From Bay to Globe: The Jiaozhou Bay Model for Ocean Sustainability

HU Ziyuan[a], SUN Song[a,b,c], ZHENG Shan[a], GUO Shujin[a], ZHAO Yongfang[a], SUN Xiaoxia[a,c,1,*]

a. Jiaozhou Bay National Marine Ecosystem Research Station, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
b. Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
c. University of Chinese Academy of Sciences, Beijing, China

Abstract: As global coastal ecosystems face compounding challenges from climate change and anthropogenic pressures, long-term ecosystem observation and integrated research are increasingly vital. The Shandong Jiaozhou Bay Marine Ecosystem National Observation and Research Station, the only national field station for marine ecosystem observation and research in China's temperate seas, has built a comprehensive platform for ecological observation and interdisciplinary research. This paper discusses how the Station leverages its long-term observation platform capacities to support both national marine strategies and global sustainability goals, through technological development, scientific research, public engagement, and international cooperation. This case study provides a replicable example for global coastal ecosystems in terms of management and sustainable development.

Keywords: Jiaozhou Bay, marine observation, scientific research, ecosystem, sustainable development

Cite this article as: HU Ziyuan, SUN Song, ZHENG Shan, GUO Shujin, ZHAO Yongfang, and SUN Xiaoxia. (2025) From Bay to Globe: The Jiaozhou Bay Model for Ocean Sustainability. *Bulletin of the Chinese Academy of Sciences*, 39(3), 187–198. DOI: https://doi.org/10.1051/ bcas/2025004

* To whom correspondence may be addressed. Email: xsun@qdio.ac.cn (SUN X.)

[1] SUN Xiaoxia, researcher at the Institute of Oceanology, Chinese Academy of Sciences (IOCAS), Director of the Shandong Jiaozhou Bay Marine Ecosystem National Observation and Research Station, Deputy Director of the IOCAS Laboratory of Marine Ecology and Environmental Sciences, and Chair Professor at the University of Chinese Academy of Sciences (UCAS). Her research interests focus on marine ecology and biological oceanography, with expertise spanning long-term ecosystem monitoring, marine ecological security, microplastic ecological risks, and health assessments of coastal and oceanic ecosystems.

Copyright © 2025 by the Chinese Academy of Sciences and published by the journal *Bulletin of the Chinese Academy of Sciences*. This article is licensed and distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives license 4.0 as given at https://creativecommons.org/licenses/by-nc-nd/4.0/.

1. Introduction: A Temperate Bay as a Global Model

Coastal ecosystems globally are confronting unprecedented pressures from intensifying anthropogenic activities and climate change (Wang et al., 2023, Dai et al., 2023). Ecological issues such as habitat degradation, biodiversity loss, and frequent ecological disasters are becoming increasingly prominent. In this context, marine ecological protection and sustainable development have emerged as core issues both in China and worldwide. Long-term observation and scientific research serve as the foundation for understanding ecosystem changes and formulating effective protection strategies.

Jiaozhou Bay (JZB), located in the temperate zone of northern China, stands as a microcosm of coastal development in the country. With its unique biogeographic features and rapid socio-economic development in surrounding urban areas, JZB's ecological evolution mirrors the complex interaction between human activities and natural processes while reflecting the challenges and transitions of coastal zones nationwide. Furthermore, it provides a valuable reference model for sustainable management globally.

The Shandong Jiaozhou Bay Marine Ecosystem National Observation and Research Station (referred to as the JZB Station), the only national field station for marine ecosystem observation and research in China's temperate seas, is part of the Institute of Oceanology of the Chinese Academy of Sciences (IOCAS), and serves as a key component of the Chinese Ecosystem Research Network (CERN). Relying on interdisciplinary teams in marine ecology, environmental science, chemistry and biological taxonomy, the JZB Station is strategically positioned as an integrated platform for observation, research, and demonstration. The accumulated long-term data from the past four decades have transformed JZB into a globally recognized "model bay" for studying temperate coastal ecosystem evolution and responses to multiple stressors, and established it as a key platform connecting basic research and practical application.

At the core of this framework is an observation system covering 14 representative observation sites across the bay. Combining quarterly, monthly, and project target or event-response observation campaigns, this system monitors over 50 key ecological and environmental parameters, including hydrological, chemical indices, phytoplankton, zooplankton, benthic organisms and sediment properties. By integrating the research vessel and continuous updates of advanced instruments, the JZB Station has established a ship/shore-based multi-disciplinary *in-situ* observation system that ensures consistent, standardized data collection aligned with national and international standards.

Beyond the observation system, the Station has also developed three core research platforms: an automated marine biological image recognition and analysis platform for rapid identification of plankton species; a marine biodiversity research platform supporting long-term tracking of species diversity dynamics; and a field-controlled experiment platform to study ecological process mechanisms under controlled conditions.

These platforms, combined with the observation system and a shared database, form an integrated ecosystem research infrastructure that enables both bay-scale ecological surveys and controlled experiments, facilitating in-depth exploration of ecological processes.

This article aims to systematically summarize the key experiences and achievements of the JZB Station in marine ecological protection and sustainable development. The article will unfold in the following sections: introduction of the Station and its integrated observation and research platform; systematic scientific research work through long-term observation to address national priorities and scientific frontiers; the translation of scientific outcomes into policy and public engagement; practices and insights in international collaboration and technology transfer; future directions and strategic visions for advancing marine ecosystem protection. Through systematic analysis of over four decades of research and observation, we aim to demonstrate how long-term ecosystem research can effectively support both national marine strategies and global sustainability goals, and to provide a replicable example for global coastal ecosystem management and sustainable development.

