

Article

Evolution and Challenges of Marine Oil Spill Governance in Taiwan over Two Decades

Chih-Wei Chang ¹, Shiau-Yun Lu ², Chun-Pei Liao ³, Wen-Yan Chiau ² and Yi-Che Shih ^{4,*} 

¹ European Semiconductor Manufacturing Company GmbH, 01067 Dresden, Germany

² Department of Marine Environment and Engineering, National Sun Yat-Sen University in Kaohsiung, Kaohsiung City 804201, Taiwan

³ Cross College Elite Tech Program, National Kaohsiung University of Science and Technology, Kaohsiung City 811, Taiwan

⁴ Institute of Ocean Technology and Marine Affairs, National Cheng Kung University, Tainan City 701, Taiwan

* Correspondence: shih@gs.ncku.edu.tw

Abstract

Marine oil spills pose critical challenges to environmental sustainability and socioeconomic stability. Taking four pivotal cases as the entry point, this study uses comparative case analysis, semi-structured stakeholder interviews, policy analysis and international gap comparison to systematically analyze the evolution of marine oil spill governance in the Taiwan region of China over two decades, aiming to identify systemic gaps and propose actionable reforms. By integrating and explicitly detailing these multiple methodologies, this research not only identifies but also systematically examines the Taiwan region of China's unique challenges as a non-UN-member entity navigating international conventions like the international convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78). Key findings reveal persistent issues in decision-support tools, fragmented inter-agency coordination, and legal inadequacies in compensation mechanisms. The study's novelty lies in its rigorous synthesis of localized case-driven insights compared with global best practices, proposing a concrete, phased model for a unified task force and context-aware, data-driven contingency plans to enhance real-time response efficiency. It further advocates for pragmatic steps to align the Taiwan region of China's Marine Pollution Control Act with international standards while critically addressing the transboundary collaboration barriers imposed by its political status, exploring potential pathways through sub-national and regional partnerships. Notably, the 2023 Angel Container case underscores the urgency of modernizing enforcement capacities and integrating advanced technologies. By bridging gaps in governance, legal accountability, and practical international engagement, this research not only advances the Taiwan region of China's preparedness but also offers a nuanced and adaptable blueprint for coastal regions facing similar geopolitical and environmental constraints. Its recommendations hold significant implications for global marine pollution management, emphasizing the interplay of policy innovation, technological adoption, and pragmatic cross-jurisdictional cooperation.

Keywords: marine pollution; oil spill response; governance; marine pollution act; ocean conservation administration; Taiwan region of China



Academic Editor: Yordan Garbatov

Received: 27 February 2026

Revised: 26 April 2026

Accepted: 6 May 2026

Published: 12 May 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and

conditions of the [Creative Commons](https://creativecommons.org/licenses/by/4.0/)

[Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Marine oil spills, as one of the most severe environmental disasters globally, pose a persistent and significant threat to the integrity of marine ecosystems, human public health and safety, and the economic development of coastal regions [1–3]. With the widespread use of supertankers and the continuous expansion of maritime oil transportation, the risk of marine oil spills has further intensified [4]. According to statistics, approximately 2 million tons of oil enter the marine environment annually through various pathways, causing irreversible damage to marine ecology [5,6]. Typical incidents such as the 2010 Deepwater Horizon oil spill and the 2018 Sanchi tanker accident not only resulted in huge economic losses but also caused devastating impacts on biodiversity and coastal ecosystems in the affected waters [7,8]. These painful lessons underscore the urgency and necessity of developing scientifically sound strategies for oil spill prevention, emergency response, and ecological restoration.

To address the challenges posed by marine oil spills, over the past few decades, oil spill response technologies and governance frameworks worldwide have been gradually improved and have achieved significant progress [9–12]. At the international level, the introduction of a series of international conventions and regulations, such as the international convention for the prevention of pollution from ships, 1973, as modified by the protocol of 1978 relating thereto (MARPOL 73/78, [13]) and the Oil Pollution Act (OPA) of 1990 [14], has established unified environmental standards and emergency response protocols for global marine oil spill governance, serving as important benchmarks for countries in their oil spill management efforts [15]. At the technical support level, the development and application of decision support tools (DSTs) have effectively enhanced real-time decision-making capabilities during emergency response to oil spills, provided scientific support for mitigation work such as oil containment and pollutant removal, and significantly improved emergency response efficiency [16,17].

Despite the many advances in global oil spill governance, current efforts to address marine oil spills still face numerous challenges that urgently need to be resolved. In emergency response, poor coordination among stakeholders often leads to delays in response mechanisms, while insufficient emergency preparedness further amplifies the environmental and socioeconomic damage caused by oil spills [18]. At the global governance level, deficiencies in international cooperation mechanisms and numerous gaps in legal frameworks seriously hinder effective responses to cross-border oil spill incidents, making it difficult to form a joint governance effort [19]. These common challenges take on even more complex forms in the specific contexts of certain regions.

The Taiwan region of China is located on major global shipping routes, and its economic development is highly dependent on maritime trade [20,21]. These geographical and economic characteristics make it a high-risk area for marine oil spills (Figure 1) [22]. Data show that the maritime transport industry accounts for 46.32% of the GDP of the Taiwan region, highlighting the core supporting role of maritime trade in the region's economy [23]. However, due to geopolitical factors, as a non-member of the United Nations, the Taiwan region cannot formally participate in international conventions related to marine governance such as MARPOL [24]. This special status not only limits its ability to align with international oil spill governance standards but also poses unique and severe challenges to its compliance and cooperation in global marine oil spill governance [25].

Based on the above background, this study focuses on the issue of marine oil spill response governance in the Taiwan region of China, systematically investigating three core research questions: First, to trace the evolution of marine oil spill response mechanisms in the Taiwan region of China from 1977 to 2023, identifying the systemic governance gaps that still exist. Second, to conduct a comparative analysis of the current oil spill response

practices in the region against international standards such as MARPOL, Oil Pollution Act of 1990 (OPA 90), and NOAA OR&R, from four key dimensions: prevention, response, compensation, and enforcement. Third, taking into account the geopolitical constraints faced by the region, to explore practical and regionally appropriate governance reform measures, thereby providing support for enhancing the effectiveness of marine oil spill response governance in the Taiwan region of China.

