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DESIGN AND APPLICATION OF A COMPREHENSIVE SUPERVISION PLATFORM FOR OCEAN PASTURES BASED ON THE INTERNET OF THINGS: A CASE STUDY OF DONGCHANG BAY, XUWEN COUNTY, ZHANJIANG CITY, GUANGDONG PROVINCE

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Abstract: Ocean pastures are the core carrier for restoring offshore ecosystems and conserving fishery resources, and an important lever for advancing the building of the "Blue Granary". At the grassroots level in China, however, ocean pastures generally suffer from practical weaknesses such as low coverage of intelligent equipment, weak capacity for environmental risk early warning and short industrial chains for the integration of the primary, secondary and tertiary industries. Taking the ocean pasture in Dongchang Bay, Xuwen County, Zhanjiang City, Guangdong Province as the research object, this study conducted water quality monitoring in the spring and autumn seasons of 2019 and 2021 and combined the results with 372 valid questionnaires answered by aquaculture practitioners to establish the environmental baseline characteristics of the sea area and the needs of practitioners, and on this basis constructed a four-layer comprehensive supervision platform covering "perception–transmission–decision–application". The platform comprises four modules: intelligent environmental monitoring, intelligent aquaculture management, risk early warning and emergency response, and resource and market matching. Benefit estimation draws on validation data for the intelligent precision feeding system for fish developed by Huazhong Agricultural University in land-based recirculating aquaculture and pond modes (a 10%–15% reduction in the feed conversion ratio) and on survival-rate data for the local "land–sea relay" mode in Zhanjiang (above 95%). Combined with the actual feed and labor expenditure of farmers in Dongchang Bay, it is estimated that after platform deployment feed waste can be reduced by 10%–15% and the aquaculture survival rate can be raised by 5%–8%.
Keywords: Ocean pasture; Internet of Things; Comprehensive supervision platform; Benefit estimation; Dongchang Bay

1 INTRODUCTION

The decline of offshore fishery resources is a long-standing problem facing the development of coastal fisheries in China. It is manifested in the continuous input of land-based pollution, habitat fragmentation in some sea areas, and the trend toward smaller and lower-value catches caused by long-term overfishing; these problems are particularly acute along the western coast of Guangdong Province. As an ecosystem-based fisheries management model, ocean pastures can effectively promote the ecological restoration and resource conservation of degraded fishing grounds through the deployment of artificial reefs, stock enhancement and release, and habitat restoration. The Fisheries Law of the People's Republic of China, newly revised in 2026, defined the legal status of ocean pastures at the legislative level for the first time, and the Outline of the 15th Five-Year Plan also makes the building of the "Blue Granary" a key task of marine economic development, providing policy support for the high-quality development of ocean pastures [1-2].

In local practice, Guangdong Province treats ocean pastures as a core lever for marine economic development. In 2024 the province's gross marine product exceeded RMB 2 trillion, accounting for more than one fifth of the national total. The Overall Plan for the Development of Modern Ocean Pastures in Guangdong Province (2024–2035) explicitly sets the target that "by 2030 the province's total mariculture output shall reach 5 million tons and the processing rate of marine products shall reach 40%" [3]. As the largest fishery city in the province, Zhanjiang accounts for 70% of the province's gravity-type deep-water cages [4].

Behind the expansion of industrial scale, however, the shortcomings of grassroots ocean pastures remain prominent. Data from the agricultural mechanization station of the Ministry of Agriculture and Rural Affairs show that the mechanization level of aquaculture is less than 36%, far below the 76.7% comprehensive mechanization rate for crop cultivation, harvesting and threshing. In Dongchang Bay, Xuwen County, Zhanjiang City, Guangdong Province (hereafter Dongchang Bay), aquaculture production is still dominated by the traditional experience-based model: most farmers judge feeding amounts from experience and assess water quality by naked-eye observation, and by the time early warning information on red tides, typhoons and other hazards reaches grassroots producers, irreversible losses such as dead fish in cages have often already occurred. Although much research has been carried out on technologies for smart ocean pastures, low-cost solutions that can be implemented by small grassroots producers remain scarce [5]. On this basis, this study addresses

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two core questions: what are the actual technical needs for ocean pasture development in Dongchang Bay, and what kind of supervision platform is genuinely affordable and usable for grassroots farmers? Water quality monitoring and a questionnaire survey are first used to establish the regional baseline conditions and the needs of local actors; on that basis, an Internet-of-Things (IoT) comprehensive supervision platform adapted to local conditions in Dongchang Bay is designed, and the expected benefits of the platform are quantitatively estimated on an explicit basis, in the hope of providing a practical pathway that can be referenced for the intelligent transformation of small and medium-sized ocean pastures in western Guangdong.

