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Strengthening Marine Resource Governance: Tackling IUU Fishing in Taiwan Through Circular Economy and Regulatory Innovation

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ABSTRACT

This study examines Taiwan's multifaceted efforts to reduce the environmental impacts of illegal, unreported, and unregulated (IUU) fishing, a challenge that gained urgency following the European Union's yellow card warning. Central reforms—including gear tagging initiatives, buy-back programs, and strengthened enforcement mechanisms—aim to address illegal catches, gear laundering, and fleet overcapacity while simultaneously promoting circular economy principles in fisheries governance. The research employs Fisheries Agency data (2022–2024) on gear tagging, returns, recovered volumes, and recycling rates, combined with stakeholder interviews and market analysis of recycled fishing gear materials, to highlight the complex relationship between IUU practices and abandoned, lost, or discarded fishing gear (ALDFG). A "follow-the-plastic" methodology, adapted from waste-tracing studies, is introduced to trace gear throughout its lifecycle from production to disposal, identifying leakage points linked to IUU activities. Policy effectiveness is critically evaluated, revealing persistent regulatory gaps, weak market incentives for recycling, and barriers to private-sector participation. The study proposes a conceptual framework that demonstrates how circular economy strategies can complement traditional enforcement by reducing gear loss, enhancing traceability, and improving compliance. Findings emphasize that international cooperation, adaptive governance, and local community engagement are essential to achieving sustainable fisheries. Taiwan's experience suggests that coupling IUU enforcement with circular economy innovations provides a practical pathway to reduce ALDFG, strengthen marine biodiversity conservation, and foster environmentally sustainable resource

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ARTICLE INFO

Received: 9 July 2025 | Revised: 29 July 2025 | Accepted: 19 August 2025 | Published Online: 27 August 2025
DOI: https://doi.org/10.30564/jees.v7i8.10951

CITATION

Shih, Y.C., 2025. Strengthening Marine Resource Governance: Tackling IUU Fishing in Taiwan Through Circular Economy and Regulatory Innovation. Journal of Environmental & Earth Sciences. 7(8): 300–316. DOI: https://doi.org/10.30564/jees.v7i8.10951

use. The study concludes that integrated governance, combining legal enforcement with economic and social instruments, is vital for long-term marine ecosystem protection and resilience.

Keywords: IUU Fishing; Marine Resources; Marine Biodiversity; Environmental Impact; Abandoned, Lost, or Discarded Fishing Gear (ALDFG)

1. Introduction

IUU fishing threatens Taiwan's maritime ecology and biodiversity, because the effects of illegal, unreported, and unregulated (IUU) fishing on the local economy, community, and environment transcend beyond ecological harmony[1]. Notably, Taiwanese maritime habitats are especially sensitive to IUU fishing. According to Shih et al.[2], IUU fishing reduces marine species richness, so the European Union has called for strong regulations to combat IUU fishing methods in the area. Additionally, Taiwan has also taken notice of this issue; however, IUU fishing, fish laundering, and fishing overcapacity persist despite efforts to address them[3]. Taiwanese IUU fishing affects the island's economy and society; hence, due to these challenges, Taiwan recognizes the necessity to address IUU fishing's environmental impacts. Nevertheless, the country has a plan to reduce illicit, unregulated, and uncontrolled fishing[4]. Naturally, preventing labour violations and IUU fishing operations like shark finning requires enforcement by the Taiwanese government[5]. Thus, IUU fishing in Taiwan has serious environmental impacts, necessitating a holistic approach that considers ecological and socio-economic factors. Therefore, Taiwan's marine resources must be balanced between conservation and enforcement to survive. IUU fishing threatens Taiwan's maritime ecology and biodiversity. In this revision, the author explicitly distinguishes between IUU fishing drivers (profit motives, weak governance, lack of vessel transparency) and ALDFG causes (accidental loss, intentional discard, storms, gear conflicts). A revised conceptual diagram now clarifies this relationship's maritime ecology and biodiversity, because, the effects of IUU fishing on the local economy, community, and environment transcend beyond ecological harmony[1]. Notably, Taiwanese maritime habitats are especially sensitive to IUU fishing. According to Shih et al.[2], IUU fishing reduces marine species richness, so the European Union has called for strong regulations to combat illicit fishing methods in the area. Additionally, Taiwan has also taken notice of this issue, however, illicit fishing, fish laundering, and fishing overcapacity persist despite efforts to address them[6]. Evidently, Taiwanese IUU fishing clearly affects the island's economy and society, hence, due to these challenges, Taiwan recognizes the necessity to address IUU fishing's environmental impacts. Nevertheless, the country has a plan to reduce illicit, unregulated, and uncontrolled fishing[4]. Naturally, preventing labour violations and IUU fishing operations like shark finning requires enforcement by the Taiwanese government[5]. Thus, IUU fishing in Taiwan has serious environmental impacts, needing a holistic approach that considers ecological and socio-economic factors, therefore, Taiwan's marine resources must be balanced between conservation and enforcement to survive.

Positively, Taiwan has made great steps in environmental protection, especially in combating the pressing problem of IUU fishing and the damage it does to the ecosystem. Notably, overcapacity, illegal, and unregulated fishing have been problems for Taiwan for a long time, and they all threaten marine biodiversity and the marine ecosystem as a whole[6]. The future of fisheries and aquatic life is threatened by this illegal practice, which in turn threatens marine ecosystems[7]. Additionally, economic, social, and environmental factors all contribute to the nature of IUU fishing's effect on Taiwan[8]. Therefore, tackling these difficulties calls for a holistic strategy, and Taiwan has started to fight illegal, unreported, and unregulated fishing. In this respect, enforcement actions are vital, as they promote sustainable fisheries management and help to reduce illicit fishing. Hence, a commitment to responsible governance in the fishing sector is shown by the fact that the Taiwanese government has acknowledged the need to tackle labour breaches and IUU fishing practices, such as shark finning[9]. In addition to protecting the rights and safety of those engaged in the fishing industry, the enforcement techniques seek to discourage unlawful activity.

Besides, to promote a circular economy and keep illicit fishing gear out of landfills, the Taiwan Fisheries Agency has

implemented gear tagging and trial run gear buy-back programs, which are examples of creative methods to retrieval systems [9]. More than a third (34%) of the world's fish stocks are overfished [10,11], meaning taken at a rate where they cannot replenish themselves. There are no reliable figures on global IUU – but experts estimate that more than one in five (22%) landed fish is caught illegally, with this figure rising to one in four off Africa [12]. Every year, an estimated $26–50 billion worth of revenue is lost to IUU [13]. Taiwan has shown its dedication to environmental protection and responsible resource management by taking the initiative to enforce legislation and establish sustainable practices in response to the changing threats posed by IUU fishing. Thus, these efforts demonstrate Taiwan's commitment to reducing the negative effects of illicit fishing on the environment and promoting a greener way of using marine resources.

