

Analysis of environmental conditions of offshore raft-culture areas in Dongshan Island

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Abstract. Dongshan Island is one of the important mariculture bases in Zhangzhou City, Fujian Province. Relying on its long coastline, it has developed three different aquaculture models: floating raft hanging culture, offshore fish cage net culture, and onshore high-position pond culture, nurturing distinctive aquaculture species such as oysters, *Decapтерus maruadsi*, green abalone, and asparagus seaweed. Fisheries serve as the primary source of livelihood income for local coastal residents. Through field interviews with aquaculture farmers on Dongshan Island, as well as reviews of the *Dongshan County Fisheries Statistical Yearbook* and local fishery materials, this study systematically examines the practical problems existing in the current offshore mariculture industry on Dongshan Island, including issues related to ecology, germplasm, costs, industrial chains, and disaster resilience. Combined with Fujian Province's supportive policies for deep-sea aquaculture and the island's ecological governance plans, this paper analyzes the industry's development prospects from five dimensions: ecological aquaculture transformation, seed industry autonomy, industrial integration, facility upgrading, and digitalized aquaculture, providing practical references for the green and sustainable development of mariculture on Dongshan Island.

Keywords: mariculture, aquaculture facility renovation, ecological aquaculture, industrial upgrading, green and sustainable development, deep-sea aquaculture

1. Introduction

The offshore aquaculture industry in Dongshan Island uses a large number of densely arranged fish farming cages, and many materials used in these cages, such as mooring ropes, floats, fishing nets, and so on, require regular maintenance and replacement. This consumes a large number of resources. According to surveys, when floats are damaged, they are sunk into the sea, which has a visible negative impact on the offshore aquaculture environment and also imposes additional costs on fishermen. Therefore, the impact of fish farming cages used in offshore aquaculture on the marine environment and the increase in fishermen's operating costs have attracted increasing attention.

As a key seawater aquaculture core area in southeastern Fujian, Dongshan Island holds a unique position in both domestic and global specialty aquaculture systems. Among these, Dongshan Island is the only core production area in the world to achieve large-scale artificial cultivation of *Decapтерus maruadsi*, with the output of artificially farmed *Decapтерus maruadsi* exclusively dominating the global market. However, due to the influence of the huge global wild-caught *Decapтерus maruadsi* production, its overall share of total global output remains relatively limited. In the abalone industry, Dongshan Island possesses extremely strong seed-stock advantages, with abalone seedling production steadily ranking first nationwide, accounting for more than 60% of the national market and nearly half of the global abalone seedling market share, making it the core seedling base supporting the development of the abalone farming industry both nationally and globally. Compared with its advantageous seedling industry, the farming of finished abalone, golden pomfret, pomfret, and *Gracilaria* seaweed and other aquaculture products on Dongshan Island only has regional industrial scale, serving only local and domestic markets, with relatively low output shares in the global aquaculture landscape and no dominant industry advantage.

The marine pollution caused by aquaculture mainly stems from the rapid replacement of aquaculture materials. During the large-scale expansion of offshore aquaculture, various types of traditional aquaculture facilities have been deployed in sea areas for long periods and at high density. Among them, foam floats, long-sleeve fixed nets, old-fashioned wooden-frame fish farming cages, and over-aged PE mooring ropes and other outdated aquaculture equipment have been used in offshore aquaculture and fishing production around Dongshan Island since 2000, with widespread bad practices of heavy use, light maintenance, overextended service life, and arbitrary disposal. Affected by wind and wave erosion in the sea area, seawater corrosion, ultraviolet radiation, and long-term wear and tear from aquaculture operations, the overall performance of such traditional aquaculture facilities has continued to deteriorate, and their inherent structural defects and aging-related problems have become increasingly prominent. They are not only unable to meet modern ecological aquaculture standards but also cause continuous and cumulative harm to the offshore water environment, benthic eco systems, and fishery resources.