2 OVERVIEW OF THE STUDY AREA AND RESEARCH METHODS

2.1 Study Area Overview

Dongchang Bay is located in the eastern waters of Xuwen County, Zhanjiang City, Guangdong Province. The core monitoring station of this study is at 109°44.4′E, 20°31.0′N. At the time of the survey, about 3,000 cubic meters of artificial reef had been deployed and more than 60 deep-water cages had been built; the main cultured species are cobia, grouper, golden pompano and *Crassostrea rivularis*. Large numbers of traditional wooden cages and oyster hanging-culture areas are also distributed around Wailuo Port. The operating entities are mainly household farmers, generally small in scale, with limited capital reserves and limited capacity to adopt technology.

New infrastructure for ocean pastures in Zhanjiang is now being deployed rapidly. In March 2026, the South China Sea Ecological Center of the Ministry of Natural Resources deployed the first batch of nine intelligent monitoring buoys in key ocean pasture waters off Zhanjiang, integrating multi-dimensional real-time observation of meteorological, hydrological and water quality parameters, and stable data return has already been achieved [6]. In June of the same year, Zhanjiang Bay Laboratory released the Marine Harmony industrial intelligent connection system, whose core software and hardware are more than 80% domestically sourced, with the underwater sensors 100% independently developed [7]. These facilities have been verified in actual operation in Zhanjiang waters and provide a localized technical basis for the platform design in this study: the Dongchang Bay platform does not need to build a technical system from scratch, but can adopt a “subtractive” design within the existing infrastructure framework, removing high-end redundant functions that small and medium-sized farmers do not use and retaining the core modules that solve practical production problems, thereby effectively reducing construction and operating costs.

2.2 Data Sources and Research Methods

The water quality data of this study come from field monitoring in April 2019 (spring) and November 2021 (autumn). Surface water samples were collected at core station P33 in Dongchang Bay, and the laboratory indicators include pH, dissolved oxygen (DO), chemical oxygen demand (COD), inorganic nitrogen and active phosphate; water quality was assessed against Class I of the Sea Water Quality Standard (GB 3097–1997) [8-9]. The questionnaire survey was conducted in June 2025 among farmers, capture fishermen, buyers and village cadres in Dongchang Bay and adjacent waters. A total of 372 questionnaires were distributed and 372 valid responses were recovered, a valid recovery rate of 100%. The questionnaire covered six dimensions: perception of resource impacts, preference for technical needs, response to environmental risks, willingness to develop tourism, financing plans and development shortcomings. All survey data were processed by descriptive statistical analysis using SPSS 26.0.

3 RESULTS AND ANALYSIS

3.1 Baseline Water Quality Characteristics of the Sea Area

Combining the monitoring results of spring and autumn, the baseline water quality of Dongchang Bay is generally good and provides the environmental basis for ocean pasture development. The pH value remained stable in the range of 7.8–8.5, dissolved oxygen was above 6 mg/L and COD ranged from 0.4 to 1.1 mg/L, all meeting the Class I sea water quality standard; inorganic nitrogen was below 0.20 mg/L in both seasons, also meeting the Class I requirement. The only indicator requiring attention is active phosphate: the spring value was below 0.015 mg/L, meeting the Class I standard, whereas the autumn value rose to 0.028–0.035mg/L, slightly above the Class I threshold but still within the Class II range of the sea water quality standard. This seasonal fluctuation may be related to increased land-based runoff input in autumn and to nutrient accumulation caused by weakened vertical water exchange; it has not yet reached the pollution level, but should be included in routine monitoring for continuous tracking.

