Roadmap for Electronic Monitoring in RFMOs

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Introduction

The Case for Increased Monitoring Coverage in RFMO Fisheries[1]

Photo: Environmental Defense Fund

Regional Fisheries Management Organizations (RFMOs) play a key role in managing highly migratory fish stocks, such as tuna, that span the jurisdictions of multiple countries as well as the high seas. Each year, tuna fisheries land approximately 5 million tons of fish with a dockside value of about 10 billion USD.[2] In order to sustainably manage this valuable resource, RFMOs and their member countries require sufficiently accurate information on target catch, bycatch, fishing effort, and compliance with regulations.

Human observers, who are deployed on fishing vessels to collect data on fishing activities, have played a critical role in collecting this information. Observers cover a large portion of fishing activity for most of the world's tuna purse seine fleets; ICCAT, WCPFC, and IATTC require human observers on all purse seine trips. However, other fleets, such as the longliners, have very low observer coverage targets that they often struggle to meet. The Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC) have, for example, a 5 percent observer target for longline vessels, but these fisheries often struggle to meet this low level of coverage. A combination of harsh working environments, costs, and the challenging logistics of deploying observers on many longline fleets make it unlikely that human observers will ever be able to achieve much higher coverage levels for these fleets. With such low monitoring coverage, there is uncertainty about what longline vessels are catching, which makes it difficult to set and enforce management measures that protect the health of fish stocks and the economic productivity of the fishery. This can lead to a bias towards inaction, as it can be difficult to understand whether there are issues in the fishery that require immediate attention.

Even in fisheries with high rates of observer coverage, there are opportunities to enhance the reliability of reported data. Although observers currently represent the gold standard in fishery data collection, observers must take breaks to sleep and eat, and cannot keep track of all activities happening at once. In the worst cases, they may also be subject to intimidation, interference, bribery, and even violence in the name of falsifying reports. These serious issues are one of the reasons observers are sometimes used solely for scientific data collection and not for compliance functions. The recent suspension of observer requirements on purse seine vessels in the WCPFC in response to coronavirus has demonstrated that there is still room to improve the reliability of monitoring, even in fisheries with 100 percent observer coverage.

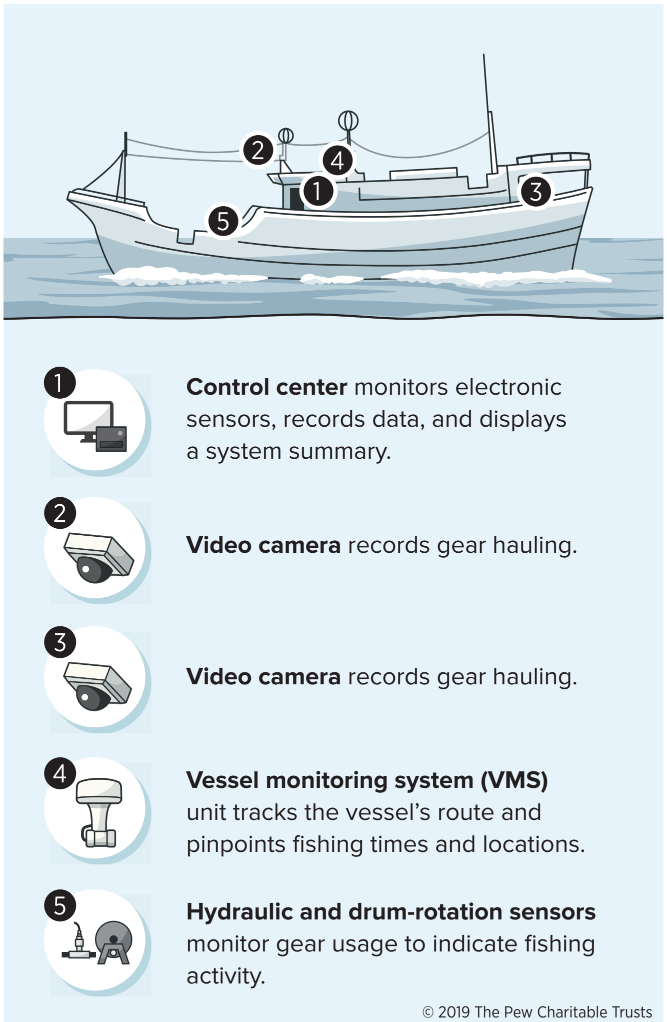
There appears to be growing interest in improving the monitoring of many of the world's fisheries managed by RFMOs. The International Commission for the Conservation of Atlantic Tunas (ICCAT), for example, recently agreed to require 100 percent observer coverage on purse seine vessels year round, and to expand longline observer coverage on vessels over 20 meters to 10 percent in 2022.[3] While human observers may be limited in their ability to monitor large portions of tuna fishing for some fleets, the emergence of electronic monitoring (EM) offers a solution to the challenge of increasing the robustness and coverage levels of at-sea monitoring. There are now more than two decades of experience with electronic monitoring in fisheries, with at least 100 trials, and 12 fully implemented programs.[4]

[1] For simplicity, the term "RFMO fisheries" is used throughout this document, which refers to fisheries that are managed partly or wholly by RFMOs.
[2] Galland et al., "Netting Billions: A Global Valuation of Tuna," *The Pew Charitable Trusts*, (May 2016).
[3] Restrepo and Koehler, "ICCAT Moves to Protect Atlantic Bigeye and Close Gaps in Monitoring and Data Collection," ISSF (December 2019).
[4] Van Helmond et al., "Electronic monitoring in fisheries: Lessons from global experiences and future opportunities," *Fish and Fisheries Wiley* Volume 21, Issue 1 (October 2019): 162-189.

What is Electronic Monitoring?

The on-vessel components of EM consist of an integrated system of cameras, gear sensors, video storage, and Global Positioning System (GPS) units, which capture video of fishing activity with associated sensor and positional information (Figure 1). The video record is typically stored on a hard drive that is collected at the end of fishing trips and can then be reviewed by an onshore analyst. Some EM vendors are moving to systems that use Wi-Fi, satellite, or cellular networks to transmit data, some in near real time, instead of physically moving hard drives. An **EM system** also includes shore-based software and hardware that supports the acquisition, analysis and reporting of EM records.

Figure 1. Overview of the On-vessel Components of an EM System on a Longline Vessel



EM requires much more than placing cameras and sensors on vessels, and computers on shore. This hardware needs to be complemented by an EM program, which includes the standards and methods to collect, analyze, and store video of fishing activities and to share the results with authorized entities (e.g., managers, scientists, vessel owners, etc.).

There are a variety of other electronic technologies for fisheries, such as electronic reporting (ER). ER is a method of data reporting that uses electronic devices instead of paper and pencil. Likewise, there are electronic technologies that report on the position of vessels, such as vessel monitoring systems (VMS) or automatic identification systems (AIS). While these technologies can serve an important role in fisheries monitoring and reporting, they do not meet the definition of EM used in this report, which is an integrated system of hardware and software that supports acquisition of video of fishing activity, sensor and positional data, as well as the analysis and reporting of EM records.

About this Report

This report presents an overview of some of the key steps and design choices that fishery managers need to consider when designing and implementing an EM program. There have been a handful of reports that summarize the current status of EM in fisheries, and toolkits that outline a process for developing an EM program. However, none of them have specifically focused on the unique challenges of designing and implementing an EM program in an RFMO context, which covers numerous countries, a wide range of vessel sizes, gear types, fishing locations, and catch compositions.

This report explores the necessary elements of a well-designed and effective EM program and explores unique considerations for fisheries that are managed by an RFMO. This is not a prescriptive recipe for creating an EM program, but a discussion of some of the important elements of an EM program and an overview of the design options that may be considered. This document can serve as a resource for a variety of stakeholders such as political leaders, staff of RFMOs and government fishery agencies, and industry members, who are interested in the applicability of EM in RFMO fisheries and the key decisions involved in developing and implementing a successful EM program.

Strengths, Challenges, and Opportunities for EM in Tuna Fisheries

There have been numerous trials and fully implemented EM programs for tuna fisheries (Appendix). These trials have covered both longline and purse seine fisheries. From these trials, some general conclusions can be reached about the efficacy of EM as a monitoring and compliance tool.

Strengths of EM

1. Provides accurate data on the location and time of fishing activity.
2. Accurately assesses the set type in purse seine fisheries.
3. Accurately estimates total catch per set in purse seine fisheries.
4. Provides good estimates of the catch of main target species in longline and purse seine fisheries.
5. Identifies most Endangered, Threatened, or Protected (ETP) species interactions.
6. Incentivizes more accurate reporting of data in logbooks.
7. Covers multiple views of the vessel at the same time, does not require breaks, and video can be reviewed multiple times.
8. Is less prone to intimidation, bribery, or interference in order to falsify reported data.
9. Review of much of the fishing activity can happen at high speed (e.g., >8x speed).
10. A space efficient solution for longline vessels with limited room for a human observer.
11. Can sometimes provide cost savings relative to human observers.
12. Helps document conformity with management measures and international obligations.
13. Scalable option to implement on various vessels with different gear types.

Challenges of EM

1. Accurate estimates of non-target species in purse seine and longline fisheries can be challenging with EM depending on catch-handling techniques and camera placement.
2. Identification of ETP species may only be accurate at higher taxonomic levels (e.g., shark or turtle, but not at the species level). However, additional or higher resolution cameras may be a solution.
3. Accurate identification of juvenile tuna (e.g., small yellowfin and bigeye) is difficult, although this is similarly difficult for human observers.
4. EM systems are not linked to fish aggregating device (FAD) buoy identification systems.
5. EM is not currently suitable for biological data collection (e.g., sex identification, otolith measurement), which could be addressed by complementing EM with dockside sample collection.
6. EM cannot be used to accurately assess the condition or life status of fish.


Photo: Shutterstock

Emerging Opportunities of EM

1. EM has been explored to monitor labor practices onboard vessels, but no results of comprehensive studies have been published in the literature.
2. EM is being explored as a tool to monitor transshipments.

In general, it is easier to extract detailed information about catch in longline fisheries where the catch is brought on board one fish at a time, but EM has proven successful in purse seine fisheries as well. In some cases where EM has not been able to match reported data from human observers (e.g., species level identification of non-target catch), changes in catch handling procedures or additional camera views may be able to overcome these challenges. For example, EM is successfully being used to identify discards in United States (US) multispecies groundfish fisheries where the crew sorts and places fish to be discarded on a measuring strip in view of the camera.[5] Likewise, identification of sensitive species in the Orthongel purse seine program has been difficult because the deck camera is positioned too far away to give a good view of all the brailing activity.[6] In the future, Orthongel will be investigating additional camera views or handling practices to improve the ability to identify sensitive species to the species level. Complementing EM with other data collection techniques, such as port sampling, can also help provide more detailed data than EM alone.

The growing body of experience with EM has demonstrated that it can be a complement to human observer programs. For longline fisheries, where low levels of human observer coverage mean that there are little data about what is happening at sea, EM can be a valuable tool to help fill this information gap.

[5] Fitz-Gerald et al., "Electronic Monitoring in the Groundfish Fishery: A summary of current programs for the Groundfish Advisory Panel and Groundfish Committee," *NOAA Fisheries*, (No Date).
[6] Briand et al., "Comparing Electronic Monitoring System with Observer Data for Estimating Non-Target Species and Discards on French Tropical Tuna Purse Seine Vessels," *Indian Ocean Tuna Commission*, (2018)

Designing an EM Program

This section provides an overview of fifteen different elements of an EM program that should be considered during development and implementation. An overview of each element is presented as well as some of the design choices or options that could be considered. Building an EM program is an iterative process. Mechanisms should be included for continuous review, refinement, and improvements as experience is gained and technology evolves.

1. Engaging Stakeholders

In designing an EM program, it is important to plan for the engagement of the full range of relevant stakeholders. According to several EM studies, a key obstacle to comprehensive implementation is lack of support from stakeholders. Involvement of stakeholders from the beginning has been shown to increase their interest and reduce the chances of stakeholders becoming a major barrier to EM implementation. Table 1 shows some common stakeholders and their perceptions of EM.

Table 1. Stakeholders and the Potential Benefits of and Concerns with EM

Stakeholder	Potential Benefits of EM	Potential Concerns with EM to Address or Mitigate
RFMO secretariat staff	• Efficient mechanism for encouraging compliance • Monitoring bycatch and catch levels, especially in fisheries with catch quotas	• Increase in workload for formulating standards and implementation • Cost of the system and associated costs of increased workload • Alienation of member countries that are reluctant to adopt EM
Coastal states	• Monitoring catch levels, especially in fisheries with catch quotas • A mechanism to deter illegal activity that cannot be corrupted • Ability to monitor observers • Deflecting criticism that tuna fisheries are unsustainable • Showing the public that tuna fleets are being effectively monitored	• Loss of revenue if vessels move to the high seas to avoid EM requirements • Hesitancy of some coastal states to be an “early adopter” • Increase in workload for program implementation • Cost of the system (e.g., added costs such as dedicated equipment) that industry does not want to pay for • Pressure by flag states that are reluctant to adopt EM • Concessions that might be made to get Distant Water Fishing Nations (DWFNs) to agree to EM
Flag states	• Deflecting criticism that tuna fisheries are unsustainable • Showing the public that tuna fleets are being effectively monitored	• Pressure from domestic vessel operators that are opposed to EM • Additional enforcement responsibilities and expenses • Cost of the system (e.g., added costs such as dedicated equipment) that industry does not want to pay for
Vessel owners	• Avoiding criticism for low human observer coverage in longline fleets • Ability to demonstrate that fishing operations are legitimate • Monitoring quality control • Protection against frivolous claims by observers or crew • Greater management flexibility afforded when vessel is fully monitored	• Cost of the system, especially (a) if industry is expected to pay all EM expenses, and (b) considering the current low profitability of the fishery. • Fear of minor or unavoidable infractions being taken out of context • Extra work and difficulty of compliance with a whole new set of rules for the fishery • Having to return to port if vessel monitoring system becomes inoperable (i.e., not convinced of reliability of system)
Science agency staff	• Ability to efficiently collect many types of data • Greater confidence in collected data • Ability to verify data collected by human observers	• Inability to collect some kinds of data (e.g., possibility of loss of human observer coverage and associated opportunities for collection of biological samples)
Major tuna companies	• Ability to demonstrate that fishing operations are legitimate • Meeting market demand for sustainably fished product	• Fear of minor or unavoidable infractions being taken out of context
Vessel crew	• Does not take up as much room as human observer • Elimination of logistical problems and loss of fishing time for observer logistics • Captain has the ability to monitor crew at all times • Protection against frivolous claims by observers • Ability to monitor labor and safety practices	• Concerned about always being recorded in their workplace and invasion of privacy (e.g., showering, defecating) • Elimination of some income-earning opportunities • Extra work during port calls of dispatching the hard drives • Fear of minor or unavoidable infractions being taken out of context
Observers	• Reduction of harassment by vessel crew • Increased observer safety • Possibility of onshore employment as EM reviewer	• Unwanted auditing of work • Loss of on-vessel employment

Almost all stakeholders see positive and negative aspects of EM, but these views vary widely across groups. For example, fishery managers often value the compliance functions of EM. Vessel owners typically appreciate EM as a quality control tool and may even fund their own EM systems. It is important to engage stakeholders at the beginning of the process to identify their primary incentives and concerns. This will allow EM program designers to address stakeholder concerns before they become intractable problems, and to develop an EM program that has broad support.

