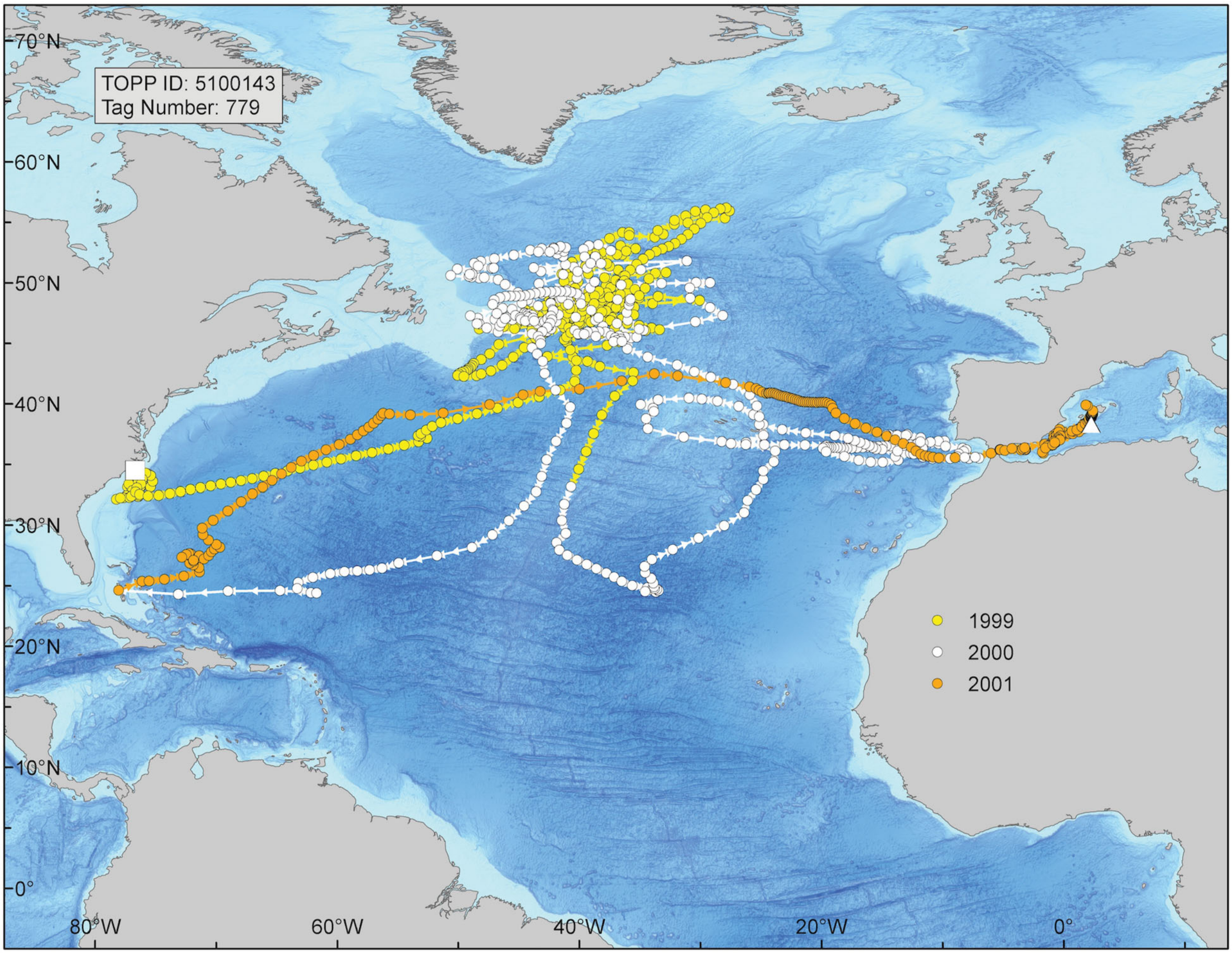

Figure 4. A single Atlantic bluefin tuna's movements over three years. *Source:* Block (unpublished).

Although these new data technologies provided evidence of mixing, the limited number of tracks left the implications of the data for scalar debate in ABT management open to interpretation. Scientists, governments, and industry on both sides of the ocean proposed multiple possibilities. One hypothesis was that the Eastern industry was catching Western fish on the Eastern side of the line, potentially undermining the hard and politically contentious work of management in the West. If, in fact, the Eastern fishery was catching Western fish, then the Western management model was underestimating fishing pressure on the already fragile Western stock and also potentially underestimating productivity of Western fish. Alternatively, tracking data could suggest that the Western industry was catching Eastern fish and had been throughout the history of the fishery. If this was the case, then Eastern fish were subsidizing the Western fishery and the Western management models were potentially overestimating the overall size and productivity of the Western stock and setting TAC higher than it should be to enable a biological recovery.

These two mixing hypotheses were distinct. Regardless, tracking data proved malleable enough for stakeholders on both sides to mobilize empirical observations of movement and mixing to support their interests. That is, the new rendering of "real" ABT movements enabled stakeholders to envision multiple political possibilities for scalar management. According to one interview subject:

> We have seen that the same folks with the same interests can use the tracking data to argue different stories. For example, if the tags show that Western fish move all over, then people will argue that they are all ours and need protection [in the West]. Or the group can switch to turn to mixing to say the data have shown mixing and a need to crack down hard on the East for management. (ABT-S-15)

Stakeholders mobilized the findings of new data technologies to propose—or produce—new possibilities for scalar debate in ABT management. The United States presented one such argument: U.S. interest groups—locked in political struggle over the prior decade—began to collaboratively turn attention to management practices on the Eastern side of the 45° line, and the U.S. government began to use the ICCAT venue to urge the East to establish and enforce quota and regulations. The United States used evidence of movement and mixing generated via new data technologies to justify intervening in Eastern management. In 2000, the United States called for the Eastern group to introduce a total allowable ABT catch and compliance measures. The United States went so far as to propose that the boundary between the fisheries should be rescaled to the east, from 45° to 30°: extending the Western zone (and attendant management strictures) would improve the results of the Western stock assessment. The Japanese delegation argued for returning to a single-stock management approach, because tracking data suggested the two stocks were strongly intermingled. As noted earlier, the Japanese fleet is the only fleet whose industrial activity spans both fisheries. Countries active in the Eastern fishery rejected both rescaling proposals and called for continuation of the status quo, not least because both the U.S. and Japanese proposals would result in a smaller share of TAC for them. The Eastern countries based their opposition on an argument that the science was not robust enough to justify shifting established boundaries (see Webster 2009).

