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RESEARCH ARTICLE

Rapids as compasses: the riverine environment, experiential knowledge, and steam navigation on the Upper Yangzi River

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Abstract

During the "steam century" between 1830 and 1930, major political and economic entities in Europe, Asia, and the Americas became increasingly connected by steam navigation and railway transportation. Against this global backdrop, steam navigation was established and became regular on the formidable Upper Yangzi River in China between the 1870s and the 1920s. This breakthrough hinged on developments in the methods of tackling rapids (*tan*) – fierce and unpredictable currents descending like small waterfalls. Previous studies have mostly focused on how agents of the British Empire and other imperial powers tried to solve such constraints in steam navigation through charts, sailing directions, and other initiatives to make the Upper Yangzi riverscape legible. Incorporating previously unused archives, this article highlights how local environmental and social conditions shaped the steam shipping system on the Upper Yangzi River. This article argues that rapids, as well as local boatmen's experiential knowledge of them, propelled British and other foreign agents to transform their ways of organizing steam shipping in terms of vessel design, crew recruitment, and infrastructure allocation. More broadly, this article exemplifies the need to look beyond imperial agents and employ more locally situated perspectives to explain the technological developments underlying the modern world.

Keywords: environment; imperialism; infrastructure; steam navigation; Upper Yangzi River

Introduction

The Upper Yangzi River extends from Yibin in Sichuan Province to Yichang in Hubei Province (Fig. 1).[1] When L. St. J. Munby, a former Upper Yangtze River Inspector, looked back on his experiences of overseeing steam navigation on this formidable river segment from the 1920s to the 1940s, he highlighted "rapids" as riverine conditions that were particularly difficult to address because they "[caused] complete changes in the navigational hazards encountered from stretch to stretch." Thus, Munby emphasized that "the surfaces of the river" should be "the mariners compass." As he explained, navigation on the Upper Yangzi did not rely much on standard instruments, such as a steering compass, but rather hinged on one's experiential tactics to tell underlying hydrodynamics based on the "ever-changing face" of the river, "continually [counter] the turbulent water," and "[skirt] the constant succession of dangers in the winding fairway."[2]

[1]Jiang 1992, p. 281. In general, I use the term "Yangzi" throughout the article. I only use "Yangtze" when referring to the name of an institution or a bureaucratic title in history, such as "Upper Yangtze River Inspector."

[2]NMM, 656.628(512), W.W. Mohimer, *The Upper Yangtze and the Upper Yangtze River Inspectorate 1915–1945*, 1989.

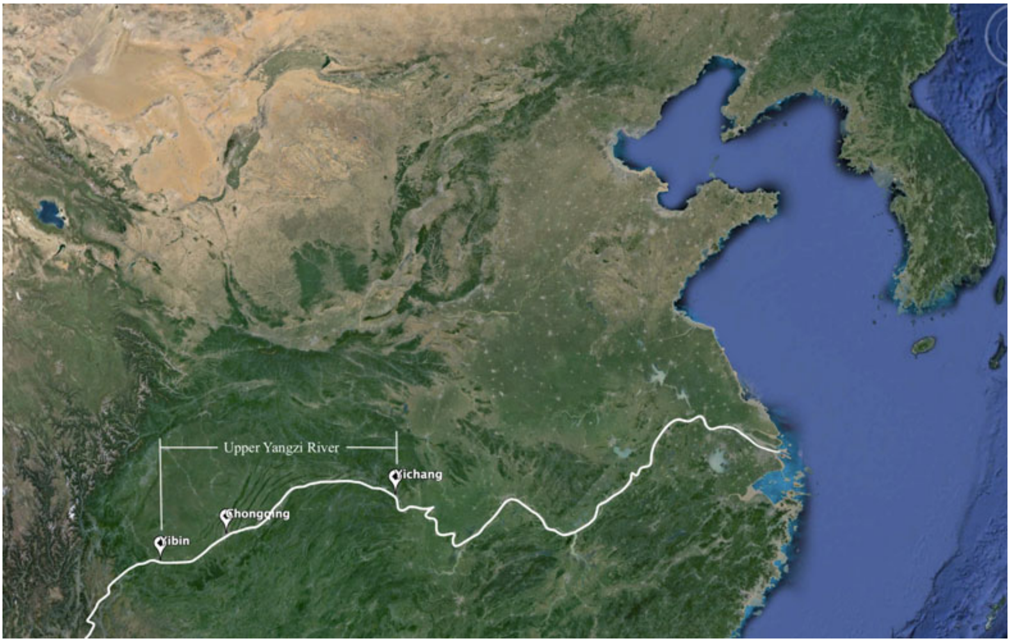

Figure 1. The Upper Yangzi River, topography: Google Earth (2015).

These comments from Munby vividly capture the central role of rapids (*tan* 灘) in shaping the daily operation of steam navigation on the Upper Yangzi well into the 1940s, more than four decades after the introduction of steam shipping into this inland waterway. The Upper Yangzi rapids were fierce, unpredictable, and turbulent currents descending like small waterfalls. They impeded navigation, particularly steam navigation, because they not only imposed technological constraints on the mechanical designs of vessels but also required shipping crews to be highly sensitive and coordinated in tackling constant changes. Most of these rapids disappeared after the Three Gorges Dam project, but the knowledge about their distribution has been inscribed into the landscape and is still used to structure many daily experiences along the river, such as the allocation of navigation infrastructures and the organization of collective responsibility units.[3] This article traces a series of initiatives to survey, chart, theorize, and cope with those rapids that took place between the 1870s and the 1920s, as regular steam navigation was gradually being established on the Upper Yangzi River. In particular, this article highlights how the riverine environment, as well as the experiential knowledge of local boatmen, reshaped the knowledge, institutions, and infrastructures of various imperial powers during the global expansion of steam technologies at the turn of the twentieth century.

The period between 1830 and 1930 has been described by historians as "the steam century," when major political and economic entities in Europe, Asia, and the Americas became increasingly connected by steam navigation and railway transportation.[4] After 1870, in particular, as the global economy became much more integrated, contestations over new resources and markets also became more

[3]"Collective responsibility unit" refers to a way of local administration that bonds a social group (e.g., people residing in the same village or people sharing the same occupation) through shared responsibilities, such as securing local social order or carrying out a public project together. *Baojia* (保甲), merchant associations, and guilds were all examples of collective responsibility units. For a study of collective responsibility units in nineteenth-century China, see Rowe 1984. For an example of collective responsibility units along the Upper Yangzi River, on a field trip to Yichang in 2021, I noticed a network of river management units organized across the towns and villages along the river, which was designed to control pollution in the river. Place names that used to be the names of rapids were still used to refer to sub-units within this network.

[4]Cafruny 1987; Pope 1995; Darwin 2020.

violent. Leading imperial powers, such as Britain, Germany, the United States, and Japan, competed to extend their steam shipping networks into the interior of different continents to expand their spheres of resource extraction and capital penetration.[5] In late nineteenth-century China, the Upper Yangzi Region became a focus of diplomatic contestation under this aspiration to extend access to global trade through new steam technologies. From the 1870s to the 1890s, the possibility of steam navigation was the focus of heated political negotiations and spurred continuous expeditions and technological explorations, which paved the way for the opening of Chongqing as a treaty port and the establishment of steam navigation in the Upper Yangzi River in the 1890s. The interlocking connection between steam navigation technology and trade rights further reinforced the competition among the Chinese, British, and other foreign shipping companies until the 1930s and motivated continuous attempts to improve the mechanical designs of steamships and re-engineer the hydraulic conditions of the river.[6]

A rich body of literature has investigated the intersection of steam shipping technology and imperialism on both global and regional scales. In his classical work on the diffusion of various technologies that facilitated imperial expansion, Daniel Headrick articulates two important features of the development of steam shipping. First, Headrick asserts that the diffusion of steam shipping was intertwined with the development of steam shipping technologies rather than preceding the latter because the varying transportation conditions in different regions propelled constant technological improvements. Second, Headrick highlights that steam shipping has facilitated the expansion of the global economy not only because of improvements in shipbuilding technologies but also because of interrelated developments in harbor reconstruction, the management of shipping logistics, and other shipping infrastructures. Nevertheless, although Headrick conceptualizes steam shipping as a complicated technological system that constantly evolved under different regional contexts, his analysis concentrates merely on how European agents introduced technological and infrastructural improvements, hence forming a narrative of steam shipping as a technological system that was diffused from Europe to "Asia and Africa."[7]

Headrick's framework, particularly the focus on analyzing steam shipping as a system of technologies that facilitated imperialism, has largely influenced studies on the expansion of steam shipping in modern China. Historians have critically analyzed the various arrangements of steam shipping and imperial control in Chinese waters in terms of cartography, navigation infrastructure, and regulatory institutions. In their studies on maps of the Upper Yangzi River, Lan Yong, Li Peng, and Corey Byrnes claim that the introduction of Western cartography oriented toward steam shipping helped various imperial agents impose the idea of global connectivity in the Chinese context.[8] Byrnes, in particular, argues that the remapping of the Upper Yangzi River "according to the metrics and optics of modern science and commerce" diminished "the power of local [and] oral forms of knowledge" that had long been used to tackle the dangerous and unpredictable Upper Yangzi waters.[9] Robert Bickers has traced the development of the lighthouse network in China. He argues that lighthouses facilitated the incorporation of China into "international engineering, scientific and information networks" that were dominated by imperial powers at the turn of the twentieth century, but this incorporation was also partly initiated by the local actors who aspired to align themselves with "international norms."[10] Anne Reinhardt examines the impacts of steam shipping on the broader daily social world and illustrates how steam shipping brought new occupations and new experiences of space and time.[11] Although some of the aforementioned studies aim to illustrate the complicated processes of knowledge exchange by attending to the roles of various local actors, the primary sources on which these studies rely still

[5]Darwin 2009, p. 64.
[6]Van Slyke 1988; Reinhardt 2018.
[7]Headrick 1988, pp. 18–35.
[8]Lan 1994; Li 2015; Byrnes 2018.
[9]Byrnes 2018, pp. 94–98.
[10]Bickers 2013, p. 456.
[11]Reinhardt 2018, p. 3.

illustrate more about how local actors appropriated the knowledge, technologies, and infrastructures introduced by imperial agents, which tends to reinforce a narrative about the subjugation of local knowledge by the technologies shaped by imperialist ideas of modernity and development. Very few studies have examined how imperial technologies, tools, and infrastructures took shape in foreign environments in the first place.[12] These processes regarding the formation of new knowledge, technologies, and infrastructures in a situated environment, however, are key to illustrating how local environments and social groups have challenged or shaped imperial knowledge in profound ways.