This article utilizes a thorough "following the plastic" methodology similar to the circular economy route to evaluate the efficacy of programs aimed at reducing IUU fishing in Taiwan. Still, Taiwan has shown a willingness to listen to civil society concerns about marine debris, according to interviews with stakeholders from different parts of the IUU fishing control system. For the same reason, the government has taken strong measures to reduce and eliminate the problem of ALDFG, or abandoned, lost, or discarded fishing gear, from the ocean. Indeed, the circular economy for illegal, unregulated, and unreported fishing in Taiwan still encounters obstacles, nonetheless.

In 2018, the Ocean Affairs Council (OAC)and its subordinate agencies, the Ocean Conservation Administration (OCA), were established in Kaohsiung, Taiwan. OCA will examine changes in Taiwan's marine environment and biodiversity, utilise technology and public participation, and establish a connection between marine conservation and the people of Taiwan. OCA has set the goals of Clean Water, Healthy Habitat, and Sustainable Resources—and will plan and implement solutions in a phased manner [14]. In 2025, the OCA began promoting marine conservation and sustainable development through Environmental, Social, and Governance (ESG) projects. Moreover, the cooperation model has been established and has entered the Ocean Conservation ESG Matching Platform.

However, a fully circular economy cannot be realized with the current buy-back scheme since it does not have the necessary market connections with recycling enterprises. Of course, the circular economy system has difficulties, especially during the resource-intensive sorting and cleaning stages, due to the financial disincentives for recycling businesses to participate in ALDFG. Therefore, due to regulatory loopholes, companies may falsely claim recycled content levels, which impacts transparency. As a whole, these obstacles reduce demand for recycled raw materials, such as the increased expense for companies using recycled resources and marketing loopholes. Companies involved in recycling, which are crucial to the circular economy, are therefore discouraged from taking an active role in its growth. Improving enforcement actions and tackling the environmental implications of IUU fishing in Taiwan requires a thorough understanding. Illicit, unreported, and unregulated (IUU) fishing in Taiwan threatens the ocean ecosystem, biodiversity, economy, and society. This article discusses IUU fishing's multiple environmental impacts and the need for a comprehensive strategy that balances conservation and sustainable enforcement to protect Taiwan's marine resources.

2. Literature Review

Since illicit, unreported, and unregulated (IUU) fishing threatens oceans and biodiversity, understanding its environmental effects and Taiwan's policy responses is crucial [15]. Overfishing (**Figure 1**), IUU fishing, and overcapacity drive fishing gear abandonment, loss, and waste in Taiwan, as well as globally [16]. Taiwanese illegal fishers discard gear at sea to evade recycling fees and space constraints [17]. For the same reason, lack of awareness of abandoned gear's environmental impact worsens the issue [18–22]. Notably, extreme weather, gear entanglement with underwater structures, and towed-static gear clashes in busy fisheries cause accidental loss [23]. Therefore, IUU fishing's impact on Taiwan's maritime environment requires a comprehensive response. Taiwan's IUU fishing action plan should include economic, social, and environmental impacts like international initiatives [24,25]. However, Taiwan's authorities struggle to combat IUU practices such as shark finning and labour infractions [22]. Thus, global recognition of IUU fishing emphasizes the need for sustainable solutions and enforcement.

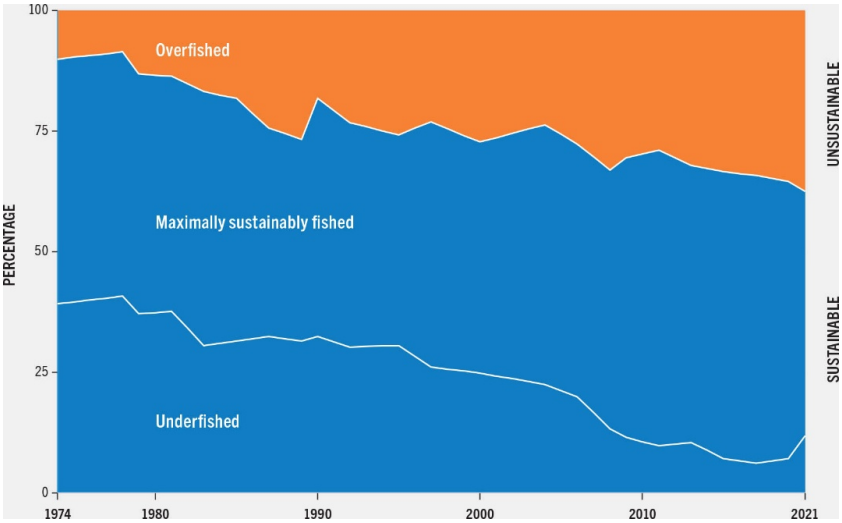

Figure 1. Global trends in the state of the world's marine fishery stocks, 1974–2021.

Source: FAO, 2024 [26].

IUU fishing is a global issue, including in Taiwan, because IUU fishing is illegal; criminals can hide in international waters, making regulation harder [27]. According to Chang and Lee [28], in countries with long coastlines, the Coast Guard's monitoring of territorial waters makes it impossible to enforce restrictions along the whole coastline. Additionally, IUU fishing often results in gear loss, which is difficult to remedy; therefore, large NGOs' remedial methods only partially alleviate Abandoned, Lost, or Discarded Fishing Gear (ALDFG) [29] (**Figure 2**). Still, some preventive measures work, but none are perfect, since policies that appear to target law-abiding fishermen rather than IUU fishermen have been criticised [29]. Thus, gear marking, a cost-effective, readily enforceable strategy, may only affect responsible fishermen who already report lost gear, limiting its usefulness in curbing irresponsible behaviour.

Figure 2. Close up of the ALDFG pile.

Source: GOV.UK, 2022 [30].