During these debates, the Eastern group was setting TAC higher than SCRS recommendations and fishing well beyond those limits, leading ABT toward a commercial and biological collapse. ICCAT began to face a legitimacy crisis: An external review deemed it a failed institution, calling it an "international disgrace" based on Eastern member states' unwillingness to curtail catch (Hurry, Hayashi, and Maguire 2008). Proposals to list ABT as endangered through the Convention on International Trade in Endangered Species began to circulate, a move that introduced a fourth scalar management option: a global limit on international trade in ABT that would halt an industry dependent on exports. Following mounting pressure, in 2010, the Eastern states cut quota dramatically in line with SCRS advice and developed monitoring and enforcement tools (Webster 2011).

Although tracking data exposed the limits of the SCRS two-box VPA model by showing, with data and accessible visuals, the mismatch between biological and management scales (Kerr et al. 2015), spatiotemporal data were insufficient (in volume and type) to "correct" existing models or develop new models that could account for movement. Parties again turned to science to resolve management uncertainties, calling for more data on mixing and movement. All felt that higher resolution data would generate more ecologically representative management advice that could resolve disputes over who should catch fish and where. In 2008, ICCAT adopted the Atlantic-wide Research Program for Bluefin Tuna, which funded mixing and population structure studies and development of stock assessment models that would include mixing. In the first six years of the program, 42 percent of the €9,557,329 budget was devoted to satellite tracking research with an explicit goal to provide information on fish movements for use in models of mixing (Sissenwine and Pearce 2017). Although it is clear from the story narrated so far that technology and politics call "the real" into question, this move suggests the continued belief that sound scientific investigation can uncover the building blocks of reality (Mol 1999), including those required to resolve scalar debate.

Early 2010s to the Present: Modeling Mixed Stocks and the Production of Management Possibilities

As the volume of tagging data, coupled with genetics and otolith microchemistry data used to assign stock of origin, grew, the SCRS experimented with integrating these data into management tools.[7] For the 2017 ABT stock assessment, the SCRS developed model versions accounting for mixing, but none was deemed robust enough to be used for management advice (SCRS 2017). One reason that it was difficult to integrate movement into these tools was that individual labs had been sharing only small portions of their tracking data (ABT-S-11).[8]

2018 proved a turning point when the SCRS coordinated a data sharing arrangement that made all tagging and stock of origin data available to the SCRS for the first time. A report that SCRS scientists circulated to the SCRS listserv (SCRS 2018) offered more complete graphical depictions of the

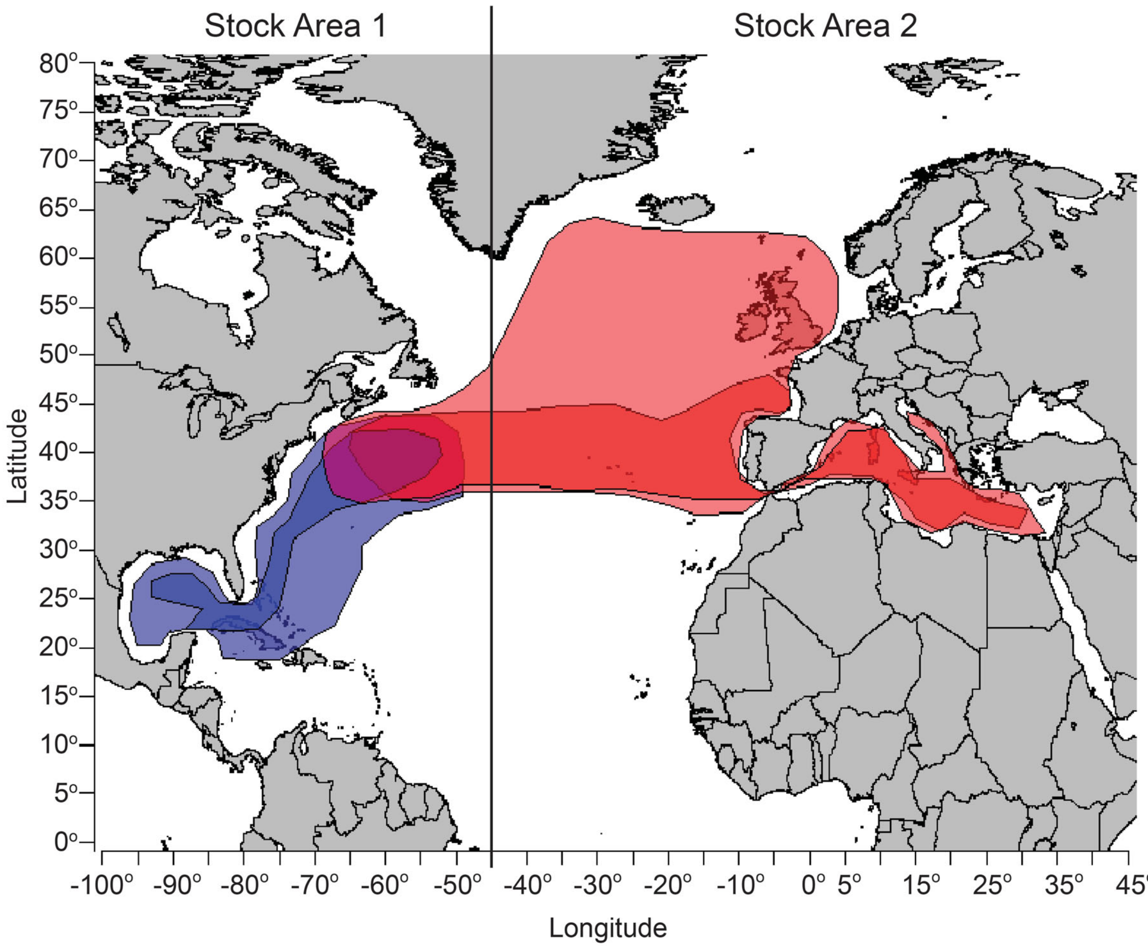

Figure 5. Conceptual simulation of spatial overlap of two populations, illustrating Eastern population across the 45° line. *Source:* Modified from Lauretta and Walters (2018).

movements of Eastern and Western (and unassigned) bluefin. According to one scientist involved, "Suddenly the fish are visible in time and space. It is pretty exciting to see—I was shocked by the new graphics. Okay, fine I get it! Given enough tags in the water, this is a useful bit of information" (ABT-S-13). With the compiled data, the picture of mixing again changed, revealing that Western fish do not have trans-Atlantic movements but Eastern fish do, and in high volumes. Figure 5 is a conceptual simulation (not based on the actual data) that depicts an Eastern population that moves across the 45° line and Western population that does not.

