Journal of Global History (2026), 21: 1, 41–59
doi:10.1017/S1740022825100235

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

Ballast: Approaching nineteenth-century maritime mobility 'from below'

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Abstract

This article explores the nineteenth-century history of ship's ballast to study global maritime mobility 'from below', both socially and materially. Though mostly overlooked by contemporaries and historians alike, ballast was both a necessary resource for and a constraint on sea travel. This article examines ballast in four steps. First, it defines ballast in terms of its function, materiality, and value. Second, it studies ballast in the littoral zone, where specialized ballasting organizations depended on precarious labour and where both its production and disposal became entangled with environmental agendas and concerns. In a third step, the article focuses on ballast at sea, where it materially and sometimes detrimentally impacted the experience of 'being in transit'. Finally, the article considers the transition to water ballast as an example for the persistence and staying-power of seemingly obsolete technologies and associated labour regimes. Ballast was an obscure but powerful enabler of sea travel. Maintaining this connectivity rested both on the widespread mobilization of labour for ballast practices and on the global movement of vast amounts of otherwise useless weight.

Keywords: ballast; history 'from below'; ports; ships; shipping; nineteenth century; environment; steam power; transit; trade

Introduction: Ballast and the underbelly of maritime mobility

For many centuries, sea travel was the dominant form of global mobility. Ships served as prime conduits of connection, carrying trade goods, passengers, and news to coasts and ports around the world. Maritime mobility only became more important during the nineteenth century when the sail-to-steam transition reduced travel times, increased tonnage, and regularized global mobility.[1] Yet sea travel at this scale, indeed sea travel itself, would have been impossible but for ballast. Ballast is a highly underappreciated and an almost entirely unstudied subject in maritime history. In this article, I use it as a lens to examine the history of global maritime mobility 'from below' with a focus on the nineteenth century.

Simply put, ballast is additional weight that ships loaded deep into their holds to lower their centre of gravity. This stabilizes the ship when carrying especially light, little, or no cargo and helps achieve the optimal trim and draft. Materially, this ballast could take many different forms, often consisting of sand, shingle, and stones, because these were cheap, dense, easily available materials. As a crucial component of global, maritime mobility infrastructure, ballast was deeply entangled with life and practices on ship and shore. Every year, millions of tonnes of ballast were produced, sold, loaded, and transported around the world, before being dumped overboard once new cargo

[1]For a concise summary of the 'globalization of the seas', Michael North, *A World History of the Seas: From Harbour to Horizon*, trans. Pamela Selwyn (Bloomsbury, 2022), 197–224.

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https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press

became available. Indisputably useful though ballast was, it was also what Roland Wenzlhuemer has called a 'mostly unwelcome by-product of maritime trade'.[2] Ballast was carried more from necessity than choice, to ensure a safe and swift passage, but it was replaced by more valuable commodities as soon as feasible.

In this article, I argue that the history of ballast in the nineteenth century presents a global history 'from below' in a dual sense.

E. P. Thompson coined the expression of a 'history from below' in 1966 with the intention of 'liberating' social and labour history from 'the established constitutional and parliamentary-political Thing' – that is, British mainstream historiography.[3] In world and global history, scholars like Antoinette Burton and Tony Ballantyne have since expanded on Thompson's work and studied world histories 'from below', which in many cases are histories of mobility and highly mobile people.[4] Ballast contributes to our understanding of these Thompsonian social histories of mobility. It was a key enabler of the sometimes involuntary and often troubled mobility of the subaltern sailor, the destitute emigrant, as well as the indentured or enslaved traveller. Their mobility at sea rested on extensive land-based efforts required to produce, deliver, and dispose of ballast. This was work performed by some of the most deprived groups of port labourers.

To this social history of making and maintaining mobility, I add a second layer: a history from below in a very literal, material sense. The physical location and placement of ballast mattered greatly. At sea, tonnes upon tonnes of sand and dirt were stowed deep below deck, a position from where such ballast could undermine an entire ship's stability and thus critically affect the quality of travel and indeed the very lives and well-being of everyone on board. Ballast could fundamentally disrupt maritime mobility itself. Moreover, near the shore, the production and disposal of ballast below the waterline also had far-reaching impacts on the navigability and ecology of harbours, riverbeds, and coastlines. In determining the historical role of ballast this dual history from below reveals the fundamental tension between ballast as a necessary resource and an enabler of global connections, but simultaneously as a source of danger and disruption. In a very immediate way, ballast could disturb the smooth sailing of any vessel; in a structural way, the stability requirements of ships made them beholden to local forms of ballast organizations, adding to costs and delays.

The nineteenth century was the heyday of ballast usage. With more and larger ships travelling the oceans than ever before, global usage of (solid) ballast reached an all-time peak. At the same time, ballast itself underwent its most fundamental transformation. The technological confluence of metal hull construction and the spread of steam propulsion made it economically viable to replace solid forms of ballast with seawater, which was pumped into and out of tanks and double bottoms. The first commercial uses of water ballast are recorded in the 1850s, but it took decades for this technology to mature, while sand and stones persisted as reliable sources of stability at sea into the twentieth century.

Despite its fundamental importance, the literature on ballast is surprisingly scarce. Ballast is missing in the latest major syntheses on maritime history and the few existing historical

[2]Roland Wenzlhuemer, 'Shipping Rocks and Sand: Ballast in Global History', *Bulletin of the German Historical Institute* 68 (2021): 3–17, 16.

[3]E. P. Thompson, 'History from Below', *Times Literary Supplement*, 7 April 1966, 279–81, 280.

[4]Antoinette Burton and Tony Ballantyne, 'Keywords: "World History," "Below," and "Dissent and Disruption"', in *World Histories From Below: Disruption and Dissent, 1750 to the Present*, ed. Antoinette Burton and Tony Ballantyne (Bloomsbury, 2016), 1–9. Recent studies of maritime mobility 'from below', both socially and spatially, include John Harris, *The Last Slave Ships: New York and the End of the Middle Passage* (Yale University Press, 2020), 93–136; Saurabh Mishra, 'Violence, Resilience and the "Coolie" Identity: Life and Survival on Ships to the Caribbean, 1834–1917', *Journal of Imperial and Commonwealth History* 50, no. 2 (2022): 241–63; Marcus Rediker, 'Toward a People's History of the Sea', in *Maritime Empires: British Imperial Maritime Trade in the Nineteenth Century*, ed. David Killingray, Margarette Lincoln, and Nigel Rigby (Boydell & Brewer, 2004), 195–206.

https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press

contributions are either local histories focussed on individual ports or institutions or have a primarily technical outlook that obscures the wider economic and social implications of ballast.[5] Although archaeologists have created a substantial body of literature documenting ballast, they have treated it more as a proxy to trace shipping routes and locate ancient ports than as an object of study in and of itself.[6] In the 1950s, biologists first identified solid ballast as a vector for the spread of invasive species, and since the 1980s, they have also recognized the ecological impact of water ballast.[7] Both archaeology and biology have thus made helpful contributions, but these hardly exhaust the potential of ballast for historical inquiry.

A closer focus on ballast sheds new light on various fields of historical research. Its significance as a transport vehicle for seeds, beetles, and micro-organisms makes it an interesting object of study for maritime history following the *oceanic turn*, which aimed to integrate environmental and ecological strands more closely into social, political, and cultural histories of the ocean.[8] Ballast is also an example of a very old and (for most of its existence) very simple technology with significant staying power. The fact that solid ballast persisted well after the sail-to-steam transition makes it an interesting case of what David Edgerton has described as the 'shock of the old'.[9] Furthermore, the practices surrounding ballast in ports and coastlines not only yield insight into everyday life on the waterfront, but also serve to blur the sharp distinction between port cities and littoral societies posited by Michael Pearson, because nautically prompted ballast needs transcended the cultural contexts of port cities and shorelines.[10] Ballast can also enrich discussions of commodity history. Shifting the focus from production and consumption to the practicalities of transporting things on the oceans raises the question of what was transported as trade goods and what materials were mainly loaded because of their ballasting properties. Finally, ballast is of interest to ongoing discussions about the nature of global connections. Globally minded historians (famously Frederick Cooper) have long criticized naive, homogenizing visions of a single globalization, but only more recently have disconnections become an object of study in and of themselves, with some scholars like Wenzlhuemer stressing the concurrent significance of

[5]For recent syntheses without reference to ballast, see North, *A World History of the Seas*; John Darwin, *Unlocking the World: Port Cities and Globalization in the Age of Steam, 1830–1930* (Allen Lane, 2020); David Abulafia, *The Boundless Sea: A Human History of the Oceans* (Allen Lane, 2019). Examples of local histories include Peter D. Wright, 'The Ballast Trade: An Economic Driver in Seventeenth- and Eighteenth-Century Newcastle upon Tyne', *Northern History* 57, no. 1 (2020): 101–19; Cori Convertito-Farrer and Ken Cozens, 'The Operations of the Trinity House Ballast Office in the late Eighteenth Century', *'Shipbuilding and Ships on the Thames': Proceedings of the Fourth Symposium, held on 28 February 2009 at the Museum of the London Docklands*, ed. Roger Owen (J.R. Owen, 2012), 44–58. Technical examples include P. W. King, 'Iron Ballast for the Georgian Navy and Its Producers', *Mariner's Mirror* 81, no. 1 (1995): 15–20; Brian Lavery, *The Arming and Fitting of English Ships of War 1600–1815* (Naval Institute Press, 1987), 186–92; Larrie D. Ferreiro, *Ships and Science: The Birth of Naval Architecture in the Scientific Revolution, 1600–1800* (MIT Press, 2010), 187–257; Stephan Gollasch, 'Historical Overview on the Use of Ballast Water in Shipping', *Journal of Sea Research* 208, December (2025): article 102649.

[6]Notable exceptions are Mats Burström, *Ballast: Laden with History*, trans. C. Merton (Nordic Academic Press, 2017); Mats Burström, 'Stranded Stones and Settled Species: Affect and Effects of Ballast', in *After Discourse: Things, Affects, Ethics*, Routledge Archaeologies of the Contemporary World, ed. Bjørnar J. Olson et al. (Routledge, 2021), 129–44; Mathias Tranchant, ed., 'Le ballast: pratiques et conséquences', *Revue d'histoire maritime* 29 (2021): 6–113.

