Recommendations for electronic monitoring program design and requests for proposal

Guidance from Electronic Monitoring Service Providers

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Acknowledgements

In February 2020, at the National Electronic Monitoring Workshop in Seattle, several electronic monitoring (EM) service providers initiated a conversation about interoperability and other opportunities for pre-competitive collaboration. This conversation led to the creation of this project which has brought together many of the world's EM service providers.

CEA Consulting led this project with the guidance of a Steering Committee consisting of Amanda Barney (Teem Fish Monitoring Inc.), Howard McElderry (Archipelago Marine Research Ltd.),[1] and Josh Wiersma (Integrated Monitoring Inc.). A Technical Working Group with representatives from thirteen EM service providers offered feedback and technical guidance throughout the project. We are also grateful to representatives of the Customer Advisory Panel who provided input during the early phases of this project and on an initial draft of this document. While some of the recommendations and findings in this report have been presented before in the EM literature, this document is unique in that it was developed through consultation with companies that compose a large portion of the EM provider community. There is generally good alignment among EM service providers on issues relevant to the EM market, but each individual organization has its own business model and varying levels of support for the recommendations of this report.

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1 Howard McElderry retired from Archipelago midway through the project and completed his role on the Steering Committee as an independent advisor.

Introduction

Over the last two decades, electronic monitoring (EM) has proven to be an effective component of fisheries monitoring programs. EM is now in use on approximately 1,500 to 2,000 vessels worldwide, but growth of the tool has been relatively slow given its potential to cost-effectively support fisheries monitoring objectives. While there are some excellent examples of well-designed EM pilots and programs, there are also examples of inefficient programs that feed a perception that EM is too costly or not easily scalable. **Members of the EM service provider community believe that improved program design, better requests for proposal (RFPs), and clearer communication and understanding of the capabilities and cost drivers of EM programs can enable better, more affordable, and scalable EM programs**. This document provides recommendations for designing and procuring EM services for fisheries, an overview of the main cost drivers, and a high-level summary of the current technological capabilities of EM.

Summary of recommendations from the EM service provider community

EM Service Provider Process Recommendations for Efficient EM Program Design

1. Define fishery monitoring objectives, data requirements, and key performance indicators as a first step to focus program design on monitoring goals.
2. Evaluate the full suite of tools and approaches to meet monitoring objectives.
3. Include the fishing industry in the design process and provide incentives for its ongoing participation.
4. Consult with EM service providers in the early phases of program development and during program updates. Their early input into program design may improve program performance and realize cost efficiencies.
5. Evaluate whether new EM programs can leverage existing methodologies or infrastructure to improve the efficiency of program delivery.
6. Carefully consider different EM service delivery models (i.e., how the program is structured and who fulfills the requirements) to determine the best fit for each fishery.
7. Assess the infrastructure requirements of an EM program in relation to the geography of the fishery.

EM Service Provider Recommendations on RFPs or Statements of Work

1. Ensure that bidders are working with a common set of assumptions concerning program operations. This includes providing fundamental information on fishery operations (e.g., number of vessels, ports of operation), providing specific parameters to bid against and, when possible, providing sample fishing activity video to all bidders.
2. Provide clear performance-based specifications for hardware and all other EM program delivery elements.
3. Clearly define roles and responsibilities at program interfaces.
4. Require EM systems to generate information that enables reporting on system performance.
5. Request clear explanation of any proposed implementation of artificial intelligence (AI). This should be accompanied by a description of the provider's current AI capabilities and the benefits and risks the provider sees to implementing AI in the EM program.
6. Consider factors that are within the direct control of EM providers and those that are not (vessel cooperation, coordination with other parties, etc.) with pricing estimates for those items outside of EM service provider control separated or excluded.

Defining EM

There are differing definitions and views of what is included in an EM program. For purposes of this paper, EM is an integrated system of hardware on fishing vessels and associated shoreside services that can provide a comprehensive record of fishing activity from which various data can be collected to inform fisheries management and ensure compliance with regulations.

An EM program is much more than placing cameras and sensors on vessels. It is a service suite that includes on-vessel and shoreside hardware, installation, data transmission, data storage, video review, service and maintenance, communication with and training of captains and crew, and reporting of accurate and verifiable data to end users (Figure 1). EM programs are one component of broader fishery monitoring frameworks, and they interact with and complement other data sources.

