

Testing and progressive integration of AI-assisted electronic monitoring in tropical tuna longline fisheries: operational feedback from La Réunion in the context of IOTC EMS objectives and DigiWaves

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Abstract

The development of Electronic Monitoring Systems (EMS) within the Indian Ocean Tuna Commission (IOTC) framework is currently structured around a set of priority objectives, including the revision of Regional Observer Scheme (ROS) minimum data requirements, the implementation of pilot projects across fleets, and the development of interoperable and scalable monitoring architectures. This study provides a detailed operational assessment of an EMS deployed onboard a Réunion-based pelagic longliner (*Reder Mor*), and evaluates how this initial implementation contributes to progressing towards these objectives. Results demonstrate that, while EMS systems can effectively document fishing operations and provide continuous observational coverage, significant gaps remain in their ability to meet ROS minimum data requirements, particularly regarding species identification, bycatch monitoring, and gear-related data. These limitations are consistent with broader findings within the IOTC WGEMS process, which highlight the challenges of collecting certain data fields through EMS alone and emphasise the need for hybrid data collection approaches combining electronic monitoring, human observation, and complementary data sources. Within this context, the DigiWaves project represents a structured response to these challenges, aiming to integrate artificial intelligence, multi-source data fusion, and interoperable data frameworks to improve data quality, reduce analytical workload, and support compliance monitoring. This case study contributes directly to this roadmap by providing empirical evidence on system limitations, operational constraints, and pathways for improvement under real fishing conditions. This work sets EMS as a key component of a broader digital monitoring ecosystem under development within the IOTC framework.

Summary of ENEZ DU involvement in DigiWaves, implemented methodology and expected outcomes

Within the DigiWaves project, Armement ENEZ DU leads the case study dedicated to tropical tuna longline fisheries operating in the western Indian Ocean, with a specific focus on Réunion-based vessels. This involvement positions ENEZ DU as a key operational partner responsible for bridging technological development with real fishing conditions, thereby ensuring that the solutions developed within the project are both technically robust and operationally feasible. ENEZ DU facilitates the deployment of Remote Electronic Monitoring (REM) systems onboard commercial vessels, provide access to high-resolution operational datasets, and contribute to the evaluation of system performance in terms of data quality, compliance support, and usability under actual fishing constraints.

The methodology implemented within this framework is based on a progressive and integrated monitoring approach combining electronic observation, artificial intelligence, and multi-source data validation. REM systems are deployed across a sample of commercial longline vessels, with video data continuously recorded during fishing operations. These data are subsequently processed using AI-assisted tools designed to automatically detect and extract relevant fishing events, such as catch handling and gear retrieval sequences. A critical component of the methodology lies in the cross-validation of these automatically extracted data with independent sources, including Vessel Monitoring System (VMS) data and Electronic Reporting System (ERS) records, allowing for the reconstruction and verification of fishing activity. In addition, human review remains integrated into the workflow to validate AI outputs and ensure data reliability, in line with current IOTC recommendations on hybrid monitoring approaches.

The expected results of this approach are both operational and scientific. From an operational perspective, the project aims to significantly reduce the analytical workload associated with EMS data processing through the use of automated video analysis, thereby improving scalability at fleet level. From a scientific standpoint, the integration of multiple data streams is expected to enhance the accuracy and consistency of fisheries-dependent data, particularly regarding fishing effort, catch composition, and activity patterns. The system is also expected to improve traceability and support compliance monitoring by enabling systematic cross-checking between declared and observed fishing activities. More broadly, the DigiWaves case study is designed to provide empirical evidence on the feasibility, robustness, and added value of AI-assisted REM systems in tropical longline fisheries, contributing directly to the ongoing development of EMS standards and data requirements within the IOTC framework.