[7]Carl H. Lindroth, *The Faunal Connections between Europe and North America* (John Wiley & Sons, Almqvist & Wiksell, 1957); Matthew Evenden, 'Stowaway Beetles: Carl Lindroth, the Ballast Theory, and Transatlantic Science in the Cold War', *Environmental History* 26 (2021): 1–26; Hans Luther, 'Laderaumkehricht als Quelle hydrochor verbreiteter Diasporen', *Acta Societatis pro Fauna et Flora Fennica* 72, no. 14 (1955): 1–18; Tore Ouren, 'The Ballast-Plants, a Moribund Element in the Norwegian Flora?', *Norsk Geografisk Tidskrift/Norwegian Journal of Geography* 22, no. 4 (1968): 245–51; Tore Ouren, 'The Impact of Shipping on the Invasion of Alien Plants to Norway', *GeoJournal* 2, no. 2 (1978): 123–32. For seminal, early research into water ballast, see James T. Carlton, 'Transoceanic and Interoceanic Dispersal of Coastal Marine Organisms: The Biology of Ballast Water', *Oceanography and Marine Biology: An Annual Review* 23 (1985): 313–71.

[8]Sujit Sivasundaram, Alison Bashford, and David Armitage, 'Introduction: Writing World Oceanic Histories', in *Oceanic Histories*, ed. Sujit Sivasundaram, Alison Bashford, and David Armitage (Cambridge University Press, 2017), 1–27, 13.

[9]David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (Profile Books, 2006).

[10]Michael N. Pearson, 'Littoral Society: The Concept and the Problems', *Journal of World History* 17, no. 4 (2006): 353–73.

https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press

connections and disruptions with the term 'dis:connections'.[11] Ballast is a lens through which we can observe the limits and the fragility of maritime connections.

In this article, I first address the definition of 'ballast', an issue on which even contemporary opinion could differ widely. To reconcile divergent ideas, I analyse its function at sea, its variable materiality, and the question of its value. In a second step, I consider ballast in the littoral zone. Ports and shorelines were crucial sites of production, loading, and disposal, all three resting on cheap, reliable, and often marginal labour. Such labour remained stationary while underpinning global mobility and was only partially impacted by the technological advances of the steam age. Loading ballast correctly was of key importance to the safety and balance of a ship in transit, while both production and disposal were entangled with broader environmental challenges and agendas and created new biological connections across space. Third, I turn to ballast at sea. Once successfully brought aboard, ballast ideally disappeared from view below deck and ensured a smooth and stable passage, but through its materiality, ballast could adversely impact the experience of 'being in transit'.[12] Due to improper stowage, ballast was a strong contributing factor to sometimes fatal stability accidents and it was also feared as a hotbed of disease. Finally, I study the transition from solid to water ballast and its complex entanglement with the sail-to-steam transition. While the shore slowly industrialized, ballast itself was gradually transformed by the technologies of the steam age – shifting from solid to liquid form – but this transition took decades while solid ballast and hybrid ballasting systems persisted.

Taken together, these strands show how ballast, a powerful if obscure(d) cog in the machinery of maritime mobility, played a central role in the making, maintenance, and sometimes disruption of global connections. Sea travel thus rested on the mobilization of labour on shore as well as the movement of vast amounts of otherwise useless materials.

Defining ballast

What, concretely, were these materials? Both contemporaries and scholars have used the term 'ballast' loosely, sometimes from ignorance but often because they prioritized different qualities in potential ballast. 'Ballast' was a protean, unstable category – metaphorically charged, legally ambiguous, and widely misunderstood beyond maritime and mercantile professionals. In 1832, Scottish economist John Ramsay McCulloch first published his monumental dictionary on *Commerce and Commercial Navigation*, in which he described ballast as 'a quantity of iron, stones, sand, gravel, or any other heavy material, laid in a ship's hold, in order to sink her deeper in the water, and to render her capable of carrying sail without being overset'.[13] This definition persisted unchanged for more than fifty years throughout the continuously revised and expanded editions of the dictionary; apparently it adequately reflected the consensus among other nautical and mercantile compilers and experts.[14]

[11]Frederick Cooper, 'What Is the Concept of Globalization Good For? An African Historian's Perspective', *African Affairs* 100 (2001): 189–213; Roland Wenzlhuemer, 'Dis:connectivity in Global History', in *Globalization: Past, Present, Future*, ed. Manfred B. Steger (Berkeley University Press, 2023), 11–23; Roland Wenzlhuemer et al., 'Forum Global Dis:Connections', *Journal of Modern European History* 21, no. 1 (2023): 2–33. A counter-narrative to the dominant framing of the seas as fundamentally connective is Alison Bashford, 'World History and the Tasman Sea', *American Historical Review* 126, no. 3 (2021): 922–48.

[12]Martin Dusinberre and Roland Wenzlhuemer, 'Editorial – Being in Transit: Ships and Global Incompatibilities', *Journal of Global History* 11, no. 2 (2016): 155–62.

[13]John R. McCulloch, *A Dictionary, Practical, Theoretical, and Historical, of Commerce and Commercial Navigation: Illustrated with Maps* (A. & R. Spottiswoode, 1832), 56.

[14]E.g. William Falconer, *An Universal Dictionary of the Marine [. . .]* (T. Cadell, 1784) [no page numbers, see BAD – BAL]; David Steel, *The Elements and Practice of Naval Architecture; or, a Treatise on Ship-Building, Theoretical and Practical, on the Best Principles Established in Great Britain*, 2 vols., 2nd ed. (David Steel, 1812), 5; G. Gregory, *New and Complete Dictionary of the Arts and Sciences*, vol. 1 (Collins and Co., 1819) [no page numbers, see BAL – BAL]. For ballast definitions in French

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McCulloch pointed to two key aspects of ballast: *function* and *materiality*. To this, I would add *value* as a third aspect. Function was of paramount importance, while both the precise materiality and value of ballast were somewhat discretionary.

What transformed a variety of materials into ballast was their application to a specific nautical purpose. McCulloch's explanation of this *function* – 'to sink [the ship] deeper in the water' – captures the essence of ballasting.[15] Ships are not constructed to travel empty.[16] Their stability at sea depends on keeping their centre of gravity below what is called a 'metacentre', the point where all the axes of a ship's movements intersect.[17] Only as long as its centre of gravity is located below this point will a ship remain upright at sea.[18] Ships were complex, interconnected systems where the failure of any one aspect could have cascading consequences resulting ultimately in disaster. Ballast's primary function was to keep a ship stable. It also served subsidiary purposes: it could be positioned fore and aft to adjust a ship's trim, thus regulating the immersion of the rudder (or for steamers, the screw), as well as contributing to better manoeuvrability and propulsion, and decreasing lateral drift.

While ballast had a clearly definable purpose, its *materiality* was always a matter of debate. A wide range of lithic and metallic substances were suggested by mariners, publicists, and engineers, who usually disagreed which material was best. To effect sufficient immersion, potential ballast only needed, in principle, to answer (some of) the following requirements: it needed to be cheap (or better even, free), plentifully available, sufficiently dense (offering great weight while occupying little cargo space), durable, and conveniently stowable.

In Hamburg, expert opinion concurred that mere earth (a common by-product of building activities) was totally unfit for the purpose of ballast, while sand (economically gained from the city's dredging operations) was considered an excellent type of ballast.[19] By contrast, French sailor, ship-owner, and maritime novelist Eduard Corbière thought that both sand and gravel were the very worst types of ballast because they introduced damp and moisture into the ship and had a tendency to clog the bilge pumps.[20] John Murphy and William Jeffers, two junior US naval officers, recommended in their successful *Nautical Routine and Stowage* using old paving stones, copper dross, shingle, and 'beach-gravel', while concurring with Corbière's opinion on sand, arguing that it 'should never be employed, if it be possible to avoid it'. However, often sand was the only ballast on offer: 'At Antwerp it is impossible to obtain other than sand-ballast, and this, being taken from the bed of the river, is so saturated with water that masters of vessels are often deceived with regard to quantity'.[21] Opinion varied even on different types of stone, based on their geological qualities.[22]

maritime dictionaries 1687–1861, see Guillaume Martins and Emmanuel Nantet, 'Le lest: éléments de terminologie à l'usage des archéologues', *Revue d'histoire maritime* 29 (2021): 15–30, 22f.

[15]For a more detailed and technical explanation of the underlying mechanics by a near-contemporary, see Thomas Walton, *Know Your Own Ship: A Simple Explanation of the Stability, Construction, Tonnage and Freeboard of Ships [. . .]* (Charles Griffin and Co., 1896), 154–60.

[16]Ibid., 103.

[17]On the development of metacentric thinking in naval architecture, see Ferreiro, *Ships and Science*, 187–257.

[18]The distance between centre of gravity and meta-centre is measured as 'metacentric height'. While nineteenth-century contemporaries understood the dangers of too much and too little ballast (alternatively making a ship 'stiff' or 'crank'), they generally recommended stowing ballast as deeply as possible, increasing its leverage; Robert White Stevens, *On the Stowage of Ships and Their Cargoes* (Stevens, Longman, 1858), 9.

[19]Memorandum by *Wasserbaudirektor* Reinhard Woltman addressed to Senator and *Hafenherr* Johann Ernst Friedrich Westphalen, 19 March 1819, [3], 371-6_736, Staatsarchiv der Freien und Hansestadt Hamburg, Hamburg (hereafter, StAHH); Petition by Johann G. von Cölln, Robert Guttery, widow Heinsen, Hinrich Holst to *Rath* of Hamburg, 8 March 1825, doc. no. 1, [2], 111-1_64437, StAHH.

[20]Edouard Corbière, 'Lest', in *Encyclopédie du commerçant: Dictionnaire du commerce et des marchandises [. . .]*, ed. Edmond de Granges, vol. 1 (Librairie de L. Hachette et Cie., 1855), 1284f.