These findings "settled" the question of whose fish are going where, at last providing the "real" picture of ABT migrations: contrary to Western concerns about "their" fish being caught in the Eastern fishery, this collection and illustration of data established that Eastern fish subsidize the Western fishery. This finding meant the West would have to frame their management arguments in new terms: any increase in Eastern quota or catches would decrease "escapes" from the East to be caught in the Western fishery—fish that the West has a historical right to catch. As in prior phases, the seemingly concrete movement data were again open for interpretation and stakeholders mobilized it around long-standing debate over national (and in turn industry) rights to, and management of, mobile ABT.

Yet, the relationship between knowledge and scalar debate also began to change in this phase. For one, the new rendering of ABT movements delinked the spatial influence of the Eastern fishery from the 45° line. Consolidated tracking data further emphasized the scalar flaws associated with managing ABT using the two-box VPA fishery area-based tool, rather than a stock abundance-based tool (Kerr et al. 2017). As the SCRS experimented with incorporating mixing data into the stock assessment model, estimates of ABT around area (the two-box

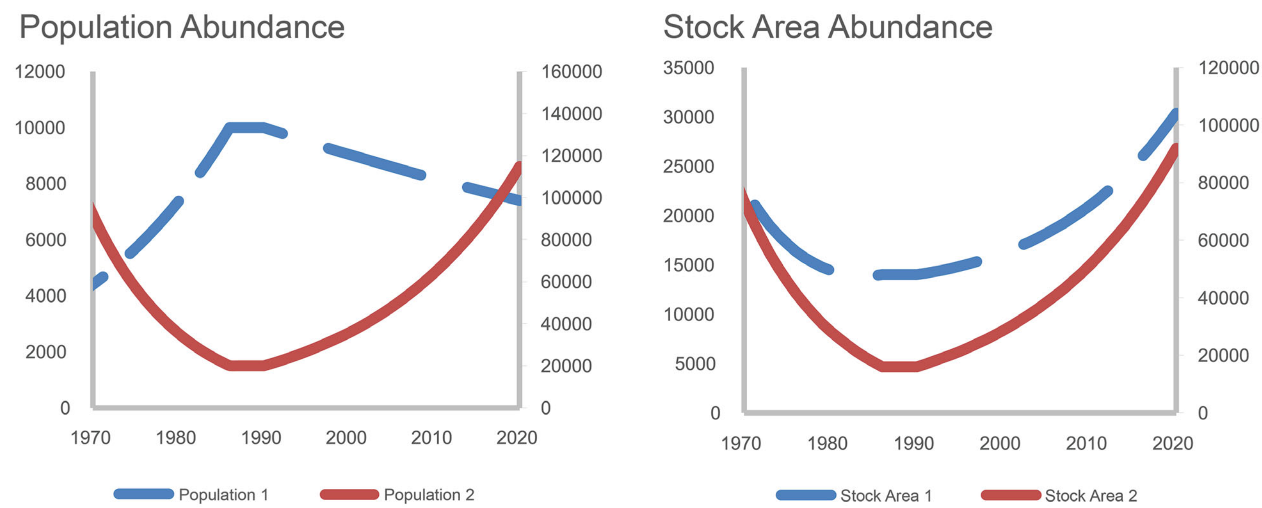

Figure 6. Conceptual depiction (not based on actual data) of abundance outcomes of (A) Western and (B) Eastern stocks according to population abundance versus stock area abundance. *Source:* Modified from Lauretta and Walters (2018).

approach to management) revealed an upward population trajectory. A stock abundance approach that assessed one stock of origin (MED or GOM) across its entire range, however, revealed a growing Eastern stock, but a Western stock (not including the Eastern fish on the Western side of the 45° line) in steady decline (Figure 6). In short, it became clearer than ever that the area-based two-box VPA is "biased because it doesn't protect the weaker stock" (ABT-S-11).

This new knowledge again called the spatiality of ABT management practices into question. As in prior phases, stock assessment modeling became a site for experimenting with management scales. However, to integrate the new data, the model has had to become more complex than the two-box VPA it will replace. Here, we parse the elements of the model to illustrate the how new data technologies are becoming a site for navigating the politics and production of scale.

First, the SCRS increased the spatial resolution of the model, moving from a two-box field of analysis (around the 45° line) to a seven-box field (Figure 7). According to one scientist involved, "This level of detail is mandatory for a good model. … The formal boxes for management matter" (ABT-S-11). As the SCRS explored which spatial boundaries to use for the model, minor changes in box boundaries shifted mixing estimates significantly (observation, SCRS meeting, February 2019).

Second, the SCRS incorporates temporality into the model. Each of the seven boxes needs to represent a unique assemblage of fish with discrete characteristics at any point in time in the year. The model includes methods to describe the seasonal and spatial biomass of tuna for each stock to estimate where fish from each side are likely to be in the ocean throughout the year, and it determines the probability that a fish will move from one box to another over the course of four seasons in the year. Third, the SCRS includes data attributes by the stock of origin (i.e., assigning Eastern or Western fish) based on otolith microchemistry, genetic data, and tracking location data. Fourth, the SCRS incorporates three age classes into the model because fish of different age have distinct spatial–temporal behaviors. Age-class data are approximated from a hodgepodge of fish length data collected from otolith sampling, tracking projects, and catch data. The SCRS also includes indexes that approximate population size and fishing pressure for each of the two populations to enhance stock of origin and age-class identified movement patterns in time and space.

