IOCMSE 2025 Conference
The 1st International Online Conference on Marine Science and Engineering
24–26 November 2025 | Online
MDPI

Comparative Assessment of Satellite Effectiveness in Marine Pollution Detection under the CleanSeaNet Program

Ante Kamber[1], Zaloa Sanchez Varela[2], Zlatko Boko[2]
[1]Military Naval Studies, Dr Franjo Tudjman Defence and Security University, Split, Croatia
[2]Faculty of Maritime Studies, University of Split, Split, Croatia

INTRODUCTION & OBJECTIVE

Oceans are vast—pollution can spread silently and quickly. Traditional monitoring struggles to keep pace. **Satellite-based SAR surveillance changes everything.** It sees through clouds, darkness, and rough seas, providing fast, wide-area detection of potential oil spills.
CleanSeaNet, operated by EMSA, integrates multiple satellite missions to safeguard European waters. Yet not all sensors perform equally.
Our objective:
To **compare four major SAR satellites**—Sentinel-1, Radarsat-2, TerraSAR-X, and PAZ—across five years of operational data, revealing:

- Which satellites detect most consistently
- Which satellites produce the highest true-positive confirmations
- How classification outcomes vary across missions
- How environmental factors influence detection reliability

By understanding these differences, we move closer to a **stronger, more resilient multi-sensor monitoring strategy** for protecting our seas.

METHODOLOGY

CleanSeaNet collects satellite detections of possible surface pollution across EU waters.
We analysed **five years of operational data (2019–2023)**, focusing on four key SAR missions:

- **Sentinel-1** — wide-area, high-frequency coverage
- **Radarsat-2** — advanced polarimetry
- **TerraSAR-X** — high-resolution targeted monitoring
- **PAZ** — complementary X-band sensing

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SAR Dark Spot Detection

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Each detection was assigned to a CleanSeaNet category:
• Mineral oil
• Natural phenomena
• Nothing observed
• Other substance
• Unknown feature

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Confirmed events were validated through:
✈ Aerial surveillance
🚢 Vessel reports
∞ On-site inspections

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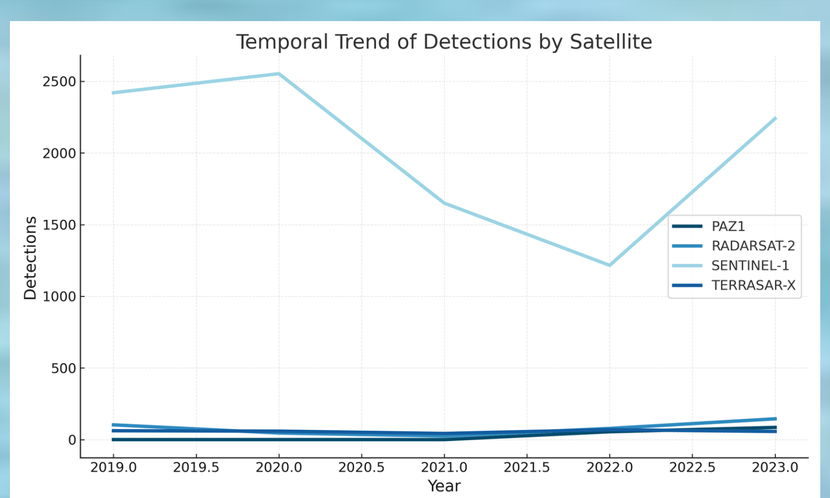
Final Determination
✓ Real Pollution
✗ False Positive



RESULTS & DISCUSSION

Detection Volume & Trends

Sentinel-1 produced the highest number of detections due to its wide coverage and frequent acquisitions. A decline in detections during 2021–2022 likely reflects operational adjustments and varying environmental conditions.

Detection Reliability

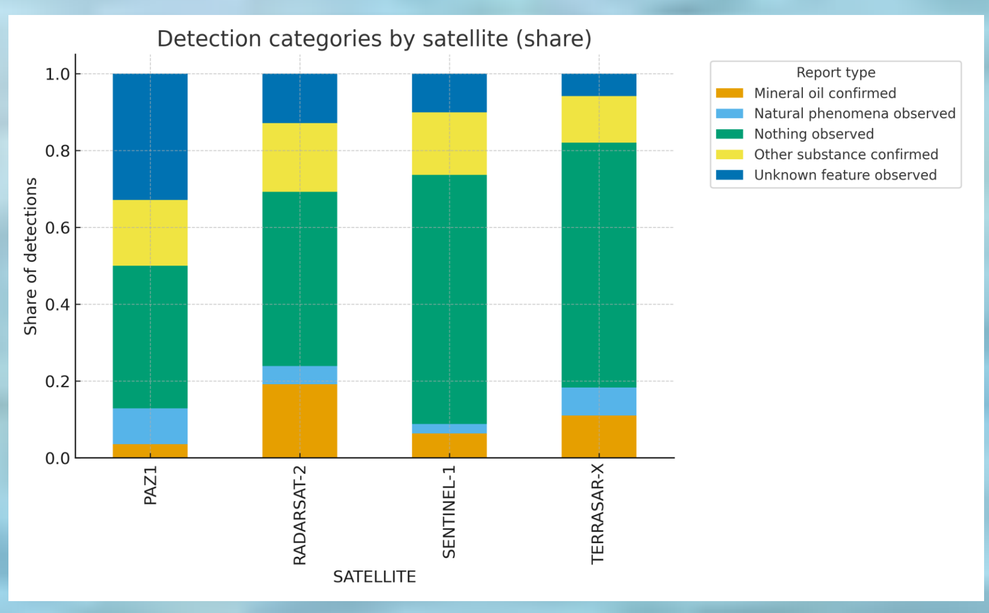
Radarsat-2 achieved the highest confirmation rate, benefiting from its fully polarimetric C-band system, which enhances oil–water contrast. TerraSAR-X delivered fewer detections but excelled in high-resolution verification, especially using Spotlight and StripMap modes. PAZ, introduced later, supplied targeted acquisitions that complemented the other missions.

Environmental Influence

Low wind speeds, biogenic slicks, and variable sea states significantly impacted detection performance—particularly for wide-swath systems—contributing to higher “Nothing observed” or “Natural phenomena” classifications.

Key Insight

Detection performance varied substantially across missions. Rather than competing, the satellites provide complementary strengths, confirming that a multi-mission approach is essential for reliable marine pollution monitoring.



CONCLUSION

A multi-sensor approach is not optional — it is essential.
Sentinel-1 ensures unmatched coverage
Radarsat-2 delivers the most reliable detections
TerraSAR-X and PAZ provide high-resolution confirmation
Together, they create a **resilient, adaptive, and effective monitoring network** for marine pollution surveillance across Europe.

FUTURE WORK / REFERENCES

To strengthen Europe’s pollution response capabilities, the next steps could include:
Sensor fusion: Integrating SAR with optical and thermal data to reduce look-alikes.
Real-time environmental layers: Wind and sea-state data can dynamically tune detection confidence.
AI-driven classification: Machine learning can improve feature recognition, reduce operator workload, and enhance reliability.

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