2. Four Decades of Discovery: Research Serving National Priorities and Scientific Frontiers

Relying on its multi-layered observation and research framework built over decades, the JZB Station has conducted transformative studies on the interplay of climate change and anthropogen-

Fig. 1. Research vessel and *in-situ* observation operation.

ic pressures. Strategically aligned with China's priorities in ecological security and sustainable ocean governance, JZB's research pushes boundaries in marine ecology and environmental science, advancing globally relevant knowledge while delivering evidence-based support for marine ecological protection.

2.1 Ecosystem evolution under climate and anthropogenic pressures

Understanding how coastal ecosystem changes in response to the combined impacts of global climate change and intensified human activities is imperative for predicting coastal ecosystem trajectories and developing adaptive management strategies. Continuous, accumulative observation has enabled significant scientific breakthroughs in understanding the long-term evolution of marine ecosystem in JZB under compounding pressures.

Analysis of multi-decadal dataset revealed profound shifts in the JZB ecosystem, accompanied by complex changes in physical and chemical environments. A fluctuating but rising trend in regional temperatures over the past century has been observed. Anthropogenically enhanced nutrient loading from industrial effluents and domestic sewage has significantly altered both the stoichiometry and concentrations of nutrients. The warming trend, combined with nutrient imbalances, synergistically triggered shifts in plankton communities.

The number and abundance of warm-water species have increased since the 1980s (Sun et al., 2011; Wang et al., 2022), with the increasing dominance of dinoflagellates as a prevailing feature, leading to altered phytoplankton species composition and community structure. Changes were also detected in zooplankton abundance and community structures as well. Since 2000, zooplankton abundance in JZB has shown an increasing trend, with a particularly notable in-

