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Environmental Monitoring for Water Heritage: Innovations and Challenges for the Grand Canal of Suzhou, China

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Abstract
The Grand Canal in China is a regional waterway infrastructure serving multiple functions, including transportation and water regulation, and historically, it has supported economic growth and urbanization along its route. Within China's unique decentralized environmental management system, the multifaceted value of the Grand Canal presents distinct challenges, including inter-regional and inter-departmental challenges. This article examines the latest water management initiatives along the Suzhou section of the Grand Canal and explores the role of environmental monitoring in protecting this UNESCO World Heritage property. The experimental integration of underwater-surface-aerial heritage monitoring with the Joint Meeting System in Suzhou provides a nuanced perspective on the interplay between technology and sustainable development.

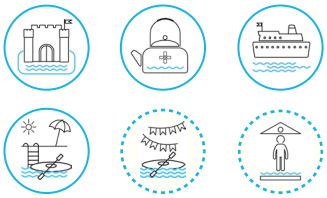
Policy Recommendations

- Grand Canal heritage management agencies should collaborate with private enterprise to assess available monitoring technologies and adapt them to contextual policies and environmental challenges, thereby establishing a localized heritage monitoring platform.
- The Grand Canal monitoring platform can be enhanced by expanding environmental monitoring beyond water resources to include biodiversity conservation, particularly in response to ecological crises.
- Technical environmental monitoring platforms need to be integrated into the reform of management mechanisms to develop a comprehensive governance model that effectively incorporates multiple government agencies, the private sector and the public.

KEYWORDS

UNESCO World Heritage
Grand Canal
environmental monitoring
water management
climate change

WATER ICONS



CLIMATE

Cfa: Humid subtropical climate

< Fig. 1 Cargo vessel on the Suzhou section of the Grand Canal, reflecting the canal's active transport role and the need for modern water management solutions (Source: 云在动, 2021. CC BY 4.0, via Wikimedia Commons).

Introduction: The Grand Canal in Suzhou

In June 2014, at the 38th Session of the UNESCO World Heritage Committee, the Grand Canal of China was inscribed on the World Heritage List. This joint application involved 27 cities along the Grand Canal, with the Suzhou section an integral component.

The heritage area of the Suzhou section of the Grand Canal stretches from the confluence of the Beijing-Hangzhou Canal (Grand Canal) and Shantang River in the north to the confluence of the Beijing-Hangzhou Canal and Taipu River in the south, covering an area of 642 ha, with a buffer zone of 675 ha (UNESCO n.d). The Suzhou section comprises seven heritage sites and five ancient river channels (fig. 2). These are the ancient sites that facilitated cultural activities associated with the Grand Canal.

These multiple canal segments, excavated across various historical periods from 495 BC to 1950, with a total length of about 73 km, represent one of the longest continuously used – and currently one of the busiest – inland water transport routes among the various sections of the Grand Canal (Huang and Yang 2023). Frequent water transportation and climate-related disasters, including storms and floods, contribute to riverbank erosion and water pollution issues in Suzhou. These challenges have made environmental monitoring an essential aspect of Suzhou's heritage management.

Existing literature on the Suzhou section of the Grand Canal mainly focuses on the preservation and development of historical culture. Vannoorbeeck and colleagues (2019) provide historiography detailing how the canal's evolution has influenced urbanization and territorial development in Suzhou since 514 BC. Xu and colleagues (2019) compare industrial heritage conservation along the Grand Canal in Suzhou with other sites in the Jiangnan area. Recent popular discourse and literature emphasize the development of the Grand Canal Culture Corridor, a new national policy associated with tourism revitalization (Wang et al. 2019; Chen 2019; Zhang et al. 2023; Gu et al. 2024). However, there is an absence of systematic analysis of the government mechanisms concerning water environment management related to World Heritage and its interplay with cultural preservation.

