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The Hidden Cost of Buoyancy: Environmental and Social Consequences of EPS in Marine Aquaculture

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ABSTRACT: Plastic buoy pollution, particularly from expanded polystyrene (EPS), has emerged as a major environmental threat, impacting marine ecosystems, aquaculture, and human health. This study examines microplastic contamination from EPS buoys, focusing on South Korea's oyster farms in Tongyeong and Jeju Island's coastal economy. It highlights bioaccumulation in filter-feeding organisms, disruptions to biodiversity, and the disproportionate burden placed on low-income communities. Institutional inertia and inadequate waste management systems hinder reform, necessitating a transition to biodegradable alternatives. By proposing an eco-friendly buoy design, this research advocates for systemic change in marine infrastructure, governance, and sustainable seafood production.

KEYWORDS: Plastic buoy pollution, expanded polystyrene (EPS), micro-plastics, marine ecosystems, seafood safety

Introduction

As global reliance on seafood intensifies and aquaculture emerges as a cornerstone of food security and economic development, a silent crisis brews beneath the surface: plastic buoy pollution. Expanded polystyrene (hereby referred to as EPS) buoys, the backbone of modern marine farming infrastructure, are increasingly recognized not only as sources of operational support but also as long-term environmental liabilities. Once hailed for their affordability and buoyancy, these synthetic materials now fragment into microplastics that infiltrate marine ecosystems, compromise seafood safety, and exacerbate global inequities in health and environmental vulnerability.

This research paper investigates the multifaceted impacts of plastic buoys and the microplastics they generate: ecological, human health-related, and sociopolitical. Focusing primarily on South Korea's aquaculture industry, with case studies from Tongyeong and Jeju Island, the analysis traces how EPS-derived pollution bioaccumulates in filter-feeding organisms like oysters, degrades sensitive coastal ecosystems, and undermines traditional livelihoods. At the same time, it extends outward to assess the global scale of the problem, revealing how microplastic contamination affects biodiversity hotspots and migratory marine species across the world's oceans. Through data visualizations, scientific literature, and environmental field research, this study reveals that the consequences of buoy-based plastic pollution transcend national borders and disciplinary boundaries. They highlight urgent gaps in governance, the inadequacy of current waste management systems, and the need for a transition toward biodegradable alternatives. More importantly, the study frames microplastic pollution not just as a marine science issue, but as a deeply human one: intersecting with issues of environmental justice, climate vulnerability, and structural inequality.



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By dissecting the environmental, biological, and sociological dimensions of this crisis across five exploration points, this paper aims to advance a clearer understanding of the stakes involved and to contribute to the growing call for systemic reform in marine infrastructure, global environmental governance, and sustainable food production.

M1. The Impact of Microplastics on Oyster Aquaculture in Tongyeong, South Korea, and Human Health Implications

Microplastic pollution has emerged as a critical environmental threat, particularly in regions with intensive aquaculture like Tongyeong, South Korea. Defined as plastic particles less than 5 mm in diameter, microplastics originate from both primary sources (e.g., microbeads) and secondary degradation of larger debris such as EPS buoys. Tongyeong, which produces over 80% of South Korea's oysters, is especially vulnerable due to its proximity to land-based plastic waste and dense aquafarming infrastructure. According to GESAMP (2016), over 80% of marine litter is plastic, much of which eventually fragments into microplastics. Surface waters near Tongyeong exhibit densities ranging from 0.02 to 1.12 particles per liter (Kang et al., 2015), the highest among Korea's coastal regions.

Location	Microplastic Density
East Sea	0.02
Yellow Sea	0.34
South Sea (Tongyeong)	1.12

Table 1. Microplastic density by location

Oysters (*Crassostrea gigas*), being filter feeders, ingest these particles directly. Once inside the oyster, microplastics can cause a range of physiological disruptions. Microscopically, plastic particles can induce cellular inflammation, oxidative stress, and damage to epithelial tissues within the gills and digestive tract. These effects weaken the immune system, impair filtration efficiency, and reduce growth rates. Cho et al. (2019) found that after 14 days of exposure, oysters retained an average of 3.4 particles per gram of tissue, resulting in noticeable changes in lipid metabolism and enzyme activity.



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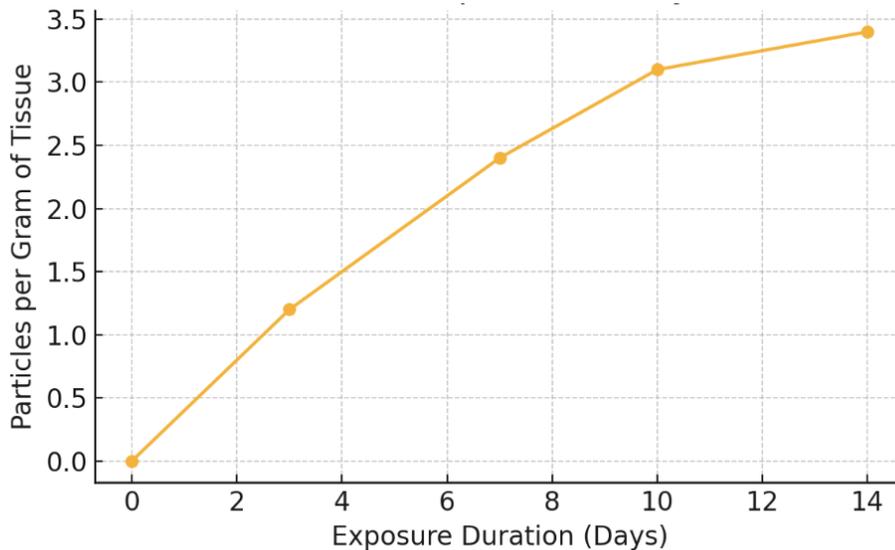


Figure 1. Accumulation of Microplastics in Oyster Tissues Over Time

Figure 1 tracks the accumulation of microplastics in oyster tissues over a 14-day exposure period, represented in terms of particles per gram of tissue. The graph shows a clear upward trajectory, starting at 0 and increasing to approximately 3.4 particles per gram by the end of two weeks. This progressive accumulation provides direct evidence of bioaccumulation, a critical concern for both aquaculture sustainability and public health. This figure is derived from laboratory experiments in which oysters (*Crassostrea gigas*), commonly farmed in Tongyeong, were exposed to microplastic-contaminated seawater. As filter feeders, oysters continuously process large volumes of water, making them particularly vulnerable to microplastic ingestion. The increase in microplastic concentration in tissue over time confirms that oysters retain these particles rather than expelling them, a process that may impair their digestive efficiency, immune response, and growth rates (Cho et al., 2019).