This article aims to fill this research gap by reconstructing the formation of regular steam communication on the Upper Yangzi River from the 1870s to the 1920s, with a particular focus on the interactions among the riverine environment, local shipping groups, and various agents of the British Empire. To this end, this article goes beyond the sources that have been used in existing studies, such as the charts and sailing directions published by the British Admiralty or the Chinese Maritime Customs Service (CMCS).[13] In addition, this case study incorporates previously unused archival materials that reflect multidirectional processes of knowledge exchange preceding the publications of the British Admiralty and the CMCS, such as intelligence reports, proposed navigation schemes, expedition survey reports preserved under the UK Hydrographic Office, and correspondence between consular officers in China and the Foreign Office in London.[14] As these new sources show, the complicated environmental features of the Upper Yangzi River – particularly rapids – compelled British officials, merchants, and pilots to localize their ways of organizing steam shipping in terms of vessel design, crew recruitment, and infrastructure allocation. Most importantly, local pilots made indispensable contributions to the codification of knowledge about rapids in the British Admiralty and CMCS publications, which, in turn, inspired the CMCS to coopt local pilots as a part of the Upper Yangzi steam shipping system until the 1940s. Far from being subjugated by the charts, sailing directions, and mechanical constructions that seemed to represent imperial shipping management, rapids, as well as local boatmen's experiential knowledge about them, constituted and reshaped the Upper Yangzi steam shipping system in significant ways during the first half of the twentieth century. This case study inspires us to look beyond imperial agents and diversify our explanations for the development of transnational technological systems that undergird the modern world.

Rapids in the Upper Yangzi River

Rapids between Yichang and Chongqing had long posed challenges to navigating the Upper Yangzi River. Records of famous rapids already appeared in poems, hydrological treatises, and governmental documents before the nineteenth century, while theorizations about rapids' features and causes began to appear at the turn of the twentieth century. Starting from that historical juncture, pilots, hydrographers, and engineers generally defined "rapids" in the Upper Yangzi as extremely fast, dangerous, and unpredictable river currents. The causes of rapids were diverse and complicated, but they often involved sudden changes in riverbed or bank conditions that significantly changed the speed, direction, and volume of river currents, such as mountain spurs or obstructions in the riverbed.

For travelers on the Upper Yangzi River before the late nineteenth century, rapids were difficult to navigate for three main reasons. First, since rapids were caused by fierce and complicated interactions between water and various riverine conditions both above and under the water, non-local and non-specialist people found it extremely difficult to see the underlying mechanisms that created rapids and employ navigation strategies accordingly. In addition, the rapids in the Yichang–Chongqing segment were distinguished from normal rapids in other parts of the Yangzi River because the water

[12]For exemplary studies that have employed this approach, see Ghosh 2022; Dong 2022.

[13]The Chinese Maritime Customs Service operated in China from 1854 to 1950. It was controlled by successive Chinese central governments but was predominantly staffed by British (and international) officials. Its initial task was to assess duties on maritime trade, but its role gradually expanded to taxation, investigation, and professional training. See Van de Ven 2014.

[14]These sources are now preserved at the UK National Archives, the UK Hydrographic Office Archives, and the UK National Maritime Museum.

currents on the surface of an Upper Yangzi rapid usually formed an inclined plane. This riverine feature made steering particularly challenging because a vessel needed to move forward and upward at the same time to successfully ascend a rapid. Finally, the illegibility of rapids was further complicated by water-level variations. The dynamics and forces of rapids changed as the depth and volume of water fluctuate. While some rapids, such as the Xin Rapid (*xintan* 新灘), were most dangerous at a low water level, others, such as the Xie Rapid (*xietan* 洩灘), were most turbulent at a medium or high water level. Moreover, under the influences of the monsoon climate and mountain erosion, the river not only had regular seasonal fluctuations but would also display sudden water-level changes during freshets.[15] Secure navigation, therefore, not only depended on knowledge about the changing dynamics of rapids in different seasons but also relied on techniques for monitoring both sudden and long-term water-level fluctuations.

Because rapids were powerful and volatile, during the late imperial period, navigating rapids always relied on collaboration among a wide range of skilled personnel and laborers. Such collaboration was often led by a helmsman (*duogong* 柁工) on the boat and a local rapids master (*tanshi* 灘師) who was familiar with the rapids at a particular place. While the former was an expert on how to steer a boat under different circumstances, the latter was skilled in reading water (*kanshui*看水) and discerning the underlying mechanisms of rapids. To guide a boat through a rapid, the rapids master would travel ahead on a small craft and send navigation guidance to the helmsman on the boat through arm gestures and verbal signals. In addition to such collaboration in determining the direction of a boat, the sailors (*naofu* 橈夫) on a boat and large groups of trackers (*qianfu* 縴夫) on the bank would also collaborate to pull a boat against a rapid when traveling upriver. Whenever boat tracking was necessary, sailors would tie several bamboo hawsers onto the boat, and tens or hundreds of trackers would pull the other ends of the hawsers on the bank to move the boat. Moreover, helmsmen would use poles to control the direction of the boat, while drummers on board would use different drum strokes to communicate the strength of the rapids to the boat-tracking team. In addition to all these specialists and laborers who were directly involved in navigation, lifeboat teams – often sponsored by local governments or elites – were stationed near extremely dangerous rapids. The divers on these lifeboats would carefully monitor the boats passing by and offer lifesaving assistance whenever accidents occurred.[16] In sum, because rapids were caused by complicated interactions among hydrological, geological, and climate factors, navigation at rapids required not only the integration of the experiential knowledge of various shipping specialists but also the deployment of human power and mechanical forces at different parts of the riverscape. Rapids, therefore, had shaped the long-term technosocial networks among shipping groups based in the Upper Yangzi region before the late nineteenth century.

At the turn of the twentieth century, when traders from Britain, France, and other colonial empires tried to extend their trade networks into the Upper Yangzi Region and introduce steam navigation, they attempted to replace the aforementioned shipping groups by standardizing their experiential knowledge. However, the tendency of rapids to integrate various environmental and social relations challenged such attempts to displace locally grounded experiential knowledge. Instead, rapids propelled agents of imperial powers, foreign pilots and engineers, and skilled local pilots to exchange their respective knowledge. The intervention of foreign imperialism, therefore, did not simply displace local and community-based navigation tactics but rather changed the form of technical collaboration in sustaining Upper Yangzi navigation.

Diplomatic contestation over the steam shipping network

From the 1860s to the 1890s, the Qing and British governments entered tedious negotiations over extending the steam shipping network to Chongqing. The diplomatic contestations were concluded by the opening of Chongqing as a treaty port in 1891, but this process also compelled British pilots,

[15]Kim 2019, pp. 64–69.

[16]Xie 2016, *Chuanchuan ji*, pp. 138–40.

traders, and diplomats to incorporate the features of rapids into their designs for steam navigation schemes in the subsequent decades.

Between 1860 and 1900, agents of the British Empire were particularly enthusiastic about expanding global trade into the interior of different continents by introducing steam communication technologies and improvement projects.[17] This aspiration for unlocking continental interiors also directed the attention of various British imperial actors to Chongqing along the Upper Yangzi River because they recognized the strategic relevance of this port city for not only facilitating their access to the enormous commercial potential of western China but also linking the British-controlled areas in China, India, and Burma. In the 1860s, several British agents, such as Thomas Blakiston and Thomas T. Cooper, organized a wave of expeditions to the Upper Yangzi Region to collect commercial intelligence and survey transportation conditions.[18] Although these explorations convinced British diplomats and merchants that western China merited long-term investment, British imperial agents also learned that the formidable "rapids and other difficulties of the [Upper Yangzi] River" precluded the possibility of steam navigation above Yichang until further breakthroughs in hydrographic survey and steam shipping technology were made.[19]

Despite this recognition of the technical constraints, the diplomatic conditions stipulated by the Qing government in 1876 motivated some British traders to investigate the possibility of steam navigation more actively. During the negotiation over the Chefoo Convention in 1876, the Qing government agreed to provisionally establish Chongqing as a treaty port, with the prerequisite that this port would not be formally open to foreign trade until it could be reached by steamship. After the signing of the Chefoo Convention, several steamship companies tried to speed up the actual opening of Chongqing by requesting to survey the navigability of the Upper Yangzi, but they were refused by the Qing Ministry of Foreign Affairs (*zongli yamen* 總理衙門).[20] These diplomatic contestations over establishing steam shipping on the Upper Yangzi River reached a pinnacle in 1887 when a British merchant, Archibald Little, demanded permission to try navigating his steamboat *Kuling* above Yichang, with the hope of establishing a steam presence in Chongqing and hence pushing the Qing state to open the port. Little's request triggered a series of intensive negotiations among the British consuls, the Ministry of Foreign Affairs of the Qing, and local officials in Sichuan and Hubei from 1887 to 1890.[21]

The multifaceted issues associated with rapids, including hydrographic and socioeconomic issues, gradually became the focus of these negotiations. On the one hand, the Ministry of Foreign Affairs and local officials tried to persuade Little to postpone the trip by highlighting the density and danger of rapids on the Upper Yangzi River. In particular, Qing officials worried that rapids would cause potential collisions between Little's steamboat and local junks, so they insisted on establishing anti-collision regulations before they allowed Little to take his trip.[22] On the other hand, the local pilots, trackers, and other laborers in the shipping industry submitted several protest proclamations, which were passed all the way up to the British Foreign Office in London during the fieriest stage of negotiation. Because the various shipping specialists and laborers had long formed technosocial networks that were oriented toward rapids, they feared that the introduction of steam navigation and potential

[17]Darwin 2020, p. xiii.