Taiwan, the third-largest tuna producer in the world with an annual value of 60 billion NT (USD 1.95 billion), is an ideal example of the environmental effects of illegal, unreported, and unregulated (IUU) fishing [31,32]. In brief, the government has historically responded to civil society advocacy, particularly in environmental preservation. However, Taiwan's approach to IUU fishing parallels its successful environmental legislation, supporting circular economy development in the face of marine waste. Therefore, the recent appeal for a circular economy is the latest public plea to the government, but Taiwan's past legislative success bodes well for IUU fishing enforcement [33]. Despite, the rise in marine protection knowledge, citizens and NGOs support this proactive strategy [34]. Taiwan has made significant progress toward a circular economy, as noted by several writers [35,36]. Emphatically, this progress goes beyond environmental concerns to include activities to incorporate abandoned, lost, or discarded fishing gear (ALDFG) into the circular economy. Thus, Taiwan has implemented new policies and regulations to prevent IUU fishing in response to public demand for a circular economy, particularly for marine debris and ALDFG [37]. In brief, Taiwan's comprehensive strategy of legislative responsiveness, grassroots action, and circular economy initiatives shows promise for tackling IUU fishing's environmental repercussions and strengthening enforcement.

Surprisingly, Taiwan's environmental social movements began to confront IUU and enforcement actions after World War II, when the Taiwan government promoted rapid industrialization and economic expansion, yet fisheries and other agricultural sectors grew throughout the 1950s [32]. Naturally, the government at the time suffered because it ignored popular social and environmental issues, causing unrest. Therefore, after growing urbanization, legislation, regulations, and safety standards were inadequate, sparking the 1970s "Pollution Protests" [27]. Notably, whereas socially and environmentally conscious, the 1980s were. The public requests for strong environmental and safety legislation. Therefore, the response spurred public protests, mainly over environmental deterioration, and the government lifted martial law in 1987, allowing free speech and protests, which led to the emergence of active NGOs. However, the legislative landscape changed from the late 1970s to the early 2000s due to shifting objectives. Still, changing views regarding environmental care were highlighted by the Environmental Protection Act [1979], Environmental Impact Assessment Act [1994], and Environmental Basic Protection Law [2002]. Thus, in 1995, powerful social movements against nuclear power and mounting concerns about plastic pollution drove decisive action [16]. In the early 2000s, efforts to ban some plastics and integrate plastic recycling into daily life grew, reflecting changing values and concerns about plastics.

Taiwan's circular economy for marine debris is part of a global effort to improve marine protection while balancing environmental and economic sustainability; hence, regional or country-specific initiatives have been adopted ad hoc, unlike previous global marine preservation guidelines, which were hampered by country priorities. Notably, UNEP and UNFAO guidelines on Abandoned, Lost, or Otherwise Discarded Fishing Gear (ALDFG) address causes, prevention, mitigation, and clean-up [5,38]. Therefore, the Global Ghost Gear Initiative, Greenpeace, and the Ellen MacArthur Foundation have published ALDFG management guidelines and materials [3]. As well, despite international efforts, marine environment protection and circular economies for marine waste face shared challenges. For the same reason, Taiwan faces similar illegal fishing and enforcement issues; thus, international marine debris management has followed marine conservation debates. Evidently, from the 1950s, circular economies gained attention in policy papers in the 1990s [6]. Again, international accords like the UN Convention on the Law of the Sea (UNCLOS) have emerged to manage marine debris, even though UNCLOS does not mention "marine litter" [9], and over the past decade, worldwide marine pollution and conservation accords have grown. As noted, MARPOL 73/78 and the London Protocol have been revised, while the UN High Seas Treaty, which seeks 30% ocean protection by 2030, is the latest worldwide initiative [22]. Thus, these agreements highlight changing ocean conservation values and the critical need to tackle marine pollution, notably plastics. While not directly tied to the circular economy for marine trash, these activities lay the groundwork for discussing circular systems to mitigate illegal fishing's environmental repercussions in Taiwan.

Taiwan struggles with the environmental impacts of IUU fishing; for the same reason, the EU considers IUU fishing a threat to marine biodiversity and the environment, requiring strong restrictions [39–41]. According to research by Liu and Chen [24] in its international fisheries manage-

ment approach, Taiwan struggles to curb IUU fishing despite worldwide concern, because IUU fishing affects Taiwan economically, socially, and environmentally, requiring a comprehensive action plan[1,42]. According to Wu[16], Taiwan's fishing vessels engage in unlawful fishing, which harms sharks and dolphins; hence, the country needs a dedicated administrative approach to enforcement and labour issues like shark finning[21,43,44]. According to Wang and Tsai[16], the worldwide community has stressed sustainability in response to IUU fishing, whereby global soft laws have been passed to tackle IUU fishing, identifying it as a major issue. Ideally, Wong and Yong[45] state that labour breaches and IUU fishing practices remain issues; thus, Taiwan's IUU fishing problem echoes global marine debris activities. Taiwan has limited marine debris circular economy approaches compared to other countries, yet technical and economic hurdles prevent marketable retrieval, sorting, and recycling of abandoned, lost, or discarded fishing gear (ALDFG). Therefore, the lack of circular economy development methods and governance and institutional constraints hinder marine trash mitigation at its source. Even if international agreements on IUU fishing and drift waste are unclear, the global community continues to address these concerns.

3. Methodology

This paper examines Taiwan's advances in maritime safety and law enforcement to combat the impact of illegal fishing on the environment. Notably, the researcher used a methodological framework inspired by the Joanna Briggs Institute's[46] and Arksey and O'Malley's[47] approach to summarize and disseminate research findings according to PRISMA guidelines (**Figures 3** and **4**). The first step in the Joanna Briggs Institute[46] three-step review process was to carefully prepare a literature review protocol to define the review's inclusion and exclusion criteria (**Table 1**). Bibliographic databases, including journals, government documents, think-tank statistics, patents, and references cited in other sources, were included. This extensive investigation examined Taiwan's maritime governance policies on the environmental implications of illegal fishing. This study employs qualitative policy analysis to make public policy management more realistic and effective. Planning, execution, and reporting are covered in the three-step review process, ensuring a methodical investigation. This methodological accuracy enhances the dependability and validity of the findings, enabling us to better comprehend Taiwan's efforts to address the multiple impacts of illegal fishing on its marine ecology.

This paper examines Taiwan's advances in maritime safety and law enforcement to address the environmental impacts of illegal fishing. A methodological framework based on the Joanna Briggs Institute approach (adapted for policy analysis) was integrated with a PRISMA-guided process, applying explicit inclusion/exclusion criteria: Inclusion—peer-reviewed articles and government or NGO reports on Taiwan's IUU fishing, ALDFG, or CE measures; Exclusion—non-Taiwan or irrelevant plastic waste studies, or those lacking methodological rigor.