[21]John Mcleod Murphy and W. N. Jeffers, Jr, *Nautical Routine and Stowage, with Short Rules in Navigation* (Henry Spear, 1849), part 3, 16f.

[22]Stevens, *On the Stowage of Ships and Their Cargoes*, 135.

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A type of ballast only found on naval ships were specifically designed bars of iron called kentledge. These 'iron pigs' or 'gueuses de fer' differed from other forms of ballast insofar as they remained on board often for the entirety of a ship's career at sea. First used in the latter half of the eighteenth century in the British navy, they had become a naval staple by the early nineteenth century but were simply too expensive for use on most merchant vessels.[23]

Yet materiality by itself was never a clear-cut criterion for ballast. Even perfect ballast materials were not necessarily carried with that function in mind. In 1828, Trinity House, the London ballast monopoly, sued one William Thompson over the trifling amount of 2 tons of gravel which he had taken aboard among other ballast but which he had not received from Trinity House. The case was quickly dismissed after Thompson produced customs papers showing that this gravel 'was of the description which is saleable at Liverpool for the Potteries that it was taken in as Cargo & ent[ered] as such at the Custom House'.[24] Thompson could thus argue that his gravel, despite looking and indeed acting like ideal ballast, was in fact a trade good.

Potential ballast materials possessed the necessary qualities in varying degrees, so in practice, ship's masters had to manage trade-offs. Some forms of ballast were cheap but arduous to load and unload, others were less compact but safer, while others were dense but expensive.[25]

In addition to function and materiality, *value* is the third facet of ballast to be considered. Ballast was sold at a price per quantity. In London, this was regulated by an Act of Parliament and varied between 1 shilling and 3 shillings and 2 pence, depending on the flag, location, and trade of a ship.[26] Additional charges for labour, delivery, and administrative fees increased the final price of ballast. These costs could quickly add up: between September and October 1806, the *Heart of Oak*, a merchant ship of 140 tons sailing for the firm of Henley & Sons, visited London and Newcastle and spent more than £20 on ballast (while paying its seamen between £3 and £5 a month).[27]

Determining how much ballast a ship needed is difficult based on tonnage alone, especially for merchantmen.[28] The amount carried could depend on various factors, like a ship's individual hull shape and dimensions, the weather and time of year, and other cargoes carried.[29] Ships with especially light cargo, like tea or cotton, would always need to carry some ballast.[30] Expert opinion was also far from precise, with one early nineteenth-century source recommending, 'one quarter,

[23]King, 'Iron Ballast'; Emmanuel Nantet and Guillaume Martins, 'From Old Cannon to Iron Pigs: The Introduction of Kentledge Ballast in the Early Modern French Navy', *Mariner's Mirror* 109, no. 4 (2023): 401–28; Murphy and Jeffers, *Nautical Routine and Stowage*, 16f.

[24]Letter from Jack Herbert, 26 March 1828, CLC/526/MS30065A, The London Archives (formerly: London Metropolitan Archives), London (hereafter, TLA).

[25]In London, the law allowed for various types of waste and even literal excrement to be sold as ballast ('rubbish' and 'dung ballast'). Ship masters however were clearly aware that these materials were insufficiently functional, so that in the years for which figures exist, only a very small quantity of these types of ballast was sold. Thames Lastage and Ballastage Act 1805, 45 Geo. 3, cap. 98, ss. 5, 9; 'Report from the Select Committee on Thames Conservancy, &c., together with the Proceedings of the Committee, Minutes of Evidence, Appendix, and Index: Ordered, by the House of Commons, to be Printed, 16 July 1863', Parliamentary Papers, 1863, vol. 12, no. 454, 308.

[26]Thames Lastage and Ballastage Act 1805, s. 23. These prices remained stable for more than sixty years, until the end of the ballast monopoly in 1866, Thames Lastage and Ballastage Act 1843, 6 & 7 Vict., cap. lvii, s. 7.

[27]Disbursement sheet of the *Heart of Oak*, entries for 8 September 1806, 3 October 1806, and 20 October 1806, HNL/69/69:2, Caird Library and Archives, London (hereafter CLA); Crew contract for the *Lord Nelson*, *c.* 1811/12, HNL/82/35:43, CLA; Crew contract of the *Lady Juliana*, *c.* 1813, HNL/77/68:53, CLA; Crew contract of the *Lady Juliana*, *c.* 1815, HNL/77/71:2, CLA.

[28]A table for naval ships is found in the early editions of McCulloch's dictionary, which is drawn from Gregory, *New and Complete Dictionary* [no page numbers, see BAL – BAL].

[29]Stevens, *On the Stowage of Ships and Their Cargoes*, 9, 11; S. J. P. Thearle, 'The Ballasting of Steamers for North Atlantic Voyages', *Transactions of the Royal Institution of Naval Architects* [hereafter *RINA*] 45 (1903): 118–33, 118f., 128; anecdotally in Charles Knowles, 'Disquisitions on Ship Building [. . .]', *Naval Chronicle* 20 (1808): 388f., 388.

[30]David R. MacGregor, *The Tea Clippers: Their History and Development 1833–1875* (Naval Institute Press, 1983), 120; Richard Dana and James Lees, *Dana's Seaman's Friend; Containing a Treatise on Practical Seamanship [. . .]* (George Philip and Son, 1856), 358.

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one third, or one half of a ship's burden, according to the difference of the bulk', while a mid-century engineer thought a sixth of the average amount of cargo was sufficient. Murphy and Jeffers suggest that a merchant ship carry 30 tons (i.e. weight) of ballast per 100 tons of tonnage (i.e. internal volume), with small vessels requiring disproportionately larger amounts.[31] Ultimately, the necessary amount of ballast could seldom be computed through theoretical calculation and was mostly determined through practical experience.[32] From the available evidence, it seems that even a small ship required dozens, and towards the second half of the century hundreds if not thousands, of tons of ballast.[33]

However, cost alone is clearly different from value. The use value of ballast was the stability it provided at sea. Its exchange value on the other hand was (at least in theory) zero. Precisely because ships 'in ballast' carried no goods of commercial value and were not expected to make a profit at the next port, they were given preferential treatment by customs official.[34] The non-existent exchange value of ballast led Wenzlhuemer to interpret ballast as a 'non-commodity'.[35] In practice, there were some exceptions to this ideal of valueless ballast and certain goods with adequate materiality (like coal) could act as ballast substitutes. But for the purposes of this article and for many nautical contemporaries, ballast was by definition worthless.

Counterintuitively, there are almost no reports of ships repurposing the ballast of other ships. Regulations were an inhibiting factor. In London, only a few hundred tons of ballast were annually reused, because the law stipulated the payments by both ships to Trinity House, as if this ballast had been provided by the corporation. This applied even if both ships had the same owner and merchants naturally resented the London ballast monopoly.[36] In this, and many other ways, ballast institutions and practices were integrally related to how it was produced, delivered and disposed of onshore or offshore.

Ballast on shore

As is often the case in maritime history, many significant developments regarding ballast occurred onshore and in the littoral zone rather than on the high seas. Research into the littoral zone has also tended to separate between shore dwellers and the inhabitants of cities. Pearson's concept of the *littoral society*, for instance, specifically excludes ports, while ports themselves have been repeatedly conceptualized as privileged nodal points mediating between land and sea.[37] Yet ballast was essential wherever ships travelled, another example of the deep entanglement of land and sea, which Alison Bashford has termed *terraqueous history*.[38] Port cities, shorelines, and river banks were all sites where ballast was produced, sold, loaded, unloaded, and finally disposed of. However, the higher demand for ballast in port cities favoured the creation of specialized institutions or at least state oversight and regulation, phenomena which increase the chances of archival transmission.

[31]Gregory, *New and Complete Dictionary* [no page numbers, see BAL – BAL]; Edward Ellis Allen, 'On the Comparative Cost of Transit by Steam and Sailing Colliers, and on the Different Modes of Ballasting', *Minutes of the Proceedings of the Institution of Civil Engineers* 14 (1855): 318–73, 328; Murphy and Jeffers, *Nautical Routine and Stowage*, 18.

[32]One early attempt was A. T. Wall, 'Safe Stability and the Economical Use of Water Ballast in Ships', in *RINA* 56 (1914): 208–23.

[33]E.g. Walton, *Know Your Own Ship*, 155.

[34]McCulloch, *A Dictionary*, 56f.

[35]Wenzlhuemer, 'Shipping Rocks and Sand', 16.

[36]Thames Lastage and Ballastage Act 1843, s. 22; *Thames Conservancy Report*, 98, Appendix 3, 319, 322.

[37]Pearson, 'Littoral Society', 356; Tai-Yong Tan, 'Port Cities and Hinterlands: A Comparative Study of Singapore and Calcutta', *Political Geography* 26, no. 7 (2007): 851–65; Isaac Land, 'Doing Urban History in the Coastal Zone', in *Port Towns and Urban Cultures: International Histories of the Waterfront, c. 1700–2000*, ed. Brad Beaven, Karl Bell, and Robert James (Palgrave Macmillan, 2016), 256–81.

[38]Alison Bashford, 'Terraqueous Histories', *Historical Journal* 60, no. 2 (2017): 253–72.

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Specialized practices emerged in the littoral zone to manage ballast. The subject of practices has rightly received much recent attention by scholars of maritime and global history.[39] As Benton and Perl-Rosenthal pointed out for the early modern period: 'practices of seafaring ... were the rarest of rare things: truly global phenomena constitutive of deep structural chance at vast scale'.[40] This holds true for the nineteenth century. The need to carry ballast was universal and applied to nearly all types of ships engaged in global movement. Ballasting practices were essential in the making and maintenance of these maritime connections. They enabled the movement of ships where no cargo was desired or available, reduced time in port, and contributed to safety at sea. These practices generally fall into three categories: production, delivery, and disposal. Both production and disposal were deeply interwoven with environmental concerns, projects, and exchanges. Often port cities were geared nearly exclusively towards either production or disposal, possibly reflecting differences between staple and entrepôt ports.

