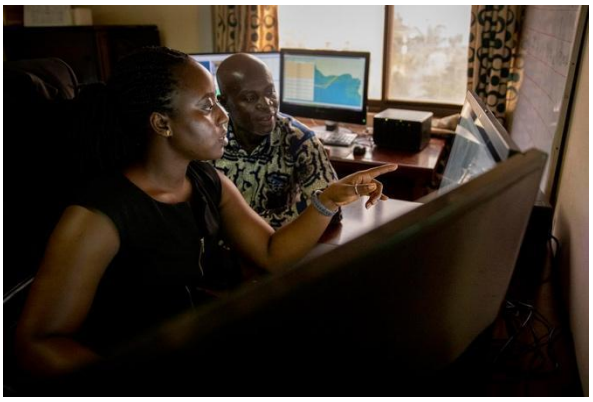
Technical Source Document on the Governance of Electronic Monitoring (EM) Systems for Industrial Tuna Fisheries



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Authors

Melissa Garren, Working Ocean Strategies
Mark Michelin, CEA Consulting
Vishwanie Maharaj, World Wildlife Fund Inc.

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Executive Summary

This work aims to serve as a technical resource document for the development of governance for Electronic Monitoring (EM) programs for industrial tuna fisheries. Research gaps and areas of greatest need for EM governance resources were identified through an extensive literature review coupled with consultations with government and non-governmental EM stakeholders and experts.

The resulting document describes the current context and progress towards the implementation of EM at the Regional Fisheries Management Organization (RFMO) level. It also defines the key elements of designing and implementing EM Programs, summarizes the existing landscape of EM standards, tools, and guidance documents, and highlights key decision points relating to EM governance that stakeholders will need to address along the way. Finally, it describes a series of legal and regulatory considerations, as well as technical and logistical considerations relating to governance decisions.

Given the relatively early developmental stage of EM Programs within RFMO tuna fisheries, this document describes different, valid implementation scenarios for stakeholders to consider. It also describes the possible implications of choosing one pathway versus another. It compares the advantages and challenges of pursuing a centralized governance structure versus a harmonized decentralized approach. The document likewise details the trade-offs of pursuing different engagement structures with EM Service Providers, such as sole-source versus multi-provider models, to implement either a centralized or harmonized decentralized EM Program. It also describes three different scenarios for EM system certification mechanisms, each of which has advantages and challenges for ensuring that only high quality, reliable systems are used to meet programs' data collection needs.

While this document aims to serve as a comprehensive reference, there remain specific topics that will require additional research beyond the scope of work presented here to achieve the RFMO-, country- or fishery-specific detail required for successful EM Program implementation. This work identifies financial considerations as the biggest need for additional research due to a lack of transparency of EM Program costs, uncertainty regarding the financial implications of different cost recovery approaches or EM system certification mechanisms, and the current information barriers to effectively share experiences across programs and geographies. This document also explores decisions surrounding Data Review Center structure, implementation, and administration as a critical set of governance decisions that can significantly influence program cost. Due to the early nature of EM programs at the RFMO level, the field lacks the empirical evidence to definitively conclude which design options are optimal under different scenarios. This experience and evidence will be gained as EM continues to advance in this context. This work concludes with a set of concrete recommendations for developing additional resources to aid in the digestibility of this document and facilitate actionable next steps for EM governance stakeholder

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Terms and Definitions

Artificial Intelligence (AI) - The theory and development of computer systems which are able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages.
Control Center - The EM control center is a computer and software system that records and stores information from EM System components (e.g., video, Sensor data, GPS data, system log data). It also controls the operation of onboard EM system components.
Data Records – Electronic or physical records or entries in a data file or database.
Data Review Center (DRC)- A facility with supporting software platform(s) used to analyze e-monitoring records and record e-monitoring data.
Electronic Monitoring (EM)- A system of cameras and sensors capable of monitoring and recording fishing activities, which can be reviewed to collect fishing data.[1]
EM Analyst - A person qualified to analyze e-monitoring records and record e-monitoring data in accordance with the EM standard and analysis procedures.
EM Analysis - The data results and reports provided by an EM analyst.
EM Analysis Rate - The proportion of e-monitored records that are analyzed.
EM Data - Data produced through an analysis of e-monitoring records that conforms to the data standards specified in the program's standards, specifications, and procedure.
EM Program- The specific set of objectives, requirements, implementation strategies, logistical protocols, and methods to collect, analyze, and store images and video of fishing activities. Such results are shared with authorized entities (e.g., managers, scientists, vessel owners, etc.).
EM Records - Imagery (still images and video) and Sensor data recorded by an EM System that can be analyzed to produce EM Data. Sensors may include any number of Sensors (e.g., hydraulic sensors) that are part of the EM equipment and whose data is recorded on the vessel as part of the EM system.
EM Records Analysis/Interpretation - The process by which an EM Analyst reviews EM records and converts them into EM Data
EM Service Provider - A third-party provider of EM technical and logistical services. An EM Program may have multiple EM Service Providers and they may provide different services within the program (e.g., on-board hardware, DRC software, DRC review services).
EM System - All the vessel and shore-based components supporting the acquisition, analysis and reporting of EM Records.
Independent - with respect to audits - no financial or current employment interest with the DRC or the fishing industry that's under review.
Machine Learning (ML) - A subset of AI that refers to the use and development of computer systems that can learn and adapt without following explicit instructions. Instead, they learn by using algorithms and statistical models to analyze and draw inferences from patterns in data.
Sensor - A device that responds to a physical stimulus (e.g., motion) and transmits a resulting impulse that can be recorded as a measurement. EM systems may be equipped with a variety

[1] Adapted from Australian Fisheries Management Authority (AFMA): https://www.afma.gov.au/fisheries-management/monitoring-tools/electronic-monitoring-program#referenced-section-1

of integrated Sensors that can provide information on fishing activity, trigger activation, or adjustment of configurations of cameras. A Sensor can also identify points of interest to expedite EM video review. This may include the use of camera imagery as a Sensor.
Vessel Monitoring Plan (VMP) - A document describing how an Electronic Monitoring system is specifically positioned and configured on a vessel and how fishing operations on that vessel will be conducted to allow effective monitoring of fishing activity and accurate generation of EM Data.

Acronyms

Acronym	Full Description
ACAP	Agreement on the Conservation of Albatrosses and Petrels
AFMA	Australian Fisheries Management Authority
AI	Artificial intelligence
DCC	Data Collection Committee
DOS	Digital Observer Services
DRCs	Data Review Centers
DWFN	Distant Water Fishing Nation
EEZ	Exclusive Economic Zone
EM	Electronic Monitoring
EMS	Electronic monitoring systems
EPO	Eastern Pacific Ocean
ETPS	Endangered, Threatened and Protected Species
EU	European Union
FAO	Food and Agriculture Organization
FFA	Forum Fisheries Agency
GEF	Global Environmental Facility
GEMS	Global Electronic Monitoring Symposium
HMS	Highly Migratory Species
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IOTC	Indian Ocean Tuna Commission
ISSF	International Seafood Sustainability Foundation

LL	Longline
LEO	Low Earth Orbit
ML	Machine Learning
NRT	Near real-time
PNA	Parties to the Nauru Agreement
REM	Remote Electronic Monitoring
RFMO	Regional Fisheries Management Organization
RFP	Requests for Proposals
SAFET	Seafood and Fisheries Emerging Technologies
SSPs	Standards, Specifications, and Procedures
TNC	The Nature Conservancy
t-RFMO	Tuna Regional Fisheries Management Organization
VMP	Vessel Monitoring Plan
VMS	Vessel Monitoring System
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WGTIFD	Working Group on Technology Integration for Fishery Dependent Data
WWF	World Wildlife Fund

Document Overview

This document aims to serve as a technical resource document for the development of governance for Electronic Monitoring systems (EM) in industrial tuna fisheries. It summarizes the existing landscape of tools and recommendations for EM Program design and implementation and highlights key questions that individual and regional stakeholders in Regional Fisheries Management Organizations (RFMOs) will need to address. It has been developed with the help of on-going stakeholder consultations and is intended to serve as a reference resource for all stakeholders engaged in the development of EM governance of tuna fisheries.

Given the relatively early developmental stage of EM Programs within RFMO tuna fisheries, this document describes different potential implementation pathways for governing officials to consider along with the possible implications of choosing one pathway versus another (see Key Scenarios section). This technical source document is intended to consolidate existing information, technical references, and resources relevant to the governance of EM into a single resource to assist stakeholders in navigating the development and implementation of EM throughout industrial tuna fisheries. This document has been developed with the aid of consultations with government stakeholders and nongovernmental EM experts (see Appendix 2). While this document aims to serve as a comprehensive reference, there remain specific topics (such as financial and cost considerations) that will require new or deeper research to achieve the country-specific detail required for successful implementation. This document concludes with a set of recommendations for additional resource development that would aid in the digestibility of this resource and facilitate actionable next steps for EM governance stakeholders.

Context for Electronic Monitoring in Tuna RMFOs

The design of a program to govern EM can proceed in several different ways, depending on what functions a government agency chooses to implement in-house, how the program will be financed, and whether it is conducted in conjunction with other government agencies, private sector technology, fishing industry stakeholders, or regional bodies. Given that most countries stand to benefit from adaptive fisheries management and transboundary cooperation for stock management in the face of a changing climate,[2] one shared priority, regardless of the specific programmatic pathway pursued, will be for regional fisheries management and regulatory strategies to explicitly build flexibility and adaptability into their base frameworks.

Policies that focus on purpose and performance, rather than specific technical attributes, are essential tools for building such an adaptive framework. They provide the necessary space for innovative management measures and technologies to evolve, and thus enable more effective

[2] Free CM, Mangin T, Molinos JG, Ojea E, Burden M, Costello C, et al. (2020) Realistic fisheries management reforms could mitigate the impacts of climate change in most countries. PLoS ONE 15(3): e0224347. https://doi.org/10.1371/ journal.pone.0224347

fisheries management over the long-term. Setting clear performance requirements and data standards can provide effective system-wide oversight while also allowing sufficient flexibility to tailor programs to local needs.[3] This performance-focused strategy is an appropriate basis for the implementation of any EM governance framework scenario that may be pursued.

I. EM Governance Needs and the Role of Standards

While minimum standards are the central focus of many current RFMO EM discussions, they are just one of several key elements that must underpin EM implementation at the local, regional and global levels. Gillman 2023 articulated the role of minimum standards, saying:

> "*Minimum standards for fisheries EM systems are needed to define technical specifications for selecting, installing, operating and maintaining EM equipment (e.g., cameras, Sensors and data storage devices) and software; logistical specifications related to how EM Data are stored and transferred; minimum requirements for EM Analysts and their accreditation; and operational specifications on EM Data fields and data collection protocols and on how EM Data are reviewed (Restrepo et al., 2018; ACAP. 2021; IATTC, 2020, 2021a; IOTC, 2021a)*"[4]

These standards set an important baseline and support structure for the development of EM Programs throughout t-RFMOs (Tuna Regional Fisheries Management Organizations). They work hand in hand with a suite of complementary and guiding structures and policies. To lay out all of those elements, this list summarizes the full complement of governance needs for EM at the RFMO level. This will be discussed in more detail in the following sections:

A. Appropriate national regulations/legislation that require data collection or monitoring that can be gathered using EM. Regulatory structures must also allow EM Data to be collected and define how it can be used, transmitted, and made accessible to external parties.
B. EM policy and guidance documents that define the objectives and needs of the programs. These documents define data needs and thus inform minimum standards for EM systems at the regional level.
C. Minimum standards for EM systems (e.g., all of the vessel and shore-based components supporting the acquisition, analysis, and reporting of EM Records) at the RFMO level to set a baseline expectation for program quality and functionality. All stakeholders will benefit if these standards are also harmonized across RFMOs.
D. Multinational or regional agreements to enable effective EM Data use in the management of highly migratory species. (i.e., to address data sharing, access, privacy, that data standards for formats and quality are met consistently, etc.)

[3] Garren M, Lewis F, Sanchez L, Spina D, & Brett A (2021) How performance standards could support innovation and technology-compatible fisheries management frameworks in the US. Marine Policy, 131, 104631. https://doi.org/10.1016/j.marpol.2021.104631

[4] Gillman, 2023 - BENCHMARKING INTERGOVERNMENTAL ORGANIZATIONS' DEVELOPMENT OF MINIMUM STANDARDS FOR FISHERIES ELECTRONIC MONITORING SYSTEMS; pg.1

E. Specifications and procedures that accompany the standards to harmonize expectations for key processes such as system approval/certification processes, installation and maintenance of systems, chain of custody for EM records and data, review and analysis processes, personnel qualifications and training procedures, auditing, management of data systems with the appropriate security, etc. This includes the elements that pertain to EM Service Provider engagement– contracting structures, roles and responsibilities, approval mechanisms, failure protocols, etc. These specifications and procedures also play an important role to ensure EM Service Providers have a clear understanding of what capabilities and design features will be need in the EM Systems.
F. The necessary infrastructure to implement the program and carry out data analysis, which can be constructed through a variety of in-house and 3rd party contractor scenarios.
G. A consultation program for relevant stakeholders to troubleshoot and improve all aspects of the system, including periodic review and updating of the standards and procedures.
H. Resources to train and maintain personnel on relevant tasks listed above.

The process of drafting and refining standards for EM can serve as an important conversation opener for other critical elements of stakeholder engagement dialogue which help define implementation strategies. In the context of t-RFMOs, the standards drafting process has helped to catalyze some of these parallel conversations in a variety of different forums including individual RFMO EM working groups,[5,6,7,8] regular RFMO membership meetings (both full membership regular sessions as well as science-focused sessions[9]), subregional membership organizations such as the Forum Fisheries Agency (FFA)[10], within individual nations as they pilot EM, and international platforms such as the Seafood and Fisheries Emerging Technologies[11] (SAFET), the online EM4Fish community,[12] and the Global Electronic Monitoring Symposium (GEMS).[13] The global gathering of stakeholders who attended GEMS helped to produce five whitepapers on key topics that arose during that symposium.[14] The white papers cover the role of market stakeholders and supply chains in driving EM,[15] Artificial

[5] https://www.iattc.org/GetAttachment/af906d33-47ec-446c-9f29-7640e045e663/WGEM-01-01_Outcomes-of-the-EMS-workshops.pdf
[6] https://iotc.org/sites/default/files/documents/2021/11/IOTC-2021-WGEMS01-10.pdf
[7] https://www.iccat.int/Documents/Meetings/Docs/2023/REPORTS/2023_EMS_ENG.pdf
[8] https://meetings.wcpfc.int/index.php/meetings/erandemwg5
[9] https://www.iattc.org/getattachment/a895f682-b6f7-4c32-8c3b-8c1d1c7b66d8/SAC-11-10-MTG_Standards-for-electronic-monitoring-(EM).pdf
[10] https://meetings.wcpfc.int/file/11841/download
[11] https://safet.fish
[12] https://em4.fish/
[13] https://www.pewtrusts.org/en/research-and-analysis/articles/2023/01/18/the-global-electronic-monitoring-symposium
https://www.pewtrusts.org/-/media/assets/2022/12/harmonizing-tuna-rfmo-electronic-monitoring-standards.pdf
[14] https://www.pewtrusts.org/en/research-and-analysis/articles/2023/01/18/the-global-electronic-monitoring-symposium
[15] The Role of Market Stakeholders in Integrating EM Into Supply Chains

Intelligence and Machine Learning considerations,[16] EM Provider engagement in standards development,[17] data for cost-benefit analysis,[18] and the importance of harmonization across RFMOs.[19] Pew Charitable Trust has been hosting follow-on meetings for stakeholders to further pursue some of those individual topics, such as Artificial Intelligence and Machine Learning[20] and EM Service Provider engagement with t-RFMO standards development and harmonization.[21]

Noteworthy topics of conversation that have been raised in these various venues and continue to be important governance questions for stakeholders include:

A. The harmonization of standards (see Box 1)
B. Options for EM certification mechanisms to ensure high quality equipment, data, and services across regions
C. The advantages and challenges of different implementation pathways with respect to EM Service Provider engagement options
D. Options for EM Program structures (see scenarios A-C and Box 2)
E. Opportunities for regulatory and policy reforms or cooperative agreements that could improve program effectiveness and efficiency (including with respect to compliance needs and data sharing) or reduce costs (e.g., bulk procurement,[22] harmonized hardware requirements for vendors, shared or centralized infrastructure for data analysis, management, and storage, etc.). (see legal/regulatory consideration section, Box 1, DRC section under Scenario C, Box 2, Box 3)
F. How regions might handle issues surrounding interoperability (see Box 3)
G. Data privacy and access (see Define access rights and ownership of EM Records and Analyzed Data)
H. The equitable distribution of the socio-economic consequences of a regional scale program
I. Program funding and cost-recovery (see Cost Recovery Guidelines for Electronic Services)

[16] Considerations for Artificial Intelligence and Machine Learning Applications in Electronic Monitoring
[17] Engagement of Electronic Monitoring Providers in Electronic Monitoring Standards Development
[18] Data for Electronic Monitoring Cost-Benefit Analysis
[19] Harmonizing Tuna RFMO Electronic Monitoring Standards
[20] https://em4.fish/wp-content/uploads/2023/07/Pew-AI-Summit-January-2023-Summary.pdf
[21] https://em4.fish/wp-content/uploads/2023/06/Pew-EMSP-Workshop-Summary-Report-6.23.23.pdf
[22] GLOBAL ELECTRONIC MONITORING ACCELERATOR: SUPPORTING INDUSTRY AND GOVERNMENT LEADERSHIP IN EM PROGRAM DESIGN & IMPLEMENTATION OVERVIEW DOCUMENT(July 2022) https://meetings.wcpfc.int/index.php/node/15643

Box 1: Harmonization Benefits

The **harmonization** of standards is the process of reducing conflicting or redundant elements from multiple sets of standards that may have evolved independently and have overlapping influence on a market, process, or field.[23] All EM stakeholders stand to benefit from increased harmonization across RFMO EM standards.