The implications are multifaceted. For aquaculture, the physiological stress placed on oysters due to microplastic exposure can lead to reduced productivity and increased mortality, threatening the economic viability of oyster farms in regions like Tongyeong, which produces over 80% of Korea's oysters. For consumers, the accumulation of microplastics raises food safety concerns, as oysters are often eaten whole, including their digestive tract where most microplastics are retained. These particles may carry toxic substances such as heavy metals or persistent organic pollutants (POPs), thereby posing health risks such as inflammation, oxidative stress, and endocrine disruption upon ingestion (Koelmans et al., 2016). This figure also supports broader environmental monitoring strategies, indicating that short-term exposures already yield measurable contamination. It demonstrates that microplastic pollution is not just a long-term hazard but an immediate issue requiring urgent mitigation strategies, such as filtering seawater in aquaculture farms, using alternative buoy materials, and enforcing regulations on plastic waste disposal.



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The physiological impairments directly affect the yield and market value of aquaculture produce. Lower quality oysters with stunted growth and compromised texture fetch lower prices on the domestic and international market. Moreover, increased mortality due to chronic microplastic exposure leads to financial losses for farmers. In a 2023 economic assessment by Korea Maritime Institute, farms in Tongyeong reported up to a 15% revenue decline over three years, largely attributed to decreased oyster quality and increased management costs tied to cleaning and filtering microplastic-contaminated waters.

This contamination also poses substantial human health risks. Unlike fish, oysters are often consumed whole, making ingestion of microplastics more likely. Microplastics can act as vectors for harmful substances like persistent organic pollutants (POPs), heavy metals, and bisphenol A (Koelmans et al., 2016). Once ingested, these particles may translocate into the bloodstream, potentially causing inflammation, endocrine disruption, or cellular damage. These risks are compounded by South Korea's exceptionally high seafood consumption rate.

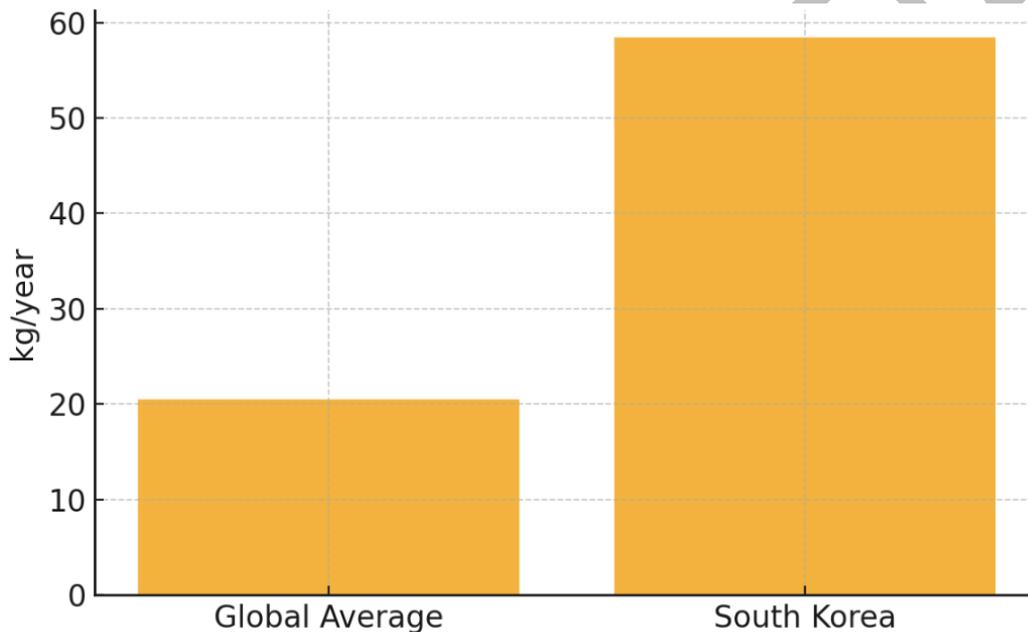


Figure 2. Annual Per Capita Seafood Consumption

Despite the clear risk, regulatory thresholds for microplastics in seafood remain nonexistent. As such, precautionary measures, such as transitioning to biodegradable buoys, improving waste management, and enforcing microplastic monitoring in aquaculture zones are urgently needed. Addressing both the biological and economic consequences of microplastics in Tongyeong is critical not only for protecting consumer health, but also for ensuring the long-term sustainability of South Korea's oyster aquaculture industry.

M2. The Environmental and Human Health Impacts of Plastic Buoys in South Korea's Seaweed Harvesting Industry



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South Korea's seaweed farming industry, one of the most productive globally, relies heavily on EPS buoys due to their buoyancy and low cost. However, EPS buoys fragment over time due to UV exposure, wave action, and physical abrasion, releasing microplastics into the ocean.