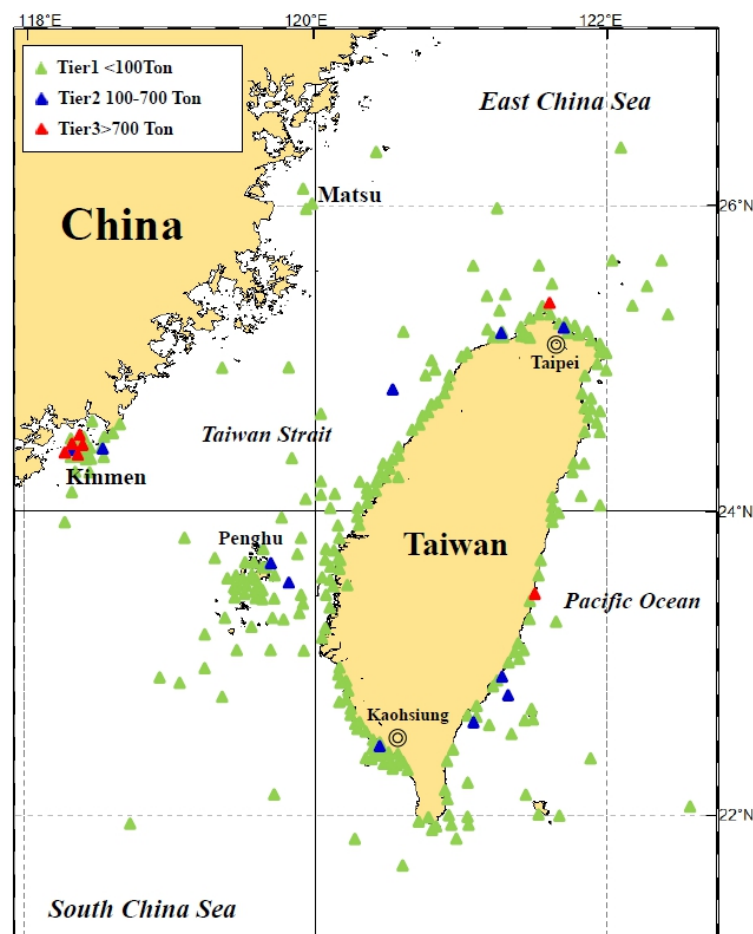


Figure 1. Oil spill accident in the Taiwan region of China. Note: Tier 1 refers to minor oil pollution, with oil spills of less than 100 metric tons; Tier 2 refers to medium oil pollution, with oil spills ranging from 100 to 700 metric tons; Tier 3 refers to major oil pollution, with oil spills exceeding 700 metric tons over the years 2001–2021.

This paper is structured as follows: Section 2 introduces the mixed-methods research design, including data collection and analysis procedures. Section 3 analyzes four pivotal oil spill cases (Borag, Amorgos, T.S. LINES, Angel Container) and synthesizes systemic governance challenges. Section 4 discusses key dilemmas in coordination, legislation, resources, international cooperation and data-driven decision-making.

2. Methods

This study employs a mixed-methods, multidisciplinary approach including comparative case analysis, semi-structured stakeholder interviews, policy review, and international gap analysis to comprehensively analyze the Taiwan's marine oil spill response mechanisms and their effectiveness. The methodology is designed to triangulate data from multiple sources, combining qualitative and quantitative analyses to provide a robust understanding of historical incidents, policy frameworks, and operational challenges.

2.1. Data Collection

2.1.1. Case Study Selection and Data Sources

Four key oil spill incidents in Taiwan—Borag in 1977, Amorgos in 2001, T.S. LINES in 2018, and Angel Container in 2023—were selected as representative cases based on predefined criteria: scale of impact (ecological and economic), triggering of policy changes, and diversity in incident type (tanker grounding, cargo ship accident). For each case, data were systematically gathered from: (a) primary sources: official investigation reports from the Ocean Conservation Administration, Coast Guard Administration, and Environmental Protection Administration; court rulings and compensation documents; (b) secondary sources: peer-reviewed academic articles, books, and dissertations specifically addressing these cases; (c) archival media reports from major Taiwanese news outlets to capture the timeline and public perception.

2.1.2. Stakeholder Interviews

Semi-structured interviews were conducted with 15 key stakeholders (5 from government agencies, 4 from shipping/insurance industries, 6 academic experts) between June and December 2023. An interview protocol was developed focusing on: perceived effectiveness of past responses, inter-agency coordination challenges, views on legal frameworks (especially Marine Pollution Control Act (MPCA)), and barriers to adopting international practices. Interviews were recorded (with consent), transcribed, and anonymized.

2.1.3. Policy and Literature Review

A systematic review of the Taiwan region of China's legislation (e.g., MPCA and its amendments, Major Marine Oil Pollution Emergency Response Plan (MMOPERP)) was conducted. Databases searched included Web of Science, Scopus, and Google Scholar (2000–2024). Keywords were: “oil spill governance,” “marine pollution Taiwan,” “MARPOL compliance.” Inclusion criteria were: peer-reviewed articles, official reports, and legal documents. Additionally, a comprehensive review of the international frameworks (MARPOL 73/78, OPA 90, International Maritime Organization (IMO), guidelines) and the scholarly literature on global best practices in oil spill governance was performed to establish a comparative benchmark.