2. Hazards of traditional fishing-raft materials to the environment and their impacts on fishermen's aquaculture costs

2.1. Negative impacts of traditional floating buoys

From the early 2000s to 2020, more than 15 million traditional Expanded Polystyrene (EPS) foam buoys were deployed across over 120,000 mu of mariculture zones in Dongshan Island, Fujian Province. Featuring extremely low density and poor ultraviolet resistance, such EPS materials have an average service life of merely 2.5 years and an annual damage rate as high as 25 %, subject to year-round scouring by Grade 3-5 ocean waves and solar exposure. Monitoring indicates that a single broken foam buoy can release 50 million to 200 million microplastic particles smaller than 5 mm into surrounding seawater each year. These particles require over 400 years for natural degradation, while the recovery rate of broken residues stands below 5 %. Abundant fragments scattered across the sea surface tend to entangle fishing-boat propellers and cause navigation accidents [1].

In terms of economic costs, field-group survey (As shown in the figure 1) show that even after deducting government financial subsidies, farmers still pay nearly 100 yuan out-of-pocket for one standard buoy. Assuming 25 buoys are allocated per mu of aquaculture water area, a single farming household incurs hardware costs of 60,000-100,000 yuan for buoy replacement every three years, in addition to annual expenses

of approximately 12,000 yuan for debris collection and manual replacement [2]. Comprehensive calculations reveal that the total life-cycle cost of traditional foam buoys over a 10-year period is more than 35% higher than that of new High-Density Polyethylene (HDPE) buoys. Their marginal advantage of lower initial procurement price is completely offset by frequent damage, repeated manual replacement, and substantial costs for marine environmental remediation.



Figure 1. Field-investigation-based interviews with fishermen on aquaculture rafts

2.2. Problems of net pollution and costs in traditional aquaculture on Dongshan Island

Over the past decades, natural-fiber fishing nets and low-quality synthetic netting gears have been widely adopted in coastal aquaculture of Dongshan Island. Such facilities are susceptible to wear and aging, continuously releasing plastic debris and fibrous microplastics, and constitute one of the primary sources of near-shore microplastic pollution in Dongshan Bay. The research group led by Cai Minggang from the College of Ocean and Earth Sciences, Xiamen University, carried out special monitoring on beach sediments of Dongshan Bay in 2025, verifying that mariculture activities generate substantial fibrous microplastics which account for a prominent proportion of the total microplastics in the bay [3].

Traditional fishing nets exhibit poor mechanical properties. Subjected to combined external forces including long-term wave erosion, reef abrasion, marine organism fouling and biting, as well as scraping by fishing vessels, they are prone to cracking and filament shedding. According to the 2025 research findings from the Chinese Research Academy of Environmental Sciences and Tianjin Binhai New Area Institute of Environmental Innovation, nylon and polyethylene fishing net materials possess extremely weak natural degradability, with their degradation periods in seawater ranging from several decades to a century [4]. Damaged net fragments are light-weight and can drift over extensive areas with tidal currents, making them highly likely to be ingested by fish and shellfish. According to the 2023 national fishing-gear census data released by the Ministry of Agriculture and Rural Affairs, manual salvage of derelict fishing nets at sea faces high operational difficulty and considerable economic costs, and the overall recycling rate of abandoned fishing gears in China's coastal waters is less than 15% [5]. Large quantities of aged and damaged fishing nets are directly discarded into the sea to form ghost gear. A 2016 thematic report by the Food and Agriculture Organization of the United Nations indicated that 46% of globally endangered marine species may die from entanglement and suffocation caused by derelict fishing nets (FAO, 2016, Food and Agriculture Organization

of the United Nations) [6]. Floating and sunken fishing nets tend to entangle ship propellers and trigger navigation failures. Once fragmented and mixed with sediments, fishing nets become extremely difficult to sort and recycle, rendering resource-oriented utilization hardly achievable.

Traditional aquaculture netting has a short service life. According to field-interview-based investigations with aquaculture farmers on Dongshan Island conducted by our research team in August 2026 (As illustrated in Figure 2), conventional traditional netting only lasts 2-5 years, and the service life will drop to 2-3 years in years with typhoons and heavy sea waves, driving up comprehensive aquaculture costs. Even with local subsidy policies for aquaculture-facility renewal, the procurement cost for a standard set of cage netting still amounts to several thousand RMB. Frequent material replacement imposes heavy economic burdens on small- and medium-scale aquaculture farmers. The low initial procurement cost of traditional fishing nets is fully offset by subsequent additional costs such as frequent renewal, offshore on-site mending, salvage of abandoned fishing gears, marine plastic pollution abatement and marine ecological restoration, leading to unsatisfactory comprehensive economic benefits (Field survey of the PBL project, 2026, Our Research Team [7].