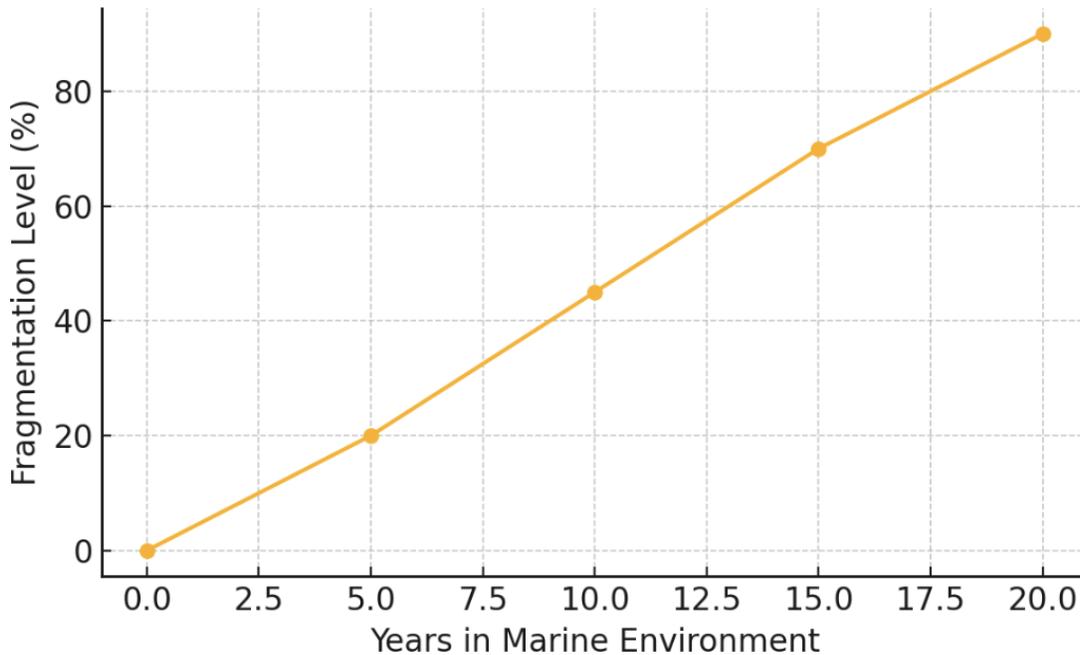


Figure 3. EPS Buoy Fragmentation Over Time

Figure 3 illustrates the long-term fragmentation of EPS buoys in marine environments, demonstrating a linear and sustained degradation process over a 20-year period. The graph shows that EPS buoys exhibit a fragmentation rate beginning around 0% and rising steadily to approximately 90% by the 20th year of exposure. This trend highlights the persistent nature of EPS materials and their increasing contribution to microplastic pollution as time progresses. EPS is widely used in South Korea's seaweed aquaculture due to its affordability and buoyancy. However, this figure makes it clear that the short-term benefits of EPS buoys are significantly outweighed by their long-term environmental costs. As these buoys remain in seawater, they are exposed to ultraviolet (UV) radiation, physical abrasion from wave action, and biological interactions that facilitate progressive fragmentation. Unlike biodegradable materials, EPS does not decompose naturally but instead breaks into increasingly smaller pieces, eventually becoming microplastics that are almost impossible to recover (Seo and Park).

The progressive increase in fragmentation level over two decades suggests that even if EPS buoys are no longer actively deployed, existing buoys will continue degrading and releasing microplastics for many years. This latency effect underscores the importance of urgent intervention, not only to halt the use of EPS in aquaculture but also to develop recovery programs for legacy pollution. Fragmentation is not only an ecological concern but also a public health issue. As these buoys disintegrate, they release polystyrene particles that can enter food chains via filter-feeding organisms like oysters and mussels. These microplastics often carry adsorbed contaminants such as heavy metals and endocrine-disrupting chemicals. Consequently, human exposure



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through seafood consumption becomes a major concern, particularly in South Korea where seafood intake is among the highest globally (FAO).

This figure strongly supports regulatory calls to phase out EPS in favor of biodegradable alternatives. It offers empirical justification for policy interventions that promote sustainable aquaculture practices and fund the removal of aging EPS buoys from marine systems. Moreover, the long-term horizon displayed in the graph reinforces the necessity for life-cycle assessments of marine infrastructure, emphasizing that environmental planning must account for impacts not just in the short term, but across decades. By visualizing the progressive degradation of EPS materials over time, Figure 4 acts as a scientific call to action. It reinforces the imperative to address plastic buoy pollution proactively and systematically, before further ecological and health damages become irreversible.