Considering that absence, this study examines the latest water management initiatives in the Suzhou section of the Grand Canal. The research questions are as follows:

1. How has the Grand Canal's World Heritage management been institutionalized in Suzhou?
2. How can new environmental monitoring technologies be integrated into World Heritage management locally?
3. What challenges hinder the technologies' implementation and how can they be addressed?

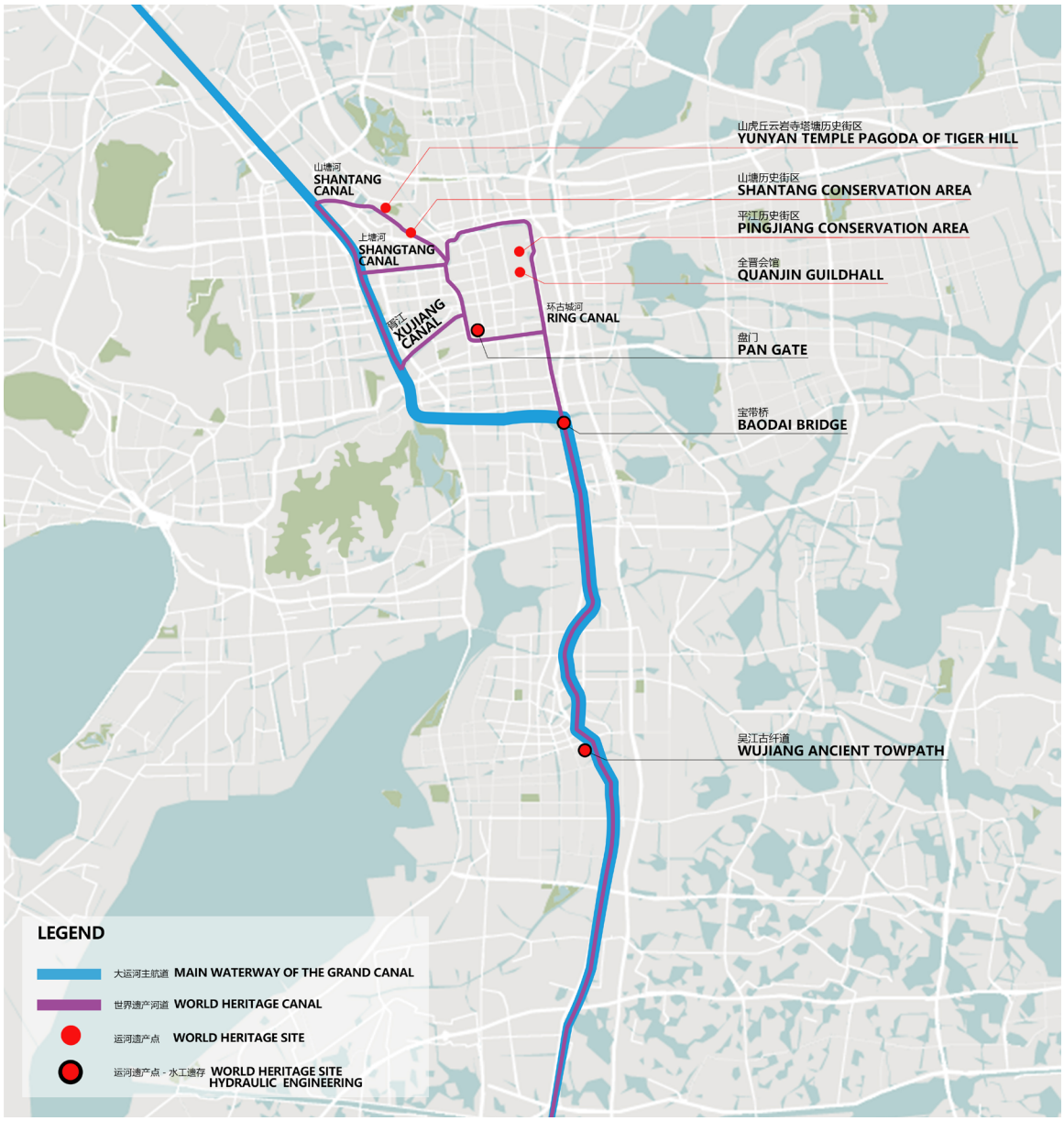
The article focuses especially on recent digital management practices along the Grand Canal in Suzhou, drawing on literature, media and interviews.