We propose that the SCRS model incorporating ABT movement should be understood as a new geo-epistemology that is becoming the grounds of debate over the politics of scale in ABT management. We support this argument by showing how complexity and spatial management possibilities that emerge from the model are now coproduced with scalar debate. On the former, the model and its products are far more complex than what they replace. This complexity introduces new uncertainty in modeling outcomes. Simulations with bluefin-like species have demonstrated that if spatial structure and movement are incorporated into the model incorrectly,

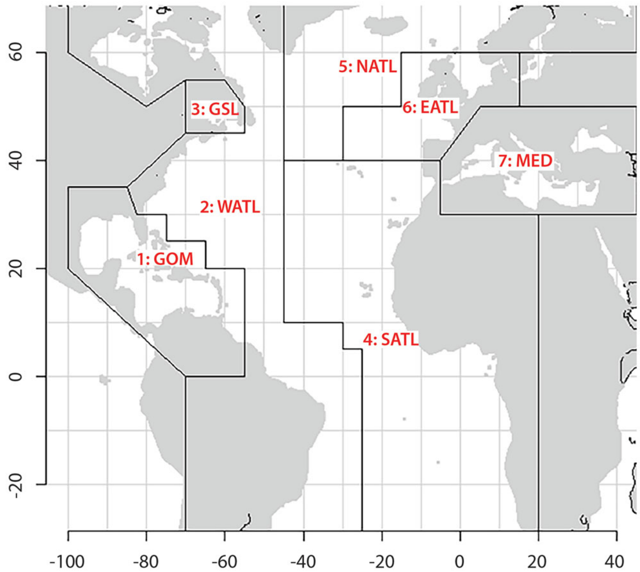

Figure 7. Standing Committee on Research and Statistics model areas used as the basis for examining Atlantic bluefin tuna movement. GOM = Gulf of Mexico; WATL = Western Atlantic; GSL = Gulf of St. Lawrence; SATL = South Atlantic; NATL = North Atlantic; EATL = Eastern Atlantic; MED = Mediterranean Sea. *Source:* Standing Committee on Research and Statistics (2019).

specifying movement can potentially lead to less "accurate" results than if movement is ignored (Porch et al. 1998). Limitations in data (e.g., incomplete data) and the model (e.g., the challenge of using and processing disparate, flawed, and partial data sources together in a meaningful way) can impede the ability to match the scale of biological processes with that of management (Kerr et al. 2017).

On the SCRS listserv and in meetings, SCRS participants routinely debate the rigor and completeness of data sources and complexity and uncertainty in the modeling process. SCRS members link these concerns to the management process, pointing out that data problems could lead to erroneous outcomes and, in turn, political destabilization at ICCAT. Some SCRS scientists have gone so far as to suggest "scaling back" the modeling exercise by running a mixing model back at a two-box scale of analysis (see also Sissenwine and Pearce 2017). According to one scientist involved, this could "eliminate some of the data conflicts, as well as reducing numerical/computation complexity," not least because "no one seems to be contemplating a more complex spatial management arrangement than what is currently in place" (SCRS e-mail communication, March 3, 2020). The model's growing complexity and uncertainty have also drawn attention in the political sphere: Before the 2017 ICCAT Commission meeting, environmental advocates took aim at the "long-awaited assessment [that] produced more questions than answers" and scolded the SCRS for the management advice it offered under conditions of "severe uncertainty" (Collette 2017, 879).

On the latter, even in the face of complexity and uncertainty, new data technologies are introducing new spatial–temporal possibilities for management action. Scientists and government officials involved in creating the mixing model frequently reflected on these possibilities, which are multiplying but are also constrained by the historical politics of scale predating the technologies. Three different people involved in the modeling exercise reflected as follows:

> One scenario is that we get East and West origin and then assign quota and a projection forward from the most recent assessment that takes on mixing in each box in each month and says how much should be caught in each box in each quarter. By doing that, we could get a formula to get a localized, geographically specific catch to maximize management goals. That's doable but then you have to decide how to allocate to the countries! And this will get to be immense. (ABT-G-3)

> We know that if we could allocate landings in the [seven] boxes we can understand what kinds of effects that might have. [Allocation could be done in] a way that would be more ecologically beneficial, for example, it would be better to fish more off of the Carolinas than further north based on stock composition. But this won't happen politically. (ABT-S-11)

> [It's] not so much the [quotas] that people are worried about, but a loss of certainty in another sense—that at least politically, there is a clear dividing line: [East and West] assess separately and allocate and manage separately. That's what [governments and industry] are used to and comfortable with. The implications of this are far reaching because they are saying that unless mixing had been trivial—and it is clearly not trivial—you have great difficulty saying we can still get away from a management perspective of managing the two separately. But the problem is that it is putting up questions that they may not like to answer. … Now this is going to raise key questions like: what degree of spatial resolution do we need—do we need to go finer than that? At the moment the fundamental thing [the

> modeling exercises are] saying is that we no longer have a situation where we can pretend that what we do the East will not affect the other side. … At least initially they are going to say, "What you are telling us will make life more difficult and can't we go back to what we had at least for the moment?" But the Pandora's box is open. (ABT-S-17)

The model offers stock-based descriptions of Eastern and Western ABT health, and their vulnerability to fishing pressure, *across their entire range*, rather than around the arbitrary 45° that has structured management for forty years. In doing so, it presents a new politics and production of scale that could destabilize the ICCAT's historical spatial practices informing recommendations on total allowable catch. To date, ICCAT has continued to require separate management advice for each side of the 45° line, although the SCRS model now must account for the fact that Eastern fish are regularly caught in the West. The "more complete" (but uncertain) picture of ABT stocks has, to date, failed to resolve scalar mismatches in ABT fisheries management.

Conclusions

Geographic research on scale is centrally concerned with the spatiality of power. The data revolution and related new data technologies, and an accompanying techno-optimism about the effects they might yield, highlight the need to situate them in the politics and production of scale. Our analysis of the changing relations between scientific knowledge and scalar debate over half a century of ABT management suggests that as new data technologies bring "the environment" into multifaceted view, they also create a new geo-epistemology that is intimately intertwined with spatialized power relations in environmental management. Here we review findings that illuminate the implications of this change for geographic understandings of the politics and production of scale.

