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Toward a political ecology of infrastructure standards: Or, how to think about ships, waterways, sediment, and communities together

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Abstract

Scholars have shown that technical standards play an important role in building global transportation and communication infrastructures, but the environmental standardization efforts associated with infrastructures have received far less attention. Combining scholarship from transportation geography, political ecology, and science and technology studies, we show how global connection is made, maintained, and contested through environmental management practices pegged to infrastructure standards. The Panama Canal expansion, completed in 2016, is a revealing illustration. The expansion has established the New Panamax shipping standard: the maximum allowable dimensions for vessels passing through the canal's massive new locks. The standard has become a benchmark for port modernization and channel deepening projects along the Atlantic and Gulf Coasts of the United States and beyond. Because the maximum underwater depth, or draft, of ships transiting the new locks is much deeper than before (50 rather than 39.5 feet), geographically dispersed governments, firms, and port authorities have scrambled to reach that standard in hopes of attracting New Panamax ships and associated revenue streams. As this case shows, global transportation depends on the expensive, ecologically destabilizing, and often-contested practices of dredging and disposing of large volumes of sediment and organic matter. By showing how shipping networks and situated politics converge around infrastructure standards, we foreground the uneven environmental burdens and benefits of transportation.

Keywords

Transportation, infrastructure, political ecology, shipping, water

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Introduction

What do a rail terminal project in Southern California, a bridge-raising plan in New Jersey, and the installation of cranes at a port in Houston have to do with environmental conflicts around a coral reef near Miami, the installation of oxygen injection machines to sustain life in a Georgia river, and the future of an abundant fishery in a degraded Louisiana marsh?

In this article, we show how infrastructure standards connect these spatially diffuse projects and environmental conflicts. To that end, we develop an analytical framework that we call the political ecology of infrastructure standards and use it to examine the deepwater shipping network organized around the Panama Canal's locks.

In the early 21st century, we find ourselves in the midst of a wave of global transportation infrastructure projects, including canal megaprojects designed to accommodate colossal new ships and expand interoceanic freight capacity. In 2015, the Egyptian government opened a second, significantly expanded Suez Canal channel between the Mediterranean Sea and Red Sea. Across the Atlantic Ocean, the Nicaraguan government and HKND, a Hong Kong–based firm, planned a new Atlantic–Pacific waterway across the impoverished country. And, in 2016, the Panamanian government completed a decade-long expansion of the Panama Canal. Because these interoceanic canals are—or might become—obligatory points of passage (chokepoints) for shipping, their dimensions set infrastructure standards for planetary transportation networks.

The Panama Canal expansion provides an opportunity to understand the diffuse infrastructure projects and environmental conflicts described above as part of a networked standardization event. Since the expansion project was approved in 2006, public and private institutions have invested billions of dollars in infrastructure projects around major ports along the US Atlantic and Gulf Coasts to meet the new shipping standards set by the expanded Panama Canal locks and compete for lock-maximizing New Panamax vessels. Many of these are straightforward technological modernization projects, such as the construction of intermodal terminals and the installation of gigantic cranes capable of loading and unloading New Panamax container ships. In addition to standardizing engineered infrastructure, transportation authorities attempt to match the dimensions of harbors and waterways to the 50-foot depth of the canal's new locks (Figure 1). This is one form of environmental standardization.

The Panama Canal expansion reveals global infrastructure's barnacled underside. Some 90% of global trade tonnage moves by ship (Rodrigue et al., 2013) and maritime traffic has expanded at an extraordinary rate. Between 1992 and 2012, the number of oceangoing ships worldwide increased an estimated four-fold (Tournadre, 2014). In this conjuncture, the planet's oceans have become spaces of logistics and extraction, as well as environmental sinks (Bélanger, 2014). Meanwhile, localities, authorities, states, and firms have been busy dredging massive volumes of sediment from rivers, harbors, channels, and ports to receive enormous oceangoing ships and capture the economic benefits of transportation (Ramos, 2014). The standardized reorganization of coastal and inland waterscapes to accommodate these ships facilitates cheap transportation across political boundaries and differences in topography, precipitation, and channel depth.

In the decade between the announcement and completion of the Panama Canal expansion (2006–2016), media outlets serving port communities and the transportation industry have speculated endlessly about the economic benefits that might accrue through modernizing facilities and dredging waterways to accommodate larger ships. Dredging operations involve the excavation and disposal of huge volumes of sediment and organic matter from estuaries, lakes, lagoons, and rivers. The dredging of navigable waterways to standardized depths is a precondition for modern shipping and transportation. This practice has a long history

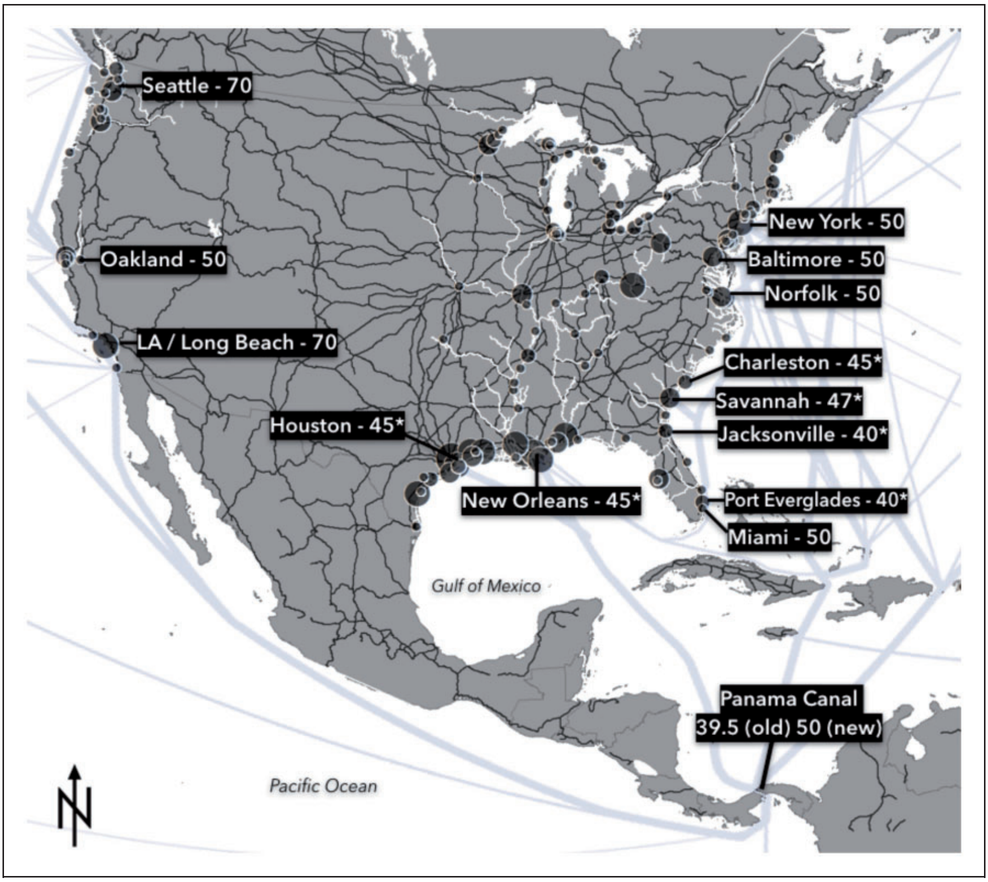

Figure 1. North American maritime shipping routes, inland waterways, and minimum channel depths (in feet) at selected ports in 2016. Shallow underwater depths may limit a port's capacity to accommodate large ships. Asterisks by port names identify major dredging projects under development in 2016 to match waterway depth to the New Panamax standard of 50 feet. Gray lines across oceans represent major shipping routes. Black circles identify ports with waterways maintained by the US Army Corps of Engineers. The sizes of these circles represent comparative tonnage, or material throughput, among ports. White lines indicate inland waterways maintained for navigation by the Army Corps. Black lines identify major freight railroads. *Sources*: Port depths from Rodrigue and Notteboom (2015). Shipping lanes drawn from CIA data as processed by Esri, Michael Horner, Story Maps team. Processing by Joshua A. Lewis.