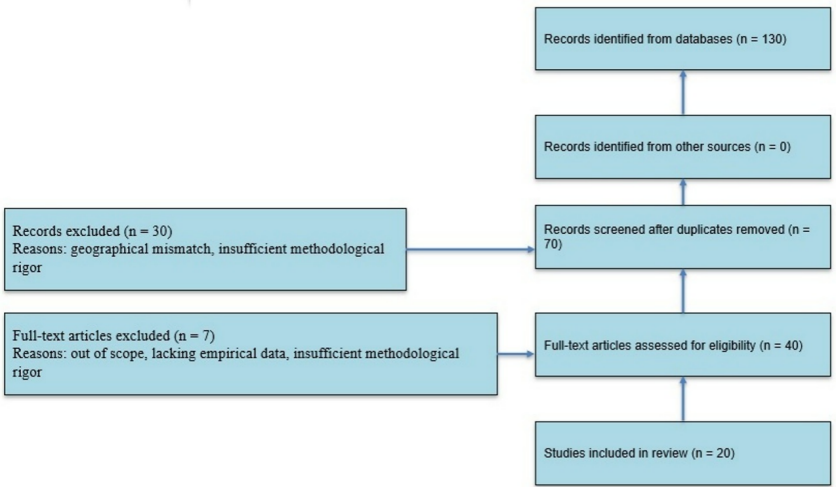

Figure 3. PRISMA flow diagram.

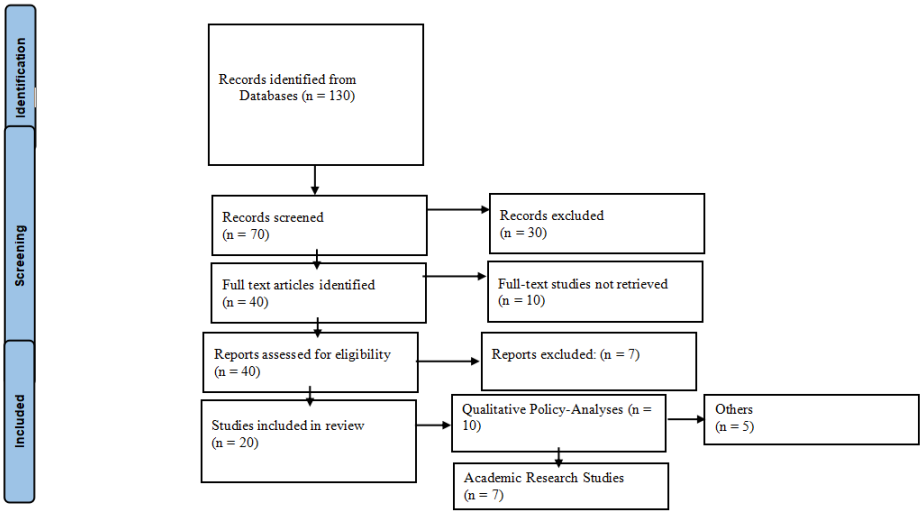

Figure 4. Results of included article.

Table 1. Inclusion and exclusion criteria for literature selection.

Criterion	Inclusion	Exclusion	Justification
Geographic Scope	Studies focusing on Taiwan or including Taiwan in regional comparisons (e.g., Asia-Pacific fisheries governance).	Studies exclusively on non-Taiwan contexts without transferable policy relevance.	Ensures relevance to Taiwanese IUU fishing and ALDFG governance.
Topic Relevance	Research addressing IUU fishing, ALDFG, circular economy in fisheries, marine policy enforcement, or related governance mechanisms.	Studies on general marine biology, unrelated aquaculture practices, or non-fisheries marine pollution.	Focuses on policy and governance interventions linked to the research aim.
Policy/Governance Content	Papers analyzing policy measures, enforcement tools, or governance frameworks (e.g., VMS, port state measures, CE initiatives).	Technical gear design studies without governance or policy linkages.	Maintains emphasis on policy analysis rather than purely technical solutions.
Publication Type	Peer-reviewed journal articles, government white papers, RFMO reports, and NGO policy briefs with documented methodology.	Editorials, news articles, and opinion pieces without empirical or methodological basis.	Ensures inclusion of credible, verifiable, and methodologically sound sources.
Timeframe	Publications from 2000 onwards.	Pre-2000 publications, unless historically significant to Taiwan's fisheries governance.	Captures contemporary governance approaches while allowing historical policy context if relevant.
Language	English and Mandarin Chinese (translated or bilingual).	Other languages without accessible translation.	Ensures accurate comprehension and reduces bias from language exclusion.
Data/Method Transparency	Studies with clear data sources, methodology, and analytical framework.	Studies lacking methodological clarity or with unverifiable claims.	Supports replicability and credibility of findings.

Following Arksey and O'Malley's[47] model, a literature review protocol was developed to guide source selection from bibliographic databases, government documents, think-tank statistics, patents, and cited references. The study employs qualitative policy analysis, using a three-step review process—planning, execution, and reporting—to ensure methodological rigor. This approach enhances the reliability and validity of findings, providing a clearer understanding of Taiwan's strategies to mitigate the ecological impacts of illegal fishing.

A rigorous three-step search method was employed to identify relevant research terms and phrases for a comprehensive literature review on the Environmental Impacts of Illegal Fishing and Enforcement Responses in Taiwan. We

searched all relevant literature for the research question. To include extensive investigations, subject headings and keywords connected to idea phrases were carefully picked and studied using the Boolean operator "OR." With no publication date limits during database searches, reliability and literature quality determined article selection. However, recent articles were preferred. When relevant publications were not found in initial database searches, cross-referencing and hand-searching included studies' reference lists to find more valuable resources. In an independent evaluation, the researcher identified publications for inclusion. Disagreements about inclusion criteria were resolved through debate and consultations. The evaluation focused on maritime governance regulations from a marine safety and law enforcement viewpoint in Taiwan. This methodology examined the environmental implications of illegal fishing in Taiwan and the enforcement responses used to address them. With a systematic search technique and strict inclusion criteria, the literature review aimed to elucidate the complex dynamics of this crucial issue.