3.2 Needs and Pain Points of Aquaculture Practitioners

The survey results show that local aquaculture practitioners have a high level of recognition of ocean pasture development: 95.16% of respondents considered that fishery resources in the sea area had “increased markedly” or “increased to some extent” after ocean pasture development, and 76.34% said that their own production development plans included arrangements related to sustainable operation, indicating that grassroots actors have formed a broad consensus on the ecological and economic benefits of ocean pastures and that the promotion of intelligent technologies has a sound cognitive foundation. In terms of perceived development shortcomings, 74.19% of respondents pointed out that the

existing supporting equipment for aquaculture production is incomplete, which is the primary factor constraining industrial development. In the ranking of technical needs, recirculating aquaculture systems (77.2% of respondents), AI and big data analysis technology (76.9%) and ecological restoration technology (76.1%) took the top three places. In coping with environmental risks, 82.0% of respondents said they needed advanced meteorological and hydrological monitoring equipment and 80.7% hoped to obtain support from data analysis and disaster prediction models. Regarding the integration of the primary, secondary and tertiary industries, 91.4% of respondents supported the development of fishing-boat sightseeing projects and 73.7% supported recreational angling projects, yet such fishery–tourism projects are almost entirely absent locally. Two typical cases obtained in semi-structured interviews directly reflect the core pain points on the production side. An offshore cage farmer, Mr. L, said that "before a typhoon we only know there is a risk, but we have no idea of the actual situation underwater; how much we lose is basically a matter of luck", reflecting the lack of underwater monitoring and early warning under extreme weather. An inland pond farmer, Mr. W, reported that "fish diseases are usually noticed too late, and once they strike we lose a whole batch; at present we only scoop up the dead fish that float to the surface, find the cause and buy medicine, and we are passive throughout the process", reflecting insufficient capacity for early identification of aquatic animal diseases. These two pain points—early warning of extreme environments and early detection of aquaculture diseases—directly define the design direction of the core functions of the supervision platform.

4 ARCHITECTURAL DESIGN OF THE IOT COMPREHENSIVE SUPERVISION PLATFORM

4.1 Overall Design

The platform adopts the classic four-layer IoT architecture and adheres to the design principle of "demand-oriented and practice first". The selection and deployment of perception-layer equipment serve entirely the production information that farmers actually need to obtain; the network-layer communication scheme is selected flexibly according to the offshore distance and marine communication conditions of Dongchang Bay, giving priority to the use of existing communication infrastructure to reduce construction costs; algorithm development at the platform layer gives priority to solving core production needs such as "automatic aeration when dissolved oxygen is abnormal", "early warning of typhoon hazards" and "early identification of abnormal fish schools"; and the application-layer interface adheres to a minimalist design, ensuring that farmers can obtain decision information that directly guides production through simple operations on a mobile phone, thus lowering the threshold for use [10].

4.2 Perception Layer: Selection and Deployment of Low-Cost Sensing Equipment

The cost of the perception layer is the core factor determining whether the platform can be promoted at scale at the grassroots level. Commercial multi-parameter water quality monitoring buoys currently cost tens of thousands of RMB per unit, far beyond the means of ordinary farmers [11]. This design refers to the low-cost water quality buoy solution developed by Hainan Vocational University of Science and Technology, in which the manufacturing cost of a single buoy is controlled at RMB 5,000–8,000 and the endurance is no less than three months, making large-scale deployment economically feasible. Taking a medium-sized aquaculture area in Dongchang Bay as an example, deploying 10–15 buoys of this type would achieve full coverage of the main cage-culture areas, with a total investment of only RMB 50,000–120,000, within the cost range acceptable to farmers and professional cooperatives.

The sensors integrated into the buoy need not be numerous; the core indicators are just four: water temperature, dissolved oxygen, pH and salinity. Following the principle of "core indicators first", the buoy integrates real-time monitoring sensors for these four indicators, which are directly related to aquaculture production, while non-core indicators such as phosphate and ammonia nitrogen can be sampled once a week instead of being monitored continuously in real time, so as to control costs. For underwater video monitoring, two to three dual-lens underwater cameras with a self-cleaning function are deployed in each aquaculture area. Referring to the application verified at the "Yangxi No.1" ocean pasture by the Fishery Machinery and Instrument Research Institute of the Chinese Academy of Fishery Sciences, an acoustic-optical fish monitoring system can perform fish counting, body-length measurement and identification of disease characteristics, and can meet the practical need to observe fish-school behavior.