(Vanderostyne and Cohen, 1999), but has accelerated due, in part, to the rapid expansion of the shipping industry and vessel sizes.

Dredging illustrates how infrastructure standards can give rise to complex forms of environmental politics. These projects are often presented as widely beneficial, but dredging is expensive and, as we will show below in a discussion of cases from the US Atlantic and Gulf Coasts, potentially ecologically and economically disruptive. It may be contested on those grounds, giving rise to what political ecologist Joan Martinez Alier (2009) calls ecological distribution conflicts.[1]

Below, we conduct what science and technology studies scholars call an infrastructural inversion: unearthing the world-making (if often ignored) histories of standardization and connection (Bowker and Star, 1999). The prefix *infra* means below, beneath, or within. It is hard to think of a more critical but overlooked class of background work for economic globalization than excavating underwater sediment to facilitate the movement of ships and their cargos from one place to another. The remainder of the article is organized in five sections. The first section explains our conceptual framework. The second section examines the role of infrastructure standards and associated forms of environmental management in global transportation. The third section summarizes the historical development of an aquatic infrastructural zone of harbors, canals, and navigable rivers connected to the Panama Canal's lock system. The fourth section analyzes the Panama Canal expansion and its widespread reverberations to illustrate how infrastructure standards can become environmental benchmarks and precipitate intentional and unexpected ecological change. The fifth section explores multi-scale environmental conflicts related to the expansion and communities' competing attachments to modified environments.

Toward a political ecology of infrastructure standards

Transportation geographers have helped us understand shipping in macrogeographic terms—as networks of nodes (ports and other facilities) connected by lines (maritime and other routes) (De Langen and Visser, 2005; Ducruet and Notteboom, 2012). Many transportation geographers have focused on understanding relationships of connectivity and competition among ports and shipping firms that vie with one another for market share. These scholars have also elucidated the critical role of common infrastructure standards like shipping containers (Levinson, 2006; Rodrigue and Notteboom, 2009) in facilitating rapid, cheap economic exchange. To date, however, environmental problems and politics have been a minor concern in the field.

Most of the interdisciplinary scholarship on transportation and environment focuses on the industry's impacts on human and non-human communities. One body of work demonstrates a growing concern with sustainability (Banister, 1993; Schiller et al., 2010; USEPA, 2000). Another focuses on transportation and environmental justice, particularly the uneven distribution of air, water, and noise pollution. Scholars have shown that socioeconomically and racially marginalized communities near ports, railroad yards, and other transportation facilities bear a disproportionate proportion of the environmental and health burdens of goods movement (Feitelson, 2002; Forkenbrock and Schweitzer, 1999; Houston et al., 2008; Kennedy 2004; Morello-Frosch et al., 2001). Research and activism around these issues have advanced more equitable policies and prompted sustainability efforts in the industry, but they tend to focus on impacts adjacent to transportation facilities. As a result, the broader spatial politics of transportation networks have received relatively little attention (Ng et al., 2014).

We argue that interdisciplinary scholarship on transportation and environment would benefit from more engagement with science and technology studies scholarship on infrastructure, particularly the concept of infrastructural zones. For Andrew Barry (2006), infrastructural zones are spaces where differences in practices, procedures, and forms are reduced through common connection standards (e.g. the shipping container). The concept builds on scholarship that conceptualizes the global scale as an outcome of assemblages and networks (Latour, 2005; Ong and Collier, 2005; Sassen, 2006; Tsing, 2005), but is more specific in its orientation. We understand the infrastructural zone as a specific type of global assemblage: a standards regime (Ong and Collier, 2005) that crosses national boundaries and links sociotechnical systems with different histories (Edwards et al., 2007; Egyedi, 2001). Therefore, the geography of the infrastructural zone—and, we would add, associated problems of environmental politics and justice—takes the form of interconnected corridors, networks, and pipelines (see also Easterling, 2014). We return to that point below, but first we provide working definitions of infrastructure and standards.

Infrastructure is a complex word with multiple and contested meanings that have changed over time (Carse, 2016). Our usage is inspired by its conceptualization as a socially constructed, historically emergent, and relational entity in science and technology studies (Edwards, 2003). The main idea is that infrastructures begin as discrete sociotechnical systems that are centrally designed and controlled by individuals, teams, or organizations known as system builders (Hughes, 1987). These systems become infrastructures as they are interconnected through social and technical standards, or gateways (Egyedi, 2001), that facilitate coordination across system boundaries. Conceptualized relationally (Star and Ruhleder, 1996), the infrastructure concept is not limited to engineered hardware. Infrastructure can incorporate a variety of components integrated through the organizational techniques (social, technical, and administrative) that Geoffrey Bowker (1994: 10) calls infrastructural work. Seen in this way, even seemingly natural landscapes like forests, prairies, reefs, and wetlands can become infrastructure through the active and inherently political work of investment, management, maintenance, and standardization (Carse, 2012).

Standards are integral to the vast, complex, and dynamic infrastructures that support modern societies and economies. But what, exactly, are they? Lawrence Busch (2011), a sociologist, argues that standards are "recipes for reality." They are the protocols, practices, procedures, and technologies that establish the rules for coordination across sociotechnical systems and, in so doing, establish path dependencies that shape future social and economic priorities. Because standards are designed and codified by particular actors in specific times and places, it follows that they are sites of power and resistance; they reflect and reproduce particular values, beliefs, and assumptions (Bowker and Star, 1999; Timmermans and Epstein, 2010). Thus, Busch writes,

> As standards are used, people and things are tested, and we determine what shall count. Those people and things that pass the test or make the grade are drawn into various networks. In contrast, those persons and things that fail the test do not count; they do not make the grade. They are downgraded. (2011: 12–13)

The shipping container is a famous illustration of how infrastructure standards work and their subtle yet world-making technopolitics. As Deborah Cowen (2014) has shown in work that merges transportation geography—which is often oriented toward industry—with critical theory and an emphasis on power dynamics, logistical rationalities and practices give rise to clear winners and losers across human communities. We extend this scholarship by focusing on the complex environmental politics of global transportation and logistics.

We combine insights from science and technology studies, transportation geography, and political ecology to analyze conflicts around the role of environmental management and standardization in the construction, interconnection, and maintenance of infrastructural zones. This moves us beyond the language of environmental effects or degradation to foreground institutional efforts to *produce* environments (Robbins, 2012: 120–121) that are pegged to infrastructure standards. Seen in this way, environmental standardization is not only a consequence of transportation to be regulated or mitigated (like pollution); it is a precondition for economic integration and value creation that gives rise to complex, multi-scale environmental politics. Finally, we emphasize that the political ecology of infrastructure standards is a heuristic that necessarily abstracts from great complexity to draw attention to the distribution conflicts that can result when ecosystems are drawn into long networks through infrastructure projects (see also Carse, 2014; Davis et al., 2015).

