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INTEGRATING ARTIFICIAL INTELLIGENCE AND SATELLITE TELEMETRY INTO COASTAL CONSERVATION AND MARINE POLLUTION LEGISLATION: A FEASIBLE LEGISLATIVE MODEL FOR SRI LANKA

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***Abstract*— The vulnerability of island nations to catastrophic marine pollution and severe coastal degradation - exemplified by the *MV X-Press Pearl* disaster in Sri Lankan waters - reveals fundamental structural limitations in traditional environmental governance. Sri Lanka's primary legislative frameworks, the *Coast Conservation and Coastal Resource Management Act No. 57 of 1981* (as amended) and the *Marine Pollution Prevention Act No. 35 of 2008*, depend primarily on post-hoc reactive physical inspections and static, periodic planning cycles. This study formulates a feasible legal model that integrates Artificial Intelligence (AI), Synthetic Aperture Radar (SAR) telemetry, multispectral optical remote sensing, and automated data fusion into Sri Lanka's statutory framework. Through an analytical examination of domestic legislation, international conventions (UNCLOS, MARPOL 73/78, Basel Convention), and recent environmental jurisprudence, this paper identifies critical statutory lacunae regarding data mandates, cross-border intelligence exchange, and the evidentiary admissibility of autonomous algorithmic detections. To resolve these deficiencies, this study proposes two statutory draft amendments: (1) Section 12A of Act No. 57 of 1981, mandating an automated, real-time "Smart Coastal Zone Management System" (Smart-CZMP); and (2) Section 25A of Act No. 35 of 2008, establishing statutory rebuttable presumptions of liability derived from validated AI satellite surveillance alongside procedural compliance with the *Evidence (Special Provisions) Act No. 14 of 1995*. This legal framework provides a proactive, technologically sovereign mechanism to mitigate marine plastic accumulation, coastal erosion, and maritime environmental crimes.**

Keywords - Coastal Zone Management Plan, Marine Pollution, Artificial Intelligence, Remote Sensing, Statutory Reform, X-Press Pearl, UNCLOS, MARPOL Annex V.

I. INTRODUCTION

The Indian Ocean maritime corridor represents one of the world's most congested shipping sea lanes, accommodating over one-third of global bulk cargo traffic and two-thirds of international petroleum transfers. Sri Lanka's strategic location along this maritime route exposes its 1,340 km coastline and Exclusive Economic Zone (EEZ) to recurring environmental threats, ranging from chronic vessel-source plastic tipping to acute industrial chemical and oil spills. The catastrophic fire and subsequent sinking of the *MV X-Press Pearl* off the coast of Colombo in May 2021 - releasing approximately 78 metric tons of plastic nurdles (microplastics), nitric acid, and dangerous chemicals into the marine ecosystem - highlighted systemic vulnerabilities in real-time surveillance, dynamic risk assessment, and enforcement capability within Sri Lanka's maritime domain.

Sri Lanka's coastal and marine governance relies principally on two legislative enactments:

1. The **Coast Conservation and Coastal Resource Management Act No. 57 of 1981** (as amended by Act No. 64 of 1988 and Act No. 49 of 2011); and
2. The **Marine Pollution Prevention Act No. 35 of 2008**.

While these enactments established important foundational administrative structures - namely the Coast Conservation Department (CCD) and the Marine Environment Protection Authority (MEPA) - their operational mechanisms remain anchored in an analog enforcement paradigm. The statutory Coastal Zone Management Plan (CZMP), mandated under Section 12 of Act No. 57 of 1981, operates on a static five-year revision cycle. This static planning framework cannot dynamically adapt to real-time shoreline erosion, illicit coastal reclamation, or localized microplastic deposition. Furthermore, enforcement under Act No. 35 of 2008 depends heavily on physical inspections and manual vessel interceptions (Sections 41 and 46),

which are functionally inadequate for continuously monitoring Sri Lanka's 532,000 km^2 maritime domain during nighttime or adverse weather conditions.