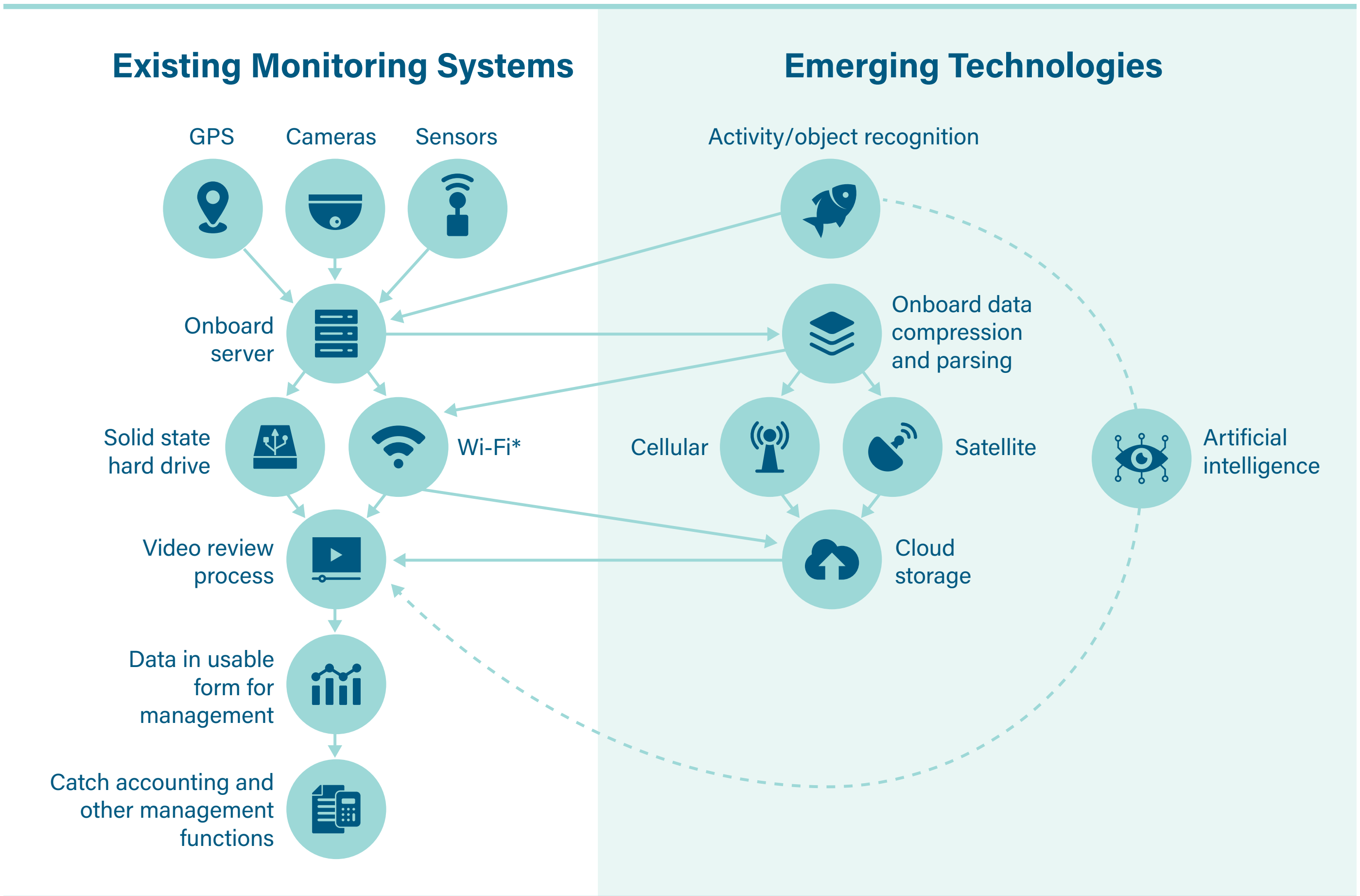

FIGURE 1. COMPONENTS OF AN EM PROGRAM[2]

*Wi-Fi applicability dependent on volume of video/data that needs to be transmitted, available bandwidth, and how long vessels stay within Wi-Fi range to upload data

2 Adapted from Rod Fujita, et al., 2018. "Designing and Implementing Electronic Monitoring Systems for Fisheries: A Supplement to the Catch Share Design Manual." Environmental Defense Fund, San Francisco.

Benefits of EM

EM has proven to be an effective component of fisheries monitoring programs. It can provide data such as fishing effort; target catch; non-target catch; endangered, threatened, and protected (ETP) species interactions; and catch handling practices that are of similar accuracy to data provided by human observers.[3] EM also offers several advantages over human observers. Multiple camera views and the ability to watch events several times can improve data capture, EM is less subject to intimidation or coercion, and it does not need to take breaks. It can also be more easily scaled to cover all activity in a fishery, thus eliminating observer and deployment effects. Human observers cover just a small fraction of fishing activity worldwide, and EM can help fill this huge at-sea monitoring gap as a complement to observer programs.

Evidence has shown that without comprehensive at-sea monitoring, data on fishing activity is often inaccurate, and that EM can drive improvements in data coverage and quality.[4] EM cannot perform all the functions of a human observer, such as taking biological samples, but it can accurately collect data for most observer data fields.[5] These data are essential for effective fisheries management, for ensuring compliance with regulations, and for the seafood industry to demonstrate sustainability to the seafood market. EM is unique in its ability to provide accurate, verifiable, and granular data on fishing activity and has enormous potential to meet the monitoring needs of many of the world's fisheries.

3 Aloysius T. M. van Helmond et al., 2019. "Electronic Monitoring in Fisheries: Lessons from Global Experiences and Future Opportunities," *Fish and Fisheries* 21, no. 1: 162–89, https://doi.org/10.1111/faf.12425.

4 Timothy J. Emery et al., 2019. "Changes in Logbook Reporting by Commercial Fishers Following the Implementation of Electronic Monitoring in Australian Commonwealth Fisheries," Marine Policy 104: 135–45, https://doi.org/10.1016/j.marpol.2019.01.018.

5 Eric Gilman, et al., 2019. "Increasing the Functionalities and Accuracy of Fisheries Electronic Monitoring Systems," *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29, 901–926.

Process recommendations for efficient EM program design

EM customers face many design choices that affect the cost and the effectiveness of an EM program. What follows is a set of high-level process recommendations to consider when developing an EM program. These recommendations can support better EM program design and build shared understanding and trust in the program across stakeholders.

Recommendation 1: Define fishery monitoring objectives, data requirements, and key performance indicators.