Chokepoints: Infrastructure standards in transportation and environmental modification

Why expand old canals and construct new ones? To accommodate a new generation of gigantic container ships like New Panamax vessels that are emblematic of a long-term trend toward integrated intermodal transportation at increasing economies of scale. International seaborne trade has grown at a remarkable pace. As noted earlier, 90% of global trade by volume moves by ship (Rodrigue et al., 2013). In 1970, the total volume was 2.6 billion tons of cargo (UNCTAD, 2014: 5). By 2013, the volume had exceeded 9.5 billion tons. There is no simple explanation of this trend, but scholars have emphasized the importance of developments—some say "revolutions"—in logistics, intermodal transportation, and containerization since the 1960s.

To understand the Panama Canal expansion as an environmental standardization event, we need to recognize the impact of logistics as a new way of imagining and organizing economic space (Cowen, 2014). Since the 1960s, businesses have adopted logistical approaches to consolidate production and distribution processes (transportation, warehousing, etc.) and maximize profits. The standardized intermodal shipping container is an icon of the logistics revolution and among the definitive technologies of economic globalization. By reducing the labor and time required to transfer cargo between ship, rail, and truck, the container dramatically reduced shipping costs, making it profitable to trade across greater distances (Levinson, 2006). Intermodal transportation took off after the container was standardized.

The International Organization for Standardization (ISO) established two container standards in the late 1960s: the 20-equivalent unit (TEU) and 40-equivalent unit (FEU) (Rodrigue and Notteboom, 2009: 2). During the next two decades, the US government deregulated the railroad, aviation, and maritime industries (Cowen, 2014: 42–44). Logistics, containerization, and deregulation transformed the footprints of port operations, decimated organized labor, and reworked transportation geographies. In pursuit of economic development, local, state, and national governments have collaborated with transportation firms to reduce friction of all kinds (organized labor, regulations, customs paperwork) and facilitate movement across borders by promoting a mix of modernization projects and neoliberal political reforms (Cowen, 2014).

The articulation of transportation infrastructure standards, environmental management, and local politics is particularly visible at maritime chokepoints. The chokepoint concept has been developed in transportation geography and strategic and security studies. Chokepoints are locations in transportation networks that "cannot be easily bypassed, if at all" (Rodrigue, 2004: 359). Maritime routes tend to converge at obligatory points of passage like river mouths, straits, capes, isthmuses, and canals to minimize costly transfers to land-based transit modes like trucks and railroads. Key maritime chokepoints include the Panama Canal, Suez Canal, and Strait of Malacca (Rodrigue et al., 2013: 32). Whether natural or engineered, chokepoints' physical characteristics like channel width and depth limit circulation capacity and set global transportation standards. Therefore, governments and private firms invest in infrastructure and environmental management to maintain channel conditions that are pegged to those at Panama, Suez, and Malacca. The goal is to accommodate standardized ships (Panamax, Suezmax, and Malaccamax) designed to maximize the dimensions of those maritime chokepoints.

A deepwater network: The historical construction of an infrastructural zone around the Panama Canal

Infrastructural zones are path dependent, meaning that standards and network relations tend to be fixed within short historical windows in ways that influence the zone's subsequent development (Barry, 2006: 242–243). The Panama Canal infrastructural zone is organized around common lock and channel dimensions that date to the canal's opening in 1914. The waterway has been a chokepoint on Atlantic–Pacific maritime traffic since then, influencing the design of oceangoing ships and the organization of networks of navigable waterways that span continents.

The construction of the Panama Canal can be seen as a pivotal moment in a long-term global effort to connect bodies of water for navigation purposes. In many cases, aquatic connections have been established and maintained through dredging, which has been employed as a means of environmental modification and standardization for over a millennium (Vanderostyne and Cohen, 1999). Societies once used drags, buckets, and rakes powered by human and animal labor to deepen rivers and harbors and excavate canals for navigation and trade purposes. In the 19th century, humans conceived and completed earth-moving and transportation projects at larger scales, including navigable waterways. Advances in dredging technology—the invention of the steam engine, new pump and cutterhead designs, and the use of steel rather than wood materials (Vanderostyne and Cohen, 1999: 17, 23)—facilitated large-scale navigation projects. Around the world, people equipped with new technologies excavated canals and deepened natural waterways to connect formerly isolated bodies of water for transportation purposes (Scarpino, 2014). This was infrastructural work. In the United States, government institutions, port communities, commodity producers, traders, and shipping companies formed coalitions to advocate that the dimensions of domestic waterways be expanded and standardized to facilitate trade. US commercial interests also called for an interoceanic canal across Central America for the same reason. In fact, the idea of an engineered waterway network linking the US interior to the country's Atlantic and Pacific Coasts via Panama dates back centuries. The establishment and maintenance of such a network has depended on dredging adequate channels, the construction of navigation locks, and managing environments to achieve predictable channel dimensions for shipping.

Since the early 19th century, the Army Corps of Engineers (hereafter "Army Corps") has been the main US government institution responsible for the planning, engineering, construction, and maintenance of domestic waterways for military, commercial, and civilian navigation. The Army Corps has pursued a comprehensive approach—emphasizing systematic management and standardized channel dimensions—as they have developed thousands of miles of networked waterways, "turning North America into one of the world's most extensive hydrological systems" (Shallat, 1994: 202). By the late 19th century, the Army Corps had influenced other actors involved in navigation—shipping companies, patrons in Congress, city and state agencies, and port communities—to work cooperatively on a comprehensive waterway network (Shallat, 1989: 21). The Army Corps took control of existing navigation projects and managed a growing number of locks, dams, and canals, which it attempted to sync to existing lock and channel standards.

The Army Corps vision of a standardized domestic waterway system—a proto-infrastructural zone—became transnational through the construction of the Panama Canal. One revealing illustration of the coordinated action involved in establishing this infrastructural zone was the Lakes-to-the-Gulf Deep Waterway Association. Established in 1905, it was comprised of trade associations and municipal agencies from across the Mississippi Valley and became an important institutional arena for engineers, politicians, and commodity producers who relied on inland navigation. Around this time, engineers and politicians leading efforts to connect the Great Lakes and Mississippi River met with leaders from across the Mississippi Valley and began holding annual conventions in the river cities of Memphis, Saint Louis, and New Orleans to encourage government investment in inland waterway improvements. These conventions emphasized the future importance of the Panama Canal, then under construction; attendees included Presidents Theodore Roosevelt and Taft and, notably, Panamanian political leaders. In 1908, the Inland Waterways Commission, organized by Roosevelt, published a 700-page report on the modernization of US navigable waterways. In his foreword to the report, Roosevelt proclaimed that "the Mississippi should be made a loop of the sea" (USIWC, 1908).

The US government employed tens of thousands of laborers, implemented public health campaigns, and used an array of technologies to open a canal across Panama between 1904 and 1914 (McCullough, 1977). During that period, North American experts and technical standards traveled from the United States to Panama together. Many of the engineers who worked on the canal had experience in lock construction, dredging, flood control, and channel modification in the Mississippi Valley and Great Lakes regions, where the dimensions associated with the Ohio River locks (110 feet wide by 600 feet long) were becoming the navigation standard. Engineers with experience in large projects across the Mississippi's lower delta were hired to work with military engineers who had participated in the design and implementation of the nascent US inland waterway system. The Panama Canal's locks, opened in 1914, were the same width as the locks along the Ohio River (110 feet). They established the Panamax standard, which the transportation and shipping industries have lived with ever since.

What is the Panamax standard? Panama Canal administrators determine and publish requirements for passing vessels, including size limits. Panamax ships maximize, but do not exceed, one or more of the usable dimensions of the canal's lock chambers (965 feet long, 106 feet wide, 39.5 feet draft). This standard was established in the early 20th century, but few commercial ships exceeded the dimensions of the original locks before the last two decades of the century (some military vessels did earlier). Traffic through the Panama Canal increased after the Second World War, following an upward trend in global shipping. By the 1970s, US Atlantic ports were deepening their channels and harbors to match (or closely approach) the Panamax draft standard: 39.5 feet.