The historical politics and production of scale shape how new data technologies intervene in transboundary environmental management. ICCAT members' decision to introduce a spatial split long before "complete" ABT movement data were available aligned with the spatiality of Eastern and Western fisheries. The United States pressed for the split to strengthen domestic management and protect its fishery; U.S. stakeholders mobilized existing knowledge and modeling techniques to this end. As a result, managers on each side of the ocean strengthened autonomy over ABT by defining separate areas of control over fish and fishing activity. In the decades following, stakeholders repeatedly turned to science to address and reconfigure political tensions emerging from the mismatch between an ocean split in two for political purposes and fish that move throughout the basin. However, the 45° degree line that fixed this spatialized power relation continues to structure scalar decisions, even as new data technologies have made it abundantly clear it is a political, not scientific artifact. In short, new data technologies cannot alone transform the scale of management. They mix with existing and historical spatial power relations embodied in (often historical) political practices. This point is worth underscoring, because the techno-optimism associated with new data technologies often overlooks that the technologies are applied to spaces with politics, and politics of scale, that have been decades in the making.

In all phases, stakeholders mobilized knowledge (or uncertainty, or both) to produce scales of management that would serve a particular purpose or attempt to solve a specific management problem (see also Mansfield and Haas 2006). As new data technologies bring "the real" into focus, scalar possibilities for management multiply and reconfigure, rather than resolve. Multiple stakeholders mobilized the same tracking data to make different arguments about the "right" political scale for managing ABT. Each deployed their interpretation to argue either for the scalar status quo or for rescaled management. Later, integrating one new data technology (tracking data and analysis) into another (stock assessment modeling) introduced finer spatial and temporal resolution management possibilities (seven boxes with four seasonal analyses per year, rather than an annual, two-box model). These advancements opened the possibility of "doing" management at a wider range of scales for which there is no existing political correlate. These dynamics, in turn, have introduced debates over which will be technically accurate and politically feasible. New data technologies open and multiply, rather than close or circumscribe, scalar possibilities in environmental management. They become a key site through which questions of reality, problem framings, potential political outcomes, and more are proposed, explored, and increasingly debated.

This is partly because as new knowledge and knowledge products resolve one topic of scalar uncertainty in management practice and politics, they destabilize others. Uncertainty cascades through related forms of new data technologies and the political processes that refer to them for management advice. As data sharing agreements brought ABT into view at a higher resolution, uncertainty about migration patterns diminished. Making use of this information, though, transferred uncertainty into stock assessment modeling, in this way increasing complexity to a degree that now plagues scientists' ability to use the models to generate management advice with high confidence. This uncertainty conflicts with ICCAT mandates and political demand for SCRS scientists to employ new data to inform scalar debate. This finding is one of the reasons we have chosen the "new data technologies" nomenclature over terms such as big data. New data technologies draws attention to not just raw data but how data are generated, processed, shared, and analyzed and what various people, parties, and stakeholder groups do with them. It thereby offers a methodological opening for scrutinizing how changes in the state and tools of knowledge are coproduced with the politics and production of scale.

Collectively, situating knowledge and new data technologies within the politics and production of scale counters a "data revolution" narrative of linear trajectory from "better" knowledge to "better" management outcomes. Instead, it positions new data technologies as a site of experimentation and debate—a new geo-epistemology—over the spatialized power relations that determine control over contested spaces and valuable resources. As such, new data technologies and the stakeholders and organizations that create them must be examined as governance actors in environmental management, not least because institutional politics and stability are likely to shift as organizations turn to new tools to attend to old (geo)political debates. From a practical perspective, this means that there is an urgent need for investment in social scientific and interdisciplinary attention to the coproduction of new data technologies and the politics and production of scale in environmental management. At stake are the ways in which engagement with new data technologies stand to become the grounds for determining spatialized power relations.

Acknowledgments

We are grateful to the many people who generously offered their time in interviews informing this project. We thank Barb Block and Matthew Lauretta for generously sharing their figures and Lorin Bruckner and the University of North Carolina, Chapel Hill Davis Library Research Hub and Michael Castleton for assistance preparing figures for publication. We also thank Amy Braun for assistance in data collection. Anonymous reviewers offered thoughtful feedback, and Katie Meehan gave exceptional editorial guidance, all of which took place during very difficult pandemic conditions. Remaining errors are our own.

Funding

This work was supported by the University of North Carolina Chapel Hill Department of Geography, the University of North Carolina Chapel Hill Institute for Arts and Humanities, the National Science Foundation Human-Environment and Geographic Sciences Program (Award #2026345 and #1539817), and the National Geographic Conservation Trust (Award #C287-14)

Notes

1. Though in related work we have shown how new data technologies intersect with preexisting management politics to reimagine the appropriate scale for conserving marine species (Havice, Campbell, and Braun 2018).
2. Recently, South Korea has not been active in this fishery.
3. Taiwan, Korea, and France (through St. Pierre et Miquelon) take nominal occasional catch in the Western fishery.
4. This political moment is summarized in National Oceanic and Atmospheric Administration (1982).
5. The United States was allocated more than double Canada and Japan's allocations (605, 250, and 305 metric tons, respectively) in the Western fishery, reflecting U.S. dominance in Western management.
6. Although stock assessment models are meant to help managers understand the relative state of population size and trends, they do not need to empirically approximate the biology of the underlying stock. If the perceived size or rate of change in the stock does not vary over a wide range of values for a certain parameter (i.e., mixing rates) it is said to be "robust," and for the purposes of modeling this parameter can be ignored.
7. Scientists outside of the SCRS also attempted spatial and temporal estimation of mixing of the Eastern and Western populations by using conventional and electronic tagging data, historic catch-at-age reconstruction, and stock composition data (Taylor et al. 2011).

8. Data sharing challenges are of broad concern in big data efforts (Bakker and Ritts 2018).

References

Aqorau, T., J. Bell, and J. N. Kittinger. 2018. Good governance for migratory species. *Science* 361 (6408):1208–9. doi: 10.1126/science.aav2051.

Bakker, K., and M. Ritts. 2018. Smart Earth: A meta-review and implications for environmental governance. *Global Environmental Change* 52:201–11. doi: 10.1016/j.gloenvcha.2018.07.011.

Bax, N. J., J. Cleary, B. Donnelly, D. C. Dunn, P. K. Dunstan, M. Fuller, and P. N. Halpin. 2016. Results of efforts by the Convention on Biological Diversity to describe ecologically or biologically significant marine areas. *Conservation Biology: The Journal of the Society for Conservation Biology* 30 (3):571–81. doi: 10.1111/cobi.12649.