Moreover, this study adopts a policy-adapted "follow-the-plastic" methodology, defined as a waste-tracing approach that systematically tracks fishing gear from its point of production, through its operational life, to its end-of-life stage. This process maps the full gear lifecycle—manufacture, distribution, use, maintenance, disposal, and potential recycling—identifying critical leakage points where gear is lost, abandoned, or discarded, particularly in scenarios associated with IUU fishing activities. The approach integrates circular economy (CE) principles with fisheries enforcement frameworks, allowing for the identification of governance gaps and the development of targeted policy interventions. Step-by-step, the methodology: included 1) Maps supply chains from gear manufacturers to fishing operators, including imports; 2) Monitors operational deployment of gear using tagging, vessel monitoring systems (VMS), and port inspection data; 3) Detects leakage points where gear loss or abandonment occurs, cross-referenced with IUU risk indicators; 4) Assesses post-use pathways, including retrieval programs, buy-back schemes, and recycling integration; 5) Evaluates policy linkages, aligning leakage point data with existing marine policy instruments such as the FAO Voluntary Guidelines on the Marking of Fishing Gear and national CE initiatives.

Comparable approaches have been applied in marine debris policy research [17,20,38] and in CE-oriented fisheries governance studies [24,36]. This adaptation for IUU-linked ALDFG contexts ensures that the methodology not only quantifies material flows but also links them to enforcement outcomes, enabling a dual focus on environmental impact mitigation and regulatory compliance.

4. Findings

The research technique and selection criteria discovered and reviewed 130 policy papers, white papers, government documents, and scholarly literature on Taiwanese ocean governance. The different perspectives in this comprehensive collection came from recognized magazines like Marine Policy, Educational Handbook, Journal of Marine Science and Technology, Marine Science and Engineering, and Energy and Environment. After carefully removing duplicates, 70 unique articles remained for review. From this narrowed pool, 30 papers did not match the inclusion requirements, leaving 40 for further evaluation. Seven studies were considered ineligible and excluded from the final review compilation—10 of 30 papers offered just abstracts after curation. A total of 20 full-text papers were chosen for the comprehensive review. **Figure 3** shows the thorough literature review process and its results in the context of illegal fishing's environmental impacts and Taiwan's enforcement responses, following PRISMA guidelines.

The analysis revealed that economic disincentives and lack of awareness contribute significantly to the improper disposal of fishing gear in Taiwan. Fishermen often discard gear at sea to avoid recycling fees or due to limited onboard storage capacity [17]. These actions are exacerbated by a low perception of environmental consequences [18,19], indicating that both behavioral and structural incentives are necessary to change disposal practices—meanwhile, Gear Loss Due to Operational Hazards. In busy fisheries, accidental gear loss due to entanglement with submerged structures or gear conflicts is a common occurrence. Fujii et al. [23] noted that clashes between towed and static gear types increase unintentional loss, contributing to ALDFG and its associated hazards. Furthermore, while Taiwan has implemented pilot gear tagging and buy-back programs, there is a notable lack of integration with downstream recycling industries.

Regulatory loopholes allow companies to make unverifiable claims about recycled content, reducing market trust and uptake [9,24]. This undermines the establishment of a viable ALDFG circular supply chain. This is also a gap in the implementation of the circular economy in Taiwan. Moreover, Taiwan's distant-water fleets often operate in international waters where enforcement is weak, which allows illegal activities to persist. As Wilcox et al. [27] explain, IUU fishers exploit jurisdictional gaps, reinforcing the need for international enforcement cooperation and improved maritime monitoring capacity.

The study found that IUU fishing has a disproportionate impact on small-scale coastal communities, reducing their income and increasing social inequalities [7,33]. Fish stock depletion due to overfishing and illegal activities reduces availability for legal, local operators, putting traditional livelihoods at risk. Another issue is the absence of standardized indicators and verification tools for ALDFG recycling performance, which complicates policy evaluation. This reduces transparency and accountability, allowing greenwashing by commercial actors [36,37]. Strengthening traceability in marine plastic supply chains is thus a priority.

In addition, global regulations and soft law have influenced the EU's yellow cards and global soft law tools, which have driven the progress of regulatory reform and awareness in Taiwan, and have become external enforcement mechanisms. These have contributed to domestic legislative responses and grassroots environmental movements [4,34,41]—further, Technological and Administrative Capacity Building. Taiwan's allocation of USD 77.5 million for enhancing coastal patrols and electronic monitoring systems represents a significant investment in marine enforcement [48]. This move parallels Indonesia's regional leadership, highlighting Taiwan's commitment to maritime security as a form of environmental stewardship. Besides, Civil society and environmental NGOs have historically played a pivotal role in pushing for reforms, particularly through pollution protests in the 1980s and subsequent campaigns against marine debris and IUU fishing. These bottom-up pressures have resulted in legislation such as the Environmental Protection Act and have supported the institutionalization of circular economy frameworks [32,49]. Finally, Comparisons with regional responses—such as the joint fisheries management in the South China Sea [5] and the Global Ghost Gear Initiative—highlight both the promise and limits of Taiwan's unilateral actions. Regional alignment remains weak, necessitating stronger cross-boundary collaboration.

5. Discussion

Vessels engaged in IUU fishing typically operate outside of regulatory frameworks. To avoid detection, such vessels may intentionally discard fishing gear, including nets, lines, and traps, especially when pursued by enforcement agencies. Because these vessels are unregistered or unmonitored, gear loss is not reported, making it difficult to trace or retrieve, thereby contributing to ALDFG [38]. Furthermore, IUU fishers often use low-cost, low-quality gear, which is more prone to loss and abandonment. Since compliance and accountability are absent, there is no incentive to retrieve lost gear, and economic loss is minimal to the operator.

Legal and well-regulated fisheries are typically required to mark their gear and report gear loss. IUU operators often bypass these regulations, resulting in untraceable gear that remains in the marine environment indefinitely. Abandoned or lost gear, especially gillnets and traps, can continue to fish passively—known as "ghost fishing"—and the catch may later be recovered by IUU actors, supporting their illegal activities. Both IUU fishing and ALDFG pose serious threats to marine biodiversity. ALDFG causes habitat destruction, bycatch, and marine mammal entanglement, worsening the impacts of IUU fishing on fish populations and ecosystems. In some regions, IUU fishers intentionally deploy gear semi-permanently without retrieval, relying on periodic collection, which mirrors ghost fishing practices.

Adopting circular economy principles—such as designing fishing gear for reuse and recyclability, integrating end-of-life collection systems, and incentivizing return and recycling—can transform ALDFG (Abandoned, Lost, and Discarded Fishing Gear) from a persistent pollutant into valuable material streams, thereby reducing marine pollution and generating socio-economic benefits (**Figure 5**).