The first step in developing an EM program is to define the fishery monitoring objective(s) you are trying to achieve, the data required to meet them, and key performance indicators. These objectives should guide your decision-making throughout the program design process and should be defined as early as possible. Being disciplined about your monitoring objectives can prevent scope creep, which can increase program cost and complexity. You may find that you can achieve most of your core objectives at a reasonable program cost, but some objectives may drive program costs beyond established budget targets. This should spur an evaluation of whether these few additional objectives should still be included in the program given their cost and value. The reverse can also be true in that some additional data can be collected at unexpectedly low cost. Thus, to optimize EM program design, customers should focus on their primary needs but be open to querying providers about what else can be captured and at what cost. Providing detailed data requirements can help facilitate a dialogue with EM providers about what can be achieved and at what cost.

Recommendation 2: Evaluate the full suite of tools and approaches to meet monitoring objectives.

EM is a powerful tool, but it is probably not the best approach to meet all a fishery's monitoring needs. A common pitfall is to assume that EM should be a drop-in replacement for human observers instead of identifying the data EM is well suited to collect and what is better addressed with other parts of the monitoring program. Designers should consider the ability of other monitoring approaches to meet fishery monitoring objectives and their cost. They should also evaluate how EM may enable adjustments to other parts of a fishery monitoring program or improve their efficacy. For example, EM could improve the accuracy of dockside monitoring by ensuring maximized retention or discard monitoring at sea. EM may also allow managers to scale back or better integrate other compliance tools (e.g., human observers, at-sea inspections, vessel monitoring systems), or use existing resources more efficiently (e.g., focus human observer activity on scientific data collection). For customers unfamiliar with the full scope of EM products and services, EM providers can provide guidance on how EM can be best integrated into an overall monitoring program.

Recommendation 3: Include the fishing industry in the design process and provide incentives for its ongoing participation.

While it is important to include all stakeholders in the design process, the fishing industry deserves specific mention. Fishers understand how a fishery operates at a practical level and will understand how to better integrate EM into their fisheries operations. They also know the characteristics of their fishing vessel that need to be considered for reliable installation and functioning of EM equipment. Their input can greatly improve the efficiency of an EM program and ensure that it will work for fishers over the long term.

Including industry in the development process and enabling a direct working relationship between industry and EM service providers also serves the critical function of socializing the EM program. Through this process, industry can contribute to the planning process and develop a clearer understanding of the goals and objectives of the EM program, how it will function, and the decision-making process that led to the final design. EM programs are often designed by regulatory agencies but impose program requirements (e.g., catch handling, system maintenance, data reporting) and costs on industry. As such, the success of an EM program depends heavily on industry cooperation, which makes industry involvement in the early planning stages essential. Providing incentives or controls for industry to meet its ongoing obligations to the EM program can be an effective approach to help ensure overall EM program success.

Recommendation 4: Consult with EM service providers in the early phases of program development.

There is an opportunity to better integrate EM service providers into the EM program design phase or the development of EM standards. Service providers' expert knowledge and understanding of technologies and process capabilities can support decisions that may influence project timing, quality, cost, and performance. Early interaction can also build trust and reduce information asymmetry (e.g., providers and customers can better understand each other's operational models and cost drivers). Although there can be concerns about soliciting guidance from providers who will ultimately bid on the work and although buyer-supplier interactions are usually regulated, there is ample room within these guideposts for communication, even during the procurement phase. Seeking EM provider guidance early in the design process on how best to meet customer monitoring objectives can be a helpful point of engagement and more effective than soliciting feedback on a narrow subset of questions after key design choices have already been made.

Recommendation 5: Evaluate whether new EM programs can leverage existing methodologies or infrastructure to improve the efficiency of EM program delivery.

The role of EM service providers is to deliver competitive and innovative products to help customers meet their fishery monitoring objectives. To meet these objectives, each fishery will have its own unique elements. But there can also be an opportunity to improve the efficiency and reduce the cost of EM program delivery by leveraging existing methodologies, requirements, or program infrastructure. For example, can programs use existing systems and specified data formats for EM data delivery? Are standard hardware and software configurations of providers well suited to meet program objectives, or are specifications that require system design changes necessary? In collaboration with providers, EM customers should evaluate where bespoke approaches will more effectively meet their overall monitoring objectives versus leaning on existing performance standards, methodologies, and infrastructure.

Recommendation 6: Carefully consider different EM service delivery models.

Early in the design phase, there are a few important structural choices to make about how EM services will be delivered, including:

1. How much of the program will be contracted to EM service providers?
2. Will the services be contracted to a single provider or multiple providers?
3. Will EM program delivery elements (e.g., hardware and video review) be split among different service providers?

There are pros and cons to each approach, and the optimal program design will vary by fishery. Therefore, customers should carefully examine and compare these different service delivery models, including an assessment of how these choices will affect their internal program administration costs.

1. **Contracting program elements to EM service providers**

   EM program managers will decide which components of EM program delivery will be contracted to EM service providers and which ones they will keep in-house. The most common decision is whether the government agency will handle EM video review and video/data storage internally or contract for these functions. There are successful examples of both approaches, and the context of the fishery will dictate which approach is preferable. For example, in some cases, government interest in maintaining control over EM video and data may lead the government agency to perform the video analysis and data storage functions of an EM program. In other cases, video review and storage are contracted to EM providers. Various factors could drive the choice to contract for these functions such as, cost, to encourage innovation, to emphasize industry ownership and access to data, or because there is already an industry-funded human at-sea monitoring program in place and the regulator is aiming for parity between the EM and observer programs.

2. **Single or multi-provider models**

   A second question is whether to use a single or multi-provider model. Traditionally, EM has been implemented under single-provider models, whereby a single provider is selected to provide services to an entire fleet and individual vessels are not allowed to choose a provider for themselves. However, some recently developed programs have implemented a multi-provider model, whereby the government agency approves several providers to service the fleet and individual vessels are free to contract with the provider they prefer. The multi-provider model has emerged as agencies have pushed the cost of EM programs on to fishing fleets and to encourage a more competitive market between providers. In pushing costs of EM on to fishing fleets, the agencies must provide vessels more control in selecting EM service providers.