The dimensions of oceangoing ships also expanded in the late 20th century. In the 1980s, shipping companies began to purchase *post*-Panamax ships (too large to transit the canal's locks) to ply busy maritime routes. The explosion of ship sizes coincided with the container and logistics revolutions described in the preceding section. Between 1973 and 1983, the number of containers shipped by US, European, and Asian operators increased from 4 to 12 million (Cowen, 2014: 57). The largest containerships had drafts greater than 40 feet and could only dock in the few ports that possessed deep harbors and container handling infrastructure. As a result, post-Panamax ship traffic from Asia with cargo bound for eastern North America used deepwater Pacific ports like Los Angeles, Long Beach, and Seattle rather than the canal. Cargo was transferred to trucks and trains and routed overland via the "landbridge" of highways and railroad tracks. Pacific ports increased channel depth, but actors on the Atlantic and Gulf Coasts had less incentive to do so because they were situated on the far side of the canal chokepoint.

The Panama Canal expansion project changes the incentive structure for US Atlantic and Gulf Coast ports. It was approved in a Panamanian national referendum in 2006. Work began in 2007 and was completed in 2016. The project involved the construction of a third flight of larger locks to complement the two flights of original locks (Figure 2), and the deepening of channels and harbors in Panama associated with the canal. The expanded locks and deeper waterways can accommodate massive cargo ships that could not previously transit the canal. Moreover, the expansion establishes a shipping standard (New Panamax) that will complement the existing Panamax standard. The New Panamax containerships could carry as many as 13,000 containers, dwarfing the 5000-container maximum of Panamax ships.

Figure 2. The Panama Canal expansion project (2006–2016) involved the construction of a third flight of larger locks to complement the two flights of original locks and the deepening of channels and harbors. The canal's original locks (right) set the Panamax shipping standard. The new locks (left), shown here during construction in 2012, allow larger ships to transit and set the New Panamax standard. Photos by Ashley Carse.

The expansion project has been called a logistics "game changer," because it is expected to redistribute market share among ports and have implications for global import and export markets. Since its approval in 2006, the expansion has catalyzed a wave of investment in modernization and dredging across the sites that the canal connects. The key maritime routes served by the canal connect the Eastern United States and Asia, but the canal is also important for trade between the Eastern United States and Western South America, and Europe and Western South America, as well as South American and North American intercoastal trade (Panama Canal Authority, 2014). Port authorities on the US Atlantic and Gulf Coasts have raced to raise bridges, modernize facilities, and deepen waterways in hopes of attracting New Panamax ships and larger revenue streams. And as Brian Davis et al. (2015) point out in a sophisticated analysis of the networked and material dimensions of the canal expansion, waterway dredging projects along the US Atlantic and Gulf Coasts have been paralleled by "counter-expansion" projects around US West Coast ports, which stand to lose business to the expanded canal. The expansion, as a result, has also precipitated a new round of environmental standardization across these sites.

Emergent environments: Institutions, standardization, and the Panama Canal expansion

The Panama Canal expansion underscores the importance of conceptualizing environmental standardization as part of the crucial, but often ignored, organizational work that makes global transportation possible. To participate in the infrastructural zone that turns on the canal, institutions dispersed across continents have modernized transportation facilities to meet infrastructure standards and have managed neighboring coastlines, harbors, and inland waterways to reduce physical geographical variation. This can involve dredging waterways and constructing dams, locks, and other water management infrastructures under very different environmental conditions. For example, between 2009 and 2014, the Army Corps reported excavating almost 300 million cubic yards of material from the sediment-laden Lower Mississippi River. By contrast, dredging totals in US regions with naturally deep coastal waters, like Seattle or Boston, were closer to half a million cubic yards over the same period (USACE-NDC, 2016).

Historically, waterway management has often been the domain of state bureaucracies, or "hydrocracies" (Molle et al., 2009). Hydrocracies like those discussed in this article—the US Army Corps, Panama Canal Authority, and Port of New Orleans—have pursued command-and-control forms of environmental management intended to decrease hydrological variation and reduce the impacts of floods and droughts on engineered systems (Holling and Meffe, 1996). Environmental standardization practices are a precondition for global economic integration, logistics, and associated forms of value creation. And yet, they are always incomplete because the non-human world is irreducible to infrastructure or part of a sociotechnical network. Water (Bakker, 2004), cattle (Gardner, 2009), forests (Prudham, 2005), and biological systems (Boyd et al., 2001) have all proven resistant to industrialization and capitalization due to their material characteristics. As a result, logistical calculations are error prone when it comes to externalities. As Davis et al. (2015) write,

> They are jeopardized by the indeterminacy of landscape processes, not to mention self-serving distortions in the calculations themselves. While logistics can account for a certain degree of uncertainty, it relies too heavily on mathematical abstractions that exclude, externalize, or otherwise bracket out material, social, and ecological concerns.

Standards are intended to reduce complexity, but new environmental problems can also be generated in the process. The reorganization of waterways for navigation purposes can lead to the introduction of invasive species, the disruption of water salinity (a key parameter in aquatic ecosystems), and drinking water supply problems. For example, the dredging of the Lower Mississippi River during droughts has contributed to the intrusion of saltwater as far upriver as the intake siphons for the New Orleans municipal supply (Roach, 2012). This, in turn, has necessitated the construction of sediment traps and sills on the river bottom to prevent dense salt water from entering critical urban infrastructure. In Mobile Bay, Alabama, maintenance dredging of harbor access channels and the disposal of sediment in the open ocean exacerbates the erosion of barrier islands (Duncan, 2013). In Nicaragua, scientists and conservationists are concerned that the dredging of Lake Nicaragua may increase water turbidity, hypoxia, eutrophication and mobilize toxic sediment (Huete-Perez et al., 2015).

Dredging can, in concert with flooding or drought, precipitate what ecologists call regime shifts (Rocha et al., 2015; Scheffer and Carpenter, 2003). Regime shifts occur when a complex system reaches a critical threshold and, following a disturbance (like dredging), ecological relationships organize around a different set of feedbacks and parameters. The environments that emerge can complicate straightforward notions of degradation (and, indeed, restoration). For example, many dredging projects linked to developments across infrastructural zones involve the "beneficial use" of sediment. When authorities at the US Port of Mobile dredged a Panamax harbor approach channel in the late 1970s (attempting to match its dimensions to the infrastructure standard set by the canal's original locks), they used the sediment removed from the channel to create a two-square-mile, vegetated, predator-free island that is now home to up to 50,000 brown pelicans during breeding season and a popular destination for birders (Gates, 2011).

The beneficial use of dredged material has continued in projects associated with the canal expansion. New York deepened its harbor to the New Panamax standard, the Army Corps moved close to a half-million cubic yards of sand and soil to nourish beaches and marshes in the region, many impacted by Hurricane Sandy in 2012 (USACE, 2015). Similarly, the Army Corps has studied the viability of dredging the Lower Mississippi River to New Panamax standard of 50 feet. This would generate tremendous volumes of river sediment, some of

Figure 3. Top: The "beneficial use" of material dredged from the Mississippi River includes building landforms near the river's mouth to mitigate coastal land loss. Below: A storm surge barrier built in 2011 across the intersection of two shipping canals near New Orleans (skyline in distance). These canals, legacy projects that date to the era of the Panama Canal's opening in the early 20th century, have been contested since Hurricane Katrina. The deeper canal was decommissioned and closed off in response to political pressure. Photos courtesy of US Army Corps of Engineers, New Orleans District.

which could be used to nourish and protect the delta's rapidly eroding coastline (Figure 3). This practice is not so much "restoration" as it is the wholesale production of new environments whose material parameters are intertwined with the infrastructure standards of the maritime transportation system.