Suzhou is actively working to leverage canal water environment data monitoring as a foundation for heritage management. Issues identified through monitoring are addressed through the Joint Meeting System for the Protection of the Grand Canal – a collaborative governance framework facilitating Grand Canal management across various government functional departments. The case of Suzhou addresses the growing demand for enhanced data and knowledge sharing in the sustainable development of

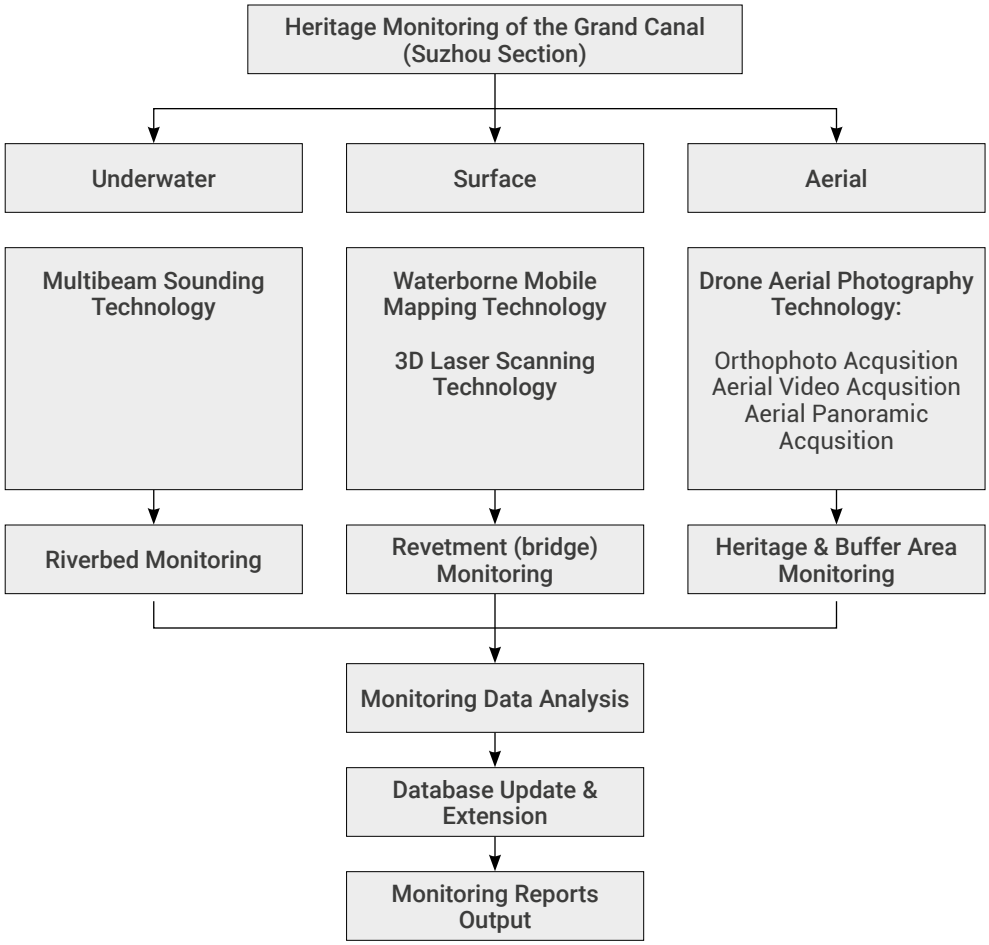
water heritage sites (Mager 2024). While Suzhou's monitoring framework has room for enhancement – e.g., involving its lack of integration with biodiversity monitoring – it highlights the potential and challenges of establishing water management practices for World Heritage properties in China and beyond.