The benefits of harmonization include:

- Cost efficiencies for all stakeholders (better for vendors, bulk procurement opportunities for programs, less customization costs to programs/fishers, no duplication of capabilities required for vessels working in multiple jurisdictions, etc.)
- Better engagement with vendors
- More reliable quality and data for compliance and science regionally
- Better stock management
- Interoperability for vessels working across multiple RMFO jurisdictions

II. Current State of t-RFMO EM Standards Development:

EM Programs are increasingly being used to meet the data needs of robust fisheries science, management, and compliance in complement with conventional onboard human observer programs or institute at-sea monitoring where none previously existed.[24] All tuna RFMOs (t-RFMOs) are discussing EM and are at various stages of progress towards solidifying policies and implementation strategies.[25] The infographic below, produced by the International Seafood Sustainability Foundation (ISSF) in 2023, provides a succinct overview of the current state of EM progress across the RFMOs. Briefly, all four major t-RFMO's have drafted EM standards as one key step towards regional EM implementation. They are in the process of refining and adopting these standards. IOTC was the first to adopt standards, with ICCAT having recently followed suit. WCPFC is seeking to adopt standards by the end of next year (2024), and IATTC is on track to adopt standards by 2025.[26] Progress towards the RMFO-level minimum standards is encouraging and can help to foster additional conversations at the RFMO, regional, and national levels that will ultimately underpin individual national and program-level implementation success. Within those conversations, we note that all stakeholders stand to benefit from increased harmonization across regions and RFMOs with respect to the minimum standards adopted for EM (see Box 1 above).

[23] Pelkmans, J. (1987). "The New Approach to Technical Harmonization and Standardization". JCMS: Journal of Common Market Studies. 25 (3): 249–269. https://onlinelibrary.wiley.com/doi/10.1111/j.1468-5965.1987.tb00294.x

[24] Van Helmond, A., Catchpole, T., Mortensen, L., et al. 2019. Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. Fish and Fisheries 21: 162-189.

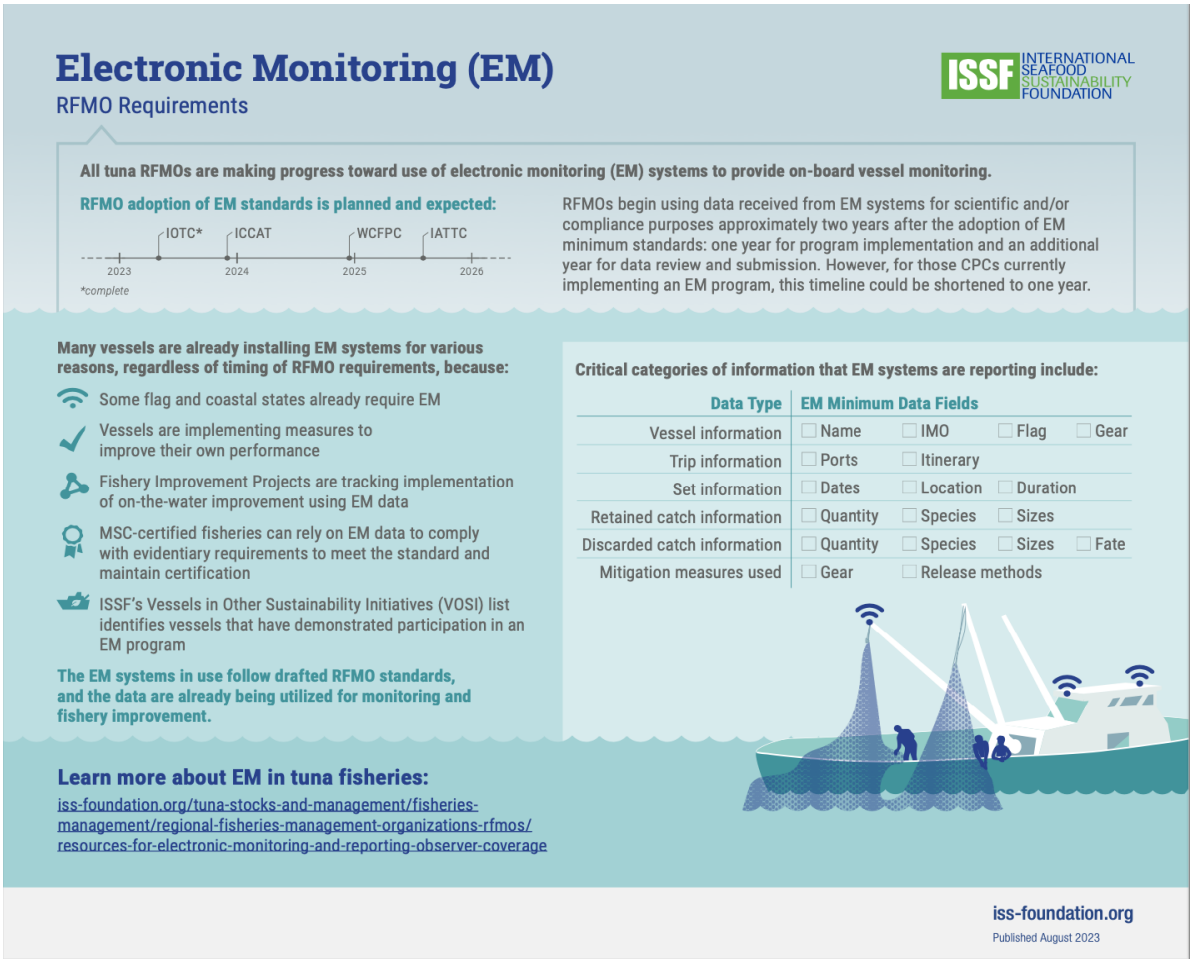
[25] Gillman, E. 2023. Benchmarking Intergovernmental Organizations' Development of Minimum Standards for Fisheries Electronic Monitoring Systems. Fisheries Circular.

[26] Links to each set of these standards are provided in the Existing t-RFMO Standards subsection below.

In May of 2023, Pew Charitable Trust hosted a noteworthy gathering of EM Service Providers to review each of the available t-RFMO EM Standards and provide a technical expert perspective of their current state. As their feedback document summarizes,

> "*Overall, there was broad agreement that RFMO standards should be focused on the EM outputs, (i.e., mandating which data are collected, reviewed, and reported, instead of how it is collected) and should incorporate flexibility to enable ongoing innovation and technical development, including the developments in relation to Artificial Intelligence and Machine Learning.*"[27]

The initial adopted standards (i.e., IOTC and ICCAT) and those en route to adoption (i.e., IATTC and WCFC) each made a commendable effort to focus on performance and outputs rather than the technical details of how those goals are achieved; however, the attendees notes areas in each set of standards that could be further refined to more fully align with the goal of implementing fully performance-focused standards. This feedback, along with the more detailed assessment of individual standards provided in that document, clearly signals that the t-RFMO-level EM Standards will need structures and processes in place to continue evolving over time.



[27] Pew. Outcomes: 2023 Workshop on RFMO Engagement for EM Service Providers. Pg. 2 (link)

Status of the development of minimum standards for Electronic Monitoring by t-RFMO[28]

No Discussions Underway	Being Discussed	Planned	Draft Standards Developed	Standards Adopted
	CCSBT 会員 みなみまぐろ保存委		CIAT IATTC Western and Central Pacific Fisheries Commission	iotc ctoi ICCAT

Existing t-RFMO standards:

A. WCPFC Draft Standards[29]
B. IATTC - Technical Standards of an EMS[30]
C. IOTC - On Electronic Monitoring Standards for IOTC Fisheries[31]
D. ICCAT- Recommendation by ICCAT to Establish Minimum Standards and Program Requirements for the use of Electronic Monitoring Systems (EMS) in ICCAT Fisheries[32]

Additional EM Standards, Program Guidelines, and Documentation

Beyond the t-RFMOs, there are also several additional standards, specifications, and procedures (SSPs); and other program documentation that have been developed for EM by other multinational organizations, countries, and nonprofits. These standards can be used to inform the development of SSPs to support implementation of RFMO minimum standards. Key examples include:

[28] Gillman, E. 2023. Benchmarking Intergovernmental Organizations' Development of Minimum Standards for Fisheries Electronic Monitoring Systems. Fisheries Circular.
[29] Western and Central Pacific Fisheries Commission, 2022. Standards Specifications and Procedures for the WCPFC Electronic Monitoring Program. Working Draft.
[30] Inter-American Tropical Tuna Commission, 2022. Technical Standards of an EMS. Document EMS-04-01.
[31] Indian Ocean Tuna Commission, 2023. Resolution 23/08 On Electronic Monitoring Standards for IOTC Fisheries.
[32] International Commission for the Conservation of Atlantic Tunas, 2023. Explanatory note to Draft Recommendation by ICCAT to Establish Minimum Standards and Program Requirements for the use of Electronic Monitoring Systems (EMS) in ICCAT Fisheries. PWG_415B/2023.

A. Forum Fisheries Agency - Draft Standards, Specifications and Procedures for hardware, data analysis, and data management (link).[33]
B. European Union (EU)
    a. Fisheries Control Regulation (EU) 2023/2842 which requires the installation of EM systems on vessels >18m in length that pose a high risk of non-compliance. It also mandates the Commission to develop detailed rules on requirements, technical specifications, installation, maintenance, functioning of EM systems, and when EM systems must be operating. (link)[34]
    b. Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries (link)[35]
B. Spain
    a. UNE 195007 Electronic monitoring on fishing vessels. Requirements. (link)[36]. This is a voluntary standard which, to our knowledge, has not been referenced in any regulatory or legislative actions.
C. Chile
    a. Chile Resolución Exenta Nº 3885 de 31 de Agosto de 2018 que Establece Estándar Técnico Único del Dispositivo de Registro de Imágenes. (link)[37]
    b. Chile Resolución Exenta Nº 876 de 13 de Abril de 2020 que Modifica Resolución Exenta Nº 3885 de 31 de Agosto de 2018 que Establece Estándar Técnico Único del Dispositivo de Registro de Imágenes. (link)[38]
D. United States
    a. Northeast Multispecies Sector EM Standards (link - See page 64)[39]
    b. Northeast Fisheries Science Center EM Reviewer Guidance (Link)[40]
    c. 2021 West Coast Groundfish Electronic Monitoring Program: Electronic Monitoring Service Plan Guidelines (link)[41]

[33] Forum Fisheries Agency, 2022. Information Paper on the FFA Final Draft EM SSPs – Endorsed as Interim Guidelines. WCPFC19-2022-DP08.
[34] The European Parliament and the Council of the European Union, 2023. REGULATION (EU) 2023/2842 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 November 2023 amending Council Regulation (EC) No 1224/2009, and amending Council Regulations (EC) No 1967/2006 and (EC) No 1005/2008 and Regulations (EU) 2016/1139, (EU) 2017/2403 and (EU) 2019/473 of the European Parliament and of the Council as regards fisheries control.
[35] European Fisheries Control Agency, 2019. Technical guidelines and specifications for the implementation of Remote Electronic Monitoring (REM) in EU fisheries.
[36] Asociación Española de Normalización, 2022. UNE 195007 Observación electrónica en buques pesqueros Requisitos.
[37]SERNAPESCA, 2018. Resolución Exenta Nº 3885 de 31 de Agosto de 2018.
[38] SERNAPESCA, 2020. Resolución Exenta Nº 876 de 13 de Abril de 2020 que Modifica Resolución Exenta Nº 3885 de 31 de Agosto de 2018 que Establece Estándar Técnico Único del Dispositivo de Registro de Imágenes.
[39] National Oceanic and Atmospheric Administration, 2023. Sector Operations Plan, Contract, and Environmental Assessment Requirements.
[40] National Oceanic and Atmospheric Administration, Northeast Fisheries Science Center, 2023. EM Reviewer Guidance Document.
[41] National Oceanic and Atmospheric Administration, 2021. 2021 West Coast Groundfish Electronic Monitoring Program: Electronic Monitoring Service Plan Guidelines.

d. National Oceanic & Atmospheric Administration Electronic Monitoring Regulation for Atlantic Highly Migratory Species (HMS) (link)[42]
e. 2024 Vessel Monitoring Plan Template EM Selection Alaska Regional Office (Link)[43]
f. Independent third-party monitoring provider standards: 50 CFR 648.87(b)(4) and 50 CFR 648.87(b)(5)[44]

E. Scotland
   a. Invitation to Tender for the Modernisation of Scotland's Inshore Commercial Fishing Fleet Framework: Tender Reference:Case/208857

F. New Zealand
   a. Fisheries (Electronic Monitoring on Vessels) Regulations 2017, updated October 2023 (link)[45]
   b. Ministry of Primary Industries, RFP 18631 On-board Cameras (link)[46]

G. Australia
   a. Request for Information (RFI) for exploration of Electronic Monitoring services, 2021. (link)[47]
   b. Overview of Australia's EM Program (2020; link)[48] and a short flier targeting the fishing industry audience that describes their responsibilities under the EM Program (link)[49]

H. International Seafood Sustainability Foundation
   a. ISSF Minimum Standards for LL and PS[50]

Available EM Roadmaps and Toolkits

Creating EM policies, standards, guidelines, and supporting documentation are essential elements of an EM Program. Developing them requires a well-structured process, or "roadmap." Several roadmaps, toolkits, recommendations, and guidelines have been published to inform the development of an EM Program. None of these roadmaps are identical, and EM Program

[42] National Oceanic and Atmospheric Administration, 2023. Title 50: Wildlife and Fisheries: Chapter VI Fishery Conservation and Management, National Oceanic and Atmospheric Administration, Department of Commerce: Part 635: Atlantic Highly Migratory Species.
[43] National Oceanic and Atmospheric Administration, 2023. 2024 Electronic Monitoring (EM) Vessel Monitoring Plan (VMP).
[44] National Oceanic and Atmospheric Administration, 2023. Title 50: Wildlife and Fisheries: Chapter VI Fishery Conservation and Management, National Oceanic and Atmospheric Administration, Department of Commerce: Part 648: Fisheries of the Northeastern United States.
[45] https://legislation.govt.nz/regulation/public/2017/0156/latest/DLM7329212.html
[46] Ministry of Primary Industries, 2019. RFP 18631 On-board Cameras.
[47] Australian Fisheries Management Authority, 2021. Request for Information (RFI) for exploration of electronic monitoring services.
[48] Australian Fisheries Management Authority, 2020. Australian Fisheries Management Authority Electronic Monitoring Program: Program Overview June 2020.
[49] Australian Fisheries Management Authority, 2023. Your E-Monitoring Responsibilities.
[50] International Seafood Sustainability Foundation, 2022. Minimum Standards for Electronic Monitoring Systems in Tropical Tuna Purse Seine and Longline Fisheries,

development will be somewhat unique for each fishery/region/ocean. However, these documents can help inform a well-structured process for developing an EM Program.