Rather than asking if dredging is good or bad in principle, we approach environmental standardization as political ecologists, asking: Who benefits? Who is adversely affected? Economic dependencies accrete around infrastructure standards as businesses and people come to rely upon navigation projects and the modified environments that reproduce them. Over time, these actors may become constituencies for more intensive management and more efficient operation. The cumulative effect, according to CS Holling and Gary Meffe (1996), is "less resilient and more vulnerable ecosystems, more myopic and rigid institutions, and more dependent and selfish economic interests all attempting to maintain short-term success" (331). Thus, hydrocracies face ecological and political developments that seem to call for more command-and-control interventions.

Dredging the Savannah River in Georgia to the New Panamax standard is expected to allow saltwater to creep dozens of miles upstream from the ocean, likely transforming hundreds of acres of freshwater marsh into open water and salt marsh (USACE, 2016). The intrusion of saltwater also has more subtle ramifications. As pockets of saltwater become established upstream, estuary ecosystems face hypoxia (oxygen depletion) and eutrophication (nutrient oversupply). These are among the most widely cited impacts of dredging in coastal river systems. They can trigger algal blooms and mass die-offs of aquatic life (Livingston, 2014). In response to hypoxia risks associated with the Savannah River deepening project, the Army Corps has awarded a US$100 million contract to a private firm to install an oxygenation system intended to mitigate some of the ecological consequences of reduced oxygen levels in the river (Landers, 2015). This is all part of the mundane but consequential infrastructural work that goes into managing environments transformed to facilitate global transportation.

Centuries of management interventions around established navigation routes like the Panama Canal or Mississippi River have transformed environments and generated complicated politics. The obduracy of infrastructure networks as a persistent landscape element over long time periods has environmental and political implications (Hommels, 2005). Economic, technological, and cultural dependencies gradually develop around modified environments, giving rise to political constituencies that are committed to maintaining particular enactments of the environment (Jørgensen, 2009; Law, 2004). These emergent environments can take on a path-dependency. Over decades, management strategies become layered, generating regional political conflicts.

Friction: Episodes of contention around infrastructure standards

Conflicts can emerge around the distribution of the economic benefits and environmental burdens of transportation projects, particularly during moments when infrastructural zones are reorganizing around new standards. Consider, for example, tensions across the Caribbean Sea and Gulf of Mexico associated with dredging projects motivated by the Panama Canal expansion. In 2015, environmental regulatory agencies and environmental groups raised concerns that a project to deepen Miami's harbor channel to the New Panamax standard would damage fragile coral reefs already distressed by changing ocean temperatures and pollution. Ocean currents have carried sediment from dredging projects near the port and buried an expanse of reef nearly a mile long, 10 times the area predicted by the Army Corps (Alvarez, 2016). The reefs of southeastern Florida, the only shallow water reef ecosystems in the continental United States, provide a natural breakwater during tropical storm surges. A coalition of environmental organizations in nearby Fort Lauderdale, Florida—where another New Panamax dredging project was approved—filed paperwork to sue the Army Corps and initiate another round of environmental impact studies and regulatory reviews (Milman, 2016; Gallagher, 2016). Meanwhile, Jamaican fishers and environmental groups opposed a Chinese company's plans to develop a transshipment hub and New Panamax harbor channel on the Goat Islands, which is currently a national protected area (Save Goat Islands, 2016). And, in the Gulf of Mexico, two competing plans to open the Mississippi River to New Panamax ships moved forward: a river dredging project and an offshore cargo port project slated for the open gulf near the river's mouth. Each of these projects, their emergent environments, and the political contention surrounding them, are linked to the lock expansion in Panama.

In addition to tensions around dredging, other modernization projects associated with the Panama Canal expansion have also been opposed on environmental grounds. A central concern associated with the expansion of ports facilities is increased emissions from containerships and the diesel-fueled trucks and locomotives that carry containers inland (Hricko, 2012). In 2013, the Port Authority of New York and New Jersey proposed to raise the Bayonne Bridge by 64 feet to allow New Panamax ships stacked higher with containers to access three area ports. Local communities protested the project to increase the bridge's "air draft" and raised concerns that bigger ships would make air quality worse. Some researchers suggest that environmental concerns extend far beyond port communities. For example, increased freight transportation due to the expansion may increase air pollution along the Interstate 95 corridor and other major East Coast highways (Corbett et al., 2012). Meanwhile, in California, a "Beat the Canal" campaign promoted the competitiveness of West Coast corridors in the face of a projected post-expansion loss of business to ports on the Atlantic and Gulf Coasts. To this end, the Los Angeles City Council approved a controversial US$500 million rail yard to be built by the ports of Los Angeles and Long Beach with the firm BNSF. This alarmed some nearby residents, who sued the terminal developers over air quality and respiratory health concerns, successfully halting the project pending further regulatory review and redesign in March 2016 (Edwards, 2016).

Scholarship on social movements can help us conceptualize how infrastructure standards and associated environmental issues emerge as sites of political contention and change (Ernstson et al., 2008; Snow et al., 2007). Contention is often punctuated and unevenly distributed across time and space (Koopmans, 2007). As it intensifies, so-called "normal politics"—persistent patterns of political power—become destabilized and new opportunities for advocates and challengers of a particular policy or interest emerge.

When infrastructure standards are subject to modernization pressure, political opportunities for various social actors may shift. The dynamics of contention are contingent and shaped by localized geographical and socio-political factors across infrastructural zones like the one that turns on the Panama Canal. The construction of a new standardized ship lock or the dredging of a new standardized waterway requires political mobilization among waterway users, port agencies, elected officials, engineers, and so forth. Other groups may contest these same initiatives through their own forms of alliance-building and collective action. And their actions may be driven by prior enactments of the environment in the same region that were linked to different long networks and competing visions of economic development and social priorities. Efforts by North American port authorities and transportation interests to modernize existing infrastructures due to the Panama Canal expansion have thus given rise to historically sedimented environmental conflicts in multiple localities.

Channel dredging, lock construction and maintenance, and environmental management technologies like river training structures, levees, bank revetments, and so forth, are financially and technologically intensive. For example, the Army Corps issued contracts in the amount of US$1.6 billion over a decade to deepen navigation channels serving four container terminals operated by the Port of New York and New Jersey to the New Panamax standard of 50 feet (USACE, 2015). The need for, benefits of, and risks associated with such projects are frequently subject to political contestation. The Army Corps, its supporters in the US Congress, and the private interests that utilize navigation projects (shipping firms, port agencies, maritime industries, real estate developers) have been described as an "iron triangle" that systematically exaggerates potential project benefits, downplays risks, and builds infrastructures with maintenance costs that rapidly exceed their benefits to the public (Baxter, 2014; Pilkey and Dixon, 1996).

Indeed, one legacy of the canal expansion, as Brian Davis et al. point out (2015), "may be a constellation of overbuilt and underutilized infrastructure projects and degraded ecosystems." In New Orleans, Army Corps planners have been accused of systematically favoring the interests of their clients (the Port of New Orleans and the firms that operate there) over the concerns of communities directly impacted by infrastructure modernization and expansion (Freudenburg et al., 2009; Lauria and Soll, 1996). The projects most maligned by New Orleans publics as potential flooding hazards and financially wasteful have absorbed millions of dollars in maintenance costs, provided few economic benefits, triggered ecological transformations, and exacerbated flooding risks (Freudenburg et al., 2009; Lewis and Ernstson, in review).