Ballast *production* usually happened in the immediate environs of a port, where sand and earth were collected on the shore and riverbanks, or dredged from the bed of the river or harbour. Both digging and dredging were judged and regulated with regard to their environmental impact on the navigability and accessibility of a port. As ports expanded, digging ballast from the riverbanks became generally frowned upon, as it was feared that this would create dangerous shallows and disrupt a waterway's current without contributing to its improvement. For example, in 1824, Hamburg issued a near-blanket ban on digging on the Elbe banks it controlled.[41] Similar edicts were issued in 1832 and 1842 to protect the banks of the Weser by the Kingdom of Hanover, whence a lot of Bremen's ballast came.[42] Practically enforcing such prohibitions, however, proved almost impossible.[43] In London, the ballast production monopoly of Trinity House made specific prohibitions against digging unnecessary. Outside of port cities, digging ballast persisted, sometimes well beyond the nineteenth century.[44]

Sometimes, littoral zones were places of social and legal liminality, in which the blurring of power dynamics and social relations benefited subaltern actors.[45] Yet ballast-work was fundamentally unskilled and generally had no such empowering effects. Where no formal structures or exclusionary mechanisms were in place, low entry barriers into the ballast business contributed to oversupply and made it a perennially precarious occupation. One example was the Weser port of Brake, where most sea-vessels with cargo for Bremen were unloaded. In the port's heyday between 1817 and 1851, Brake's many ballast producers made repeated attempts to improve their lot by forming a privileged association but were unsuccessful due to infighting and official distrust.[46]

[39]See Angelika Epple, 'Calling for a Practice Turn in Global History: Practices as Drivers of Globalization/s', *History and Theory* 57, no. 3 (2018): 390–407; specifically on ports, see Eva Brugger, Isabelle Schürch, and Birgit Tremml-Werner, 'Der Hafen. Praxeologische Perspektiven auf Zirkulation, Transfer und Transformation', *Historische Anthropologie* 26, no. 1 (2018): 29–42; for maritime legal practices, see Renaux Morieux and Jeppe Mulich, eds., 'Ordering Oceans, Ordering the World', *Past and Present* 265, supplement 17 (2024): 1–281.

[40]Lauren Benton and Nathan Perl-Rosenthal, 'Introduction: Making Maritime History Global', in *A World at Sea: Maritime Practices and Global History*, ed. Lauren Benton and Nathan Perl-Rosenthal (University of Pennsylvania Press, 2020), 1–14, 7f.

[41]Mandate concerning the dredging and digging of sand from the Elbe, 17 September 1824, 111-1_64436, StAHH.

[42]Proclamation banning sand digging on the banks of the Weser by *Landrost* Engelberg Johann von Marschalck, 12 July 1832, 2–r. 10. d. 5, Staatsarchiv Bremen, Bremen (hereafter StAB); Repeated proclamation banning sand digging by *Landrost* Ernst von Bülow, 6 September 1842, StAB.

[43]List of infringements since 1841 by shippers from Hamburg's neighbour Altona, 24 July 1844, 111-1_64448, StAHH.

[44]W. C. Fox, 'Barges Taking Sand and Gravel at Low Tide on "The Crow", North of Appledore, North Devon, Early Twentieth Century', P24528, National Maritime Museum Greenwich, London.

[45]E.g. Kevin Dawson, 'Enslaved Ship Pilots in the Age of Revolutions: Challenging Notions of Race and Slavery between the Boundaries of Land and Sea', *Journal of Social History* 47, no. 1 (2013): 71–100.

[46]For information on the first and last attempt, see Petition by Hermann Witte and compatriots to Treasury (*Cammer*) of the Duchy of Oldenburg to form a *Ballast-Comptoir*, 9 May 1817, Best. 70, Nr. 7193, Niedersächsisches Landesarchiv,

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While lighters, shovels, and manpower were sufficient for digging ballast, dredging sand and soil from riverbeds required increasingly advanced equipment. Various forms of man-powered dredgers had collected ballast before the nineteenth century, which saw the application of steam power to dredging.[47] As early as 1806, Cornish inventor Richard Trevithick experimented with a steam-powered dredger on the River Thames.[48] Regular steam dredging commenced in 1827, and by the middle of the century, the *Hercules*, *Samson*, and *Goliath* were a daily sight on the Thames.[49] Steam dredging also spread to the Continent. Hamburg purchased its first three steam dredgers from Britain in 1833, 1837, and 1845. In 1842, a group of Hamburg ballast merchants also petitioned their government for permission to operate a private steam dredger, although it took a decade for this project to come to fruition.[50] By the end of the century, Hamburg had acquired eleven more dredgers (from German producers) and a small fleet of lighters to dispose of the dredged materials.[51]

Ballasting and river conservation were deeply interwoven. For thirty years (from 1824 to 1839 and again from 1845 to 1861), Hamburg paid its ballast merchants a subsidy, provided they only dredged in designated zones and documented their deliveries to ships.[52] Ballasting also served as a convenient disposal mechanism for the sand dredged up by city dredgers.[53] Unlike digging, dredging was generally framed as a public service, which kept rivers and harbours navigable for the commerce of the port. But riverine improvement and producing ballast were not necessarily aligned motivations for dredging. In London, Trinity House jealously protected its exclusive privilege to dredge the Thames, but refused to dredge if the recovered materials could not be sold as ballast, while also refusing to allow others to dredge in their place.[54]

Production figures from Hamburg and London provide an impression of the amount of materials collected and later dispersed along major trade routes. In 1800, 283,648 (Imperial/long) tons of ballast were delivered to outgoing ships in the port of London.[55] By 1862, this figure had almost tripled, to 768,615 tons of river soil, chalk, and shingle.[56] Around the same time (in 1860), the city state of Hamburg sold around 114,500 (metric) tonnes of ballast and an average of 109,585 tonnes during each of the ten preceding years.[57] To put this into context, in 1860, about 37 per cent of ships (1,873 out of 5,045) left Hamburg 'in ballast'. This understates the case, as it only

Abteilung Oldenburg (hereafter, NLA Oldenburg); Report from *Amt Brake* to Chancellery (*Regierung*) of the Grand-Duchy of Oldenburg, 3 November 1851, Best. 76-4, B Nr. 291, NLA Oldenburg.

[47]For London, see Henry Mayhew, *London Labour and the London Poor; A Cyclopaedia of the Condition and Earnings [. . .]*, vol. 3 (Griffin, Bohn, and Company, 1861), 270. For Hamburg, see Petition by the ballast merchants Streland, Holst, Guthery, and von Kölln to operate a dredging machine, 14 October 1832, 111-1_64443, StAHH.

[48]A. W. Skempton, 'A History of the Steam Dredger, 1797–1830', *Transactions of the Newcomen Society* 47, no. 1 (1974): 97–116, 104–6.

[49]Mayhew, *London Labour*, vol. 3, 269.

[50]Petition by the ballast merchants J. T. Guttery, D. Hauschildt, A. F. Streland, B. Möller, Hinr. Holst to *Syndicus* Johann Christian Kauffmann to operate a private steam dredger, 24 October 1842, 371-6_665, StAHH; Friedrich Carl Hasenjäger, Annual and monthly reports on ballast dredging, 1850–1860, 326-2 I_471, StAHH, see report for 1852.

[51]W. Thele, 'Das hamburgisches Baggerwesen', *Jahrbuch der Schiffbautechnischen Gesellschaft* 15 (1914): 286–393, 292, 295, 374f.

[52]Mandate, 111-1_64436, StAHH; Mandate concerning the dredging and digging of sand from the Elbe, 13 November 1839, 111-1_64445, StAHH; Proclamation, 23 May 1845, 111-1_64448, StAHH; Proclamation, 9 December 1861, 371-6_667, StAHH.

[53]Mandate, 111-1_64445, StAHH.

[54]Llewelyn Rodwell Jones, *The Geography of London River* (Methuen & Co., 1931), 32, 104.

[55]'Ballastage: Quantity Delivered, and Profit, in the Last 30 Years, With the Cost and Price. Ordered to be Printed 6th May 1805', Parliamentary Papers, 1805, vol. 9, no. 112.

[56]*Thames Conservancy Report*, vi.

[57]Hasenjäger, Reports, 326-2 I_471, StAHH. These tables count lighters carrying nine *Schiffslasten*, one *Last* weighing roughly 2 metric tonnes (Hamburgische Gesellschaft zur Verbreitung mathematischer Kenntnisse, ed., *Technische Hülfstabellen*, 3rd ed. (Otto Meissner, 1872), table 9).

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counts ships carrying nothing but ballast, while ships with some cargo would still have carried some ballast. Thus, at least more than a third of all ships needed ballast from the city's production facilities.[58] Shipping statistics for London are extremely unreliable and do not specify ships 'in ballast' before 1873, when 13 per cent of all ships and 30 per cent of ships engaged in foreign trade (2,548 out of 18,895) left in ballast.[59]

After production, the next step was *delivery*. Delivering and stowing ballast in ships could take days or weeks even if ready ballast was available.[60] Moving hundreds of tons of ballast into a ship was arduous manual labour. Sailors were often involved in this work but, in port cities, a specialized labour force evolved. In the early nineteenth century, London's Trinity House employed at least 240 men for the production and delivery of ballast, excluding supervisors and administrators.[61] This number did also not include the several hundred men actually loading ballast into and out of ships. The plight and destitution of London's ballast-heavers, who moved thousands of tons of ballast every day, often with little more than shovels and mostly at night, were publicized by Henry Mayhew's 1850 articles in the *Morning Chronicle*.[62] While steam power was sometimes applied to loading and unloading ballast, it did not replace human labour but rather intensified the demand for it.[63] Nor was ballast labour limited to major ports. Even in areas of the Pacific, like the Samoan islands, ballastmen advertised their services.[64] Ballast-heavers might have been only dimly aware of the wider impact of their toiling to move mountains of material, yet their work was crucial to forge and maintain global connections.