As can be observed in Table below, different fishing-net materials show prominent divergence in purchase expense, total cost and residual value within a 5-year service cycle.

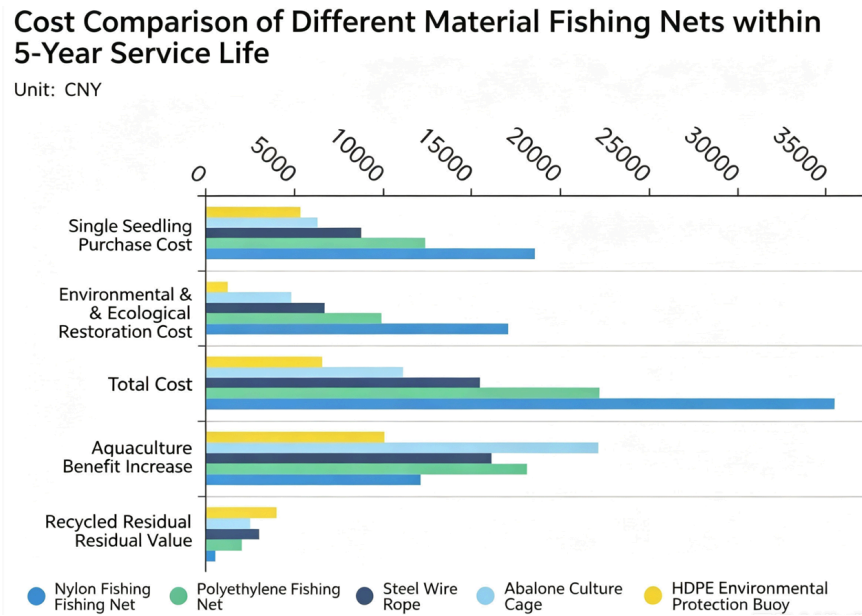


Figure 2. Five fishingrelated materials' costs and benefits over 5 years (unit: CNY)

2.3. Pollution and disposal of abandoned vessels at sea

A large number of small- and medium-sized fishing vessels for aquaculture and fishing are perennially distributed in the mariculture waters of Dongshan Island. Harmful substances such as diesel engine exhaust and oily bilge water are discharged during vessel operations. Nevertheless, the vast majority of local small fishing vessels are not equipped with supporting exhaust-gas purification and sewage collection-treatment devices, resulting in persistent pollution problems.

In terms of exhaust emissions, most nearshore small- and medium-sized fishing vessels around Dongshan Island are powered by diesel engines, which directly emit exhaust pollutants including nitrogen oxides and sulfur oxides during operation and berthing. According to the investigation and evidence-collection work conducted by the People's Procuratorate of Dongshan County on the Coral Provincial Nature Reserve in 2021,

unlicensed diving fishing rafts and small operating vessels existed within the reserve from 2020 to 2021. The sedimentation of diesel-engine exhaust fumes and oil gas from these vessels exerted continuous adverse impacts on coral-surviving environments [8]. The procurement cost for installing tail-gas purification devices on small fishing vessels can reach several thousand yuan, and regular maintenance is required in subsequent phases, which imposes substantial economic pressure on ordinary fishermen; hence, the local retrofitting penetration rate remains low. As the bay is a semi-enclosed water body, exhaust gases are difficult to disperse. Carbon-black particulate matter settles into seawater, further aggravating surface-water pollution. Apart from exhaust emissions, fishing vessels also generate multiple types of water-body and solid-waste pollution. Many small fishing vessels lack bilge oily-water storage tanks, so bilge oily wastewater is directly discharged into the sea during operations. Plastic packaging, domestic waste onboard, as well as aged and frayed old ropes and fishing nets are sometimes discarded into the sea by crew members. In August 2022, Zhangzhou Coast Guard uncovered three cases of illegal marine waste dumping by vessels in waters near Dachan Village of Dongshan, detaining three vessels with approximately 1,500 cubic meters of illegally dumped waste in total [9]. From late 2022 to early 2023, Dongshan also cracked a major cross-province case of illegal waste-oil dumping. A total of 164.645 tons of oily hazardous waste involved in the case flowed into tidal flats and nearshore waters and damaged nearshore aquaculture, indirectly reflecting regulatory pressure concerning the disposal of vessel- and oil-related waste in nearshore sea areas [10].