[18]Reinhardt 2018, pp. 46–48.

[19]Michie *et al.* 1869.

[20]The Qing officials used this prerequisite to delay the actual extension of the trade network to Sichuan partly because of their concern over the loss of *lijin* 釐金, a type of tax on domestic commerce that became a crucial source of the state's fiscal income after the Taiping Rebellions (1850–1864). Because foreign ships were exempted from *lijin* charges, Chinese merchants would sometimes deputize foreign ships to transport their cargo and, thereby, evade *lijin*. For the Qing government's attempt to interlock the treaty system and steam shipping network, see Reinhardt 2018, pp. 22–48.

[21]*Navigation of the Upper Yangtze. Mr Little's Schemes* 1887–1889.

[22]NAK, FO405/51, "Memorandum on the question of the navigation of the Upper Yangtze," 1890; FO228/864, "The Upriver Steamer Project," 1888–1889, pp. 251–95.

reengineering projects at rapids would threaten their livelihood in the future. They claimed that they would use rapids as bases to organize allied attacks all the way from Yichang to Chongqing to deter the arrival of Little's steamboat.[23] Although the British government still enforced the actual opening of Chongqing as a treaty port through other diplomatic strategies, Little did postpone his expedition for a decade because of the warnings of Qing officials, pressure from local shipping groups, and the technical limits of his steamboat.[24] More importantly, these diplomatic negotiations compelled British agents and other foreigners to recognize how central rapids were for organizing Upper Yangzi shipping. Therefore, beginning in the 1880s, an increasing number of British officials, scholars, and pilots emphasized the necessity of thoroughly surveying, documenting, and charting the Upper Yangzi.

Before the intensive diplomatic negotiations over Little's expedition, Qing officials had already tried to synthesize local knowledge about rapids into written records and illustrations. In 1876, an official named Ding Baozhen (丁寶楨1820–1886) began to restore and expand lifeboats along the Upper Yangzi River, a service that had existed before the interruption of the Taiping Rebellion.[25] Ding assigned this project to a Hubei navy officer, Luo Jinshen (羅縉紳), who subsequently established twenty-nine new lifeboats between Yichang and Chongqing. As a part of the preparations for this project, Luo and his team conducted systematic surveys of the dangerous spots that would create rapids and compiled *Guide to the Lifeboats in the Yangzi Gorges* (*Xiajiang jiusheng chuanzhi* 峽江救生船志). This guide documents more than 1,000 dangerous spots between Yichang and Chongqing as well as the distances between the locations. The majority of the entries include tips on how to navigate each location at different water levels (Fig. 2). The guide also includes a glossary explaining the navigation terms used by local boatmen.[26] To accompany this guide, Luo Jinshen also compiled *Illustrations of the Yangzi Gorges* (*Xiajiang tukao* 峽江圖考), a 140-leaf pamphlet that provides a continuous illustration of the riverscape from Yichang to Chongqing. Meant to be read alongside *Guide*, *Illustrations* maps the dangerous spots to specific locations in or near the river and visualizes their relative positions. Many leaves in the pamphlet also include textual annotations in the upper register, highlighting particularly formidable rapids and sharing navigation tips accordingly (Fig. 3).[27] Taken as a whole, *Guide* and *Illustrations* formed the earliest traceable accounts that systematically document Upper Yangzi rapids in terms of their names, locations, and seasonal variations.

Luo Jinshen assisted many scholars, hydrographers, and officials who conducted surveys to determine the possibility of establishing steam navigation on the Upper Yangzi River. He dispatched lifeboats to help foreigners who had obtained governmental permission to travel on the Upper Yangzi River, and some surveyors relied on the *Guide* and *Illustrations* compiled by Luo to gain basic knowledge about the riverscape. One British consular officer, Edward H. Parker, even translated parts of *Guide*, including the entries on the Yichang–Kuizhou segment and the glossary of local shipping terms, in his ethnographic travelogue *Up the Yang-tse*.[28] As a sinologist with expertise in the study of the Chinese language, Parker devoted his efforts to clarifying the pronunciations of the names of

[23]NAK, FO228/1031, "Ichang," 1887–1889, pp. 55–115.

[24]Regarding how diplomatic negotiations over Little's test trip were ultimately resolved, see NAK, FO405/51. Several British pilots and merchants did point out that Little's steamship *Kuling* was not ready for a test trip because the draught of that steamboat was too deep for the riverine conditions on the Upper Yangzi. See NAK, FO228/864.

[25]Lifeboats were equipped with skillful boatmen who would rescue passengers when accidents occurred. The earliest available record of lifeboats can be traced back to the seventeenth century, when a magistrate of Guizhou named Zhou Changqi (周昌期) used his own funds to arrange for the operation of two lifeboats near Zigui (秭歸) city. The systematic organization of lifeboats appeared in Sichuan in the mid-eighteenth century. By 1744, seventy-seven lifeboats had been arranged at the major rapids along the Upper Yangzi River. The maintenance of the boats and the salaries of the boatmen were supported by funds from the local government. Although the exact number of boats and personnel fluctuated, this system of lifeboats continued operating into the early nineteenth century until they were interrupted by the Taiping Rebellion. Kim 2019, pp. 252–54.

[26]Luo 1883a [1878].

[27]Luo 1883b [1878].

[28]Parker 1891, pp. 23–52.

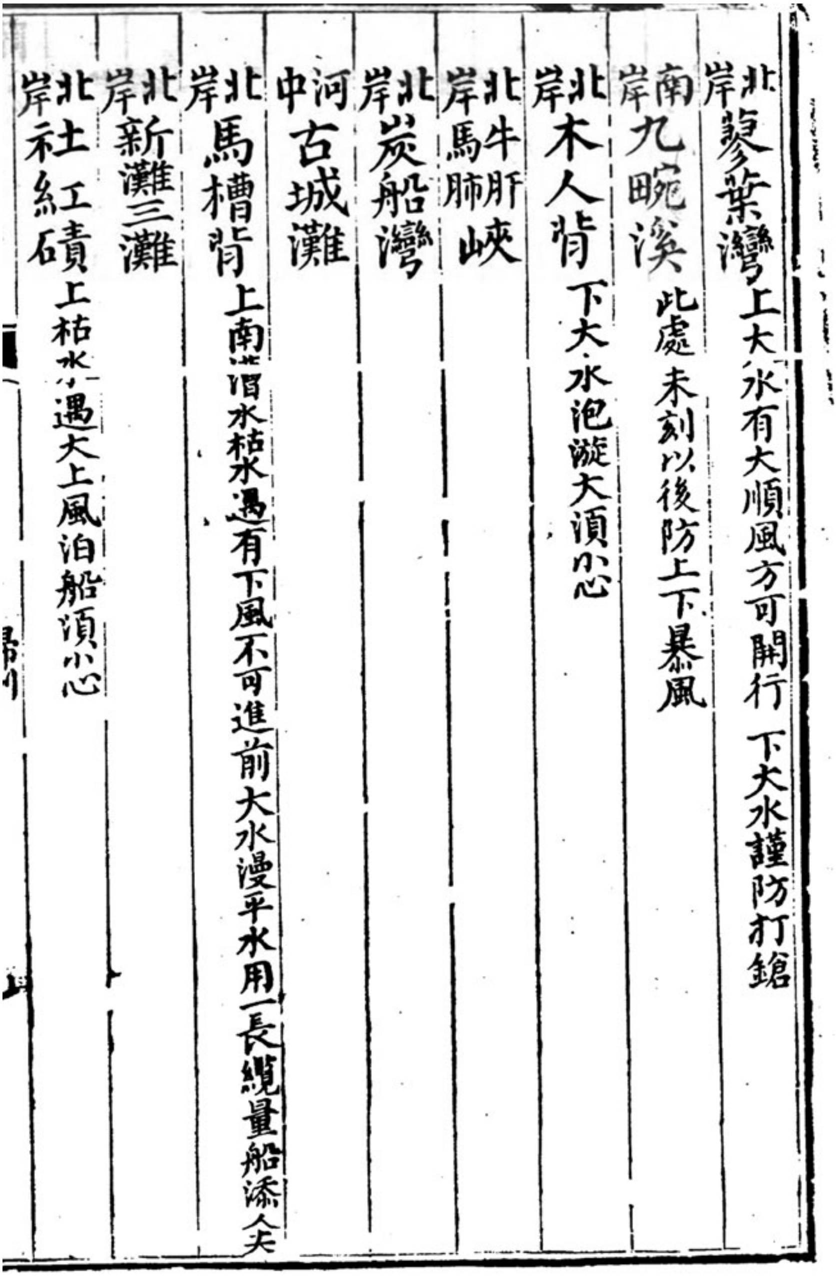
北岸[illegible]葉灣上大水有大順風方可開行 下大水謹防打鎗
南岸九畹溪此處未刻以後防上下暴風
北岸木人背下大水泡漩大須小心
北岸牛肝馬肺峽
北岸炭船灣
河中古城灘
北岸馬槽背上南沱水枯漲遇有下風不可進前大水漫平水用一長纜量船添人夫
北岸新灘三灘
北岸社紅磧上枯水小遇大上風泊船須小心