4.3 Network Layer: Adaptation of a Multi-Network Converged Communication Scheme

Dongchang Bay is close to shore, and the nearshore area can be covered by 4G/5G signals; marine signals, however, are unstable for practical reasons and a backup scheme is required. Existing marine communication networking practice in Zhanjiang provides a mature reference: nearshore areas use a 5G marine production private network together with MESH broadband networking to achieve high-bandwidth communication, while offshore areas are supplemented by low-orbit high-throughput satellite communication, forming a "land–sea–subsea" full-domain communication system. Given the short offshore distance of the aquaculture areas in Dongchang Bay, this scheme gives priority to a combined "5G + LoRa" communication mode: the 5G network handles high-bandwidth services such as underwater video return and the transmission of equipment control instructions, while LoRa handles the low-power return of low-frequency sensor data, reducing communication energy consumption and cost. For local signal blind spots, satellite communication modules can be added as required, without the need for full-area coverage.

4.4 Platform Layer: Development of Core Algorithms for Practical Scenarios

Algorithm development at the platform layer adheres to a "problem-oriented" approach and does not pursue the construction of an all-purpose analysis system; priority is given to two core algorithms that can directly solve production pain points.

(1) Dissolved oxygen prediction. A prediction model is built on a long short-term memory (LSTM) network. The input variables include the historical dissolved oxygen series, real-time water temperature data, and the air temperature, air pressure and wind speed forecast by the meteorological service; the output is the trend of dissolved oxygen in the aquaculture area over the next 24–72 hours, providing a basis for taking aeration measures in advance. Similar early warning systems have already been successfully practiced in Zhanjiang: in response to an outbreak of a novel rhabdovirus in golden pompano, the monitoring and early warning system built by Zhanjiang Bay Laboratory issued an early warning at the first opportunity, buying time for the prevention and control of the golden pompano industry in the Wanshan sea area of Zhuhai. Likewise, golden pompano and grouper aquaculture in Dongchang Bay has a clear need for a similar early warning response.

(2) Identification of abnormal fish-school behavior. A lightweight recognition model is trained with the YOLOv8 object detection algorithm, focusing on anomalous changes in the swimming patterns of fish schools, including reduced feeding activity, unbalanced swimming posture and abnormal aggregation. The algorithm does not need to identify specific fish disease types precisely; as long as abnormal fish-school behavior can be detected one to two days in advance, it buys time for farmers to deal with the disease and greatly changes the current passive situation in which "disease is only noticed when fish die".

4.5 Application Layer: Implementation of Production-Oriented Functional Modules

The design principle of the application layer is that all information farmers see on their mobile phones must be directly translatable into concrete production actions, avoiding the accumulation of data of no practical value [12].

First, guidance for precise daily feeding. The system integrates real-time water temperature and dissolved oxygen monitoring data with information on the feeding activity of the fish school obtained from underwater cameras to generate a recommended daily feeding amount and feeding frequency. Farmers do not need to understand the logic of the model and only need to adjust the feeding amount following the system prompt, which effectively avoids the feed waste and water pollution caused by overfeeding.

Second, decision support for typhoon emergency response. Forty-eight hours before a typhoon arrives, the system pushes targeted information for the farmer's own aquaculture area—the typhoon track, the expected wind force and wave height, and the recommended sinking depth of the cages—rather than a generic typhoon warning, directly guiding farmers in carrying out disaster preparation and responding to the core demand of offshore farmers who "do not know the underwater situation and do not know how to prepare".

Third, automatic early warning and control of dissolved oxygen anomalies. When dissolved oxygen in the aquaculture area falls below the safety threshold at night, the system can automatically start the aerators in areas equipped with automatic control devices, and at the same time push an alarm to the farmer's mobile phone. Farmers without automatic control devices also receive an explicit prompt that "dissolved oxygen is continuing to decline and the aerators should be started immediately", reducing the risk of nighttime mass mortality in the pond.

Fourth, production and marketing information matching. The platform aggregates the demand information of aquatic product buyers. Farmers can publish the expected harvest time, harvest size and expected price on the platform in advance, and buyers can make online inquiries beforehand, reducing problems such as difficulty in selling fish and price-cutting purchases caused by information asymmetry between production and marketing.