Beyond dynamic pollutant discharge from fishing-vessel operations, prominent environmental problems featured by stranded abandoned ownerless fishing vessels and disorderly disposal have long persisted in nearshore waters off Dongshan Island. Field investigations in this study revealed that numerous old and abandoned fishing vessels have been arbitrarily anchored and left unmanaged for long periods along fishing-port shorelines, around mariculture rafts and in nearshore shallow-sea zones. Exposed persistently to sea winds, salt spray and wave scouring, these abandoned hulls generally suffer from ageing phenomena including wood decay, hull corrosion and weathering-induced structural damage. As marine weathering intensifies continuously, broken hull planks, corroded metal fragments, aged ship paint and plastic components keep sloughing off and entering nearshore waters.

Drifting with tidal currents, dislodged hull fragments not only exacerbate nearshore pollution from solid plastics and debris and degrade marine ecological environments, but also readily abrade and collide with normally operating aquaculture cages, fishing-raft facilities and working vessels under the action of tides and wind-waves, triggering problems such as net-cloth rupture, aquaculture organism escape and equipment damage. Debris and corrosive substances shed from abandoned hulls continuously enter seawater, further raising the load of suspended pollutants in nearshore waters and threatening benthic organisms and aquaculture water environments. Meanwhile, floating hull fragments inflict persistent physical damage on fishermen's production facilities, aggravating cumulative nearshore ecological pollution and frequently causing property losses and reduced aquaculture yields for fishermen. Owing to the absence of regular cleaning, recycling and dismantling mechanisms for nearshore abandoned fishing vessels at present, large quantities of ageing vessels remain stranded on the sea surface over long periods, constituting hidden and persistent ecological and production-safety hazards for mariculture zones off Dongshan Island.

3. Advantages and disadvantages of new building materials used in off-shore aquaculture in Dongshan Island

3.1. Performance improvement, environmental friendliness and pain points of new-style HDPE floating pontoons

In recent years, the government has begun to adopt certain measures such as providing subsidies to encourage fishermen to replace plastic HDPE floating pontoons. Although new-style HDPE floating pontoons exhibit superior seawater corrosion resistance, impact resistance and high fracture resistance compared with traditional foam floats and have been widely promoted and applied in offshore raft aquaculture, they still have unavoidable practical shortcomings. HDPE materials are relatively sensitive to temperature differences; drastic fluctuations in ambient temperature will accelerate material ageing. Meanwhile, once the shell of a floating pontoon is scratched and damaged by hard objects such as reefs and fishing gear, its internal sealed structure will be destroyed and buoyancy will decline, rendering it unfit for further aquaculture operations.

The most prominent industry pain point is that due to uneven raw-material quality and inconsistent production processes, the actual service life of floating pontoons purchased by fishermen often differs greatly from the theoretical design life claimed by manufacturers. These pontoons frequently suffer ageing-induced cracking long before reaching their nominal service life, forcing fishermen to conduct frequent batch replacements. Frequent purchases of new floating pontoons directly raise fishermen's equipment investment costs, while the marine salvage of discarded pontoons consumes vessel fuel and labour, further increasing the economic burden of aquaculture. As shown in Figure 3, aquaculture consumables including pontoons, rafts and fuel impose considerable financial pressure on local operators. In addition, the relatively heavy self-weight of individual HDPE floating pontoons makes marine salvage and recovery time-consuming and labor-intensive, resulting in high overall recovery costs. Consequently, many fishermen, in order to cut expenses and simplify operations, fail to salvage discarded pontoons ashore for compliant recycling. Instead, they simply cut off the mooring ropes and abandon waste pontoons in offshore waters. Large quantities of waste plastic floating pontoons, either drifting on the sea surface or sinking to the seabed, not only damage the offshore marine ecosystem and threaten the survival of marine organisms but also aggravate marine plastic pollution and impose considerable pressure on marine environmental governance in waters surrounding Dongshan Island [11].