It should be noted that engagement is more than getting all sides together in a room. Management must also be willing to accommodate different interests. Special attention should be given to the fishing industry. Although industry is sometimes left out of the design process, several EM specialists feel their inclusion is crucial to successful implementation. This is because the fishing industry is likely to pay much of the EM costs, may be required to do additional work to meet the requirements of an EM program, and will have their fishing activity subject to extra scrutiny.

Experience with EM programs points to the importance of effective stakeholder engagement, as illustrated by the following examples:

- The British Columbia groundfish fishery sought to better monitor bycatch and discards using ER/EM systems on their vessels. A comprehensive four-year pilot study, beginning in 2006, was conducted concurrently with stakeholder discussions about standards, feasibility, and costs. Ultimately, the successful pilot, informative stakeholder discussions, and continued adaptation have allowed for continued use of ER/EM in the fishery.[7]
- The US New England longline fishery was unsuccessful in ER/EM implementation. In the early 2000s, managers proposed using ER/EM to monitor and limit bycatch. However, because of a lack of infrastructure and support, minimal industry buy-in, and insufficient communication, full scale implementation of the ER/EM program has stalled.[8]

In the RFMO context, engaging stakeholders is more complex than in an EM program that covers only a single country or sub-region. There is typically a greater diversity of stakeholders, making it more difficult to obtain agreement. Due to the large geographical area covered by RFMOs, it is not always possible to have adequate representation of all stakeholders at one meeting.

There are several possible mechanisms for engaging EM stakeholders in RFMO fisheries, which can be conducted in person or remotely (e.g., via WebEx, Zoom, webinars, online trainings, etc.):

- An RFMO EM working group
- Workshops organized by regional organizations (e.g., Forum Fisheries Agency (FFA))
- Skipper seminars (e.g., those organized by IATTC)
- Industry meetings
- Meetings of pilot EM project groups
- Forums organized by NGOs (e.g., The Nature Conservancy (TNC) and agencies such as the Food and Agriculture Organization of the United Nations (FAO))
- Individual stakeholder interviews

Communication and Outreach

Effective design and implementation of an EM program depends on regular, transparent communication with all relevant stakeholders. This engagement should occur throughout the program design process and as the program is implemented. Stakeholder outreach is critical at the outset to build support for EM adoption. Communications should be aimed at helping stakeholders understand the consequences of failing to fill gaps in the current monitoring system. Framing communications around avoiding losses (e.g., EM will help better regulate the fishery, ensure other fishers are being monitored, and could protect against lower catch rates), and facilitating a process in which stakeholders can discuss and address their concerns, can reduce resistance and build motivation for establishing an EM program.[9] Fishermen may be more likely to reduce their resistance to EM when it is equally applied across the fishery, such that each fisherman knows their competition will also be monitored.[10]

Collaboration with industry stakeholders in the early phases of designing an EM program is important to learn about the needs and challenges of those who will be using the EM system, and to ensure that these insights are incorporated in the final design. Industry engagement should be inclusive of vessel owners, captains, and crew. Partnerships between industry and government on pilots, with the results of the pilot informing decisions about a wider EM program, are an example of effective collaboration that help ease industry uncertainty about how EM will affect fishing operations. Making the process of planning the EM system as transparent and participatory as possible can reduce uncertainty, and reluctance to change. Outreach processes in the RFMO context should allow both top down and bottom up communication between the secretariat, member states, government fisheries agencies, and industry.

[7] Zollett et al., “Guiding Principles for Development of Effective Commercial Fishery Monitoring Programs,” *Fisheries* Volume 40, Issue 1 (January 2015): 20-25.
[8] Fujita et al., “Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual,” *Environmental Defense Fund San Francisco*, (2018).
[9] Ibid.
[10] Howard McElderry, Personal Communication, (2020).

2. Establishing Program Objectives

Many reviews of EM programs show that the establishment of clear objectives is an important prerequisite for success – but the complexity of the process should not be underestimated. EM program objectives should be based on management goals for the fishery (e.g., ensuring compliance with catch and bycatch limits) and associated monitoring objectives (e.g., account for 100 percent of catch and bycatch or audit logbooks), and an evaluation of data type and collection mechanism needed to meet those objectives.

EM is an information collection tool; therefore, EM objectives are largely related to the types of information to be collected and analyzed. Accordingly, an initial step in defining EM program objectives is to determine answers to the following questions, in the context of the overall management objectives of the concerned fishery:

- What information is (a) important for the management and scientific processes, (b) not currently collected, and (c) could be collected by EM?
- What information presently collected by human observers, could be obtained more economically, efficiently, accurately, or safely by EM?
- What information currently collected from human observers or vessel logbooks, could be improved when complemented with EM?

The objectives of an EM program should largely flow from the answers to these questions, and the overall monitoring objectives for the fishery. Ensuring that EM objectives are based on clear monitoring objectives, and fishery management goals, makes it easier to communicate with stakeholders about the rationale and stimulate agreement about what must be done. It will also inform the video review process, and what data should be extracted from EM records, as discussed in a later section.

While defining program objectives, it is important to consider the costs and benefits of collecting and analyzing the information. Although EM can be used to collect many types of data, the cost of collecting that information may be greater than the benefits. For example, EM has been used in pilot projects to count the hook number between floats of longline gear, but in one trial collecting this information consumed approximately 50 percent of video analysts' time. Table 2 provides a selection of possible nested fishery management goals, monitoring objectives, and what the implications of each may be for the design of the EM program.

Table 2. Examples of Typical Fishery Management Goals, Monitoring Objectives, and Implications for EM (Fujita et al., 2018)

Fishery Management Goal	Associated Monitoring Objective	Implication for EM
Ensure compliance with catch and bycatch limits to ensure high sustainable yields and reduce adverse impacts on ocean wildlife	Account for 100 percent of the catch and bycatch; or audit logbooks to ensure reliable catch accounting	• Full camera views of all catch handling activity with full recording • Relatively high video review costs, especially if there is 100 percent review • Risk of misreporting with logbook audit approach
Ensure high compliance with spatial fishing restrictions, reduce bycatch of vulnerable species, or protect biodiversity and ecosystem function	Increase probability that violations will be detected to levels that result in deterrence	• GPS data and gear sensor data to determine vessel activity and location of activity • May need software that alerts enforcement officials to violations based on location data in order to focus enforcement efforts
Ensure compliance with bycatch limits	Quantify bycatch, including discards	• High resolution cameras required to identify species • Need clear catch handling requirements by crew to position fish to enable accurate identification of discarded and retained catch from images

In the RFMO context, purse seine and longline vessels may have very different requirements for observer coverage and will likely have different objectives for EM. Separate evaluations will need to be conducted for each gear type to determine what information is needed from, and could be collected by, EM. For example, bycatch may be of particular interest in longline fisheries.

To ensure appropriate EM program objectives are selected, it is helpful to look at the monitoring challenges that need to be addressed. This includes identifying the main reason that EM is being introduced, such as:

- Collecting information on fleets where there is little or no human observer coverage
- Replacing human observers
- Complementing the work of human observers
- Meeting market demands for increased monitoring
- Improving the accuracy of logbook data

In a discussion of EM program objectives some attention should be paid to whether EM will be replacing or complementing human observers. Some stakeholders (e.g., vessel operators) assume EM will replace observers and are interested in discussing whether EM or humans would be cheaper. Other stakeholders (e.g., some scientists) feel strongly that EM should be used in addition to human observers. Although this debate is far from settled, there is currently 100 percent human observer coverage of most purse seine fleets, so EM is likely to complement human coverage on those vessels for the foreseeable future. Conditions for observers aboard longliners are not likely to improve in the near term, and the small amount of human observer coverage is extremely useful. Accordingly, the ideal situation may be to maintain or increase the current level of human observer coverage on longline vessels while also implementing 100 percent EM coverage to ensure full accountability.

In some RFMOs, there is also discussion of setting compliance versus scientific objectives for EM. EM programs are likely to follow the pattern established by human observer programs. That is, historically, some flag states initially resist compliance objectives, but the reality eventually sets in that both science and compliance objectives are important in proper fisheries management, and the resulting observer programs have mostly both compliance and scientific data objectives.

The various stakeholders in the concerned fishery are likely to have very different perceptions of priority objectives. Building agreement on what fishery management and monitoring objectives the EM program is trying to achieve is a critical first step. An EM working group is an example of a forum that can build agreement on these objectives, share stakeholder perceptions, discuss tradeoffs, and facilitate negotiations.

3. Mitigating Challenges to Advancing EM

It is evident that the various stakeholders in RFMO fisheries have very different views on the costs and benefits of EM. Table 1 shows that the identified stakeholders have a multitude of attitudes towards EM, but all can see some benefits.

Although conditions vary considerably across all the RFMOs, there are two commonly cited concerns about EM. One is the cost of an EM program and who will pay for it, and a second is that vessel operators and flag states can be resistant to additional monitoring requirements. Under these two broad headings, there are some related challenges, which are briefly described below:

- **For the coastal states that license DWFN fleets, there is concern that an EM requirement will drive fleets from their exclusive economic zone (EEZ), and they will lose license revenue.** This challenge could be addressed with a synchronized roll out of EM across the entire fishery. There is growing recognition that RFMO fisheries need to be better monitored and fleets that attempt to subvert this trend by moving into the high seas will be increasingly considered as renegades, which could have repercussions for the fleet vessel owners and flag states. International pressure at the RFMOs and in the market will also help to mitigate this challenge. Over time, this concern is likely to fade.
- **It may be difficult to reconcile the coastal states' contention that industry should be responsible for all costs associated with the management of a fishery (including EM), with the industry's thinking that the cost of EM is the major constraint of implementation, especially for fisheries that are not very profitable.** Addressing this challenge may require some flexibility on the part of coastal states in allocating EM costs, especially during the start of a program. It may be possible to provide additional incentives to industry or obtain external support for the initial implementation of a new EM program (e.g., foreign aid, foundation grants).
- **Numerous stakeholders may face a "fear of the unknown" or an aversion to change due to uncertainty about system costs, reliability, impact of additional monitoring, and the extra work EM may require.** Pilot projects, and effective dissemination of the results, could dispel much of this fear. Inter-RFMO cooperation and exchange of experiences could also help demystify EM.

As experience with EM increases, more mitigating mechanisms for addressing these challenges are emerging. Several stakeholders are likely to be strong supporters of EM for RFMO fisheries, and their support can help positively influence others. These may include:

- Early adopting countries, especially those with individuals who are fishery champions;
- Coastal states, especially if they anticipate that costs to them will not be great; and
- Branded tuna companies, especially those that wish to promote the image that the concerned fishery is transparent and sustainable.

Drawing out positive experience with EM through pilot projects is another mechanism that can mitigate some challenges to introducing EM. Pilots can help resolve some of the technical and operational challenges of developing an EM program, address stakeholder concerns, and highlight the benefits of EM. For example, after using EM in a pilot project for a few years, longline captains in Fiji have stated they would prefer to work on vessels that have EM because they can keep track of various activities simultaneously during the fishing process. Several tuna fishing companies have installed their own EM systems after pilot projects demonstrated the benefits of being able to remotely monitor catch handing and improve quality control. Pilots may at least partially address the "fear of the unknown" challenge mentioned above.

Although it may take some time, there is a growing recognition that better information is required for effective management of RFMO fisheries. This sentiment is growing among even the most reluctant stakeholders. This concept, combined with the push from supportive stakeholders, suggests that other actors are likely to come around. In the planning of an EM program and the associated strategies for implementation, it is important to visualize the changes that may occur after an EM program is fully functional. Similar to the rollout of the mandate for electronic vessel monitoring systems (VMS) on many of the tuna fleets of the world, the introduction of EM is likely to initially face some opposition, but this opposition will fade over time. Judging from the pilot studies, it is expected that there will be an initial spike in detection of IUU fishing, followed by an improvement in compliance. Over the longer term, there will be better data to manage the fishery. If effective awareness campaigns are used, there will also be an improvement in the public perception of fishery transparency and sustainability.

There could, however, be some negative consequences of introducing EM. In the RFMO negotiation process, EM-reluctant flag states may want some form of concession for agreeing to EM. Fishing patterns could change, such as leakage to areas where EM requirements are less stringent. Some marginal operators may drop out of the fishery. There may be a push by DWFNs for less human observer coverage. Recognizing the challenges of introducing EM and taking advantage of opportunities for their mitigation can have a large influence on the success of an EM program.

4. Defining EM Program Standards

Once stakeholders agree on an objective in line with the fishery management goals, and stakeholders have fully wrestled with the functional elements of the program (e.g., through pilots), defining standards for an EM program is a logical step for formalizing an RFMO requirement for EM. This is because the requirements for an EM program must be very specific in order to make it possible to enforce compliance, so standards are a precursor to creating legally enforceable EM requirements. Discussions around standards can help generate agreement about moving towards EM, when other discussions may be more difficult (e.g., increasing overall accountability in the fishery, cost recovery). Standards can help to create compatibility in a network of EM programs where all the data collected can be used by a centralized management authority, such as an RFMO.

EM program standards are minimum specifications that the EM system and program participants (e.g., countries, vendors, and vessel operators) must meet. These standards should cover everything from the overall program design to the technical hardware details, including the entire flow of EM data from boat to manager (Box 1). The standards should be based on the EM program goals that dictate what data is needed and what it will be used for. These minimum requirements for the EM program should ensure that at least certain data will be collected by all vessels operating within the fishery, and that the data will be used for its intended purpose. As a starting point for establishing EM program standards, it may be helpful to look at RFMO observer programs which have a set of comprehensive minimum standards already in place. Several documents exist that outline minimum technical standards for EM systems, and those interested in diving into the details of these specifications can explore those resources.[11, 12]

Box 1. Checklist For EM Program Standards

At a minimum, EM program standards should cover hardware and procedural requirements for:

- On-vessel data capture
- Video retrieval
- Video review
- Video and data access
- EM records storage
- Privacy and confidentiality
- System servicing

They may contain requirements for:

- Cost reduction and how costs are allocated
- Vendor contracting

[11] "Technical guidelines and specifications for the implementation of R emote Electronic Monitoring (REM) in EU fisheries," *European Fisheries Control Agency Union*, (April 2019): 43.
[12] Ruiz et al., "Minimum Standards for the Implementation of Electronic Monitoring Systems for the Tropical Tuna Purse Seine Fleet," *Collect.* Vol. Sci. Pap. ICCAT, 73(2) (2017): 818-828.

There are a couple of principles to keep in mind for EM program standards:

1) **Align standards with the objectives of the program** – The objectives of an EM program will strongly influence hardware and other program requirements. If the program has basic monitoring objectives, a simpler and lower cost system and processes may be sufficient.
2) **Use performance standards when practical** – To allow vendors the flexibility to meet overall objectives, standards should be performance-based whenever practical (rather than prescribing specific technical details). This can prevent lock-in on a specific technology when better options become available. For example, rather than stipulating the specific details of the camera setup on vessels, it may be preferable to specify what the system must be capable of. The US National Marine Fisheries Service (NMFS) ruling to implement EM in two groundfish fisheries exemplifies this performance-based approach, stating that the onboard EM system must "allow easy and complete viewing, identification, and quantification, of catch items discarded at sea, including during low light conditions."[13]
3) **Standards can be adaptive and evolve as the fishery gains experience with EM** – The EM program standards may initially be simple, and evolve to be more rigorous over time as the program is tested and implemented across the fishery. Putting in place an expectation that this process of adaptation will occur could help generate agreement around the standards, and stimulate productive conversations based on direct experience with EM, rather than speculative debate.