Bestor, T. C. 2000. How sushi went global. *Foreign Policy* 121 (November–December):54. doi: 10.2307/1149619.

Block, B. A., H. Dewar, S. B. Blackwell, T. D. Williams, E. D. Prince, C. J. Farwell, A. Boustany, S. L. H. Teo, A. Seitz, A. Walli, et al. 2001. Electronic tags reveal migratory movements, depth preferences, and thermal biology of Atlantic bluefin tuna. *Science* 293 (5533):1310–14. doi: 10.1126/science.1061197.

Block, B. A., S. L. H. Teo, A. Walli, A. Boustany, M. J. W. Stokesbury, C. J. Farwell, K. C. Weng, H. Dewar, and T. D. Williams. 2005. Electronic tagging and population structure of Atlantic bluefin tuna. *Nature* 434 (7037):1121–27. doi: 10.1038/nature03463.

Boucquey, N., L. Fairbanks, K. St. Martin, L. M. Campbell, and B. McCay. 2016. The ontological politics of marine spatial planning: Assembling the ocean and shaping the capacities of "community" and "environment." *Geoforum* 75:1–11. doi: 10.1016/j.geoforum.2016.06.014.

boyd, d., and K. Crawford. 2012. Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, Communication & Society* 15 (5):662–79.

Boyle, M. 2002. Cleaning up after the Celtic Tiger: Scalar 'fixes' in the political ecology of Tiger economies. *Transactions of the Institute of British Geographers* 27 (2):172–94.

Brown, B. E., and M. Parrack. 1985. Status of the Atlantic bluefin tuna resource. Paper presented at World Angling Resources and Challenges, the First World Angling Conference, Fort Lauderdale, FL.

Butterworth, D. S., and A. E. Punt. 1994. *The robustness of estimates of stock status for the western North Atlantic bluefin tuna population to violations of the assumptions underlying the associated assessment models. ICCAT Collective Volumes of Scientific Papers. 42: 192–210 (SCRS/93/068)*. Madrid: International Commission on the Conservation of Atlantic Tunas.

Campbell, L. M., L. Fairbanks, G. Murray, J. S. Stoll, L. D'Anna, and J. Bingham. 2021. From blue economy to blue communities: Reorienting aquaculture expansion for community wellbeing. *Marine Policy* 124:104361. doi: 10.1016/j.marpol.2020.104361.

Campbell, L. M., and M. H. Godfrey. 2010. Geo-political genetics: Claiming the commons through species mapping. *Geoforum* 41 (6):897–907.

Campbell, L. M., N. J. Gray, L. Fairbanks, J. J. Silver, R. L. Gruby, B. A. Dubik, and X. Basurto. 2016. Global oceans governance: New and emerging issues. *Annual Review of Environment and Resources* 41 (1):517–43. doi: 10.1146/annurev-environ-102014-021121.

Cohen, A., and K. Bakker. 2014. The eco-scalar fix: Rescaling environmental governance and the politics of ecological boundaries in Alberta, Canada. *Environment and Planning D: Society and Space* 32 (1):128–46. doi: 10.1068/d0813.

Cohen, A., and J. McCarthy. 2015. Reviewing rescaling: Strengthening the case for environmental considerations. *Progress in Human Geography* 39 (1):3–25. doi: 10.1177/0309132514521483.

Collette, B. B. 2017. Bluefin tuna science remains vague. *Science* 358 (6365):879–80.

Cox, K. R. 1998. Spaces of dependence, spaces of engagement and the politics of scale, or: Looking for local politics. *Political Geography* 17 (1):1–23. doi: 10.1016/S0962-6298(97)00048-6.

Drakopulos, L. 2020. New materialist approaches to fisheries. *Environment and Society* 11 (1):100–114. doi: 10.3167/ares.2020.110107.

Dunn, D. C., S. M. Maxwell, A. M. Boustany, and P. N. Halpin. 2016. Dynamic ocean management increases the efficiency and efficacy of fisheries management. *Proceedings of the National Academy of Sciences of the United States of America* 113 (3):668–73. doi: 10.1073/pnas.1513626113.

Fairbanks, L., N. Boucquey, L. M. Campbell, and S. Wise. 2019. Remaking oceans governance: Critical perspectives on marine spatial planning. *Environment and Society* 10 (1):122–40. doi: 10.3167/ares.2019.100108.

Gabrys, J. 2016. *Program earth: Environmental sensing technology and the making of a computational planet*. Minneapolis: University of Minnesota Press.

Goldman, M. J., P. Nadasdy, and M. D. Turner, eds. 2011. *Knowing nature: Conversations at the intersection of political ecology and science studies*. Chicago: University of Chicago Press.

Goldstein, J. E. 2020. The volumetric political forest: Territory, satellite fire mapping, and Indonesia's burning peatland. *Antipode* 52 (4):1060–82. doi: 10.1111/anti.12576.

Gruby, R. L., and L. M. Campbell. 2013. Scalar politics and the region: strategies for transcending Pacific Island smallness on a global environmental governance stage. *Environment and Planning A* 45 (9):2046–63.

Halpern, B., S. Walbridge, K. Selkoe, C. Kappel, F. Micheli, C. D'Agrosa, J. Bruno, K. Casey, C. Ebert, H. Fox, et al. 2008. A global map of human impact on marine ecosystems. *Science* 319 (5865):948–52. doi: 10.1126/science.1149345.

Haraway, D. 1988. Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies* 14 (3):575–99. doi: 10.2307/3178066.

Havice, E., L. M. Campbell, and A. Braun. 2018. Science, scale and the frontier of governing mobile marine species. *International Social Science Journal* 68 (229–230):273–90. doi: 10.1111/issj.12166.

Hays, G., H. Bailey, S. Bograd, D. Bowen, C. Campagna, R. Carmichael, P. Casale, A. Chiaradia, D. Costa, E. Cuevas, et al. 2019. Translating marine animal tracking data into conservation policy and management. *Trends in Ecology & Evolution* 34 (5):459–73. doi: 10.1016/j.tree.2019.01.009.

Hoover, D. 1983. A case against international management of highly migratory marine fishery resources: The Atlantic bluefin tuna. *Boston College Environmental Affairs Law Review* 11:11–62.