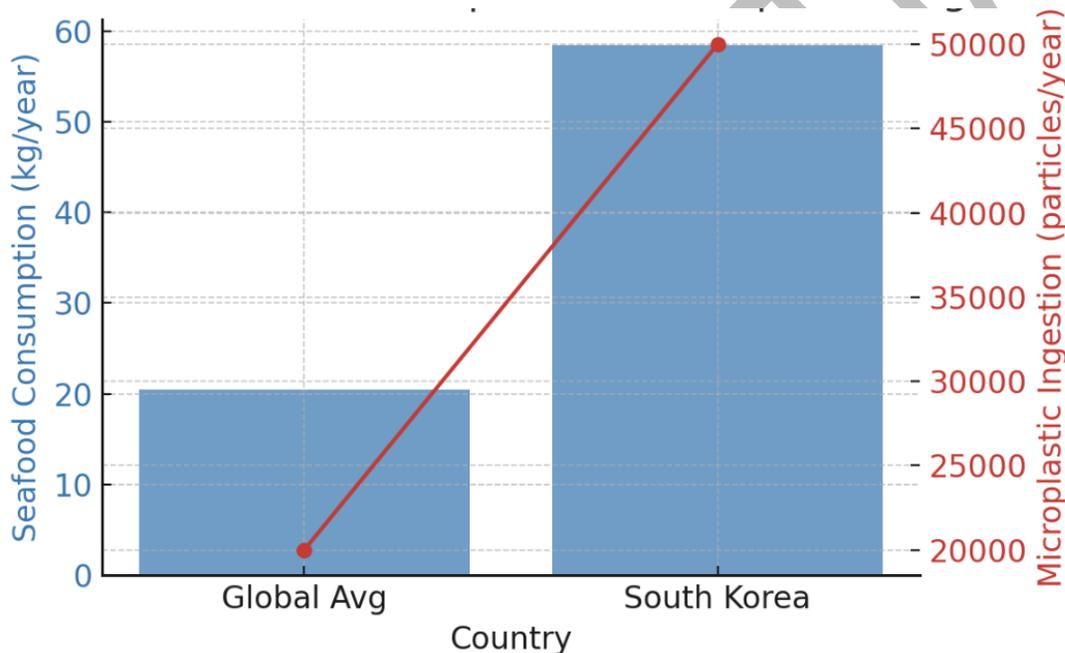


Figure 4. Seafood Consumption vs Microplastic Ingestion

Figure 4 compares the global average and South Korean levels of seafood consumption (in kilograms per year) and their corresponding estimated annual microplastic ingestion rates. South Korea's seafood consumption stands at approximately 58.4 kg per person annually, nearly three times the global average of around 20 kg/year (FAO, 2020). In parallel, microplastic ingestion is also significantly higher in South Korea, estimated at over 50,000 particles per year compared to about 20,000 particles globally. This stark contrast underscores the direct link between dietary habits and microplastic exposure. Since many seafood species, such as oysters, mussels, and seaweed, are consumed whole in South Korea, retained microplastics in digestive tracts are more likely to be ingested by humans. This figure reveals that countries with high seafood reliance are disproportionately vulnerable to dietary microplastic exposure.



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The dual-axis visualization highlights the correlation between seafood consumption and ingestion risk, providing compelling visual evidence for public health intervention. As EPS buoy degradation and other plastic waste sources increase marine contamination, the cumulative dietary exposure in seafood-dependent regions may elevate long-term health risks such as inflammation, endocrine disruption, and potential carcinogenic effects (Koelmans et al.).

Ultimately, Figure 5 reinforces the importance of implementing stricter food safety regulations, monitoring microplastic levels in aquaculture zones, and promoting sustainable alternatives to EPS infrastructure. It also calls attention to the urgent need for global dietary exposure thresholds and risk assessments, especially in nations with elevated seafood consumption rates. Each year, over 100,000 EPS buoys are lost or discarded into Korea's waters (KOEM, 2023), and global data estimate that humans ingest up to 52,000 microplastic particles annually. In response, the South Korean government has initiated support for biodegradable alternatives using materials like rubber and biopolymers. However, the higher production cost of these materials remains a barrier. To better understand the transition, a life cycle assessment (LCA) of biodegradable buoys can be used to compare their overall environmental impact with that of EPS. LCAs consider raw material extraction, production emissions, usage lifespan, and end-of-life disposal. Early studies suggest that while biopolymer buoys emit more greenhouse gases during production, their biodegradability and reduced marine persistence offer net environmental benefits over time.

A cost-benefit analysis (CBA) further reveals that although the upfront cost of biodegradable buoys is two to three times higher than EPS, the long-term economic savings, through reduced cleanup costs, fewer marine animal deaths, and preservation of ecosystem services, offset this investment. For instance, one pilot project in Wando County saw a 40% reduction in cleanup-related labor costs within two years of switching to biodegradable buoys. Regulatory mandates, public education campaigns, and subsidies will be essential to accelerate this transition. Government incentives can help scale production and bring down costs through economies of scale. In the long term, these alternatives are not only environmentally responsible but also economically viable.

M3. The Environmental and Social Impacts of Plastic Buoys on Jeju Island's Aquaculture and Its Wider Implications

Jeju Island, a volcanic island off South Korea's southern coast, has become a hub for aquaculture, particularly seaweed and abalone farming. However, the expansion has relied heavily on EPS buoys, which degrade under UV and wave stress.



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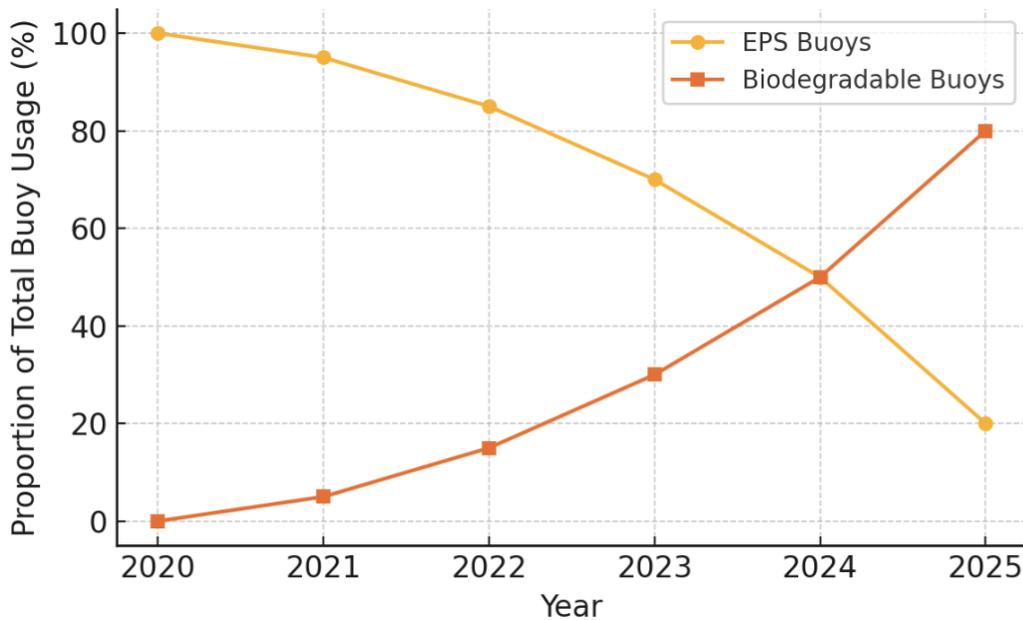