Progress Towards Standards at the RFMOs

A few of the RFMOs have developed or are engaged in discussions to create EM program standards.

- The FFA member countries have produced for future consideration by their governing body a draft regional longline fisheries electronic monitoring policy, which includes standards on EM systems, data management, data ownership and access, and data security and confidentiality.
- The WCPFC has established an ER/EM working group for developing EM standards, which were presented to the annual meeting of WCPFC in December 2019.
- In 2019, ICCAT adopted a measure to propose longline EM standards by 2021.[14]
- The Indian Ocean Tuna Commission (IOTC) is conducting EM trials that will eventually inform draft standards.
- The IATTC is developing standards for both longline and purse seine and will be presenting them for discussion to its Scientific Advisory Committee (SAC) in 2020.

In recent years, the WCPFC has extensively discussed the need for EM, and their progress in this area may provide some guidance to the other commissions. The Pacific island nations (the largest voting bloc in the Commission) formed a consensus that EM should be developed as a network of national programs operating under common Commission standards, similar to the observer program. Those standards and other aspects of starting an EM program have been discussed at three formal meetings for the WCPFC ER and EM Intersessional Working Group. The stated purpose of that group was "improving the management of data and streamlining data flows from members and their vessels to the Commission."

ICCAT recently agreed to increase the observer coverage of longline vessels over 20 meters to 10 percent by 2022 and has agreed to develop minimum standards for EM by 2021. The simultaneous expansion of observer requirements and development of EM standards is likely indicative of steady progress towards increasing coverage using EM.

IATTC is also making progress towards developing EM standards having recently adopted resolution C-19-08. The resolution includes the statement that "The IATTC Scientific Staff, in consultation with all parties, co-operating non-parties, co-operating fishing entities or regional economic integration organizations (CPCs), shall prepare a draft proposal for the development of minimum standards for the implementation of an EMS for the longline fleets, taking into account the experience of CPCs that are implementing EMS on longline vessels and progress made in other tuna RFMOs, to be submitted to the SAC meeting of 2020."

IATTC staff have already prepared EM standards for the SAC to consider, which contain technical (e.g., camera resolution), logistical (e.g., handling data), data collection, and data reporting considerations. The SAC will deliberate on the EM standards and will forward its recommendation to the full IATTC meeting, which will be held a few months later.

Considerations for Developing EM Program Standards

When developing EM program standards, regular meetings to discuss options and trade-offs can be an invaluable learning tool for stakeholders. However, it is possible to get overly focused on technical details, so it is important to constantly refer to the overarching EM program objectives to make decisions.

It is possible that in some cases, RFMOs may agree on EM program standards without coming to agreement around increasing monitoring coverage to ensure full accountability. If this occurs, it will be important to revisit the conversation around the percent of trips that should be covered by human observers or EM. As countries gain familiarity with EM and overcome concerns about the difficulty of meeting the standards, they may be more amenable to a requirement for full monitoring coverage.

[13] "Final Rule (84 FR 31146)," *NOAA Federal Register* Vol. 84, no. 125 (June 2019): 31146-31169.
[14] Restrepo and Koehler, "ICCAT Moves to Protect Atlantic Bigeye and Close Gaps in Monitoring and Data Collection," *ISSF*, December 4, 2019.

From Standards to Regulation

Despite growing RFMO EM activity, there are currently no RFMOs in which use of EM is required. Once RFMO members agree on EM program standards, they are likely to be promulgated into a management measure or resolution. This may be just about the standards themselves (i.e., "When EM is used to fulfill a requirement of the Commission, the following minimum standards shall apply…"). Management measures may also include requirements beyond the EM standards, such as the percentage of trips that need to be monitored (e.g., 100 percent), or that human observers or EM may be used. However, this may be agreed to at a later point via a separate management measure.

Countries must incorporate management measures passed by RFMOs into domestic requirements because of legal obligations under the relevant conventions. The mechanism varies between countries, but sometimes consists of incorporating a management measure into domestic licensing conditions. Licensing conditions are a quick way to implement EM, but may not be the best approach in the long term as the provisions for penalties are usually less robust than those of acts or regulations.[15] All countries within established RFMOs have processes in place to transform management measures into regulations under their national fisheries legislation. This has been done successfully in some RFMOs with VMS requirements, for example.

The process of agreeing on standards and then moving standards into an RFMO management measure is likely to be the same regardless of what EM program structure is chosen. However, the EM management measure may specify the structure, so in the next section, we discuss three options for the structure of an RFMO EM program.

[15] MRAG, "Cost Recovery Guidelines for Monitoring Services," *MRAG Asia Pacific*, (September 2018).

Photo: Environmental Defense Fund

5. Structuring the EM Program

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. 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, 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.

Some of the advantages and challenges to address for each of the EM program structure options are given in Table 3.

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

In settling on the structure of an EM program, cost is an important factor. There have been few, if any, studies that compare the start-up and recurrent costs between the different EM program structures. Pilot studies are mostly confined to national EM programs and therefore do not provide much cost comparison information. Intuitively, an RFMO-wide program would have economies of scale and could be cheaper for RFMO member countries.

The Western and Central Pacific Ocean (WCPO) is the region that is closest to making a decision about the structure of its EM program. In October 2019, Forum Fisheries Agency (FFA) member countries established a draft Regional Longline Fisheries Electronic Monitoring Policy in which the countries agreed to pursue national EM programs for longline fisheries.[16] An EM program for the purse seine fisheries of the WCPO is likely to follow the same structure (e.g., national, sub-regional).

6. Calculating and Allocating Costs

Because the costs associated with an EM program are a concern for many stakeholders, additional attention to expenses is required. To date, most of the costs for EM programs in tuna fisheries have been paid by NGOs and international organizations, but this model will not continue forever. Currently, much of the enthusiasm by coastal states for EM is related to the idea that in the future, industry will be responsible for paying most, or all, of the costs. The draft Regional Longline Fisheries Electronic Monitoring Policy formulated by FFA member countries states as a guiding principle: "User pays - full cost recovery as a default." Many segments of the fishing industry feel that costs could be high and are also uncertain about how an EM program will affect their business. As the group that will be most impacted, they may believe that it is unfair for them to be entirely responsible for funding an EM program. This difference of opinion on who should pay for EM is seen by many as the most significant impasse for EM implementation.

Many reports on EM state that a major advantage of EM is its cost relative to human observers. However, human observers can have a cost advantage where observer wages are low (e.g., in Pacific Island countries, Latin American national observer programs).

The costs of EM are also quite clear and immediate, while the benefits of EM can be more uncertain and diffuse. For example, there are costs of inadequate knowledge of fishing activity (e.g., depleted fisheries) but those costs are not very clear, especially in fisheries with limited data. A report done for the FFA places EM costs into four types: (1) on vessel costs; (2) program administration and operational costs; (3) policy and regulatory development costs; and (4) analytical costs (Box 2).[17]

Box 2. Taxonomy of EM Costs

A report on EM costs done for FFA and WWF places costs into four categories:

- **Type 1: On vessel costs**. These costs are associated with the installation and operation of EM hardware and supporting systems on board fishing vessels.
- **Type 2: Program administration and operational costs**. These costs are associated with the administration and operation of the EM program, usually undertaken by national (or regional) fisheries administrations. These costs typically form the 'core' of the annual EM program budget, and would be a main focus for cost recovery.
- **Type 3: Policy and regulatory development costs.** These costs are associated with the establishment of relevant regulatory and policy arrangements to support effective EM systems.
- **Type 4: Analytical costs.** These costs are associated with the analysis of EM generated information to produce outputs in support of the administration and management of fisheries by national fisheries administrations (e.g., production of reports analyzing annual trends in EM information).

Cost comparisons between programs can be difficult, and it is necessary to determine what costs will be included, what types of fisheries are involved, what type of program will be established (e.g., pilot vs. full-scale), and how much video is reviewed. Examples from Fiji and the US can provide a reference for the range of total costs involved:

- An EM pilot project funded by the Food and Agriculture Organization of the United Nations (FAO) for 50 tuna longliners based in Fiji operated for three years (2015-2018).[18] The total fixed and variable costs for the three years were US$986,575, which came out to US$6,577 per vessel per year. The pilot was able to review approximately 44 percent of the EM trips over the pilot's duration.[19]
- The cost of providing EM to 18 vessels in the US New England groundfish fishery was estimated in a pilot project sponsored by the Nature Conservancy in 2017. The start-up costs, purchasing and installing equipment, and reviewing 100 percent of the video on 276 fishing trips was about US$15,000 per vessel per year.[20]

[16] Draft Regional Longline Fisheries Electronic Monitoring Policy," *Forum Fisheries Agency* Version 1 (October 2019): 12.
[17] MRAG, "Cost Recovery Guidelines for Monitoring Services," *MRAG Asia Pacific*, (September 2018).
[18] Hurry, "Building a Business Case for Electronic Monitoring (EM) for the Fiji long line (LL) fishing industry," *Ministry of Fisheries, Suva, Fiji,* (February 2019).
[19] Stobberup et al. "Electronic Monitoring in Tuna Fisheries: Strengthening Monitoring and Compliance in the Context of Two Developing States." *FAO* (in-press).
[20] Cap Log Group, LLC, "Projected Costs of Providing Electronic Monitoring to 100 Vessels in New England's Groundfish Fishery," *The Nature Conservancy*, (March 2019).

Most of the information on EM costs in tuna fisheries is from pilot projects and from the national level. There is little information on EM costs at the RFMO level. However, there are likely savings to be made per vessel over smaller national programs due to the large number of vessels involved. In addition, the large size of an RFMO program can give considerable power to dictate favorable cost conditions. On the other hand, cost recovery can be more complex in a system that involves dozens of countries and thousands of vessels.

Cost Recovery

In modern fisheries management, the concept of recovering management costs from fishery participants is based on the concept that the fishing industry profits from the use of a public resource. Fishery cost recovery is covered extensively in the general fisheries literature and there has been some attention given to EM in tuna fisheries.[21,22,23] The references give some general principles of cost recovery, including:

- Costs should be recovered from fishery participants in proportion to the benefits they receive.
- The system of cost recovery should incorporate features that encourage compliant behavior by fishers and efficient use of program resources.
- There is a responsibility on the part of fishery managers to reduce costs as much as possible.
- Those groups that are being charged for management services should be included in the discussions of attributing costs.
- EM is just one of the costs involved in fisheries management, so it may be appropriate to consider and attribute all management costs as a package instead of just focusing on cost recovery for EM.

Although the phrase "full cost recovery" is being used in EM discussions, in reality some costs may not be appropriate for recovery. The costs of considering, drafting and enactment of legislation enabling an EM program are significant, but it may be difficult to justify recouping those costs from the fishing industry. Although there may be some opportunity costs of EM to government fisheries agencies and RFMOs, such as training provided at no cost by outside agencies, it may not be appropriate for the fishing industry to pay those costs. The FFA report on costs cited above indicates that program administration and operational costs (i.e., type 2 costs) are usually the focus for cost recovery efforts.[24]

Industry concerns about cost recovery can be addressed in several ways. An EM program could start with partial recovery and evolve into full recovery as participants become more comfortable with the system. Alternatively, in some places to ease introduction, government funds equipment costs and vessel operators pay for the on-going costs. Vessel owners may also become more willing to fund the program as they are permitted to use some of the features of EM for their own benefit (e.g., monitoring fish handling by the crew). In the British Columbia groundfish fishery, there is an arrangement for EM cost recovery that incentivizes good behavior: vessel operators that have a good compliance record (as judged by EM video review) have their videos audited less frequently and consequently pay considerably less in viewing charges.[25]

Cost Reduction

Reducing EM program costs may help increase acceptance of EM, especially by the cost-sensitive private sector. In economic terms, EM costs borne by industry reduce the economic rent in a fishery, so less rent is available for capture through access fees or other charges. As such, there are incentives for several types of stakeholders to reduce costs.

Video review can be the most expensive part of an EM program. EM can record almost all fishing activities, but the amount of the video that is actually reviewed by EM analysts has a large effect on overall EM program costs. Cost reductions can be made by viewing only a selection of fishing events, either chosen randomly or by certain criteria. There is hope that eventually artificial intelligence (AI) may tremendously speed up the process of video viewing (Box 3). In the short term, less sophisticated technology may help. A recent report on EM states that review costs should decrease with continued technological advancements that automatically flag key events, reduce file size based on activity, truncate video footage for review, and improve the efficiency of EM.[26]

Other ways of decreasing EM program costs include:

- Reducing program complexity (e.g., choosing appropriate program objectives and data to collect with EM)
- Reducing the time that the EM records are stored (i.e., purging after a shorter amount of time)
- Regularly consulting stakeholders to obtain their ideas on cost reduction opportunities
- Reducing program uncertainty (e.g., establishing government policies, clear legislation)

[21] Garcia et al., "The ecosystem approach to fisheries. Issues, terminology, principles, institutional foundations, implementation and outlook," *FAO Fisheries Technical Paper* No. 443 (2003): 71.
[22] MRAG, "Cost Recovery Guidelines for Monitoring Services," MRAG *Asia Pacific*, (September 2018).
[23] Fujita et al., "Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual," *Environmental Defense Fund* San Francisco, (2018).
[24] Ibid.
[25] Howard McElderry, Personal Communication, (2020).
[26] Michelin et al., "Catalyzing the Growth of Electronic Monitoring in Fisheries: Building Greater Transparency and Accountability at Sea," *California Environmental Associates and The Nature Conservancy*, (September 2018): 64.


Photo: Shutterstock

Box 3. Artificial Intelligence

Advances in processing power, chip design, and the availability of enormous data sets have transitioned AI from a promising idea to something that is a part of our everyday lives. From self-driving cars, to speech recognition, to credit card fraud detection – artificial intelligence is all around us. It is a powerful tool and it can quickly bring to mind a future world in which all types of human tasks are quickly displaced by computers. Excitement about the potential of AI is ubiquitous, and the fisheries sector is no exception.

With video review being one of the most time-consuming and costly components of EM programs, there is a huge amount of interest in the potential of AI for this function. The long-term vision would be for on-vessel AI that is capable of automatically processing video footage into data about the fishing trip – catch volumes, species, lengths, discards, etc. – and reporting the data back to fisheries managers in real time.

There are numerous efforts underway to use AI for the analysis of EM video. A collaborative effort between NOAA and the University of Washington has developed AI that can successfully identify fish species with greater than 95 percent accuracy for a multispecies fishery that captures more than 30 types of fish. Visual recognition has also been used in EM trials in Scotland to count the number of dredges deployed on scallop vessels.

EM vendors are beginning to explore AI and how to integrate it into their systems, and several other academic institutions have AI projects underway for fish identification, including University of East Anglia and Wageningen University. Many of these projects have produced successful prototypes. The Nature Conservancy (TNC) ran a competition to classify longline fishing activity in which the winning team achieved close to 100 percent accuracy in count and 75 percent accuracy in species. These research efforts are promising, but there is a wide gap between a successful prototype and a product-ready solution.

A bottleneck for the development of visual recognition algorithms for EM systems is the availability of tagged training data. An image classifier needs thousands of tagged images to be able to reliably identify fish species. TNC is trying to address this challenge with the creation of Fishnet.AI, which is a library of tagged images from EM systems that developers can use to train their algorithms.