2.2. Data Analysis

2.2.1. Comparative Case Analysis

A structured comparative analysis framework was applied to the four cases. We developed a matrix comparing each case across dimensions. The dimensions of the evaluation matrix were determined based on the core focus of this study: assessing the effectiveness of oil spill governance and identifying systemic gaps in the governance process; to comprehensively cover the entire emergency response cycle and the multi-faceted performance of governance, six key dimensions were carefully selected, including response initiation time, clarity of command structure, efficiency of inter-agency coordination, application of legal and compensation mechanisms, use of technology and DSTs, and long-term ecological impact assessment; to ensure the representativeness and comprehensiveness of the study [26,27]. Four typical oil spill incidents were selected as research cases based on three key criteria—incident scale, policy impact, and diversity of incident types—namely, the Borag incident, the Amorgos incident, the T.S. LINES incident, and the Angel Container incident. To ensure the accuracy and reliability of the matrix data, multi-source data were collected for each cell in the matrix, including official investigation reports released by relevant authorities, court judgment documents related to the incidents, peer-reviewed academic studies, historical media archives, and transcripts of interviews with key stake-

holders (including government departments, environmental organizations, and relevant enterprises); the matrix served as a core tool for cross-case comparison, enabling both quantitative and qualitative side-by-side analysis of the four selected oil spill incidents across the six predefined dimensions, which made the differences and similarities in governance performance between different cases directly visible and laid a foundation for subsequent in-depth analysis. By systematically sorting out and analyzing the data filled in the matrix, this study identified persistent challenges in oil spill governance such as fragmented inter-agency coordination and weak legal enforcement, and tracked the evolutionary trend of oil spill governance over nearly two decades, which showed a clear progression from the absence of a systematic governance framework to the establishment of relevant laws and regulations, then to the emergence of compensation mechanism issues, and finally to the practice and testing of law enforcement. Additionally, the findings derived from the matrix analysis formed a solid evidence base for the study's gap analysis, as the study compared the current oil spill governance performance with international standards (including MARPOL 73/78 and OPA 90) to identify existing gaps, and on this basis, proposed targeted governance reform recommendations, including the establishment of a unified task force for oil spill emergency response, the upgrading of DSTs, and the improvement of legal and compensation mechanisms.

2.2.2. Qualitative Content and Thematic Analysis

Interview transcripts were analyzed using NVivo 14 following Zhang's six-phase thematic analysis framework [28]. An initial codebook was developed from the research questions and then iteratively refined. Inter-coder reliability was assessed using Cohen's $\kappa = 0.84$ (substantial agreement). Major themes were identified: "fragmentation vs. centralization," "legal enforcement gaps," "resource dependency," and "international participation dilemma."

2.2.3. Gap Analysis Against International Standards

Gap analysis compared the Taiwan region of China's practices against four benchmarks: (1) MARPOL 73/78 Annex I (prevention); (2) OPA 90 (response and compensation); (3) IMO international convention on oil pollution preparedness, response and co-operation convention (preparedness); and (4) NOAA OR&R (ecological assessment). Each benchmark was evaluated on a 5-point scale (1 = non-existent to 5 = fully aligned) across four domains: prevention, response, compensation, enforcement.

2.3. Validation and Limitations

To ensure validity, data triangulation was rigorously employed, cross-verifying findings from case documents, interview responses, and policy analysis. Potential biases in retrospective case data and interviewee perspectives are acknowledged as a limitation. The study's focus on major cases may not capture challenges in smaller, frequent spills.

3. Results

3.1. Historical Trend of Oil Spill Cases

From 2001 to 2021, oil spill cases in the Taiwan region fluctuated between 20 and 96 per year, with Tier 1 (<100 tons) accounting for 95.1% (Table 1; Figures 1 and 2). The number of cases increased significantly after 2018, reflecting higher risk exposure. Since the 1977 Borag oil spill—Taiwan's first recorded marine oil pollution incident—the country has faced numerous oil spill events, including the Amorgos in 2001 and T.S. LINES in 2018 cases (Figure 3). In 2001, there were only five oil spill cases, but, by 2021, the number had risen to as high as 61, generally increasing year by year (Table 1) [25]. These incidents revealed

systemic issues, such as fragmented response efforts and inadequate resources for large-scale spills. Although the MPCA was enacted in 2000 and amended in 2023 to enhance legal and operational frameworks, gaps remain in contingency planning, inter-agency coordination, and public communication during emergencies [29].

Table 1. Statistics of oil spill pollution cases in Taiwan.

Year	Tier 1	Tier 2	Tier 3	Undefined Cases	Total Cases
2001	5				5
2002	78				78
2003	34				34
2004	66				66
2005	86				86
2006	75				75
2007	78				78
2008	96				96
2009	50				50
2010	51	1		1	53
2011	19	4			23
2012	14	3		3	20
2013	34				34
2014	30	1		3	34
2015	34			4	38
2016	47	2		2	51
2017	53	3		5	61
2018	57	12		4	73
2019	73	3		5	81
2020	72			1	73
2021	61				61
Total	1113	29	0	28	1170

Note: Tier 1 refers to minor oil pollution, with oil spills of less than 100 metric tons; Tier 2 refers to medium oil pollution, with oil spills ranging from 100 to 700 metric tons; Tier 3 refers to major oil pollution, with oil spills exceeding 700 metric tons.

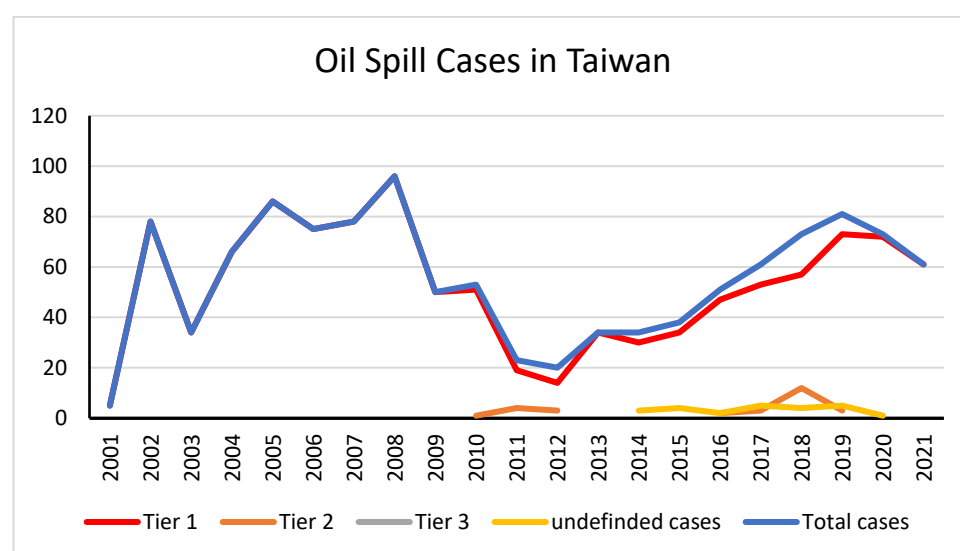


Figure 2. Annual statistics of oil spill cases in the Taiwan region of China. Note: Tier 1 refers to minor oil pollution, with oil spills of less than 100 metric tons; Tier 2 refers to medium oil pollution, with oil spills ranging from 100 to 700 metric tons; Tier 3 refers to major oil pollution, with oil spills exceeding 700 metric tons.