Institutionalized Management: Data Monitoring, Platform and the Joint Meeting System

The Grand Canal Heritage Conservation and Management Office in Yangzhou, formerly the office responsible for the joint application for the World Heritage status of the Grand Canal,

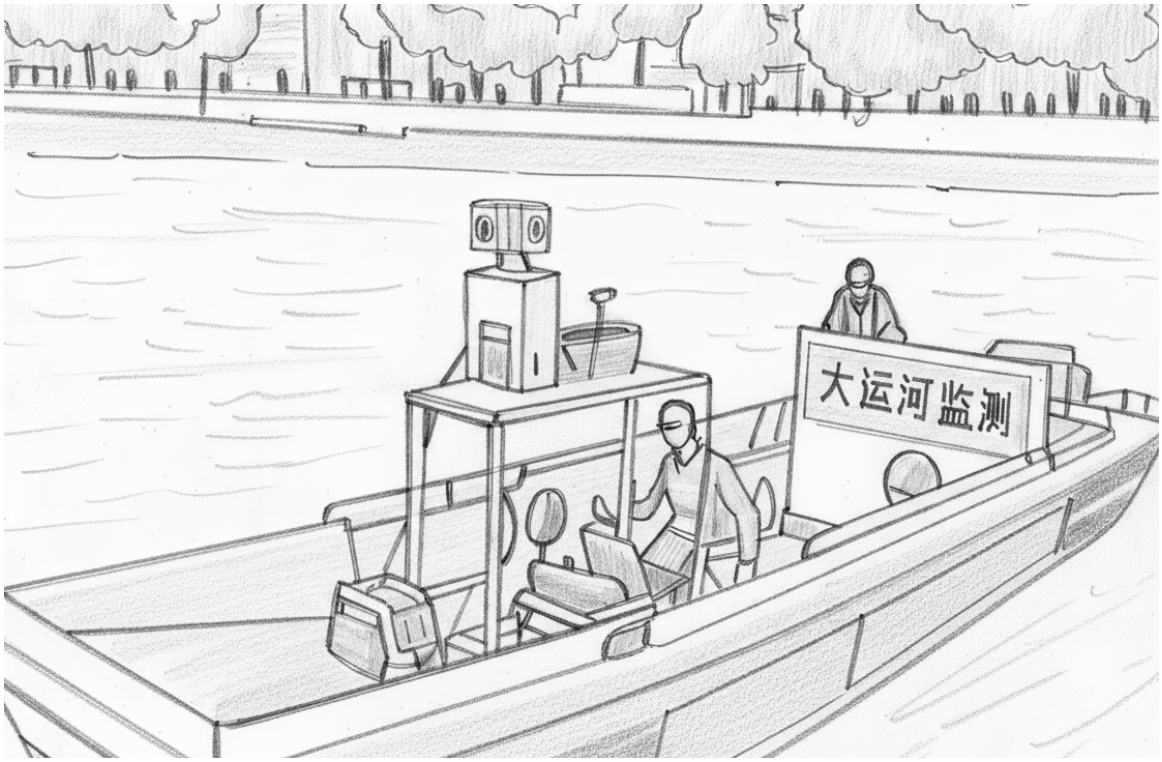


^ Fig. 2 The UNESCO World Heritage area of the Suzhou section of the Grand Canal in China (Source: Ting Wang, 2024).



^ Fig. 3 Heritage Monitoring Framework for the Suzhou Section of the Grand Canal (Source: Ting Wang, 2024).

serves as the primary institution overseeing cross-city regional heritage protection management along the Grand Canal. The management plan requires each city to have a corresponding leading management institution. In 2014, the Suzhou government established the Suzhou Grand Canal Heritage Monitoring Center (SGCHMC) under the Suzhou Cultural Heritage Conservation Institution (a subsidiary unit of the Municipal Bureau of Culture, Radio, Television, and Tourism), tasked with heritage monitoring and daily management of the Grand Canal heritage (Suzhou section). The Suzhou Cultural Heritage Conservation Institution was primarily responsible for managing architectural assets in Suzhou, but it lacked experience in handling water and environmental issues. Existing canals are managed separately by different departments related to distinct functions: the water bureau oversees water storage, the transportation department handles shipping volumes, the environmental department monitors water quality and the urban planning and construction department is responsible for tourism development. These divisions reflect the evolving culture of the Grand Canal in modern society. However, when conflicts arise between these functions, how can they be addressed?