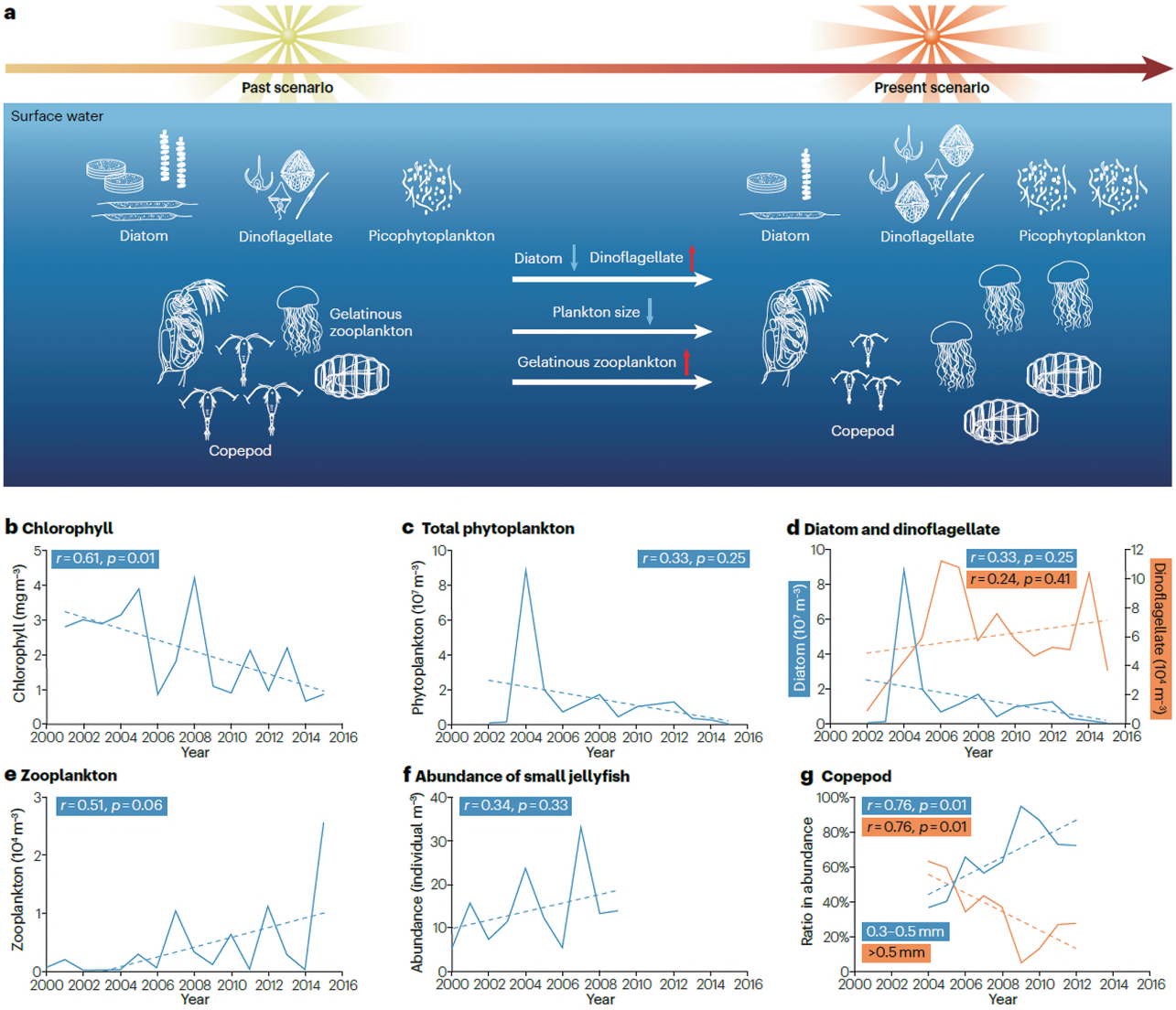

Fig. 2. Changes in plankton communities. a, schematic comparison of the plankton communities in the past and the warmer present. b, surface chlorophyll-*a* concentration; c, total phytoplankton cell abundance; d, cell abundance of diatoms (blue) and dinoflagellates (yellow); e, zooplankton abundance; f, abundance of small jellyfish; g, the abundance ratios of small-sized (0.3–0.5 mm; blue) and large-sized (>0.5 mm; orange) copepods (Wang et al., 2023).

crease in gelatinous zooplankton (Sun et al., 2012). For instance, the abundance of small jellyfish in JZB surged to fivefold levels relative to the 2000s. Conversely, the abundance of prey-type zooplankton like large copepods decreased significantly during the same period (Wang et al., 2018).

Large jellyfish outbreaks can reduce zooplankton availability, compete with small fish for food, and inefficiently transfer energy to higher trophic levels, potentially impacting fisheries through bottom-up control (Wang et al., 2024). The JZB ecosystem has evolved toward a state characterized by nutrient imbalance, increased dinoflagellate populations, miniaturization of zooplankton, and dominance of gelatinous species.

Through long-term observations, the research team at the Station revealed the over-summering mechanism of *Calanus sinicus* and confirmed that *Calanus sinicus* in China's coastal waters belong to one interconnected population, laying a foundation for marine ecosystem dynamics modeling. Furthermore, JZB Station innovated zooplankton ecology research by systematically proposing the concept and classification of marine zooplankton functional groups, dividing crustacean into subcategories and identifying distinct gelatinous groups based on their ecological roles and trophic transfer efficiencies (Sun et al., 2010). This theoretical innovation has revolutionized the research paradigm

of zooplankton ecology, and provided an important framework for ecosystem health assessment, fishery resource research, and ecological dynamics modeling.

2.2 Understanding and managing coastal ecological disasters

Coastal ecological disasters have become increasingly frequent and pose severe threats to marine sustainability, by altering trophic structures, reducing biodiversity, degrading habitats and causing economic losses, etc. Investigating the underlying mechanisms of these disasters is essential for safeguarding ecological security and achieving sustainable development goals. The JZB Station has become globally renowned for unraveling the mechanisms behind major ecological disasters.

The Station pioneered the understanding of jellyfish outbreak dynamics in Chinese seas (Sun et al., 2011b; Sun et al.,2012; Wang et al., 2012; Zheng et al., 2015; Zhang et al., 2017; Wang et al., 2020; Zang et al., 2022; Wang et al., 2024), building upon its continuous monitoring and research that provided an indispensable data foundation for identifying driving factors. This long-term work formed the scientific basis for the investigation of outbreak mechanisms and the development of control strategies. These efforts led to breakthroughs like the first *in vitro* cultivation of the full life cycle of giant jellyfish (*Nemopilema nomurai*), identifying temperature as the key trigger for transitions between asexual (polyps) and sexual stages (medusae) (Chi et al., 2022), and revealing the critical role of benthic environments and filter-feeding organisms in polyp settlement control (Zang et al., 2023).

The JZB Station also achieved a systematic breakthrough in green tide (*Ulva prolifera*) research after a decade of investigation. The research team systematically clarified the origin, occurrence mechanism, and prevention and control mechanism of *Ulva prolifera* (Liu et al., 2022a, b; Sun et al., 2024), and proposed a novel green-tide index for green-tide detection in the Yellow Sea, which can predict the scale of the Yellow Sea green tide 30 to 40 days in advance and successfully predicted the significant decline in the green tide scale in 2017.

Targeting the outbreak species of sea star (*Asterias amurensis*)

Fig. 3. Scenes from some past ecological disasters occurring in Chinese coastal areas: a, green tide; b, red tide; c, jellyfish outbreak; d, sea star outbreak.

in JZB, the team has also established a quantitative analysis framework comprising a length-based method for estimating individual sea star biomass and an *in-situ* monitoring approach using small ROVs. Through this integrated methodology, quantitative studies have been conducted to investigate the habitat density and biomass of the sea star and to reveal its spatial distribution patterns, enabling rapid quantification of spatiotemporal distribution and variation trends of sea stars in JZB, and providing critical technical support for outbreak early-warning and disaster response (Zhu et al., 2023).

2.3 Microplastics: From distribution patterns to control strategies

As a globally pervasive emerging pollutant, microplastics have become a critical concern due to their persistence, wide distribution, and potential ecological risks. The accumulation of microplastics in marine organisms could be transferred through food webs and have potential threats to ecosystem integrity and human health via seafood consumption. Investigating their distribution patterns, bioaccumulation pathways, and ecological effects is key to assessing pollution risks and formulating targeted mitigation strategies.