While heaving ballast into ships required brawn and stamina, stowing it was an 'art' which called for care and attention.[65] Often, the individual circumstances of the ship determined where in the hold ballast was best placed and in what quantities, how it was to be secured, and how other cargo and the bilge pumps were best protected from the ballast.[66] Nor was loading ballast without peril. Spontaneous shifts could trap workers, crush limbs, or even kill, although the latter was rare.[67] Some of the most complex ballast practices revolved around stowage, but these are the most difficult to uncover, given that this was practical knowledge rarely written down and printed.[68]

The production and delivery of ballast were intentionally conducted activities to enable maritime mobility. Practices of *disposal* were also deeply connective but in less obvious and less intentional ways. While great care was taken in loading and securing ballast in place, it was

[58]Handelsstatistisches Bureau, ed., *Tabellarische Uebersichten des Hamburgischen Handels im Jahre 1860* (A.F.M. Kümpel, 1861), 80.

[59]David J. Starkey, ed., *Shipping Movements in the Ports of the United Kingdom, 1871–1913: A Statistical Profile* (Exeter University Press 1999), xxvi, 158f. Starkey's London data is of extremely poor quality, with the number of ships entering and clearing often significantly diverging.

[60]Allen, 'On the Comparative Cost', 329; Benjamin Martell, 'On Water Ballast', *RINA* 18 (1877): 336–48, 337, 339. On stowage practices, see Brugger, Schürch, Tremml-Werner, 'Der Hafen', 34–8.

[61]Hilary P. Mead, *Trinity House* (Sampson Low, Marston & Co., [1947]), 142.

[62][Henry Mayhew], 'Labour and the Poor. The Metropolitan Districts. (From our Special Correspondent.) Letter XXII', *Morning Chronicle*, 1 January 1850, 4f.; [Henry Mayhew], 'Labour and the Poor. The Metropolitan Districts. (From our Special Correspondent.) Letter XXIII', *Morning Chronicle*, 4 January 1850, 4f.; [Henry Mayhew], 'Labour and the Poor. The Metropolitan Districts. (From our Special Correspondent.) Letter XXIV', *Morning Chronicle*, 8 January 1850, 5; [Henry Barthorp], *Dialogue between Thomas Truck, a Ballast Heaver and John Searchout, an Inhabitant of the District where the Ballast Heavers Reside [. . .]* (F. H. List, [1850]), 9. After the absorption of ballast heaving into the purview of Trinity House in 1853, the number of employed labourers rose to around 400; detailed figures in *Thames Conservancy Report*, 321.

[63]On ballast cranes, see Committee of Lloyd's Register, ed., 'Particulars of Wet Docks, Tidal Harbours, Quays, etc.', in *Lloyd's Register of British and Foreign Shipping: Universal Register. From the 1st of April, 1888, to the 31st of March, 1889* (William Clowes & Sons, 1889), 26, 28–38, 42, 44, 49, 51–4, 56.

[64]'Harrington and Huch', *Samoa Weekly Herald*, 7 May 1894, 4.

[65]Stevens, *On the Stowage of Ships and Their Cargoes*, 9.

[66]Ibid., 9–11.

[67]'Plymouth Report. From November 26 to December 25', *Naval Chronicle* 6 (1801): 511–13, 512.

[68]Burström, 'Stranded Stones', 130f. A rare, first-hand account of ballasting from the twentieth century is Thomas Wells, 'Ballast and Cargo Handling On Board the Bark Passat', *Log of Mystic Seaport* 45, no. 4 (1994): 110–15.

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disposed of the moment a ship had prospects of profitable cargo. Usually, local authorities charged a fee for unloading ballast or required payments to local labourers, so whenever possible, ballast was simply dumped overboard.[69] Some sailors adopted a rather cavalier attitude about this process. Richard Dana, a young man from good family spending two years in the US merchant marine, participated in ballast dumping at San Diego during the early 1830s:

> A regulation of the port forbids any ballast to be thrown overboard; accordingly, our long-boat was lined inside with rough boards and brought alongside the gangway, but where one tub-full went into the boat, twenty went overboard. This is done by every vessel, for the ballast can make but little difference in the channel, and it saves more than a week of labor, which would be spend in loading the boats, rowing them to the point and unloading them ... This is one of the petty frauds which every vessel practises in ports of inferior foreign nations, and which are lost sight of, among the countless deeds of greater weight which are hardly less common.[70]

Port authorities all over the world were less relaxed about the impact continuous ballast dumping could have on the long-term navigability of rivers and ports.[71] There were even reports of small ports having become nearly inaccessible because of discarded ballast.[72] Documented cases of ballast dumping are almost as old as the laws prohibiting it. Rivers were difficult to police and the temptation to save time and money by improperly discarding ballast was ever-present, even if offenders risked hefty fines and imprisonment.[73] Sometimes, these cases dragged on for years due to the difficulty of investigating highly mobile groups like sailors. In 1833, two shipmasters from Papenburg, Wilhelm Schneiders und Georg Jongbloed, were accused by the Hanoverian authorities of having tossed ballast into the Weser. This charge seems to have been serious enough to generate dozens of reports and depositions over the following years. Jongbloed absconded and disappeared with his ship and crew during a storm that autumn, but the authorities continued to pursue charges against Schneiders until he too died in an accident on the Thames in 1837, ending the case inconclusively.[74]

Even when ballast was legally unloaded, it left its mark on the landscape. Along the banks of the Tyne near Newcastle, centuries of ballast deposits had created mounds dozens of metres high. One contemporary described them as 'monstrous accumulation[s] of earth, chalk, and Thames mud' which would 'probably ... form a puzzle for future antiquaries and geologists, when the origin of these immense hills along the Tyne has been forgotten'.[75] Ballast collected from riverbanks and riverbeds was biologically rich material, and foreign flowers were frequently discovered on ballast hills around the world. Botanists took note and began cataloguing scores of 'ballast plants' in

[69]Port labour was generally gendered as male and most ballast-related work was done by men, but there were exceptions. In the Swedish timber port of Nyland women unloaded ballast. That this brought them into close contact with foreign seamen outraged self-appointed, local 'guardians of public morals': Burström, *Ballast*, 79–80.

[70]Richard Dana, *Two Years before the Mast: A Personal Narrative of Life at Sea* (Harper & Brothers, 1840), 324f.

[71]Laws and regulations against ballast dumping existed at least since the sixteenth century; e.g. Thierry Sauzeau, 'Le Délestage dans la mer des pertuis charentais (XVIe–XIXe siècle)', *Revue d'histoire maritime* 29 (2021): 49–61; *Der Stadt Hamburg Statuta und Gerichts Ordnung* (Heinrich Volckers, [1603]), 357 [4. Teil, Artic. 11]; competing edicts for the protection of the Weser by Frederick IV of Denmark and George I of Great Britain in 1723, in Rep. 31, Nr. 318, docs. no. 10 and 26, Niedersächsisches Landesarchiv, Abt. Stade (hereafter NLA Stade); Thames Lastage and Ballastage Act 1805, s. 19.

[72]See reporting on the siltation of the Sea of Azov ('Vermischte Nachrichten', *Kölnische Zeitung*, 21 February 1882, second issue, [2]) or the Irish port of Crookhaven ('[description of] Plate CCCLX', *Naval Chronicle* 27 (1812), 318).

[73]'Harbour Pollution', *The Straits Budget*, 26 January 1897, 12.

[74]File concerning the ship masters Schneiders and Jongbloed, 1833–1837, Rep. 74 Blumenthal Nr. 4312, NLA Stade; file concerning the ship masters Schneiders and Jongbloed, 1833–1837, Rep. 80 Nr. 03445, NLA Stade.

[75]Samuel Smiles, *Lives of the Engineers, with an Account of their principal works [...]*, vol. III: *George and Robert Stephenson* (John Murray, 1862), 38f.

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littoral sites.[76] Interestingly, this was not generally framed as a problem of invasive species or of lasting ecological connection. Victorian naturalist John Hogg argued that this foreign flora wilted and disappeared within a few seasons due to English climatic conditions.[77] Only in the twentieth century did biologists like Henry Ridley and Carl Lindroth begin to understand the lasting impact of ballast flora and fauna.[78] Dumping ballast at sea could also have long-term ecological consequences, but these remained equally unnoticed at the time. For instance, John McManus has outlined how gravel ballast dumped into the Tay estuary supported a growing population of mussels, which in turn attracted a growing population of Eider ducks.[79]

Digging, dredging, and dumping ballast were practices entangled with the making of port environments. They could serve or undermine agendas aimed at navigability and commercial improvement, but they were also biologically connective. These practices principally shaped ports in their role as connected nodes. Loading and stowing ballast were essential to fulfil its primary function, ensuring a ship's stable passage. As we will now see, this impacted on the character and quality of maritime connections themselves.

Ballast in transit

Even on shore, amid bustling activity, ballast rarely became visible. It was dredged from rivers, carried in small lighters, and immediately loaded into ships. Stored on land it would have blocked valuable space in docks and wharves. Once at sea, ballast ideally required no further attention. In transit, it quietly performed its stabilizing function in the most obscure and inaccessible location at the bottom of the ship and remained unnoticed by passengers. There are few documented instances of adjustments to ballast under ordinary circumstances. During an episode from the golden age of piracy, a pursuing vessel jettisoned its ballast to reduce its draft and gain upon its quarry, but that was a tactical manoeuvre by a small craft in shallow waters.[80] When a ship was severely leaking, ballast might also be thrown overboard, but this was an act of desperation, intended only to raise the ship long enough to patch the leaks.[81] Naval ships might be surrendered once the water had risen above the ballast.[82]

The lack of noteworthy routine interactions with ballast at sea has led to the emergence of some unsubstantiated myths. Ballast was neither used for floating agriculture, nor was it a place of burial on Catholic ships, as has been claimed in the Anglophone literature.[83] The idea of corpses interred in ballast is of course highly evocative, given the inaccessible, dark, and miasmic environment at

[76]E.g. Isaac Burk, 'List of Plants Recently Collected on Ships' Ballast in the Neighborhood of Philadelphia', *Proceedings of the Academy of Natural Sciences of Philadelphia* 29 (1877): 105–9; Isaac Martindale, 'More about Ballast Plants', *Botanical Gazette* 2, no. 10 (1877): 127f.; Charles E. Perkins, 'Ballast Plants in Boston and Vicinity', *Botanical Gazette* 8, no. 3 (1883): 188–90.