^ Fig. 4 The Grand Canal water survey boat, equipped with a quantitative river landscape collection system including laser scanning, image capture, positioning and orientation capabilities, completes the image data collection of the water surface, embankments and bridges of the Grand Canal (Source: Ting Wang, 2025).

What is the impact of excessive cultural development on water environment conservation? How to position the new heritage management of the Grand Canal within the existing urban governance framework? SGCHMC was established to answer such questions and has proposed data monitoring to integrate cultural and water environment management in the Grand Canal heritage.

Monitoring is the first step in water environment management. Monitoring the Suzhou section of the Grand Canal involves daily manual inspection, specialized monitoring by various functional departments and heritage-specific monitoring (Suzhou Cultural Heritage Conservation Institution 2019). Since 2019, heritage-specific monitoring has included the underwater–surface–aerial three-dimensional monitoring method. "Underwater" refers to using multi-beam technology to collect depth and underwater bed morphology data, recording changes in the Grand Canal's watercourse. "Surface" involves comparing data from multiple periods to monitor changes in embankments and hydraulic structures. "Aerial" involves using remote sensing and aerial photogrammetry to survey and monitor land use changes within the protection zone. This enables monitoring of construction activities, environmental protection and landscape control along the Grand Canal.

Integrating monitoring data with existing government platforms has been a major challenge in

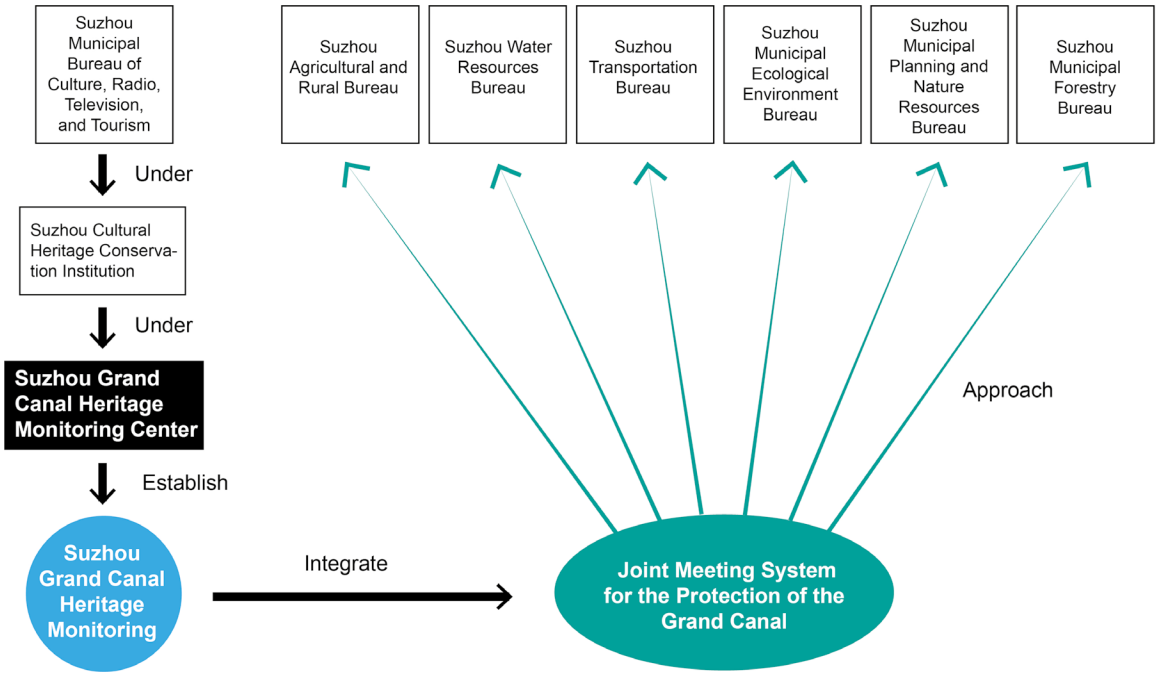
Target	Category	Indicator	Data Source
Active Canals; Historical Canals; World Heritage properties	Heritage Entity	Riverbed morphology / Structural and material stability	Underwater monitoring by SGCHMC / Aerial monitoring by SGCHMC
		Embankment preservation	Water surface monitoring by SGCHMC
		Water quality	Environmental Protection Bureau
		Water level	River Management Office
		Water surface floating objects	River Management Office
	Influencing Factors	Precipitation	Meteorological Bureau
		Natural disasters	Meteorological Bureau
		Navigation traffic	Navigation Management Bureau
		Ship collisions	Water surface and aerial monitoring by SGCHMC
		Construction projects	Aerial monitoring by SGCHMC & Planning Bureau
		Tourist volume	Tourism Administration Office
	Supporting System	Fire safety hazards	Tourism Administration Office