The JZB Station has taken a leading role in microplastic research (Sun et al., 2017; Sun et al., 2018a; Sun et al., 2018b; Sun et al., 2019). Research teams investigated the abundance, characteristics, and spatial distribution of microplastics in the atmosphere, seawater, sediments, zooplankton, and benthic organisms of JZB. The multi-media occurrence and biological transport of microplastics were revealed, and an innovative bioremediation method suitable for bay environments was proposed. These studies provided an in-depth analysis of the spatial distribution patterns and transport processes of microplastics in typical bays, offering a scientific basis for ecological risk assessment as well as pollution prevention and control of microplastics.

Atmospheric deposition was one of the important sources of microplastics in JZB. The annual mass of microplastics entering JZB via atmospheric deposition was estimated at 7.612 ± 3.474 tons (Zhao et al., 2023). The average annual concentration of microplastics in surface seawater in JZB was 0.94 particles/m^3 (Liu et al., 2020). In zooplankton communities, the average microplastic abundance was approximately 0.28 ± 0.13 particles per individual (ind.), and the potential risk of microplastic transfer along the planktonic food chain was revealed (Meng et al., 2024c; Zheng et al., 2021). Further estimates of microplastic abundance and load in benthic organisms revealed an average of 1.00 ± 0.11 particles/ind. (or 15.49 ± 3.49 particles/g). Based on population density, the total microplastic load in benthic fauna was estimated to be approximately 50.64 kg (Zhang et al., 2023).

Researchers also quantitatively revealed the transport processes and settlement fluxes of microplastics in different media, and highlighted the crucial role of filter-feeding organisms in the vertical transport of microplastics between water bodies and sediments (Meng et al., 2024a), and emphasized the great potential of bioremediation of microplastic pollution in natural waters based on the "biological microplastic pump" effect of filter-feeding organisms (Meng et al., 2024b).

2.4 Ecosystem health assessment: Tracking bay-wide conditions and trends

Marine ecosystem health assessments can provide scientific insights for the protection of marine ecosystems and environment, as well as for ecological management. Therefore, marine ecosystem health assessments are considered instrumental in ocean governance and the development and use of oceans and seas.

The JZB Station developed a coastal ecosystem health assessment system to scientifically evaluate the overall health status of the bay and its long-term trends, translate observation data, research results and scientific understanding into information accessible to the public and policy makers, thereby supporting progress on marine environment protection and resources management.

By analyzing the long-term trends of key ecosystem elements of the bay, along with relationships between critical ecological processes and systemic shifts (Sun et al., 2015), the team developed a heath assessment framework (Report Card) for JZB (Logan et al., 2020; Sun et al.,2025) to quantitatively evaluate ecosystem condition and track shifts over time. This innovative tool, coupled with machine learning technology, integrates a wide array of physical, chemical, and biological data into a holistic score of ecosystem health and highlights the nonlinear impacts of urban development and human pressures on coastal ecological health.

The results of the health assessment show that the health grade of the JZB ecosystem was "B" in 2021, indicating that the bay ecosystem is in relatively good condition. No significant difference in the health condition is observed among different regions of the bay, as all regions received a "B" grade. For the