Project funding, consortium structure and extended scope

The DigiWaves project is funded under the European Union's Horizon Europe framework programme, which supports research and innovation initiatives addressing key societal and environmental challenges, including the digital transformation of marine and fisheries sectors. Within this context, DigiWaves is designed as a multi-partner, multidisciplinary project combining technological development, fisheries science, and governance innovation, with the objective of accelerating the transition towards integrated and data-driven Monitoring, Control and Surveillance (MCS) systems.

The consortium brings together a diverse set of stakeholders, including research institutions, technology providers, fisheries organisations, and policy actors. This multi-actor structure reflects the complexity of EMS implementation, which requires the integration of hardware systems, data infrastructures, analytical tools, and regulatory frameworks. In parallel, technology partners are responsible for the

development of REM systems and AI-based analytical tools, while scientific institutions contribute to the design of validation protocols, data analysis methodologies, and the assessment of system performance.

Beyond its technological objectives, the project adopts a systemic approach structured around several complementary components. These include an initial assessment of digital readiness across fisheries, the co-development of monitoring technologies, the deployment of pilot systems under real fishing conditions, and the construction of inter-operable data infrastructures. In addition, DigiWaves explicitly incorporates policy and governance dimensions, aiming to support the harmonisation of monitoring standards and facilitate the integration of EMS-derived data into existing regulatory frameworks. This approach is consistent with the need identified within the IOTC to align EMS capabilities with ROS data requirements and to ensure compatibility between different data collection and reporting systems.

The scope of the project extends across multiple fisheries contexts, including small-scale, long-distance, and recreational fisheries, thereby allowing for comparative analysis of EMS applicability across diverse operational settings. The Réunion case study focuses specifically on tropical tuna longline fisheries, providing a high-value test environment due to the complexity of operations, the diversity of target and non-target species, and the regulatory requirements associated with international tuna fisheries. Within this framework, the project not only aims to improve data collection and compliance monitoring but also to assess broader environmental and social sustainability aspects associated with the deployment of digital monitoring systems.

Overall, DigiWaves is designed as both a technological and institutional test bed, intended to generate empirical evidence on the feasibility, scalability, and added value of AI-assisted REM systems. By combining field deployment, data integration, and governance analysis, the project contributes to the development of next-generation fisheries monitoring systems capable of supporting more transparent, efficient, and science-based management at regional and international levels.

Introduction

The increasing demand for transparent, reliable, and cost-effective fisheries monitoring systems has become a central issue for Regional Fisheries Management Organizations (RFMOs), including the Indian Ocean Tuna Commission (IOTC). In this context, Electronic Monitoring Systems (EMS) are being progressively considered as a complementary or alternative tool to human observers within the Regional Observer Scheme (ROS), provided that they are capable of meeting minimum data requirements defined for scientific and compliance purposes. Recent developments within the IOTC framework, including the adoption of EMS standards and the ongoing revision of ROS data fields, highlight both the potential and the current limitations of these technologies. In particular, the IOTC Working Group on Electronic Monitoring Systems (WGEMS) has identified key challenges related to the ability of EMS to collect certain critical data fields, the need for cross-validation with other data sources, and the importance of pilot projects to assess operational feasibility under real fishing conditions. Within this evolving regulatory and technical context, the deployment of EMS systems in tropical tuna longline fisheries offers a valuable opportunity to generate empirical evidence on system performance, data quality, and integration pathways. The present study contributes to this effort by providing a first operational evaluation of EMS implementation onboard a Réunion-based longliner, and by positioning these results within the broader development framework of the DigiWaves project, which aims to support the transition towards integrated, AI-assisted, and interoperable monitoring systems in the Indian Ocean.

Methodology

This report is based on a first operational EMS deployment conducted onboard the pelagic longliner *Reder Mor*, operating in the western Indian Ocean under the Armement ENEZ DU fleet. The evaluation followed a dual observation protocol combining a human observer operating under the IOTC Regional Observer Scheme (ROS) and an Electronic Monitoring System (OceanLive, Thalos). This design allowed for a direct comparison between human-collected and EMS-derived datasets, in line with WGEMS recommendations to cross-validate electronic monitoring outputs with other data sources.