To address these enforcement limits, this paper introduces a statutory amendment model designed to integrate modern technologies - including satellite-based Synthetic Aperture Radar (SAR), multi-spectral optical remote sensing, computer vision algorithms, and predictive machine learning - directly into Sri Lanka's coastal and marine statutory framework.

II. METHODOLOGY

This study employs a qualitative legal research methodology combining doctrinal legal analysis, statutory interpretation, and comparative legal modeling. First, a doctrinal audit of Sri Lanka's primary statutory enactments - specifically the Coast Conservation and Coastal Resource Management Act No. 57 of 1981 (as amended) and the Marine Pollution Prevention Act No. 35 of 2008 - was conducted to identify procedural lacunae regarding real-time surveillance, evidentiary standards, and data mandates. Second, international treaty obligations under UNCLOS (Articles 192, 194, 204) and MARPOL Annex V were analyzed alongside domestic jurisprudence (notably the Supreme Court's X-Press Pearl Fundamental Rights litigation) to establish the state's legal duties regarding continuous monitoring. Third, utilizing formal legislative drafting techniques, legislative amendment clauses (Draft Sections 12A and 25A) were formulated. These proposed provisions integrate satellite remote sensing and algorithmic detection into the existing evidentiary framework of the Evidence (Special Provisions) Act No. 14 of 1995 while safeguarding constitutional guarantees under Article 13(5).

III. CURRENT STATUTORY LANDSCAPE AND LEGISLATIVE GAPS

A. Coast Conservation and Coastal Resource Management Act No. 57 of 1981 (as amended)

Act No. 57 of 1981 establishes the legal regime governing development activities and resource management within the coastal zone. Section 42 (as amended by Act No. 49 of 2011) defines the "Coastal Zone" as:

"the area lying within a limit of three hundred meters landward of the Mean High Water Line and a limit of two kilometers seaward of the Mean Low Water Line..."

Section 12 of the Act requires the Director-General of Coast Conservation to prepare a comprehensive Coastal Zone Management Plan, which has undergone successive updates across the 1990, 2018, and 2024 iterations. However, legal analysis reveals three key structural constraints:

Static Plan Revision Cycles: Section 12(4) mandates plan revisions only once every five years. Static five-year planning cycles fail to account for rapid shoreline alterations driven by extreme climate events, unauthorized coastal engineering, or sudden changes in sediment transport vectors.

Absence of Mandatory Real-Time Spatial Data Integration: The Act contains no explicit statutory mandate requiring the incorporation of dynamic spatial telemetry, remote sensing, or automated GIS tracking into coastal policy planning.

Reactive Permitting and Enforcement: Under Section 14, development activities within the Coastal Zone require a permit issued by the Director-General. However, the discovery of unpermitted construction or illegal coastal structures relies primarily on manual field inspections, allowing widespread non-compliance to proceed undetected.

B. Marine Pollution Prevention Act No. 35 of 2008

Act No. 35 of 2008 serves as Sri Lanka's primary legislation for preventing, controlling, and mitigating marine pollution. It empowers the Marine Environment Protection Authority (MEPA) under Section 2, establishing criminal liability (Part II, Sections 3–5) and civil liability (Part III, Sections 6–13) for pollutant discharges.

Despite these statutory provisions, enforcement faces significant operational hurdles:

Identification Deficits in High-Seas Discharges: Section 3 of Act No. 35 of 2008 establishes criminal liability for the discharge of oil or other harmful pollutants from ships or offshore installations into Sri Lanka waters. However, securing a conviction under Section 3 requires establishing the identity of the offending vessel beyond a reasonable doubt - an evidentiary threshold that frequently fails during unmonitored nighttime discharges due to the lack of statutory provisions authorizing autonomous satellite telemetry as *prima facie* evidence.

Lack of Automated Data-Ingestion Mandates: Section 26 empowers the Minister to declare Pollution Prevention Zones. However, the statute lacks mechanisms to automatically ingest real-time international maritime telemetry - such as Automatic Identification System (AIS) transponder signals—to

detect deliberate transponder disabling (AIS spoofing) by rogue vessels.