^ Table 1. Adapted 12 key indicators for the Suzhou Grand Canal Monitoring Platform (Source: Ting Wang, 2024).

implementing the Heritage Monitoring Framework in Suzhou. Previously, the Suzhou Cultural Heritage Conservation Institution relied on a national monitoring platform with 59 indicators, many of which were irrelevant to the management of the canal, difficult to access due to cross-departmental constraints, or unsuitable for quantitative assessment. To address this, the government institution partnered with a private technology company to develop a tailored Suzhou Grand Canal Monitoring Platform, refining the monitoring platform to 12 key indicators through fieldwork and interviewing frontline monitoring officers and other stakeholders (table 1). By leveraging drone footage and automated reporting, heritage officers can detect anomalies, such as unauthorized construction or environmental degradation, and submit digital inquiries to relevant authorities for verification and enforcement. Additionally, the platform facilitates cross-departmental data sharing through enterprise service bus (ESB) integration, allowing agencies to log in and contribute monitoring data securely. This initiative enhances localized heritage management and improves interdepartmental collaboration, streamlining administrative processes and ensuring more effective protection of the Grand Canal's cultural and environmental integrity.

To improve the utilization of environmental monitoring data in addressing conflicts between cultural development, in 2014, the Suzhou government established the Joint Meeting System for the Protection of the Grand Canal Heritage.

Unlike the vertical management model used in Canada's Rideau Canal, where a specific department handles administration and enforcement for the Canal (Parks Canada 2005), Suzhou's



^ Fig. 5 The heritage management mechanism of the Grand Canal of China (Suzhou Section) (Source: Ting Wang, 2024).

"Joint Meeting System" operates horizontally, coordinating the management of the canal across different departments. Representatives from 14 government functional departments, such as Ecology, Water Affairs, and Forestry, participate in preserving and utilizing the Grand Canal's cultural heritage. This system involves holding regular interdepartmental meetings to address issues related to illegal construction, water use conflicts and data sharing that cannot be resolved through the online platform (Xiong 2019). Starting as a pilot program in Jiangsu Province, the Joint Meeting System was officially legitimized at the national level in 2019, involving different ministerial leaders managing the China Grand Canal (State Council Office 2019).