A second challenge is environmental variability, which can make visual recognition difficult. Conditions at sea are particularly challenging – variable light, splash and spray, different vessel and background configurations. Similarly, fish may be in different orientations or stacked on top of each other – presenting additional challenges for accurate classification. This may make the use of AI more likely on belts and chutes as the technology is rolled out.

Finally, the market for EM systems is currently small, which makes it difficult for an EM vendor to make a large investment in research and development when AI may only have applicability to a small number of systems. And in cases when someone else is doing the video review (e.g., in a government center), the vendors have little financial incentive to invest in AI development.

Despite these challenges, there is a lot of ongoing effort to advance AI for EM video analysis. While the hope is that it will eventually enable complete capture of species, length, and volume data, the next steps are going to be advances in AI-assisted review (e.g., identifying key events). In thinking about how AI will impact an EM program, perhaps the guidance of Silicon Valley pioneer Roy Amara is useful, “We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run.”

7. Defining Program Coverage Levels

Fisheries managers will need to determine what portion of the fleet will ultimately be required to have EM systems and what portion of their fishing activity needs to be recorded. In most cases, 100 percent coverage will be preferable to ensure compliance objectives are universally met and that there is a level playing field across the fishery, but there are challenges to achieving this target. This section outlines the rationale for 100 percent EM coverage and discusses when some flexibility with this target may be warranted.

Why Is 100 Percent EM Coverage Important?

In fisheries that have less than 100 percent observer coverage, there is a risk that the data collected by observers, shoreside inspectors, or in the vessel logbook is not representative of the entire fishery. Fishers may operate differently in the presence of observers to reduce the likelihood of problematic events being seen, such as ETP species interactions. This change in behavior in the presence of observers, called the observer effect, has been documented in numerous fisheries.[27,28] Likewise, deployment effects, where the placing of observers on vessels may not cover a representative sample of the fishery, can lead to biased data collection. One solution to these issues is to increase human observer coverage to much higher levels, but this is not realistic for many fisheries.

In many cases EM is easier to scale across an entire fleet than human observers and, once installed, the additional cost of recording 100 percent of the fishing activity is low. By having EM on all vessels, recording all fishing activity, the crew knows that all fishing could be reviewed. This eliminates the ability of vessels to fish differently while being observed and is a powerful incentive for accurate data reporting.

A recent study in Australia found that reported discards and interactions with protected species increased significantly with the adoption of EM, indicating that EM led to changes in logbook reporting behavior.[29] Many other trials demonstrate that EM is a powerful driver for compliance and improved reporting. Full EM coverage also allows for scientists and managers to select truly random samples of fishing activity.

Full coverage is also important for creating a level playing field. EM can be a powerful tool for compliance, but if it is not required on all vessels, those that are required to participate can become frustrated with the lack of full accountability across the entire fishery.

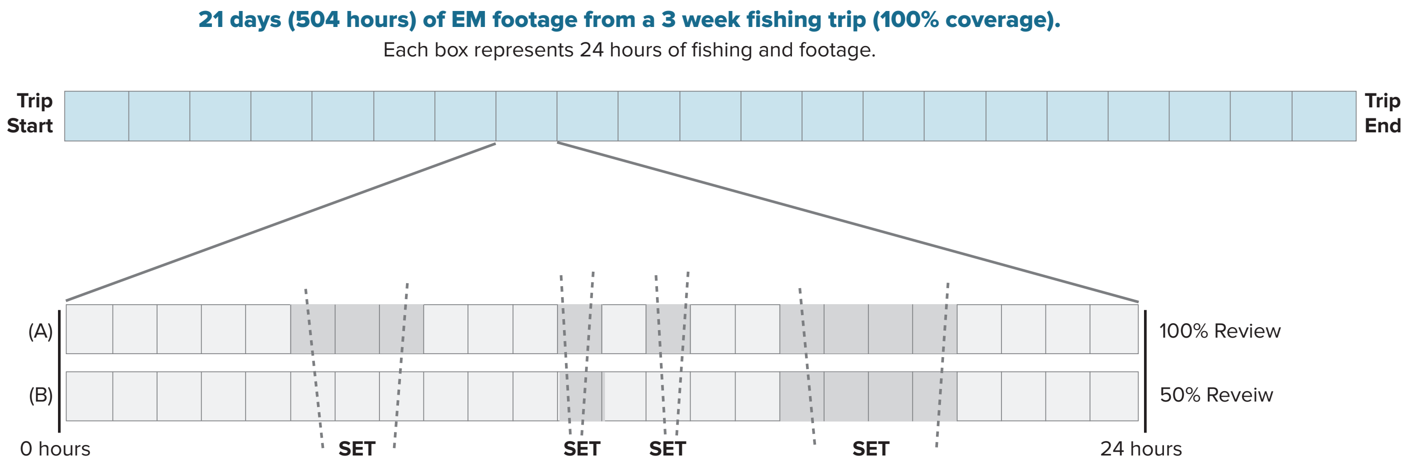
100 Percent EM Coverage Does Not Mean 100 Percent Review

EM coverage rate can be defined as the share of fishing activity that is recorded in the fishery, while the EM video review rate is the percentage of EM video recorded that is reviewed. While it is important to aim for 100 percent EM coverage of vessels in a fishery, this does not mean that all the video of fishing activity should be reviewed. The time and cost of complete video review could make an EM program impractical, depending on the data that is being collected. Instead, fully implemented EM programs typically review a random sample of fishing activity that is sufficient to accurately extrapolate data to fishery-level estimates or check the accuracy of logbooks (Figure 2). This is discussed in more detail in the video review section.

[27] Sampson, "Final Report to the Oregon Trawl Commission on Analysis of Data from the At-Sea Data Collection Project," *Oregon State University*, (2002).
[28] Demarest, "Observer Effects in the Northeast U.S. Groundfish Fishery," NOAA, (2018)
[29] Emery et al., "Changes in logbook reporting by commercial fishers following the implementation of electronic monitoring in Australian Commonwealth fisheries," *Marine Policy Volume* 104, (June 2019): 135-145.

Figure 2. EM Coverage Rate versus Review Rate

Hypothetical 3 week purse seine finishing trip. The entire trip is recorded by EM. There are periodic sets, where the gear is deployed and then hauled in. Below are different review options.



Zoomed in on one day of the trip, each box represents 1 hour of fishing and footage. Dark gray shows reviewed footage, light gray indicates non-reviewed footage. Four fishing events were detected by the EM system. In (A) 100% of fishing events are reviewed, whereas in (B) the review rate is set at 50%, and half of all fishing events are randomly selected for review.

Possible Exceptions to the 100 Percent Coverage Target

While 100 percent coverage of the fleet is usually a desired target, there are some situations that may warrant exceptions or flexibility.

- **Vessels with limited fishing activity** – Within a fishery there may be vessels with limited fishing activity. For these vessels, the cost of installing an EM system can be prohibitively expensive since they cannot spread out the cost over many days at sea. A common approach that can provide flexibility for these low activity vessels is to allow them to choose between EM or having a human observer on board. Alternatively, these vessels could share simple, portable EM systems.
- **Small-scale vessels** – Small-scale vessels with limited catch volumes may also struggle to shoulder the costs of EM or human observers. In these cases, it may be appropriate to consider exceptions to EM requirements for some vessels (e.g., those with low total catch levels, small vessels), although this requires a full assessment of the risk that this unmonitored portion of the fleet presents. Another option would be to grant financial subsidies for small-scale vessels. This situation may also be conducive to sharing simpler, more portable EM systems across several vessels.
- **Fisheries with minimal compliance concerns** – If the goal of the EM program is limited to collecting scientific information, and there is minimal concern that boats with EM will operate differently than those without, coverage levels lower than 100 percent may meet monitoring objectives at a much lower cost. This is uncommon, as most fully implemented EM programs have opted for 100 percent coverage of fishing activity. If the science objective is to collect data on rare events (e.g., some ETP interactions) 100 percent coverage may still be required.
- **Stepwise rollout** – In many cases, it may be challenging to roll out EM across the entirety of a fishery all at once. This may be the case within RFMO fisheries that can have thousands of vessels, many flag states, and fishing activity that spans numerous member states and the high seas. There can be a lot of variation between fleets and between member states in terms of their capacity to implement an EM program. In this context, it may be helpful to consider a fleet-by-fleet or subregion-by-subregion rollout towards a goal of 100 percent coverage. However, a stepwise rollout can generate concerns about an unequal playing field between the vessels that have EM and those that do not.

8. Capturing EM Records

EM programs will need to define minimum specifications for the hardware used on vessels to capture data. On-vessel EM systems typically consist of digital cameras, sensors (e.g., a drum-rotation sensor) to trigger video recording or tag fishing events, GPS, hard drives, control box, satellite modem (to report system status), and a video monitor in the wheel house to display the system status and camera views. There are numerous aspects of hardware that should be considered, and this can be complicated with a fleet that is made up of a variety of vessels. For example, a longline fleet may include small vessels that lack sufficient protected dry space to house an EM system, as well as large vessels equipped with modern technology. The ideal camera placement will vary based on vessel type and program objectives. An example diagram from the Hawaiian longline EM pilot shows the field of view for two cameras, which each capture different information (Figure 3).

Given the diversity of vessel setups, it can be challenging to define prescriptive hardware standards, and therefore performance-based standards should be used when practical. These give vendors the flexibility to setup systems that can meet the overall program objectives in the most efficient way and give them the flexibility to apply different setups across the different types of boats in a fishery. The NMFS final rule implementing EM in two US groundfish fisheries illustrates this approach. The rule does not include any prescriptive hardware specifications, but instead says that the configuration of the on-vessel system and its specifications (e.g., image resolution, frame rate, number of cameras, etc.) must be sufficient to meet the program objectives, such as accurate viewing, identification, and quantification of discards; continuously recording the vessel location; and recording and storing image data from all sets and hauls.[30]

[30] Final Rule (84 FR 31146)," *NOAA Federal Register* Vol. 84, no. 125 (June 2019): 31146-31169.
[31] Carnes, et al., "Evaluation of Electronic Monitoring Pre-implementation in the Hawai'i-based Longline Fisheries." *NOAA Fisheries*, (October 2019): 4.

Figure 3. Diagram of Recommended EM Camera Configurations for Hawaiian Longline Vessels[31]

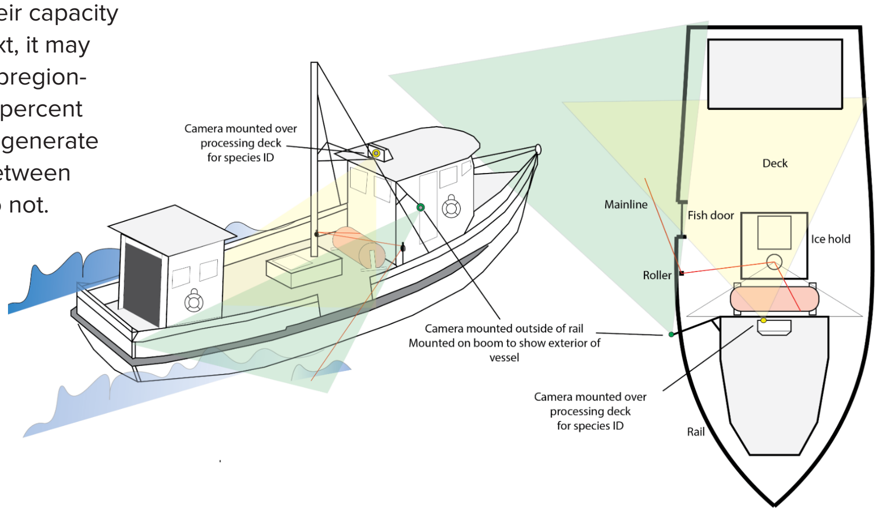


Photo: Shutterstock

9. Retrieving EM Records

Data collected by on-vessel EM systems will eventually need to be transferred to an appropriate agency for review and analysis. These files include many hours of high-resolution video and can be tens to hundreds of gigabytes in size, which makes transferring them to video review centers challenging. There are several ways that EM records (e.g., video files) can be transmitted from vessels, which vary in cost, reliability, and how quickly after a fishing event the data can be reviewed.

The primary three options for data transfer are transmission via satellite networks in real time (or near real time), transmission via Wi-Fi or mobile data networks when vessels come into range of shore, and manual replacement and shipping of hard drives containing EM data when a vessel comes into port (Table 4).

Table 4. Summary of Primary Video and Data Retrieval Options

Satellite

Satellite is currently the most expensive option, and could be especially expensive for long tuna fishing trips with lots of video. It could become more cost-effective with the use of emerging technologies, such as improved use of sensors or AI to detect fishing events to minimize recording time or to minimize the size of the files to be transmitted. Some data can be transmitted cost-effectively, including paired sensor and location data, which can inform managers when and where fishing is occurring in near real time. This method works well for uploads of text data. Video data requires broadband (VSAT) and most providers have much higher data transfer prices for uploads than downloads.

Upload speed: 0.1 - 3 Mbps

Wi-Fi or Mobile Data Networks

Wi-Fi transmission is much more affordable than satellite, but requires reliable network connectivity in all ports vessels might visit, which is not uniformly available. Trials in Denmark for bottom trawl, gill net, and purse seine fisheries tested a new system that allowed vessels to wirelessly transmit EM data via 3G, 4G, or Wi-Fi, which reduced operational costs compared to exchanging hard-drives. Initially, data transfer speeds were averaging 10 to 20 Mbps, which required an average of 8 hours to upload video from one trip. At this rate, many vessels could not complete video transfer before departing on their next trip. This problem was largely solved later in the trial as upload rates increased to 50 to 90 Mbps.[32]

Upload Speeds:

- Wi-Fi: 10 - 100 Mbps
- 3G: 0.1 - 1.2 Mbps
- 4G LTE: 2 - 15 Mbps

Hard Drive Exchange

Exchanging hard drives is the most common approach used in EM pilots and implemented programs. For fisheries that operate at large geographic scales, out of many ports, the logistics for replacing and mailing used hard drives securely and efficiently are likely to be complex. It is important that each hard drive have a verifiable chain of custody, ensuring security of the hard drive in transit to minimize opportunity for loss, damage, and make tampering attempts evident. In addition to submitting used hard drives, vessels will need to restock with empty hard drives periodically.

[32] Plet-Hansen, et al. "More data for the money: Improvements in design and cost efficiency of electronic monitoring in the Danish cod catch quota management trial," *Fisheries Research* 215, (2019), 114-122.

Logistical Considerations of Hard Drive Exchange

Since hard drive exchange is the most trialed option, it is the primary model being considered for video retrieval for current EM development efforts (e.g., in the WCPFC, IATTC). RFMOs can expect complex logistics associated with this option due to the many ports across multiple countries with varying degrees of infrastructure visited by thousands of participating vessels.