C. Evidentiary Framework: Act No. 14 of 1995 & Act No. 19 of 2006

The legal admissibility of AI-generated satellite telemetry and algorithmic outputs in Sri Lankan judicial proceedings is governed by the *Evidence (Special Provisions) Act No. 14 of 1995* and the *Electronic Transactions Act No. 19 of 2006*.

Under Section 5 of Act No. 14 of 1995, computer-generated evidence is admissible provided the proponent tenders an official certificate authenticating system reliability, operational integrity, and human custody chains. However, autonomous AI data pipelines - which ingest raw electromagnetic satellite reflections and transform them into automated violation alerts - present novel challenges regarding algorithmic validation. Without explicit statutory presumptions embedded directly in environmental statutes, complex evidentiary challenges regarding machine learning calibration can stall legal proceedings.

IV. INTERNATIONAL LEGAL OBLIGATIONS AND JURISPRUDENTIAL MANDATES

A. UNCLOS and MARPOL 73/78

Sri Lanka ratified the *United Nations Convention on the Law of the Sea (UNCLOS)* in 1989. UNCLOS imposes affirmative legal duties on coastal States regarding environmental surveillance:

Article 192: Establishes the overarching obligation of States to protect and preserve the marine environment.

Article 194(1): Mandates that States take all measures necessary to prevent, reduce, and control pollution using the *"best practicable means at their disposal."*

Article 204(1): Explicitly requires States to keep under surveillance the effects of any activities which risk polluting the marine environment.

Articles 211 and 220: Grant coastal States comprehensive legislative and enforcement jurisdiction to penalize environmental violations within their Territorial Sea and EEZ.

Complementing UNCLOS, the *International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)*, specifically **Annex V (Regulations for the Prevention of Pollution by Garbage from Ships)**, imposes a complete ban on discharging plastics into the sea. Integrating satellite surveillance and predictive AI into domestic legislation directly fulfills UNCLOS Article 204 and MARPOL Annex V by deploying the best available technology for environmental monitoring.

B. Environmental Jurisprudence and the X-Press Pearl Precedent

The duty of continuous environmental monitoring is well-established in international environmental jurisprudence. In *Pulp Mills on the River Uruguay (Argentina v. Uruguay)*, the International Court of Justice (ICJ) ruled that conducting environmental impact assessments and continuous post-project monitoring is a binding requirement of customary international law.

In Sri Lanka, the Supreme Court established pivotal environmental precedents in the *X-Press Pearl Fundamental Rights Litigation (Centre for Environmental Justice v. MEPA et al., SC/FR Application No. 168/2021 et al.*, Interim Directives & Judgment 2024–2025):

1. **Public Trust Doctrine & Polluter Pays Principle:** The Supreme Court affirmed that the marine environment is held in public trust by the State, directing interim environmental restoration frameworks and reinforcing strict liability principles in relation to multi billion dollar environmental damage claims.

2. **Information Asymmetry and Real-Time Duty:** The Court highlighted that delayed, incomplete, or fragmented information regarding marine hazards directly infringes citizens' fundamental rights under Article 12(1) (Right to Equal Protection of the Law) and Article 14(1)(g) (Right to Freedom of Occupation/Livelihood) of the Constitution.

V. PROPOSED DRAFT LEGISLATIVE AMENDMENT MODEL

A. Draft Bill 01: Coast Conservation and Coastal Resource Management (Amendment) Act

AN ACT TO AMEND THE COAST CONSERVATION AND COASTAL RESOURCE MANAGEMENT ACT, NO. 57 OF 1981

1. Short Title

This Act may be cited as the Coast Conservation and Coastal Resource Management (Amendment) Act, No. [X] of 2026.

2. Insertion of Section 12A in Act No. 57 of 1981

The Coast Conservation and Coastal Resource Management Act, No. 57 of 1981 is hereby amended by the insertion immediately after Section 12 thereof, of the following new Section, which shall have effect as Section 12A of that Act:

"Establishment of Smart Coastal Zone Management System (Smart-CZMP)"

12A.