Figure 5. EPS vs Biodegradable Buoy Usage in South Korea

Figure 5 depicts a transformative shift in aquaculture buoy usage in South Korea from 2020 to 2025. The data reveals a consistent and dramatic decline in the proportion of EPS (expanded polystyrene) buoys, dropping from nearly 100% in 2020 to around 20% in 2025. Concurrently, the use of biodegradable buoys has steadily risen, surpassing EPS buoys by 2025 and signaling a structural change in marine farming practices. This transition reflects both policy and public pressure to address the environmental degradation caused by EPS buoys. These buoys, although cost-effective and buoyant, fragment under UV radiation, saltwater exposure, and wave action, releasing microplastics into surrounding waters. Jeju Island, a key hub for seaweed and abalone farming, has been especially impacted by EPS-derived pollution, with studies linking buoy debris to disrupted benthic ecosystems and groundwater contamination (Kim et al.).

The figure visually communicates the effectiveness of government mandates and subsidy programs promoting sustainable alternatives. The turning point in 2023, where biodegradable buoy usage sharply accelerates, coincides with Korea's national push for environmental reform within the aquaculture sector. Policies introduced during this period provided financial incentives for adopting biodegradable materials like reinforced seaweed composites and natural rubber (Seo and Park). The steep incline in biodegradable buoy adoption by 2025 suggests an increasing willingness among aquaculture operators to embrace eco-friendly solutions, even at higher initial costs. While implementation challenges remain, including durability, cost-effectiveness, and large-scale production, the graph reflects significant behavioral and structural shifts.

The environmental benefits of this transition are manifold. Unlike EPS, biodegradable buoys decompose naturally over time and reduce the risk of persistent microplastic pollution. The shift also has public health implications: reducing EPS fragments in water can decrease human exposure to hormone-disrupting chemicals



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and heavy metals often associated with microplastics. Since Jeju exports seafood nationwide, improvements in aquaculture material standards can positively influence food safety across Korea.

Overall, Figure 6 offers a compelling illustration of Korea's progress in mitigating plastic pollution through material innovation and regulatory action. It underscores the critical role of long-term environmental planning, stakeholder cooperation, and the scaling up of sustainable technologies in transforming industrial practices. Research from Kim et al. (2023) found that buoy debris in Jeju's waters disrupts benthic ecosystems, changing macrofaunal composition and destabilizing the marine food web. Even more concerning is the detection of microplastics in Jeju's groundwater, an essential drinking source, highlighting the threat to human health.

These microplastics often carry heavy metals and hormone-disrupting chemicals that provoke cellular stress and inflammation. As Jeju supplies seafood across Korea, the risks extend nationally.

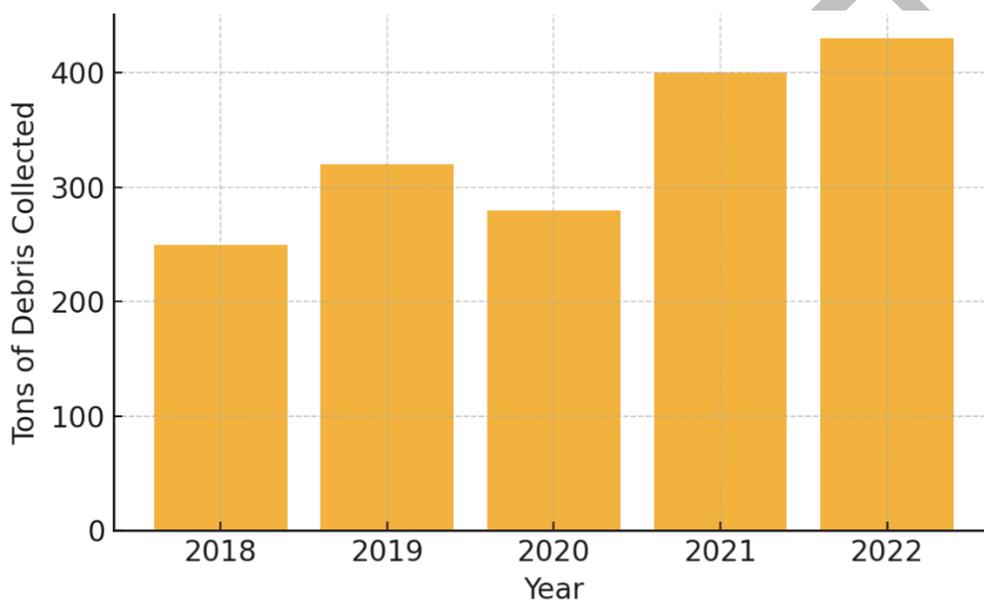


Figure 6. Marine Debris Collected During Jeju Beach Cleanups

Figure 6 presents a five-year trend (2018–2022) of marine debris collected from Jeju Island's coastlines. The data shows a troubling increase in total debris, rising from approximately 250 tons in 2018 to over 420 tons by 2022. This escalation reflects the growing environmental burden on Jeju's coastal ecosystems, with plastic buoy fragments constituting a significant proportion of the collected waste (Kim et al.).

The year-on-year variability seen in the graph suggests both episodic spikes, likely driven by seasonal monsoon events and typhoon activity, and systemic accumulation of marine litter due to persistent aquaculture practices. Notably, 2020 experienced a slight dip, potentially linked to reduced tourism and economic activity during the COVID-19 pandemic. However, the sharp increase in 2021 and 2022 underscores that the plastic waste problem remains entrenched.