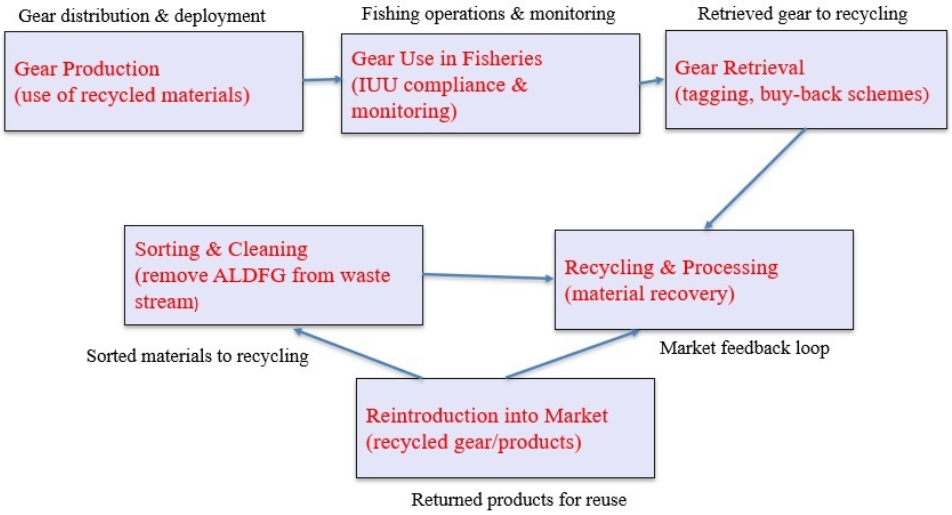

Figure 5. Conceptual circular economy framework for Taiwanese fisheries.

Note: This conceptual model illustrates the integration of circular economy strategies within Taiwan's fisheries governance. It maps the fishing gear lifecycle from production to market reintroduction, highlighting intervention points that reduce Abandoned, Lost, or Discarded Fishing Gear (ALDFG), mitigate plastic pollution, and conserve resources. The model emphasizes how CE strategies complement IUU enforcement measures.

5.1. Policy Effectiveness and Implementation Gaps

This subsection critically evaluates the actual effectiveness of Taiwan's IUU fishing policies, including gear tagging, buy-back programs, and circular economy (CE) measures. While these initiatives demonstrate innovative integration of waste reduction into fisheries governance, implementation gaps persist. For example, inter-agency coordination challenges often result in overlapping responsibilities and delayed policy execution. Economic disincentives discourage recycling enterprises from participating in ALDFG retrieval due to high sorting and cleaning costs. Moreover, distant-water fleets frequently operate in areas with weak enforcement, undermining compliance. The absence of standardized metrics for ALDFG recycling verification further reduces transparency and accountability, creating opportunities for greenwashing by commercial actors. Addressing these gaps requires coordinated enforcement, stronger market incentives for recycled fishing gear, and the integration of CE principles into national fisheries enforcement strategies.

Moreover, the ecological consequences of ALDFG—particularly ghost fishing and habitat damage—have led scientists to frame derelict gear as a persistent pollutant with multi-generational effects on marine biodiversity [50]. In this context, Taiwan's CE-oriented retrieval and recycling programs serve as both waste management and biodiversity protection mechanisms.

Cross-sector collaboration—especially among port authorities, fishery agencies, recyclers, and environmental NGOs—is essential to closing the loop in the gear lifecycle and disrupting IUU-related waste streams [51]. The study's proposed conceptual framework can aid in identifying governance gaps and leverage points for integrating CE principles into anti-IUU enforcement.

Illegal, Unreported, and Unregulated (IUU) fishing threatens Taiwan's maritime ecosystem in several ways. To begin with, IUU fishing disrupts Taiwan's maritime ecosystems and endangers its varied marine animals; hence, the probable reduction of marine biodiversity could have serious and long-term repercussions on Taiwan's maritime ecosystem [52]. Additionally, reports show that Taiwan struggles to stop IUU fishing despite efforts, whereby fish laundering and fishing overcapacity continue to plague the region, showing that IUU fishing practices may evade regulations. These issues demonstrate the difficulty and generality of illegal fishing, requiring a stronger and more comprehensive enforcement and control strategy [53]. Ideally, IUU fishing in Taiwan threatens living aquatic resources and responsible and ethical fisheries management; still, IUU fishing threatens the environment and the economy and society of Taiwan's fishing industry. At the International Marine Forum Conference held in Taiwan in July 2025, Cynthia Barzuna, Director of the Ocean Action 2030, World Resources Institute (WRI),

stated in her keynote speech that Taiwan's investments in coastal patrol capabilities, electronic monitoring, and monitoring of illegal, unreported, and unregulated (IUU) fishing are not only security measures but also economic drivers. Taiwan has committed to investing 77.5 million USD to combat IUU fishing, while Indonesia has allocated 73.3 million USD for monitoring efforts [48]. Therefore, the interconnection of these challenges highlights the need for strict rules and international cooperation to solve IUU fishing [49]. Notably, IUU fishing threatens Taiwan's marine ecosystem with ecological imbalances, biodiversity loss, and regulatory enforcement issues. Thus, these concerns demand national and international cooperation to execute effective policies, increase transparency, and promote responsible fisheries management.

Furthermore, Illegal, Unreported, and Unregulated (IUU) fishing has serious economic, social, and environmental effects on Taiwan; thus, these effects require a comprehensive action plan to address the issues raised by illegal fishing [36]. Taiwan's dependence on marine resources renders IUU fishing economically harmful; simultaneously, the nation's fishing economy is threatened by illicit marine species exploitation. To demonstrate, depletion of targeted species by IUU fishing disrupts marine ecosystems, thus, dwindling fish populations endanger the livelihoods of fishermen, worsening economic inequality in coastal areas [33]. Additionally, IUU fishing also harms Taiwan's marine ecosystems beyond the economy, because overfishing and species extinction may result from unmanaged marine species harvesting. In this case, disruptions to marine ecosystem interdependencies cause impacts that harm marine animals; hence, Taiwan's aquatic ecosystem is threatened by this environmental degradation. Importantly, environmental impact includes human rights murders; and the illicit exploitation of sharks and dolphins by IUU fishing is particularly disturbing. According to findings, Taiwanese fishing vessel operators destroy marine life and violate human rights. Therefore, shark and dolphin fishing are unlawful, adding an ethical component to IUU fishing's environmental effects [35]. Again, Taiwan recognizes the need to establish a comprehensive action plan to address these diverse repercussions. This approach must address IUU fishing's human rights abuses as well as ecological sustainability and economic feasibility. In turn, Taiwan wants to use marine resources more sustainably and ethically by realizing the interconnection of economic, social, and environmental factors. Thus, this comprehensive approach highlights IUU fishing's complex issues and the need for a multifaceted approach to protect Taiwan's marine environment and people.