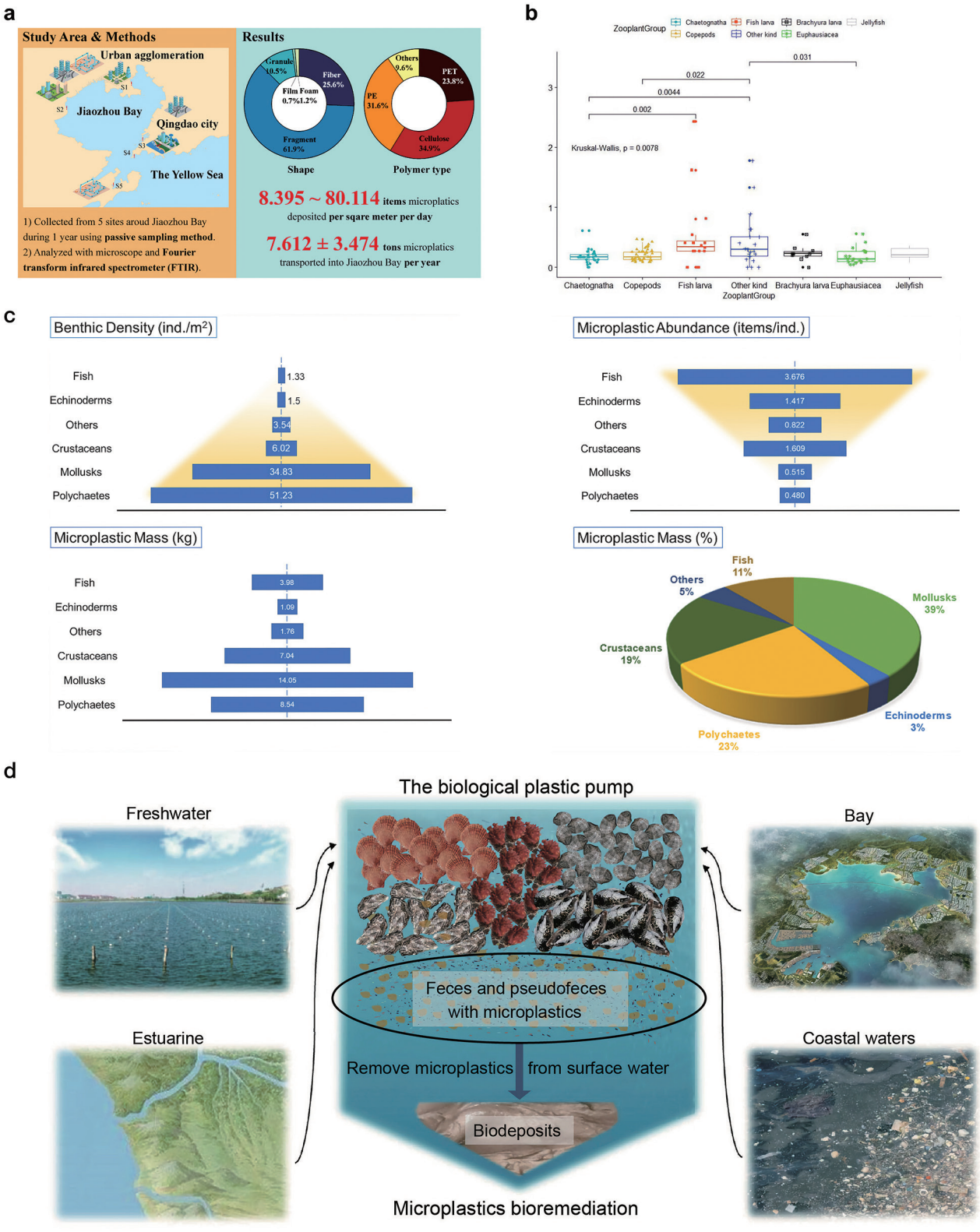

Fig. 4. Microplastics in the atmosphere (a), zooplankton (b), and benthic organisms (c) of Jiaozhou Bay, along with risk prevention and control strategies (d).

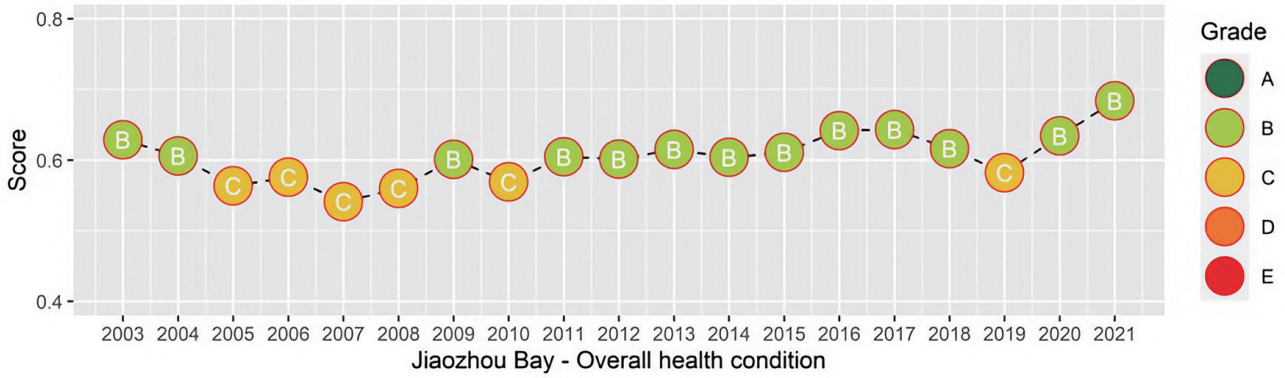

Fig. 5. Evolution trend of marine ecosystem condition in Jiaozhou Bay from 2003 to 2021.

long-term perspective, the overall health assessment score of the bay has shown continuous improvement since 2010, with a fluctuation in 2019 due to outbreaks of jellyfish and *Noctiluca*. The health condition of the bay in 2021 reached its highest level in nearly two decades. While the bay's marine ecosystem continues to improve, the local city (Qingdao) maintains rapid and high-quality economic growth and ranks first among similar coastal cities in China, providing feasible approaches for achieving the goal of sustainable development in the bay.

These research efforts have yielded a series of results with significant scientific value and practical significance. Research explorations and results have been published in top-tier national/international journals, with numerous articles achieving high citation rates, reflecting widespread recognition by global peers. Technological innovations, covering ecological monitoring equipment and restoration techniques, have been converted into practical applications through patents and have been successfully applied in typical marine areas, bridging scientific research and practical conservation.

Notably, the research projects of "Long-term Observation and Systematic Research on JZB Ecosystem" and "Life History of Large Disaster-Causing Jellyfish in the Yellow Sea and East China Sea and their outbreak mechanism" were awarded the First Prize of the Marine Science and Technology Award of China in 2016 and 2018 respectively, highlighting its groundbreaking contributions to the research field. These achievements deepened the understanding of coastal ecosystems and provided scientific supporting tools for the sustainable management.

3. Translating Science into Action: Policy Impact and Public Engagement

The value of long-term marine research lies not only in scientific discoveries but also in its ability to inform policy decision-making and ecological management, and to improve public awareness. The JZB Station has transformed its long-term scientific data and research outcomes into practical solutions that address national and regional challenges while guiding public participation.

Based on systematic observation data and research results, the JZB Station has provided a series of practical policy recommendations for marine governance at both national and local levels, integrating scientific insights into national/regional development strategies. For instance, the consultation report on marine productivity and sustainable fisheries management in China coastal waters got direct feedback from the national government. Its recommendation report of China's participation in global ocean governance was also adopted by the national government. These reports have promoted initiatives by national and local governments to optimize marine resource management, shared China's experiences in marine ecological protection with the global community, and contributed to the coordinated development of the economy, society, and marine ecosystems.