Figure 2. Sample leaf listing dangerous spots, *Xiajiang jiusheng chuanzhi*, 1883 edition.

rapids by confirming them with local boatmen. Parker anticipated that his translation would lay the foundation for a thorough investigation of the topographical and riverine conditions between Yichang and Chongqing, which he regarded as indispensable for the development of steam navigation. He claimed that such an investigation should meticulously note the shape of the summer riverbed and "the position of the rocks on either bank." Toward that end, he hoped that a precise translation of the names of the sites of rapids and shipping terms would help future surveyors better learn from local boatmen and incorporate their experiential knowledge about the complicated Upper Yangzi

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Figure 3. Illustration of the Xin Rapid, *Xiajiang tukao*, 1883 edition.

riverscape.[29] Parker's comment on the necessity of the meticulous study of rapids foreshadowed a wave of surveys aimed at codifying knowledge about rapids at the turn of the twentieth century. His

[29]Parker 1891, pp. 14, 21.

translation of Luo's *Guide* was fundamental to a series of reports, charts, and sailing directions that emerged from this wave of hydrographic surveys.

Codification of knowledge about rapids

In 1898, Archibald Little organized the first successful steam trip to Chongqing with the small 7-ton vessel *Leechuan*. This breakthrough excited many British merchants and diplomats who had been pushing for steam navigation to begin on the Upper Yangzi River.[30] The China Association, for instance, immediately wrote to the Marquess of Salisbury, requesting that the British government commission "exhaustive survey[s]" of the Upper Yangzi River and plan schemes for commercial steam communication.[31] Responding to such proposals, the Hydrographic Office under the British Admiralty soon organized a series of expeditions. From 1899 to 1901, two admiralty commanders, H. D. R. Watson and Henry E. Hillman, navigated the gunboats *Woodlark* and *Woodcock* and conducted several hydrographic surveys of the Yangzi segment between Yichang and Xuzhou (敘州) as well as Yangzi's upper tributary, the Min River (岷江). In their survey reports, Watson and Hillman meticulously analyzed and illustrated the Upper Yangzi rapids in terms of their causes, locations, variations, and technical implications for organizing regular steam communication.[32]

Paralleling government initiatives, merchants and pilots also actively sought opportunities to gather hydrographic information about the Upper Yangzi River. One representative figure was the pilot Samuel Cornell Plant. In 1897, Plant was invited by Little to navigate the commercial steamboat *Pioneer* because Plant was known for his expertise in river navigation and his experience of surveying several formidable rapids and races in the Karun River.[33] After arriving in China, Plant spent his first two years surveying the riverine conditions of the Upper Yangzi before actually navigating the *Pioneer* to Chongqing in 1900. However, because Little lacked the funds to continue operating his shipping company, he then sold the *Pioneer* to the British Admiralty in 1901. Although the Admiralty recruited Plant to navigate the *Pioneer* to its new base, Shanghai, and sponsored that trip, the British authorities did not provide a long-term position for Plant in China. Nevertheless, because of Plant's fame as a skilled river pilot, agents of other imperial powers quickly approached him with job offers.[34] Plant might have briefly worked for a Japanese company before being recruited by the French Navy in late 1901. The latter, though sharing in the general imperialist interest in the trade potential of western China, cared more about the geopolitical relevance of the broader Upper Yangzi Region than other imperial powers did. Driven by the greater goal of securing control over Indochina, the French authorities had long hoped to establish communication channels in the Upper Yangzi Region that could connect China to their colonies in Southeast Asia. From 1901 to 1903, the French Lieutenant Émile Auguste Léon Hourst organized several expeditions between Chongqing and Xuzhou on the gunboat *Olry*, and he appointed Plant as the commanding pilot.[35] Following the expeditions, Hourst, largely with the assistance of Plant, compiled their surveys and navigation techniques into a collection of navigation guides and charts under the commission of the French Naval Hydrographic Service in 1904 and 1905.[36]

[30]*Memorandum on Indian Trade with Western China* 1898.

[31]NAK, FO17/1405, "The Upper Yangtze," 1899, pp. 219–21.

[32]These reports are now preserved at the UK Hydrographic Office Archive (UKHOA). They include HTP/7/176, *Report on the Navigation of the Upper Yangtse between Ichang and Sui Fu* 1901; HTP/7/180, *Appendix to Report on the Navigation of the Upper Yangtse* 1901; HTP/7/181/2, *Addendum of Appendix to Report on the Navigation of the Upper Yangtse* 1902.

[33]NMM, NOT/43/2, NOT/43/3; Plant 1893.

[34]The German Hamburg-America Line offered Plant a generous five-year contract, while the Osaka Shosen Kaisha from Japan promised to offer a new steamer for Plant to command. NAK, FO228/1403, "Mr. Plant's Present Position as to the Steam Navigation of this Upper River," 1901, pp. 177–79.

[35]Core members of this expedition team also included three French ensigns, six Chinese boatmen who were familiar with rapids, and a former navy officer at Chongqing who made many logistical arrangements for the team.

[36]This collection consists of three publications that were designed to be read together: *Notice on the Navigation of River Rapids* (*Notice sur La Navigation des Fleuves à Rapides*), *Sketches of the Rapids between Yichang and Xufu* (*Croquis Des*

Watson, Hillman, Plant, and their colleagues made important breakthroughs in codifying a wide range of experiential knowledge about rapids into statistics, charts, models, and analytical notes. Their synthesis largely determined the methods of documenting rapids and establishing related navigation aids until the mid-twentieth century because the survey reports and charts they compiled constituted the foundation of many official charts and sailing directions later published by the British Admiralty and the CMCS. Most importantly, these hydrographers and pilots identified two main features of rapids that would impose technical constraints on steam navigation: the first was seasonal variation, and the second was that the Upper Yangzi rapids often formed a "tongue" shape. Intriguingly, because these hydrographers and pilots largely relied on local boatmen to recognize and analyze these two features, the process of codifying knowledge about rapids, in turn, encouraged them to incorporate experiential knowledge rather than replace it in their designs of steam navigation schemes.

Various sources have long noted that the Upper Yangzi rapids exhibited wide seasonal variation in terms of their degree of danger. For instance, two famous rapids, the Xin Rapid and the Xie Rapid, were most formidable in different seasons. While the former was most dangerous in winter because of exposed rocks, the latter was most challenging in spring and summer due to freshets. These discrepant seasonal variations in rapids created more difficulties for steamboats than for local junks. Because steamboats had deep draughts, they could travel only in the middle of the river, where the water was the deepest but the currents were also the strongest. While junks could utilize different routes to avoid the most dangerous part of a rapid in different seasons, steamboats had no such flexibility and were more constrained in their navigable periods.

Therefore, in the earliest steam expeditions commissioned by the British Admiralty, the hydrographers devoted particular efforts to synthesizing statistics about the seasonal variations in rapids and determining a potential navigation schedule for steamboats. In their survey reports for the *Woodlark* and *Woodcock* expeditions, Watson and Hillman included a table documenting 35 rapids that were particularly dangerous for steam vessels, with the purpose of preparing pilots for the seasonal variations and informing the authorities of where and when to arrange navigation aids. They tried to present various quantitative data, such as the specific months when a particular rapid was the strongest or the slackest and the rate of a rapid at its strongest (Table 1). Intriguingly, Watson and Hillman also emphasized that such data compilation hinged on the experiential knowledge of local pilots. For instance, the rates of currents on Watson and Hillman's table were estimated based on the speed of the *Woodlark* and the difficulty it encountered when crossing certain rapids. However, because the conditions of rapids varied seasonally and because the British Admiralty could sponsor only a limited number of expeditions, Watson and Hillman did not encounter all the difficult rapids on their survey trips. For the rapids that they were not able to observe in person, Watson and Hillman relied on their Chinese pilot on board to provide estimated data and other information based on his long years of experience.[37]

Apart from synthesizing statistics about the seasonal variations in rapids, hydrographers and pilots also developed the concept of "tongue" to encapsulate the key features of rapids that could impede steam navigation. In their reports, Watson and Hillman articulated that the Upper Yangzi rapids often ran downward in an "inclined plane," forming a tongue-like shape. The declivity of such an inclined plane varied across a rapid, which "[was] usually greatest near the center of the channel and least close to the banks." Because steamboats must travel in the middle of the river due to their deep draughts, an ascending steamboat needed a motive power that could pull it not only against the current but also up the plane, which could not be realized only with a steam engine.[38] This effect of rapids inspired foreign hydrographers and pilots to recognize the necessity of separating the motive

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Rapides Entre Itchang Et Sui-fou), and *The Upper Yangtze From Yichang To Xufu and the Tributaries Upriver of Xufu* (*Haut Yang-Tse: Entre Itchang Et Suifou Et Ses Affluents En Amont De Suifou*).