(1) The Director-General shall, in coordination with the Marine Environment Protection Authority, the National Aquatic Resources Research and Development Agency (NARA), and the National Remote Sensing Agency, establish and operate a continuous spatial surveillance network designated as the 'Smart Coastal Zone Management System' (hereinafter referred to as 'Smart-CZMP').

(2) The Smart-CZMP shall integrate synthetic aperture radar satellite telemetry, multispectral optical imaging, unmanned aerial system (UAS) spatial data, and machine learning predictive analytics to:

(a) Monitor real-time shoreline erosion, accretion, and coastal geomorphological alterations across designated coastal stretches;

(b) Detect unpermitted developments, illegal land reclamations, or destruction of coastal ecosystems within the Coastal Zone as defined under Section 42; and

(c) Identify microplastic accumulation zones, marine debris transportation vectors, and coastal habitat degradation.

(3) Revisions to the Coastal Zone Management Plan prepared under Section 12 shall continuously incorporate digital datasets generated by the Smart-CZMP.

(4) Where the Smart-CZMP detects accelerated coastal erosion or critical environmental damage exceeding prescribed statutory thresholds, the system shall automatically trigger a mandatory interim review by the Coastal Advisory Council within twenty-one (21) days of detection.

B. Draft Bill 02: Marine Pollution Prevention (Amendment) Act

AN ACT TO AMEND THE MARINE POLLUTION PREVENTION ACT, NO. 35 OF 2008

1. Short Title

This Act may be cited as the Marine Pollution Prevention (Amendment) Act, No. [X] of 2026.

2. Insertion of Section 25A in Act No. 35 of 2008

The Marine Pollution Prevention Act, No. 35 of 2008 is hereby amended by the insertion immediately after Section 25 thereof, of the following new Section, which shall have effect as Section 25A of that Act:

"Algorithmic Surveillance, Satellite Telemetry, and Legal Presumptions"

25A.

(1) The Authority is authorized to deploy Artificial Intelligence algorithms, Synthetic Aperture Radar (SAR) remote sensing, satellite optical surveillance, Automatic Identification System (AIS) cross-referencing, and oceanographic dispersion modeling to monitor Sri Lanka Waters for illegal discharges, oil slicks, and plastic waste dumping.

(2) Where an automated surveillance platform validated under subsection (4) detects a pollutant discharge signature originating from a vessel within the Territorial Waters or Exclusive Economic Zone of Sri Lanka and correlates such discharge with the tracked AIS spatial coordinates of a vessel, the output generated by such platform shall be admissible in any civil or criminal proceeding under this Act as prima facie evidence of the discharge by that vessel.

(3) The legal presumption established under subsection (2) shall be rebuttable, and the burden of rebutting such presumption shall rest upon the owner, master, or agent of the implicated vessel.

(4) Section 5 of the Evidence (Special Provisions) Act, No. 14 of 1995 shall apply to outputs generated under this Section, provided that a certificate signed by the Head of Information Technology of the Authority attesting to the algorithmic validation, system calibration, and cryptographic hash verification of the raw telemetry shall be conclusive proof of data integrity.

(5) The Minister may make regulations prescribing standard operating procedures for international satellite data exchange, cross-border maritime intelligence sharing, and public access to redacted environmental monitoring data.

VI. CONSTITUTIONAL SAFEGUARDS AND EVIDENTIARY FEASIBILITY

To establish algorithmic confidence for judicial enforcement, the detection probability threshold ($\mathcal{D}_{\text{pollute}}$) combining SAR backscatter ratios (σ^0) and Normalized Difference Vegetation/Water Indices (NDWI) is mathematically modeled as:

$$\mathcal{D}_{\text{pollute}} = f\left(w_1 \cdot \sigma^0_{\text{anomaly}} + w_2 \cdot \text{NDWI}_{\text{spectral}} + w_3 \cdot \Delta\text{AIS}_{\text{vector}}\right) \geq \tau_{\text{threshold}} \quad (1)$$

where $\tau_{\text{threshold}}$ represents the statutory certainty index required to trigger a Section 25A(2) presumption of discharge.