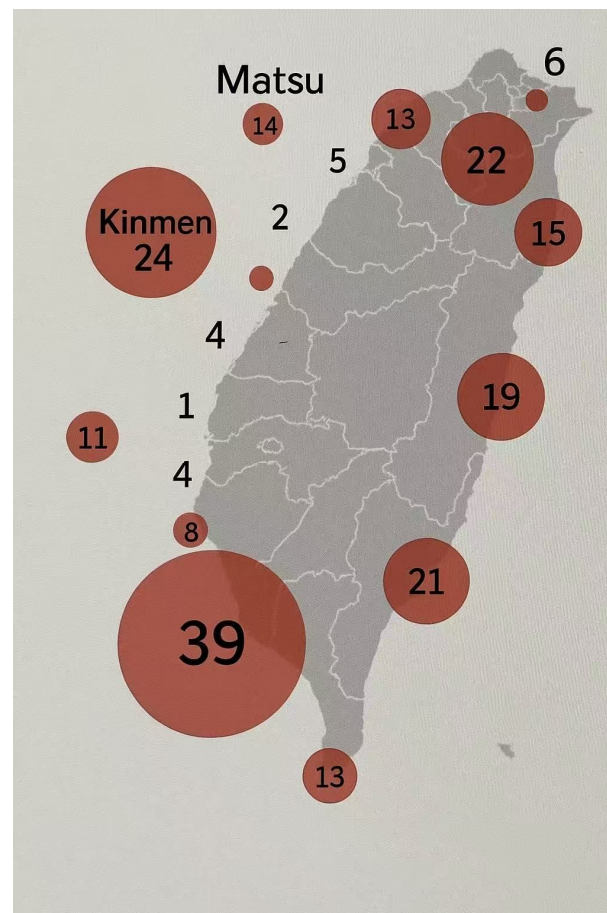


Figure 3. Oil spill case distribution in the Taiwan region of China. Note: The numbers indicate the number of marine pollution incidents that have occurred in the surrounding waters over the years 2001–2021. The red circles highlight the number of oil spills above 6 in an area. The gray areas represent the regions/or coastal areas.

3.2. Institutional Genesis: The Borag Incident (1977)—Awakening of Governance Awareness, and Exposure of Institutional Gaps

On 7 February 1977, the Kuwaiti tanker *Borag* ran aground 2.5 nautical miles north of Keelung Port, spilling 15,000 tons of fuel oil—the most severe oil spill in Taiwan’s maritime history. The pollution affected Keelung Port and nearly 70 km of coastline [30]. This incident became a “critical trigger point” for marine environmental governance in Taiwan, bringing marine pollution onto the public policy agenda for the first time. However, the response exhibited classic “temporary governance” characteristics: no unified command system, cleanup relying on ad hoc mobilization of local communities and the military, and four major institutional gaps—no designated lead agency, no legal framework, no technical equipment, and no compensation mechanism. Although this case planted the seeds for a marine environmental governance system, due to the political and economic priorities of the time, substantive institutional reform was delayed by nearly two decades, forming a pattern of “institutional delayed response.” Notably, this coordination ambiguity has been path-dependent: although the Marine Pollution Control Act (2000) and the Ocean Affairs Council (2018) have since been established, interviews for this study show that 27% of 15 stakeholders still list “unclear lead agency within 48 h of an incident” as a primary current concern.

3.3. Law-Enforcement Gap: The Amorgos Incident (2001)—Policy Response Failure and Fragmented Coordination Mechanisms

In 2001, the Greek cargo ship Amorgos sank off the coast of Kenting National Park, spilling large quantities of fuel oil. The accident occurred on the eve of the Lunar New Year in a remote location, and an inter-ministerial emergency response task force was not established until 21 days later—a serious violation of the timeliness principle for emergency response [25]. This incident highlighted the “law-enforcement gap” following the enactment of the Marine Pollution Control Act (2000): confusion over authority among the Environmental Protection Administration (nominal lead), the Coast Guard Administration, and local governments, leading to fragmented command. Moreover, the lack of baseline ecological data for Kenting National Park made it impossible to document initial ecological impacts, undermining the scientific basis for damage assessment. The incident directly led to the creation of the MMOPERP, designating the Environmental Protection Administration as the central competent authority. However, the plan lacked dedicated staffing and equipment, and the disconnect between marine pollution response and maritime operations persisted. This institutional coordination failure has proven persistent: 60% of 15 interviewees in this study still described coordination as “fragmented” or “ad hoc” during the 2023 Angel incident, indicating that the establishment of the Ocean Conservation Administration in 2018 did not fundamentally resolve the problem of fragmented coordination.

3.4. Compensation–Restoration Dilemma: The T.S. Lines Incident (2018)—Forensic Ecology Gap and Insufficient Scientific Evidence

In 2018, the T.S. Lines container vessel ran aground and broke apart off Shimen Coast, New Taipei City, leading to compensation claims from over 9000 fishermen totaling new Taiwan dollar (NT\$) 178.78 million [31]. The first-instance court ruled in favor of compensation, but the second-instance high court reversed the decision, citing “inability to prove fishery damages,” exposing a structural weakness in the post-incident compensation phase: lack of baseline marine resource data, leading to inability to establish a causal link between pollution and damage and hindering the application of forensic ecology. Meanwhile, operational silos between ship salvage (Maritime and Port Bureau, MOTC) and pollution control (Environmental Protection Administration) made strategy optimization difficult; the process for commissioning fishery damage surveys was lengthy, and damages were difficult to estimate after oil had dispersed. Post-incident review recommendations pointed to integrated operational procedures, proactive investigations, and route adjustments in high-risk areas—indicating that learning effects are occurring, but the pace of institutional integration is slow. Although the Ocean Affairs Council has initiated the construction of a marine resources database, as of 2024, only 15% of nearshore waters have completed baseline ecological surveys, showing a significant capacity-building lag.