A. Roadmaps

A. Lowman, 2013 - Fisheries Monitoring Roadmap[51]
Although more than a decade old, this roadmap provides an overview of the key steps to develop a monitoring program, including EM. It includes deep investigations of specific topics including costs, the strengths of various monitoring tools, and a collection of fishery case studies. It emphasizes the importance of stakeholder engagement throughout the monitoring program development process. The document is North American focused, which is a reflection of where EM was being piloted at the time of its publication. It is also process-focused, so does not dive deeply into the details of some program elements (e.g., minimum standards, Vessel Monitoring Plans (VMPs), data specifications, EM provider certifications, etc.).

B. EDF - EM Design Manual[52]
This document provides a high-level overview of the process steps to developing an EM Program. There is a strong emphasis on stakeholder engagement throughout the document, and the importance of building appropriate governance structures throughout all aspects of the program. The manual is accompanied by a cost-calculator spreadsheet that can be used to estimate the cost of an EM Program. It also includes brief one-page summaries of 20 EM pilots/programs. Like the Fisheries Monitoring Roadmap, this document is a high-level overview of process steps. With the exception of the cost calculator, the EM Design Manual does not dive deeply into the details of specific program design choices.

C. Pew - EM Roadmap for RFMOs[53]
This roadmap was one of the first to look at EM Program development for fisheries managed by RFMOs. It applies the earlier process guidance from EM roadmaps to the multinational context of tuna fisheries, and dives into some of the detailed considerations of EM Program design and governance.

D. NOAA, 2023. Roadmap for EM Implementation in the Pacific Islands Region[54]
This roadmap provides a snapshot of how the application of an EM Roadmap looks for pelagic longline fisheries in the U.S. Pacific Islands. The region has been testing EM since 2017 in these fisheries, and this roadmap provides some contextual background

[51] Lowman, DM, R Fisher, MC Holliday, SA McTee, and S Stebbins. 2013. Fishery Monitoring Roadmap.
[52] Fujita, R., C. Cusack, R. Karasik, and H. Takade-Heumacher (2018). Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual. Environmental Defense Fund, San Francisco. 63 pages.
[53] Michelin, M, NM Sarto, R Gillett. 2020. Roadmap for Electronic Monitoring in RFMOs.
[54] Fitzgerald, C. 2023. Roadmap for the Potential Future Implementation of Electronic Monitoring in the Pacific Islands Region. National Oceanic and Atmospheric Administration: Pacific Islands Regional Office

on the fisheries, the monitoring goals, identifies key next steps in the development process, and raises design questions that need to be answered.

B. Toolkits/Recommendations/Guidelines

A. FAO - Electronic Monitoring in Tuna Fisheries[55]
A detailed summary and lessons learned from two trials of Electronic Monitoring for tuna fisheries in Ghana and Fiji.

B. CEA Consulting, 2021 - Recommendations for Electronic Monitoring program design and requests for proposal[56]
This document provides guidance on drafting requests for proposals (RFPs) and overall program design recommendations from a group of EM Service Providers.

C. ICES WGTIFD 2022 proceedings[57]
This is the 2022 summary work from the International Council for the Exploration of the Sea's (ICES) Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD). The group includes government staff, scientists, EM Service Providers, and NGOs. The 2022 report includes six brief case studies on the implementation of EM, and explores a variety of EM topics including: legal and policy; data transmission and storage; managing stakeholder expectations; monitoring slippage events; video review; VMPs; RFPs; and data standards, integration, and processes for accepting data.

D. TNC - Electronic Monitoring Program Toolkit[58]
A concise document that provides a summary of the key steps and decision points in the design of an EM Program.

E. IATTC, 2022 - Electronic Monitoring System Management Considerations[59]
A document provided in advance of an IATTC workshop on Electronic Monitoring systems in the Eastern Pacific Ocean held in April 2022. The document includes recommendations and discussion questions on several topics including: coordination and compatibility of EM Data with other data collection programs; confidentiality of EM records and data; compliance with EM standards; EM equipment; and EM coverage and review rate.

[55] Stobberup, K, et al. 2021. Electronic monitoring in tuna fisheries Strengthening monitoring and compliance in the context of two developing states.
[56] CEA Consulting, 2021.Recommendations for electronic monitoring program design and requests for proposal.
[57] ICES. 2023. Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD; outputs from 2022 meeting).
[58] The Nature Conservancy, 2018.Electronic Monitoring Program Toolkit A Guide for Designing and Implementing Electronic Monitoring Programs.
[59] Inter-American Tropical Tuna Commission, 2022. Workshop of an Electronic Monitoring System (EMS) in the EPO: EMS Management Considerations. Document EMS-03-01.

F. IOTC, 2020 - Minimum standards for designing and implementing Electronic Monitoring systems in Indian Ocean tuna fisheries[60]
Draft EM standards that were developed in 2020 and were the precursor document for EM standards adopted by IOTC in 2023.

G. ACAP - Guidelines on Fisheries Electronic Monitoring Systems[61]
A report from the Agreement on the Conservation of Albatrosses and Petrels (ACAP) that presents guidelines for Electronic Monitoring systems for the monitoring of seabird interactions. The report includes detailed appendices on essential and desirable data fields for seabird interactions, a collection protocol for those data fields, and an assessment of whether the data fields can be collected using EM.

H. Pew - Toolkits and FAQs – 5 Key Elements of Designing an EM Program[62]
A collection of brief toolkits and FAQs that are derived from the 2021 CEA Consulting Report, "EM Roadmap for RFMOs" These are very concise and digestible overviews of a few of the key topics of EM Program design.

- Program Objectives and Coverage Levels in Electronic Monitoring
- Effective Electronic Monitoring Systems Incorporate Stakeholder Input
- Electronic Monitoring Benefits Every Link in Seafood Supply Chain
- How to Structure and Review EM Programs
- How to Manage Data
- How to Review Data While Safeguarding Privacy

Key elements required for successful design and implementation of an EM Program

While each roadmap or toolkit for EM Program development is unique, they generally all cover a few main stages of development: Assessment, Program Design, Pre-Implementation, Initial Implementation, and Ongoing Management. Each of these stages are described below.

I. Phase I - Assessment

The first stage of EM Program development should bring stakeholders to the table to achieve three main objectives: 1) Build agreement on the monitoring and management objectives, 2)

[60] H. Murua, F. Fiorellato, J. Ruiz, E. Chassot, V. Restrepo. 2020. Minimum standards for designing and implementing Electronic Monitoring systems in Indian Ocean tuna fisheries. IOTC–2020–SC23–12[E] rev2
[61] Agreement on the Conservation of Albatrosses and Petrels, 2021. ACAP Guidelines on Fisheries Electronic Monitoring Systems. Submission to CCSBT-TCWG/2210/Info 02
[62] Pew Charitable Trusts, 2020. 5 Key Elements for Designing an Electronic Monitoring Program
A guide to improve oversight by regional fisheries management organizations.

Identify the most promising approaches to achieving those objectives (i.e., what monitoring tools (e.g., human observers, EM, dockside monitoring, vessel tracking) could meet the desired objectives), and 3) Build a participatory process for all relevant stakeholders throughout the EM Program development life cycle.

Some of the key steps in this phase include:

A. **Engaging stakeholders** - Determine who needs to be a part of the EM Program design, set up a process for engaging all relevant stakeholders, and identify potential barriers to participation or points of resistance and try to address them to ensure inclusivity and to build EM acceptance. Be sure to include all stakeholders (e.g., fishing industry (e.g., captains, crew, companies) , science bodies, compliance committees, EM Providers, nonprofits, etc.). This may also include general public outreach to build awareness of the need for improved monitoring and that EM is being explored as a tool to meet that need.
B. **Identifying Monitoring and Management Objectives** - Get stakeholders to agree on the primary monitoring and management goals that need to be addressed through improved data collection and the timelines on which it will occur. This should include agreement on whether EM will be used for science, compliance, or both.
C. **Evaluating a Suite of Monitoring Tools** - Evaluate the full suite of monitoring tools that could be used to collect data needed to meet monitoring goals and determine what an appropriate and cost-effective use of EM may be. Be sure to consider how multiple monitoring approaches may be used in concert for more efficient data collection.
    a. See IFOMC, 2023 Proceedings EM Workshop Summary for information on the use of multiple monitoring approaches. https://www.ifomc.ag/information/proceedings
D. **Assessing Existing Capacity and Potential Capacity Development Needs** - An initial assessment of existing capacity and development potential can inform the discussion of what suite of monitoring tools may be viable to adopt and implement to meet overall management objectives. This assessment should include an exploration of what functions could be contracted out to EM Service Providers or other 3rd-party providers versus what functions the fisheries management agency will execute in-house.
E. **Assessing Potential Legislative or Regulatory Gaps or Needs** - An initial assessment of the relevant, existing legislative and regulatory landscape can help identify potential hurdles for designing and implementing EM. This is especially important in contexts where national or fisheries-specific regulations many not have been updated to accommodate modernized or digital practices. For example, overarching legislation or regulation that requires a physical signature could hinder the electronic delivery of some information that may be important to the program design or implementation.
F. **Exploring Potential Tradeoffs -** Evaluate promising options for improved monitoring and assess potential tradeoffs between options (e.g., cost, data quality/completeness, impact on commercial operators, flexibility, etc.). Maintain focus on meeting quality standards and cost-effectively meeting monitoring needs, not necessarily collecting all available data.

G. **Evaluating Potential Costs and Cost-Recovery Mechanisms** - Conduct a high-level assessment of the potential cost of preferred options, cost-effectiveness, and potential cost recovery mechanisms to determine whether monitoring options can be funded.
H. **Developing Overall EM Development Plan, Timeline, and Funding Assessment -** Develop an overall EM development plan that includes planning, piloting, program design, an overall timeline for building the EM program, and an assessment of the funding and resource requirements for each stage.

II. Phase II - Program Design

Once you have agreement on the management objectives and the most promising monitoring tools and approaches to obtain that data, you can move on to the details of your EM Program design. During this phase you will make important decisions about the data that will be collected, the program standards and specifications, who will be performing different functions, how data will flow, and who has access rights to different data streams. It is important throughout this phase to continue to focus on your overall management objectives and the costs and benefits of design decisions (e.g., what level of accuracy is sufficient, what data is essential for good management versus what data is nice-to-have).

For each component of an EM Program, there can be a variety of approaches to implementation. Each choice has tradeoffs, including cost implications, that need to be evaluated to select the option that best meets the goals and constraints of a particular fisheries monitoring program. For example, there are a variety of video review approaches ranging from viewing 100 percent of video captured (census review), to reviewing a subsample of EM Video, to reviewing a small fraction of EM Records to validate self-reported data in logbooks. Census review may provide the most complete and accurate data but comes with significant additional cost due to the additional video review time. By contrast, subsampling and logbook auditing provide data at lower cost, but the data could have less accuracy than census data depending on logbook quality, sample sizes, and the representativeness of the samples selected for analysis. The logbook audit approach has lower video review costs since only a small portion of video will need to be reviewed. However, it takes time and resources to build a norm of accurate logbook reporting with vessel captains and the operational mechanics to enable accurate and timely comparisons of EM Data to logbook data. In some cases getting sufficiently detailed and accurate logbook reporting may not be achievable in a reasonable time frame. (see Box 2 for an overview of different options for EM Records transmission and analysis)

Within an RFMO context, a key element of this stage is to determine how the different roles and elements of an EM Program will be coordinated or harmonized between member states and RFMO structures. For example, if EM standards are set at the RFMO level, what governance structures are in place to ensure that member state EM Programs are meeting those standards and that data generated from different programs meets a minimum threshold of quality?

It is during this phase where many of the important details of an EM program will be decided and it is essential to maintain strong stakeholder engagement and communication to ensure good program design and to build buy-in to the program.

Box 2: Selected design options for transmission and EM Records analysis.

Transmission of EM Records	EM Records Analysis Approaches
• **Physical removal of hard drives** - Standard method of transmission for tuna fisheries. Can be mailed to DRC, or data can be uploaded to the cloud in a local office. • **WiFi** - Viability will depend on bandwidth and cost of WiFi in port, length of fishing trips, volume of data uploaded, and time in port between trips. • **Cellular** - Viability depends on volume of data, cellular bandwidth, cellular coverage, data costs, time spent in cellular range, and the volume of data to be uploaded. • **Satellite -** Historically only cost effective for small volumes of data transmission (i.e., text files, still photos). However, emerging tech (e.g., Starlink) may make the transfer of longer video files viable.	• **Census** - EM Records are generated and analyzed for all fishing events (i.e., 100% review). This approach has high accuracy but high costs. This approach may be particularly useful during the pilot stage of EM Program development to get a clear and accurate baseline to inform an analysis approach for full program implementation, and to compare EM and human observer observations, which can highlight what data elements EM is capable of collecting accurately. It may also be appropriate if a primary objective of the program is to detect rare events. • **Sampling** - EM Records are generated for all fishing activity, and a subset is reviewed and extrapolated to estimate all fishing activity. Accuracy of sampling is dependent on frequency of events (i.e., low standard deviation for frequently caught species, but high for rare events). See Pierre, 2022 for more detailed information on review rates. • **Logbook Audit** - EM Records are generated for all fishing activity and a small sample of is reviewed and compared to logbook data. If they are closely aligned, the logbook data is accepted for the fishing activity data. A risk-based approach to review may strengthen a logbook audit program. • **Using EM to leverage other data collection methods** - For example, using EM to ensure there are no discards at sea, and using dockside monitoring to collect catch data. • **Shoreside AI -** AI may be used with any of the above approaches to streamline analysis. For example, in 1x1 (e.g., longline) fisheries AI may reduce review times by enabling reviewers to jump to segments with activity on deck or fish in the frame. • **AI analysis on the edge -** An emerging approach to identify potential events of concern that can then be transmitted to shore for immediate review. This can complement any of the approaches listed above.

Below are some key steps of this phase of program development.