Hurry, G. D., M. Hayashi, and J. J. Maguire. 2008. Report of the independent performance review of ICCAT. International Commission for the Conservation of Atlantic Tunas, Madrid.

ICCAT. 1994. *Report for the biennial period 1992–1993. Part II*. Madrid: International Commission for the Conservation of Atlantic Tunas.

Jeffers, V. F., and B. J. Godley. 2016. Satellite tracking in sea turtles: How do we find our way to the conservation dividends? *Biological Conservation* 199:172–84. doi: 10.1016/j.biocon.2016.04.032.

Kerr, L. A., S. X. Cadrin, D. H. Secor, and N. Taylor. 2015. Evaluating the effect of Atlantic bluefin tuna movement on the perception of stock units. *Collective Volume of Scientific Papers—International Commission for the Conservation of Atlantic Tunas* 71:1660–82.

Kerr, L. A., N. T. Hintzen, S. X. Cadrin, L. W. Clausen, M. Dickey-Collas, D. R. Goethel, E. M. Hatfield, J. P. Kritzer, and R. D. Nash. 2017. Lessons learned from practical approaches to reconcile mismatches between biological population structure and stock units of marine fish. *ICES Journal of Marine Science* 74 (6):1708–22. doi: 10.1093/icesjms/fsw188.

Kitchin, R. 2014. Big data, new epistemologies and paradigm shifts. *Big Data & Society* 1 (1). doi: 10.1177/2053951714528481.

Kroodsma, D., J. Mayorga, T. Hochberg, N. Miller, K. Boerder, F. Ferretti, A. Wilson, B. Bergman, T. White, B. Block, et al. 2018. Tracking the global footprint of fisheries. *Science* 359 (6378):904–8. doi: 10.1126/science.aao5646.

Larsen, H. G. 2008. Scaling the Baltic Sea environment. *Geoforum* 39 (6):2000–2008. doi: 10.1016/j.geoforum.2008.07.002.

Lauretta, M., and J. F. Walters. 2018. Genomics based fishery management of highly migratory species. NOAA Southeast Fisheries Science Center Atlantic Oceanographic and Meteorological Laboratory Science Workshop, September.

Lave, R. 2012. *Fields and streams: Stream restoration, neoliberalism, and the future of environmental science*. Athens: University of Georgia Press.

Lee, K. N. 1993. Greed, scale mismatch, and learning. *Ecological Applications: A Publication of the Ecological Society of America* 3 (4):560–64.

Lehman, J. 2016. A sea of potential: The politics of global ocean observations. *Political Geography* 55:113–23. doi: 10.1016/j.polgeo.2016.09.006.

Longo, S. B., and B. Clark. 2012. The commodification of bluefin tuna: The historical transformation of the Mediterranean fishery. *Journal of Agrarian Change* 12 (2–3):204–26. doi: 10.1111/j.1471-0366.2011.00348.x.

Magnuson, J. J., C. Safina, and M. P. Sissenwine. 2001. Ecology and conservation. Whose fish are they anyway? *Science* 293 (5533):1267–68. doi: 10.1126/science.1064052.

Mansfield, B. 2001. Thinking through scale: The role of state governance in globalizing North Pacific fisheries. *Environment and Planning A: Economy and Space* 33 (10):1807–27. doi: 10.1068/a3469.

Mansfield, B., and J. Haas. 2006. Scale framing of scientific uncertainty in controversy over the endangered Steller sea lion. *Environmental Politics* 15 (1):78–94.

Marston, S. A. 2000. The social construction of scale. *Progress in Human Geography* 24 (2):219–42. doi: 10.1191/030913200674086272.

Massey, D. 1994. *Space, place, and gender*. Minneapolis: University of Minnesota Press.

Mather, F. J., J. M. Mason, and A. C. Jones. 1995. *Historical document: Life history and fisheries of Atlantic bluefin tuna*. NOAA Technical Memorandum, NMFS-SEFSC-370, Department of Commerce.

Maxwell, S., E. Hazen, R. Lewison, D. Dunn, H. Bailey, S. Bograd, D. Briscoe, S. Fossette, A. Hobday, M. Bennett, et al. 2015. Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. *Marine Policy* 58:42–50. doi: 10.1016/j.marpol.2015.03.014.

Mol, A. 1999. Ontological politics. A word and some questions. *The Sociological Review* 47 (1_Suppl.):74–89. doi: 10.1111/j.1467-954X.1999.tb03483.x.

National Oceanic and Atmospheric Administration. 1982. Proposed Rule, 50 CFR Part 285, Atlantic tuna fisheries. *Federal Register* 47(77).

National Research Council. 1994. *An assessment of Atlantic bluefin tuna*. Washington, DC: The National Academies Press.

Neumann, R. P. 2015. Political ecology of scale. In *The international handbook of political ecology*, ed. R. L. Bryant, 475–86. Cheltenham, UK: Edward Elgar.

Nost, E., and J. E. Goldstein. 2022. A political ecology of data. *Environment and Planning E: Nature and Space* 5 (1):3–17.

Peters, K., and R. Squire. 2019. Oceanic travels: Future voyages for moving deep and wide within the "new mobilities paradigm." *Transfers* 9 (2):101–11. doi: 10.3167/TRANS.2019.090207.

Pinsky, M. L., G. Reygondeau, R. Caddell, J. Palacios-Abrantes, J. Spijkers, and W. W. L. Cheung. 2018. Preparing ocean governance for species on the move. *Science* 360 (6394):1189–91. doi: 10.1126/science.aat2360.

Porch, C. E., P. Kleiber, S. Turner, J. Sibert, R. Bailey, and J. Cort. 1998. The efficacy of VPA models in the presence of complicated movement patterns. *Collective Volume of Scientific Papers—International Commission for the Conservation of Atlantic Tunas* 50:591–622.

Porch, C. E., S. C. Turner, and J. E. Powers. 2001. Virtual population analyses of Atlantic bluefin tuna with alternative models of transatlantic migration: 1970-1997. *Collective Volume of Scientific Papers—International Commission for the Conservation of Atlantic Tunas* 52:1022–45.

Rankin, W. 2016. *After the map: cartography, navigation, and the transformation of territory in the twentieth century*. Chicago: University of Chicago Press.