   There are potential pros and cons of each approach, but the choice may not always pan out as expected. For example, a single provider model could allow the chosen provider to achieve greater economies of scale and simplify program administration since the customer will only need to communicate with and manage processes with one EM provider, which could reduce overall program delivery costs. But it is also possible that single provider models will magnify switching costs and reduce customer leverage to decrease costs or improve service quality.

   Likewise, multi-provider models could empower industry to contract with the EM provider they believe offers the best value to their businesses, increase competition among EM providers, and promote innovation. Providers may also have business models or existing infrastructure that would allow them to cost-effectively service a small portion of a fleet under a multi-provider model. But in some instances, multi-provider models may end up being more costly overall than an equivalent single provider model, and there may still be significant switching costs.

   The best model will depend on the fishery context. But to assess the pricing implications of different program models (e.g., single versus multi-provider), customers can request quotations at different minimum order quantities (e.g., 10 vessels, 50 vessels, whole region, whole fishery). This could illuminate whether there are significant economies of scale in larger procurements that may outweigh the benefits of multi-provider models.

3. **Disaggregation of service delivery**

   An emerging idea is to disaggregate the components of service delivery across different EM providers. To some extent, this already occurs in the marketplace where governments have contracted for EM hardware and maintenance but use their own staff for video review. In most of these cases, the government uses the analysis software from the same EM provider that is providing EM hardware to the fleet. A developing option is to use different EM providers for different components of the EM program. The most likely division of services would be for one provider to be responsible for hardware and maintenance and a second provider to be responsible for video analysis. This structure has not been widely deployed in the market, and there are inherent tradeoffs between disaggregated and end-to-end service delivery.

Disaggregating services could improve customer choice and drive specialization in the EM provider market (i.e., companies will focus on software and EM data review or hardware). It could potentially improve competition in the market and may be a cost-effective option for vessels that participate in multiple fisheries with EM programs (i.e., they could use the same hardware even if different parties performed the video analysis). But having separate companies responsible for different components of the program might also create more complexity or risk in program administration (e.g., ensuring appropriate coordination between the hardware and software/analysis providers and allocating responsibilities to ensure program quality).

Recommendation 7: Assess the infrastructure requirements of an EM program in relation to the geography of the fishery.

An EM program has many important infrastructure components. For example, having a set of trained technicians to service systems, having program staff or technicians to serve as touch points with industry in the ports where they operate, potentially building a video review center, building a team of trained video review analysts, and developing staff to manage the program and its operations. The geography of a fishery is an important factor in determining the balance between program cost and quality and the associated impact on required program infrastructure. For example, under a traditional EM service model with on-the-ground technicians, it could be more costly to meet short service response service times in fisheries with remote ports or with few vessels in several ports than in fisheries with vessels concentrated in a small number of ports. Fisheries with few vessels or remote ports may be better suited to different service models (e.g., more reliance on remote diagnostics, local contractors, training of captains/crew to do repairs). Customers should closely evaluate the appropriate infrastructure to meet overall program goals and performance requirements, its relationship to the fishery's geography, and the potential impacts on program cost and quality. Interaction with EM providers during program design can help customers understand different service models, their suitability to a fishery's geography, and the associated impacts on program cost and quality.

EM service provider recommendations on RFPs or statements of work

Recommendation 1: RFPs should ensure that bidders are working with a common set of assumptions concerning program operations.

A well-crafted RFP is essential to drive competition between service providers and achieve cost-effective EM service delivery. If the customer would like to attract multiple bidders, the RFP should clearly describe the program requirements and fishery information in a way that allows all capable providers to submit a competitive proposal.

At a minimum, RFPs should provide fundamental information on fishery operations, such as the number of vessels, vessel type and gear used, number of trips, ports of operation, typical trip details (e.g., duration, number of fishing operations, typical set/haul duration), catch characteristics, and overall monitoring objectives. Providing details on vessel characteristics, including photos and diagrams, can also be helpful. Providers should be asked to bid against these specific fishery and activity metrics to ensure all providers are costing the same parameters. If possible, providing sample video of fishing activity to all bidders can further level the playing field.

Recommendation 2: RFPs should provide clear performance-based specifications for hardware and all other EM program delivery elements.

RFPs often over-define the hardware requirements and under-define other program elements, yet these other program elements drive most variation in program cost and complexity. Specifications should be performance-based to the extent possible. For example, providers should be able to determine the number and types of cameras on a given vessel based on the events that need to be viewed (e.g., cameras must be sufficient to enable complete viewing, identification, and quantification of catch items), rather than defining a fixed number or specific type of camera.

Customers should also define the non-hardware components of the program and identify responsible parties. For example:

- What are the service requirements in the event of system failures?
- Who will train captain and crew on EM system operation and maintenance?
- What are the data standards, formats, and data collection requirements (e.g., 24/7, during fishing activity)?
- What is the data transfer frequency (e.g., real-time, periodical, on port arrival) and data storage requirements (e.g., what data needs to be stored and for how long)?
- What are the required data elements, review methodologies (e.g., full census review, logbook audit, random sampling, basic event detection), quality assurance needs, and reporting requirements?
- What are the anticipated project management needs (e.g., meetings, outreach, check-in points, adjustments)?

The more clearly an RFP can define the full suite of program delivery elements and the obligations of the EM provider, the more certainty EM providers will have about how much it will cost them to meet their responsibilities. This should help open the market to more bidders and reduce bid prices.

Recommendation 3: The roles and responsibilities at program interfaces should be clearly defined.