3.5. Enforcement Challenges: The Angel Incident (2023)—Testing the Effectiveness of Revised Legal Frameworks and Limitations of International Status

In July 2023, the Palau-flagged container ship Angel sank off Kaohsiung Port, setting approximately 600 empty containers adrift [32]. This was the first major case after the passage of amendments to the Marine Pollution Control Act. The Ocean Affairs Council issued five consecutive fines totaling NT\$5.4 million, demonstrating an assertive enforcement stance. However, initially, the foreign shipowner ignored the competent authority and refused to submit an oil removal plan, revealing the challenges of non-cooperative behavior by international shipowners: fines alone have limited effectiveness against uncooperative international owners, and Taiwan’s lack of membership in informal international mechanisms such as the IMO weakens its enforcement power. Moreover, insufficient accuracy in predictive models for container drift trajectories and oil spill dispersion has affected

the efficiency of pre-positioned emergency response [33]. This case shows that, while the legal framework has been strengthened, international legal status constraints and technical preparedness gaps at the enforcement level continue to pose structural limitations.

3.6. Comparative Analysis of Four Key Cases

The evolutionary trajectory of Taiwan's marine oil pollution emergency governance system exhibits a classic "crisis-driven institutional change" model. The four critical cases—Borag, Amorgos, T.S. Lines, and Angel—spanning 46 years, reveal the transition logic from "institutional void" to "legal completeness" and its structural dilemmas [34]. The Borag incident (15,000 tons of fuel oil spilled, 70 km of coastline contaminated) (Table 2) served as a "critical trigger," exposing a completely pre-institutionalized state—no dedicated agency, no legal framework, no technical equipment, no compensation mechanism. The response relied on ad hoc mobilization of the military and local communities, planting the seeds of governance awareness but resulting in a 20-year "institutional delay response." The Amorgos incident occurred in the early implementation phase of the Marine Pollution Control Act (2000). A 21-day decision-making lag, inter-ministerial coordination failures, and baseline data deficiencies highlighted the core contradiction of a "law-implementation gap," directly spurring the creation of the MMOPERP. However, the plan lacked dedicated resources and substantive coordination mechanisms. The T.S. Lines incident exposed the forensic ecological gap in the compensation and recovery phase. The appellate court reversed the compensation ruling on the grounds that "fishery damages could not be proven," revealing structural weaknesses in scientific evidence and operational silos (separation of salvage and pollution response). This prompted the development of a marine resource database, but, as of 2024, only 15% of the coastline had completed baseline surveys, reflecting a significant "capacity-building lag." The Angel incident, the first major case following the 2023 legal amendments, tested the effectiveness of enhanced enforcement tools. Despite cumulative fines of NT\$5.4 million, it remained difficult to restrain uncooperative international shipowners, exposing the structural constraints of Taiwan's non-IMO-member status and insufficient accuracy of technical prediction models. A comparative analysis of the four cases shows that institutional evolution follows an incremental path: "crisis exposes gap → public pressure → legal/plan/institutional patch → next crisis exposes new gap." Early coordination ambiguity (27% of respondents still concerned about unclear lead agency within 48 h), resource insufficiency (60% describe coordination as "fragmented/ad hoc"), and scientific deficits persist in various forms, creating path dependence. Meanwhile, the nature of challenges has shifted from domestic institutional voids to international shipowner dynamics, forensic ecological methodological gaps, and technical complexity, resulting in a state of "high institutionalization but low effectiveness." This trajectory aligns with historical institutionalism's "critical juncture–path dependence" framework and disaster sociology's theories of risk "social amplification/attenuation" (the visual residue of the Borag incident in the urban core produced an amplification effect, while the remote location and holiday timing of the Amorgos incident led to response attenuation) [35,36]. It demonstrates that legal and institutional completeness does not automatically translate into governance effectiveness. Future reforms must move beyond incremental logic to achieve a systematic modernization of governance capacity—from "formal coordination" to "substantive integration" and from "reactive response" to "proactive prevention."

Table 2. Summary of four oil spill cases.

Case	Time	Spill Scale	Core Response Problems	Lessons
Borag	1977	15,000 tons	No agency, no law, no equipment	Establish basic governance awareness
Amorgos	2001	~1000 tons	21-day delay, role ambiguity	Enact MPCA and MMOPERP
T.S. LINES	2018	Medium	Compensation loophole, no resource database	Need forensic ecology data
Angel Container	2023	~600 containers	Shipowner non-compliance, weak enforcement	Strengthen penalty and technical capacity

4. Discussion

4.1. Theoretical Framing: From Reactive Response to Integrated Risk Governance

The Amorgos oil spill case illuminates a critical gap in Taiwan's marine pollution governance: the misalignment between institutional design and operational capacity. Drawing on Birkland's "focusing event" theory [37], major oil spills typically catalyze policy reforms by revealing systemic vulnerabilities. However, Taiwan's experience deviates from this pattern. Despite the Borag (1977) and Amorgos (2001) incidents—separated by 24 years—fundamental reforms only materialized with the 2023 MPCA amendment. This latency suggests that focusing events alone are insufficient without enabling institutional conditions, particularly a centralized authority capable of translating crisis learning into structural change.

Perrow's "normal accident" theory further contextualizes Taiwan's predicament [38]. The interaction of multiple autonomous agencies (Environmental Protection Administration (EPD), Coast Guard, Port and Maritime Bureau, local environmental protection bureaus) creates a tightly coupled yet decentralized system, in which operational interdependence coexists with fragmented command authority. Such configurations are prone to "system accidents" in which component failures cascade due to coordination breakdowns rather than individual errors. The Amorgos response delays—attributed to inter-agency jurisdictional disputes—exemplify this dynamic.

4.2. Empirical Findings: Structural Deficits in Taiwan's Oil Spill Response System

Our analysis identifies three interconnected structural deficits that undermine Taiwan's oil spill preparedness and response effectiveness.