C. **Identify specific data needs** to meet overall management goals. This can usually build off of existing data fields/requirements for a fishery.
    a. For example: Draft DCC Longline EM minimum data field standards[63]
D. **Define overall approach for using EM Data** including:
    a. Direct data collection, or using EM to improve other data collection methods (e.g., logbook audit, EM discard monitoring paired with dockside monitoring)
E. **Develop policies and governing documents** that define the purpose and structure of the program, the roles and responsibilities of the stakeholders, the processes and procedures by which the program will be continuously implemented and operated, the financial rights and obligations of various stakeholders, the standards, rules and requirements for all of the program components, etc. A few key elements to consider will include:
    a. Defining standards, specifications and procedures for the program, including for:
        i. **On-board EM Systems** which describe all on-vessel components supporting the acquisition and reporting of EM Records as required by the EM Program Policies. The on-board EM System components typically include a Control Center, user interface, cameras, geolocation device, uninterruptible power supply, Sensors, and communication system. They should also describe when the EM system must be operational and recording data. Together, these components enable the required information to be collected, including system health status, in support of fisheries management and enforcement objectives.
        ii. **Data review center (DRC),** which is an entity with access to supporting software platform(s) used to analyze EM Records collected by the on-board EM equipment to generate EM Data and staffed by qualified EM Analysts. DRCs and their Analysts may serve individual members, subregional groupings, or an entire RFMO membership. They may also be administered by individual members, a sub-regional or regional body, or a third-party (commercial) provider.
        iii. **EM Records transmission**, which defines how EM Records are moved from a vessel to a DRC, and all of the associated security, confidentiality, and chain of custody requirements. Note that technological advancements will change how EM Records are moved from vessels to DRCs, (e.g., hard drives, cellular, Wi-Fi, satellite, etc.). This is an example of how performance standards that allow for technological flexibility can be beneficial.
        iv. **EM Records review**, including:

[63] Secretariat of the Pacific Community: Data Collection Committee, 2020. Draft DCC Longline EM minimum data field standards (version DCC-November 2020).

1. Defining what share of EM Records will be reviewed
2. If reviewing a subsample of EM Records, defining how subsamples should be selected (e.g., random, risk-based)
3. Data that will be collected during video review, including their syntax and units
    a. See Northeast Multispecies Fishery EM Reviewer Guidance (link - see page 47 for detailed data fields)[64]
    b. See section 9 of ICES WGTIFD 2022 Outputs (link)[65]
4. Protocols for collecting data from video (e.g., how do you measure the time at the start of a set)

v. **EM analyst training requirements** to ensure analysts meet a minimum quality standard.
    1. See IATTC December 2023 meeting for a brief discussion on EM analyst training. (link)[66]

vi. **Quality assurance mechanisms**, including consideration of 3rd-party audit of EM Records review to ensure data quality

vii. **Delivering analyzed data to the final users** (e.g., API)
    1. See section 9 of ICES WGTIFD 2022 Outputs (link)[67]

viii. **Storage requirements** for EM Records and Data (e.g., what data, how long, where, and what form (e.g., compressed video, cold or hot data storage)
    1. See U.S. NOAA policy on EM Data retention (link)[68]

ix. **Data security and integrity**, including requirements for data encryption and mechanisms and data loss protections

x. **Captain/crew obligations** and incorporate them into a **Vessel Monitoring Plan**, including decision trees for vessel obligations in the event of EM system malfunctions
    1. NOAA, 2021 - US West Coast Vessel Monitoring Plan Guidelines[69]
    2. NOAA, 2017 - North Pacific Fisheries Management Council Vessel Monitoring Plan[70]

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[64] National Oceanic and Atmospheric Administration: Northeast Fisheries Science Center, 2023. Electronic Monitoring Audit Model Program Reviewer Guidance Manual: Video Review Protocols for Multispecies SectorTrips 5/1/2023 to 4/30/2024.
[65] ICES. 2023. Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD; outputs from 2022 meeting).
[66] IATTC, 2023. Workshop of an Electronic Monitoring System (EMS) in the EPO: Standards for an EMS in the EPO 6TH Meeting.
[67] Ibid
[68] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, 2020. Third-party Minimum Data Retention Period in Electronic Monitoring Programs for Federally Managed U.S. Fisheries.
[69] National Oceanic and Atmospheric Administration, 2021. 2021 West Coast Groundfish Electronic Monitoring Program: Vessel Monitoring Plan Guidelines.
[70] National Oceanic and Atmospheric Administration, 2017. 2017 Electronic Monitoring (EM) Cooperative Research Program Vessel Monitoring Plan.

xi. **EM certification mechanism**, which is the process used to ensure the program operates using high quality records and data that is fit for purpose. These mechanisms should include requirements that anyone providing EM services should be independent from and hold no conflicts of interest with any entity in the fishery they are providing services to. There are at least three different models that could be used to meet this need. (see EM Certification section below)

1. See U.S. standards 50 CFR 648.87(b)(4) and 50 CFR 648.87(b)(5) as an example of an EM Provider Certification mechanism[71]
2. See U.S. standards 648.11(h)(6) for an example definition of conflicts of interest that would exclude an entity from providing EM services.[72]

b. **Define roles and responsibilities of different actors**. In the case of RFMOs delineate how roles will be harmonized between member states and RFMO structures. (see the section on Key Scenarios for EM Implementation Structures)

i. Determine which functions will be in-housed by the regulatory agency and which functions will be outsourced to third party providers and how these entities will coordinate (see the section on Key Scenarios for EM Implementation Structures)

F. **Define access rights and ownership of EM Records and Analyzed Data.**
The multinational structure of fisheries managed by t-RFMOs make this a more complex discussion than in a fishery managed by a single country. For example, what are the access rights of different parties (e.g., flag state, member state) to EM Records from a trip that is executed across multiple EEZs and in the high seas, and who will review those EM Records and generate EM Data. Will EM Records from a multi-zone trip need to be partitioned, and if so, who will be responsible for that partitioning?

a. What parties are allowed to access EM records, including video?
b. What parties are allowed to access EM Data (i.e., analyzed EM records) and at what level of aggregation?
c. What are the privacy/confidentiality guidelines/requirements for sharing analyzed EM Data? Some of these guidelines already exist for human observer data at the RFMOs and could be referenced or extended to EM Data.
   i. See Environmental Defense Fund, 2020 for more detail[73]
   ii. See Kate Wing, 2019 for more info[74]
d. Which party is responsible for reviewing EM Records for different types of trips?

G. **Define funding structure for the EM Program**

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[71] National Oceanic and Atmospheric Administration, 2023. Title 50: Wildlife and Fisheries: Chapter VI Fishery Conservation and Management, National Oceanic and Atmospheric Administration, Department of Commerce: Part 648: Fisheries of the Northeastern United States.
[72] Ibid.
[73] Westfall, Katie, et al. 2020. Electronic Technologies and Data Policy for U.S. Fisheries: Key Topics, Barriers, and Opportunities.
[74] Wing, K, E Franke, J Sullivan, 2019. EM Data Sharing WORKSHOP Background Document.

a. Consider both public funding and cost-recovery mechanisms.
    i. See U.S. NOAA Cost Allocation in Electronic Monitoring Programs for Federally Managed Fisheries (link)[75]
    ii. See AFMA (Australia Fisheries Management Authority) Cost Recovery implementation Statement 2021-2022 (link)[76]
    iii. See MRAG Cost Recovery Guidelines for Electronic Monitoring Services (link)[77]

II. Phase III - Pre-Implementation and Policy/Regulatory Alignment

After developing the program design, the next step is to prepare for program implementation. The goal of this phase is to ensure that all parts of the EM Program are prepared and ready for implementation, including the policy and regulatory framework, the fishing industry, and the human resources for various parts of program execution. A pre-implementation of the program design at a small-scale may be a useful way to stress test systems and ensure they are ready for full-scale implementation.

The multinational context of t-RFMOs will require thoughtful coordination between different stakeholders to identify, communicate, and address any gaps that would prevent effective EM Program implementation.

A. Determine if any new overarching policies are needed (e.g., monitoring/EM mandates, cost recovery guidelines, data storage requirements)
    a. See NOAA for example policy updates[78]
B. Determine if the specific regulatory framework used to implement policy needs updating for EM adoption (e.g., a new Conservation and Management Measure)
C. Develop and test systems for transferring and storing EM Records and data with dummy data sets or with pilot data
D. Develop harmonized EM data forms so all parties submit the data in the same format
E. Develop capital and human resource plan for EM Program implementation (e.g., EM Analysts, data technicians, program manager)
F. Develop guides and training materials
    a. Develop EM Analyst training materials
    b. Develop EM reviewer manuals

[75] U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, 2019. Cost Allocation in Electronic Monitoring Programs for Federally Managed U.S. Fisheries.
[76] Australian Fisheries Management Authority, 2022. Cost Recovery Implementation Statement.
[77] MRAG Asia Pacific, 2018. Cost Recovery Guidelines for Electronic Monitoring Services.
[78] National Oceanic and Atmospheric Administration, ND. Electronic Monitoring. https://www.fisheries.noaa.gov/national/fisheries-observers/electronic-monitoring . Accessed December 2023.

i. See US Northeast for example[79]

F. Communication and outreach with fishing industry and other stakeholders
G. Consider incentives to encourage participation of early adopters

III. Phase IV - Initial Implementation

This stage is the full-scale implementation of Electronic Monitoring in the fishery. During this stage, tenders will be executed, systems installed, video reviewed, and all elements of the EM Program will go live. During this stage there will be bumps and challenges, which will require active management, refinement and troubleshooting until the program reaches a steady state.

A. Communication and outreach with fishing industry and other stakeholders
B. Execute an RFP and Procurement of EM Hardware and, if desired, engage third party EM Video Review services
   a. See CEA Consulting, 2021 for RFP Recommendations[80]
   b. See ICES WGTIFD (Annex 3) for list of previous RFPs and project contacts[81]
C. Consider an RFP and procurement of third-party auditing or developing a procedure for in-house auditing
D. Implement a human resource plan to ensure appropriate staffing to manage and operate the program
E. Install EM Equipment on vessels and begin collecting and reviewing EM Records, and sharing EM Data.
F. Collect and respond to feedback from and the performance of program stakeholders. There are multiple layers of feedback loops that need to be defined and initiated, for example:
   1. Feedback from EM Analysts to vessels on whether they are meeting their duty of care (e.g., wiping lenses) and catch-handling requirements.
   2. Feedback from program manager to EM Service Providers on performance (e.g., data/video quality, system uptime, field service quality/timeliness).
   3. Feedback from vessels to EM Program manager on operational challenges/opportunities to improve efficiency.
   4. Feedback from members, flag states, and RFMOs on the overall structure and performance of the program.

V. Phase V - Ongoing Management and Continuous Improvement

Once a program has kicked off and initial troubleshooting and refinements have been completed, it should be continually monitored to understand whether it is meeting the desired

[79] National Oceanic and Atmospheric Administration: Northeast Fisheries Science Center, 2023. EM Reviewer Guidance Document.
[80] CEA Consulting, 2021. Recommendations for electronic monitoring program design and requests for proposal: Guidance from Electronic Monitoring Service Providers
[81] ICES. 2023. Working Group on Technology Integration for Fishery-Dependent Data (WGTIFD; outputs from 2022 meeting).

management objectives cost-effectively. No matter how much careful planning is undertaken, there will be challenges during the implementation of a program that will need to be addressed. Experience with program implementation will also reveal opportunities to improve processes and data quality, and to reduce program costs. On a longer timescale, program reviews should scan the technological landscape and communicate with other EM Programs to determine if there are any new technologies or approaches that can improve EM Program implementation, reduce costs, or expand the data that the EM Program can provide in support of fisheries management.

Within an RFMO context, governance design will need to be carefully considered to ensure that EM Programs and the data they are generating meet performance standards. This structure will look different depending on the scenario chosen for EM Program development. For example, if the RFMO sets EM Program standards, but member states develop and implement their own EM Programs against those standards, mechanisms must be put in place to ensure that these programs are meeting the minimum performance standards. These assurance mechanisms are essential to ensure a level playing field across the jurisdiction of the RFMO.

In addition, a governance structure must be implemented to enable the evolution of the overall EM Program design. This should include regular review of the financial performance of the program which highlights opportunities for cost reduction, the performance of funding/cost recovery mechanisms, and whether the program is financially sustainable.

Key Scenarios for EM Implementation Structures

One of the key decision points for establishing EM governance at scale comes with defining the way in which EM Programs will be structured and implemented from the RFMO perspective. The Pew and CEA 2020 Roadmap for EM in RFMOs succinctly summarizes the diverse landscape of options and provides a clear table summarizing the main advantages and challenges of different pathway choices:

> "*EM Programs for international fisheries could have several types of structures, including an RFMO-wide program, individual national programs, sub-regional programs, or aspects of national programs being pooled between countries. Each type has its advantages and disadvantages, with the most appropriate type for a region being influenced by the fishery management history, geography, and politics of the area. If a region has previously enjoyed an effective network of national observer programs, countries may feel comfortable staying with that model for an EM Program.*
>
> *An RFMO-wide EM Program might be appropriate if a region has experience with a regional observer program, such as ICCAT's Regional Observer Programme for At-Sea Transshipments, or has much of the tuna fishing on the high seas, such as the Indian Ocean. The preference for an RFMO-wide versus national programs is also affected by the relationship between coastal states and DWFNs (Distant Water Fishing Nations). As*

DWFNs can exert considerable influence within RFMOs, a coastal state may prefer a national program where they have much more control over the operation of the system and management of the EM Data.

Several countries may wish to share EM Program components, such as a shared video review center[82], as part of a sub-regional program. For the national EM Program structure, there are two main variations for dealing with the high seas. One option is for the RFMO to cover the high seas, and the other is for flag states to be responsible for EM coverage of their vessels when they fish in those areas.[83]

Some of the advantages and challenges to address for each of the EM Program structure options are given in Table 3 [below]."[84]

Table 3. Advantages and Challenges of the Options for EM Program Structures

Program Structure	Advantages	Challenges to Address
1) A regional RFMO program	• Uniformity across the region, with consistent quality of data • Vessels can use the same system across all EEZs in a region • Economies of scale in program set up and video review • Helpful for small countries and countries with low access fee revenue who cannot afford to finance their own program	• RFMOs move very slowly; may take longer to get a program up and running • Coastal states may be concerned that DWFNs have too much influence in the RFMOs • RFMOs may not have the technical capacity, funding, or ability to raise the funding • The EM program would have to cover many countries and a huge geographic area • Concerns around data ownership and use • Countries with substantial access fee revenue may wish to develop and finance their own independent programs
2) Coastal state national programs	• Avoids stalling in the RFMO negotiation process, as coastal states can dictate conditions of access to foreign vessels • Easier to operationalize than a huge EM program covering many EEZs • Coastal states may be more likely to support this structure than an RFMO program • Coastal states can control their own data • Local job creation • Can be designed to meet the needs of the in-zone fishing fleet and other local stakeholders • Works best in areas where there are strong regional institutions to help the coastal states	• Less likely to be supported by DWFNs as they have less control than in a program managed by an RFMO • Less economies of scale and higher start-up costs as each country will need to develop their own program • Can result in disparate programs with varying degrees of funding and capacity • Potential issues with interoperability across zones (e.g., a vessel having a SatLink system for one zone, but then fishes in another EEZ that has a review center that can only review Archipelago video) • Will require agreement between member states and the RFMO on how to handle data from multi-zone trips • Need to develop a mechanism to ensure high seas coverage (e.g., still require RFMO coverage of the high seas, or make flag states responsible for high seas EM coverage)
3) Sub-regional programs	• In some regions, this option could incorporate the advantages of both regional and national EM programs (e.g., job creation, economies of scale, etc.) • Countries may form like-minded sub-regional groups wherein consensus around objectives and standards is easier to achieve	• Need to ensure the countries that are not part of a sub-regional group are still included in the EM program • Ensure programs allow vessels to move seamlessly between sub-regional and other types of programs (e.g., data management and interoperability) • For coastal states, regional solidarity in fisheries issues is crucially important to maximize benefits such as access fees, but sub-regional groupings may dilute regional solidarity

[82] "Video review center" is another term used to describe Data Review Center (DRC)

[83] Note that there is potentially a 3rd option in some regions, such at the Western and Central Pacific Ocean (WCPO), whereby a sub-regional entity (e.g., Parties to the Nauru Agreement (PNA) or Forum Fisheries Agency (FFA)) could host a DRC that reviews high seas EM Records for licensed vessels operating within sub-regional entity waters.