The JZB Station has also turned research results into practical actions, achieving significant results in ecological restoration and coastal ecological disaster prevention and control. Innovative seagrass bed rehabilitation techniques have significantly improved restoration success rates,

making significant contributions to China's "blue carbon" strategy. Artificial oyster reef construction and environmentally friendly sea cucumber aquaculture models have been adopted in coastal areas, balancing economic development with ecological protection. Research on jellyfish bloom mechanisms led to actionable recommendations that local companies adopted to ensure the safe operation of nuclear facilities. The JZB Station proposed a "Three-Line Defense" strategy for green tide prevention and control, which contributed to the formation of a "land-sea integrated" national model. Further, the Station's marine ecosystem health assessment tools have been applied across China's coasts to analyze the links between urban development and ecosystem health to search for feasible approaches for high-quality marine economic development under effective land-sea integrated management.

Recognizing that environmental conservation requires public support, the JZB Station has built a multi-layered public engagement framework. Public lectures and training workshops for researchers and policymakers have provided comprehensive marine approaches for governments and enterprises. Through collaborations with mainstream media such as Xinhua News Agency, CCTVs, and *Chinese National Geography*, reports on jellyfish outbreaks and microplastic pollution have raised widespread concern and public awareness of marine health issues. Partnerships with primary and secondary schools have engaged students and teachers through field trips and interactive lectures, inspiring the next generation of marine stewards. These efforts, combined with advisory roles in local and national projects, have created a public engagement framework in which scientific knowledge informs policy, and the informed public advocates for sustainable marine development.

4. Building Global Networks: International Collaboration for Ocean Sustainability

As a key node in global marine research networks, the JZB Station has addressed the urgent challenges of marine conservation and sustainable development through strategic international cooperation. Leveraging its long-term observation data, interdisciplinary team, and advanced research platforms, the Station has established long-term partnerships with leading global institutions and serves as a key link between China and global marine ecological observation and research.

The JZB Station has established a global cooperation network and implemented a series of international projects through collaborations. In the "Sino-Australian Joint Assessment of Coastal Ecosystem Health" project, the JZB Station research team co-founded the "Sino-Australian Joint Research Center for Healthy Oceans" with marine research institutions from Australia and jointly developed marine ecosystem health assessment models that support coastal management in both countries. Sino-Russian cooperation focuses on biodiversity changes, and the "Sino-Russian Joint Laboratory for Marine Biological Ecology" was established to reveal the response mechanisms of species distribution under global change. The microplastic collaborative project with Sweden has unraveled microplastic distribution patterns and bioaccumulation mechanisms in the Yellow Sea, providing a scientific basis for transnational pollutant governance. The Sino-French Joint Laboratory for Marine Microbial Ecology has advanced research on marine microbial ecology through a joint laboratory, using JZB and Marseille Bay as model systems. Additionally, participation in Sino-European project on jellyfish bloom management has promoted international sharing of ecological disaster prevention technologies.

The participation of the JZB Station in international organizations further highlights its global impact. Team members hold important positions in organizations such as the Scientific Committee on Oceanic Research (SCOR) and the International Association for Biological Oceanography (IABO), facilitating the integration of Chinese research outcomes into international policy frameworks. Researchers from the Station have also been invited to top academic conferences such as the World Conference on Marine Stations (WCMS) to share Chinese experiences, significantly enhancing China's influence in marine ecological research.

These global collaborations and engagements have resulted in benefits that are scientifically valuable and politically influential. The research results on ecosystem health assessment have been recognized as Chinese case studies for the United Nations Sustainable Development Goals (SDGs) Summit, providing not only innovative evaluation methods for SDGs indicators, but also a "Chinese solution" for the sustainable development of global coastal zones. The Station has become a member of the World Alliance of Marine Stations and is promoting the integration

Fig. 6. Top left: Representatives at the inauguration ceremony of the "Sino-Australian Joint Research Center for Healthy Oceans," among whom third from left is the Chinese Ambassador to Australia CHENG Jingye; Top right: Dr. SUN Song from the JZB Station giving an interview to Australian media; Group photo of JZB Station members with then Australian Ambassador to China Jan ADAMS (center in bottom left) and then Swedish Ambassador to China Helena SÅNGELAND (fifth from left, front row in bottom right).

of China's coastal observation network into the global system. The implementation of joint research center, laboratories and projects has further promoted high-level diplomatic exchanges, including ambassadors, science and technology officials from several countries visiting the JZB Station. The JZB Station advances scientific diplomacy through international research cooperation, playing a positive role in strengthening ties between China and the global scientific community in marine and related fields.

5. Next-Generation Marine Observatory: Strategic Vision for the Future

Envisioning the future, the JZB Station aims to further strengthen its role in marine ecological research and sustainable development. By converging artificial intelligence (AI)-driven technologies, frontier science, and international partnerships, the Station seeks to evolve into a next-generation marine observatory and innovation hub.

Building upon its foundation of long-term observation and interdisciplinary research, the Station plans to enhance its capabilities for real-time, multi-dimensional ecological observation by integrating autonomous observation platforms, remote sensing technologies and AI-powered analytics. These updates will enable more precise forecasting of ecosystem dynamics, early warning of environmental risks, and deeper understanding of complex interactions under the influence of global change.