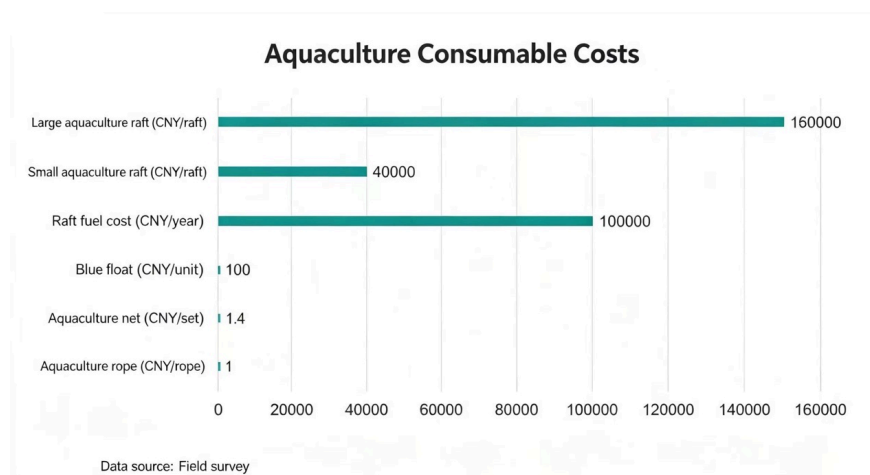


Figure 3. aquaculture consumable costs from fieldsurvey data

3.2. Performance improvement, environmental friendliness and pain points of new-type plastic panels compared with traditional wooden boards

Pilot applications of new-type HDPE plastic panels matched with plastic aquaculture raft frames were carried out in Xiaxikeng Village during 2019-2020, and county-wide popularization was launched in 2021 [12]. Compared with traditional wooden tread boards, new-type plastic panels possess multiple advantages. First, they feature seawater corrosion resistance and anti-UV ageing performance. With anti-UV additives incorporated, the panels are resistant to rotting and fragmentation under long-term seawater immersion and solar exposure, which can reduce the release of foam-derived microplastics at the source. Second, they deliver better wind-wave resistance and operational safety. Boasting favourable toughness and adopting modular assembly, the plastic panels together with HDPE floating pontoons can withstand strong typhoons with low fracture risks under wind-wave impact. Fishermen can walk more safely during operations, and damages to aquaculture rafts and escape of cultured organisms caused by typhoons can be mitigated. Third, they have a longer service life. Qualified plastic panels made from virgin materials have a theoretical service life of 10-15 years, far exceeding the 2-4-year service cycle of wooden tread boards. This reduces the frequency of facility replacement and saves material procurement and labour maintenance costs in the long run. Fourth, assembly and maintenance are convenient. The modular splicing structure facilitates on-site installation, and locally damaged panels can be replaced individually without dismantling the entire aquaculture raft. Fifth, they are recyclable. After being scrapped upon expiration of service life, they can be salvaged ashore for crushing and reprocessing. Different from hard-to-recover broken foam floats, they effectively relieve the disposal pressure of marine waste.

Meanwhile, numerous practical pain points have emerged in the field application of new-type plastic panels. Firstly, there are limitations in material physical properties. HDPE exhibits prominent thermal expansion and contraction effects. Temperature differences tend to cause warpage and deformation of panel surfaces, resulting in widened splicing gaps as well as dislocation and loosening of panels. Due to insufficient material rigidity, bending deformation may occur under repeated wave impact and manual operation loads. Secondly, product quality varies greatly across the market. Many low-cost products adopt recycled materials with insufficient addition of anti-UV additives. Even for virgin-material products with a nominal service life of 10-15 years, their actual service cycles are often shorter than theoretical design values under complex marine environmental conditions [13]. Thirdly, the upfront procurement cost is relatively high. Even with government subsidies for aquaculture upgrading, the overall investment for complete plastic-panel facilities remains higher than that of traditional wooden tread boards, imposing considerable initial-capital pressure on small- and medium-scale aquaculture households. Fourthly, the recycling mechanism is imperfect with risks of secondary pollution. Owing to the heavy self-weight of plastic panels, marine salvage consumes substantial manpower and material resources while recycling channels are limited, so some damaged panels cannot be disposed of ashore. Once panels break and fall into the sea, they become large-sized marine plastic waste and may still release plastic particles after ageing and fragmentation. Fifthly, connector wear is a notable issue. Bolts and fasteners for fixation are prone to corrosion under long-term seawater immersion, which leads to panel loosening, accompanied by potential risks of trace heavy-metal leaching [14].