[84] Michelin, Sarto, & Gillett (2020) Roadmap for Electronic Monitoring in RFMOs. pg. 13

Following the guidance received during stakeholder consultations in 2023 regarding the implementation pathways for highest interest, this technical resource document focuses on three main implementation scenarios:

- Scenario A describes opportunities for a centralized governance structure
- Scenario B describes options for a harmonized and decentralized governance structure
- Scenario C describes an array of EM Service Provider engagement options that would be available to choose from under both centralized and decentralized implementation structures

The aim is to provide concrete structure around the suite of decisions that would need to be made by governance to successfully implement each scenario. We note here that while cost considerations will certainly be a primary driving factor for any EM Program structuring discussion, a detailed cost comparison is outside the scope of this globally focused technical source document due to the need for extensive region-specific cost accounting. An overview of key cost considerations is provided in Box 4.

I. Scenario A: Centralized Governance

Under this structure, the RFMO (or similar regional body) would be responsible for implementing the EM Program for all vessels and for harmonizing the program with other RFMOs/regional bodies. Examples of successful cross-regional harmonizations at the RFMO level include between IOTC and ICCAT for the Transhipment Regional Observer Program[85] and between IATTC and WCPFC with cross-endorsement of high seas observers.[86] This means that the RFMO secretariat would add staffing capacity (in house or via a 3rd-party contractor– see Scenario C below) to administer a regional EM Program. The full suite of governance needs (described in Context section on Governance Needs at the beginning of the document) would be a centralized responsibility housed within the RFMO secretariat (or another agreed upon regional governance body). Individual members would be responsible for updating their national legislation and policies to enable effective EM Program implementation at the RFMO level. The governing regional body could provide templates for legislative and policy actions needed from individual members. The advantages and challenges described above in Table 3 with respect to "Regional RFMO Program Structure" all apply.

II. Scenario B: Decentralized and Harmonized Governance

Under this broad category, the RFMO sets minimum standards for EM Program elements and data requirements/outputs while individual members, consortia of members, or subregional organizations are responsible for implementing programs that meet the standards. There are multiple options for how to implement a decentralized and harmonized governance structure, as outlined by line items 2 and 3 in Table 3 above. Regardless of which entity will implement and

[85] https://mrag.co.uk/articles/transhipment-regional-observer-programmes

[86] Memorandum of Cooperation (MOC) on the Cross-Endorsement WCPFC and IATTC Approved Observers when Observing on the High Seas (2011)

manage an EM Program (e.g., individual RFMO members or cooperating parties, consortia of RFMO members/cooperating parties, or another subregional organizations), harmonization across programs within an RFMO will be critical for achieving effective management of highly migratory species and for building trust among members with respect to data quality and transparency. Harmonization across multiple RFMOs (or similar regional fisheries management bodies) remains beneficial under this structure and would be a responsibility that also falls to the secretariats of the RFMOs. The benefits of cross-regional harmonization include potential cost-savings through bulk procurement opportunities, reduction of customization costs with EM Service Providers, and cost efficiencies for vessels that work in multiple jurisdictions. Harmonization also provides uniform data quality and interoperable data structures that can maximize the fisheries management benefits for highly migratory stocks (see Box 1).

III. Scenario C: EM Service Provider Engagement Landscape

Within any structure described in Scenarios A or B, there are multiple options regarding which implementation elements the governing bodies keep in-house and which are delegated to external partners, such as EM Service Providers and the fishing Industry.

There are a number of dedicated EM Service Providers[87] (see Section on summary of EM Service Providers below) that offer a range of hardware, software, and services to support Electronic Monitoring in fisheries as well as a growing number of fishing companies that are working to develop Electronic Monitoring technologies in-house.[88] EM Service Providers often play critical and varying roles in EM Program implementation, and it is worth understanding the overarching landscape of possibilities for engagement with them when discussing how to structure an EM Program. Each of the options described here apply equally to Scenarios A and B.

Key EM Service Provider decision points include:

1) Will the EM Program work with a single Provider or multiple Providers to meet its needs for EM hardware, software, or services?

H. Sole Provider Models:

A Program might choose to open a competitive bidding process where EM Service Providers propose end to end solutions for meeting all of the Program's EM needs. The Program then selects one Provider as their implementation partner for the term. All vessels are subsequently outfitted with hardware and software solutions from that provider. The tender could include the provision of data review services and data review software, or those elements could potentially remain separate from the mandate of the sole-source Provider. If the Provider is not asked to fulfill all of the required roles in an end-to-end scenario, it tends to be more common that the

[87] EM Service Providers (June 2021) Recommendations for electronic monitoring program design and requests for proposal. (link)
[88] R. Gillett (Feb 2022) Luen Thai/ Lian Cheng Case Study. Pacific Community Fisheries Newsletter #166

data review software is included in their set of responsibilities while only the data analyst services are excluded from the tender. This is the case because the staffing capacity to analyze the raw EM Records to produce EM Data using the specified software is more likely to be kept in-house for a given EM Program administering body than the creation of data review software itself (see below). For the Scenario B context, it is the individual national programs that would generally recruit for an EM Service Provider to serve their individual needs rather than the entire RFMO attempting to coordinate recruitment for a sole provider.

I. Multiple Provider Models:

Alternatively, a Program might opt to allow hardware, software, or services from multiple vendors to be used to meet each of those needs. In this scenario, a certification mechanism (see EM System and Service Provider Considerations Section II) would be used to ensure that all options meet the Program's needs. It will be important to decide whether all of the footage from different on-vessel systems are required to feed into a single review platform, as Chile has done, or if the Data Review Center(s) will be outfitted with multiple analysis software platforms to accommodate the different brands of on-vessel hardware, as NOAA has done in New England to audit the EM Data coming from multiple service providers that are authorized in their region.[89] [90] [91] In either case, providers could be certified to offer any or all components. For example, an EM Service Provider might receive certification to offer hardware, software, and services or a provider may only be certified for a subset of offerings (i.e., only to provide hardware, or both hardware and software but not EM analyst services, etc.). Under the multiple provider model, ideally there would be multiple vendors who meet the criteria for each category of Program needs. As with the sole provider model, the Program can choose to outsource as little or as much of the programmatic needs as they wish. For example, a Program may choose to keep the DRC in-house while outsourcing the hardware, installation, and maintenance to an EM Service Provider or it may choose to outsource EM Analysis services to some EM Service Providers while individual vessels choose from a broader set of providers to supply their hardware.

J. Comparing Models

There are examples of both sole-Provider[92] and multi-Provider[93] [94] [95] implementation strategies being successful, and each has some potential cost efficiencies associated with it. Under the

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[89] https://www.fisheries.noaa.gov/new-england-mid-atlantic/commercial-fishing/northeast-groundfish-monitoring-program

[90] https://media.fisheries.noaa.gov/2022-05/EM-spring2022-508nefsc.pdf

[91] https://www.fisheries.noaa.gov/resource/data/fishery-monitoring-service-providers-northeast-and-mid-atlantic-programs

[92] https://www.afma.gov.au/fisheries-management/monitoring-tools/electronic-monitoring-program: "AFMA has contracted Archipelago Asia Pacific (AAP), a subsidiary of Archipelago Marine Research, to deliver e-monitoring system installation and associated services, and the analysis of e-monitoring data."

[93] US Westcoast https://www.fisheries.noaa.gov/resource/data/list-approved-electronic-monitoring-em-service-providers

[94] US Northeast https://www.fisheries.noaa.gov/bulletin/approved-sea-monitoring-and-electronic-monitoring-providers-groundfish-sectors

[95] Chile https://www.sernapesca.cl/app/uploads/2023/11/res.ex_.3885-2018.pdf

sole Provider model, there can be cost savings that come with having a tightly integrated end-to-end program with efficient feedback mechanisms. Under the multiple Provider scenario, there may be more on-going incentive for Providers to innovate, reduce costs, and compete with each other. Under any scenario, the Providers are generally incentivized to maximize their own profits and thus any cost efficiencies gained as the program matures may be shared (or even disproportionately absorbed) by the EM Service Providers. Under either scenario, it is important to build in feedback mechanisms and periodic review to avoid getting locked into a specific vendor or EM System that is no longer meeting the data collection needs at a competitive price point as the market continues to evolve. Drafting performance-focused standards at the onset of EM Program design and implementation is another way to help avoid getting locked into systems that are no longer performing well.

The greatest areas for consideration with respect to balancing costs are likely to be those surrounding DRCs and EM Records Analysis. This is the case because they are the elements that may gain the most cost-efficiencies when kept in-house by the EM Program's governing body if the start-up and maintenance costs of establishing the required infrastructure do not outweigh the potential savings with in-house staffing (see Data Review Centers Section below).

Within the multi-provider model, the single review software scenario can add upfront costs for creating necessary interoperability given that most Providers use footage formats that feed into their proprietary review software, while the multi-review platform scenario will incur some additional upfront costs for training analysts on multiple review platforms.

2) Which elements of the program will be kept in-house, and which may best be outsourced to a third-party Provider?

There are several options at each step of implementation where the EM Program can choose to administer the logistics in-house or outsource it to a third-party EM Service Provider. The following list provides examples of where a governing body may want to make explicit choices in their implementation strategy about items they may wish to keep in-house, or they may wish to contract an outside Service Provider to undertake:

A. Who will be responsible for designing individual Vessel Monitoring Plans (VMPs) for each member of the fleet?
B. Who will be responsible for installing and maintaining on-vessel systems?
C. Who will administer, train, and staff the Data Review Center (DRC)?
D. Who will undertake independent audits of the EM Data produced from EM Records?
E. Who will collect/transport the EM Records and ensure their security and proper chain of custody? [Note: the answer to this question is highly likely to evolve in the foreseeable future due to advances in data transmission technologies.]
F. Who will respond to a system error or failure?
G. Who will house and store the EM Records and EM Data?

There are no wrong answers to any of these questions, and what makes the most sense for a given program or region will vary with the local context of existing capacity, existing political will and collaborations, existing parallel programs that may serve as a local model for structuring EM (such as human observer programs or VMS programs), and the objectives and needs of a program. However, among all of these important and valid questions, there are a couple of prime candidates to discuss early-on in program design: DRCs and Auditing.

K. Data Review Centers (DRCs) and Auditing

A Data Review Centre (DRC) is an entity with access to the software platform(s) required to analyze EM Records and generate EM Data for a program (or programs). Auditing is the process of cross-checking and verifying EM Records and Data through secondary review to maintain uniformly high-quality EM Data throughout a program and across multiple programs.

DRCs may be housed and administered by RFMOs, individual RFMO members or cooperating parties, consortia of members or cooperating parties, sub-regional or regional bodies, or by a third-party Service Provider. It is important to consider DRC structures early in the stakeholder engagement process of developing EM Program governance because these choices may have a large impact on the initial and on-going costs of the program.

Case studies evaluating the costs of EM for tuna fisheries in the Eastern Pacific Ocean [96] and FFA membership fishing in the Western and Central Pacific Ocean[97] have considered costs associated with some potential DRC structures. There are some intuitive benefits for many RFMO members and cooperating parties associated with establishing their own national DRC, such as local employment opportunities and high degrees of data control. However, managing and operating a DRC also includes the challenges of establishing infrastructure, purchasing and maintaining equipment, ensuring reliable internet/connectivity, and a variety of other responsibilities that some nations may not wish to undertake and/or the costs of doing so may outweigh the benefits (Rogers, Squires, & Zivin, 2022). Where this is the case, establishing shared DRCs (at the subregional or regional level) or outsourcing the primary EM Records Analysis to a third-party Service Provider may be more beneficial. If a third party will be contracted to perform the primary EM Records Analysis, there remains the same suite of options for establishing oversight and auditing mechanisms in-house at the national, subregional, or regional level that essentially serve as a scaled-back DRC responsible for auditing the 3rd party provider. Each of the DRC structures described above could also be considered for filling that auditing EM Review and Records Analysis need. Finally, an external auditor could also be contracted to provide that oversight as an independent fourth party that provides oversight of either an in-house or EM Provider contracted DRC. Regardless of the

[96] http://seachangeecon.com/wp-content/uploads/2022/06/Potential-costs-and-benefits-of-electronic-monitoring-for-the-longline-fishery-in-the-Eastern-Pacific-Ocean-2022.pdf

[97] Poseidon Aquatic Resources, 2021. “Electronic Monitoring of Tuna Longline Fishing Vessels and Associated Operations in FFA Members’ Waters and the High Seas of the WCPO -- A Cost Benefit Analysis.”

pathway and structures chosen for a Program, it is critical to ensure that the review and auditing processes remain independent of conflicts of interest to ensure they function properly.

There is a suite of associated cost considerations linked to DRC and auditing protocols/requirements that accompany EM Program design. These include issues such as transmission protocols (e.g., how much of the EM Records must be transmitted, to whom, and by what means (hard drives, electronically, etc) and whether or not it must be transmitted in near real-time), review rates[98] (e.g., what percentage of raw EM Records will be reviewed and on what percentage will secondary auditing review be undertaken), and data storage (e.g., how long will the records be stored and what are the duplication/backup requirements).

EM System and Service Provider Considerations

I. Summary of EM Service Providers

There are approximately 2,500 EM systems currently installed globally across a variety of vessel sizes, fisheries, and gear types to meet a variety of fisheries monitoring functions. Individual EM Service Providers typically have multiple system configurations in operation, which is reflective of the evolution of their products and configuration updates required due to changes in component availability in their supply chain. In addition, many EM Service Providers offer multiple models targeting different segments of the market including smaller/lower cost systems to target smaller-scale vessels (e.g., Satlink Nanotube, Archipelago FishVue LIME or Vantage, Integrated Monitoring Minnow, Saltwater SWIM Nano, etc.). In some programs, EM Systems must be moved between vessels and there are models that have been specifically designed for that purpose (e.g., Saltwater SWIM-Mobile).

EM Service Providers[99]	**Examples of EM Programs served**
Anchor Lab	● Denmark Bottom Trawl ● Scotland Scallop Dredge ● Chile (In partnership with CLS) ● Australia Queensland Inshore

[98] Pew Project: 2021-IF-02 “How much is enough? Review optimization methods to deliver best value from electronic monitoring of commercial fisheries” (link)

[99] This list is not exhaustive as new companies are emerging regularly. A criterion used for inclusion on this list was that an entity must be able to solicit a quote for EM services from the provider today. There are additional companies exploring this market and planning to start offering options that are not currently included in the list because they are not yet active in the market while others may be active in a single fishery and are not yet known to the broader market. Seafood and Fisheries Emerging Technologies (SAFET) and EM4Fish are resources that often highlight new providers as they enter the market.