Within an EM program there can be multiple interfaces between different parties, and clearly articulating roles and responsibilities at these boundaries is key for overall program quality. Examples of interfaces include the handoff of raw EM data and video for review and the communication of video capture issues (e.g., camera placement, obscured cameras) to vessels, regulators, and/or hardware providers. As the market considers disaggregating service provision (e.g., separating hardware and maintenance from video review, data analysis, and report generation), the need to clearly define hand-offs and interfaces will only become more important. For example, if the video analyst identifies issues with the video capture on a vessel, what are the obligations of the video review analyst and what are the obligations of the hardware provider? What role and responsibility does the customer or regulatory agency have in ensuring adequate response from the vessel and EM hardware provider? Identifying key interface points, and clearly defining the roles and responsibilities at these junctures, can improve program quality and reduce uncertainty for providers in the bidding process.

Recommendation 4: RFPs should require EM systems to generate information that enables reporting on system performance.

An EM system is much more than just placing sensors and cameras onboard a fishing vessel. The system must be able to deliver accurate and verifiable video and data to end users. To assure that EM systems meet this objective, RFPs should require that systems capture sufficient data to enable clear reporting on system performance (e.g., camera recording status, planned or unplanned shutdown detection, sensor recording errors) so that customers understand data capture effectiveness and how well their monitoring goals are being achieved.

Recommendation 5: RFPs should require clear explanation of any proposed implementation of AI.

There is great enthusiasm for the potential of AI in EM programs, and EM providers are actively developing AI capabilities. RFPs should require that any proposed implementation of AI be clearly explained. This should be accompanied by a description of the provider's current AI capabilities and the benefits and risks they see to implementing AI in the EM program. This should include outlining the expected benefits from the specific applications of AI, such as reduced video review time. RFPs should also require that providers articulate whether they are incorporating third-party AI technology or developing their own.

Recommendation 6: RFPs should consider factors that are within the direct control of EM providers and those that are not.

Within an EM program, many factors influence the quality and cost of program delivery. Many of these factors are firmly under the control of EM service providers, but many depend on other actors, the characteristics of the fishery, or program incentives. Factors that are largely out of the control of the EM provider (Table 1) should be excluded from the RFP to the extent possible (e.g., extra installation hours due to vessel no-shows can be billed as additional fees). In addition, program designers should consider including incentives to mitigate some of these challenges.

Table 1 provides an overview of some of the key EM program elements, the factors that affect their cost and quality, and whether these factors are predominantly controlled by the service provider or other actors.

TABLE 1. KEY PROGRAM COMPONENTS AND FACTORS THAT ARE PREDOMINANTLY UNDER EM PROVIDER CONTROL OR OUTSIDE EM PROVIDER CONTROL

Program Component	Predominantly Under Provider Control	Predominantly Outside Provider Control
Program development and in-season adjustments	▪ Faithful participation in program development process as requested ▪ Providing recommendations to improve program design/efficiency as requested	▪ Defining program objectives ▪ Regulatory stakeholder engagement
Hardware	▪ Robust and cost-effective EM hardware design	▪ Overspecification of hardware ▪ Activities that must be viewed to meet program objectives
Installation	▪ Efficient installation plan and high-quality installation	▪ Preparedness and cooperation of the fleet ▪ Condition of the vessel ▪ Geographic distribution of the fleet ▪ Local labor rates
Service and maintenance	▪ Efficient service plan, including technician, captain, and crew training to meet program service requirements ▪ Robust hardware design	▪ Captain and crew compliance with duty of care and reporting responsibilities ▪ Level of service requirements (e.g., 24-hour response) ▪ Geographic distribution of the fleet
Data transmission, upload, storage, and custodianship	▪ Minimizing file sizes ▪ Choosing least-cost option within program specifications	▪ Technology available to transfer data to analysts ▪ Required location, form, duration, and accessibility of stored video/data ▪ Preparedness of the customer to accept and use EM data streams
Video review	▪ Efficient and accurate video analysis (including analyst training) to extract required information ▪ Analysis software that enables efficient EM video and data review ▪ Clear trip reports for captain and crew to highlight improvement opportunities	▪ Required video review rates ▪ Required data collection ▪ Captain and crew compliance with duty-of-care responsibilities (e.g., not obstructing cameras, wiping lenses) ▪ Trip report content requirements and format ▪ Program design that ensures the efficient use of EM resources (e.g., increase review rates and charge vessels that fail audits)

Key drivers of EM program cost

An oft-cited concern about EM programs is cost, given the budgetary constraints of regulatory agencies and given that industry-funded programs place a financial burden on the fishing sector. The following section outlines some of the important cost drivers of an EM program and suggestions for how to keep overall program costs down. In many cases, early program design choices lock in higher than anticipated costs.

Cost should not be considered in isolation nor solely in comparison to the costs of current monitoring programs. EM provides information that can support effective fisheries management and generate commercial value for the fishing industry. Therefore, the cost of EM programs—to both regulators and industry—should be viewed in balance with the additional value they provide.

EM Program Objectives and Data Requirements

Perhaps the most important cost driver is the overall EM program objectives. EM can deliver many types of data, but every data element has an associated cost. The overall EM objectives should be selected by carefully weighing the primary monitoring needs of the fishery and the cost of collecting that data with EM. It is important to solidify program objectives and data requirements before program commencement, as after-the fact changes can significantly increase cost.

As noted earlier, EM should be evaluated in the context of all monitoring tools that are available. EM programs should focus on what the technology does well, which is providing 100 percent coverage of fishing activity, eliminating the observer effect, driving compliance, providing detailed effort and catch monitoring, and improving the accuracy and reliability of self-reported data. EM customers should also acknowledge that EM data, like observer data, is not perfect, so EM customers should define acceptable levels of performance to meet program objectives.