3.3. Advantages and disadvantages of new-type cables and aquaculture raft nets

In recent years, several domestic and foreign research institutions have carried out relevant studies and realized technical improvements targeting the existing problems of traditional cables and aquaculture raft nets, so that the durability and sustainability of rope-net products have been enhanced. Compared with conventional

natural-fiber rope-nets and low-quality synthetic rope-nets, the upgraded new-type anti-UV PE cables and nylon knot-less aquaculture raft nets show obvious improvements in comprehensive performance.

The new-type PE cables feature seawater corrosion resistance, low water absorption and excellent wear resistance. Qualified products have a theoretical service life of 4-7 years and possess recycling and reprocessing potential as thermoplastic materials after scrapping. The nylon knot-less fishing nets eliminate knot structures to mitigate stress concentration, delivering superior elasticity and wave-impact resistance. Their smooth net surfaces reduce skin abrasions of farmed fish and meanwhile achieve better water exchange in sea areas; qualified net fabrics have a theoretical service life of 3-6 years [15]. Nevertheless, under the actual offshore aquaculture environment of Dongshan Island, both types of products still have prominent practical limitations. A large quantity of low-cost products on the market adopt recycled raw materials with insufficient addition of anti-ultraviolet additives, resulting in a service life remarkably shorter than the theoretical design value. Severe biofouling by marine organisms such as barnacles and seaweeds requires substantial manpower for regular cleaning and maintenance [16]. The upfront procurement cost of rope-net facilities is relatively high. Even with local subsidies for aquaculture upgrading, certain financial pressure is still imposed on small- and medium-scale aquaculture households. No convenient and sound recycling system for waste rope-nets has been established in offshore waters. High costs are incurred for salvaging broken cables and damaged fishing nets at sea. Some discarded rope-nets are directly abandoned into the ocean, continuously releasing fibrous microplastics and forming ghost fishing gear, which poses threats to the ecological security of offshore marine environments [17].

4. Presumptive future feasible measures for cost reduction and environmental pollution mitigation

4.1. Suggestions for future improvements of aquaculture raft floating pontoons in terms of materials and policies

Large-scale application of HDPE floating pontoons has been realized at present (show in figure 4), yet shortcomings such as microplastic leaching, severe biofouling and single-function performance still exist [18]. Next-generation pontoon materials that are still in the experimental and demonstration stage can be prioritized for future development. In terms of materials, basalt-fiber thermoplastic composite floating pontoons can be adopted. Under laboratory conditions, their designed service life can reach 25-30 years, with better typhoon-resistance performance than HDPE. They allow on-site repair via thermal welding and achieve a material recyclability rate above 80% [19]. Pilot trials can be carried out on PHB bio-based degradable composite floating pontoons. In case of loss or damage under extreme conditions, such pontoons can be gradually mineralized in the marine environment to reduce the risk of fishing-gear-related pollution. Sea-trial results show that their microplastic release is 92% lower than that of HDPE [20]. In terms of policies, special subsidies for offshore marine trials of new-type floating-body materials can be set up to provide appropriate equipment allowances for small- and medium-scale aquaculture households participating in pilot projects and lower the threshold for new material trial application. Meanwhile, a marine in situ testing and certification system for new type marine floating facilities shall be established, with anti-fouling performance, recyclability and degradation safety listed as mandatory testing indicators. The traceability mechanism for end-of-life fishing gear shall be improved, and scrapping and recycling subsidies for new material floating pontoons shall be formulated to guide enterprises to build a closed-loop chain of "production-use-recovery-reprocessing". Demonstration applications shall be implemented in the offshore aquaculture areas of Dongshan Island to

realize gradual technological iteration [21]. Successfully extending the service life of floating pontoons and launching corresponding government subsidies can substantially improve the cost-effectiveness of pontoon purchase for fishermen, thereby promoting the development of fishery production and achieving more efficient protection of the offshore marine environment.