5 BENEFIT ESTIMATION AND RATIONALITY ANALYSIS

5.1 Estimation of the Effect on Reducing Feed Loss

5.1.1 Estimation logic

In deep-water cage culture, feed accounts for 50%–80% of the total cost of aquaculture, and some studies show that the share of feed cost can reach 70%–90%, making it the core element of aquaculture cost control [13]. Under the traditional manual feeding mode, the feed conversion ratio (FCR) is usually between 1.5 and 2.0, and the problem of feed waste is pronounced. According to the empirical validation of the intelligent precision feeding system for fish developed by the College of Fisheries of Huazhong Agricultural University from 2021 to 2023 in multiple modes including land-based recirculating aquaculture, pond enclosure culture and ordinary ponds, precision feeding technology based on sensor feedback of fish feeding behavior can reduce the FCR by 10%–15% and improve comprehensive aquaculture benefits by 15%–20%, while reducing nitrogen emissions from feed sources by an average of 17% and phosphorus emissions by 19%. The system has been put into application with 24 units at Wuhan Wuqi Dongfang Aquaculture Co., Ltd., with cumulative output value exceeding RMB 10 million, and the conclusion that the FCR can be reduced by 10%–15% is supported by operating data from three consecutive years [14].

5.1.2 Applicability analysis for Dongchang Bay

Dongchang Bay mainly cultures golden pompano and grouper, and farmers currently generally adopt manual, experience-based feeding, so the problem of feed waste is widespread. Referring to the empirical data above, after platform

deployment the underwater cameras and feeding behavior analysis provide real-time feedback on the feeding status of the fish school, which can effectively solve the dilemma of "wasting feed when feeding too much and leaving the fish underfed when feeding too little". This study takes a 10%–15% reduction in feed waste as the lower bound of the existing validated data, which is a conservative estimate. It should be noted that the validation scenarios above are mainly land-based and pond culture modes; in the offshore cage environment of Dongchang Bay, factors such as water currents and water transparency may cause some difference in actual performance, which is one of the core reasons for proposing pilot validation first in this study.

5.2 Estimation of the Effect on Improving the Aquaculture Survival Rate

5.2.1 Estimation logic

The effect of the platform on the aquaculture survival rate mainly comes from three pathways. First, environmental early warning reduces sudden mortality caused by extreme hazards: farmers in Dongchang Bay currently have almost "zero warning" of typhoons, red tides and other hazards, and precise warnings pushed 48 hours in advance by the platform can greatly reduce large-scale losses from hypoxia and red tides. Second, early identification of disease reduces losses from the spread of disease: under the traditional mode detection lags behind, whereas AI-based behavior recognition can detect fish-school anomalies one to two days in advance and greatly reduce the scale of mortality caused by disease transmission. Third, precise feeding reduces the stress response of fish: both underfeeding and overfeeding lower the immunity of the fish, and precise feeding can improve the health level of the fish school and reduce the probability of disease.

5.2.2 Reference basis

The environmental impact prediction model built on an environmental database for the "Gesheng No.1" truss-type intelligent aquaculture platform in Zhuhai, Guangdong Province, achieved a survival rate above 98% for the fingerlings stocked in the new season in 2026, whereas the fingerling survival rate under the traditional offshore raft culture mode is usually only 70%–80%. In the "land–sea relay" culture mode adopted by Zhanjiang Hengxing Group, golden pompano fry are first reared in land ponds for 15–20 days and then transferred to deep-sea cages, and the fry survival rate can reach above 95% [15]. Although the culture mode in Dongchang Bay differs to some extent from the cases above, the effect of the two functions—environmental early warning and early identification of disease—on the survival rate is generally applicable. This study adopts an estimated improvement of 5%–8% in the survival rate, which has taken into comprehensive account the current aquaculture level in Dongchang Bay, the characteristics of the main cultured species and the functional coverage of the platform, and is a conservative estimate.

5.3 Input Cost and Investment Payback Period

5.3.1 Input-side estimation

A medium-sized aquaculture area with 50 deep-water cages is taken as the calculation unit. Perception-layer equipment includes 10 low-cost monitoring buoys at about RMB 50,000–80,000, six underwater cameras at about RMB 30,000–50,000, and communication equipment and edge computing terminals at about RMB 50,000–80,000. The cost of platform software development can be apportioned through reuse across multiple aquaculture areas, at about RMB 100,000–150,000 for a single area. In summary, the total platform investment for a single medium-sized aquaculture area is about RMB 250,000–350,000.