TABLE I. Algorithmic Governance Matrix

Technical Challenge	Operational Risk	Legal / Statutory Safeguard
Algorithmic False Positives	Natural algal blooms or wind slicks misidentified as oil/plastic discharges.	Dual-Spectral Cross-Verification Protocol (Section 25A(4)).
Data Tampering	Manipulation of satellite telemetry during ground station transmission.	Immutable Cryptographic Hash Ledger (SHA-256 Protocol).
Presumption of Innocence	Conflict with constitutional safeguards under Article 13(5) of the Constitution.	Rebuttable Presumption Framework (Section 25A(3)).

1. **Rebuttable Presumption vs. Presumption of Innocence:** The legal feasibility of proposed Section 25A relies on a balanced evidentiary construction. Rather than creating an unconstitutional irrebuttable presumption of guilt, Section 25A(3) establishes a statutory rebuttable presumption of fact. This structure complies with Article 13(5) of the Constitution of Sri Lanka by preserving the presumption of innocence. It shifts only the evidential burden - requiring the vessel owner, master, or agent to produce contrary operational logs (such as certified oil record books or engine telemetry) - while the legal burden of proof remains with the prosecution.
2. **Mitigating False Positives via Multi-Spectral Protocols:** To prevent technical errors caused by natural oceanic phenomena (such as algal blooms or wind slicks), statutory regulations under Section 25A(5) mandate a Dual-Validation Protocol. Under this requirement, algorithmic alerts generated from SAR radar imagery must be cross-verified against high-resolution optical spectral bands prior to initiating formal legal proceedings.
3. **Data Integrity via Cryptographic Hashing:** Procedural reliability is guaranteed by requiring full compliance with Section 5 of the Evidence (Special Provisions) Act No. 14 of 1995. Raw satellite telemetry received by ground stations must be immediately hashed using SHA-256 cryptographic ledgers. Attaching a signed certificate attesting to algorithmic validation and cryptographic hash verification ensures that automated satellite telemetry remains tamper-proof throughout the judicial chain of custody.

VII. POLICY RECOMMENDATIONS AND ROADMAP

- **Phase I (Months 1–6): Legislative Enactment & Guidelines** — Enact the proposed draft amendments to Act No. 57 of 1981 and Act No. 35 of 2008 in Parliament. Publish ministerial regulations establishing technical thresholds for satellite data verification under Section 25A(4).
- **Phase II (Months 7–12): Technical Center Integration** — Establish the **National Marine Intelligence Centre (NMIC)** connecting MEPA, CCD, Sri Lanka Navy, Sri Lanka Coast Guard, and NARA to operate a shared data dashboard combining Sentinel-1/2 imagery with AIS telemetry.
- **Phase III (Months 13–24): International Intelligence Exchange** — Conclude regional MoUs under UNCLOS Article 197 across SAARC and IORA littoral states to exchange satellite tracking data on non-compliant vessels operating in international sea lanes.

VIII. DISCUSSION & CONCLUSION

The legal and enforcement limitations exposed by recent maritime disasters demonstrate that traditional, analog statutory frameworks face inherent structural limits when responding to modern, rapid marine degradation. Reactive physical inspections and static five-year planning cycles are functionally incapable of detecting unmonitored nighttime vessel discharges or rapid shoreline erosion in real time. Integrating Artificial Intelligence, satellite telemetry, and dynamic data systems into the *Coast Conservation Act No. 57 of 1981* and the *Marine Pollution Prevention Act No. 35 of 2008* offers a technically feasible and legally justified pathway to enhance enforcement efficiency. While operational adoption will require structured inter-agency coordination - such as joint data-sharing dashboards connecting MEPA, the Coast Conservation Department, and the Sri Lanka Navy, alongside initial investment in ground-station data processing, the proposed statutory draft models establish the necessary legal authority, clear evidentiary procedures under Act No. 14 of 1995, and constitutional safeguards under Article 13(5). This ensures that automated surveillance telemetry translates directly into judicially enforceable legal accountability rather than remaining an unutilized technical asset.

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