Figure 4. Current new-type environment-friendly plastic aquaculture rafts photographed during field investigation by the research group

4.2. Hierarchical optimization of financial subsidies and centralized procurement modes

The high one-time investment of new-type plastic aquaculture rafts constitutes the core economic barrier hindering their comprehensive promotion. Dongshan Island may draw on the existing subsidy policies of Taizhou City and adopt unified standards without distinguishing small-scale household operators and large-scale aquaculture entities. The prevalence of inferior products made from recycled materials further aggravates cost losses during transformation. Optimization should be carried out from three aspects: subsidy structure, centralized procurement and quality control. First, implement differentiated stepped subsidies with preference for small- and medium-scale household operators. Following the subsidy framework for plastic aquaculture raft renovation in Fujian Province, adjust the fund-sharing ratio: the provincial government bears 60%, the municipal government 20%, and the county-level government 10%, while household operators only need to raise 10% of the funds themselves. For small family-run aquaculture households with an aquaculture area below 5 mu, the subsidy rate shall be increased by 10%. The subsidy for renovating a complete set of plastic aquaculture rafts shall be raised to 2800 CNY per raft, and the subsidy for merely replacing HDPE floats shall be increased to 1,300 CNY. Special clearance subsidies are provided for the dismantling of old wooden aquaculture rafts, with a maximum of 100 CNY per raft to cover the labour costs for dismantling old rafts and salvaging foam floats, to reduce the one-time cash expenditure of aquaculture households. Targeting the shortened service life of inferior HDPE building materials made from recycled materials, special incentives for high-quality virgin materials shall be established. Aquaculture households purchasing brand-new virgin-material HDPE panels and floating pontoons with sufficient anti-UV additives and complying with national mechanical-property standards will receive an additional special incentive equivalent to 8% of the purchase value. This will force the market to phase out low-price and low-quality recycled-material products and cut long-term implicit costs caused by frequent short-term replacements [22].

Second, promote county-level joint centralized procurement to curb premium prices for building-material purchases. The Fishery Association of Dongshan County shall serve as a unified liaison with qualified HDPE manufacturers. Taking the total volume of aquaculture-raft renovation across the county as bargaining leverage, it conducts bulk centralized procurement of floating pontoons, plastic panels and anti-UV rope-nets to eliminate successive price mark-ups by distributors, which can reduce the unit purchase price by 15%-22%.

Meanwhile, product traceability ledgers shall be established. The origin, production year and material identification shall be engraved on all aquaculture-raft building materials. Market supervision and marine-fishery authorities shall conduct regular sampling inspections. Manufacturers guilty of adulteration with recycled materials or sub-standard anti-ageing additives shall be disqualified from county-level supply, preventing aquaculture households from repeated capital investment due to low-price inferior materials [23].

Third, launch instalment interest-subsidized credit to ease capital-turnover pressure. Cooperate with rural commercial banks to develop the "Special-purpose Loan for Green Renovation of Aquaculture Rafts", with full government interest-subsidization for three years. Aquaculture households are not required to pay their self-funded portion in a lump sum and may repay the loan over 2-3 years according to aquaculture production cycles. Large-scale aquaculture cooperatives may apply for group credit granting to realize village-wide unified renovation and unified settlement, lowering individual credit-processing costs and addressing the short-term cash-flow shortage of small- and medium-scale aquaculture households [24].

4.3. Technical iteration and improvement of fishing raft building materials to extend service life, reduce loss and replacement frequency

Aiming at the performance defects of existing HDPE materials such as thermal expansion and cold contraction, marine organism fouling, corrosion of connecting components and insufficient weather resistance, joint research institutes of marine materials carry out improvement research and development adapted to the high-temperature and high-salinity environment of Dongshan Bay to reduce the long-term comprehensive operation and maintenance cost from the material perspective [15].

First, research, development and promotion of modified HDPE composite plates and floats. Anti-UV and temperature-resistant modification additives are added into raw materials to mitigate warpage and deformation caused by thermal expansion and cold contraction; float shells are thickened and their surface layers are toughened to improve resistance to abrasion by reefs and fishing gears; integrated anti-corrosion stainless steel fasteners and non-metallic composite bolts are developed to replace traditional corrosion-prone metal connectors, eliminating risks of heavy-metal leaching and lowering maintenance frequency for plate loosening. The theoretical service life of qualified modified products is increased to 15–20 years, greatly cutting the total equipment replacement expenditure within 10 years, with a comprehensive cost reduction of more than 20% compared with conventional HDPE products [13].