Archipelago Marine Research / Marine Instruments	• Australia Gillnet Hook and Trap • Australia Eastern Tuna and Billfish • Canada BC Groundfish • US Washington State Dungeness Crab • US West Coast Groundfish • US Alaska Fixed Gear • US Alaska Pollock Trawl
Flywire	• Mexico Baja Small-Scale Vessels • US Northeast Multispecies
Integrated Monitoring	• Chile Industrial Fleet • Maldives Pole and Line Tuna • New Zealand
New England Marine Monitoring	• US Atlantic HMS
Saltwater Inc.	• Alaska Small Boat fixed gear • US Western Gulf of Alaska Trawl • US Atlantic Herring Midwater Trawl • US Gulf of Mexico Reef Fishery
Satlink / Digital Observer Services (DOS)	• Fiji longline • Ghana Purse Seine • Seychelles tuna • Federated States of Micronesia longline • Republic of the Marshall Islands longline • OPAGAC industry-led tuna
Shellcatch	• Pakistan Tuna • Chile Artisanal • Brazil longline tuna • Norway arctic fishery
SnapIt / Teem Fish Monitoring	• US Northeast Multispecies Fishery • US New England Scallop • US, Quinault Indian Nation Dungeness Crab Trap Fishery • Canada BC Area A Dungeness Crab
Thalos	• Seychelles Purse Seine Tuna
OLSPS Marine	• Portugal
CVision.AI	• An AI service provider that is exploring the development of their own hardware systems

II. EM Certification Mechanism Scenarios

One element of successful t-RFMO scale implementation will be ensuring that all stakeholders feel confident in the quality, affordability, security and comparability of EM hardware, software, and data. Some form of EM certification will be a necessary piece of the EM governance framework to enable this. There are at least three different models that could be used for EM certification, each with its own set of pros and cons. The three scenarios described here, which have been discussed at length in Forum Fisheries Agency (FFA) EM consultations[100], include a service provider approval model, a type approval model, and a minimum standards model.

1) EM Service Provider Approval by the RFMO Secretariat or other Designated Body

Under this model, individual EM Service Providers apply to an oversight organization (such as the RFMO secretariats or other agreed upon regional or global body) that reviews their qualifications and certifies that they meet the standards required of EM Service Providers for the regional/RFMO-level EM Program(s), and the oversight organization regularly evaluates provider performance to ensure standards are maintained. Once a provider is certified to provide EM services (or a subset of services) to the program, then that provider is responsible for ensuring that all hardware, software, and/or services that they provide remain in compliance with the standards, specifications, and procedures set forth by the program. Individual member states and/or fishing vessels can then choose to work with any or all of the certified EM Service Providers to meet their EM needs without the need for an independent assessment of whether or not a given product/service offering meets regional program standards.

An advantage of this model is that it allows providers to innovate more fluidly. They can evolve their products and services to improve performance and drive down costs without the additional burden of having to submit each new version for type approval. The providers remain accountable for ensuring that any changes made to their product or service offerings remain in compliance with appropriate EM Program requirements. This may allow for more seamless integration of validated and verified technological innovations such as Artificial Intelligence (AI), Machine Learning (ML), cloud computing, and novel Sensors into the program as they become available.

For this model to work best, there are a few key enabling conditions. Firstly, EM Service Providers should be reviewed frequently (annually or biennially) to ensure that the oversight organization(s) remains abreast of developments and changes within each company and can decertify a provider in a timely manner if it is not performing adequately. Given the nature of the industry, frequent review should not be overly burdensome on the oversight body due to the limited number of companies in the market. As the market continues to grow

[100] WCPFC19-2022-DP08: October 2022 INFORMATION PAPER ON THE FFA FINAL DRAFT EM SSPs – ENDORSED AS INTERIM GUIDELINES (link)

over time, it would be reasonable to anticipate having tens of companies eventually working in the space, though it is not likely there will ever be hundreds of companies.

Secondly, this model necessitates a tight feedback relationship between the data produced by EM Service Providers and the oversight body responsible for certifying them. The certifying body should include representatives that are deeply involved in the quality assurance and quality control processes (QA/QC) across the region. This might include those responsible for data QA/QC at the national, sub-regional, and regional levels. This ensures that individuals who are most familiar with the challenges actively experienced with different EM systems and Service Providers can highlight weaknesses and ensure they are corrected by the provider in a timely manner to maintain certification.

Finally, this model works best where there is regular, constructive feedback and open communication between the oversight organization(s) and the EM Service Providers. If this type of constructive dialogue is built into a routine EM Records troubleshooting process, then the relationship that the EM Program develops with EM Service Providers can be one of routine progress and positive evolution of the EM products and services.

2) Type Approval by the RFMO Secretariat (or other Designated Body)

Under this model, individual EM systems are evaluated with respect to a set of minimum standards established by the RFMO and certified by an oversight organization (such as the RFMO Secretariat or other designated body). Individual member states and/or fishing vessels can choose to implement any certified system, and member states retain the right to further narrow down the list of acceptable choices for their programs by specifying more stringent standards than the RFMO minimum standards.

This model has the advantage of already being familiar to most regions from Vessel Monitoring System (VMS) unit type approval processes, though it is important to note that EM hardware is substantially more complex and configurable than VMS technology. The biggest draw of this model is that the concrete guidance on acceptable specific hardware and software components that it provides can be reassuring for those responsible for purchasing and/or leasing EM systems to meet program requirements. However, there are several drawbacks to consider. Firstly, this model is more time consuming to execute for both the certification body and the EM providers as every individual EM system offered by a given provider must be independently evaluated for type approval. This model is both slower and more burdensome in terms of paperwork and time for all parties than a provider-focused approval process.

Furthermore, the added level of complexity that any EM system encompasses compared with the relatively simple technologies that typically go through a type approval process, such as VMS, adds additional burden and challenge to the process. The type approval model provides less flexibility for EM Programs to adapt and respond in a timely manner to changing needs and the availability of technology innovations. It slows the rate at which innovations can be incorporated into the program because each change or update to a

system is typically subject to the approval process, and the approval requirements themselves may require updating before they can accommodate new features or system characteristics. Some programs have suffered from these limitations because only a limited number of providers may choose to engage in the market if there are burdensome or prescriptive requirements[101] or because the cumbersome process of approving new hardware developments has hindered timely installation on vessels[102].

3) Minimum Standards Set by the RFMO Secretariat (or other Designated Body)

Under this model as in Model 2, a set of minimum standards and specifications are established by the RFMO for the regional EM Program(s); however, in this scenario individual RFMO members then undertake their own processes for determining which systems and/or EM Service Providers meet (or exceed) the minimum requirements set out by the RFMO and are approved for use in their national programs. The advantage of this model is that it provides individual member states with the greatest amount of autonomy; however, this model is least recommended because it presents the greatest challenge to harmonizing a regional program, leaves the greatest room for different interpretations of the standards that may lead to more heterogeneity in data quality, requires the most duplication of effort for member states (and for the EM Service Providers as well) given that they independently evaluate many of the same EM systems, and creates the strongest barrier to an adaptive and responsive EM Program at the regional level as new needs and technological innovations arise.

Governance Decisions to Address Technical and Physical Challenges

One of the dually promising and challenging facets of building fisheries management programs with emerging technologies is the rapid rate of technological evolution. There are several technical and physical challenges associated with EM today that are poised to change as technology continues to advance. Today's EM Programs are working effectively in many fisheries around the globe, and technological advancements will expand EM's accessibility to a broader range of use-cases and geographies and will increase the types of data elements it can reliably collect. While some technological advancements aim to reduce costs, others, like some

[101] Chile Resolución Exenta No 3885 de 31 de Agosto de 2018 que Establece Estándar Técnico Único del Dispositivo de Registro de Imágenes (link to pdf) provides an example of technical standards containing a level of detail that was not feasible to comply with for many EM providers.
[102] A discussion of challenges experienced in the U.S.due to technically specific VMS type approval requirements compared with the more adaptable experience with AIS implementation using performance-focused standards can be found in Garren, M., Lewis, F., Sanchez, L., Spina, D., & Brett, A. (2021). How performance standards could support innovation and technology-compatible fisheries management frameworks in the US. *Marine Policy*, 131, 104631.

that focus on improving EM's ability to meet compliance or fisheries science needs, may increase costs. Thus, there will be a need for ongoing decision making around the programmatic needs and objectives that enable adaptive EM Programs and adaptive fisheries management. From this perspective, some key areas for consideration at the outset of program design include:

I. Making space for rapid technology evolution

Given the mismatched paces of policy evolution (slow) and technology evolution (rapid), it is helpful to plan ahead during EM Program design and initial governance structure development, as this accommodates technological evolution from the start. The following subsections highlight areas that are in discussion at the RFMO level and are known to be important topics that will impact EM Programs in the present or near future.

1) Performance standards vs. technical standards

There has been extensive discussion in the fisheries management space evaluating the advantages of shifting from technical-focused standards to performance standards to accommodate the rapid pace of technological innovation that has been observed in fisheries management tools in recent years. Garren et al. (2020) provide a more detailed examination of the topic, and this except from page 3 of the manuscript provides a succinct overview:

"*The fundamental distinction between a performance standard and a technical standard (sometimes also referred to as a design standard) is that the first specifies the outcomes a regulated entity must achieve without prescribing the specific means of achieving them while the latter explicitly describes the details and design of how an entity will achieve an outcome [17]. Similar to a performance standard, a data standard may describe the specific information that must be collected, establish acceptable formats and margins of error, and clarify expectations of how the data must be validated without specifying the specific tools or methodologies that must be used. There has been on-going encouragement from the executive branch for U.S. regulatory agencies to shift from technical standards to performance standards from every administration since President Clinton's 1993 Executive Order that directed agencies to "specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt" [18].*

While performance-focused standards are generally considered to promote flexibility and innovation with respect to technology, they can be challenging to skillfully craft because a regulated entity must feel sufficiently clear in what is expected of it and how it can demonstrate compliance, as well as have enough transparency to feel confident that all regulated entities will be evaluated similarly and fairly [19]. Any poorly or incompletely crafted policy will perform sub-optimally, and thus it is important to take a comprehensive rather than piecemeal approach to building the regulation, [20] as well as to clearly and transparently articulate both the requirements for satisfying a performance standard and guidance on how to demonstrate compliance [21]."

It is commendable that all RFMOs currently developing or having recently implemented standards for EM have emphasized a performance-focused approach. The development of standards for EM is inherently an iterative process that will offer continued opportunities to augment the performance-focused nature of the standards and continue to refine them in alignment with technological innovation and programmatic needs.

2) Automation, Artificial Intelligence, and Machine Learning

There is much interest and promise in harnessing the power of advancing computer capabilities to support EM. There are four main terms that are worth becoming familiar with as EM governance decisions are made with an eye toward future developments. These terms are often used interchangeably, but they are not the same.

Automation is defined by IBM as "the use of technology to perform tasks where human input is minimized."[103] This category typically refers to decisions and actions that are made by a predefined and programmed set of rules rather than those that are made to adapt to situational differences detected by the technology.

Artificial intelligence (AI) is defined by Columbia University as "the field of developing computers and robots that are capable of behaving in ways that both mimic and go beyond human capabilities. AI-enabled programs can analyze and contextualize data to provide information or automatically trigger actions without human interference."[104]

Machine learning (ML) is defined by Columbia University as "a pathway to Artificial Intelligence. This subcategory of AI uses algorithms to automatically learn insights and recognize patterns from data, applying that learning to make increasingly better decisions."

Computer vision is defined by IBM as the "field of Artificial Intelligence (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs."[105]

From the EM governance perspective, an important differentiating characteristic of ML is its ability to learn and improve its efficiency in completing tasks as it gains more experience. With ML, training data (e.g., images of fish that are marked and labeled) can be used to create models that identify catch events, detect fish, or identify species.[106] [107] Those models

[103] https://www.ibm.com/topics/automation
[104] https://ai.engineering.columbia.edu/ai-vs-machine-learning/
[105] https://www.ibm.com/topics/computer-vision
[106] Qiao, M., Wang, D., Tuck, G. N., Little, L. R., Punt, A. E., & Gerner, M. (2021). Deep learning methods applied to electronic monitoring data: automated catch event detection for longline fishing. ICES Journal of Marine Science, 78(1), 25-35. (link)
[107] Lekunberri, X., Ruiz, J., Quincoces, I., Dornaika, F., Arganda-Carreras, I., & Fernandes, J. A. (2022). Identification and measurement of tropical tuna species in purse seiner catches using computer vision and deep learning. Ecological Informatics, 67, 101495. (link)

can then be used to analyze new images and videos and generate data regarding the number of fish, for example.

Key questions for those governing EM Programs will include:

A. How will new automation processes, AI tools, or ML algorithms be tested and approved?
B. How will the program audit the accuracy and effectiveness of AI/ML processes?
C. What are acceptable levels of error, and what are the potential management or cost trade-offs that accompany the threshold of acceptable error? (e.g., if an automated or ML-driven process can collect the required EM Data with slightly higher error rates than human analysts do without the support of ML, is that increase in error rate significant to the fisheries management or compliance decisions that need to be addressed? Are there added costs to achieve the added accuracy, and if so, are they justifiable for the level of improvement gained?)

It is also useful to have a sense of what types of tasks within an EM Program may be readily automated and which are harder to develop from a technological perspective. Woodward et al. (2020) released a manual for designing EM systems with an eye towards automation entitled "Electronic Monitoring: Best Practices for Automation."[108] This document is a good resource to consult when, for example, the program is defining the hardware and software elements that it may require.

This excerpt from page 7 illustrates how hardware choices link to future automation capabilities:

"*EM systems typically consist of an array of machine vision cameras. The camera configuration will determine the automation capacity of footage collected from each camera in the system. Desired camera sensitivity, image blur, and field of view are achieved by balancing the camera configurations to the optimal level for the captured scene or activity.*"

This excerpt from page 9 provides an initial sense of how the different tasks required for EM Record Analysis intersect with automation processes:

"*Algorithms used for EM generally fall into one of two categories: object identification or activity recognition. Object identification is used to recognize an object within a scene and possibly perform some tasks related to that object. Activity recognition is used to identify instances of a particular action or activity occurring in the video footage. Activity recognition and object identification algorithms are able to build off of each other to perform more complex tasks and further reduce the burden to human review, but as the level of automation increases, so does the level of difficulty in creating that automation pathway.*"

[108] https://em4.fish/wp-content/uploads/2020/02/2020-02-04-EMAutomationBestPractices_Final-Proof.pdf

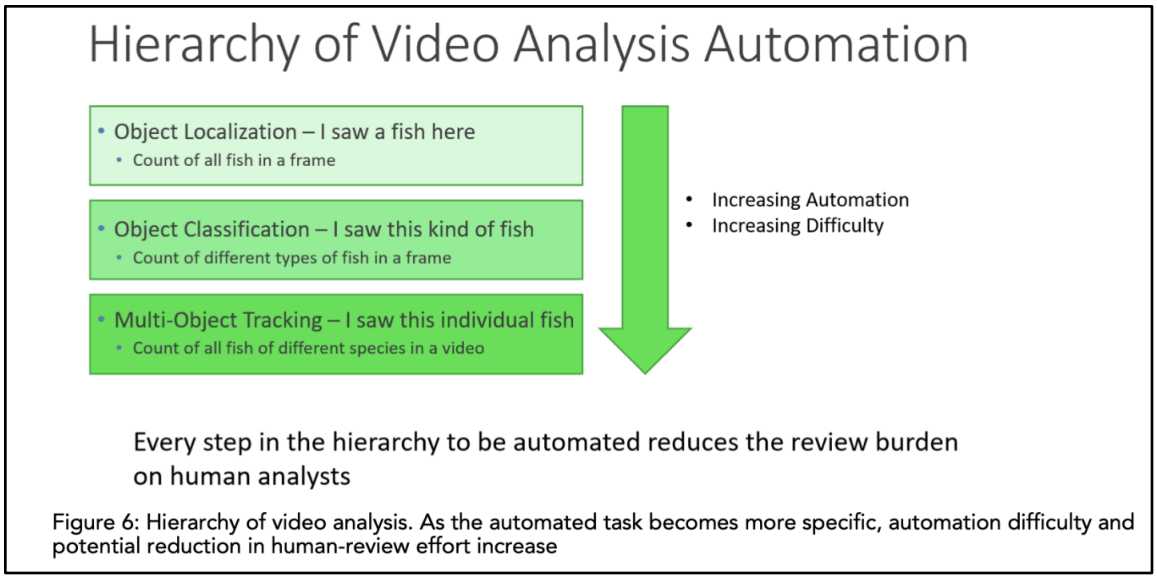

Figure 6: Hierarchy of video analysis. As the automated task becomes more specific, automation difficulty and potential reduction in human-review effort increase

Figure 6 (pg. 10) provides a visual representation of how different object identification automation tasks rank in terms of their technical difficulty to achieve, along with the relative gains that may be made with respect to reducing burdens on human analysts.