- **Deficit 1: Fragmented command authority without statutory integration.** The EPD's role under MPCA is confined to monitoring and approving cleanup plans submitted by vessel insurers, with enforcement limited to "urging" compliance through crew detention. This creates a responsibility–authority asymmetry: the agency bears public accountability for environmental outcomes but lacks directive power over operational execution. The 2023 amendment's establishment of the Ocean Affairs Council (OAC) as the coordinating body represents partial rectification, yet implementation of regulations delineating OAC–EPD–Coast Guard authority boundaries remains pending [39].
- **Deficit 2: Absence of ecological baselines for damage assessment and compensation.** Taiwan's waters host approximately 30,000 tanker transits annually, with 800+ grounding-related spills documented over four decades [40]. However, systematic benthic and pelagic ecosystem surveys are lacking. This baseline deficit constrains three critical functions: (a) pre-spill risk zoning; (b) post-spill injury quantification for natural resource damage assessment; and (c) compensation negotiations grounded in ecosystem service valuation rather than cleanup cost recovery alone. The maritime

research community’s advocacy for a “national marine census” reflects recognition of this vulnerability [41].

- Deficit 3: International isolation limiting resource access and norm diffusion. Taiwan’s non-party status to MARPOL 73/78 and exclusion from international tanker owners’ pollution federation membership restrict access to international oil spill response networks, technical protocols, and compensation conventions. While bilateral arrangements with regional partners provide partial alternatives, the absence of formalized joint training exercises and mutual aid agreements leaves Taiwan dependent on ad hoc cooperation during transboundary incidents [34].

4.3. Policy Implications: Pathways Toward Integrated Marine Pollution Governance

Based on the identified deficits, we propose a phased reform trajectory aligned with the 2023 MPCA amendment framework (Table 3).

Table 3. Phased recommendations for strengthening Taiwan’s oil spill response system.

Phase	Priority Area	Key Actions	Lead Agency	Performance Indicators
Short term (1–2 years)	Institutional integration	Establish statutory Oil Spill Response Task Force under OAC with unified field command authority; clarify agency protocols through inter-ministerial memoranda	Ocean Affairs Council	Response initiation time; inter-agency dispute incidents
Medium term (3–5 years)	Capacity building	(a) Complete national marine ecological baseline survey; (b) deploy (DSTs) integrating real-time spill trajectory modeling and resource optimization	OAC + Academia Sinica/National Energy Research	Baseline coverage (% territorial waters); DST deployment in exercises
Long term (5+ years)	International alignment	Pursue MARPOL adherence through “Taiwan Clause” or equivalent arrangement; institutionalize regional joint exercises via Northwest Pacific Action Plan or bilateral frameworks	Foreign Ministry + OAC	Formalized mutual aid agreements; annual joint exercise participation

Critical design considerations:

First, the proposed task force should incorporate dual-hierarchy structures observed in effective regimes (e.g., U.S. National Response Team/Regional Response Teams under OPA 1990): a strategic level for policy coordination and a tactical level for field operations [42]. This addresses the safety–pollution prevention tension by embedding human life prioritization within, rather than parallel to, operational protocols.

Second, ecological baseline development should prioritize habitat equivalency analysis methodologies compatible with natural resource damage assessment frameworks under the OPA and the European Union environmental liability directive [43]. This enables future compensation claims to incorporate restoration scaling based on ecosystem service losses, transcending the current “cleanup cost plus” approach.

Third, international engagement should leverage Taiwan’s functional participation in non-political maritime bodies (e.g., World Ocean Council, the World Association for Waterborne Transport infrastructure) as stepping stones toward technical protocol alignment, pending formal convention accession [44].

5. Conclusions

This study addressed three core research questions, with key findings as follows. Regarding the evolution and gaps of oil spill governance, a four-phase evolution process

from institutional void (1977) to enforcement testing (2023) was identified, and persistent gaps include fragmented coordination, weak evidence bases, and limited international leverage. For actionable reforms, four evidence-based strategies are proposed, including unified command, digital science and technology (DST) integration, compensation fund expansion, and enforcement enhancement.

This study makes three theoretical contributions: first, it establishes a phased evolution model for non-UN-member oil spill governance; second, it develops a systematic gap analysis framework applicable to other coastal regions with constrained international status; third, it provides empirical validation of the “fragmentation-persistence” phenomenon, which reveals that structural centralization does not guarantee operational coordination. In terms of practical contributions, three key outputs are presented: evidence-based recommendations for the amendment of the MPCA, a template for unified task force protocols, and enforcement escalation pathways (from fines to detention to port bans).

This study has several limitations, including a small interview sample ($n = 15$), retrospective case bias, and a focus on major oil spills only. Based on these limitations and the study’s findings, five future research priorities are identified: first, conduct quantitative impact assessment by developing econometric models to estimate fishery losses from spills, thereby addressing the T.S. LINES evidence gap; second, perform DST validation by calibrating and validating oil spill trajectory models tailored to the unique hydrodynamics of the Taiwan Strait; third, carry out comparative governance research by comparing non-UN-member governance models across Taiwan, Hong Kong, and Macao; fourth, evaluate the effectiveness of enforcement by examining the deterrent effects of graduated sanctions (fines, detention, port bans) through a longitudinal study; fifth, conduct sub-national diplomacy mapping to identify and test technical cooperation pathways with IMO-member states.

Marine oil spills demand robust governance. While the Taiwan region of China has made progress from institutional void (1977) to the establishment of a legal framework (2000) and further to enforcement testing (2023), persistent gaps in coordination, evidence, compensation, and international leverage remain. The staged, context-aware roadmap proposed in this study—prioritizing domestic institutional innovation over unrealistic international accession—offers a pragmatic path forward. This approach not only serves the interests of the Taiwan region but also contributes to regional marine environmental security, providing valuable lessons for similarly situated coastal regions worldwide.

Author Contributions: Methodology, S.-Y.L.; Software, W.-Y.C.; Resources, C.-P.L.; Data curation, C.-P.L.; Writing—review and editing, C.-W.C.; Visualization, W.-Y.C.; Project administration, Y.-C.S.; Funding acquisition, Y.-C.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Taiwan National Science and Technology Council (Grant Number NSTC 112-2410-H-006-09 and NSTC 112-2119-M-004-001).

Institutional Review Board Statement: In accordance with institutional guidelines, this study is exempt from ethical review and approval as it involves non-sensitive, anonymized data collected from professional stakeholders.

Informed Consent Statement: Informed consent was obtained from all participants prior to the interviews. Participation was voluntary, and interviewees were informed of the study’s purpose. All interview data has been anonymized and treated confidentially.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Acknowledgments: In addition to the participants in the field survey, the authors also thank colleagues from the Coast Guard Administration, Marine Conservation Agency, and Environmental Protection Agency for providing relevant information, interviews, and finally providing valuable experiences in this research. Finally, the authors would also like to thank the respondents who participated in this interview for their time and responses.