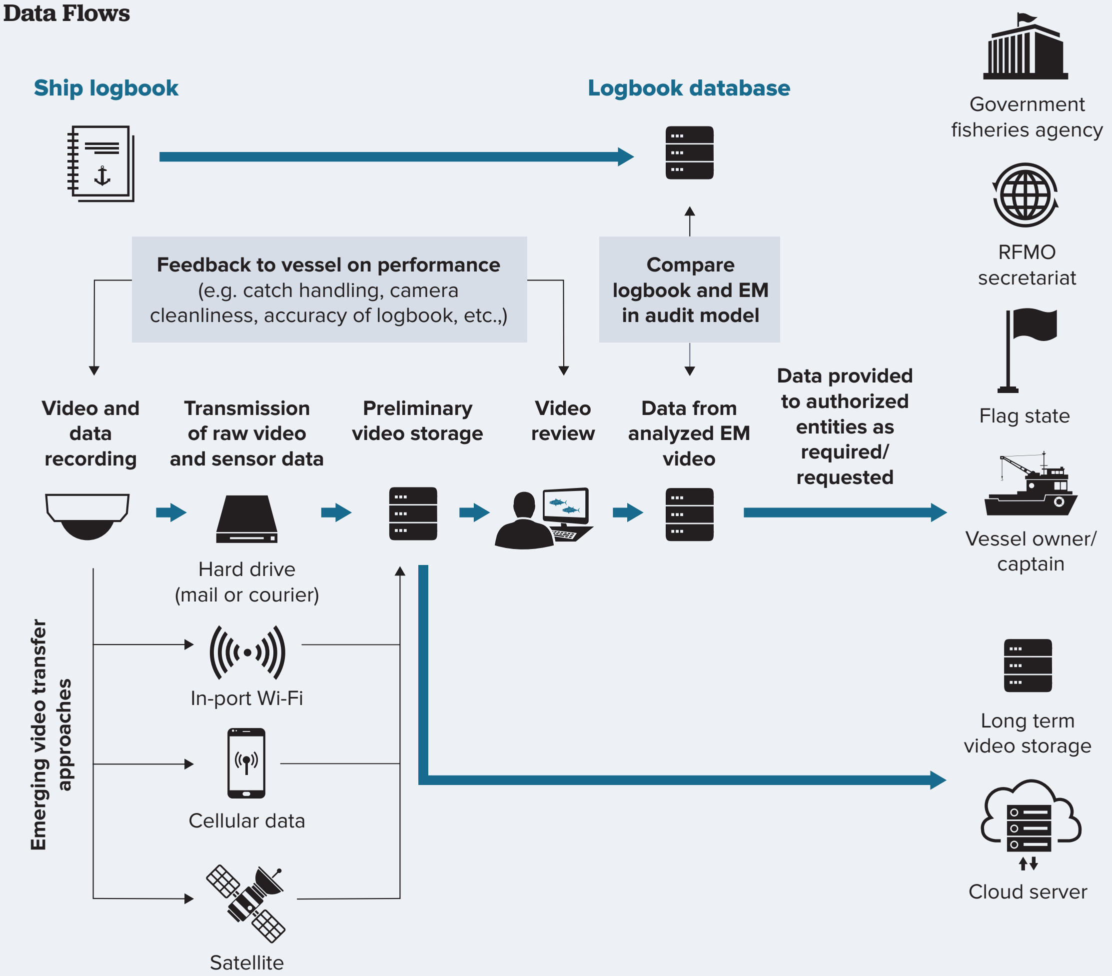
For the EM system to work effectively, vessel owners and operators who submit the hard drive should have confidence that the data seen by the reviewer accurately reflects what was recorded on the vessel, as confirmed by a reliable chain of custody and supported by data encryption. The RFMO secretariat should determine whether hard drives can be sent through certified mail services or via courier throughout the entire region. But even this can present challenges. In the US Atlantic Highly Migratory Species (HMS) EM program, which requires vessels to mail in hard drives at the conclusion of each trip, "the most substantial logistical constraint was hard drives that were mailed late or not mailed in at all."[33] Couriers may also be used to pick up or deliver fresh hard drives to vessels.

Alternatively, vessels could turn over hard drives to a dedicated collector stationed at each major port These collectors could be trained staff affiliated with the national fisheries agency or human observer program, or a port agent. The collector should be able to meet vessels, swap hard drives, and upload video in a local office to transmit via Wi-Fi or physically pass off the hard drives to the appropriate centralized video review office. A locker system could also be used so that pickups and drop-offs would not require a person to be available the moment a vessel comes into port. In IATTC's pilot EM program, staff of the commercial EM service provider pick up the hard drives directly from the vessels and pass them to IATTC staff traveling to IATTC headquarters. These hard drive retrieval methods would help to limit the risks associated with mailing physical hard drives from remote ports with limited infrastructure. SatLink has worked in multiple countries and has found that with adequate preparation and partnerships with entities such as the Port Authority, an in-country review center, local fisheries authorities, and the observer program, successful hard drive swaps can be done without major problems.

[33] NOAA, "Three-Year Review of the Individual Bluefin Quota Program," *NOAA Fisheries*, (September 2019): 166.

Figure 4. EM System Data Flows

This diagram shows a generic EM system and associated data flows, including multiple possible pathways leading into the video review process. As shown in the diagram, existing monitoring systems tend to record data from the on-vessel EM system directly onto hard drives on the vessel, which are then sent for video review. Emerging technologies may help to increase efficiency and reduce costs associated with video retrieval.



10. Reviewing EM Video

The process for reviewing and extracting data from video footage is a critical element of EM program design. Video review is typically the costliest component of an EM program – often about 50 percent of overall program costs – and decisions about how much video to review and what data to extract need to be guided by and aligned with the overall EM program objectives. The more video that is reviewed and the more detailed the data extracted, the more costly it will be.

There are different models for assigning responsibility of the video review process, each with their own pros and cons. EM vendors also have their own proprietary review software, which vary in terms of the efficiency of video review. Thus, software performance is an important consideration when structuring the video review component of an EM program. This section discusses some of the key elements of the video review process.

What Data to Extract from EM Video?

There have been several pilots on purse seine and longline vessels that provide guidance on what types of data EM can collect (Appendix). The Pacific Community (SPC) and Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) completed a study that evaluated EM's ability to collect all of the longline data fields required under WCPFC's observer program minimum standards.[34] But the decision of what data to collect with EM should include much more than the technical capability of the EM system to provide that observer-type data. In February 2020, SPC's Data Collection Committee put forward draft longline EM minimum standards, recommending which required data fields should be collected with EM and outlining the protocols for collection.[35]

EM programs can make the costs and benefits of data collection much clearer than with human observers. Every additional piece of data collected with EM will require more of a review analyst's time. This is different than with an at-sea observer who will be paid for a full day of vessel deployment regardless of the data they collect. For example, it may be relatively easy to assess the overall shark bycatch from a longline vessel with EM, but trying to obtain accurate identification of shark bycatch to the species level could require much longer review times and have limited accuracy. Collection of some data may also require that the crew to take on additional work, such as adopting specific on-board catch handling protocols. In some EM programs, fishers are required to sort and measure fish that will be discarded in view of the camera to allow for accurate accounting of discards.

Program designers need to think holistically about the goals of the EM program and the costs and benefits of extracting various data using EM. As an example, in an EM pilot in the Western Pacific, video reviewers were spending more than half of their time identifying the hook number between adjacent floats of each catch event. While the hook counts can be valuable information, there is a question of whether the information is worth the additional cost of an EM analyst's time to gather that information. The process of counting hooks was also believed to have an impact on the job satisfaction of video analysts.

While more information is generally better, it comes at a cost and EM program designers have the challenge of striking the right balance. Collecting certain types of data may not be worth the additional cost or operational burden. There are a variety of other monitoring tools that can be used and EM may not always be the right tool for a given data need.

Video Review Approaches

There are three main approaches for obtaining data from EM systems: direct data collection with a census or subsample approach, logbook auditing, and basic event detection.

With direct data collection, an EM analyst reviews the video footage and documents the desired data on the fishing activity (e.g., fishing effort, times, locations, target and non-target catch data). The analyst may review all fishing activity or a subsample that is then scaled up to create fishery-wide estimates. In this approach, the data from the EM video analysis is the primary data source for fishing activity and catch. The minimum video review rate required to accurately scale a subsample of data to a fishery-wide estimate will depend on a number of factors (e.g., frequency of events to be detected, variability across sets/hauls, etc.), but recent research in New England found that review rates of approximately 20 percent resulted in accurate discard estimates for multiple bycatch species in the groundfish fishery.[36] Another study concluded that if the sampling is unbiased, coverage rates of 20 percent may be sufficient for common species and 50 percent for rare species, although this can vary depending on the structure of the fishery.[37]

With the logbook audit approach, a random sample of fishing activity is reviewed and the data is compared to vessel-reported logbook data. If there is sufficient alignment between these two sources, all of the logbook data is accepted and used to calculate trip-level and fishery-wide estimates. A review of EM for the New England groundfish fishery found that the overall costs of the program would be almost 60 percent lower with an audit approach compared to a census approach with 100 percent review.[38] This method also orients fishers to their data reporting responsibilities, and has been shown to build industry support for EM programs as the fishers' self-reported data is used for management decisions.[39]

[34] Emery et al., "The use of electronic monitoring within tuna longline fisheries: implications for international data collection, analysis and reporting," *Reviews in Fish Biology and Fisheries*, (2018), Volume 28, 887-907.
[35] SPC, FFA, PNAO Data Collection Committee, "Draft DCC Longline EM minimum data field standards (version DCC-2020-Feb)," (Feb 4-6, 2020), Nadi, Fiji.
[36] Linden, "Determining a minimum video review rate to estimate discards in New England groundfish." *NOAA Fisheries*, (November 2019).
[37] Babcock et al., "How much observer coverage is enough to adequately estimate bycatch," *University of Miami*, (2011).
[38] Demarest et al., "Analyzing the Operational Costs of Electronic Monitoring," *NOAA Fisheries*, NEFSC, (November 2019):19.
[39] Stanley et al., "The advantages of an audit over a census approach to the review of video imagery in fishery monitoring," *ICES Journal of Marine Science*," (September 2011), Volume 68, Issue 8, 1621–1627

A final approach is basic compliance review, in which the video is reviewed for the presence of a prohibited event (e.g., discarding). This approach is typically used to leverage other data collection tools. For example, if EM is used to validate that no discarding is happening at sea, then managers can be confident that the data collected dockside are representative of what is happening on the water. This can be a low-cost option but is only applicable for basic compliance functions. For example, the whiting fishery on the West Coast of the US uses EM to ensure maximized retention (i.e., no unnecessary discards).[40] These events are easy to detect on video and therefore video review costs are as low as US$11 per fishing day. The advantages and disadvantages to each of these approaches should be carefully considered (Table 5).[41]

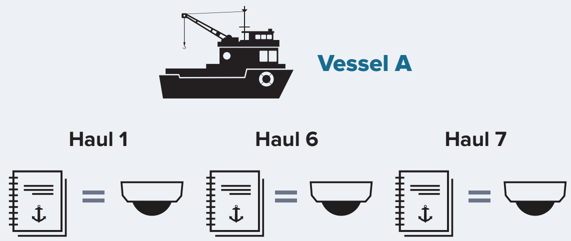
Table 5. Advantages and Disadvantages of EM Video Review Approaches[42]

Review Approach	Primary Data Source	Disadvantages	Advantages
Census	Data from EM video	• High review time/cost • May require specific catch handling practices	• High data quality
Logbook Audit	Logbook	• May require specific catch handling practices • Can only be used for data reported in the logbook	• Lower review time/cost • Enables the verification and subsequent use of fisher-provided data • Good quality data
Compliance (i.e., basic event detection)	Data from EM video	• Limited to most basic functions (e.g., did a discard event happen?)	• Lower review time/cost • No specific catch handling procedures

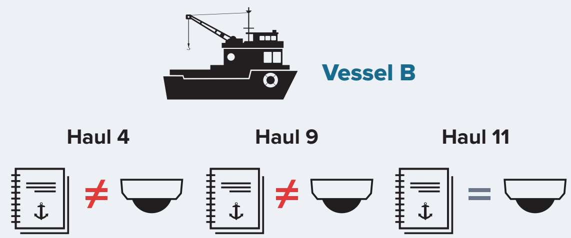
The logbook audit approach (Figure 5) has been chosen in most fully-implemented EM programs (e.g., British Columbia Groundfish, US Atlantic Highly Migratory Species, Australia Tuna and Billfish). In these programs, it is typical for just 10 percent of the video to be reviewed and compared to the logbook. Selecting an appropriate review rate when using an audit approach depends on a variety of factors, but the review rate generally needs to be high enough that the expected cost of noncompliance (i.e., the probability of detection multiplied by the penalties for noncompliance and likelihood of enforcement) is greater than the benefits. This will ensure that the program derives accurate vessel-reported data. The audit approach has the benefit of dramatically reducing review costs, but a less-appreciated benefit is that it also helps build industry buy-in to the program, as their self-reported data is being used to inform management decisions.

Figure 5. Logbook Audit Approach

Hauls from each vessel are randomly selected to be reviewed. If the EM data does match with the log book this may trigger a more complete review of the trip. If a vessel's logbook data does not match the EM data, this vessel may be sanctioned and flagged for more frequent audits at the expense of the vessel. Vessels with a clean record may have hauls reviewed less frequently on future trips.



The logbook and EM data match for all three of this vessel's randomly slected hauls. Managers will accept all of the vessel's logbook data from this trip to use for science and management purposes.



The logbook and EM data do not match. Managers will not accept any logbook data from this trip, and the vessel may need to pay additional fees for a full review of all EM footage to replace their logbook data.

In many RFMO EM pilots, 100 percent of the video footage is reviewed. Given the number and length of trips, especially in longline fisheries, subsampling of video will likely be the preferred approach moving forward to limit the volume of video that must be reviewed. Artificial intelligence may solve this challenge in the long run, but is still not market ready (Box 3). Less sophisticated improvements in technology (e.g., automatic fast forwarding between important events) are currently improving the efficiency of the reviewing process.

[40] "Catch monitoring in the Pacific whiting fishery," Archipelago, accessed February 26, 2020, https://www.archipelago.ca/case-studies/case-study-catch-monitoring-us-pacific-whiting-trawl-fishery/.
[41] NMFS, "Regulatory Impact Review and Final Regulatory Flexibility Analysis for the Regulatory Amendment to the Pacific Coast Groundfish Fishery Management Plan to Implement an Electronic Monitoring Program," (March 2019): 19.
[42] Demarest et al., "Analyzing the Operational Costs of Electronic Monitoring," *NOAA Fisheries*, NEFSC, (November 2019): 19.

How to Structure Video Review

EM program designers will also have to decide who will be responsible for video review. This can either be a third-party vendor, a government fishery agency, or RFMO staff.

Government Fisheries Agency Review – In many of the tropical tuna EM pilots, video review has been undertaken by the government agencies of the member states (e.g., Palau, Marshall Islands, Fiji) with the support of external funding. This option can be attractive to member states that prefer to maintain control of the video footage from fishing in their waters, and it can generate jobs for the local economy. This review option may also be attractive for at-sea observers who would be strong candidates to become EM analysts ashore in a review center, although the jobs are quite different.

A data review center is a complex operational system. Establishing such a center will require countries to increase budgets, purchase review stations, hire and train staff, to review a huge volume of video. There are also inefficiencies to having each member state set up their own review center instead of consolidating the review process. Experience from pilots has demonstrated the challenges of building efficient in-country review capacity, with cases of long backlogs, and difficulty getting local reviewers to meet the same level of review efficiency as third-party vendors. EM pilots have also shown a wide variation in the performance of national review centers, and this type of variability across RFMO member states could be detrimental to an EM program. The draft FFA Longline EM Policy commits the FFA Secretariat, SPC, and Parties to the Nauru Agreement (PNA) to collaborate to provide technical support and training to EM review centers, a signal that there is a recognition of the challenge of building and operating these centers and that many countries will need assistance.[43] One possibility to mitigate the cited difficulties is to create sub-regional review centers.