Second, supporting application of novel low-fouling and self-cleaning ropes and nets. Coated nylon knot-less nets and bionic anti-fouling PE cables are popularized. Anti-fouling coatings against marine organisms are applied on surfaces to restrain massive attachment of barnacles and algae, cutting annual man-hours for manual cleaning and maintenance by 60% and substantially saving labour costs for offshore cleaning. The knot-less structure further reduces fish abrasion losses, improves the survival rate of abalones and Japanese *Decapтерus maruadsi*, and meanwhile lowers the frequency of net mending and replacement [25].

Third, lightweight design with modular segmentation for fishing rafts. The single dimension of plastic plates and self-weight of individual floats are optimized, and detachable small-scale unit components are developed. Only partial modules need to be replaced upon damage instead of disassembling and reassembling the whole fishing raft, which reduces labour and fuel consumption for hoisting and transportation. Matched standard splicing accessories enable general interchangeability of plates from different batches and lower the separate procurement cost of spare parts [26].

4.4. Digital transformation of offshore aquaculture: reducing labor and ecological costs via unmanned management

Relying on Fujian's supporting policies for smart deep-sea fisheries, lightweight digital devices are deployed in phases on connected plastic fishing rafts in Dongshan Island. Remote monitoring and intelligent operation and maintenance are adopted to reduce sea-going inspections, manual feeding and losses caused by diseases, while realizing precise control over aquaculture pollution discharge [27].

First, popularization of low-cost marine Internet-of-Things monitoring systems. Solar-powered wireless network bridges are constructed for clusters of connected fishing rafts, equipped with water-quality sensors, underwater high-definition cameras and meteorological monitoring terminals to remotely monitor water temperature, dissolved oxygen, water flow and net-cloth damage in real time. Small underwater inspection robots are deployed to automatically detect net cracking and buoy damage, replacing daily manual sea-going inspections. The annual average manual inspection cost for each household is reduced by more than 35%. Early detection of damaged facilities prevents escape of cultured organisms and marine pollution caused by plastic debris [28].

Second, deployment of equipment for precision intelligent feeding and tail-water regulation. Small photovoltaic automatic feeders are popularized. Feeding dosage is dynamically adjusted according to water dissolved oxygen and fish growth data, raising feed utilization efficiency by 12%-18% and reducing benthic environmental pollution induced by settled residual feed, to cut hidden costs for marine ecological restoration. Simple ecological floating beds (co-cultivation modules of *Gracilaria lemaneiformis* and seaweeds) are installed beneath fishing rafts to absorb nitrogen and phosphorus in situ, realizing on-site purification of aquaculture tail water without constructing additional onshore tail-water treatment facilities and saving environmental-governance expenditures [29].

Third, construction of a digital recycling and traceability platform. Breeders register recycling information of waste buoys and plates through mobile mini-programs. The system automatically calculates removal-and-transport subsidies and deposit refunds and generates carbon emission reduction certificates simultaneously. Accumulated carbon points can be exchanged for fishing-raft maintenance consumables and aquaculture supplies. Digital incentives improve recycling initiative, and a whole-chain pollution traceability database is established to facilitate regulatory authorities to precisely curb illegal ocean dumping [30].

5. Conclusion

In conclusion, although traditional foam buoys and wooden fishing rafts feature low initial procurement costs, their short service life of 2.5 years, annual damage rate of 25%, and recycling rate below 5% result in a more than 35% higher full-cycle cost over 10 years compared with HDPE plastic fishing rafts. Moreover, they continuously release microplastics and trigger irreversible damage to marine ecosystems. Despite higher upfront investment, new-type plastic fishing rafts possess a service life of 10-15 years and recyclable properties, which can substantially lower long-term economic costs and environmental impacts.

Overall, three recommendations are put forward to promote such transformation. First, implement differentiated stepped subsidies and lower the self-funded proportion for individual fish farmers to 10%, to phase out inferior products made from recycled materials. Second, popularize modified HDPE and anti-fouling rope-net systems to extend facility service life by more than 20%. Third, establish a digital recycling and traceability platform, and adopt carbon-point incentives to encourage onshore disposal of waste fishing gear, to achieve synergistic improvement of ecological and economic benefits.

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