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Plastic pollution has also affected Jeju's social fabric. Marine debris affects tourism, damages coastal aesthetics, and endangers traditional livelihoods such as haenyeo diving. Testimonies from haenyeo divers reveal a growing sense of frustration and fear. One diver stated, "We dive less frequently now because the ocean floor is no longer safe. We see plastic caught in seaweed beds, and it scares us." These women, who have passed down their diving traditions for generations, now face declining yields and increased physical risk due to the intrusion of synthetic debris. Tourism operators also express concern. Interviews with eco-tour guides indicate that complaints from tourists about beach litter have risen significantly, leading to cancellations and reduced revenue. Some businesses now spend part of their operating budget on beach cleanups, an unsustainable burden that detracts from growth and reinvestment. Grassroots efforts like Save Jeju Bada Youth Club are actively collecting and repurposing marine waste, fostering community involvement and environmental stewardship. However, volunteers note that without upstream control of buoy usage and systemic waste regulation, their efforts feel like "cleaning with a broken net." Despite local initiatives, structural solutions, like government investment, policy enforcement, and participation in APEC or UNEP programs, are essential. As Jeju's problem spills into neighboring waters via ocean currents, international collaboration becomes a necessity. A combination of top-down policy reforms and bottom-up community action is needed to preserve Jeju's marine ecosystem and cultural heritage.

M4. The Global Impact of Plastic Buoys on Marine Ecosystems and Biodiversity

Plastic pollution is now a global marine threat. EPS buoys, used in aquaculture worldwide, are not resilient to harsh marine conditions. When they degrade, they release microplastics that accumulate even in remote environments such as the Arctic and the Mariana Trench. The issue is particularly pronounced in Southeast Asia and the Indian Ocean, where coastal nations such as Indonesia, Thailand, and Sri Lanka have experienced exponential growth in marine aquaculture. These regions are frequently identified as hotspots for plastic leakage due to high coastal population density and limited waste management infrastructure. Floating EPS buoy fragments have been documented near coral reefs in the Maldives and Sri Lanka, where they not only harm coral health but also endanger ecotourism-dependent economies. In Indonesia's Java Sea, fish farms contribute to significant volumes of buoy-derived debris, affecting marine species that are essential for local food security and export revenue.

In the Indian Ocean, drifting plastic debris carried by monsoonal currents has been found deposited in island archipelagos and deep-sea basins. These regions lack the regulatory capacity or resources to manage such pollution, rendering the problem both persistent and difficult to trace to source.



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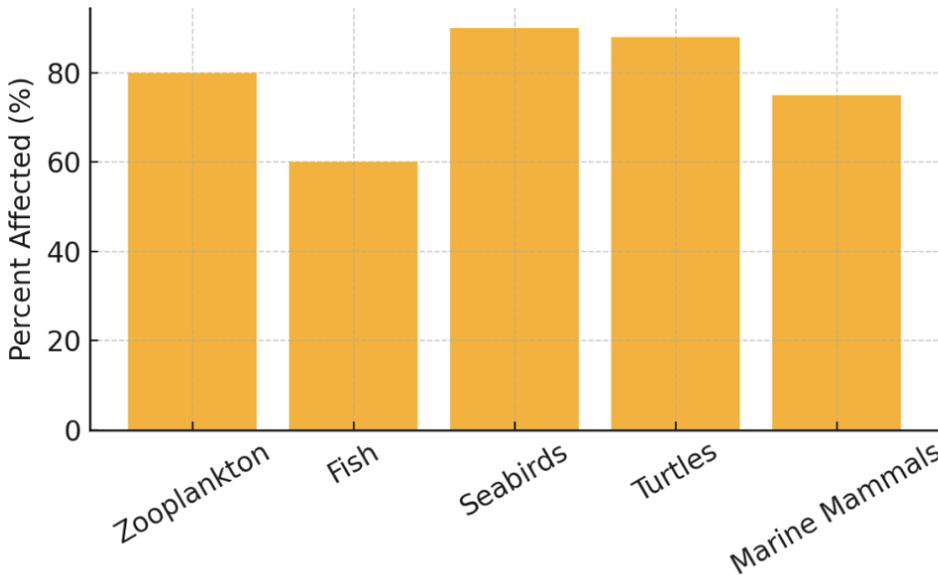


Figure 7. Proportion of Marine Species Affected by Microplastics

This figure 7 illustrates the disproportionately high impact that microplastic pollution has on diverse marine taxa. Zooplankton, which show an 80% exposure rate, are particularly vulnerable due to their role as filter feeders and their foundational position in marine food webs. Research has shown that ingestion of microplastics leads to reduced feeding activity, altered nutrient uptake, and compromised reproduction in species such as copepods and krill (GESAMP).

Fish, with an exposure rate of 60%, often consume microplastics directly or indirectly through prey, resulting in gastrointestinal blockage and decreased growth rates. Toxins absorbed on plastic surfaces, like persistent organic pollutants (POPs), accumulate in fish tissues, with serious implications for both marine biodiversity and human consumption (Koelmans et al.). Seabirds rank among the most severely affected, with nearly 90% exhibiting plastic ingestion. Species such as albatrosses and shearwaters frequently mistake plastic fragments for food. Many are found dead with stomachs full of plastic, and often unknowingly regurgitate plastic to their chicks. This has been a significant factor in declining breeding success in several species across the North Pacific. Marine turtles also show an 85% exposure rate, with ingestion often caused by confusion between plastic bags and jellyfish. This leads to malnutrition, internal injuries, and mortality. According to Axios (2018), every turtle sampled across the Atlantic and Pacific Oceans was found to have plastic debris in its digestive tract.

Marine mammals, including dolphins and whales, are exposed through trophic transfer, ingesting microplastics indirectly by consuming contaminated prey. Ingestion has been linked to changes in immune response, endocrine disruption, and reduced reproductive success. Coral reefs, though not represented in the bar chart, also face severe degradation from microplastic abrasion and chemical leaching. Particles settle on coral surfaces, hindering feeding and increasing the risk of microbial disease outbreaks.