Video and Data Review Methods

The choice of how fishing data will be extracted from EM video and sensor data is an important cost driver. Achieving monitoring objectives in some fisheries can be much simpler than in others. For example, monitoring effort in crab fisheries can be completed largely through automated analysis of sensor and location data, with video reviewed only when there is an event of concern (e.g., a trap was pulled without the associated ID tag being scanned or a trap was pulled in a closed area). Basic event detection, such as ensuring maximized retention, as is done in the Pacific Whiting fishery, or counting the total number of sets can also be well suited for EM. In these cases, video can be reviewed at high speed, resulting in low cost. Basic event detection can also be conducive to the use of AI for video review, and this technology is already operational for some basic functions.

Achieving monitoring objectives in many fisheries, however, such as assessing discarded catch, requires considerable effort to review the video. In these cases, different analysis approaches can be used with consequent impact on cost. The three main methods in order of increasing costs are audit of self-reported data, sample-based EM review, and census-based EM review.

For some fisheries monitoring objectives (e.g., discard accounting), using EM as an auditing tool to ensure accurate self-reported fishing data can be an efficient application of the technology. Under this model, a small sample of video from a trip is reviewed and the data is compared with what is reported in the fisher's logbook. If the EM data matches what is in the logbook, the entire logbook is accepted as valid data for the fishing trip. The logbook audit model can efficiently cover 100 percent of fishing activity, stamp out the observer effect, and improve the quality and reliability of the existing logbook data stream.

A second approach is to review a larger sample of fishing activity, with no accompanying logbook data, which can be scaled up to generate data estimates for an entire fishing trip or fishery. Low sampling rates can provide accurate estimates for common events such as accounting of common discard species, but rare events such as ETP interactions require higher sampling rates. Like the logbook audit model, the presence of cameras during all fishing activity and uncertainty about what footage will be reviewed can drive improved compliance in the fishery even though only a portion of video is reviewed.

Some EM objectives may require 100 percent review of video. This census review model is the highest-cost approach but may be appropriate in certain contexts. Full video review may also be helpful in early piloting to build baseline data and support program design decisions.

These approaches are not mutually exclusive within a fishery, and multiple approaches may be used if there are several different data requirements in a fishery.

Table 2 provides an overview of the typical review processes of EM data and their relative costs.

TABLE 2. EM REVIEW PROCESS AND IMPLICATIONS FOR PROGRAM DELIVERY COST

	Logbook Audit Model	Sampling	Census
Description	A selection of fishing activity is reviewed and compared to self-reported data in vessel logbooks. If the audited video matches what is in the logbook, the logbook data for the entire trip is accepted as valid data for the fishing trip.	A sample of the fishing activity is reviewed and then these samples are extrapolated to estimate data for the entire trip or fishery.	All video is reviewed to obtain a complete record of fishing activity data.
Cost	Low	Medium	High
Considerations	The combination of audit rate and sanctions for misreporting must make the cost of misreporting sufficient to drive accurate reporting.	For common events, low rates of sampling can provide accurate estimates, but for rare events (e.g., ETP interactions), high rates of sampling will be required.	Given the high cost of this approach, it is best used in the piloting or testing phase to troubleshoot program design and/or obtain baseline data.
Example program	British Columbia Groundfish, Australia Gillnet Hook and Trap	Alaska Demersal Fixed Gear	US West Coast Groundfish (Discards)

Industry Participation

The degree of industry participation and cooperation can significantly affect program cost and quality. This begins with program design, where industry participation can ensure that the program will dovetail with how a fishery operates on the water. The importance of industry cooperation continues into program implementation and operation. For example, vessel no-shows or vessels that are unprepared for system installations can result in significantly higher costs. Additionally, vessels that do not meet their duty of care or catch handling obligations can drive service, maintenance, and video review costs higher or even compromise the program's ability to produce accurate and verifiable data. Therefore, incentives or controls should be built into the program to encourage industry cooperation in all phases.

Geography of the Fishery

The geographic footprint of a fishery can have significant implications for program cost. Fisheries that are distributed across many ports may result in higher program infrastructure costs to ensure adequate levels of service, depending on the program design. Fisheries with ports in remote locations, especially with few vessels operating out of these locations, can be particularly challenging. EM service providers have different approaches to solve this challenge, and customers should evaluate the cost and quality of service that can be achieved with these different approaches in their fishery.

Program Scale and Durability

Many of the up-front EM program planning and development costs are largely fixed. In addition, some economies of scale may be achieved in hardware and operations for a larger fishery. While not always the case, this means that per unit costs may be lower in larger programs.

Higher confidence in program durability (i.e., how long the program will last) can also help reduce costs of EM programs. In the case of pilot programs, service providers must try to recoup the program development costs during the expected lifetime of the pilot program or risk losing money if the pilot does not continue or evolve into a full-fledged EM program. Thus, customers should expect the costs of EM service delivery for a short-term contract to be higher than for a longer-term engagement.

Customer Readiness to Receive and Manage EM Data

A customer's level of preparedness to receive EM data can significantly influence the cost of an EM program. A customer should have a well-defined set of required data, a preferred format for receipt, and a method of transmission and storage. Customers should also define appropriate access and use of EM data. If these are not well defined at the program outset, it can take a significant amount of development time to build and iterate these systems and specifications on the fly. This can be especially challenging if EM is providing entirely new data streams for fisheries. This is one of the reasons why the logbook audit model can be an easier type of EM model to develop. While the logbook audit model does not address all of these data management challenges, this model offers the advantage of EM simply driving improvements in the accuracy and reliability of an existing data stream that is already integrated into the customer's data and management operations. Customers should thoroughly understand the capacity of their existing data systems and incorporate that knowledge into EM program design.