The EMS system consisted of multiple cameras, GPS positioning, and onboard recording infrastructure. The assessment framework was structured around the capacity of the EMS to collect data aligned with ROS minimum requirements, including fishing operations, catch composition, bycatch interactions, and gear configuration. Particular emphasis was placed on identifying which data fields could be reliably collected through EMS, which required complementary sources (e.g. logbooks, VMS, ERS), and which remained inaccessible under current technological configurations.

Video data were analysed post-trip using dedicated software, with full review of fishing operations. Analytical effort was quantified in terms of processing time per fishing event and per trip. Additional evaluation criteria included camera coverage, image resolution, temporal synchronisation between sensors, and the ability to reconstruct fishing events and biological observations.

This initial phase is directly extended within the DigiWaves framework through the deployment of Remote Electronic Monitoring (REM) systems across six vessels, combined with the implementation of AI-assisted video processing, automated event detection, and integration with external data sources such as VMS and ERS. This approach aligns with WGEMS priorities related to pilot project development, cross-validation of data sources, and the identification of EMS capabilities and limitations in relation to ROS data requirements.

Results and progress towards IOTC EMS objectives

The results of the EMS deployment provide a detailed insight into the current capabilities and limitations of electronic monitoring systems in tropical tuna longline fisheries, and allow for a direct evaluation of progress against the priority objectives defined by the IOTC WGEMS programme of work.

First, the system demonstrated its capacity to document fishing operations continuously, confirming that EMS can provide a robust baseline for recording fishing effort and operational sequences. This directly contributes to the WGEMS objective of facilitating EMS pilot projects and assessing their ability to support fisheries monitoring under operational conditions. However, the analysis also revealed that camera coverage remains a critical limitation, with persistent blind spots in key operational areas such as stern sections and handling zones. These gaps significantly reduce the probability of detecting bycatch events, particularly when individuals are not brought onboard, thereby limiting the system's ability to fulfil ROS requirements related to species interactions and ecosystem monitoring.

Second, the study confirms that species identification remains one of the main bottlenecks for EMS implementation. The inability to reliably distinguish between morphologically similar tuna species, as well as the difficulty in identifying shark species under typical fishing conditions, directly affects the scientific usability of the data. This limitation is consistent with WGEMS findings indicating that some ROS data fields, particularly those requiring fine taxonomic resolution, are difficult or currently impossible to collect using EMS alone. As a result, the current EMS configuration does not yet meet the minimum data standards required for stock assessment and bycatch evaluation.

Third, the analysis highlights a structural limitation related to the absence of gear-specific data. Key parameters such as hook type, bait characteristics, and line configuration could not be captured through video observation. This finding aligns with WGEMS conclusions that several gear-related data fields must be collected through alternative means, such as logbooks, national registries, or direct reporting by fishers, rather than through EMS systems. This reinforces the need for integrated data collection frameworks combining multiple sources of information.

Fourth, the analytical workload associated with EMS data processing remains a major constraint. The time required to analyse video data, estimated at 6 to 9 hours per fishing operation, highlights the current lack of scalability of EMS systems when applied to full fleets. This issue directly relates to WGEMS priorities concerning the development of innovative tools, including artificial intelligence and machine learning, to improve data processing efficiency and reduce operational costs.

Despite these limitations, the study demonstrates clear progress towards several key WGEMS objectives. The implementation of a real-scale pilot provides empirical evidence on system performance, contributes to the identification of data fields that can be reliably collected through EMS, and supports the ongoing revision of ROS minimum data requirements. Furthermore, the comparison between EMS and human observer data contributes to the cross-validation efforts explicitly identified as a priority within the WGEMS programme of work.

Expected results under DigiWaves

The DigiWaves project is expected to significantly improve the performance of EMS systems by addressing the key limitations identified in this study through a combination of technological and methodological innovations. The integration of artificial intelligence for automated video analysis will enable the detection and extraction of relevant fishing events from large datasets, thereby reducing the

analytical workload and improving scalability. This directly contributes to the WGEMS objective of developing innovative tools and strategies for EMS data analysis.