5.3.2 Revenue-side estimation

First, precise feeding reduces feed costs by 10%–15%. Taking the annual feed cost of a single cage with a circumference of 60 m as RMB 15,000 (the local feed price for golden pompano in Zhanjiang is about RMB 9,000 per ton, and the annual feed consumption of a single cage is about 1.5–1.7 tons), 50 cages can save RMB 75,000–110,000 in feed costs per year. Second, reducing the frequency of manual patrolling saves labor costs of RMB 100,000–120,000 per year, calculated on the basis of releasing two resident aquaculture workers. Third, early identification of disease reduces aquaculture losses, conservatively estimated at RMB 30,000–50,000 per year. Taken together, these three items can generate direct economic benefits of RMB 200,000–280,000 per year.

5.3.3 Payback period estimation

Without considering operation and maintenance costs, an initial investment of RMB 250,000–350,000 corresponding to annual savings of RMB 200,000–280,000 gives a static payback period of about 1.5–2years; if annual equipment maintenance and data traffic costs of about RMB 30,000–50,000 are included, the static payback period is about 2–2.5 years, indicating good economic feasibility.

5.4 Limitations of the Estimation Results

The benefit estimation in this study has three limitations that need to be stated clearly. First, the 10%–15% reduction in the FCR was validated in land-based recirculating aquaculture and ponds, and the actual effect in the offshore cage environment of Dongchang Bay requires pilot validation. Second, the 5%–8% improvement in the survival rate is an estimate based on the superimposed effect of the two functions of environmental early warning and early detection of disease, and the actual effect is affected by weather, management level, stocking density and other factors. Third, the calculation of the payback period is based on the current actual cost structure of farmers in Dongchang Bay; if the cultured species or the scale changes, the payback period needs to be recalculated. The estimation results above should therefore

be defined as “estimated values based on the literature and comparable local cases” rather than the inevitable “predicted values” after platform application.

6 CONCLUSIONS AND PROSPECTS

The core design idea of the IoT comprehensive supervision platform designed in this study adheres to the grassroots adaptation principle of “sufficient for use, affordable and acceptable to use”. At the perception layer, low-cost self-developed buoys replace commercial equipment costing tens of thousands of RMB per unit, greatly lowering the threshold of initial investment. At the network layer, the new infrastructure already deployed in Zhanjiang, such as 5G and Marine Harmony, is fully reused to avoid duplicated construction. At the platform layer, development focuses on two core production pain points, dissolved oxygen prediction and identification of abnormal fish-school behavior, without the development of redundant functions. At the application layer, monitoring data are directly converted into production instructions that farmers can execute, around four high-frequency production scenarios. In the benefit estimation, the conclusion that feed waste can be reduced by 10%–15% refers to the multi-mode empirical data of the intelligent feeding system of Huazhong Agricultural University, and the 5%–8% improvement in the aquaculture survival rate refers to local case data such as “Gesheng No.1” in Zhuhai and the “land–sea relay” mode of Zhanjiang Hengxing; all are conservative estimated values, and the derivation logic and reference sources are specified item by item. It should be particularly emphasized that the estimated values above are not equivalent to the actual operating effect of the platform, and the real application benefits of the platform can only be assessed accurately after pilot operation over a complete aquaculture cycle.

For the implementation path of the platform, a promotion model of “small steps and rapid iteration” is recommended. First, one aquaculture cooperative with strong willingness is selected as the pilot, deploying three to five monitoring buoys, two underwater cameras and a simplified mobile application, and operating continuously for six to eight months to collect actual usage data and farmer feedback for iterative optimization of the platform functions. Once the pilot results are generally recognized by farmers, the platform can be extended gradually to the surrounding aquaculture areas. Compared with building a large system with full coverage at one time, this construction path of “verification first and promotion later” better fits the actual development of grassroots ocean pastures, and can also respond to the question of the reliability of the benefit estimation through measured pilot data. After the platform matures in future operation, extended functions such as fishery–tourism integration services, aquaculture carbon accounting and fisheries finance matching can be further developed, to promote the integrated development of the primary, secondary and tertiary industries of the Dongchang Bay ocean pasture.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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