RFMO Staff Review – Another option is to have RFMO staff review and analyze EM video. IATTC currently uses two of their staff to review EM footage from their pilot program, and this structure could be an option for a broader EM program. Building a review center from scratch is a challenge, but there are benefits of centralizing review in one location rather than setting up multiple review centers. However, there may be resistance from member states to this approach as they may wish to maintain control of the review process and may be reluctant to share video of fishing activity within their EEZ or of their flagged vessels.

Third-Party Review – A third option for video review is to contract the service through a third party. This could be a commercial EM vendor or a quasi-governmental agency. Several existing EM programs, including the Organization of Producers of Large Freezer Tuna Freezers (OPAGAC) and Orthongel's purse seine fleets, the British Columbia groundfish fishery, and the US Atlantic HMS contract the video review to third parties. In the US West Coast, the Pacific States Marine Fisheries Commission (PSMFC), a quasi-governmental organization, handles the video review for several EM programs on the West Coast and Alaska. Under this model, the government or industry contracts with a third-party entity to review the video and deliver processed data that meets a set of specified standards (e.g., data fields, quality, timing, review rates). This can be a more efficient way to handle the review of data as the government can act solely as a contract manager instead of building its own capacity to review EM video from scratch. If local jobs are an important concern, it may be possible to structure contracts to require hiring of in-country reviewers. For low wage countries, the third-party approach could be more expensive than analyzing the data themselves, but the start-up costs and inefficiency of building a review center from scratch could limit the cost savings.

11. Accessing EM Video and Data

There are many entities that would like to be able to access raw video footage or processed data from EM programs, and therefore a data management plan will need to be developed that covers many issues, such as data movement, confidentiality, and access. Eventually the plan needs to be integrated into the agency's or organization's overall data policy.

All RFMOs have very detailed data policies in place that cover confidentiality and sharing. Examples of this are the IATTC's "Data Confidentiality Policy and Procedures", ICCAT's "Rules and Procedures for the Protection, Access to, and Dissemination of Data", and the IOTC's "Data Confidentiality Policy and Procedures." Although none of these policies cover EM data, there are procedures in these policy documents for covering new types of data. It is likely that in many of the RFMOs, the EM data policy and procedures will follow those of the observer programs.

There are a number of stakeholders that may be interested in or need to access video or data from an EM program (Box 4). The data management plan will need to make clear what level of access these entities will have, in what form, how the data will flow, and how they can use it.

Box 4. Stakeholder Groups That May Be Interested In or Need to Access Video or Data from an EM Program

- Fisheries agencies of member states (both coastal and flag states)
  - Managers
  - Scientists
  - Compliance staff
- Law enforcement personnel
- Industry
- EM vendors
- RFMO secretariats
- International, regional and sub-regional organizations
- Other stakeholders (e.g., NGOs, academics, data analytics companies)

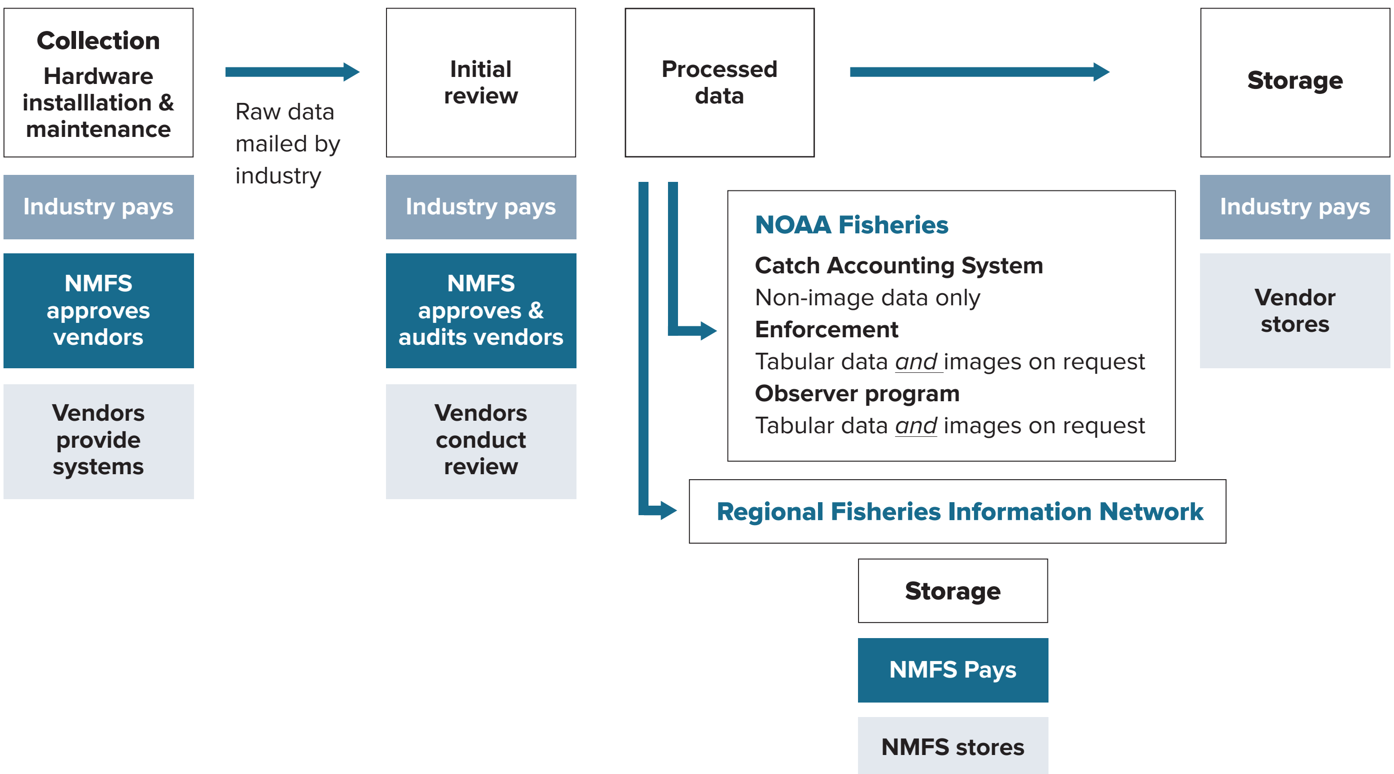
[43] "Draft Regional Longline Fisheries Electronic Monitoring Policy," *Forum Fisheries Agency* Version 1 (October 2019): 12.

Handling EM data access may be more complicated in a fishery managed by an RFMO than in a national fishery. Rules or agreements will need to be made on how to handle the video footage and data that is generated from a trip that may span the EEZs of multiple countries and the high seas. In this case, the flag state and the countries where the fishing occurred may want access to the footage and data from the trip. But this creates questions as to what information from the trip they will be entitled to access. For example, can countries access raw video or processed data? Can countries only access the information from activity that happened in their EEZ and, if so, who will divide and distribute information from a trip that spans multiple EEZs? IATTC's "Data Confidentiality Policy and Procedures" does not specifically mention EM data, but in practice, it could be applicable to answering some of these questions about access. The Commission follows the same data sharing procedure as for observer data, which requires parties interested in viewing EM data to obtain permission from the national authorities and from the IATTC.

How data access is structured varies across implemented EM programs, but there are several advantages of ensuring vessel operators have access to the video and data from their trips. This information can be valuable for industry (e.g., evaluating on-vessel operations, monitoring for safety, liability) and is an important incentive for building industry support.

Creating a map of EM data flow can help clarify who is responsible, who pays, and how data will be used. Figure 6 illustrates how these design choices are treated in a typical EM program in the US. Although this structure is probably different than how it will look in an RFMO fishery, it is informative to see how data flow, data access, and responsibilities have been structured in other EM programs.

Figure 6. Illustrative EM Video and Data Flow Diagram for US Fisheries[44]



12. Storing EM Records

Where, how, and for how long video footage and associated data will be stored is an important consideration for any EM program. Costs associated with storage are typically a fraction of video review costs and are declining. However, storing large files for long periods of time can have significant costs and should be carefully balanced against the possible benefits, or legal and scientific requirements. Depending on the overall EM program design, the raw EM records may consist of anything from video footage covering an entire fishing trip, to processed data with video stills of key events (e.g., gear deployment, transshipment). After the EM records are reviewed, they may be deleted, stored for a finite period of time, or stored indefinitely. In the past, local hard drives and local servers were used for storage, but increasingly cloud storage (e.g., remote servers operated by a third party) is seen as an appropriate solution. Local storage options can be more expensive and time-consuming to maintain, and if the hardware fails due to mechanical issues or a natural disaster, records can be lost without adequate back up. Cloud storage offers universal remote access, more computing power, and built-in redundancy at a lower cost.

[44] Wing and Franke, "EM Data Sharing Workshop Background Document," *The Net Gains Alliance, The Nature Conservancy*, and the databranch, (June 2019): 18.

Decisions about data storage should be based on the goals of the EM program and a thorough understanding of who will need to access the EM records, how frequently, and for what purposes, after the initial review process has been completed. The design of the data storage component also depends on whether the EM program is a national program or an RFMO-wide program, and whether fishing companies have copies of the EM records for their own purposes.

Many countries have legal requirements that dictate how long digital records should be stored to support possible future prosecution of civil and criminal activities. RFMOs, therefore, may need to balance different legal requirements from member states when setting standards for data storage. In the US, the National Oceanic and Atmospheric Administration (NOAA) recommends that all records and data be maintained by the entity or agency that collected it for a minimum of five years (civil statute of limitations) to support potential enforcement actions. However, a proposal was recently made to reduce EM storage requirements to one year from the current indefinite requirement, highlighting the movement to reduce retention time for cost-savings.

Enforcement agencies may desire to retain all video footage, seeing value in retrospective review, but the ability to purge this raw footage quickly after analysis can help to reduce costs of the EM program significantly. In another example of the move to reduce retention time, Australia's fisheries management authority received an exemption from the government's standard seven-year storage requirement for EM video, to allow purging after six months.

There is also an argument to be made for the future scientific value of EM records which is yet unknown. Scientists may wish to retain EM records that contain data of biological interest to allow for future developments in assessment methodologies that may require the data recorded in the distant past.

RFMO EM programs need to balance the need for legal records and the scientific value of EM records, with the risks and expenses of preserving a huge volume of data. Large files from vessels with extended fishing trips are more expensive to store, as data storage costs are driven by file size and how often, and how quickly, the files are accessed. Stored data can also be hacked or leaked, particularly if there are not adequate security measures in place. Security may be especially challenging for RFMOs since there are more stakeholders that may need to access stored EM records than in a typical fishery.

An EM program will also need to specify who is responsible for managing data storage. This will be dependent on the overall program design, but anyone from the RFMO, to individual governments, national agencies, industry, or third-party vendors could be responsible, although it is typically the same entity responsible for video review. There may be economies of scale that can be realized by aggregating EM records for storage, or it could be beneficial to decentralize responsibility to the country or fleet level. Attention should also be given to data access laws (e.g., the US Freedom of Information Act) and what impact that may have on where video should be stored.

If the RFMO is responsible, they will have to manage large volumes of video, but there are potential benefits of scale. A challenge of having the RFMO handle video storage is that member states may wish to maintain control of the video of their flagged vessels or vessel fishing in their waters. If national agencies take responsibility, they will need to budget for the cost of setting up storage contracts, hardware, and protocols, but there may be a strong incentive to take on this responsibility to maintain ownership of video from vessels in their EM program.

Making third-party providers responsible for video storage is likely the most efficient and independent solution, but governments may be reluctant to outsource video storage and it may be more expensive for developing coastal states. In the end, managers need the processed data from EM, and using the third-party frees the agency from managing the challenges of video storage. This model is used in several existing programs.

13. Maintaining Privacy and Confidentiality

Privacy and confidentiality are some of the top concerns of stakeholders about EM systems. There are several layers of issues to consider, including privacy of crew in their workplace, and confidentiality of the data after it leaves the vessel. Both should be addressed in order to create a system that allows relevant stakeholders to access the data they need without compromising the privacy of others.

Workplace Privacy

Space is at a premium onboard fishing vessels and privacy is often hard to come by. Fishers tend to be reluctant to compromise on the limited privacy they do have, and are often resistant to allowing cameras to record activity on the vessel where they may live and work for extended periods of time. The fishing deck often serves multiple purposes for crew, including a place where they might shower, use the toilet, or spend time relaxing when not fishing. In addition to fearing compromised privacy, the crew may be opposed to being recorded on principle, especially because EM systems can be perceived as a "Big Brother" system imposed by a distrustful government or company. For an EM system to be fully effective, data collection needs should be prioritized above these privacy considerations. Cameras should be placed where they most efficiently capture the required information – but wherever possible, privacy expectations should be met. Having clarity on how the video and data can and cannot be used can also help alleviate privacy concerns.

Because RFMOs are an additional level removed from the fishing industry than a national government, extra steps should be taken to understand crew concerns about privacy and ensure that they are addressed in the design of an RFMO-wide EM program. There are several ways to mitigate the workplace privacy concerns outlined above, although these each could add additional burden to the program, and it will be more efficient to simply ensure that appropriate uses and handling of EM video are in place.

To the extent possible, cameras should primarily be focused on fish and fishing gear, not people. On a conveyor belt, the camera should be looking at only what is placed on the belt: occasionally capturing arms, but not faces. An overview camera might be placed to obtain a birds' eye view of larger vessels, to watch for discarding or transshipment, but the resolution can be adjusted, or face blurring can be used to keep individuals anonymous. In order to ensure captains and vessel owners can tell which individuals might be handling fish poorly or working dangerously, there is the possibility that these adjustments are only be made just before transferring data beyond these stakeholders. Giving crew a chance to see what is being viewed by the cameras when they are first installed can help address their concerns.

The EM system can also protect crew privacy in the time between fishing events by using sensors to trigger recording only when fishing activity is occurring, which also minimizes the storage capacity needed. However, if the goals of the EM program can only be met with 24/7 recording, sensor data can still be used during data processing to focus in on fishing activity. For example, purse seine operators cite the need for recording 24/7 for liability purposes, to identify responsibility for workplace injuries or missing persons.

Experience has shown that over time, vessel captains and deck crew become accustomed to the EM system and their privacy concerns tend to fade away as they see how the video and data is used in the program. Positive perceptions of EM increase as industry gains more experience with the system on their vessels.

Privacy issues have been discussed for more than a decade, as can be seen in this excerpt from a report for an International Convention for the Exploration of the Sea (ICES) conference in 2006:

> "There is concern by industry that EM data may be analyzed for purposes outside the fishery monitoring objectives that fishermen accepted in allowing the EM system aboard. The problem is mainly with image data that could compromise the privacy expectations of vessel crew or reveal various techniques, work practices, safety procedures, etc., which were not part of the fishery monitoring objectives. As well, fishing activities, especially those involving sensitive species, portrayed in a motion picture medium (as opposed to a data point), could be used to appeal to the public's emotional sentiments, straying from scientifically objectivity. Fisheries jurisdictions may have difficulty controlling how EM imagery is used and who has access, particularly if the program is publicly funded."