As AI and automation capabilities advance, they will eventually be incorporated directly into the on-vessel EM system. This is referred to as “the edge” -- edge computing or edge AI. Such capabilities could unlock efficiency enhancements for EM Programs or provide additional value. For example, using activity recognition on the edge could be used to reduce the volume of video that must be transmitted or stored, focusing only on clips necessary for meeting the program objectives. This could more readily enable cellular or satellite transmission of EM Data in near real time, which has historically been cost prohibitive in most cases. With advancements in satellite transmission (e.g., Starlink) near real-time transmission of video files will become a viable approach for an increasing number of cases.

Defining governance processes for overseeing and ensuring the accuracy of these tools will be critical. How and when may EM Service Providers use these tools? How will the program ensure transparency with respect to how and why automation/AI/ML tools are used, and what will be the requirements for ongoing auditing of such tools to ensure continued high-quality data? How and when will a specific automation/AI/ML element transition from being considered “novel practice” to “standard practice”?

3) Integrated Sensors

Sensors can be integrated to expand the data fields collected by EM or to increase the efficiency of collecting existing data fields.[109] They can also be used to increase the efficiency of an EM Program from the cost or logistics perspective by, for example, triggering

[109] Gilman, E., Castejón, V. D. R., Loganimoce, E., & Chaloupka, M. (2020). Capability of a pilot fisheries electronic monitoring system to meet scientific and compliance monitoring objectives. *Marine Policy*, *113*, 103792.

cameras to record only under specific conditions to reduce the volume of EM records that must be captured, transmitted, or analyzed. The opportunities to use Sensors to improve EM system functionality is covered in Gilman et al.'s (2018) comprehensive analysis of opportunities to improve EM functionality.[110] Furthermore, an area where future developments are anticipated is the use of AI/ML tools that may function as an integrated Sensor to detect events in the EM Records that could also be detected by an auxiliary Sensor on board the vessel.

Governance decisions during EM Program design and implementation may include defining what Sensors improve the efficiency of data collection for the required data fields, establishing protocols for evaluating Sensors as part of the EM System certification mechanism (see Certification section above), and explicitly incorporating Sensor data to the auditing workflows.

4) File sizes, transmission, and storage of records

Video files, especially those from long fishing trips common in tuna fisheries, can be very large. This makes it challenging to quickly transfer video files from vessels to DRCs due to bandwidth constraints and the cost of data plans. The cost for storing these files, while rapidly declining, is a non-trivial cost of EM Programs. The transmission bottleneck is an opportunity for innovation and an example of where performance standards may be helpful. For example, the ongoing rollout of higher bandwidth and lower cost satellite plans may enable the cost-effective transfer of video files, but if the minimum standards for data transmission specify a specific mode of transmission (e.g., movement of physical hard drives), the minimum standards may lock in outdated technology or require amendments.

While digital storage costs are rapidly declining, it can be a burden for a program to store large volumes of video for long periods of time. This has led countries, such as the US and Australia, to allow for the disposal of EM Records after a relatively short period of time (e.g., 12 months in the U.S.). Governance decisions will need to be made on how long EM Records must be stored for, whether all EM Records must be stored or only when events of interest occur, as well as additional retention requirements when they are of interest (e.g., in the case of a criminal investigation).

II. Interoperability

Interoperability of EM Records has emerged as a topic of discussion for EM Programs with the advent of multiprovider EM Programs. Different multiprovider programs have taken different approaches to this challenge. Chile has required that all participating EM Providers provide their EM Records to the government in the same format, which government analysts can then review with a single software platform. New England, on the other hand, accepts EM Records in unique

[110] Gilman, E., Legorburu, G., Fedoruk, A., Heberer, C., Zimring, M., Barkai, A., 2019. Increasing the functionalities and accuracy of fisheries electronic monitoring systems. Aquat. Conserv. Mar. Freshw. Ecosyst. 29, 901–926. https://doi.org/10.1002/aqc.3086

formats from each participating provider and uses multiple software platforms for video review. There are trade-offs across these different approaches (see Box 3), but an EM Program with multiple providers will need to decide how to address this challenge.

Box 3: FFA Interoperability Discussion Case Study[111]

"Interoperability is the requirement for EM Analysis software to be able to facilitate the generation of EM Data from all EM Records that will be reviewed in the DRC…. The main Options for consideration [for FFA members were discussed to be]:

OPTION 1: Requiring the use of a single EM Service Provider for onboard hardware for all vessels that will deliver EM Records to the DRC for analysis and using EM Analysis software from the same EM Service Provider.

OPTION 2: Using multiple EM Analysis software packages; one from each onboard hardware provider delivering EM Records to the DRC.

OPTION 3: Using EM Analysis software that can analyze EM Records from multiple EM Service Providers. This may be facilitated by:

- Requiring EM Service Providers to share the file types, data structures, syntax, and semantics of their EM Records and reference datasets.
- Specifying a common format for exchange of EM Records."

Legal/Regulatory Considerations

In broad terms, the main legal and regulatory considerations pertain to (1) ensuring that individual RFMO members/cooperating parties have the necessary national policy frameworks in place to effectively implement an EM Program (be it a centralized or decentralized and harmonized EM Program structure); (2) ensuring that EM standards and policies set forth at the regional/RFMO level can meet the requirements and needs of existing member legislation; and (3) ensuring that sufficient policy structures are in place among members/cooperating parties within an RFMO and across neighboring RFMOs to ensure effective management of tuna stocks. It is worth noting that 25 years ago, Vessel Monitoring Systems (VMS) were first being introduced into global fisheries management systems, and many parallel legal and regulatory considerations were undertaken. A detailed legal analysis from the period of VMS's initial uptake era commissioned by the United Nations Food and Agriculture Organization (FAO) in 2020 provides helpful context for thinking through the suite of legal issues that may be raised by EM.[112] VMS has helped to pave the way for other electronic technologies by precipitating initial

[111] Direct except from pages 1-2 of the WCPFC Oct 2022 document entitled "WCPFC19-2022-DP08", which summarizes the outcomes of the 2022 FFA EM Workshop on the topic of interoperability

[112] Cacaud, P. (2000). Legal issues related to Vessel Monitoring Systems. Report of a Regional Workshop on Fisheries Monitoring, Control and Surveillance. Muscat, Sultanate of Oman, 1999. Technical Paper 11. FAO GCP/INT/648/NOR: Field Report C-3 (En): 211-244. (link)

updates to existing legal frameworks that enable their use, and many lessons can be learned and applied to EM.[113]

I. Appropriate national regulations/legislation

While all members of established t-RFMOs have existing processes in place by which they can transform RFMO management measures into national regulation under their fisheries management laws, not all members/cooperating parties will have the suite of complementary laws and regulations in place needed to support EM. For example, just because a nation has the necessary fisheries management legal structures in place does not guarantee that it will have other relevant legal structures in place that may be necessary to fully implement and administer an EM Program. For instance, a nation may or may not already have legal structures pertaining to data retention, data security, data access, data privacy, electronic device certification, or wireless communication that could impact the implementation of EM domestically. The establishment of an appropriate legal framework to mandate the use of EM could simply make it a mandatory condition of licensing within the scope of powers under relevant fisheries legislation. Similarly, there could be a variety of other related mandates or requirements that need to be addressed to permit this in full. The more pertinent decision would be to consider a regulation or direction granted directly under the relevant national fisheries legislation, noting that typically fisheries management acts include provisions for issuing regulations and/or amending an existing regulation.

A 2016 study[114] by The World Wildlife Fund (WWF) outlined legal and regulatory considerations that Forum Fisheries Agency (FFA) members in the Pacific would need to account for during implementation of EM and other electronic-based monitoring programs. In addition to issues like the right to privacy and access to data, the WWF study counted data classification, retention, and confidentiality to be among the main legal considerations arising from EM implementation. Anticipating that many countries may use EM as a compliance tool, a national legal framework to support the use of EM Data in legal proceedings was identified as a prerequisite for robust national EM implementation, though regulations and related directives could potentially serve as a stop-gap to accommodate EM compliance needs in the shorter term. It will be important to consider the evidentiary requirements of each member/cooperating party and ensure that the EM Records will meet all of the requirements to be used in any nation's proceedings.

Legal provisions for cost recovery might also be needed. A 2018 report by MRAG[115] on cost recovery for monitoring services identified the following key legal considerations:

A. Determining the most appropriate laws to enable and mandate the use of EM;

[113] See the case study "VMS Regulation Slowing Modernization" in Garren et al. (2021) Marine Policy for a discussion of challenges VMS has incurred due to initial regulations and VMS definitions being technical in nature rather than performance focused.
[114] Poseidon, 2016. "Analysis of the costs and benefits of electronic fisheries information systems applied in FFA countries and identification of the legislative, regulatory and policy supporting requirements"
[115] MRAG, 2018. "Cost Recovery Guidelines for Monitoring Services."

B. Reviewing and amending evidentiary laws to ensure that EM Records can be used as evidence and that handling of EM Records meets chain of custody requirements; and
C. Ensuring an appropriate legal framework exists to support recovering costs and obtaining relevant approvals.

Some countries have legal capacity embedded in fisheries administrations, and others do not. Those that do not would benefit from seeking early drafting assistance from external bodies such as RFMO Secretariats, particularly if centralized government legal capacity, e.g., an attorney general's office, is not available in a timely manner to progress fisheries related laws. In general, national legislative processes tend to be lengthy, and this will require consideration of a region's ability to move toward EM implementation in a coordinated manner, particularly with respect to fleets operating in multiple countries' or RFMOs' jurisdictions.

Potential ways to catalyze EM implementation and uptake at the regional level:

1. RFMO Secretariats could develop appropriate template legal mechanisms (e.g., legislation, regulation, licensing conditions) to support member/cooperating party uptake of EM legal framework requirements in a timely manner;
2. Explore whether structures such as Minimum Terms and Conditions can accommodate EM through licensing conditions for fishing access.

II. RFMO requirements meet local regulatory requirements

While it is critical that individual RFMO members/cooperating parties establish legal frameworks to meet the implementation and administration needs of the EM Program, it is also important that existing national legal frameworks are considered during the design of the RFMO EM policies. For example, nations may have existing data retention laws that may need to be considered during the development of regional EM Standards. Additional considerations for harmonization among national legal frameworks and RFMO EM policy structures might include laws or regulations governing confidentiality of information, disclosure restrictions/requirements, all elements of data governance/use/access/retention, evidentiary requirements, and potentially intellectual property issues that may intersect with EM and the fishing industry.

III. Appropriate multinational agreements

A critical thread in the ongoing EM governance conversations at the RFMO level pertains to the need for multiple nations to cooperate in order to attain the tuna fisheries management obligations set out by the United Nations Convention on the Law of the Sea (UNCLOS). Some of the biggest sticking points for the progress of EM at the RMFO level include issues surrounding EM Data beyond national boundaries and the costs associated with gathering said data.

It will be important to establish agreements among members/cooperating parties/flag states regarding issues such as how data will be used (e.g., For compliance and science purposes? By whom and under what conditions?), who will be responsible for collecting the data and sharing data (e.g., Which data? When and why?), who will pay the costs associated with data collection/sharing/storage, and how data privacy/security/confidentiality requirements will be developed. As discussed above (see Section Phase II, D. Define access rights and ownership of EM Records and Analyzed Data), there are concrete technical issues of data management that require multinational agreements to resolve issues such as data collection and analysis for vessels that fish in multiple EEZs on a single trip or that fish within the jurisdictions of multiple RFMOs.

Box 4: Cost Considerations

There is strong agreement among all stakeholder groups that cost considerations are of critical importance to the successful development and scaling of Electronic Monitoring in industrial tuna fisheries. While stakeholders take varied views on whether EM costs constitute a new burden or are a cost-effective opportunity to correct historically insufficient levels of observer coverage (e.g., observer coverage was historically lower than appropriate for robust fisheries management), the ability to more fully understand the cost implications of implementing EM programs at scale is required. EM costs can be binned into four main categories: (1) on-vessel costs; (2) program administration and operational costs; (3) policy and regulatory development costs; and (4) analytical costs.[116] As stakeholders prepare to pursue cost evaluations for the specific set of programmatic and governance choices of highest interest, there are several existing cost assessments for EM in tuna fisheries that can serve as guides regarding the array of specific costs that should be accounted for.[117,118] This technical source document focuses on highlighting the ways in which governance decisions regarding EM Program design and implementation intersect with cost considerations. Here we provide a consolidated overview of key decision areas where cost considerations are discussed:

Program Design Decisions

- Programmatic choices on which data elements to collect to meet the program's science or compliance needs, which tools to use (see Phase II), and how to certify the systems to be used (see EM Certification section).
- Benefit of/need for cost planning during the design phase and available cost calculation spreadsheet tools[119] (see roadmaps section, particularly Lowman 2013 and EDF's EM Design Manual).

[116] MRAG, "Cost Recovery Guidelines for Monitoring Services," MRAG Asia Pacific, (September 2018). (link)
[117] Rogers, A., Squires, D., Graff Zivin, J. (2021) Assessing the potential costs and benefits of electronic monitoring for the longline fishery in the Eastern Pacific Ocean (link)
[118] DOCUMENT EMS-05-01 (2023) FINANCIAL CONSIDERATIONS OF AN EMS IN THE EPO for IATTC WORKSHOP OF AN ELECTRONIC MONITORING SYSTEM (EMS) IN THE EPO: FINANCIAL CONSIDERATIONS 5TH MEETING (link)
[119] https://fisherysolutionscenter.edf.org/em-cost-calculator-0

- How much video to review, how to transmit the data, EM Records storage requirements, and the quantity of secondary EM Records review (see Phase I - Assessment (specifically points C., E., and F.); Phase II: Box 2 and section E. Define funding structure; Summary of EM Service Provider section that addresses different system models that target different market segments; Intro paragraph of the Governance Decisions to Address Tech and Phys Challenges and iv. File sizes, transmission, and storage of records)

Structural Decisions

- Cost considerations associated with EM Service provider engagement choices, such as sole source vs. multi-vendor EM Service Provider models and which elements of program implementation to keep in house vs. outsource. (see Comparing Models under EM Service Provider section.
- Decisions surrounding who and where will house DRCs and auditors, what training will be required for analysts/auditors, and the associated review rates that may be chosen for each (see DRC and Auditing section)

Operational Decisions

- Cost recovery approaches will determine who will be responsible for the cost of different aspects of an EM Program. The structure, however, can also have indirect impacts on program cost due to the incentives it creates. Legal provisions may be required to enable cost recovery. (see appropriate national regulations/legislations section)
- Governance decisions around integrating technical advancements like AI/ML (see Key Questions subsection under Automation/AI section), Sensors (see Integrated Sensor subsection), transmission protocols and new compression techniques (see iv. File sizes, transmission and storage subsection] can all influence cost. These sections also highlight that while as many technical advancements hold the potential to reduce costs, others may increase the type or quality of data that can be collected by EM at an added cost.