Future scientific research will focus on addressing complex challenges under intensifying global change. The Station will enhance predictive ecosystem modeling, integrating AI to forecast ecological trends and potential disasters. Research priorities will include investigating emerging pollutants beyond microplastics, deciphering the impacts of marine heat waves on coastal food webs, and quantifying marine ecosystem carrying capacity. Additionally, efforts will be made to develop ecosystem-based marine management tools, transforming research outcomes into operational policy guidelines and industrial standards. The Station

will actively participate in national/regional marine initiatives, translating scientific research into actionable policies.

Future collaboration strategies include deepening partnerships with global research networks. The Station will continue to expand its contributions to global sustainability frameworks through enhanced data sharing, collaborative research programs, and technology transfer initiatives to share its best practices in marine observation and research. Aligning its efforts with UN SDGs, the Station will strengthen its role as a contributor to global marine governance, particularly in coastal ecosystem resilience and sustainability. By integrating research, education, training and national/international exchanges, the Station aims to position itself as a global hub for marine science research and for cultivating globally competitive marine scientists.

Through these initiatives, the Station will synthesize capacity building, scientific research, education, and public engagement to ensure scientific advances are translated into practical solutions addressing marine sustainability challenges confronting both China and the global community.

ACKNOWLEDGMENTS

This work was financially supported by the National Natural Science Foundation of China (No. 42130411, No. 42349301, No. U2006206), the International Science Partnership Program of the Chinese Academy of Sciences (No. 133137KYSB20200002), the National Key Research and Development Program of China (2024YFF0506902).

References

Chi X, Zhang F. and Sun S. (2022). Transgenerational effects and temperature variation alter life history traits of the moon jellyfish. *Front. Mar. Sci.* 9:913654. doi: 10.3389/fmars.2022.913654.

Dai M., Zhao Y., Chai F, et al. (2023). Persistent eutrophication and hypoxia in the coastal ocean [J]. *Cambridge Prisms: Coastal Futures*, 1: e19.

Liu T., Zhao Y., Zhu M., Zheng S., Sun X. (2020). Seasonal variation of micro- and meso-plastics in the seawater of Jiaozhou Bay, the Yellow Sea. *Mar. Pollut. Bull*. 152, 110922. https://doi.org/10.1016/j.marpolbul.2020.110922.

Liu S., Cui Z., Zhao Y., Chen N. (2022). Composition and spatial-temporal dynamics of phytoplankton community shaped by environmental selection and interactions in the Jiaozhou Bay. *Water Research*, 218, 30: 118488.

Liu F., Wang H., Song W. (2022a). Tandem integration of circular plasmid contributes significantly to the expanded mitochondrial genomes of the green-tide forming alga Ulva meridionalis (*Ulvophyceae, Chlorophyta*). *Front. Plant Sci*. 13: 937398. https://www.frontiersin.org/articles/10.3389/fpls.2022.937398/full

Liu F., Melton J., Wang H., Wang J., Lopez-Bautista J. (2022b). Understanding the evolution of mitochondrial genomes in the green macroalgal genus Ulva (*Ulvophyceae, Chlorophyta*). *Frontiers in Marine Science*. 9: 850710.

Logan M., Hu Z., Brinkman R, et al. (2019). Ecosystem health report cards: An overview of frameworks and analytical methodologies[J]. *Ecological Indicators*, 2019:105834. doi: 10.1016/j.ecolind.2019.105834.

Meng L., Sun X., Li Q., Zheng S., Lian, J., Zhao C. (2024a). Quantification of the vertical transport of microplastics by biodeposition of typical mariculture filter-feeding organisms. *Sci. Total Environ*. 908, 168226. https://doi.org/10.1016/j.scitotenv.2023.168226.

Meng L., Sun X., Zheng S. (2024b). The potential of biodeposition by filter-feeding organisms for microplastic remediation in natural waters. *Sci. Bull*. 69, 2319–2322. https://doi.org/10.1016/j.scib.2024.05.041.

Meng, L., Zheng S., Zhao Y., Liu T., Liang J., Zhu M., Sun X. (2024c). Seasonal microplastic ingestion by carnivorous chaetognaths in Jiaozhou Bay, China: Field evidence revealing microplastic trophic transfer. *J. Hazard. Mater.* 478, 135532. https://doi.org/10.1016/j.jhazmat.2024.135532.

Song H., Wang Y., Ding X., Chen N. (2022). Genetic Analysis of a Large-Scale *Phaeocystis globosa* Bloom Offshore Qingdao, China. *Microorganisms*. 10(9): 1723. https://doi.org/10.3390/microorganisms10091723

Sun S., Huo Y., Yang B. (2010). Zooplankton functional groups on the continental shelf of the yellow sea. *Deep Sea Research II*, 57(11–12): 1006–1016.Sun X., Sun S., Wu Y., Zhang Y., Zheng S., (2011). Long-term changes of phytoplankton community structure in the jiaozhou bay. *Ocean. Limnol. Sin.* 42 (5), 639–646. (in Chinese)

Sun S., Li C., Zhang G., Sun X., Yang B., (2011b). Long-term changes in the zooplankton community in the jiaozhou bay. *Ocean. Limnol. Sin*. 42 (5), 625–631. (in Chinese)

Sun S, Li Y H, Sun X X. (2012). Changes in the small-jellyfish community in recent decades in Jiaozhou Bay, China. *Journal of Oceanology and Limnology*, 30: 507–518.

Sun S, Sun X. (2015). Theory and Practice of Bay Ecosystems: A Case Study of Jiaozhou Bay[M], Beijing: Science Press.