Taiwan struggles to enforce fishing sector standards and manage labour abuses, especially in the face of IUU fishing techniques like shark finning. This issue combines environmental protection, labour rights, and sustainable fisheries management, whereby the nature of these issues highlights the need for a sophisticated and targeted approach to Taiwan's fishing industry. Notably, to counteract IUU fishing, a widespread issue with far-reaching environmental impacts, legislation must be enforced [28]. Surprisingly, illicit fishermen typically hide in international waters to avoid punishment due to enforcement loopholes; hence, Taiwan's leadership recognizes the need to focus on enforcement. This acknowledges the importance of IUU fishing's environmental dangers and supports global efforts to end unsustainable fishing. In this case, labour breaches, including shark finning, complicate Taiwan's fishing sector; thus, labour exploitation and environmental damage raise ethical and legal issues. Concurrently, the administration must protect marine habitats and fishermen's rights and well-being [22]. Now, this intersection of environmental conservation and labour rights highlights the necessity for comprehensive policies that balance environmental sustainability and worker rights, because managing these issues requires a holistic and collaborative approach. Enforcement tactics should discourage illicit activity and protect fishermen, since regulatory frameworks, monitoring mechanisms, and education are needed to combat labour breaches and IUU fishing. Therefore, Taiwan can create a more sustainable and ethical fishing business that meets global resource management standards. In brief, Taiwan's enforcement and labour issues show how environmental protection, human rights, and marine resource sustainability are linked.

The international community, particularly the EU, has stressed the need for strong policies to prevent IUU fishing in Taiwan. To illustrate, this global initiative recognizes the issue's seriousness and emphasizes the need for comprehensive marine ecosystem and biodiversity protection [4]. Notably, the EU's advocacy of strict laws in Taiwan shows how environmental preservation, international collaboration,

and the global impact of IUU fishing are linked. Thus, soft regulations have become essential tools for combating IUU fishing worldwide because these soft rules help recognize the transboundary nature of unlawful fishing and promote sustainable solutions and strong enforcement [6]. Surprisingly, these soft rules encourage governments to work together to address IUU fishing by recognizing it as a global issue, since they stress that the international community must protect marine resources and preserve the global ecology. Notably, the EU's stance on Taiwan's IUU fishing matches global soft law efforts; thus, these multinational initiatives realize that IUU fishing threatens nations and the world's oceans. Again, these global accords emphasise sustainable ways to combat IUU fishing, promote responsible fisheries management, and protect coastal populations who depend on healthy marine ecosystems. Therefore, the EU's strong measures in Taiwan and the global acceptance of soft laws demonstrate a concerted international approach to IUU fishing. Thus, this collaborative approach seeks to unify against IUU fishing and promote sustainable marine resource use worldwide.

Next, Taiwan has implemented creative circular economy efforts to counteract IUU fishing's environmental implications, whereby gear marking and trial run gear buy-back programs are part of a holistic approach to IUU fishing and its environmental impacts [17]. Notably, gear marking is crucial to Taiwan's circular economy concept in ocean governance, because this method identifies and labels fishing gear to track its use and deter illicit use. As well, gear labelling helps authorities identify and punish IUU fishermen by tracking their gear back to its source; hence, this proactive technique deters unlawful fishing and promotes a transparent and accountable fishing business [17]. Notably, Taiwan's pilot gear buy-back scheme complements the gear tagging project and shows a forward-thinking approach to fishing gear disposal and reuse. This initiative rewards careful disposal by paying for returned gear; therefore, the buy-back program encourages fishermen to properly dispose of their gear by providing a financial incentive, minimizing gear abandonment and marine trash. This effort supports circular economy ideas and encourages stakeholders to take responsibility for gear, promoting its use as a resource rather than trash [24]. Taiwan's commitment to holistic solutions for fishing gear's production, use, disposal, and recycling is highlighted, since Taiwan wants to tackle IUU fishing and create a circular economy that reduces the fishing industry's environmental impact by combining these activities. Naturally, this integrative approach acknowledges the linked difficulties of IUU fishing and stresses the need for sustainable practices in protecting marine ecosystems because Taiwan's circular economy measures for IUU fishing are a proactive reaction to global resource management calls. Thus, these actions demonstrate Taiwan's commitment to enforcing laws and promoting a sustainable marine resource future, where Taiwan's initiatives demonstrate how regulatory measures and economic incentives can promote a more responsible and sustainable fishing industry as circular economy principles gain popularity in marine conservation (**Figure 6**).

Figure 6. Development of the circular economy in Taiwan.

Source: Circular Taiwan Network, 2024 [54].

The international community recognizes illicit, unreported, and unregulated (IUU) fishing as a global issue; thus, a shared commitment to global marine conservation standards has prompted efforts to address this issue. The global recognition of IUU fishing highlights the interconnectedness of marine ecosystems and underscores the need for coordinated solutions. Therefore, this emphasises the need for global plans to tackle illegal fishing; hence, nations must collaborate to enforce legislation, promote sustainable practices, and protect marine biodiversity due to the difficulty of IUU fishing [29]. Next, despite global efforts to control IUU fishing, circular economies for marine debris remain difficult to build, because this comprises abandoned, lost, or discarded fishing gear (ALDFG), which affects the ecosystem due to IUU fishing. As well, circular economies present technical, economic, and governance challenges; hence, these obstacles obstruct marketable ALDFG recovery, sorting, and recycling. Without a doubt, technical obstacles include the complicated process of cleaning and classifying gear, while economic constraints include the greater cost of recycled materials for firms. Governance impediments, such as failing circular economy development procedures, further hinder marine debris removal at its source [36]. Collaboration and coordination are needed to navigate the worldwide landscape of IUU fishing and circular economies for marine trash. The issues encountered by nations are part of the global ecosystem; hence, international cooperation, knowledge-sharing, and generally applicable standards are needed to solve these obstacles. Ideally, addressing circular economy development difficulties is crucial for the sustainability of global marine resource usage as the international community grapples with IUU fishing and its environmental impacts. Thus, to overcome obstacles and create frameworks that encourage environmental conservation and ocean health, nations must work together.