[77]John Hogg, 'On the Ballast-Flora of the Coasts of Durham and Northumberland', *Annals and Magazine of Natural History* 19, no. 109 (1867): 38–43, 43.

[78]Henry N. Ridley, *The Dispersal of Plants Throughout the World* (L. Reeve & Co., 1930), 645–8; Lindroth, *The Faunal Connections*; Luther, 'Laderaumkehricht'; Ouren, 'The Ballast-Plants'; Ouren, 'The Impact of Shipping'.

[79]John McManus, 'Ballast and the Tay Eider Duck Populations', *Environment and History* 5, no. 2 (1999): 237–44.

[80]This was during the hunt for the pirate Edward 'Blackbeard' Teach; Charles Johnson, *A General History of the Pyrates, From the First Rise and Settlement of the Island of Providence, to the Present Time [. . .]*, 2nd ed. (T. Warner, 1724), 81f. Or see 'Correspondence', *Naval Chronicle* 37 (1817): 30–54, 31.

[81]'Dangers of the Astrea Frigate', *Naval Chronicle* 17 (1807): 42–4, 44.

[82]Jean Baptiste Boyer, 'Correspondence', *Naval Chronicle* 27 (1812): 18f., 19.

[83]On 'ballast agriculture', see Robert C. Leslie, *Old Sea Wings, Ways, and Words, in the Days of Oak and Hemp* (Chapman and Hall, 1890), 209. On 'ballast burials', see Noelene Bloomfield, 'Overview: France's Quest for Terra Australis: Strategies, Maladies and Triumphs', *Great Circle* 39, no. 2 (2017): 8–24, 13; Stephen Bown, *Scurvy: How a Surgeon, a Mariner and a Gentleman Solved the Greatest Medical Mystery of the Age of Sail* (Penguin Books, 2004), 22f.; Burström, *Ballast*, 24; N. A. M. Rodger, *The Wooden World: An Anatomy of the Georgian Navy* (Folio Society, 2009), 87; Joe J. Simmons, *Those Vulgar Tubes: External Sanitary Accommodations aboard European Ships of the Fifteenth through Seventeenth Century*, 2nd ed. (Chatham Publishing, 1998), 8.

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the very bottom of a ship's hold. And while indiscriminately collected ballast might occasionally contain human remains, there is no primary evidence to support the idea of ballast-specific burial practices.[84] Perhaps this notion speaks more to a fascination with ballast, hidden in the lowest, most underworld-like part of a ship.

Stephen Graham, when discussing urban infrastructure, pointed out that successful infrastructure can become so ingrained that it is taken for granted and is 'naturalized'. '[C]ultural invisibility' is one criterion of effective infrastructure and, by this measure, ballast was very effective indeed.[85] While many travellers were all too aware that they were trusting their lives to a few centimetres of wooden plank or iron hull, few would have known that their safety equally depended on several dozen tons of sand and shingle below them. Nineteenth-century sea voyages were still dangerous, still prone to delays, and although perhaps less deadly than in previous centuries, ships remained isolated and at the mercy of the elements.

Ballast had the power to affect in a very immediate way the experience of what Dusinberre and Wenzlhuemer have described as 'being in transit', appreciating ships as social and physical spaces in their own right, rather than merely connective vehicles.[86] Historians have so far mainly applied this concept to the isolated micro-societies forming on board, but the parameters of the transit phase were heavily determined by the stowage and materiality of ballast.

Ballast was a common cause or a contributor to stability accidents at sea. Because of its materiality or improper stowage, ballast could shift below deck, throw the ship off balance, and thus amplify rather than counteract the influences of wind and waves. Once a critical angle was passed, ships capsized or even sank. Sand ballast in particular was known to exacerbate movements if it was wet, and it could also easily block the bilge pumps, causing water to fill the ship. In 1881, when reporting on the loss of the *Golden Sea*, a Bristol newspaper railed against the 'evils attending the use of sand, soil, clay &c., for ballast', arguing that 'many vessels, otherwise sound and well conditioned, are rendered practically unseaworthy by the use of it, their owners are verily guilty of homicidal crime for all loss of life that is caused. The only excuse that is made for the use of sand ballast is that it is generally cheaper and more conveniently obtainable than any other.'[87] Such accidents remained common even at the very end of the nineteenth century, even if they were not always deadly.[88] As late as the 1940s, Atlantic supply convoys suffered from stability accidents when solid ballast was not properly secured.[89]

Another issue associated with ballast at sea is disease. There are occasional remarks in the literature on the smell ballast produced and associations with disease, although there is no conclusive evidence so far.[90] That freshly dredged ballast stored in the dark, damp environment of a ship's hold would smell unpleasant is intuitive and in the era of miasma theory such malodours would likely have been interpreted as causes of illness. One contemporary expert on stowage warned that 'Sand, or mud ballast impregnated with sewage or other deleterious matter, may subsequently cause severe and sometimes fatal sickness among the crew.'[91] Tainted ballast was commonly believed to be a health hazard. In 1850, numerous deaths of Chinese indentured

[84]'Ship's Remarkable Ballast', *Straits Times*, 12 July 1909, 8.

[85]Stephen Graham, 'When Infrastructures Fail', in *Disrupted Cities: When Infrastructure Fails*, ed. Stephen Graham (Routledge, 2010), 1–26, 2, 9.

[86]Dusinberre and Wenzlhuemer, 'Editorial – Being in Transit'.

[87]'Bad Ballast', *Bristol Mercury and Daily Post*, 27 December 1881, 7. See also Henry C. Rothery and Tucker F. Squarey, *A Digest of the Judgments in Board of Trade Inquiries into Shipping Casualties [. . .] from 1876–1880* (Waterlow Bros. & Layton, 1882), 54f., 57f., 60–2.

[88]'A North Sea Shipping Disaster: Board of Trade Inquiry', *Manchester Guardian*, 26 January 1895, 8; Walton, *Know Your Own Ship*, 154.

[89]R. A. Beattie, 'Shifting Boards for Ballasted Cargo Vessels', *RINA* 92 (1950): 238–61.

[90]Burström, *Ballast*, 19; G. G. Harris, *The Trinity House of Deptford: 1514–1660* (The Athlone Press University of London, 1969), 133; Mead, *Trinity House*, 143f., 150.

[91]Robert White Stevens, *On the Stowage of Ships and Their Cargoes: With Information Regarding Freights, Charter-Parties, &c., &c.*, 7th ed. (Longmans, Green, Reader, & Dyer, 1878), 547.

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labourers aboard the *Lady Montague* were blamed on the ballast taken at Shanghai.[92] Since placement and position on board corresponded with notions of power and hierarchy, it is no surprise that those lowest in the social order were most likely to come close to the ballast.[93] In 1864, the British Colonial Office received reports of 'large mortality' occurring on vessels from British Guiana ballasted with 'Tidal Mud' and anxiously inquired of London's Trinity House if such practices existed in Britain.[94] Fear of disease-carrying ballast could lead to an inversion of ordinary disposal practices. Some ports, like the Australian coal-port of Newcastle, required ships to dump their ballast into the harbour if it was sand and earth taken from tropical ports.[95]

Such measures seem to reflect the contemporaries' uncertainties regarding the causes and spread of disease. In general, there is little solid evidence for direct adverse health effects of ballast. Wet ballast in warm environments would certainly not have improved an already insalubrious atmosphere below deck and could (as in the case of the *Lady Montague*) have contaminated stores and provisions. But on ships crowded with travellers, there is little reason to assume that ballast was the principal vector for the spread of disease.

Aside from shifting ballast and medical concerns, supply issues onshore could also affect ships at sea. Interruptions in the steady flow of ballast threatened the very maritime connectivity it enabled. Tardy deliveries of ballast were common, yet total failures of ballast production and delivery are only infrequently documented. When they occurred, the consequences could be devastating. In 1877, Benjamin Martell, chief surveyor for Lloyd's, described at a meeting of the Institution of Naval Architects how rising ballast prices had worsened the effects of an ongoing famine in Southern India. The famine had

> caused every available steamer there to be employed ... for carrying rice to Madras ... The result ... was to fill Madras Roads with a greater amount of tonnage than had ever anchored there before. This naturally led to exorbitant demands being made by the native boatmen, and it was with the utmost difficulty they could be induced to carry ballast to steamers ... at six rupees per ton, or about ten or twelve times the ordinary cost, and even at this exorbitant charge such steamers might have to wait two months for an amount of 200 tons.

This was so intolerable that many steamers chose 'to keep part of their former cargo on board and go down to Pondicherry, where dry ballast was obtainable at a reasonable rate, and after getting ballasted had to return to Madras to discharge the remainder of their cargo, and then start to a loading port for rice'.[96] Pondicherry (Puducherry) lies about 140 km south of Madras (Chennai), so this was a not inconsiderable detour. Martell, rather callously, was mostly concerned with the economic loss to shipping caused by this disruption (which he estimated at £500 per voyage), for which he explicitly blamed the local port population. While certainly an extreme situation, the story of the Madras ballast shortage shows literally how far some shipmasters were ready to go to decrease ballast costs. It also shows how ballast supply could affect the traffic of a port and compound a major humanitarian crisis. When the port-based practices surrounding ballast came to a halt, the consequences rippled through maritime traffic, diverted ships with life-saving cargo from their course, lengthened journeys, and exposed the inherent fragility of maritime connections. Just as the presence of ballast could suddenly disrupt a journey at sea, its absence from the ship could be just as disruptive.

[92]Wenzlhuemer, 'Shipping Rocks and Sand', 15.

[93]Famously, for Dening's reflection on the social aspects of ship-space, although in a military context, see Greg Dening, *Mr Bligh's Bad Language: Passion, Power and Theatre on the Bounty* (Cambridge University Press, 1992), 19–20, 23f., 81.

[94]Minutes for 22 November 1864, Board Minutes 1864–1866, 40, CLC/526/MS30010/045, TLA.