Conflicts of Interest: Chih-Wei Chang is employed by European Semiconductor Manufacturing Company GmbH. The remaining authors declare no conflicts of interest.

References

- White, C.; Halpern, B.S.; Kappel, C.V. Ecosystem service tradeoff analysis reveals the value of marine spatial planning for multiple ocean uses. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 4696–4701. [CrossRef]
- Huang, Y.; Liu, B.; Liu, B.; Li, Y.; Bing, L.; Cheng, L. DeepLab-AFOS: A marine oil spill detection method based on advantageous features from polarimetric SAR. *Mar. Pollut. Bull.* **2026**, *227*, 119526. [CrossRef]
- Liu, P.; Shao, P.; Zhao, X.; Wang, X.; Chen, P.; Zhu, X.; Li, Y.; Xu, J.; Liu, B. Noise reduction based on the characteristics of X-band marine radar images for oil spill detection. *Remote Sens. Lett.* **2026**, *17*, 190–197. [CrossRef]
- Wu, X.; Lu, X.W. Addressing oil pollution compensation in China: An analysis of the CLC and domestic fund models. *Front. Mar. Sci.* **2025**, *12*, 1602260. [CrossRef]
- Mohammadiun, S.; Hu, G.; Gharahbagh, A.A.; Li, J.; Hewage, K.; Sadiq, R. Intelligent computational techniques in marine oil spill management: A critical review. *J. Hazard. Mater.* **2021**, *419*, 126425. [CrossRef]
- Ivshina, I.B.; Kuyukina, M.S.; Krivoruchko, A.V.; Elkin, A.A.; Makarov, S.O.; Cunningham, C.J.; Peshkur, T.A.; Atlas, R.M.; Philp, J.C. Oil spill problems and sustainable response strategies through new technologies. *Environ. Sci. Process. Impacts* **2015**, *17*, 1201–1219. [CrossRef] [PubMed]
- Yang, Z.; Chen, Z.; Lee, K.; Owens, E.; Boufadel, M.C.; An, C.; Taylor, E. Decision support tools for oil spill response (OSR-DSTs): Approaches, challenges, and future research perspectives. *Mar. Pollut. Bull.* **2021**, *167*, 112313. [CrossRef] [PubMed]
- Farrow, K.; Brinson, A.; Wallmo, K.; Lew, D.K. Environmental attitudes in the aftermath of the Gulf Oil Spill. *Ocean Coast. Manag.* **2016**, *119*, 128–134. [CrossRef]
- Etkin, D.S. *Trends in 50 Years of Oil Spill Statistics, International Oil Spill Conference Proceedings*; Allen Press: Lawrence, KS, USA, 2024.
- Liu, P.; Wang, X.; Shao, P.; Zhao, X.; Liu, B.; Chen, P.; Zhu, X.; Xu, J.; Li, Y. Oil spill segmentation in marine radar images based on the improved Sauvola algorithm. *Remote Sens. Lett.* **2026**, *17*, 182–189. [CrossRef]
- Lyu, X.; Su, H.; Grecos, C.; Ren, P. A novel framework for marine oil spill detection in SAR imagery fusing edge supervision enhancement and group attention mechanism. *Remote Sens. Appl. Soc. Environ.* **2026**, *41*, 101901. [CrossRef]
- Wan, Y.; Peng, L.; Zhang, R.; Zhang, R.; Wang, H. A Dual-Branch EfficientNetV2-S-Based Method for Marine Oil Spill Detection Using Multisource Satellite Data Fusion. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2026**, *19*, 1549–1566. [CrossRef]
- The International Maritime Organization. “Marpol 73/78: Consolidated Edition, 2002: Articles, Protocols, Annexes, Unified Interpretations of the International Convention for the Prevention of Pollution from Ships, 1973, as Modified by the Protocol of 1978 Relating Thereto”. London: IMO, 2002. Text. Available online: <https://treaties.un.org/pages/showDetails.aspx?objid=0800000280291139> (accessed on 10 January 2026).
- Oil Pollution Act of 1990, Pub. L. No. 101-380, 104 Stat. 484 (18 August 1990). Available online: https://www.uscg.mil/Mariners/National-Pollution-Funds-Center/About_NPFC/OPA/ (accessed on 10 January 2026).
- Ye, X.; Chen, B.; Li, P.; Jing, L.; Zeng, G. A simulation-based multi-agent particle swarm optimization approach for supporting dynamic decision making in marine oil spill responses. *Ocean Coast. Manag.* **2019**, *172*, 128–136. [CrossRef]
- Bajracharya, B.; Pradhan, S.; Shrestha, B.; Salerno, F. An integrated Decision Support Toolbox (DST) for the management of mountain protected areas. *Mt. Res. Dev.* **2010**, *30*, 94–102. [CrossRef]
- Chen, B.; Ye, X.; Zhang, B.; Jing, L.; Lee, K. Marine oil spills—Preparedness and countermeasures. *World Seas Environ. Eval.* **2019**, *3*, 407–426. [CrossRef]
- Diez, E.; McIntosh, B.S. Organisational drivers for, constraints on and impacts of decision and information support tool use in desertification policy and management. *Environ. Model. Softw.* **2011**, *26*, 317–327. [CrossRef]
- Sabela-Rikhotso, P.T.Z.; van Niekerk, D.; Nema-konde, L.D. A critical analysis of the legal frameworks governing oil spill management in South Africa. *Mar. Policy* **2021**, *127*, 104433. [CrossRef]
- Solis, J.R.R. Taiwan’s Economy at a Crossroads. Challenges and Opportunities for the Future. *Portes-Rev. Mex. Estud. Sobre Cuenca Del Pac.* **2026**, *3*, 206–228. [CrossRef]
- Huang, Y.H.; Chan, Y.S. The Economic and Environmental Impacts of Floating Offshore Wind Power Generation in a Leading Emerging Market: The Case of Taiwan. *Sustainability* **2026**, *18*, 804. [CrossRef]