Cooperative and Adaptive Management Decisions

- Harmonization of standards across programs and RFMOs offers potential for cost efficiencies. (see Box 1)
- Ongoing adaptive management and improvement mechanisms for EM Programs to enable optimizing cost-effectiveness over time is a key element of successful, long-term programs. (see Phase V)
- International agreements may be needed to maximize cost-efficiencies of managing highly migratory species and to specify who will cover specific cost elements associated with cooperation on EM. (see Appropriate multinational agreement subsection)
- Cost considerations are highlighted as one of the areas most in need of additional research and resource development to help RFMO-level EM governance implementation to advance. (see Recommendations section)

Conclusions & Recommendations

At the time of initial drafting of this document, the main t-RFMOs were at different stages of defining and adopting minimum standards for Electronic Monitoring. Each RFMO has members with extensive EM implementation experience as well as members who are just beginning their journey and becoming familiar with the EM landscape. While the discussions surrounding minimum standards have progressed everywhere, there remain some shared areas of concern or confusion. Issues of costs and the sources of financial support are key shared concerns that demands attention and additional research. Questions of interoperability, scalability, and privacy/data sharing/ownership/access also remain key elements to be resolved. The need for harmonization within and across RFMOs and the benefits of engaging with EM Service Providers to most effectively focus the standards on performance outcomes for futureproofing remain insufficiently understood and discussed among many stakeholders. If these issues are not brought more explicitly to the forefront of the conversations, stakeholders are likely to find hidden cost burdens in the future associated with lack of planning on those fronts.[120]

For RFMO members who are newer to EM, the suite of options that exist for engagement with EM Service Providers is a particular area of governance development that will require more capacity building and exploration as RFMOs look to begin implementing EM standards. A centralized database that documents EM Program case studies (both pilot and full-scale) could increase the speed of research, understanding, and level of transparency among programs and regions with respect to governance decisions and their associated costs. More opportunities for stakeholders to exchange information with each other directly could also support such outcomes. Below we summarize a series of specific recommendations that can be broadly categorized into two categories: (1) products that can be developed with the information contained in this document to support decision making and increase the digestibility and useability of this technical source document; and (2) resources needed by the field to advance EM governance that require additional technical work that is beyond the scope of this document.

I. Recommendations to develop further resources and toolkit in support of the usability of this document

Outreach and Education

- Create short (2-3 page) topical information fliers on key elements of this technical source document to help decision makers digest specific topics, such as EM Certification Mechanisms, Key Implementation Scenarios, or Legal/Regulatory Considerations.
- Generate a guidance graphic that illustrates what steps follow the adoption of minimum standards in an RFMO to achieve full EM Governance Implementation. Each of these steps are described in the document; however, additional visuals that provide a sense of the flow of information and steps could be helpful.

[120] Garren M, Lewis F, Sanchez L, Spina D, & Brett A (2021) How performance standards could support innovation and technology-compatible fisheries management frameworks in the US. Marine Policy, 131, 104631. https://doi.org/10.1016/j.marpol.2021.104631

- Facilitate government to government engagement opportunities to share experiences and learnings between peers and discuss key questions highlighted throughout this document.

Decision Support

- Develop a decision tree to illustrate and clarify the different elements that have to be considered under each of the three main implementation scenarios.
- Produce a decision tool that guides stakeholders through the suite of EM Service Provider engagement options for a given governance structure.

II. Recommendations for further resource development that require technical work beyond the scope of this document

- Develop a centralized database of global EM Programs (inclusive of pilot phase programs) that details programmatic structures, costs, and governance decisions. This database would aid stakeholders and researchers to more rapidly integrate learnings and help the field to make data-driven decisions to scale EM at the t-RFMO level.
- Undertake a harmonization exercise of EM technical standards across all t-RFMOs.
- Advance the available cost accounting templates to guide budgeting and cost estimations for different pathways that incorporate more nuanced governance decisions as the field advances and experience is gained. For example, clarify the costs associated with different EM Certification Mechanism choices, DRC structures, and different auditing protocols.
- Research and develop staffing/capacity planning templates for different implementation scenarios from national and regional perspectives that describe the different roles that will need to be filled and the options for structuring staffing plans to fill the needed roles (e.g., scenarios in which multiple roles could be filled by a single person in house or outsourced to an external contractor)
- Expand the scope of the technical source documentation to encompass EM governance and technical capabilities as they relate to semi-industrial and small-scale tuna fleets.

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Appendix 2: Consultations

The first phase of WWF's consultations on EM were held with EM experts, RFMO staff, IATTC staff and Commissioners and members of OSPESCA. The objectives were to inform these groups about WWF's project, key milestones and identify gaps. We presented the main elements of the governance of EM programs detailed in this document. Later consultations in this first phase focused on gaps in the cost and financing of EM programs.

The second phase of consultations built off the first phase insights and results. We subsequently consulted EM experts from RFMOs and non-governmental organizations on an initial draft table of contents outlining the document to provide feedback on the overall structure and proposed content of this technical source document. We then workshopped an initial draft of the manuscript with governmental stakeholders to assess any gaps or additional needs for research. All feedback was incorporated into this document, and a near-final draft was shared again with the EM experts from RFMOs and non-governmental organizations for a final round of feedback incorporation.

Representatives from the following organizations generously participated in both the initial and final consultation phases:

- WWF
- International Seafood Sustainability Foundation
- The Pew Charitable Trusts
- The Nature Conservancy
- WCPFC (staff)
- IATTC (staff and commissioners)
- Ministerio de Producción, Comercio Exterior, Inversiones y Pesca, Ecuador
- Servicio Nacional de Pesca y Acuicultura, Chile

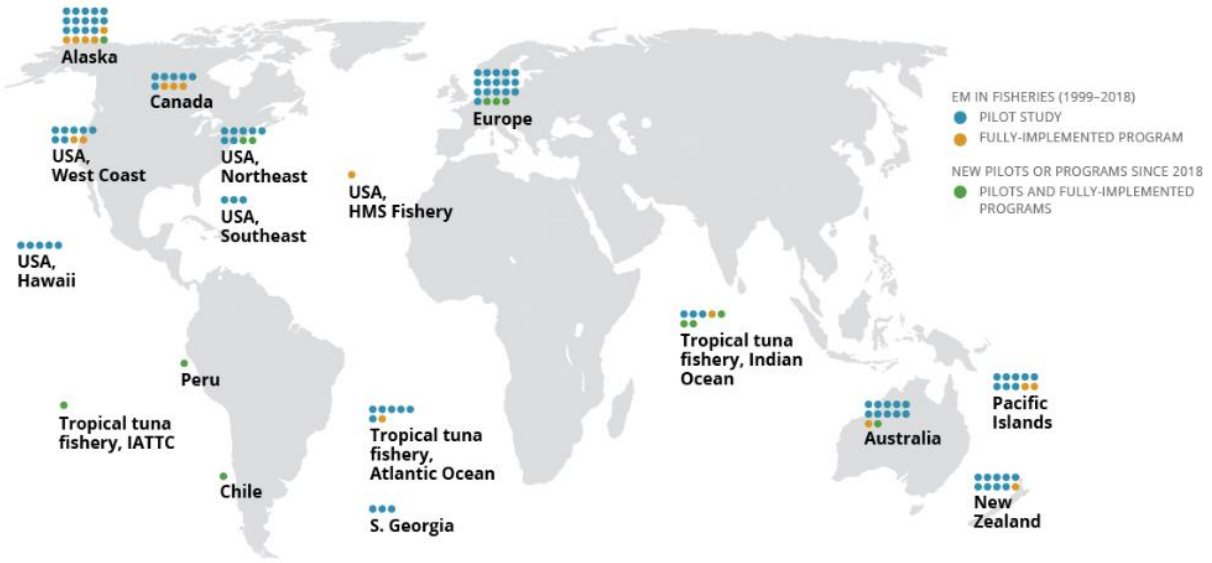
Appendix 3: EM Pilots and Programs

There is no comprehensive database of EM pilots and programs, but there have been trials and programs all around the world. The figure below identifies the locations of a selection of EM pilots and programs from 1999 to 2018 and a selection of new pilots and programs from 2018 to early 2020. Since that time, there have been several additional EM trials and programs, including:

1) Initial implementation of rollout of EM across New Zealand's fishing fleet
2) Voluntary EM trial for tuna longline vessels in the Western and Central Pacific
3) Danish Kattegat Nephrops fishery
4) Longline large pelagic vessels in Costa Rica

There have also been several studies of EM in tuna fisheries, and a selection of those studies and their findings on the benefits and challenges of EM are in the table below.

Number of EM pilots and programs from 1999–2018 and a selection of new pilots and programs since the end of 2018[121]



[121] Michelin, M, M Zimring, 2020. Catalyzing the Growth of Electronic Monitoring in Fisheries: Progress Update August 2020. Figure adapted from Adapted from Aloysius T. M. van Helmond et al., "Electronic Monitoring in Fisheries: Lessons from Global Experiences and Future Opportunities," Fish and Fisheries 21, no. 1 (2020): 162–89, https://doi.org/10.1111/faf.12425.

Studies of selected EM Pilots and Programs in Tuna Fisheries[122]

Study	Name of EM Pilot or Program	Number of Vessels	Gear Type	Strengths of EM Program	Challenges of EM Program
Piasente et al, 2012	Australia, Eastern Tuna and Billfish Fishery	10 vessels	Longline	· Aligned very closely with observer data for retained catch; "in clear view of the camera" · Detected all protected species interactions reported in logbooks · Net benefits of $451,247 over 40 boats and 10 years · Promising tool for monitoring compliance with various regulations	· Significant differences compared to observers for released catch
Larcombe et al, 2016	Australian Pacific Tuna Longline Fishery	Full coverage of the Australian longline fleet	Longline	· EM recorded slightly higher amounts of retained catch · Differences ranged from 2% for bigeye tuna to 12% for swordfish and mahi- mahi · EM was associated with a "clear and substantial increase in the reporting rates of discards for almost all species across all categories including wildlife"	· EM has trouble observing discarded fish which are cut or jerked free of the line while in the water · Reports lower discard catch than logbooks · Biggest discrepancy in the shark's category
McElderry et al, 2010	Hawaii	3 vessels	Longline, pelagic (shallow-set swordfish & deep-set tuna)	· More accurate than observers for fishing time and location and counts of gear used	· 40% of discard catch not detected by EM because it was out of camera view · EM species identifications

[122] Updated from Michelin, M, N Sarto, R Gillett, 2020. Roadmap for Electronic Monitoring in RFMOs.

					more general than by observers · Less accurate than observers for counting and identification of catch and bycatch
Emery et al, 2018	Australia	Eight years of data from Australian fisheries	Longline, pelagic (tuna, swordfish, marlin) & Demersal trap, gillnet, demersal longline, dropline, auto-longline (gummy shark)	· Evidence that EM led to significant changes in logbook reporting of discarded catch and protected species, particularly in the Eastern Tuna and Billfish Fishery	
Emery et al, 2019	Australia; Eastern Tuna and Billfish Fishery and Gillnet, Hook, and Trap sector	Two years of EM & logbook data	Longline, pelagic (tuna, swordfish, marlin) & Demersal trap, gillnet, demersal longline, dropline, auto-longline (gummy shark)	· High congruence for retained target species that improved over time · Higher congruence for longline (one individual at a time)	·Low congruence for escolar, rudderfish, sharks, bronze whalers, and non-retainable marlin species · High variability for sharks, boarfishes, elephant fish, pike spurdogs · Lower congruence for gillnet catch and discard catch generally · Difficulty identifying at species level · Difficulty recording species which are quickly discarded

Gilman et al, 2018	Palau EEZ (North Pacific, Philippines)	4 vessels, 67 sets	Longline; 3 locally-based pelagic, 1 distant-water pelagic	· Catch rates from EM data were about an order of magnitude higher than from logbook data, and had about twice the species richness	· Presence of EM appears to not change logbook data recording · Suspected substantial underreporting in logbooks
Monteagudo et al, 2014	Atlantic Ocean	2 vessels	Purse seine	· No systematic differences compared to human observers · "Capable of delivering and/or validating many of the same observations that a regular observer program can deliver"	· EM estimates of catch per set tended to be 5% lower, on average, than human observers · Lower number of sharks in all trips · Significant differences, compared to observers, in estimation of species composition, particularly Bigeye vs. Skipjack tuna
Chavance et al, 2013	Seychelles	1 vessel	Purse seine, tropical tuna	· Similar catch composition and total catch weight by event to observers · Correctly identified set type (FAD or FSC) 78% of the time	· Couldn't distinguish certain species e.g. yellowfin and bigeye tuna (partially due to inexperience of reviewers)
Ruiz et al, 2015	Indian/Atlantic and West Pacific Oceans	3 vessels, 7 trips	Purse seine, tuna	·Total catch per set · Main species identification · Large-bodied species	· Other species identifications not comparable to observers · Set-type identification success varied between 98.3% and 56.3% depending on camera placement

					· Bycatch species underestimated
Briand et al, 2018	Indian/Atlantic Oceans	2 vessels	Purse seine, tuna	· Equal to human observers for total tuna discards, categories of main tuna species · Can cover upper and lower decks simultaneously	· Shark bycatch underestimated · Less precise for species and weight identification
Ruiz et al, 2013	Ivory Coast	1 vessel, 3 trips	Purse seine, tuna	· Correctly identified set-type for 60 of 61 sets · Total catch per set · Catch composition · Large-bodied species	· Catch for larger volume sets underestimated · Bycatch species underestimated

MRAG, 2017	Ghana (ICATT)	14 vessels, 163 trips monitored, 154 trips reviewed	Ghanaian purse seine fleet (registered under ICATT)	· Biggest benefit was contribution to lifting the EU yellow card - price boost from accessing EU market · Cost benefit analysis showed strong positive return to industry - suggests the program is a viable and sustainable investment	· Schedule for remote data review not fully implemented · Consultation with industry and MOFAD showed that there were no reports of improved reporting as a result of EMS installation. · No integration between the EMS and VMS unless there is a particular infraction or anomaly detected by the land observers. · No integration between the at sea observer programme and the land observers analysing the footage.
Hurry, 2019	Fiji (WCPFC)	50 vessels - 310 fishing trips monitored - 150 fishing trips reviewed	Fijian longline fleet	· Costs can be recovered from industry, clear benefits to industry: MCS, compliance, product certification, and operational improvements	· Moving to EM increases costs, partially offset by the trial investment in hardware, etc. · Wholly-owned Fijian domestic sector could be adversely affected without cost defrayment

Hosken et al., 2016	Solomon Islands (WCPFC)	2 vessels	CT-4 freezer longline tuna vessels	· Data collected was at least as good as the data recorded by the human observer, and coverage was higher · Positional data was more accurate · Effort data was more detailed · Able to go back and review footage if any issues/doubts arose	· Couldn't provide sex data for most species · Issues with correspondence of condition (life status) of individual catch · Comparative analysis of observer and EM data required painstaking and time-consuming data preparation
Brown, et al., 2021	Palau, Federated States of Micronesia, Republic of the Marshall Islands (WCPFC)	15 vessels	Longline tuna vessels	· Significant incongruence between catch levels reported in logbooks and with EM for both target and bycatch species, believed to be caused by logbook underreporting.	· Significant incongruence between catch levels reported by human observers and with EM both target and bycatch species, but unclear cause of the deviation.
Ruiz, et al. 2021	Spanish and associated flagged vessels (ICCAT and IOTC)	22 vessels	14 purse seine vessels and 8 supply vessels	· Lower cost of EM compared to human observers · Ability to re-review events with EM · EM capable to accurately determine, in many cases, discards, target species, associated fauna, ETPS	· EM equipment failures · Time lag between EM Record collection and completed video analysis · Some limitations in identifying catch to species level · Need for crew to conduct duty-of-care tasks (e.g., cleaning camera lenses) · Difficulty providing technical service in the case of EM system malfunctions · In some cases, EM unable to collect desired data
	Spanish bait boat and troll tuna fisheries (ICCAT)	6 vessels	3 bait boat and 3 troll vessels		
	Spanish Longline vessels (ICCAT, IOTC, and IATTC)	14 vessels	Longline		