While it is the case that changes in infrastructural zones provide opportunities to build alliances around new projects, they can also provide openings to introduce regulatory requirements, resist the status quo, and decommission projects. This echoes the commonplace idea in science and technology studies that infrastructures become more visible and, thus, politicized at moments of systemic change (Star and Ruhleder, 1996). Examples from New Orleans and the extensively urbanized and intensively managed Mississippi River Delta help illustrate this observation. Navigation infrastructures and environmental management practices across the lower delta have historically been tied to the Panama Canal for the reasons explained above. An ongoing initiative to dredge the lowermost Mississippi River to the New Panamax standard has garnered support from shipping interests throughout the Mississippi Valley who rely on the economies of scale generated by large ships accessing the Ports of New Orleans and South Louisiana. Layered over this elite initiative is a push by community and environmental groups to utilize the large sediment volumes that would be dredged to restore parts of the Mississippi's rapidly eroding deltaic plain—erosion brought on, in part, by infrastructural and environmental standardization measures intended to enhance the area's navigability for large ships (Figure 3).

Infrastructural crises provide political openings for those seeking to promote other projects and policies, or to address grievances. In the swamps and marshes surrounding New Orleans, the region's port agencies have developed a powerful land use planning and development coalition to dig and maintain oceanic canal networks through the delta (Azcona, 2006). While the so-called "iron triangle" of waterway users, the US Congress, and Army Corps had maintained a powerful development coalition for much of the 20th century, Hurricane Katrina temporarily disturbed these relationships and created an opportunity to alter the region's waterway networks and dredging practices. Following Hurricane Katrina in 2005, collective action led to the successful closure of the Mississippi River–Gulf Outlet channel, a 75-mile navigation channel between the Gulf of Mexico and New Orleans' inner harbor Industrial Canal that was designed and built just after the opening of the Panama Canal in 1914 by engineers who had worked on the isthmus (Figure 3). The Army Corps' poor management of the project—long criticized by the region's marginalized communities and environmentalists—has led to intensified urban flooding and ecological regime shifts across a vast territory (Saltus et al., 2012). After Katrina, a coalition of environmentalists and community groups successfully pressured US officials to close the channel in two locations with rock and concrete structures, which decreased tidal flows and lowered salinity levels in surrounding estuaries (Marshall, 2015).

After the channel closure, constituencies made competing claims to different enactments of the environment—some historical, some actual, and some unrealized. Many urban residents, business interests, and environmental groups hailed declines in salinity in the marshes surrounding New Orleans as a sign that the freshwater coastal forests that once ringed the city could be restored as an urban resilience strategy, creating a natural buffer against storm surges to complement the city's extensive engineered flood protection infrastructures (Lewis et al., 2015; Lewis and Ernstson, in review). However, a coalition of fishing industry groups organized by the Save Louisiana Coalition have opposed any project designed to decrease salinity in the state's southeastern marshes on the grounds that it would destroy productive saltwater fisheries (despite the fact that freshwater conditions predominated before 1960). Thus, infrastructure standards gave rise to an environment that is more vulnerable to storm surges and more lucrative for commercial fishing and associated industries. Controversies over how to identify ecological baselines in systems transformed by transportation projects and management interventions have become a consistent theme in regional politics, because debates over shipping channels are also debates about storm surge hydro-dynamics, environmental racism, and failing oyster fisheries (Lewis et al., 2015; Lewis and Ernstson, in review).

Conclusion

What do hulking container ships have to do with conflicts about a reef buried in sediment near Miami, the height of a bridge in New Jersey, the construction of a new rail yard in Los Angeles, and the restoration of coastal marshes in Louisiana? The thread that connects ships, waterways, sediment, and communities across these cases is the expansion of the Panama Canal and, more generally, the environmental politics, values, and assumptions associated with infrastructure standards. While the opening of the canal's expanded locks in 2016 may appear to be the culmination of a megaproject situated in Panama, we have approached it as a networked environmental standardization event that reveals something important about how global infrastructures articulate with situated environmental politics.

In this article, we have drawn attention to the political ecology of infrastructure standards. Scholars of infrastructure have rightly emphasized the crucial, but often ignored, role of sociotechnical standards or gateway technologies in coordinating systems across space, but have tended to overlook the essential role of environmental standardization practices in making and maintaining global connection. This way of seeing recalls Bruno Latour's (1993) memorable question—"Is a railroad local or global?"—and his provocative reply:

> Neither. It is local at all points since you always find sleepers and railroad workers, and you have stations and automatic ticket machines scattered along the way. Yet it is global, since it takes you from Madrid to Berlin or from Brest to Vladivostok. (117)

More interesting for our purposes is the more general claim that follows:

> [technical networks] are composed of particular places, aligned by a series of branchings that cross other places and require other branchings in order to spread. Between the lines of the network there is, strictly speaking, nothing at all: no train, no telephone, no intake pipe, no television set. Technological networks, as the name indicates, are nets thrown over spaces. They are connected lines, not surfaces. (Latour, 1993: 117–118)

If we replace Latour's train lines with waterways, the geography of the network becomes more fluid and layered. Below the water's surface are currents and moving sediment and ecological communities. Around it are human communities that use—or would like to use—that same water for fishing, irrigation, drinking water, and recreation. By emphasizing geographies of lines and nodes we tend to minimize the degree to which our sociotechnical networks are inextricable from landscapes and waterscapes.

To understand the political ecology of global transportation, we have to analyze infrastructure and environment together. This does not simply mean paying attention to the unequal distribution of the direct environmental impacts of transportation networks like water and air pollution, but attending to how ecologies are modified in more subtle, but still political ways. By focusing on infrastructure standards, we draw attention to environmental and political connections that may otherwise go unnoticed. Our examples from Panama and associated ports and waterways in North America show how technical and environmental standards can be transported across and embedded in landscapes and waterscapes. We also described how those standards are maintained and destabilized by processes of political mobilization and contention.

Driven by the New Panamax connection standard—fixed to the expanded dimensions of the Panama Canal's new flight of locks—local, state, and regional institutions in North America are once again deepening waterways and modernizing facilities in order to be able to participate in the 21st-century version of an old infrastructural zone. Following other political ecologists studying global assemblages (Ogden et al., 2013), planetary urbanization (Brenner, 2013), territorial development (Storper and Walker, 1989), situated environmental conflicts (Lawhon et al., 2014), and the environmental history of the world system (Moore, 2011), we believe that networked environmental transformations associated with transportation demand new ways of conceptualizing the geographies and politics of environmental change at a moment when the human reorganization of the planet is a matter of great concern. Following Paul Robbins (2014), we might view infrastructural zones as chains of accumulation where political contention and ecological change play out in the gaps between networked capital investments (infrastructures), landscapes, and waterscapes. The conflicts over environmental transformation that emerge through relations between distant chokepoints, waterways, and ports are, as Robbins points out, "not merely isolated objects in an unfortunate state of momentary geographic association," but "a set of connected sites through which *value flows*, which are mutually constituted by their relationships along far more vast chains of accumulation" (Robbins, 2014: 233, emphasis original). We believe that a political ecological of infrastructure standards might render these complex geographic associations more legible for analysts, activists, and policymakers alike.

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References

Alvarez L (2016) Dredging of Miami Port badly damaged coral reef, study finds. *New York Times,* 1 May.