An EM program that is aggregating data at the RFMO level is likely to face some challenges managing data confidentiality. Deciding who has access to data, for what purposes, and mechanisms for preventing video footage from falling into the wrong hands should all be outlined in the program's minimum standards – as has been done successfully for data from RFMO observer programs. The WCPFC's draft minimum standard about privacy says: "Cooperating members, Cooperating non-members, and Participating Territories (CCMs) shall adopt protocols that ensure personal data (including EM records) is handled in a manner that maintains an individual's privacy and confidentiality."

Ex-Vessel Data Confidentiality

Beyond workplace privacy and general concerns about being monitored, industry members can be wary of the confidentiality of recorded data and its possible misuse. If the EM program is not carefully designed with data confidentiality in mind, data may be exploited or used for nefarious purposes outside the agreed upon purposes of the EM program.

There are many solutions for ensuring data confidentiality, which is a requirement in many industries besides fisheries. Data privacy standards used for observer programs and RFMO logbook catch data confidentiality arrangements also have applicability to EM. In some cases, EM data may be treated like logbook catch data or observer data and, accordingly, use established confidentiality arrangements. One option would be to require EM records to be reviewed by an independent third party under strict contractual obligations to only analyze data for specific purposes and delete raw imagery once analyzed. In this option, fisheries agencies or other stakeholders would only receive raw imagery if, and when, any specific noncompliance events or other agreed-upon incidents are observed.

Most important for addressing privacy concerns of all stakeholders is to ensure that the process for creating the EM system is transparent and participatory, that there is agreement about how EM data will be used to improve the fishery, and there are mechanisms in place to ensure EM records are not shared outside of the boundaries of established confidentiality policies.

[45] Plet-Hansen et al., "Remote electronic monitoring and the landing obligation – some insights into fishers' and fishery inspectors' opinions," *Marine Policy* Volume 76, (February 2017): 98-106.
[46] McElderry, "At-Sea Observing Using Video-Based Electronic Monitoring," *ICES Annual Science Conference 2006* (2006), Session CM 2006/N:14, Archipelago Marine Research.

14. Servicing EM Hardware Systems

In recent years, the experience from EM pilots and fully implemented programs has contributed to improved reliability of EM hardware. Nevertheless, EM hardware may break or malfunction, so it is essential to have a good servicing plan in place that clearly articulates responsibilities and minimum levels of service. In tuna EM pilots, major repairs were often undertaken by EM technicians who needed to fly to the repair site – a time consuming and expensive approach. Even when only a phone consultation was needed, time zone differences between the vessel location and the EM vendor could result in significant delays. With these challenges in mind, EM programs will need to set clear service expectations with the EM vendor, and ensure that maintenance issues are promptly addressed. EM vendors can use a variety of approaches to meet these requirements, such as training local capacity (e.g., marine electronic technicians), engineers, or deck crew to undertake common repairs, placing EM technicians in-region, or providing 24/7 remote consultation. Given the length and remoteness of many fishing trips in RFMOs, empowering captains and crew to make EM repairs at sea will be important. This will include supplying spare parts, providing additional training on certain maintenance functions, and establishing communication protocols for technical support at sea. This has been done in other fisheries where vessels make long trips with EM (e.g., in the Southern Ocean).

Equally important to creating a servicing plan is setting the obligations for vessels that experience equipment malfunctions. Vessel operators should be required to perform basic functions to keep EM hardware in working order at sea, such as ensuring that the lenses remain clean and that camera views remain unobstructed. If a system malfunctions, operators should be required to report it immediately to management authorities. The vessel would then need to follow an agreed procedure when the EM system malfunctions. The strictest option would be to require vessels to return to port immediately. This would be a strong deterrent for intentional sabotage of EM systems, but could also place significant economic burdens on the fleet, and could potentially be a disincentive for fleets and flag states to participate in an EM program. Other options could include a risk-based approach, where vessels that have demonstrated strong compliance may be allowed to continue fishing, while less compliant vessels would be required to return to port. This approach has been used in the US Atlantic HMS longline EM program which has the flexibility to grant waivers to vessels that have non-operational EM systems. In addition to past compliance, the managers in this program can also consider the level of functionality of the EM system, whether the operator immediately reported the system malfunction and made efforts to troubleshoot the problem, and other factors in deciding whether to grant the operator a waiver.[47] A limited number of exemptions for malfunctions may also be considered (e.g., a vessel can keep fishing for the first malfunction in a calendar year).

With some vessels taking trips several months in length and far away from port, the decision of how vessels need to respond to a malfunctioning EM system is likely to have a larger impact in RFMOs than in other EM programs in which trips are typically shorter and closer to shore.

[47] NOAA, "Three-Year Review of the Individual Bluefin Quota Program," *NOAA Fisheries*, (September 2019): 166.

Photo: Environmental Defense Fund

15. Contracting Vendors

There are two primary approaches to vendor contracting: a single vendor approach, and a standards approach.

Single vendor approach – In a single vendor approach, the responsible agency selects a vendor that will provide EM systems for the fleet. This model can be attractive for its simplicity – the contracting agency only has to coordinate with a single vendor. Additionally, it may be more efficient for the vendor to install and service systems across a whole program, rather than for a handful of vessels, and it may ease ongoing communication between the vendor and industry stakeholders. Some have suggested that a downside of the single vendor model is that once the EM program is committed to a single vendor, there is limited incentive for innovation and improved efficiency because the costs of switching to a new provider are quite high. This reflects the typical concerns of sole-provider models, but it has not been proven that multi-vendor models are cheaper, more innovative, or provide better service. Most fully implemented programs have used the single vendor model, but there appears to be growing interest in multi-vendor approaches.

Standards-based approach – Under a standards-based approach, the fishery manager creates minimum performance standards for EM systems and then certifies vendors that can meet these requirements. Vessels within the fleet are then free to choose systems from any of the pre-approved vendors. This allows vessels to choose the least expensive system that will work best for their needs. One of the arguments for this approach is that it will stimulate competition and innovation among the EM vendors, although there are few working models of this multi-vendor approach, and it is not known whether these potential benefits will be proven. This approach is potentially more complicated, as it requires the agency to work with multiple vendors across a single fishery. A multi-vendor approach will work best in a large fishery with many vessels as it gives vendors some certainty that they will have ample vessels enrolled to justify infrastructure investments in the program. Given the large number of vessels in some RFMO fisheries, a multi-vendor approach may also be necessary as the scale may outstrip the capacity of a single vendor to deliver.

Photo: Archipelago Marine Research

Standards-based contracting places the burden of contracting on industry. At the outset of a program, industry may focus on price rather than other elements that ensure long-term program quality and service delivery. This approach may also require multiple software analysis platforms, or multiple different vendors reviewing the footage from their vessels. This could be addressed by requiring interoperability between vendors, but interoperability requirements have not been implemented in any existing EM programs. There is open-source software available that can be used to analyze video and data from multiple EM vendors,[48] but it is not widely used.

[48] Torgerson, "Open Source Software Platform for Electronic Monitoring," *Sea State Inc, Saltwater Inc, Chordata LLC*, (August 2017).

EM Program Implementation

Considerations for EM Pilots

Most, if not every, EM program has started with a pilot. Pilots can test many different components of an EM program, find strategies to address stakeholder concerns, and build confidence that EM can meet fisheries management objectives. However, many EM pilots – even ones that have demonstrated the efficacy of the tool – have not led to a fully implemented program. In many of these cases the technical success of the pilot was insufficient to overcome the underlying barriers to EM. In other cases, pilots have not scaled because they were not designed to, were not representative of the entire fishery, were largely focused on the technical feasibility of EM, or did not have a clear scaling objective or timeline.

With numerous previous EM trials and a growing number of fully implemented programs, there is evidence of the ability of EM to contribute to a variety of objectives in different types of fisheries. EM is now a proven tool for a variety of monitoring needs. Therefore, if the goal of a pilot program is to lead to widespread implementation, it needs to be structured to answer the key questions or concerns of the various stakeholders, bearing in mind that EM has already moved beyond the basic proof of concept stage. Pilot programs can also benefit from clearly articulated next steps at the culmination of the program. The lack of a firm timeline and commitment to scaling EM has been cited as a reason that many technically successful pilots failed to move to broad implementation.[49]

A common challenge for pilots is that they often cover a very small component of the fleet or otherwise fail to reflect the full diversity of vessels that would be incorporated into an implemented program. This may be due to the ability to find early adopters willing to participate in a trial, as well as the availability of financial resources to run a large trial. Managers should be cognizant of the limitations of these small trials. For example, early trial participants may be the vessels that are most supportive of EM. A small pilot will also not present a complete picture of the challenge of data management for an EM program that covers a much larger portion of the fishery.

Despite the limitations of pilots, they are an important step to help build expertise and comfort with EM, and to help plan and prepare for a larger program. New pilots should be designed to work with previously under-represented stakeholders or test new assumptions, that complement rather than replicate past trials. In addition, stakeholders need to think critically about how the lessons from smaller pilots can be extrapolated to a larger, fully implemented program.

Another important lesson from recent FAO EM pilot projects in Fiji and Ghana is that engaging international partners in pilots can help effectively communicate the success of the pilot and convey to governments and industry the benefits of sustaining the EM program.

EM Pilots at the RFMOs

Presently, there are national level pilot projects in several Pacific Island countries for longline vessels, including Federated States of Micronesia, Republic of the Marshall Islands, Palau, Solomon Islands and Fiji. The objective of several of these pilots was to test the capability of EM to collect as many of the WCPFC's Regional Observer Program's Minimum Data Fields as possible and to develop in-country video review capacity. These pilots have helped clarify what data fields EM can collect, the costs of collecting various data, and helped identify challenges what will need to be addressed in a scaled-up program. The WCPFC is now working to develop a distinct set of longline EM data fields.[50] The pilot project in Fiji was supported by FAO and was designed to test EM program implementation processes so that information from EM systems could be used for compliance. These trials are building EM expertise and confidence in the tool to meet various monitoring and compliance objectives. The Federated States of Micronesia (FSM) recently issued a commitment and challenge to other nations to use EM to achieve full transparency of tuna operations by 2023, an indication of growing confidence that EM can help fill current monitoring gaps in the region.

[49] Fujita et al., "Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual," *Environmental Defense Fund San Francisco*, (2018).
[50] SPC, FFA, PNAO Data Collection Committee, "Draft DCC Longline EM minimum data field standards (version DCC-2020-Feb)," (Feb 4-6, 2020), Nadi, Fiji.

In 2016, IOTC passed a resolution to explore the use of EM in a pilot project in Sri Lanka for small longline and gillnet vessels to help enhance the implementation of a regional observer scheme. IOTC is primarily interested in exploring EM because it is impractical to have human observers on board much of the fleet. OPAGAC and Orthongel have vessels using EM in the region but are not closely coordinated with IOTC. IOTC is unaware which of these vessels are using observers and which are using EM because they only receive the processed data. A pilot is also underway in the Seychelles, and the Maldives received funding to install EM on pole and line tuna boats. Some of the countries beginning to move forward with EM in the IOTC (e.g., Sri Lanka and the Maldives) can leverage this to meet the demands of the European Union (EU) to control illegal, unreported, and unregulated (IUU) fishing – Sri Lanka received an IUU yellow card in 2012 and a red card in 2015 from the EU.[51]

Within ICCAT there have also been some EM pilots, including the FAO Areas Beyond National Jurisdiction (ABNJ) project in Ghana. Some vessels in the purse seine fleet are voluntarily using EM (e.g., OPAGAC and Orthongel) in order to meet market demands for better monitoring.

IATTC is in the early stages of exploring EM, particularly to collect data from purse seine vessels. There is an EM pilot underway with two small vessels and two larger Ecuadorian-flagged vessels (class 6, greater than 363 metric tons of carrying capacity). One of the objectives of the IATTC EM program on purse seine vessels is to determine the effectiveness of EM compared to human observers, and the preliminary results indicate:

- EM is equal or better than human observers for collecting bycatch data
- EM is worse than human observers in situations of gear malfunctions (e.g., determining the period of the set during non-normal conditions
- EM is worse than human observers for determining the identity of FADs that are set on

Moving Toward Full EM Implementation

Pilot studies play an important role in getting both fishery managers and vessel operators comfortable with the concept and benefits of EM. In national programs where EM is mandatory, the usual pattern is that successful pilots evolve into mandatory EM programs. Although, as mentioned earlier, successful pilots do not necessarily result in effective, fully implemented programs.

In addition to starting EM via pilot studies, there are situations in which it is clear that EM is needed. For example, when RFMO members have agreed to a certain level of human observer coverage for longliners, but some fleets have been negligent on meeting that coverage. Those vessels could be the first to be legally required to use EM in addition to meeting the overall human observer coverage requirement. This appears to be the direction the WCPFC EM working group is headed. The group has met formally three times and has agreed to the principle of prioritizing EM in areas where independent data collection and verification is currently low.

In discussions of EM, two variations of this scheme have emerged:

- One possibility is to set mandatory monitoring coverage levels and allow vessels, fleets or flag states the flexibility to meet that with human observers or EM.
- Another possibility is to have penalties applied to fleets that have less than the mandatory human observer coverage and no EM.

EM could also help provide increased accountability around transshipment. Transshipment is an important issue that the RFMOs are actively working to address, which may provide an opportunity to introduce EM. For example, the WCPFC is now working on a transshipment measure, and there is likely to be a draft recommendation for requiring EM on high seas transshipments proposed in 2021.

Another way that EM may be more likely to gain early traction could be to engage portions of the fleet that would like to demonstrate sustainable practices to maintain or improve market access, or meet import requirements. International branded tuna companies have been involved in many of the early EM projects, and some countries that have been under pressure from international trade rules (e.g., countries that have been carded under the EU IUU carding system) have been early adopters of EM. This can create an opportunity for starting an EM program and eventually extending it to others on a mandatory basis. The EM activities of OPAGAC in ICCAT and IOTC are an example of voluntary participation to meet market demands for sustainability and to use EM as a replacement to human observers to supply processed data to the RFMO.

Finally, some coastal states that would like more reliable information on the activity of vessels licensed to fish in their EEZs could also be particularly amenable to participating in an EM pilot or to be an early implementer.

[51] Cliff White, "European Commission removes red card from Sri Lanka, warns others," *SeafoodSource*, (April 2016).

Capacity Building, Training, and Communicating Roles and Responsibilities

When an EM program moves to implementation, a major capacity-building effort will be needed to help manage all the components of the new program. While some of this will have taken place during pilot phases, the expansion of the program during full implementation will likely demand additional capacity-building efforts. Member countries will need staff to help administer the program and, if they choose to take on the responsibility to review video themselves, they will need to hire and train a number of video analysts and information technology (IT) staff. Pilot EM programs in the Western Pacific have had varying degrees of success in building local capacity that can efficiently perform the functions required. The FFA's Draft Regional Longline Fisheries Monitoring Policy identifies training and capacity building as a critical component for a successful EM program and highlights that it will likely involve member countries, EM service providers, and regional bodies (e.g., PNA, FFA, and SPC).

An important lesson learned from the FAO pilot EM projects in Fiji and Ghana is that it is necessary to follow up on the initial EM training with regular refresher courses to bring all EM analysts up to the same level, introduce new software and analysis protocols, and to clarify any uncertainties they may have.