Status of EM Technology

Imperfect information about the capabilities of EM systems is a challenge for the EM market and can lead to unrealistic customer expectations. EM providers continue to expand the capabilities of their systems, and while there may be some variation across providers, the following section provides a high-level overview of the current capabilities of EM.

Applicability of EM to Different Fishery Types and Catch Monitoring Functions

EM has been successfully applied in a wide variety of fishery types (e.g., pot, trap, longline, trawl, purse seine) for a variety of functions, such as logbook auditing, catch and bycatch monitoring, discard monitoring and accounting, effort monitoring, identifying ETP interactions, and monitoring catch-handling practices. In high-volume fisheries (e.g., trawl, purse seine), EM programs may need to include specific catch handling protocols to enable video reviewers to accurately collect data, but there are numerous examples of successful EM programs in these types of fisheries. Likewise, EM can be an excellent tool for monitoring ETP interactions, but collecting accurate data may require specific catch handling protocols or including additional cameras (e.g., overhead camera focused over the rail of longline vessels), which will increase cost. Typically, these requirements and protocols are defined in a Vessel Monitoring Plan (VMP). The VMP describes the EM system, the goals and objectives of the program, and the catch-handling, sorting, maintenance, and troubleshooting requirements of the crew and EM service provider. Table 4 provides a high-level overview of the capability of EM for different combinations of fishery type and catch-related monitoring objectives.

EM is also expanding to areas outside of traditional catch monitoring, including monitoring observer safety, labor practices, bunkering and transshipment activity, traceability, compliance with the International Convention for the Prevention of Pollution from Ships, and segregation of catch in wells. These monitoring functions may require different camera configurations and monitoring strategies than more traditional catch monitoring. Customers should consult with EM providers to understand their ability to meet these monitoring objectives with EM, their approach, and the associated cost.

EM for Labor Monitoring

Ensuring the safety and fair treatment of crew is an issue of growing concern in the seafood sector. There is significant interest in the potential of EM to support human rights and safety. This could include ensuring appropriate safety equipment is in use and adherence to safety protocols, validating working hours, or monitoring for labor abuse. This is an emerging application of EM technology, and more effort is needed to fully understand how EM can address these monitoring needs. While privacy concerns may prevent the use of EM for this function in some jurisdictions in the near term, EM probably could be an effective tool for monitoring and reporting on labor issues that can be readily seen on deck, such as issues related to work hours and safety practices. But issues that may occur out of sight of standard camera views or that may be more difficult to detect (like some forms of harassment and intimidation) will be more challenging to confirm with a traditional EM model.

Overall System Performance

EM hardware operates in extremely harsh and variable environments, but the reliability of EM systems has improved greatly over time. Very high rates of system uptime and usable video are now regularly achieved. But depending on the fishery and monitoring objectives, a small amount of missing data or system downtime could compromise the integrity of the data set. For example, if the hardware failed the moment an endangered species was caught, a short period of downtime could seriously affect data and program integrity. Therefore, hardware performance criteria in the RFP should reflect the associated risk of failures to data integrity. For example, the risk to data integrity from system failure on a trip in an EM program to monitor crab trap effort probably will be lower than the risk of a system failure in an EM program in a quota-managed fishery with choke stocks, or in a program that is monitoring for ETP interactions.

Risk to data integrity can also vary within a trip. For example, missing data while the vessel is steaming and has yet to undertake any fishing is very low risk, while failures during fishing activity are high risk.

EM program designers should develop system performance requirements (Table 3) that reflect the risk of failures to data integrity and the cost that system failures may place on industry (e.g., lost fishing time). These performance criteria should also be set with the recognition that, in some instances, higher performance may come with higher costs. In addition, achieving some performance criteria will require that captains and crew meet their program obligations (e.g., wiping lenses, duty of care). EM service providers can communicate program responsibilities to vessels and provide feedback on performance but cannot enforce compliance. Therefore, crews should be trained effectively on vessel obligations, VMPs should clearly articulate the obligations, and crew fulfillment of obligations should be backed by performance incentives and compliance mechanisms in EM regulations.

TABLE 3. ILLUSTRATIVE SYSTEM PERFORMANCE REQUIREMENTS

Illustrative Performance Requirements	Notes/Considerations
Frequency of maintenance calls and software updates	▪ Largely determined by system robustness, but proper care can affect frequency of maintenance calls.
System uptime	▪ Largely determined by system robustness, but proper care and captain/crew adherence to program responsibilities can strongly influence system uptime. ▪ Should include all sensors and cameras of the system.
Percent of usable EM video and data	▪ Onboard responsibilities (e.g., wiping lenses) can have a big influence. ▪ The timing of video loss can have different risk levels for data/program integrity.

AI and EM

The gap between customer expectations and current capabilities of EM technology is probably largest with regard to machine learning/AI for the automation of video review. Video review is one of the main cost drivers of an EM program, and there is great interest in the potential for automated event detection, species identification, and length measurement to help streamline that process. It can also reduce the overall cost of wirelessly transmitting EM data from a vessel to a remote data storage system via cellular network, Wi-Fi, or satellite by preemptively identifying footage of interest to reduce the overall volume of data that must be offloaded from the vessel.

In practice, the successful application of AI for image recognition depends on training algorithms with large sets of data in which the relevant characteristics of the image have been annotated. A key challenge in fisheries is the highly variable environment in which these algorithms must operate. It is much easier to successfully apply image classification in a highly controlled environment (e.g., a factory line) than at sea with different vessel configurations, variable lighting, inconsistent image quality (e.g., spray on the lens), and fish and people in varying positions and orientations.