Azcona BL (2006) The razing tide of the Port of New Orleans: power, ideology, economic growth and the destruction of community. *Social Thought and Research* 27: 69–109.

Bakker K (2004) *Uncooperative Commodity: Privatising Water in England and Wales*. Oxford: Oxford University Press.

Banister D (1993) *Transport, the Environment and Sustainable Development*. London: Spon Press.

Barry A (2006) Technological zones. *European Journal of Social Theory* 9(2): 239–253.

Baxter V (2014) Rent, real estate, and flood mitigation in New Orleans East. *Antipode* 46(4): 1014–1031.

Bélanger P (ed.) (2014) Wet matter. *Harvard Design Magazine* 39.

Bowker GC (1994) *Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920-1940*. Cambridge, MA: MIT Press.

Bowker GC and Star SL (1999) *Sorting Things Out: Classification and its Consequences*. Cambridge, MA: MIT Press.

Boyd W, Prudham WSP and Schurman RA (2001) Industrial dynamics and the problem of nature. *Society and Natural Resources* 14: 555–570.

Brenner N (2013) Theses on urbanization. *Public Culture* 25(1): 85–114.

Busch L (2011) *Standards: Recipes for Reality*. Cambridge, MA: MIT Press.

Carse A (2012) Nature as infrastructure: making and managing the Panama Canal watershed. *Social Studies of Science* 42(1): 539–563.

Carse A (2014) *Beyond the Big Ditch: Politics, Ecology, and Infrastructure at the Panama Canal*. Cambridge, MA: MIT Press.

Carse A (2016) Keyword: infrastructure - how a humble French engineering term shaped the modern world. In: Harvey P, Jensen CB and Morita A (eds) *Infrastructures and Social Complexity: A Routledge Companion*. London and New York: Routledge.

Corbett JJ, Deans E, Silberman J, et al. (2012) Panama Canal expansion: emission changes from possible US West Coast modal shift. *Carbon Management* 3(6): 569–588.

Cowen D (2014) *The Deadly Life of Logistics: Mapping Violence in Global Trade*. Minneapolis: University of Minnesota Press.

Davis B, Holmes R and Milligan B (2015) Isthmus: on the Panama Canal expansion. *Places Journal*.

De Langen PW and Visser EJ (2005) Collective action regimes in seaport clusters: the case of the Lower Mississippi port cluster. *Journal of Transport Geography* 13(2): 173–186.

Ducruet C and Notteboom T (2012) The worldwide maritime network of container shipping: spatial structure and regional dynamics. *Global Networks* 12(3): 395–423.

Duncan RS (2013) *Southern Wonder: Alabama's Surprising Biodiversity*. Tuscaloosa: University of Alabama Press.

Easterling K (2014) *Extrastatecraft: The Power of Infrastructure Space*. London and New York: Verso.

Edwards A (2016) Long Beach wins lawsuit over $500 million rail yard plan for Port of Los Angeles. *Long Beach Press-Telegram,* 30 March.

Edwards PN (2003) Infrastructure and modernity: Force, time, and social organization in the history of sociotechnical systems. In: Misa TJ, Brey P and Feenberg A (eds) *Modernity and Technology*. Cambridge, MA: MIT Press, pp. 185–226.

Edwards PN, Jackson SJ, Bowker GC, et al. (2007) Understanding infrastructure: dynamics, tensions, and design. *Workshop on History and Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures*. Washington, DC: National Science Foundation.

Egyedi T (2001) Infrastructure flexibility created by standardized gateways: the cases of XML and the ISO container. *Knowledge, Technology and Policy* 14(3): 41–54.

Ernstson H, Sörlin S and Elmqvist T (2008) Social movements and ecosystem services—the role of social network structure in protecting and managing urban green areas in Stockholm. *Ecology and Society* 13(2): 39.

Feitelson E (2002) Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls. *Transportation Research Part D: Transport and Environment* 7(2): 99–118.

Forkenbrock DJ and Schweitzer LA (1999) Environmental justice in transportation planning. *Journal of the American Planning Association* 65(1): 96–112.

Freudenburg WR, Gramling R, Laska S, et al. (2009) *Catastrophe in the Making: The Engineering of Katrina and the Disasters of Tomorrow*. Washington, DC: Island Press.

Gallagher J (2016) Wildlife advocates team up against Port Everglades dredging. *IHS Marine Fairplay Magazine*.

Gardner B (2009) Are livestock a troublesome commodity? *Geoforum* 40(5): 781–783.
Gates V (2011) Island off Alabama coast bursting with birds after oil spill. Reuters News Agency. Available at: http://www.reuters.com/article/2011/07/10/us-oil-alabama-birds-idUSTRE7692FL20110710 (accessed 25 July 2016).
Holling CS and Meffe GK (1996) Command and control and the pathology of natural resource management. *Conservation Biology* 10(2): 328–337.
Hommels A (2005) Studying obduracy in the city: Toward a productive fusion between technology studies and urban studies. *Science, Technology and Human Values* 30(3): 323–351.
Houston D, Krudysz M and Winer A (2008) Diesel truck traffic in low-income and minority communities adjacent to ports: environmental justice implications of near-roadway land use conflicts. *Transportation Research Record: Journal of the Transportation Research Board* 2067(1): 38–46.
Hricko A (2012) Progress and pollution: Port cities prepare for the Panama Canal expansion. *Environmental Health Perspectives* 120(12): A471–A473.
Huete-Perez JA, Meyer A and Alvarez PJ (2015) Rethink the Nicaragua canal. *Science* 347(6220): 355–355.
Hughes TP (1987) The evolution of large technological systems. In: Hughes TP, Bijker WE and Pinch T (eds) *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge, MA: MIT Press, pp. 51–82.
Jørgensen D (2009) An oasis in a watery desert? Discourses on an industrial ecosystem in the Gulf of Mexico Rigs-to-Reefs Program. *History and Technology* 25: 343–364.
Kennedy L (2004) *Transportation and Environmental Justice*. Bristol, UK: Policy Press.
Koopmans R (2007) Protest in time and space: the evolution of waves of contention. In: Snow DA, Soule SA and Kriesi H (eds) *The Blackwell Companion to Social Movements*. Malden, MA: Blackwell, pp. 19–46.
Landers M (2015) Corps awards $100 million oxygen 'bubbler' contract for Savannah harbor deepening. *Savannah Morning News* 3 August. Available at: http://savannahnow.com/news-latest-news-harbor-deepening/2015-08-03/corps-awards-100-million-oxygen-bubbler-contract (accessed 25 July 2016).
Latour B (1993) *We Have Never Been Modern*. Cambridge, MA: Harvard University Press.
Latour B (2005) *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford, UK: Oxford University Press.
Lauria M and Soll MJ (1996) Communicative action, power, and misinformation in a site selection process. *Journal of Planning Education and Research* 15(3): 199–211.
Law J (2004) Enacting naturecultures: a note from STS. Center for Science Studies, Lancaster University, Lancaster, UK. Available at: http://www.comp.lancs.ac.uk/sociology/papers/law-enacting-naturecultures.pdf (accessed 25 July 2016).
Lawhon M, Ernstson H and Silver J (2014) Provincializing urban political ecology: Towards a situated UPE through African urbanism. *Antipode* 46(2): 497–516.
Levinson M (2006) *The Box: How the Shipping Container made the World Smaller and the World Economy Bigger*. Princeton, NJ: Princeton University Press.
Lewis JA, Yoachim A and Meffert D (2015) Crisis on the delta: Emerging trajectories for New Orleans. In: Glavovic B, Kelly M, Kay R, et al. (eds) *Climate Change and the Coast: Building Resilient Communities*. London: CRC Press.
Lewis JA and Ernstson H (in review) Contesting the coast: Socioecological cleavages and coastal planning in the Mississippi River Delta. *Progress in Planning*.
Livingston RJ (2014) *Climate Change and Coastal Ecosystems: Long-Term Effects of Climate and Nutrient Loading on Trophic Organization*. Boca Raton, FL: CRC Press.
Marshall B (2015) Dam it: Fishers frustrated by closing of MRGO, but some catches increase. *The New Orleans Lens*, 13 March. Available at: http://thelensnola.org/2015/03/13/dam-it-fishers-frustrated-by-closing-of-mrgo-but-catches-are-up/ (accessed 25 July 2016).
Martinez Alier J (2009) Social metabolism, ecological distribution conflicts, and languages of valuation. *Capitalism Nature Socialism* 20(1): 58–87.