Taiwan's environmental commitment has evolved through social movements and legislative changes, whereby the Taiwanese government began fast industrialization and economic expansion after World War II. Notably, fisheries and other agricultural businesses grew in the 1950s; however, the government ignored popular social and environmental issues, causing anger [49]. The 1980s marked a turning point. Socially and environmentally conscious, the government sought to meet public requests for strong environmental and safety legislation; hence, the response spurred public protests, especially over environmental deterioration. The government lifted martial law in 1987, allowing free speech and protests, which led to the emergence of active NGOs. Environmental laws like the Environmental Protection Act [1979], Environmental Impact Assessment Act [1994], and Environmental Basic Protection Law [2002] were passed during this time. In the 1970s, the "Pollution Protests" highlighted the inadequacy of policies, regulations, and safety standards in the face of growing urbanization. In 1995, large mass movements against nuclear power and plastic pollution emerged. In response to these concerns, the early 2000s saw initiatives to ban specific plastics and integrate plastic recycling into daily life. Taiwan's diverse strategy of legislative responsiveness, grassroots action, and circular economy initiatives shows promise for addressing IUU fishing's environmental impacts and strengthening enforcement. This history should demonstrate Taiwan's environmental and resource management commitment.

5.2. Enforcement Challenges and International Cooperation

Taiwan's unique geopolitical status creates a structural limitation on its ability to fully participate in international fisheries governance, affecting efforts to combat IUU fishing. Being excluded from major Regional Fisheries Management Organizations (RFMOs) like the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC) restricts access to real-time vessel monitoring data, joint patrol arrangements, and coordinated high seas interdiction protocols. This lack of formal membership also prevents Taiwan from becoming a party to binding agreements like the Port State Measures Agreement (PSMA) through standard intergovernmental channels, reducing its capacity to enforce port inspections in cooperation with other nations. The PSMA is the first global treaty aimed at stopping illegal, unreported, and unregulated (IUU) fishing by preventing vessels involved in such activities from entering ports or unloading their catches. To address these challenges, Taiwan has adopted alternative strategies, including unilateral implementation of RFMO conservation and enforcement measures, forming partnerships with like-minded countries and NGOs for targeted surveillance and

information exchange, and using the European Union's "yellow card" process as both an external compliance benchmark and a driver for domestic regulatory reform. Although these adaptive measures have led to some improvements in monitoring, control, and surveillance (MCS), they cannot fully compensate for the lack of institutionalized cooperation, which remains a core structural obstacle shaping Taiwan's international efforts to combat IUU fishing.

6. Conclusion

Taiwan's IUU fishing issues require a coordinated, comprehensive solution that tackles environmental, economic, and social dimensions. Innovative solutions that promote sustainable behaviors and responsible resource management while enforcing regulations are necessary to address these interconnected challenges. Taiwan's circular economy initiatives—gear marking and gear buy-back programs—illustrate a shift toward greener fisheries governance. However, these programs primarily address ALDFG, an environmental consequence of IUU fishing, rather than its root causes, such as profit motives, jurisdictional gaps, and lack of vessel transparency. This paper clarifies the distinction and interaction between IUU fishing and ALDFG in the Taiwanese context, proposing a policy model where the circular economy serves as a complementary strategy to traditional enforcement tools. For example, while Vessel Monitoring Systems (VMS), port state controls, and sanctions are essential for deterring illegal behavior, CE approaches contribute to reducing gear waste, promoting traceability, and fostering cross-sectoral accountability. A visual framework is developed (**Figure 7**) to illustrate the feedback loops between illegal fishing operations, gear loss, environmental damage, and circular economy-based interventions. Given Taiwan's limited participation in Regional Fisheries Management Organizations due to geopolitical constraints, reinforcing domestic interagency coordination and collaborating with NGOs and the private sector becomes even more critical. Enhancing market demand for recycled fishing gear, improving verification of recycled content, and closing regulatory loopholes are key to realizing the full potential of CE in marine governance. While full implementation of circular economy strategies and IUU deterrence remains a work in progress, Taiwan offers an emerging model for integrating waste governance and fisheries enforcement—highlighting a pathway toward environmentally sustainable and ethically managed marine resources.

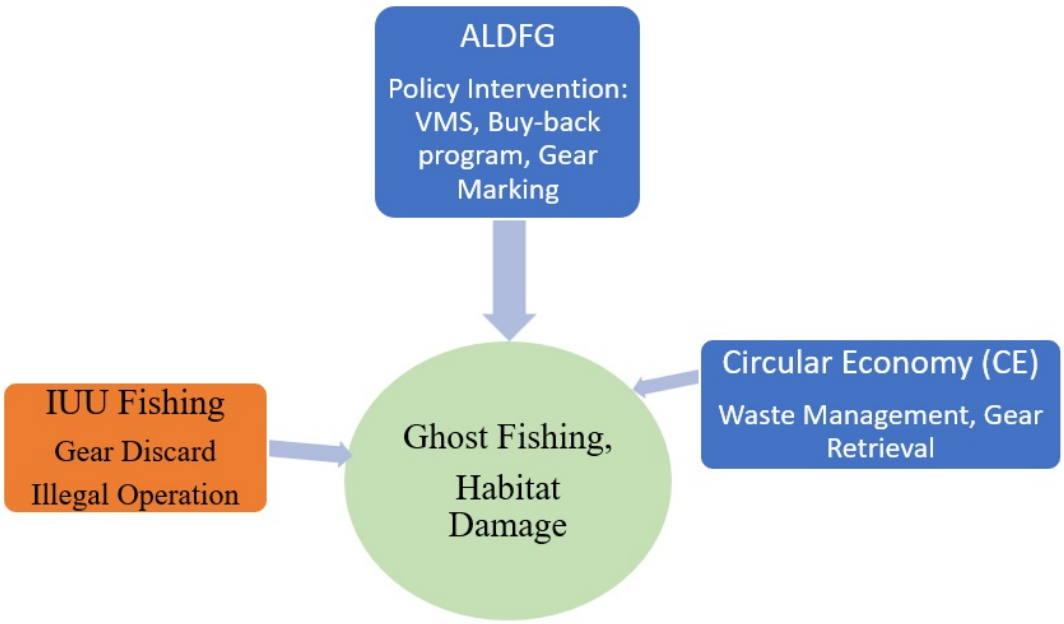

Figure 7. Conceptual linkages between IUU fishing, ALDFG, and circular economy (CE).

Note: This figure illustrates the interaction of IUU activities, resulting ALDFG, and the role of circular economy strategies in mitigating environmental impacts.

Funding

The Grants from the Taiwan National Science and Technology Council financed this study (NSTC 112-2410-H-006-099, NSTC 114-2410-H-006 -108 -).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

All data generated during this study are included in this published article.

Conflicts of Interest

The author declares no conflicts of interest.

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