In addition, the integration of multiple data streams, including VMS and ERS data, will enable cross-validation of fishing activity and improve the reliability of reconstructed fishing events. This approach aligns with WGEMS priorities related to data interoperability and the harmonisation of data collection systems across fleets and jurisdictions.

Improvements in camera systems, including optimized positioning and enhanced image quality, are expected to reduce blind spots and improve species identification capabilities. While these improvements may not fully resolve all limitations, they are expected to significantly increase the proportion of usable data for scientific and compliance purposes.

Finally, the development of interoperable data infrastructures will facilitate the integration of EMS data into existing IOTC reporting frameworks, supporting both scientific analyses and compliance monitoring. The Réunion case study will provide critical empirical data to evaluate these improvements under real fishing conditions.

Expected advancements in relation to IOTC roadmap

The work presented here contributes directly to the implementation roadmap defined by the IOTC WGEMS for the period 2024–2028. In particular, it supports priority actions related to the review of EMS data fields, the development of pilot projects, and the identification of EMS capabilities and limitations in relation to ROS requirements.

By providing detailed operational feedback, this study contributes to refining the understanding of which data fields can realistically be collected through EMS, which require complementary data sources, and which may need to be redefined within the ROS framework. This directly feeds into the ongoing revision of ROS minimum data requirements, which remains a central objective of the WGEMS.

Furthermore, the integration of EMS within a broader digital ecosystem, as proposed by DigiWaves, represents a significant step towards achieving interoperability between monitoring systems, improving data quality, and enabling scalable deployment across fleets. This approach is consistent with WGEMS priorities related to compatibility between databases, standardisation of data formats, and the development of innovative monitoring tools.

Ultimately, this study demonstrates that progress towards fully operational EMS-based monitoring systems will require a combination of technological innovation, methodological adaptation, and regulatory evolution. EMS should therefore be considered not as a replacement for existing monitoring systems, but as a central component of a hybrid and progressively integrated monitoring framework within the IOTC.

Conclusion

This study provides a first operational evaluation of an Electronic Monitoring System (EMS) deployed in a tropical tuna longline fishery in the western Indian Ocean, and situates these results within the broader framework of IOTC EMS development. The findings confirm that EMS technologies are capable of delivering continuous and verifiable records of fishing operations, thereby contributing to improved transparency and supporting key Monitoring, Control and Surveillance (MCS) objectives. However, the results also demonstrate that, under current configurations, EMS systems remain limited

in their ability to fully meet the minimum data requirements of the Regional Observer Scheme (ROS), particularly with respect to species identification, bycatch monitoring, and the collection of gear-specific information.

These limitations are consistent with the broader conclusions of the IOTC WGEMS process, which emphasises that certain data fields cannot currently be collected reliably through EMS alone and require complementary data sources or methodological adaptations. In this context, the results of this study reinforce the relevance of hybrid monitoring approaches combining EMS, human observation, and additional reporting systems, as an interim solution for ensuring compliance and data quality.

At the same time, the study demonstrates that EMS pilot deployments play a critical role in advancing the IOTC roadmap by providing empirical evidence on system capabilities, identifying operational constraints, and informing the ongoing revision of ROS data requirements. The transition towards more advanced systems, as proposed under the DigiWaves project, is expected to address several of the key limitations identified, notably through the integration of artificial intelligence, multi-source data fusion, and interoperable data infrastructures.

Ultimately, the results support a progressive and adaptive implementation pathway for EMS within the IOTC, in which technological innovation, regulatory evolution, and operational experience are developed in parallel. EMS should therefore be considered not as a direct substitute for human observers in the short term, but as a foundational component of an integrated and scalable monitoring system capable of supporting more transparent, data-driven, and effective fisheries management in the Indian Ocean.