McCullough D (1977) *The Path Between the Seas: The Creation of the Panama Canal 1870–1914*. New York: Simon & Schuster Paperbacks.

Milman O (2016) Dredging Florida coral reef is 'lunacy' says Phillippe Cousteau, grandson of Jacques. *The Guardian*. 24 March.

Molle F, Mollinga PP and Wester P (2009) Hydraulic bureaucracies and the hydraulic mission: flows of water, flows of power. *Water Alternatives* 2(3): 328–349.

Moore JW (2011) Transcending the metabolic rift: a theory of crises in the capitalist world-ecology. *The Journal of Peasant Studies* 38(1): 1–46.

Morello-Frosch R, Pastor M and Sadd J (2001) Environmental justice and Southern California's "riskscape": the distribution of air toxics exposures and health risks among diverse communities. *Urban Affairs Review* 36: 551–578.

Ng AK, Ducruet C, Jacobs W, et al. (2014) Port geography at the crossroads with human geography: between flows and spaces. *Journal of Transport Geography* 41: 84–96.

Ogden L, Heynen N, Oslender U, et al. (2013) Global assemblages, resilience, and earth stewardship in the Anthropocene. *Frontiers in Ecology and the Environment* 11(7): 341–347.

Ong A and Collier SJ (eds) (2005) *Global Assemblages: Technology, Politics, and Ethics as Anthropological Problems*. Malden, MA: Blackwell.

Panama Canal Authority (2014) Annual report 2014. Available at: https://www.pancanal.com/eng/general/reporte-anual/2014/pdf/annual-report-2014.pdf (accessed 25 July 2016).

Pilkey OH and Dixon KL (1996) *The Corps and the Shore*. Washington, DC: Island Press.

Prudham WS (2005) *Knock on Wood: Nature as Commodity in Douglas-Fir Country*. London: Routledge.

Ramos SJ (2014) Planning for competitive port expansion on the US Eastern Seaboard: the case of the Savannah Harbor Expansion Project. *Journal of Transport Geography* 36: 32–41.

Roach J (2012) Drought reaches New Orleans; Hurricane Isaac could add insult to injury. *National Geographic News,* 25 August.

Robbins P (2012) *Political Ecology: A Critical Introduction*, 2nd ed. West Sussex: Wiley-Blackwell.

Robbins P (2014) Cries along the chain of accumulation. *Geoforum* 54: 233–235.

Rocha J, Yletyinen J, Biggs R, et al. (2015) Marine regime shifts: drivers and impacts on ecosystems services. *Philosophical Transactions of the Royal Society B* 370: 1–12.

Rodrigue JP (2004) Straits, passages and chokepoints: a maritime geostrategy of petroleum distribution. *Cahiers de Geographie de Quebec* 48(135): 357–374.

Rodrigue JP and Notteboom T (2009) The geography of containerization: half a century of revolution, adaptation and diffusion. *GeoJournal* 74(1): 1–5.

Rodrigue JP and Notteboom T (2015) The legacy and future of the Panama Canal: from point of transit to transshipment hub. *TR News* 296.

Rodrigue JP, Comtois C and Slack B (2013) *The Geography of Transport Systems*, 3rd ed. London and New York: Routledge.

Saltus CL, Suir GM and Barras JA (2012) *Land and forest area changes in the vicinity of the Mississippi River Gulf Outlet, Central Wetlands Region, 1935–2010*. United States Army Corps of Engineers Report, No. ERDC/EL-TR-12-7. Vicksburg, MS: Engineer Research and Development Center Environmental Lab.

Sassen S (2006) *Territory, Authority, Rights: From Medieval to Global Assemblages*. Princeton, NJ: Princeton University Press.

Save Goat Islands (2016). Available at: http://savegoatislands.org/ (accessed 25 July 2016).

Scarpino PV (2014) A historian's perspective on rivers of the Anthropocene. In: Bhaduri A, Bogardi J, Leentvaar J, et al. (eds) *The Global Water System in the Anthropocene*. Cham: Springer, pp. 161–171.

Scheffer M and Carpenter SR (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. *Trends in Ecology & Evolution* 18(12): 648–656.

Schiller PL, Bruun EC and Kenworthy JR (2010) *An Introduction to Sustainable Transportation*. London: Routledge.

Shallat TA (1989) Engineering policy: the US Army Corps of Engineers and the historical foundation of power. *The Public Historian* 11(3): 7–27.

Shallat TA (1994) *Structures in the Stream: Water, Science, and the Rise of the US Army Corps of Engineers*. Austin: University of Texas Press.

Snow DA, Soule SA and Kriesi H (eds) (2007) *The Blackwell Companion to Social Movements*. Malden, MA: Blackwell.

Star SL and Ruhleder K (1996) Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information Systems Research* 7(1): 111–134.

Storper M and Walker R (1989) *The Capitalist Imperative: Territory, Technology, and Industrial Growth*. New York: Blackwell.

Timmermans S and Epstein S (2010) A world of standards but not a standard world: toward a sociology of standards and standardization. *Annual Review of Sociology* 36: 69–89.

Tournadre J (2014) Anthropogenic pressure on the open ocean: the growth of ship traffic revealed by altimeter data analysis. *Geophysical Research Letters* 41: 1–9.

Tsing AL (2005) *Friction: An Ethnography of Global Connection*. Princeton, NJ: Princeton University Press.

UNCTAD (2014) Review of maritime transport, 2014. *United Nations Conference on Trade and Development*. Geneva and New York: United Nations.

USACE (2015) Fact Sheet – New York and New Jersey Harbor (50 ft. Deepening). United States Army Corps of Engineers, New York District. Available at: http://www.nan.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/11241/Article/487407/fact-sheet-new-york-and-new-jersey-harbor-50-ft-deepening.aspx (accessed 25 July 2016).

USACE (2016) "Savannah Harbor Expansion" United States Army Corps of Engineers, Savannah District. Available at: http://www.sas.usace.army.mil/Missions/Civil-Works/Savannah-Harbor-Expansion/ (accessed 25 July 2016).

USACE-NDC (2016) *US Waterway Data: Dredging Information System*. Alexandria, VA: United States Army Corps of Engineers Navigation Data Center.

USEPA (2000) *The Lean and Green Supply Chain: A Practical Guide for Materials Managers and Supply Chain Managers to Reduce Costs and Improve Environmental Performance*. United States Environmental Protection Agency Report, 742-R-00-001. Washington, DC: Office of Pollution Prevention and Toxics.

USIWC (1908) *Preliminary report of the Inland Waterways Commission: Message from the President transmitting a preliminary report*. United States Inland Waterways Commission. Washington, DC: Government Printing Office.

Vanderostyne M and Cohen M (1999) From hand-drag to jumbo: a millennium of dredging. *Terra et Aqua* 77: 1–47.