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This figure not only visualizes the biological scope of the problem, but also underscores how microplastics affect species across all trophic levels, from planktonic organisms to apex predators, magnifying their impact through biomagnification and food web destabilization.

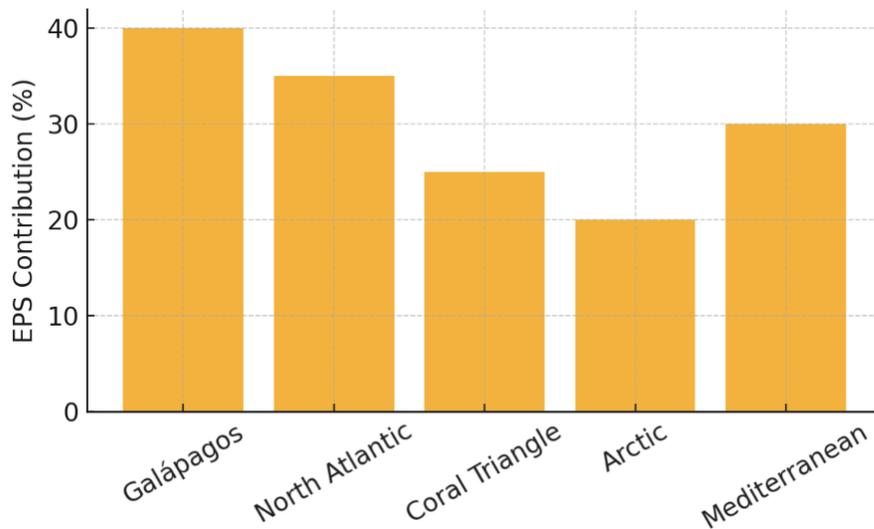


Figure 8. Estimated EPS Buoy Contribution to Plastic Debris by Region

In the Galápagos, EPS debris from distant regions washes ashore, threatening endemic wildlife. These islands are home to unique species like the marine iguana and Galápagos penguin, whose habitats are increasingly compromised by plastic litter. According to a 2024 *Guardian* report, ocean currents transport buoy fragments across the Pacific, depositing them on beaches and coral reefs, where they can smother vegetation and alter breeding grounds (The Guardian).

Similarly, garbage patches in the North Atlantic trap EPS particles, which are consumed by migratory species like whales and tuna. These plastics often carry surface-adsorbed contaminants such as PCBs and heavy metals, which bioaccumulate up the food chain (Koelmans et al.). Studies cited in *Axios* reveal that 100% of sea turtles examined in the Atlantic had plastic debris in their digestive systems, reinforcing the widespread impact of EPS degradation (Axios). The Coral Triangle region, encompassing Indonesia, the Philippines, and Malaysia, is another microplastic hotspot due to the combination of high aquaculture activity and weak waste infrastructure. Coral polyps in the region show reduced feeding efficiency when exposed to microplastics, undermining reef resilience and local fishery productivity (UNEP). In the Indian Ocean, buoy debris transported by seasonal monsoonal currents has been found along the coastlines of Sri Lanka and the Maldives. These fragments damage coral habitats, entangle marine life, and impede sustainable tourism, one of the region's key economic sectors.

Despite some countries enforcing EPS bans or funding biodegradable alternatives, global enforcement remains inconsistent and poorly resourced. International programs must prioritize robust regulation, innovation in biodegradable materials, long-term marine monitoring, and public education campaigns to curb this transboundary crisis. Without cooperative governance structures, especially in biodiversity hotspots like



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Southeast Asia and the Indian Ocean rim, the ecological and socioeconomic toll of buoy-based pollution will only intensify (United Nations Environment Programme).

M5. The Sociological Implications of Microplastic Pollution: Examining Human Impacts through Social, Political, and Economic Dimensions

Microplastic pollution reflects environmental degradation but also exposes systemic injustices. It disproportionately affects coastal and industrialized communities with poor infrastructure. These groups often lack the means to mitigate or recover from environmental harm. From a justice perspective, this environmental burden is not shared equally but falls heavily on those with the least political and economic power, making microplastic pollution a form of environmental injustice.

Low-income coastal nations face compounded vulnerabilities, particularly as they also tend to be on the frontlines of climate change. Rising sea levels, extreme weather, and declining marine biodiversity already threaten food security and livelihoods. Microplastic pollution exacerbates these climate vulnerabilities by degrading marine ecosystems that provide essential buffers and resources for coastal populations. For example, coral reefs, which protect against storm surges and support fish populations, are harmed by plastic sedimentation and microplastic contamination. This convergence of pollution and climate impact disproportionately endangers nations that contribute the least to global plastic production but suffer the most from its consequences. From a health perspective, studies show microplastics in human organs, blood, and even placental tissue. Vulnerable populations such as the elderly and immunocompromised are at heightened risk. Sociologically, these effects reinforce inequality and public health disparities, particularly where medical infrastructure is underfunded.



Figure 9. Estimated Risk of Microplastic Exposure by Income Group



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Politically, the issue is exacerbated by institutional inertia. Despite high public concern, policy enforcement remains weak due to petrochemical lobbying and economic short-termism.