[37]UKHOA, HTP/7/176, pp. 22–23.

[38]UKHOA, HTP/7/176, p. 17.

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Table 1. Table of the principal rapids between Ichang and Chungking

No.	Name of rapid (from Admiralty and Chevalier's Charts)	Distance from Ichang in miles	Period when running strongest	Period when running slackest	Rate of current approximately at worst period (Kts. per hr.)	Period when a vessel with a speed of 13 knots can or cannot steam rapid
1	Ta tung tan	32	June, July, Aug., Sept.	Slightly slacker during remainder of year	6–8	Can be steamed at all times
2	Kung ling tan	$39\frac{1}{2}$	Dec., Jan., Feb.	August	6–8	Channel dangerous for steamers at very low river on account of rocks in channel
3	Shin tan (or Sin tan).	44	Dec., Jan., Feb., March	Improves rapidly with a rise	12–14	Cannot be steamed at worst period
4	Huang yu tan	50	Apr., May, June, July	A little slacker at low river	6–8	Can be steamed at all times
5	Ling hua tan	52	About same all the year round	–	6–8	Can be steamed at all times
6	Ye tan	$56\frac{1}{2}$	May, June, July, Aug., Sept., sometimes Oct.	Slackest at low river and at a very high river	Over 12	Can be steamed at low river and at a very high river
7	Niu ko tan	64	June, July, Aug., Sept., and part of Oct.	Slacker during remainder of year	Over 12	Cannot be steamed at worst period
8	Tsing chu piao	$71\frac{1}{2}$	Dec., Jan., Feb., March	June, July, Aug., Sept.	9–11	Can be steamed at all times
9	Fu li tsi	$87\frac{1}{4}$	Nov., Dec., Jan., Feb.	Not recognised as a rapid at high river	6–8	Can be steamed at all times
10	Tiao shi tan	$104\frac{3}{4}$	Nov., Dec., Jan., Feb., March	Improves with rising river	7–9	Can be steamed at all times
11	Shiu shih tze	$106\frac{1}{2}$	Dec., Jan., Feb., March	Improves with rising river	6–8	Can be steamed at all times
12	Wu kee tan	109	Nov., Dec., Jan., Feb.	Improves with rising river	8–10	Can be steamed at all times

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13	Hea ma tan	110	Nov., Dec., Jan., Feb., March	July, Aug., Sept. rapid almost disappears	10–12	Can be steamed at all times
14	Tuo tu tse	112	Nov., Dec., Jan., Feb.	Improves with rise, disappearing at high river	6–8	Can be steamed at all times
15	Kiao tan	115	Nov., Dec., Jan., Feb.	Improves with rise, disappearing at high river	6–8	Can be steamed at all times
16	Pao tse tan	116	July, Aug., Sept.	Improves with falling river	Over 12	Cannot be steamed at worst period
17	Tsei ka tse or Yeou cha tsi	120	Nov., Dec., Jan., Feb.	Improves with rise, almost disappearing	7–9	Can be steamed at all times
18	Tiei tan	$122\frac{3}{4}$	Nov., Dec., Jan., Feb.	Improves with rise, almost disappearing	7–9	Can be steamed at all times
19	Hei shih tan	124	July, Aug., Sept., Oct.	Improves with falling river	–	Can be steamed at all times
20	Hao kan tan	$138\frac{3}{4}$	April, May, June, Oct, Nov.	Current slacker in intervening months	–	Can be steamed at all times
21	Ngan ping tan	$142\frac{1}{2}$	Dec., Jan., Feb., March	Improves with rise, almost disappearing	8–9	Can be steamed at all times
22	Huang shi tsui	$144\frac{1}{2}$	April, May, June, and perhaps July	Remaining months hardly exists	Over 12	Cannot be steamed at worst period
23	Er tao hsi	149	Dec., Jan., Feb., March	Remaining months does not exist	–	Can be steamed at all times
24	Shi pan tan	$154\frac{3}{4}$	Nov., Dec., Jan., Feb., March	Remaining months does not exist	–	Can be steamed at all times
25	Miao ki tse	157	All the year round, except Aug. and Sept.	Aug. and Sept. almost ceases to exist	9–10	Can be steamed at all times
26	Tung yang tse	162	Nov., Dec., Jan., Feb.	Improves with rise, almost disappearing at high river	9–10	Can be steamed at all times

(*Continued*)

Table 1. (*Continued.*)

No.	Name of rapid (from Admiralty and Chevalier's Charts)	Distance from Ichang in miles	Period when running strongest	Period when running slackest	Rate of current approximately at worst period (Kts. per hr.)	Period when a vessel with a speed of 13 knots can or cannot steam rapid
27	Hsin lung tan or Sin tan (New Rapid)	178	Nov., Dec., Jan., Feb., March	Improves with rise, almost disappearing at high river	Over 13	Cannot be steamed at worst period
28	Hu tan	214	July, Aug., Sept.	Improves with falling river	Over 12	Cannot be steamed at worst period
29	Hu siu tan	275	Dec., Jan., Feb., March	Improves with rise, disappearing at high river	–	Can be steamed at all times
30	Tsan pei leang	$291\frac{1}{4}$	Middle rise	Extreme low or extreme high water disappears	–	Can be steamed at all times
31	Koan in tan and Fu mien tan	$294\frac{1}{4}$	July, Aug., Sept.	Does not exist at low river	Over 12	Cannot be steamed at worst period
32	Ta tu tsi	347	Dec., Jan., Feb., March	Improves with rise	–	Can steam at all times
33	Hiang lu tan	348	Aug., Sept., Oct.	Little current at low river	Over 12	Cannot be steamed at worst period
34	Cha hu tsi	349	July, Aug., Sept.	Disappears at low river	About 12	Steaming doubtful
35	Yei luo tse	$387\frac{1}{2}$	Nov., Dec., Jan., Feb., March	Improves with rise	–	Can be steamed at all times

Note (provided by H. D. R. Watson and H. E. Hillman): –The information contained in the above table has been obtained chiefly from the Chinese pilot of H.M.S. "Woodlark," who has had twenty years' experience on the upper river, and who has seen what this ship can do when steaming at her best. The behavior of the ship when steaming the Ye tan, and which she only just succeeded in crossing, has been used as a standard for comparing the other rapids. The table is, of course, only approximate, as it would be impossible to state definitely, when a particular rapid was running strongest or slackest, owing to the sudden rise that may occur from day to day, so that a rapid may be bad one day and greatly improved the next, and *vice versa*. The table is intended to show at what season of the year particular caution is required at the various rapids. It also shows those rapids which a vessel with a speed of 13 knots per hour cannot steam at all times.
Source: UKHOA, HTP/7/176, p. 23

power and carrying capacity of a steam vessel, pushing them to investigate different ways of combining steam navigation and local boat-tracking practices.

In addition to the material constraints of steam vessels, tongue-shaped rapids were also challenging for foreign steam pilots because they lacked the experiential knowledge to discern the changing dynamics of currents at different positions in the rapids. Watson and Hillman, for instance, noted that the fall of strong currents would cause strong swirls and eddies close to the entrance of the "tongue," making it difficult for vessels to enter the rapid.[39] When Plant and the French Navy later surveyed rapids in more detail, they realized that the currents in the major part of the "tongue" were also complicated. Below the strongest currents on the surface of a rapid, there were many undercurrents descending at variable rates and in different directions. Hence, it was difficult for pilots to steer ascending vessels in the middle of a rapid if they encountered such messy undercurrents.[40] Since the early stage of their surveys, foreign hydrographers and pilots continued to emphasize the indispensability of local experiential knowledge for secure steam navigation. On the one hand, knowledge about undercurrents, whirlpools, and eddies could be obtained only through long years of navigation experience because the dynamics of currents varied strikingly in different rapids and in different seasons. On the other hand, to secure navigation, pilots needed to be familiar with the typical routes of junks through each rapid. Because of the narrow channel and complicated conditions of currents in the Upper Yangzi River, it would have been nearly impossible for pilots to steer away if they encountered another vessel in the rapids. To avoid collision, pilots needed to know the typical routes of vessels traveling in the opposite direction and plan navigation beforehand. Such knowledge also hinged on the rich experiences of the locals.[41]

As foreign hydrographers and pilots documented the tongue-like features of rapids, they tried to articulate some general patterns of rapids and better prepare foreign pilots for local particularities. Cornell Plant made the leading contribution to the codification of the patterns of rapids. Together with colleagues in the French Navy, he developed a diagram illustrating the dynamics of four parts of a rapid. In this diagram (Fig. 4), A refers to the head of a rapid, where currents on the surface are still calm and steady. B refers to the part where currents are lifted and thus form a slope. C is the part where water falls and causes eddies on both sides of the strongest current in the middle of the rapid. Finally, D is the tip of the rapid, usually with violent whirlpools and backwaters. Using this diagram, Plant and his colleagues attempted to synthesize some general methods of ascending a rapid, sharing suggestions for the position and the angle to enter a rapid, the best speed to move at different parts of the rapid, and tips for steering.[42] This diagram became an analytical model and was appropriated in nearly all the English and Chinese navigation guides published later. Because the majority of these guides were commissioned by governmental institutions, their authors not only used the diagram to provide instructions for navigating through a rapid but also used it as strong evidence for proposing the construction of new navigation infrastructures and the reorganization of navigation-related personnel and logistics along the Upper Yangzi River. Therefore, by codifying the particularities of rapids into a diagram, Plant and his fellow hydrographers initiated a long-term process of transforming features of rapids into constituent elements of steam navigation infrastructures along the Upper Yangzi River.