The integration of the Joint Meeting System and data monitoring serves as a reference for developing water management in relation to the Grand Canal heritage. China's water management challenges have long been known as "Nine Dragons Run the Water" (Hou 2001; Xing 2015). While the Water Affairs Bureau oversees rivers, the issues of waterways and their adjacent spaces also involve responsibilities across various management departments, such as those devoted to urban planning, ecological environment, forestry, transportation and cultural relics. Land ownership on the sides of the canal also varies, further complicating water management efforts. Monitoring data in the Suzhou section of the Grand Canal helps to visualize water management issues primarily related to water pollution, degradation and erosion of embankments, and unauthorized construction in buffer zones around the waterway. In 2020, the Suzhou Grand Canal Heritage Monitoring Center issued 28 management letters to territorial government departments addressing the identified issues with data support (Suzhou Gov-

ernment 2021), convening multiple joint meetings with relevant departments to resolve these issues. Meanwhile, data from riverbed scans in heritage-specific monitoring supported the river dredging process initiated by the Water Affairs Department.

Biodiversity Monitoring and Multiple Actors Involved in Platform Governance

The impacts of climate change on the Grand Canal are multifaceted. Climate disasters like storms, typhoons, and floods directly impact the canal, along with changes in precipitation patterns that affect water levels and flows (Fu 2022). Meanwhile, some slow-onset impacts of climate change – e.g., riverbank weathering, erosion, changes in groundwater levels, and foundation settlement – also pose a danger to cultural heritage sites (Lefèvre 2014). Suzhou Grand Canal heritage monitoring has tackled the drastic and less visible impacts of climate change by including data on water level and quality submitted by the Water Affairs Department – such as (temperature, total suspended solids, total nitrogen, total phosphorus and chlorophyll a), as well as river spatial data (riverbed topography, depth ratios and water depth changes) (Suzhou Cultural Heritage Conservation Institution 2023).

It is important to note that climate change also affects the biodiversity of canals and their surroundings, in a process of "slow violence" (Nixon 2011). The Grand Canal not only serves as a national corridor for economic and cultural exchanges but also as a biodiversity corridor. Shifts in temperature can alter habitat conditions within and around the canal, affecting the

^ Fig. 6 A white heron standing on the Wujiang Ancient Towpath with naturally growing weeds. The towpath divides the canal into two different wetland ecosystems (Source: Ting Wang, 2024).

species that can thrive there, such as water microorganisms and birds. Warmer temperatures and altered water patterns can create more favorable conditions for invasive species (Zhang 2022). The natural decay of the canal heritage also creates a site for spontaneous plant growth, which lacks proper monitoring (DeSilvey 2017; fig. 6).

There remains a significant gap in the collection of biodiversity data for the Grand Canal and its adjacent areas. The Suzhou Grand Canal Heritage Monitoring Center can further explore how to link biodiversity data with monitoring efforts in other connected areas, such as rivers and wetlands managed by other departments. This effort will enhance environmental conservation management in Suzhou on a broader scale.

The newly enacted Regulations on the Protection, Inheritance, and Utilization of the Grand Canal Culture in Suzhou City in 2023 emphasize the importance of involving diverse actors in heritage management (Suzhou Government 2023). As China advances the development of the Grand Canal Cultural Corridor, the need for effective management coordination will increase, necessitating greater involvement from non-governmental entities such as community residents, local businesses and international organizations. Exploring reforms to the Joint Meeting System that might make it a more inclusive platform for governance of the Grand Canal is a direction worth considering.

Conclusion

As a continuous and dynamic landscape, the Grand Canal presents complexity in spatial and cultural conservation. Suzhou's management of the Grand Canal illustrates how data and technologies can be integrated with managerial innovation. The combination of the underwater-surface-aerial monitoring platform and the Joint Meeting System exemplify Suzhou's innovative approach to Grand Canal heritage management. The applicability to other parts of the Grand Canal system and to UNESCO Heritage assets worldwide merits investigation. While technological advancements have made data monitoring the primary step in management, it is important to note that heritage conservation should not solely rely on technological fixes (Huesemann and Huesemann 2011; Fomin and Laužikas 2024). Designing collaborative management systems involving diverse participants effectively prompts reflection about what data to collect and how to utilize it, highlighting the key to World Heritage management, especially in the field of water.

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