[95]'Newcastle Ballast Regulations', *Sydney Morning Herald*, 2 November 1899, 4.

[96]Martell, 'On Water Ballast', 339.

https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press

Liquidating ballast

Martell's solution to the dependence on shore-based ballast suppliers was to lobby for the adoption of a new form of ballast: water. On its surface, the transition from solid to water ballast was the single most important development in the technological history of ballast, fundamentally shifting the responsibility for balance from shore-based ballast organizations and practices to technical systems on board. However, this transition, much like the sail-to-steam transition, was a slow, uneven, and gradual process, with solid ballast doggedly persisting into the twentieth century.

Using water to balance ships was not a radically new idea. Water barrels, once emptied of drinkable water, had long been refilled with seawater to maintain the ship's balance.[97] Even if it was not framed as a form of ballast at the time, water was clearly a part of practices aimed at providing stability. The eighteenth century saw some interesting early (thought) experiments, such as the 1718 *fish-pool*, a fishing vessel with a perforated hold, permanently filled with water, which served both to ballast the ship and store live fish for sale in London.[98] Similarly impractical designs followed in the nineteenth century. In 1830, the *Mechanics' Magazine* published the courageous scheme of one G. Dakin, who proposed sealing off a portion of the hold, which would be filled by opening a valve. To empty this tank, Dakin suggested setting off a controlled gunpowder explosion in a combustion chamber, connected by a pipe to the water compartment. The pressure of the expanding gas would – Dakin hoped – quickly clear the compartment, which might then be used again for cargo. Why this design was not widely adopted needs no explanation. What is interesting, however, are the advantages Dakin promised: it would 'save all the expense of taking in and throwing out ballast, as well as the loss of time this would take, which is often of more consequence than the expense'.[99] Water ballast thus aimed at reducing a ship's dependence on the unsteady supply of ballast of varying materiality and with no resale value.

The first commercially viable experiments with water ballast occurred only a few years later in the context of the coal trade between London and Northumberland.[100] Colliers were so specialized that they undertook half their voyages in ballast, each ballast trip costing time and money. In 1844, the *Illustrated London News* reported the launch of the aptly named Newcastle collier *Q.E.D.*, which boasted a double bottom 'to be filled with water by means of large taps, for the purpose of ballast – so that the only ballast is the liquid element which may, if required, be pumped out again in a very short time by the engine'. The collier's tanks eliminated the need to order, pay for, wait for, and manually stow or unload ballast. But the *Q.E.D.* was cutting-edge technology, combining several advancements of the early age of steam: an iron hull, a steam engine, a screw propeller, and steam-powered pumps.[101] This was impressive but also prohibitively expensive for possible imitators.

A cheaper alternative was offered in the 1850s by a Newcastle physician named Blair White who had patented large water-proofed canvas bags, which could be filled with water whenever ballast was required. White's water ballast system was touted to cost less than half of 'a vessel's

[97]Jean-Sébastien Guibert, 'Lest et pratiques de lestage sur les navires à destination des Antilles: état des lieux et perspectives de recherche en histoire et en archéologie maritimes (fin XVIIe–début XIXe siècle)', *Revue d'histoire maritime* 29 (2021): 77–102, 89. 'Nautical Anecdotes and Selections', *Naval Chronicle* 34 (1815): 457–465, 458; 'Biographical Memoir of Captain William Layman, of the Royal Navy', *Naval Chronicle* 38 (1817): 89–113, 104; Charles Nordhoff, *Whaling and Fishing* (Moore, Wilstach, Keys & Co., 1856), 357.

[98]Richard Steele and Joseph Gillmore, *An Account of the Fish-Pool: Consisting of a Description of the Vessel so Call'd, lately Invented and Built for the Importation of Fish Alive [. . .]* (H. Meere, 1718).

[99]G. Dakin, 'Plan of a Ship that Would Ballast and Unballast Herself', *Mechanics' Magazine*, 6 November 1830, 186.

[100]C. F. Steinhaus, *Abhandlungen aus dem Gebiete des Gesammten* [*sic*] *Schiffbauwesens*, vol. 2 (L. Friederichsen & Co., 1899), 38.

[101]'The "Q.E.D." Screw Steam Collier', *Illustrated London News*, 28 September 1844, 205. Later sources often referred instead to the *John Bowes* of Newcastle, launched in 1852, or the *Samuel Laing* from Jarrow, launched in 1854 (Steinhaus, *Abhandlungen*, vol. 2, 39; Martell, 'On Water Ballast', 336f.; Gollasch, 'Historical Overview', 4f.).

https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press

ordinary outlay for ballast in twelve months' and was allegedly 'in no danger of being gnawed by rats'.[102] An article in *The Economist* had high hopes for this invention and expected that solid ballast would disappear within a few years. While water ballast would save time and money, its most important benefit was social: 'None of the advantages ... of the invention ... will be greater than that of putting an end to the disagreeable occupation of ballast-heavers.' Technological and personal obsolescence rather than legislative reform would end the plight of London's ballast-heavers, who were at that time campaigning for protective regulations.[103] *The Economist* was wrong on both counts. It was not technological advancement, but the patient lobbying of political benefactors, that ultimately improved the condition of London's ballast-heavers, who were integrated into Trinity House in 1853.[104]

Neither Dr White's canvas bags nor water ballast in general quickly replaced solid ballast. As is often the case with the proliferation of new technologies, different systems initially competed, both with each other as well as established forms of ballasting.[105] Water ballast systems did not necessarily require steam power, and early designs like White's canvas bags and Dakin's explosive scheme were aimed at sailing vessels. This complicates the link between steam power and water ballast. The underlying mechanics of ballasting had not changed for steamships, but they were compounded by additional challenges. Steamships became rapidly lighter while burning fuel, so that a steamer ideally had to carry enough ballast to ensure operational immersion even near the end of its journey, after having consumed most of its coal.[106] Of course, this ballast then blocked space that might have been used for additional coal or cargo. Having a technology that could regulate immersion at sea was therefore particularly attractive for steamers.[107] Another factor was time. Given both the initial and the operating cost of a steamship, keeping it idle while waiting for the delivery and stowage or disposal of ballast was far costlier for steamers than for sailing ships.[108] When water ballast was gradually adopted, it was along the lines of the *Q.E.D.* Ballast was pumped into and out of compartmentalized sections of the hull and stored in tanks and double bottoms. The sail-to-steam transition catalysed rather than caused the development of water ballast, which not only solved the unique predicament of steamships, but also profited from the general advancements in naval architecture and steam power (like pumps, watertight compartments, and tanks) to make water ballasting more feasible.

How quickly did the adoption of water ballast take place and was this the end of solid ballast? Water ballasting technology first proliferated in the 1850s among British and other colliers transporting British coal to ports around the North Sea.[109] From colliers, water ballast spread, slowly and unevenly, to steamers over the next fifty years, with solid ballast often persisting and complementing water. This was the context of Martell's 1877 address, when he bemoaned the fact that the steamers carrying rice to Madras did not use water ballast and were thus at the mercy of

[102]'Dr. White's Water Ballast', *Daily News*, 5 September 1851, 6; Gollasch, 'Historical Overview', 3.

[103]'New Law for Ballast-Heavers', *The Economist*, 17 April 1852, 423f., quote 424.

[104]The 1853 Merchant Shipping Law Amendment Act (16 & 17 Vict., cap. cxxxi, s. 14) explicitly empowered Trinity House to charge for loading ballast (in addition to charging for production and delivery). Earlier, failed proposals, had envisioned creating a separate, more monopolistic entity under the control of the ballast-heavers themselves ('Ballast-heavers (Port of London) Bill: A Bill for Establishing an Office for the Benefit of the Ballast-heavers of the Port of London', Parliamentary Papers, 1852, vol. 1, no. 255).

[105]Various systems for both steam and sail colliers were discussed by Allen, 'On the Comparative Cost'.

[106]John Nicholson, 'Method of Arranging the Coal Bunkers of a Steamer so as to Reduce the Ballast to a Minimum', *RINA* 26 (1885): 98–110, 98f.; Mark Twain, *The £1,000,000 Bank-Note and Other New Stories* (Chatto & Windus, 1893), 201; Thearle, 'The Ballasting of Steamers', 120.

[107]See in discussion of Benjamin Martell, 'On Causes of Unseaworthiness in Merchant Steamers', *RINA* 21 (1880): 1–57, 47.

[108]Martell, 'On Water Ballast', 338.

[109]Allen, 'On the Comparative Cost'; Steinhaus, *Abhandlungen*, 39. Barak suggested that 'water ballasting was developed in response to the need to regulate a steamer's weight as it moved', but this is not borne out by the chronology of adoption. On Barak, 'Outsourcing: Energy and Empire in the Age of Coal, 1820–1911', *International Journal of Middle East Studies* 47, no. 3 (2015), 425–445, 435.