Nevertheless, Plant and other hydrographers were very clear about the limits of charts and navigation guides in transferring local experiential knowledge to foreign pilots and facilitating steam navigation on the Upper Yangzi River. In their survey reports, the hydrographers of the British Admiralty always proposed the routine recruitment of local pilots on steamboats because the hydrographers heavily relied on them to tackle the constantly changing hydrodynamics at each rapid.[43] More

[39]UKHOA, HTP/7/176, p. 11.
[40]Hourst 1904, pp. 5–6.
[41]UKHOA, HTP/7/176, pp. 11–12.
[42]Hourst 1904, pp. 9–10, 18.
[43]NAK, FO17/1405, pp. 31–51; UKHOA, HTP/7/176, p. 10.

importantly, as foreign hydrographers and pilots recognized the tongue-like feature of rapids and understood the resultant technical constraints, they highlighted the necessity of diversifying the motive power of steam vessels by incorporating local tracking practices as a part of steam navigation schemes.[44] Influenced by the findings of these early hydrographic surveys, when designing initial commercial steam navigation schemes on the Upper Yangzi, many pilots, merchants, and officials decided to follow the traits of rapids and explore ways to emulate and incorporate the technosocial networks among local shipping groups.

Rapids as compasses

After Archibald Little's first steam trip in 1898, British merchants in China circulated various proposals for developing commercial steam navigation services on the Upper Yangzi River. One of these schemes was to conduct a thorough improvement project. Hydraulic improvement, normally including the deepening and straightening of river channels, was a more overarching strategy that British colonial agents employed in the greater British Empire, such as in India and Egypt, in the nineteenth and twentieth centuries.[45] River improvement was hence an intuitive plan for many investors as discussions on Upper Yangzi steam navigation proliferated. Moreover, an incident at the time helped proposals for river improvement to gain more attention. In 1896, a serious landslide in Yunyang (雲陽) caused extremely formidable obstructions in the river and created one of the most dangerous rapids, the Xinglong Rapid (興隆灘). In subsequent years, local officials, merchants, and the CMCS launched small improvement projects to remove the obstructions. Therefore, some foreign investors used the incident as a justification and tried to encourage a thorough re-engineering of the Upper Yangzi River.

John Lister Kaye was one representative figure among these investors. As an ambitious merchant, Kaye tried his chances across several different emerging enterprises in China at the turn of the twentieth century, ranging from railway syndicates to mining concessions.[46] Regarding communication in western China, his original agenda was to construct a railway from Guangdong to Chengdu, with branches along the Yangzi River extending from Hankou to Xuzhou (敘州). His long-term goal was to connect these railways to the Burma system of railways through Yunnan. Because the Qing government generally declined railway construction proposals at the time, Kaye began advocating for the hydraulic improvement of the Upper Yangzi River in 1898 and widely advertised his plan among various stakeholders, ranging from the Qing official Zeng Guangquan (曾廣荃) to Indian colonial generals such as William Nichols. Kaye's plan was to comprehensively remake the hydraulic conditions of the Upper Yangzi River using similar improvement projects on the Columbia River and the Panama Canal as models. He mentioned recruiting local shipping groups to carry out the improvement project but did not address how to accommodate these local boatmen after the thorough remaking of the Upper Yangzi riverscape.[47] Nevertheless, British consular officers in China did not support Kaye's proposal due to concerns about engineering practicability, commercial returns, and the incitement of social unrest. Most importantly, influenced by the series of hydrographic surveys in the 1900s, British diplomats on the ground recognized that it was impractical to completely modify the numerous rapids and accepted that it would be necessary to incorporate the features of rapids into steam navigation schemes.

At that time, British diplomats such as Ernest Satow were more interested in a series of schemes proposed by Cornell Plant, which were based on his continuous surveys of the features of rapids

[44]UKHOA, HTP/7/181, p. 2.

[45]For studies on the ideology of improving water management in the greater British Empire, see D'Souza 2006; Beattie and Morgan 2017; Ramesh 2021.

[46]For instance, he was successful in starting and running a coal mining concession in Anhui from 1901 to 1905. See NAK, FO17/1723.

[47]John Lister Kaye actively advertised his scheme around from 1898 to 1902; see NAK, FO17/1372, "Yangtze Corporation's Mining Rights in Yangtze Provinces," 1899, pp. 374–94; FO17/1400, pp. 27–30; FO17/1449, "Improve of Navigation of Yangtze River from Ichang to Suchou-fu," 1900, pp. 72–87; FO17/1584, pp. 38–71.

and local tactics used to handle rapids. In the decade before realizing his plan in 1910, Plant adjusted the components of his scheme several times, but it was always based on a "tug and tow" system. The design of this system was inspired by two main lessons that Plant had learned through rich experiences of confronting rapids in both steamboats and wooden junks: one lesson was to separate the motive power and carrying capacity of a vessel, and the other was the importance of experiential knowledge in tackling all the changes in rapids. Specifically, the "tug and tow" system would include a steam vessel, which could provide motive power, and a light junk carrying cargo. The steam vessel would tow the junk alongside it, while the junk would be shifted from one side to the other side of the steamer on an upriver journey depending on the direction and angle advised to enter each rapid. To ensure that the "tug and tow" system would be similar to that used with an ordinary junk in terms of draught, sturdiness, and flexibility, Plant suggested employing a Hunan type of junk as the tow because it was best adapted for the Upper Yangzi riverine environment. Regarding the crew managing this "tug and tow" system, Plant suggested recruiting a local pilot, a local helmsman, and approximately fifteen local boatmen to serve as the main body of deck hands. He claimed that these local specialists would be indispensable not only for ensuring safe navigation but also because they could train the European pilots to become familiar with the river and learn local dialects.[48]

In different versions of his scheme, Plant also suggested establishing an array of infrastructures that would be supplementary to the tug and tow system. One of Plant's focuses was the construction of new tracking equipment because, compared to junks, tracking steam vessels required a stronger pulling force and longer tracking distance. To address this new technical need, in an early scheme in 1901, Plant proposed constructing winding engines (mechanical trackers) at the most dangerous rapids and reorganizing local trackers to manage these engines.[49] As he traveled more on the Upper Yangzi River, Plant gradually adjusted this plan because he realized that fixed winding engines on the bank could not be used to tackle the seasonal variations of rapids; moreover, many banks near the formidable rapids were too steep to construct anything on. When he later worked for the French Navy, Plant developed a more feasible method, which was to use a capstan placed onboard to adjust the tracking hawser and to employ a floating sampan to extend the hawser to the tracking teams on the bank.[50] Therefore, in later versions of his scheme, Plant proposed equipping the steam tug with a capstan and a sampan to facilitate tracking.[51] In addition to tracking, Plant also pushed to establish new infrastructures that regulate the traffic of steamboats and junks. Through his surveys, Plant had learned from local boatmen that ignorance of local junk routes might lead to collisions in rapids. Inspired by earlier proposals from local skippers, Plant suggested establishing signal stations at the principal rapids to inform pilots about the traffic and prevent collisions. According to local boatmen and Plant's design, when a steamboat and a junk were about to encounter at a rapid, the staff at a signal station would hang a flag bearing a signal and guide the vessels through the correct sequence to pass through.[52] Although the authorities did not attend to this suggestion during the initial stage of establishing commercial steam navigation, the CMCS later began to implement such signal stations in the late 1910s as steam navigation on the Upper Yangzi River became more frequent.

Plant's schemes reflected attempts to emulate and incorporate the local technosocial networks that had long been used to confront rapids. On the one hand, the "tug and tow" system and proposals on tracking infrastructures had their roots in a long-existing local strategy of ascending rapids, which involved diversifying the motive forces that pull a vessel over a rapid. On the other hand, Plant's strategy for the crew members and his plan for signal stations showed his idea to address problems resulting from foreign pilots' limited experiential knowledge. The British consular and customs officials on the ground appreciated these practical considerations and showed continuous interest in Plant's

[48]NAK, FO17/1671, pp. 78–80.

[49]NAK, FO17/1474, "Mr. Plant's Confidential Report on the Steam Navigation of the River Yangtse and Min," 1901, pp. 344–73.

[50]Hourst 1904, pp. 20–26.

[51]UKHOA, HTP/7/181, p. 2; NAK, FO17/1671, pp. 77–80.

[52]NAK, FO17/1474, pp. 359–60.

schemes, but several failed steam expeditions on the Upper Yangzi River and political chaos in China made it difficult for them to convince higher authorities in London to implement the schemes.[53] Nevertheless, Plant managed to gain funding and support from merchants and officials in Sichuan.[54] In 1910, with financial support from the Szechuan Steam Navigation Company, Plant successfully launched *Shutong* (蜀通) and started commercial steam navigation services on the Upper Yangzi River according to his design of the "tug and tow" system.[55]

Taking the precedent of *Shutong* as a model, Chinese and foreign shipping companies gradually increased their steam shipping lines on the Upper Yangzi River beginning in the 1910s.[56] Then, institutions such as the Marine Department under the CMCS recognized the need to regulate navigation and localize an array of navigation infrastructures based on the environmental features of the Upper Yangzi River.[57] Therefore, in 1915, the Marine Department inaugurated a new unit, the Upper Yangtze River Inspectorate, and appointed Cornel Plant as the first Upper Yangtze River Inspector.[58] In the following years, Plant had the opportunity to implement some of the infrastructures that he designed in earlier versions of his scheme. Starting in 1918, the CMCS began to establish signal stations at dangerous rapids; originally, there were twenty-seven stations, and these gradually expanded to sixty-three stations by 1945. Beginning in the 1920s, the CMCS further expanded the allocation of navigation aids, including distributing a group of mark boats at dangerous locations that might create rapids and shifting the locations of these boats seasonally.[59] Through these processes, key features of the Upper Yangzi rapids, such as their locations and seasonal variations, became increasingly relevant in shaping the navigation infrastructures organized by the CMCS.