Given these challenges, AI for image recognition is still in the early stages of development for fisheries EM (Figure 2). At this time, AI can be applied on a limited scale for basic functions such as identifying whether a fish or a person is in frame. While not as intuitive as the potential cost savings from species recognition, the use of AI to identify events of interest, such as the presence of a fish or ETP in the frame (or crew on deck) is likely to be more immediately effective in driving cost reductions and is already being operationalized. However, the technology is not mature enough yet to be applied broadly across many fisheries out of the box—customers should be aware that at this time AI often requires development and application on a vessel-by-vessel or fishery-by-fishery basis.

While there are prototypes and academic studies that have demonstrated successful use of AI to accurately identify fish species, this use case has not yet been operationalized in EM programs. Customers should also be aware that achieving a fully automated video review in most fisheries requires AI to perform multiple simultaneous functions (e.g., target catch identification and enumeration, discard species identification and enumeration, length estimation, active fishing, fish in frame, person in frame, discard event, transshipment identification). For example, if AI could successfully detect and identify retained species, there might be less video review cost savings than anticipated if human analysts still needed to gather other pertinent information such as identification of discard species.

Although the application of AI for EM is still relatively early in its development, it will be one of the tools that will create efficiencies and help bring EM to scale moving forward. This will take time, and, as AI technology advances, EM providers will clearly communicate their current AI capabilities and any risks they see to successfully implementing novel AI functionality.

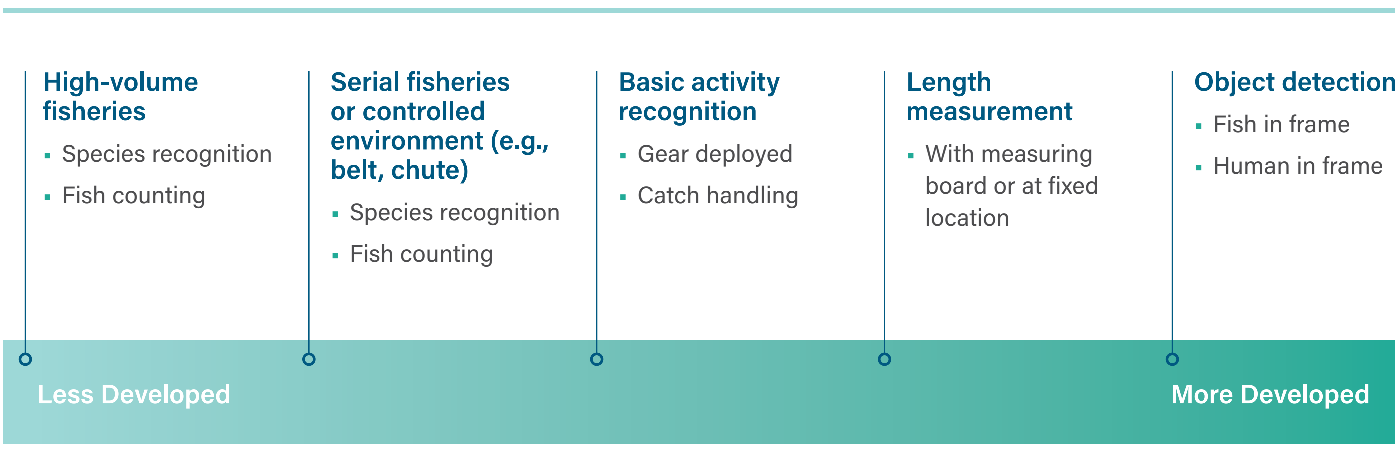

FIGURE 2. RELATIVE DEVELOPMENT STATUS OF AN ILLUSTRATIVE SAMPLE OF AI FUNCTIONS FOR EM

Future Technology Development

Technology development will be essential to increase EM's contribution to fisheries monitoring, and EM service providers are continually improving their products. EM products and services have come a long way since their initial deployment about 20 years ago, and providers will continue to innovate and improve their products. These efforts will be focused on overall market needs and where providers have a high degree of control for driving innovation and cost reductions.

TABLE 4 - EM APPLICABILITY FOR CATCH-RELATED MONITORING OBJECTIVES BY FISHERY TYPE[6]

Suitability of EM to meet monitoring objective:

Moderate | High

		Low-Volume or Serial Fishing Gear (pots, traps, longline, gillnet)	High-Volume Gear (trawl, purse seine)	
			Single target species	Multispecies
Retained Catch	Retained Catch Composition			Requires catch handling protocols
Discarded Catch	Validate Full Retention			
	Discarded Catch Composition		Requires catch handling protocols	Requires catch handling protocols
Fishing Effort	Spatial/ Temporal Data of Fishing Events			
	Gear Characteristics			
	Trap/ Gear Limits			
ETP Species Interactions and Avoidance	Species ID	May require specific camera placement or catch handling procedures	May only be possible to higher level (e.g., Cheloniidae versus species of turtle)	
	Handling Method			
	Release Condition	Not all release conditions may be accurately observed	Not all release conditions may be accurately observed	
	Discarded or Retained			
	Bycatch Mitigation Device Deployment	Reliable confirmation of mitigation measures depends on the specific measure and camera placements	Reliable confirmation of mitigation measures depends on the specific measure and camera placements	

6 Adapted from Lowman, D., et al., 2013. "Fisheries Monitoring Roadmap: A Guide to Evaluate, Design and Implement an Effective Fishery Monitoring Program that Incorporates Electronic Monitoring and Electronic Reporting Tools,"

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