22. Ding, J.-F.; Tseng, W.-J.; Hsu, F.-T. An evaluation of key risk factors affecting shipping market operations across the Taiwan Strait for liner carriers. *Proc. Inst. Mech. Eng. Part M J. Eng. Marit. Environ.* **2014**, *228*, 302–311. [\[CrossRef\]](#)
23. Shih, Y.-C. Taiwan's progress towards becoming an ocean country. *Mar. Policy* **2020**, *111*, 103725. [\[CrossRef\]](#)
24. Lin, S.H.; Wang, Y.C. Enhancing Marine Environmental Protection Enforcement in Taiwan: Legal and Policy Reforms in the Context of International Conventions. *Laws* **2025**, *14*, 60. [\[CrossRef\]](#)
25. Chiau, W.-Y. Changes in the marine pollution management system in response to the Amorgos oil spill in Taiwan. *Mar. Pollut. Bull.* **2005**, *51*, 1041–1047. [\[CrossRef\]](#)
26. Kandel, S.; Stumpf, A.C.; Joshi, A.; Sharma, S.; Taylor, L.E.; Jefferson, A.J.; Kenney, M.A. Comparing Flood Inundation Map Features and Diagnosing Decision Support Design Challenges. *Hydrol. Process.* **2026**, *40*, e70362. [\[CrossRef\]](#)
27. Savvadelli, E.; Kiourekis, Y.; Kokkinaki, A. A Literature Review on Rule-Based Systems as Decision Support Systems. In *19th International Symposium on Human Aspects of Information Security and Assurance-HAISA-Annual, Mytilene, GREECE*; Springer Nature: Cham, Switzerland, 2025; pp. 376–388. [\[CrossRef\]](#)
28. Zhang, L.L.; McCartney, G. The Mediating Role of Positive Empathy in Resident Participation in Sustainable Tourism: Evidence from an Ancient Chinese Town. *Int. J. Tour. Res.* **2026**, *28*, e70301. [\[CrossRef\]](#)
29. Fan, C.; Hsu, C.-J.; Lin, J.-Y.; Kuan, Y.-K.; Yang, C.-C.; Liu, J.-H.; Yeh, J.-H. Taiwan's legal framework for marine pollution control and responses to marine oil spills and its implementation on TS Taipei cargo shipwreck salvage. *Mar. Pollut. Bull.* **2018**, *136*, 84–91. [\[CrossRef\]](#) [\[PubMed\]](#)
30. Ye, J.A.; Pan, Y.M.; Jung, C.H.; Liu, T.K. Good news or bad news? The portrayal and evolution of marine pollution issues in Taiwan's news coverage. *Mar. Pollut. Bull.* **2025**, *213*, 117663. [\[CrossRef\]](#)
31. Abdel-Mawgoud, A.M.; Aboulwafa, M.M.; Hassouna, N.A. Optimization of surfactin production by *Bacillus subtilis* isolate BS5. *Appl. Biochem. Biotechnol.* **2008**, *150*, 305–325. [\[CrossRef\]](#)
32. Ahmed, A.; Liu, Y.; Khan, R.; He, P.; He, P.; Wu, Y.; Munir, S.; He, Y. Molecular insights from integrated metabolome-transcriptome into endophyte *Bacillus subtilis* L1-21 surfactin against citrus Huanglongbing. *Microbiol. Res.* **2025**, *290*, 127942. [\[CrossRef\]](#)
33. Chen, X.; Gong, X. Electrochemically fast preparation of superhydrophobic copper mesh for high-efficiency oil spill adsorption and oil-water separation. *J. Hazard. Mater.* **2024**, *472*, 134465. [\[CrossRef\]](#)
34. Nguyen, T.H.H.; Hou, T.H.; Pham, H.A.; Tsai, C.C. Oil Spill Sensitivity Analysis of the Coastal Waters of Taiwan Using an Integrated Modelling Approach. *J. Mar. Sci. Eng.* **2024**, *12*, 155. [\[CrossRef\]](#)
35. Báscolo, E.; Houghton, N.; Bennett, S. Political economy of primary health care resilience in Latin America and the Caribbean: Insights from the WB/PAHO Commission recommendations. *Lancet Reg. Health Am.* **2025**, *50*, 101241. [\[CrossRef\]](#)
36. Puryear, C.; Vandello, J.A.; Gray, K. Moral panics on social media are fueled by signals of virality. *J. Personal. Soc. Psychol.* **2024**, *127*, 84–103. [\[CrossRef\]](#)
37. Straub, A.M. Post-tropical cyclone Fiona and Atlantic Canada: Media framing of hazard risk in the Anthropocene. *Disasters* **2024**, *48*, e12641. [\[CrossRef\]](#)
38. Chen, I.C. Reframing the Itaewon crowd crush: A systems analysis using Perrow's framework. *Disaster Prev. Manag.* **2025**, *34*, 624–637. [\[CrossRef\]](#)
39. Tsai, C.T.; Yi, C.H. Taiwan Comparison of Law of the Sea Approaches between 2012–2016 and 2016–2018: Implementation of the Ocean Affairs Council, Strict Regulation of Distant Water Fisheries Agency, and Progress on Marine Spatial Planning. *Asia-Pac. J. Ocean Law Policy* **2019**, *4*, 103–108. [\[CrossRef\]](#)
40. Huang, W.C.; Chang, C.W. Water shortage risk in Taiwan's Silicon Valley. *J. Chin. Inst. Eng.* **2022**, *45*, 513–520. [\[CrossRef\]](#)
41. Liu, T.K.; Chang, H.; Chen, Y.S. Public awareness of marine environmental quality and its relationship for policy support on marine waste management. *Mar. Pollut. Bull.* **2023**, *195*, 115456. [\[CrossRef\]](#) [\[PubMed\]](#)
42. Swanson, S.R. OPA 90+10: The oil pollution act of 1990 after ten years. *J. Marit. Law Commer.* **2001**, *32*, 135–174.
43. Stout, S.A. Oil spill fingerprinting method for oily matrices used in the Deepwater Horizon NRDA. *Environ. Forensics* **2016**, *17*, 218–243. [\[CrossRef\]](#)
44. Peschken, G.; Langrock, N. PIANC: Global knowledge network for waterborne transport infrastructure. *Bautechnik* **2025**, *102*, 382–389. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.