More importantly, as the Upper Yangtze River Inspector, Plant promoted the institutional incorporation of local experiential knowledge by introducing a pilot training and registration system. Although the British Admiralty and the CMCS had been trying to codify knowledge about rapids into charts and sailing directions since the turn of the twentieth century, these guides could not replace experiential knowledge in helping pilots handle the variable rapids and ensure safe navigation. As reflected in L. St. J. Munby's remarks, at the most dangerous spots on the Upper Yangzi River, secure navigation depended heavily on the captain's ability to interpret riverine features based on the surface of the river and to swiftly counter the turbulent water from time to time.[60] Because this ability could be attained only through long years of experience of passing through rapids, no foreign captains could pilot a steam trip independently on the Upper Yangzi River before the 1930s. Hence, Plant's strategy was to institutionally incorporate local pilots as a part of the steam navigation system. In 1917, Plant established a school to train local junk pilots to become familiar with the features of steam navigation. The Upper Yangtze River Inspectorate organized examinations to assess the pilots and register the qualified candidates under the CMCS. According to the stipulations of the CMCS, only these trained and registered pilots could provide pilotage services to the shipping companies. The way these pilots

[53]For example, the German steamer *Suisiang* was seriously damaged on its first trip above Yichang, prompting many foreign authorities to become more conservative about Upper Yangzi steam navigation again.

[54]NAK, FO228/1647, "Steam Navigation on the Upper Yangtze," 1907; NMM, NOT/43/3, "Verse and Preface Written by Mr. Tsao Shou-shan for Captain S. C. Plant," 1912.

[55]NMM, NOT/43/3, "Speech made by A.E. Eastes, Esq., British Consul at Ichang, Hupeh, China, on the occasion of the unveiling of the Plant Memorial at the Hsin Tan," 1924.

[56]Steam navigation on the Upper Yangzi River developed quickly from 1910 to 1922. By 1922, there were forty steam vessels running regularly between Yichang and Chongqing. The year 1922 was also the year when all-year-round steam navigation became feasible. See Plant and Everest 1932, p. 2.

[57]The Marine Department was established by the Inspector General Robert Hart in 1868. Before 1915, this department predominantly focused on maritime spaces and had devoted great efforts to collecting meteorological knowledge, establishing aids (e.g., buoys, water gauges) to coastal navigation, and constructing lighthouses along the coastline. Although the Yangzi River had become the main inland channel for foreign trade since the 1870s, only one river inspectorate was established in Jiujiang before 1915. For the history of the Marine Department, see Van de Ven 2014, pp. 83–87.

[58]"Inspector General's Circular No. 2842," 1918, in *Inspector General's Circulars*, Vol. 15, Second Series, 1916–1919.

[59]NMM, 656.628(512).

[60]NMM, 656.628(512).

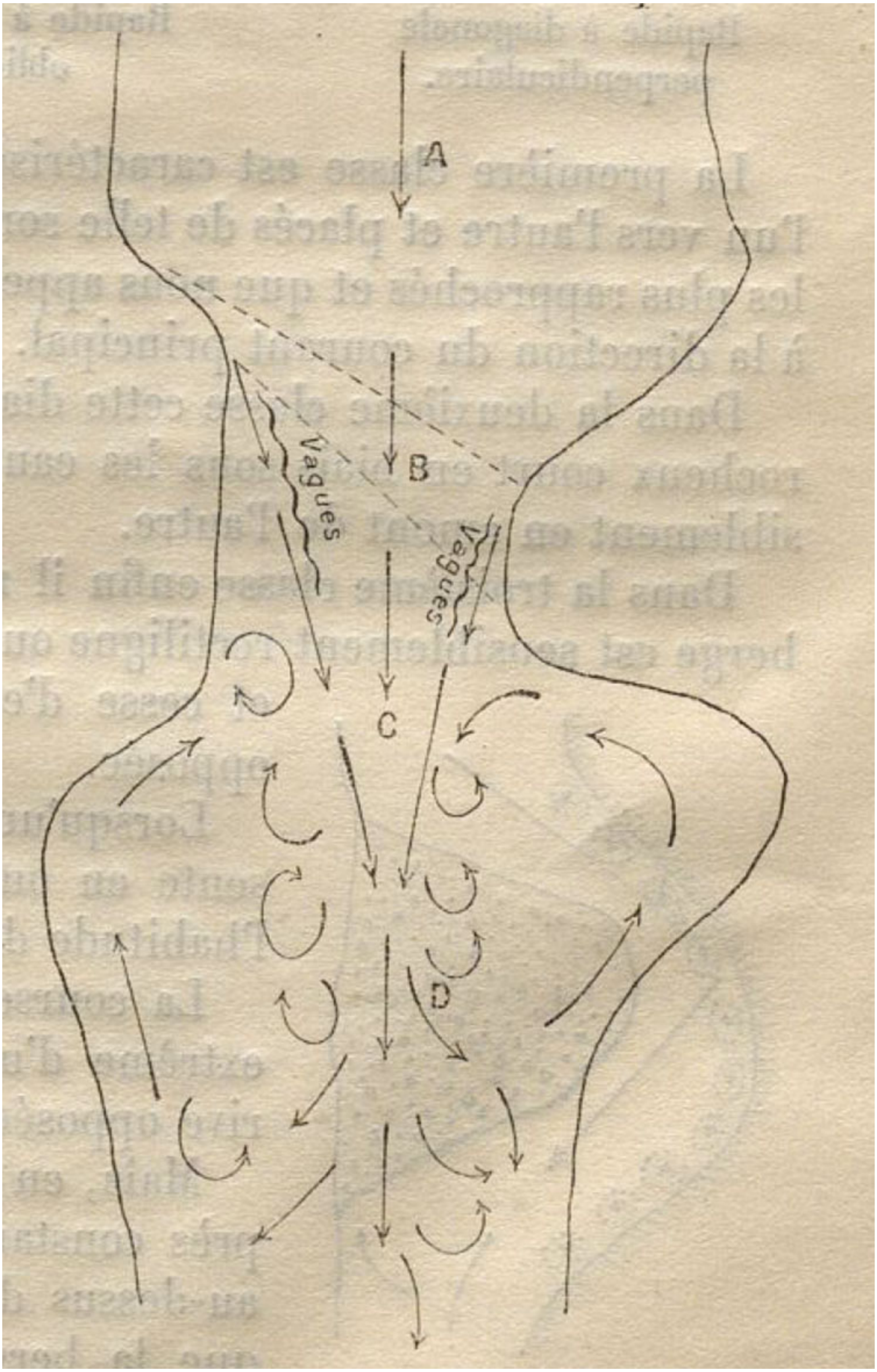

Figure 4. Diagram illustrating the dynamics of a rapid, Hourst 1904.

worked on steamboats was reminiscent of the way rapids masters guided junk skippers. Standing in front of the helmsman and the shipmaster in the engine room, the pilot had to be attentive to the constantly altering river conditions and use quick hand movements to give navigation instructions, such as signaling the helmsman on whether to alter directions or alerting the shipmaster to increase or reduce speed.[61] By 1925, the number of registered pilots under the CMCS had already exceeded 200 and remained on that scale until the CMCS ended its service in the 1940s. All the foreign steam shipping companies at that time relied on this system of pilotage service to secure their trips.[62]

At the same time, because the institutionalization of pilotage service involved multidirectional exchange of practices, it also facilitated the introduction of a new hierarchy of skills and professionalization cultures among the shipping groups in the Upper Yangzi Region. The Upper Yangtze River Inspectorate classified registered pilots into three ranks, No. 1 Pilot, No. 2 Pilot, and Apprentice.[63] A pilot with a good service record, by passing different levels of exams organized by the CMCS, could be promoted along the ladder of hierarchy and receive corresponding licenses, while a pilot who made mistakes during service would be punished and degraded.[64] This system of professional training and appraisal reshaped the working cultures among the Upper Yangzi shipping groups, allowing the CMCS-licensed pilots to gain more esteem and bargain privileges in local pilotage business disputes. For instance, a group of pilots with the CMCS licenses established an Upper Yangzi Pilot Association (*Changjiang shangyou shangduan lingjiang gonghui* 長江上游上段領江公會) in 1924 with permissions from the Ministry of Communications and the Upper Yangtze River Inspectorate. Through this association, the pilots collectively negotiated remunerations and other benefits with the shipping companies. As commercial shipping along the Upper Yangzi continued to develop in the 1920s, some junk pilots who were not certificated by the CMCS also hoped to benefit from pilotage services for steamships, so they established another Sichuan Inland Shipping Pilot Association (*Chuanjiang neihe hangye lingjiang gonghui* 川江內河航業領江公會) and began to contract pilotage businesses with shipping companies at a much lower rate. To defend their control over the pilotage businesses, the Upper Yangzi Pilot Association urged the Ministry of Communications to disband the Sichuan Inland Shipping Pilot Association, emphasizing that professional pilotage training and license should be indispensable for securing steam navigation. As they explained, the CMCS-licensed pilots not only possessed experiential knowledge about the constant variations of

[61]NMM, 656.628(512).