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shore-based ballast suppliers.[110] Water ballast became more common on cargo steamers during the 1870s. Lloyd's systematically included water ballast into its register in 1881.[111] But even by the middle of the 1880s, it was not yet self-evident that a steamer would be ballasted with water.[112]

Like its solid alternative, water ballast remained out of the public eye. When American author Mark Twain crossed the Atlantic on board the newly constructed steamer *Havel* in 1892, he declared himself to be totally surprised when one particular innovation caught his eye:

> I did not know that a ship had ever been ballasted with water. I had merely read, some time or other, that such an experiment was to be tried … The modern ship is full of beautiful ingenuities, but it seems to me that this one is the king. I would rather be the originator of that idea than of any of the others. Perhaps the trim of a ship was never perfectly ordered and preserved until now.[113]

Whatever its advantages, the materiality of water ballast came with its own problems. Water is less dense than sand and shingle, so more of the ship's interior had to be devoted to ballasting. Unlike solid ballast, which could be cleared out at any time to make room for cargo, water tanks and double hulls permanently reduced the available space.[114] And the best water ballast technology was useless if the pumps failed and tanks could not be filled.[115]

There was another, more insidious problem. Water ballast was anything but a clean, automated, and even more hidden sublimation of solid ballast. As the tanks were routinely filled with unfiltered seawater, they became covered with a 'deposit, more or less thick, of mud'.[116] Cleaning crews suffered from bad air and even the threat of asphyxiation in this crammed environment, but engineers saw this as beneficial against corrosion.[117] While some nineteenth-century botanists drew up lists of exotic ballast plants, it appears that the contemporaries did not realized that unfiltered water ballast had become a prime conduit for the global spread of invasive marine species. Marine biologists only began to take notice in the 1980s.[118] Since then, ballast has acquired a new importance for lawyers, engineers, biologists, and environmentalists.[119]

Despite the proliferation of water ballast technology, steamers did not immediately replace established forms of ballast but rather supplemented them. In the first years of the twentieth century, steamers using water ballast and coal still carried sand and gravel by the hundreds of tons.[120] Solid ballast also persisted alongside sailing ships into the twentieth century.[121] While steamers dominated major trade routes, sailing ships continued to carve out economic niches, where their lower operating costs gave them an edge.[122] As late as the 1930s, Finnish deep-water windjammers from the Åland Islands travelled with several thousand tons of ballast as far as

[110]Martell, 'On Water Ballast', 339.
[111]*Lloyd's Register of British and Foreign Shipping, from 1st July, 1881, to the 30th June, 1882* (Wyman and Sons, 1881), [5].
[112]Nicholson, 'Method', 99.
[113]Twain, *The £1,000,000 Bank-Note*, 201f.
[114]Steinhaus, *Abhandlungen*, 42.
[115]As in the 1877 case of the steamer *Beverly*; Rothery and Squarey, *A Digest of the Judgments*, 22f.
[116]Andrew K. Hamilton, 'Wear and Tear in Ballast Tanks', *RINA* 35 (1894): 60–9, 61.
[117]Steinhaus, *Abhandlungen*, 43.
[118]James T. Carlton, 'Marine Bioinvasions: The Alteration of Marine Ecosystems by Nonindigenous Species', *Oceanography* 9, no. 1 (1996), 36–43; Ian C. Davidson and Christina Simkanin, 'The Biology of Ballast Water 25 Years Later', *Biological Invasions* 14 (2012): 9–13.
[119]Matej David and Stephen Gollasch, eds., *Global Maritime Transport and Ballast Water Management: Issues and Solutions* (Springer 2015).
[120]Thearle, 'The Ballasting of Steamers', 120.
[121]Martin Lee, 'The Ballasting of the Twentieth-Century Deep Water Square Rigger', *Mariner's Mirror* 86, no. 2 (2000): 186–96.
[122]Sandro Mendonça, 'The "Sailing Ship Effect": Reassessing History as a Source of Insight on Technical Change', *Research Policy* 42, no. 10 (2013): 1724–38, 1724–6.

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Australia, and the 'Liberty Ships' of the Second World War used the rubble of bombed British cities to cross the Atlantic.[123] Nonetheless, by the early twentieth century, solid ballast, one of mankind's most persistent technologies, was in terminal decline.

The story of water ballast is then not so much one of rapid innovation thanks to a superior invention, but one of the persistence and staying power of a simple yet effective technology like solid ballast. David Edgerton has rightly critiqued innovation-centred histories of technologies by prioritizing the history of 'use' and 'things' over 'invention'. Solid ballast remained in constant use due to the persistence of sailing ships well into the steam age. The fact that water ballast was only 'marginally better' than solid ballast is a case of 'new technologies [being] indeed often additions to existing, alternative technologies'.[124]

Did water ballast ultimately increase the autonomy of ships from shore? Ships no longer depended on port-based infrastructure and labour regimes to supply the hundreds of tons of ballast they required for balance at sea. This certainly ended the tension between dredging for profit (through the sale of ballast) and dredging for navigation. Instead of organization on shore, ships now required new technological expertise and maintenance on board to ensure their stability and safe ballasting. But generally speaking, if the transition to water ballast removed one older dependency, this was negligible compared to the dependence on a global fuelling infrastructure that evolved as a consequence of steam shipping. Compared to coal, which had to be mined and shipped to coaling stations around the world, ballast water was available almost universally.[125] With the transition from sail to steam, this newfound ballasting flexibility did little to reduce the reliance of maritime activities on the terrestrial infrastructures that underpinned them.

Conclusion: Maritime connections and ballast's dual history 'from below'

Taking inspiration from E. P. Thompson, this article has investigated ballast on ship and shore. Following sand and shingle on their journey across the oceans leads deep into ships, often into the lowest, least accessible, and least visible spaces. Conceptually, this part of the hold was a place of hidden things, and in literature and the imagination it was associated with death and miasma, treasure and smuggled goods.[126] In reality, it was little more than a damp, dark space, filled with mundane mud dredged from the Thames or sand dug from the banks of the Elbe. Such ballast materials also had a non-human history by becoming a vehicle for the spread of plants, animals, and other organisms.[127] At the end of its journey, ballast was sunk again to the bed of rivers and the floor of the sea if the authorities were not quick to intervene. The spatial position(ing) of ballast was crucial, both in making seafaring work and keeping waterways unobstructed, but when viewed from a vantage point below the waterline, the materiality of ballast could easily become a threat to stability (i.e. shifting ballast) and navigability (i.e. dumped ballast). Ballast encapsulates the 'simultaneity of integration and disintegration', of connections being both enabled and undermined by the same source.[128]

[123]Abulafia, *The Boundless Sea*, 874–6, Burström, *Ballast*, 61–7; Göte Sundberg, *The Last Windjammers: Grain Races round Cape Horn* (Åland Maritime Museum, 1998), 26; Wells, 'Ballast and Cargo Handling'.

[124]Edgerton, *The Shock of the Old*, 4, xvii, 8f.; British steam tonnage only surpassed sailing tonnage in 1883; Mendonça, 'The "Sailing Ship Effect"', 1727.

[125]Steven Gray, *Steam Power and Sea Power: Coal, the Royal Navy, and the British Empire, c. 1870–1914*, Cambridge Imperial and Post-Colonial Studies Series (Cambridge University Press, 2018).

[126]See above for 'Ballast in transit'. On smuggling, see Gavin Daly, 'Napoleon and the "City of Smugglers", 1810–1814', *Historical Journal* 50, no. 2 (2007): 333–52, 343; Nauticus Britannicus [*sic*], '[Description of] Plate CCXIII', *Naval Chronicle* 16 (1806): 219–22, 221; Eric Tagliacozzo, *Secret Trades, Porous Borders: Smuggling and States Along a Southeast Asian Frontier, 1865–1915* (Yale University Press, 2005), 296; Robert Percy Whitworth, *Lost and Found: A Romance of the Desolate Region* (Melbourne, 1873), chs. 18 and 19 published in *Millicent Times*, 18 November 1899, 2.

[127]For a recent study of other non-human travellers 'below', see Jules Skotnes-Brown, 'Scurrying Seafarers: Shipboard Rats, Plague, and the Land/Sea Border', *Journal of Global History* 18, no. 1 (2023): 108–30.

[128]Wenzlhuemer et al., 'Forum Global Dis:connections', 4.

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If ballast offers a glimpse of a material history from below, it also sheds new light on the social relations that made nineteenth-century global mobility possible. Like many other tasks in the maritime world and the history of infrastructure, producing, loading, stowing, and unloading ballast rested on the mobilization of marginalized labour.[129] During its journey, ballast came into contact with destitute ballast-heavers and sailors seeking to rid themselves of the non-commodity as quickly and as easily as possible.

Taking the social and material history of ballast together does much to explain its historical and scholarly obscurity. In his study of coaling stations, Steven Gray, while drawing on Latour, argued that 'efficient infrastructure is often made invisible by its own success ... often the only time it becomes noteworthy to contemporaries, or evident to historians, is when it fails'.[130] This phenomenon, commonly called *blackboxing*, applies equally to ballast.[131] It was such an ingrained part of mobility infrastructure that most passengers did not even realize its presence just metres beneath their feet. Taken together with ballast's uninspiring materiality and the lack of major physical structures left behind by practices that relied on mobilizing labour and deploying mobile machines like boats and dredgers, it is no wonder that the history of ballast, despite its utility, ubiquity, and maritime universality, has faded from view.

Combining social and material histories from below also sheds new light on the underpinnings of global mobility in the nineteenth century. Maritime connections were created and maintained not just through complex machinery, valves, and tanks, but through drudgery, sand, and soil. Ballast reveals the literally muddy underbelly of nineteenth-century seafaring. Historians of the global and maritime history of the nineteenth century have rightly emphasized the immense transformation and acceleration of (maritime) movement in this period. By any empirical measure – speed, regularity, scale, or tonnage – the maritime world of the nineteenth century underwent a transport revolution. Yet amid these unprecedented changes, solid ballast persisted and ballast labour continued to be required for decades after the introduction of water ballast technologies. Ballast furthers our sensitivity to the realities of how global connections were maintained, and how inherently fragile such connections could be.

Acknowledgements. I wish to thank Professor Corey Ross, Professor Roland Wenzlhuemer, Lars von Felten-Kury, MA, as well as the editors of the journal, and the anonymous reviewers for their kind encouragement and helpful feedback during the preparation of this article.

Financial support. The Travel Fund of the University of Basel supported archival research in London. The Käte Hamburger Kolleg 'global dis:connect' at LMU Munich supported archival research in Hamburg, Bremen, Oldenburg, and Stade.

Competing interests. The author declares none.

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[129]Comparable cases are coal heavers and dock works. E.g. John Chalcraft, 'The Coal Heavers of Port Sa'id: State-Making and Worker Protest, 1869–1914', *International Labor and Working-Class History* 60 (2001): 110–24; Jonathan Schneer, *London 1900: The Imperial Metropolis* (Yale University Press, 1990), 39–63.

[130]Gray, *Steam Power*, 108.

[131]Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Harvard University Press, 1999), 304.

Cite this article: Blickle, P., 'Ballast: Approaching nineteenth-century maritime mobility 'from below'', *Journal of Global History* (2026) 21: 41–59, doi:10.1017/S1740022825100235

https://doi.org/10.1017/S1740022825100235 Published online by Cambridge University Press