Sun X., Li Q., Zhu M., Liang J., Zheng S., Zhao Y. (2017). Ingestion of microplastics by natural zooplankton groups in the northern South China Sea, *Marine Pollution Bulletin*, 2017, 115: 217–224.

Sun X., Liu T., Zhu M., Liang J., Zhao Y., Zhang B. (2018). Retention and characteristics of microplastics in natural zooplankton taxa from the East China Sea, 640-641: 232–242.

Sun X., Liang J., Zhu M., Zhao Y., Zhang B. (2018b). Microplastics in seawater and zooplankton from the Yellow Sea. *Environmental Pollution*. 2018, 242: 585–595.

Sun X., Li Q., Shi Y., Zhao Y., Zheng S. (2019). Characteristics and retention of microplastics in the digestive tracts of fish from the Yellow Sea. *Environmental Pollution*, 249:878–885.

Sun S, Ma W W, Wang N, Feng S, Sun Y. (2024). Genome-wide SNP markers provided insights into the reproductive strategy and genetic diversity of the green tide causative species Ulva prolifera in China. *Journal of Oceanology and Limnology*, 42: 533–543.

Wang, F., Li, X., Tang, X. et al. (2023). The seas around China in a warming climate. *Nat Rev Earth Environ* 4, 535–551. https://doi.org/10.1038/s43017-023-00453-6

Wang J, Duan Z L, He Z Y, Chen N S. (2023).

Molecular analysis of Asterias Amurensis from a starfish outbreak in Jiaozhou Bay in summer 2022. *Oceanologia et Limnologia Sinica*, 54(6): 1656–1671.

Wang P., Zhang F., Sun S., Yang T. (2020). Distribution of giant jellyfish in the Bohai sea in June 2018. *Oceanologia et Limnologia Sinica*, 51(01): 85–94.

Wang P P, Zhang F, Guo D J, Chi X P, Feng S, Sun S. (2024). Trophic effects of jellyfish blooms on fish populations in ecosystems of the coastal waters of China. *Science of the Total Environment*, 948: 174832.

Wang S., Zhang G., Sun S., Wang Y., Zhao Z. (2012). Population dynamics of three scyphozoan jellyfish species during summer of 2011 in jiaozhou bay. *Oceanologia et Limnologia Sinica*, 43(3): 471–479.

Wang S W, Wan A Y, Zhang G T, Sun S. (2022). Northward expansion of a warm-water Doliolid *Dolioletta gegenbauri* (Uljanin, 1884) into a temperate bay, China. *Water*, 14, 1685.

Wang W C, Sun S, Zhang F, Sun X X, Zhang G T. (2018). Zooplankton community structure, abundance and biovolume in Jiaozhou Bay and the adjacent coastal Yellow Sea during summers of 2005-2012: relationships with increasing water temperature. *Journal of Oceanology and Limnology*, 36: 1655–1670.

Wang Y Q, Ding X X, Song H Y, Chen N S. (2023). Metabarcoding analysis of *Phaeocystis globose* in Qingdao coastal regions. *Oceanologia et Limnologia Sinica*, 5: 1351–1362.

Yang S M, Guo S J, Zhu M L, Zhao Y F, Zheng S, Sun X X. (2025). Long-term dynamics of net-phytoplankton community under environmental drivers of Jiaozhou Bay, China. *Journal of Oceanology and Limnology*, https://doi.org/10.1007/s00343-025-4293-z.

Zang W X, Zhang F, Sun Y, Xu Z Q, Sun S. (2023). Benthic ecosystem determines jellyfish blooms by controlling the polyp colony development. *Marine Pollution Bulletin*, 193: 115232.

Zhang F., Li C., Sun S., Wei H., Wang Y. (2017). Progress on studying jellyfish bloom, and the monitoring and control. *Oceanologia et Limnologia Sinica*, 48(6): 1187–1195.

Zhang, K., Zheng, S., Liang, J., Zhao, Y., Li, Q., Zhu, M., Dai, S., Sun, X., (2023). Microplastic load of benthic fauna in Jiaozhou Bay, China. *Environ. Pollut.* 320, 121073. https://doi.org/10.1016/j.envpol.2023.121073.

Zhao, C., Liang, J., Zhu, M., Zheng, S., Zhao, Y., Sun, X., (2023). Occurrence, characteristics, and factors influencing the atmospheric microplastics around Jiaozhou Bay, the Yellow Sea. *Mar. Pollut. Bull.* 196, 115568. https://doi.org/10.1016/j.marpolbul.2023.115568.

Zheng S., Sun X., Wang Y., Sun S. (2015). Significance of Different Microalgal Species for Growth of Moon Jellyfish Ephyrae, Aurelia sp.1. *Journal of Ocean University of China*, 2015, 14(05): 823–828.

Zheng, S., Zhao, Y., Liu, T., Liang, J., Zhu, M., Sun, X. (2021). Seasonal characteristics of microplastics ingested by copepods in Jiaozhou Bay, the Yellow Sea. Sci. *Total Environ.* 776, 145936. https://doi.org/10.1016/j.scitotenv.2021.145936.

Zhu M L, Sun X X, Zhao C H, Liang J H, Zhao Y F. (2024). Monitoring methods based on in-situ image observation technology for sea stars. *Marine Science*, 48(9), 77–84. (in Chinese)