Reed, M. G., and S. Bruyneel. 2010. Rescaling environmental governance, rethinking the state: A three-dimensional review. *Progress in Human Geography* 34 (5):646–53. doi: 10.1177/0309132509354836.

Robertson, M. M., and J. D. Wainwright. 2013. The value of nature to the state. *Annals of the Association of American Geographers* 103 (4):890–905. doi: 10.1080/00045608.2013.765772.

Ruis, R. 2011. Bluefin extinction myth: Part 3. Evolution of the two-stock hypothesis. *Commercial Fisheries News* 39:8–10.

Runting, R. K., S. Phinn, Z. Xie, O. Venter, and J. E. M. Watson. 2020. Opportunities for big data in conservation and sustainability. *Nature Communications* 11 (1):2003. doi: 10.1038/s41467-020-15870-0.

Rykiel, E. 1998. Relationships of scale to policy and decision making. In *Ecological scale: Theory and applications*, ed. D. L. Peterson and V. T. Parker, 485–98. New York: Columbia University Press.

Safina, C. 1993. Bluefin tuna in the West Atlantic: Negligent management and the making of an endangered species. *Conservation Biology* 7 (2):229–34. doi: 10.1046/j.1523-1739.1993.07020229.x.

Sayre, N. F. 2005. Ecological and geographical scale: Parallels and potential for integration. *Progress in Human Geography* 29 (3):276–90. doi: 10.1191/0309132505ph546oa.

Sayre, N. F. 2015. Scales and polities. In *The Routledge handbook of political ecology*, ed. T. Perreault, G. Bridge, and J. McCarthy, 504–15. London and New York: Routledge.

Sissenwine, M. P., P. M. Mace, J. E. Powers, and G. P. Scott. 1998. A commentary on western Atlantic bluefin tuna assessments. *Transactions of the American Fisheries Society* 127 (5):838–55. doi: 10.1577/1548-8659(1998)127<0838:ACOWAB>2.0.CO;2.

Sissenwine, M. P., and J. Pearce. 2017. Second review of the ICCAT Atlantic-wide research programme on bluefin tuna (ICCAT GBYP Phase 6-2016). *Collective Volume of Scientific Papers—International Commission for the Conservation of Atlantic Tunas* 73:2340–423.

Standing Committee on Research and Statistics. 2017. Report of the 2017 ICCAT Bluefin Stock Assessment Meeting, International Commission on the Conservation of Atlantic Tunas, Madrid.

Standing Committee on Research and Statistics. 2018. A look at mixing/movement in the Oms [Operating models]. Report circulated to the SCRS listserv, October 22.

Standing Committee on Research and Statistics. 2019. *Operating model summary report*. June. Madrid: International Commission on the Conservation of Atlantic Bluefin Tunas.

St. Martin, K. 2001. Making space for community resource management in fisheries. *Annals of the Association of American Geographers* 91 (1):122–42.

Swyngedouw, E. 1997a. Excluding the other: The production of scale and scaled politics. In *Geographies of economies*, ed. R. R. Lee and J. Wills, 167–76. London and New York: Arnold.

Swyngedouw, E. 1997b. Neither global nor local: "Glocalization" and the politics of scale. In *Spaces of globalization: Reasserting the power of the local*, ed. K. R. Cox, 137–66. New York: Guilford.

Swyngedouw, E. 2004a. Globalisation or "glocalisation"? Networks, territories and rescaling. *Cambridge Review of International Affairs* 17 (1):25–48. doi: 10.1080/0955757042000203632.

Swyngedouw, E. 2004b. Scaled geographies: Nature, place, and the politics of scale. In *Scale and geographic inquiry: Nature, society, and method*, ed. E. Sheppard and R. B. McMaster, 129–53. Oxford, UK: Blackwell.

Taylor, N. G., M. K. McAllister, G. L. Lawson, T. Carruthers, and B. A. Block. 2011. Atlantic bluefin tuna: A novel multistock spatial model for assessing population biomass. *PLoS ONE* 6 (12):e27693. doi: 10.1371/journal.pone.0027693.

Turner, M. D. 2006. *Shifting scales, lines, and lives: The politics of conservation science and development in the Sahel*. Chicago: University of Chicago Press.

Valdivia, G., M. Himley, and E. Havice. 2021. Critical resource geography: An introduction. In *The Routledge handbook of critical resource geography*, ed. M. Himley, E. Havice, and G. Valdivia, 1–20. London and New York: Routledge.

Visbeck, M. 2018. Ocean science research is key for a sustainable future. *Nature Communications* 9 (1):1–3. doi: 10.1038/s41467-018-03158-3.

Webster, D. G. 2009. *Adaptive governance: The dynamics of Atlantic fisheries management*. Cambridge, MA: MIT Press.

Webster, D. G. 2011. The irony and the exclusivity of Atlantic bluefin tuna management. *Marine Policy* 35 (2):249–51. doi: 10.1016/j.marpol.2010.08.004.

Zimmerer, K. S. 2000. Rescaling irrigation in Latin America: The cultural images and political ecology of water resources. *Ecumene* 7 (2):150–75. doi: 10.1177/096746080000700202.

ELIZABETH HAVICE is a Professor in the Department of Geography at University of North Carolina–Chapel Hill, Chapel Hill, NC 27599. E-mail: havice@email.unc.edu. Her research uses the lens of governance to explore distributional outcomes in marine resources sectors and spaces, food systems, and global value chains. She is presently examining the intersection between new data technologies and oceans governance.

LISA CAMPBELL is the Rachel Carson Professor of Marine Affairs and Policy at Duke University's Nicholas School of Environment, Duke University Marine Lab, Beaufort, NC 28516. E-mail: lisa.m.campbell@duke.edu.

She studies oceans governance at a variety of scales (international, national, local) in relation to diverse issues (protected species, fisheries, marine protected areas, etc.) and is particularly interested in how science and nonstate actors inform governance processes and outcomes.

ANDRE BOUSTANY is the Principal Investigator of Fisheries at Monterey Bay Aquarium, Monterey, CA 93940. He is also an Adjunct in the Duke University Nicholas School of the Environment, Duke University Marine Lab, Beaufort, NC 28516. E-mail: aboustany@mbayaq.org. His research interests cover a wide range of marine ecological questions, particularly around international fisheries management, sustainable seafood, and conservation of protected marine species.