In order to harness the data collection power of an EM system, there needs to be a regular interaction between the people on board fishing vessels creating the data and the people collecting and analyzing the data. Captains and crew will have a variety of obligations to facilitate the EM program. This will include tasks such as ensuring the EM system is operational, reporting EM system malfunctions, and communicating departures and arrivals as necessary for hard drive or data transfer. In addition, captains and crew may have specific obligations for handling their catch based on the data requirements of the program, such as not blocking camera views, handling fish in view of the camera, or sorting and presenting fish to the camera as necessary. A well-run program should constantly work at providing feedback to ensure onboard practices support the data collection effort.

Continuous Review and Improvement

Once the EM program is implemented and stakeholders have acquired direct experience with the EM system, managers should harness lessons learned to improve the program.

The EM program should be designed from the outset to be adaptive, with regular evaluations against well-defined indicators (both process and outcome metrics) to ensure the program reaches its performance objectives over time. Updates to the EM program based on the results of these evaluations might include improving program efficiency, addressing unexpected challenges, refining data analysis protocols, adjusting minimum standards, adding program infrastructure, hiring additional personnel, or reprioritizing human resources. These regular reviews and program adjustments also give EM programs the flexibility to incorporate new technologies, such as improved cameras, artificial intelligence, and less cumbersome data transmission methods (e.g., satellite), as they become market-ready.

If the EM program was created with help from an advisory committee or working group, soliciting feedback from them throughout program implementation can help to facilitate adaptation. Otherwise, the program should contain specific mechanisms for a variety of stakeholders to give feedback (e.g., through a yearly performance review). Ongoing program evaluation is critical to ensure the program remains effective as fishery conditions change. It also can help generate additional industry support, as it allows managers to demonstrate the results of the program.

If the EM program can successfully incorporate improved technology and lessons learned from increased experience with EM systems, fisheries management is likely to become more effective.

Concluding Remarks

Photo: Getty Images

A clear movement appears to be underway in which demand for better data and accountability in fisheries is increasing. Seafood and fishing companies are taking more action to improve the sustainability of their products driven by market pressure and as a way to mitigate risk of illegal or unsavory practices in their supply chains. Import regulations, such as the EU IUU carding system and the US Marine Mammal Protection Act, are also compelling countries to improve the monitoring and accountability in their fisheries. Many fisheries managers and scientists would also like to have better data so that they can have a clearer picture of the status of fishery resources and how much fish is being caught. These forces appear to be driving a slow but steady increase in monitoring requirements in fisheries, and modern fisheries management is turning towards EM as a tool to help meet these objectives. With thousands of vessels and low rates of observer coverage in some fleets, EM appears to be especially relevant for RFMO fisheries.

EM programs have now been in place for almost two decades and they have demonstrated the ability to meet a variety of monitoring objectives across many types of fisheries. There is a large body of experience to draw from as RFMOs inevitably progress toward the use of EM as a monitoring tool. In this paper we have tried to draw on these experiences to understand whether the unique characteristics of fisheries managed in part or wholly by RFMOs will demand different approaches or considerations when designing and implementing an EM program. In many ways, the answer to this is no – the elements of a well-constructed EM program, and the process for designing it, are similar to those in any fishery. However, the RFMOs context includes more stakeholders and more complicated operations than other fisheries.

Multiple factors have the potential to make implementing EM more challenging in RFMO fisheries. Numerous countries that span a wide range of development, thousands of vessels that fish over an enormous area and out of many ports, high seas fishing, distant water fishing, and fishing trips that can cover multiple EEZs all serve to increase the technical complexity of developing an EM program. This paper has presented many of the key design decisions of an EM program and how these unique characteristics of RFMO-managed fisheries may complicate them. We have also outlined some of the options that have been used in other EM programs and their relative pros and cons in an RFMO context.

Many of the design choices are operational or technical in nature (e.g., what hardware should be selected, how much video should be reviewed), but perhaps the most important lesson from the development of other programs is that "[getting an EM program adopted] is a people challenge not a technical challenge."[52] The reality is that, like most new solutions, there will be opposition along the way. Industry members will likely have concerns about additional monitoring, privacy, the costs of the program, and a general fear of the unknown. Fisheries managers may be concerned about the cost and complexity of the program and whether they will be able to effectively manage it. These concerns are legitimate and have emerged in the development of most, if not every, EM program. These issues cannot be sidestepped, and stakeholders need to be integrated into to the design process so that their concerns are recognized and addressed. In particular, industry needs to be involved as they will be the ones most impacted and their acceptance of the program will be critical to its success.

There is a growing recognition that better information is required for the effective management of RFMO fisheries, and this sentiment is growing among even the most reluctant stakeholders. Human observers will continue to play an important role in collecting this information, but it is unrealistic that they will be able to cover the required percentage of fishing. The emergence of EM offers a solution to scale up monitoring coverage and to help meet this need for better information. There are real challenges to developing an EM program, and the characteristics of RFMO fisheries can make this a bit more complex, but these are solvable challenges. Time appears to be on the side of EM and the question is no longer whether EM will become a widely used tool in RFMO fisheries, but when.

[52] Howard McElderry, Personal Communication, 2018.

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Abbreviations

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABNJ	Areas Beyond National Jurisdiction
AI	Artificial intelligence
AIS	Automatic Identification System
CCM(s)	Commission Members, Cooperating Non-Members and Participating Territories (of the WCPFC)
CPC(s)	Parties, co-operating non-parties, co-operating fishing entities or regional economic integration organizations (of IATTC)
DWFN(s)	Distant Water Fishing Nation(s)
EEZ	Exclusive Economic Zone
EM	Electronic Monitoring
ER	Electronic Reporting
ETP species	Endangered, threatened, and protected species
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organization of the United Nations
FFA	Forum Fisheries Agency
FSM	Federated States of Micronesia
FOIA	Freedom of Information Act
GPS	Global Positioning System
HMS	Highly Migratory Species
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICES	International Convention for the Exploration of the Sea
IOTC	Indian Ocean Tuna Commission
IT	Information Technology
IUU	Illegal, Unreported and Unregulated Fishing
MOFAD	Ministry of Fisheries and Aquaculture Development of Ghana
NMFS	National Marine Fisheries Service
NOAA	NOAA: National Oceanic and Atmospheric Administration
OPAGAC	The Organization of Producers of Large Freezer Tuna Freezers
PIRFO	Pacific Islands Regional Fisheries Observer.
PNA	Parties to the Nauru Agreement
PSMFC	Pacific States Marine Fishery Council
RFMO(s)	Regional fisheries management organization(s)
SAC	Scientific Advisory Committee
SPC	Pacific Community
US	United States (of America)
VMS	Vessel Monitoring System
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean

Glossary[53]

Audit can refer to **Logbook Audit** or **Vendor Audit**.

Data Confidentiality [*also* Data Privacy]: Data associated with an EM program is protected from being accessed by unauthorized parties. In other words, only the people who are authorized to do so can gain access to sensitive data.

Distant Water Fishing Nation (DWFN) Fleets: The fishing vessels that operate within the 200 mile Exclusive Economic Zones of other countries, and less often, further offshore, in what is known as the high seas.

Electronic Monitoring (EM): An integrated system of on-vessel technology that records fishing activity, usually including video cameras as well as GPS or other location tracking technology and sensors that detect specific actions like gear deployment. Van Helmond et al. (2019) describe EM systems as generally consisting of "various activity sensors, GPS, computer hardware and cameras which allow for video monitoring and documentation of catches and detailed fishing effort estimation."

Electronic Reporting (ER): The process of collecting and transmitting fisheries data using digital technology in place of paper forms. The distinction between EM and ER has generally been that EM systems include cameras and ER systems do not, but new tools and innovations in monitoring may blur this distinction in the future.

EM Analyst [also Video Reviewer]: A person qualified to analyze EM records and record EM data in accordance with the EM standard and analysis procedures.

EM Analysis Rate [also EM Video Review Rate]: The proportion of EM records that are analyzed.

EM Certifier: An individual or organization which has been accredited by the appropriate authority to inspect and approve e-monitoring systems for use.

EM Costs: Costs involved in implementing an EM program, including direct costs as well as the indirect costs associated with delivering services or keeping the overall program functioning. EM program costs can be broadly categorized as one of four types:

> **On vessel costs:** These costs are associated with the installation and operation of EM hardware and supporting systems on board fishing vessels;
> **Program administration and operational costs:** These costs are associated with the administration and operation of the EM program, usually undertaken by national (or regional) fisheries administrations. These costs typically form the 'core' of the annual EM program budget, and would be a main focus for cost recovery;
> **Policy and regulatory development costs:** These costs associated with the establishment of relevant regulatory and policy arrangements to support effective EM systems; and
>
> **Analytical costs:** These costs are associated with the analysis of EM generated information to produce outputs in support of the administration and management of longline fisheries by national fisheries administrations (e.g., production of reports analysing annual trends in EM information).

EM Coverage: The proportion of vessels licensed to fish in areas under national jurisdiction and the adjacent high seas that have an EM system installed and operating, or the share of fishing activity recorded.

EM Data [*also* Processed or Reviewed EM Data]: The result of analyzing and/or summarizing raw EM data. These can also be called "data products." "Processed" is a term with a specific technical meaning when referring to video recording while "processed data" may be used in policy discussions to refer to video that's been reviewed and the reports from that review.

EM Data Management Plan: A plan that specifies who is able to access raw video footage or processed data from EM programs, and what procedures or requirements they must follow. It covers data movement, confidentially, and access, and may fall under existing data policies.

EM Hardware: The physical equipment used in an EM system. This includes cameras, sensors, cables/wiring, computers, hard drives, and other physical components of the EM system.

EM Pilot [*also* EM Trial]: An initial small-scale implementation of an EM system to generate insights about how to improve EM hardware and processes before a full EM program is designed and implemented.

EM Program: The entire structure for implementing EM in a fishery, including the goals, policies, and supporting technology. A process administered by a national fisheries regulator(s) that includes the use of EM systems on vessels to independently collect and verify fisheries data and information.

EM Records [*also* Raw EM Data or EM Video]: The data recorded by the on-vessel electronic monitoring system, including input from cameras and sensors, that can be analyzed to produce EM data. Generally, raw data has not been subject to review by human reviewers or AI.

EM System: The hardware, software, and data processes that are used within an EM program. This includes all of the vessel and shore-based components supporting the acquisition, analysis and reporting of EM Records.

[53] This is compiled from a variety of sources, notably a collaborative glossary created by EM4Fish in June 2019 at a EM Workshop available at: https://em4.fish/our-library/electronic-monitoring-glossary/

EM Vendor [*also* EM service provider *or* Contractor *or* Third-party provider]: an entity that provides technical and logistical EM services. These may include: installing and maintaining hardware and software, overseeing initial data collection and transmission from vessels, analysis and reviews of the data for regulatory agencies, and data storage. Vendors may need to be approved, certified, and audited by a government body to satisfy management compliance; in some cases, vessels may voluntarily opt to carry EM from the vendor of their choice, or companies may require their vessels to carry EM outside of any government requirements. In some cases, the term "third-party provider" is being used to describe vendors or EM service providers that are outside a regulating government agency and independent from the fishing industry.

Fishery Cost Recovery: The concept that costs of fishery management and improvement should be recovered from fishery participants in proportion to the benefits they receive. "Full cost recovery" is often used in EM discussions to mean that the fishing industry should be responsible for paying all of the costs associated with an EM program.

Human Observer Coverage: The percentage of vessels and/or trips that are required to have a human observer on board.

Minimum Hardware Standards [*also* Minimum Hardware Specifications]: EM hardware requirements that are aligned with the objectives of the program, ideally performance standards that allow vendors the flexibility to meet overall objectives (minimum resolution, frame rate, low light capabilities, etc.).

Observer Effect: A change in behavior by fishers in the presence of observers that reduces the likelihood of events that may be problematic for the vessel or fishery, such as endangered, threatened, and protected (ETP) species interactions.

Review Center [*also* Video Review Center *or* Data Review Center *or* Record Review Center]: Office facility used to analyze EM records and record EM data.

RFMO Fisheries: Refers to fisheries that are partly or wholly managed by RFMOs.

Transshipment: The act of transferring goods such as catch, cargo, personnel, and equipment from one ship to another. It is a common practice in global fisheries and typically takes place between smaller fishing vessels and large specialized refrigerated transport vessels. Transshipping their catch allows fishing vessels to remain at sea for months or even years and cover large areas of fishing grounds. Many distant-water fishing fleets (e.g., Taiwanese purse seiners) depend on transshipment at sea as a major factor of their support lines, supplying them with fuel, fishing bait, food, water, and new crew members

Vendor Audit [*also* Secondary Review *or* Third-party Audit]: the process of evaluating a vendor's review of EM video data to ensure video review accuracy and consistency. In addition to video review, vendor audit should also include evaluation of vendor business processes like data security, data storage, chain of custody, etc.

Video Review [*also* Data Review *or* Record Review]: The process of analyzing EM records (video and other raw EM data) to extract analyzed EM data. This often involves processing and watching video to pull out important frames and distill the contents of the video into tabular data. There are three main approaches for obtaining data from EM systems: census, auditing, and basic event detection.

> **Census:** An EM analyst reviews the video footage and documents the desired data on the fishing activity (e.g., fishing effort, times, locations; target and non-target catch data). The analyst may review all of the fishing activity or a subsample that is then scaled up to create fishery-wide estimates.
>
> **Logbook Audit [*also* Audit-model]:** using EM data to validate logbooks or other non-EM fishery records, such as for catch, discards, and/or bycatch monitoring
>
> **Basic Event Detection:** A compliance review in which the video is reviewed for the presence of a prohibited event (e.g., discarding).

Video Review Rate: The percent of fishing activity recorded that is reviewed.

Appendix: Selected EM Pilots and Programs in Tuna Fisheries

Study	Name of EM Pilot, Program, or Region	Number of Vessels	Gear Type	Strengths of EM Program	Challenges of EM Program
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 discarded catch not detected by EM because it was out of camera view • EM species identifications more general than by observers • Less accurate than observers for counting and identification of catch and bycatch
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 cameras" • 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
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
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 free school) 78% of the time	• Could not distinguish certain species e.g., yellowfin and bigeye tuna (partially due to inexperience of reviewers)
Monteagudo et al., 2014	Atlantic Ocean	2 vessels	Purse seine	• "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
Ruiz et al., 2015	Indian/Atlantic and Western 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

Study	Name of EM Pilot, Program, or Region	Number of Vessels	Gear Type	Strengths of EM Program	Challenges of EM Program
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 and 12% for swordfish and mahi-mahi • EM 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 category
Hosken et al., 2016	Solomon Islands (WCPFC)	2 vessels	Taiwanese 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	• Could not 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
MRAG, 2017	Ghana (ICATT)	14 vessels, 163 trips monitored, 1 54 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 analyzing the footage.
Gilman et al., 2018	Palau (locally-based and distant water)	4 vessels, 67 sets	Longline; 3 locally-based pelagic, 1 distant-water pelagic		• Presence of EM appears to not change logbook data recording • Catch rates from EM data were about an order of magnitude higher than from logbook data, and had about twice the species richness • Suspected substantial underreporting in logbooks

Study	Name of EM Pilot, Program, or Region	Number of Vessels	Gear Type	Strengths of EM Program	Challenges of EM Program
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	
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
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 which improved over time • Higher congruence for longline (one individual brought on board 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 to species level • Difficulty recording species which are quickly discarded
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, mostly offset to operators by FAO funding the hardware

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