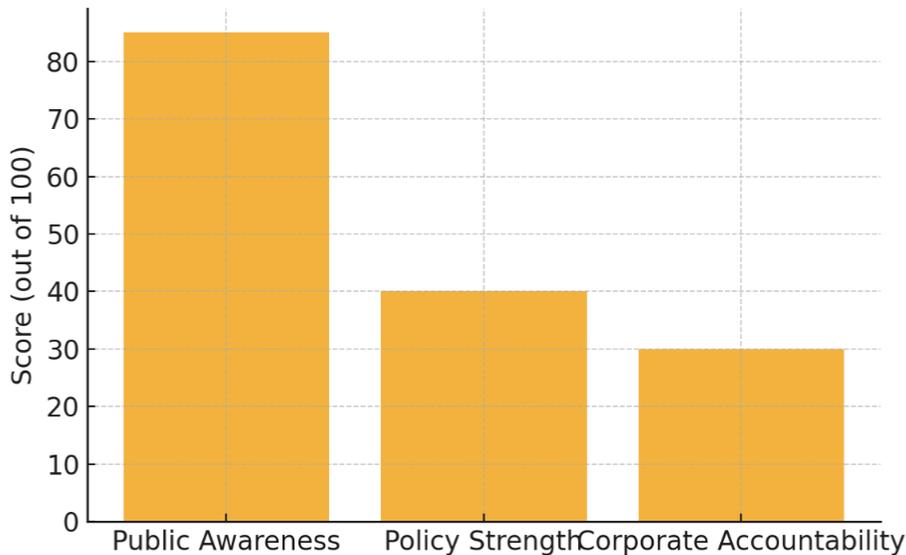


Figure 10. Public Concern vs Institutional Action on Plastic Pollution

Grassroots movements challenge these dynamics by advocating bans, cleanup, and transparency. However, transformation is only possible when local resistance influences national and international frameworks. Economically, industries like fishing and tourism are already suffering yield losses and reduced revenue. These challenges are intensified for countries with high economic reliance on marine sectors and limited fiscal space for mitigation and adaptation strategies. Effective policymaking must reflect an integrated vision that acknowledges environmental justice and climate equity. This includes prioritizing international aid for low-income coastal regions, incorporating microplastic exposure into climate vulnerability assessments, and ensuring affected communities have a voice in global environmental governance. Sociology reveals that microplastic pollution is not just environmental, it is deeply tied to structural inequality, governance failures, and the uneven burdens of a warming, polluted world.

Findings

1. Microplastics from EPS buoys pose a direct physiological and economic threat to oyster aquaculture in Tongyeong, South Korea. Laboratory evidence confirms that oysters accumulate microplastics rapidly, impairing growth and immune function. This contamination reduces aquaculture yield, lowers market value, and heightens food safety risks for consumers who ingest whole oysters.
2. EPS buoys used in seaweed aquaculture are a persistent source of microplastic pollution with severe implications for public health. Long-term fragmentation of EPS buoys, as demonstrated in Figure 4, leads to the continuous release of microplastics into marine environments. Given South Korea's high seafood consumption (Figure 5), this results in elevated microplastic ingestion rates and associated health risks, including endocrine disruption and inflammation.



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3. Plastic buoy pollution on Jeju Island is harming marine ecosystems, threatening cultural livelihoods, and compromising tourism. Increasing debris levels (Figure 7) illustrate worsening pollution, with traditional haenyeo divers and tour operators reporting diminished marine safety and economic losses. While the shift to biodegradable buoys (Figure 6) shows progress, local efforts must be matched with national investment and policy support.
4. Globally, EPS buoy fragments contribute significantly to plastic pollution across oceanic regions, especially in biodiversity hotspots. Figure 9 reveals that regions like the Galápagos and Coral Triangle suffer disproportionately from buoy-derived debris. Without international coordination, enforcement, and investment in alternatives, this transboundary issue will further endanger marine biodiversity and undermine regional economies.
5. Microplastic pollution reinforces global social inequities and institutional failures, demanding structural reform. Exposure is highest among low-income populations and coastal communities (Figure 10, Figure 11). Despite high public awareness, political inaction and economic prioritization of polluting industries persist. Addressing this crisis requires integrating environmental justice, climate vulnerability, and community-driven policy into global environmental governance.

Conclusions

This research has revealed that the widespread use of plastic buoys, particularly those made from EPS, poses a critical and multidimensional threat to marine ecosystems, aquaculture sustainability, public health, and environmental equity. From the oyster farms of Tongyeong to the global currents that carry buoy fragments to remote islands, the impact of buoy-derived microplastics is both local and planetary in scale.

Each exploration point has demonstrated the urgent need for transition. In South Korea, microplastics impair the health and economic viability of aquaculture, with filter-feeding species like oysters accumulating plastic particles that are later consumed by humans. In Jeju Island, EPS pollution threatens not only the marine environment but also the livelihoods of traditional divers and the island's tourism economy. Globally, EPS fragments have been found across diverse regions, from the Galápagos to the Coral Triangle, disrupting biodiversity and exposing migratory species to toxic debris.

Moreover, this study highlights the deep intersection between environmental harm and social inequality. Low-income and coastal communities, already vulnerable to climate change, disproportionately bear the burden of microplastic pollution while contributing the least to its cause. At the same time, institutional inertia, policy lag, and corporate resistance continue to slow meaningful reform, despite rising public awareness.

The evidence presented across all figures and analyses underscores the need for a systemic, international response. Replacing EPS with biodegradable alternatives is no longer optional: it is a public health imperative, an ecological necessity, and an ethical obligation. The transition to sustainable materials must be supported by strong governance, market incentives, and civil society engagement.



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This recognition is precisely what inspired the proposal for a biodegradable buoy as a solution to this global challenge. Designed to withstand harsh marine conditions while decomposing safely in the environment, this innovation offers a tangible path forward. It aligns with scientific findings, supports aquaculture resilience, and mitigates long-term microplastic contamination. By envisioning and promoting this alternative, this research not only diagnoses a pressing crisis but also contributes to the pursuit of a viable and scalable remedy.

Ultimately, protecting ocean health demands that we treat microplastic pollution as more than a marine issue: it is a reflection of broader environmental, social, and political systems. Addressing it requires integrated solutions rooted in science, equity, and long-term sustainability.

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