[62]NMM, 656.628(512). Pilotage services also existed on the Lower and Middle Yangzi River, but they were very different from the Upper Yangzi pilotage service, particularly before the 1930s. First, from the 1860s to 1930, pilotage businesses on the Lower and Middle Yangzi were dominated by foreign pilots. At the port of Shanghai, licensed Chinese pilots became marginalized since 1868. Between 1903 and 1929, there were even no licensed Chinese pilots on service. Pilotage services between Shanghai and Hankou were managed by three pilots associations: Western Pilots Association, Japanese Pilots Association, and Chinese Pilots Association. Although the members of the Chinese Pilots Association outnumbered those of the former two combined, the Western Pilots Association largely controlled the important pilotage businesses (particularly services for steamships). Second, the CMCS had very limited control over the examination of pilots on the Lower and Middle Yangzi, not mentioning making efforts to train Chinese pilots. At the Shanghai port, a Pilotage Board was formed in 1868 for assessing pilots and issuing licenses. The Harbor Master under the CMCS served on this board, but his authority was constrained by other stakeholders, such as the representative of the Shanghai Chamber of Commerce. For the Shanghai–Hankou segment, the three pilots associations were not even supervised by such a Pilotage Board. These differences illustrate that the CMCS devoted particular attention to the pilotage service on the Upper Yangzi River because they knew that local experiential knowledge could not be codified and, therefore, they had to institutionally coopt local shipping experts. For a brief history of pilotage services on the Yangzi River, see K. T. Ting, "Memorandum on Pilotage Affairs," 1945, in *D.I.G.I.G.S. Letters to Chungking* 1945; Xu and Li 2001.

[63]The remunerations for these three types of pilots were also differentiated based on ranks. According to the regulations in 1936, for pilots who had long-term service contracts with shipping companies, the suggested monthly rate for a No. 1 Pilot was 280 *yuan* in national currency (*guobi* 國幣), the rate for a No. 2 Pilot was 180 *yuan*, and the rate for an Apprentice was 68 *yuan*. See "Upper Yangtze Pilotage," 1936, in *Yangtze Ports: Smuggling and Preventive Work* (1930–1936). However, these pilots who worked for steam shipping companies were generally better paid than those who offered pilotage services to junks. For discussions on this issue, see CMA, 02970002027900000065000, 1937.

[64]CMA, 03510001003830000001, 1938–1939.

rapids but had also procured the skills to apply these knowledge within specific navigation contexts based on the draught, length, and mechanical power of a steamship.[65] To strike a balance between the interests of the two associations, the Ministry of Communications instructed that the Upper Yangzi Pilot Association and the Sichuan Inland Shipping Pilot Association be reorganized into one association in 1931, but they sided with the Upper Yangzi Pilot Association in using the CMCS licensing system to supervise over the order of pilotage businesses. After combining the two associations, the Ministry of Communications asked the Upper Yangtze River Inspectorate to reassess all the association members. The former members of the Upper Yangzi Pilot Association who could not perform well in the assessment would be constrained in getting pilotage service businesses, while the former members of the Sichuan Inland Shipping Pilot Association who could not pass the exam would be denied membership at once.[66]

As this dispute shows, professional training and licensing was gradually entrenched in the Upper Yangzi Region as an authoritative rationale for determining the hierarchy of skills, which might be mobilized by different institutions and social groups to propel their respective agendas and navigate the power dynamics in the Upper Yangzi steam shipping industry. Moreover, this system of professional training and assessment also influenced the pilots who primarily worked in the junk shipping industry. By the 1930s, a group of junk pilots also planned to gather funds from merchants and banks to establish a professional junk pilot association. Modeled on the steam shipping pilotage training system, this junk pilot association was also designed to offer professional training, conduct regular assessments, and allocate junk pilotage businesses based on the pilots' performances in the examinations.[67] Although the actual operation of this junk pilot association is so far unclear because of the limit of archives, the proposal about such an association already reflected how the institutionalization of steam pilotage service helped to expand professionalization practices and cultures among the broader groups that might not be directly involved in the steam shipping industry.[68]

In sum, the formation of the steam shipping system in the Upper Yangzi River hinged on incorporating various components of the long-existing local technosocial networks that were oriented toward tackling rapids. These strategies for incorporation included building hybrid vessels, adapting tracking practices for steam shipping conditions, and employing local pilots as regular staff of the steam shipping system. By reconstructing these practices through additional archives, I argue that local and community-based tactics for navigating rapids were reorganized into the Upper Yangzi steam shipping system in the early twentieth century, even though the more widely circulated technical publications tend to marginalize these tactics and hence shape impressions of their displacement in documentation.

Conclusion

From the 1870s to the 1920s, steam navigation was established and became regular on the formidable Upper Yangzi River. This breakthrough hinged on new developments in the methods of tackling rapids, which once imposed particular technical constraints on steam shipping. The existing scholarship has concentrated more on how agents associated with foreign imperial powers, such as the CMCS and various imperial navies, tried to solve such technological problems through charts, sailing directions, and other navigation infrastructures. Incorporating previously unused archives, this article reconstructs the active roles of various local actors in shaping and sustaining the steam shipping system on the Upper Yangzi River.

As this article demonstrates, a range of local actors contributed to the multidirectional processes of knowledge exchange that facilitated the formation of the Upper Yangzi steam shipping system. Before

[65]"Jiaotong bu xunling (3656 hao)," 1930, pp. 5–6.
[66]"Buling liang lingjiang gonghui hebing," 1931.
[67]CMA, 0297000202790000065000.
[68]The development of pilotage service for steam shipping on the Upper Yangzi River was a complicated history, so I plan to further explore this topic in another article.

political contestations over steam shipping arose, local scholar-officials had already codified boatmen's experiential knowledge into textual and graphic records, which laid the foundation for later surveys oriented toward the possibility of steam navigation. When diplomatic negotiations over extending steam navigation inland intensified in the 1870s, local boatmen and trackers, through their protests, compelled foreign diplomats, merchants, and pilots not only to recognize the hydrological importance of rapids but also to understand the technosocial stakes associated with them. During the numerous expedition surveys in the early twentieth century, local pilots contributed their experiential knowledge about rapids and more directly shaped the statistics that were later included in authoritative navigation publications, such as those commissioned by the British Admiralty and the CMCS. Most importantly, influenced by the knowledge and demands of local shipping groups, some foreign pilots and diplomats recognized the limits of codified knowledge and learned to incorporate local pilots and trackers into the steam shipping system. In 1917, the CMCS began to recruit local pilots to offer regular pilotage services, and this along with other better-known navigation aids, such as charts, sailing directions, and mechanical tracking equipment, secured the operation of the Upper Yangzi steam shipping system.

Although local junk shipping groups along the Upper Yangzi remained important until the late twentieth century, their knowledge and labor were gradually marginalized in published records.[69] While earlier sources, such as Edward H. Parker's travelogue and the earliest expedition reports of the British Admiralty, still highlighted local boatmen's experiential knowledge, the importance of their knowledge and services was rarely mentioned in navigation publications after the mid-1910s. In 1920, the CMCS published Cornell Plant's *Handbook for the Guidance of Shipmasters on the Ichang-Chungking Section of the Yangtze River*, which has long been regarded as a milestone work in synthesizing knowledge about Upper Yangzi navigation. Plant claimed in the preface that the handbook was supposed to familiarize foreign pilots with the Upper Yangzi riverscape and help them become independent of "the hands of the Chinese pilot."[70] It is worth recalling that paralleling the publication of this handbook, Plant, representing the CMCS, was also developing a scheme for training local junk pilots and coopting them to provide regular pilotage services. This ironic contrast is a good reminder to diversify our archival base and go beyond the narrative about the displacement of local knowledge under modern imperialism – a narrative that remains influential because of its prevalence in many historical documents. More broadly, this case study calls further attention to the locally situated and multidirectional technosocial interactions for explaining the expansion of global economy in the modern period.

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[69]Because of the lack of statistics, it is difficult to thoroughly compare the transforming scale of junk trade on the Upper Yangzi versus that of steam trade throughout the twentieth century. Historians of the Upper Yangzi Region generally agree that junks were largely replaced by steamships in sustaining long-distance international trade in the late 1920s, but they remained important in short-distance domestic trade. Junk communication resurged in the late 1930s and 1940s because of the urgent demands for large-scale inland relocations during the second Sino-Japanese War, though it confronted another decline in the 1950s and 1960s under industrialization initiatives. Nevertheless, junk trade remained its presence and importance on the Upper Yangzi River until the late twentieth century, when the Three Gorges Dam project completely reshaped the hydraulic conditions of this river segment. Moreover, the operation of Upper Yangzi steam communication continued to rely on the aids of local shipping groups until the 1960s. For instance, before the introduction of mechanical trackers in 1938, steamships still needed large groups of local trackers to provide navigation aids at the most dangerous rapids. Even after 1938, manual ship-tracking remained indispensable until the geographical distribution of mechanical trackers significantly expanded in the late 1960s. For comparisons of the junk trade and steam trade on the Upper Yangzi, see Jiang 1992; Xu 1993; Lan 2018.

[70]Plant 1920, "Prefatory Note."

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