Challenges, Opportunities, and Costs of Electronic Fisheries Monitoring

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Commonly Used Acronyms

ASOs: At-Sea (Human) Observers

BSAI: Bering Sea and Aleutian Islands

DSMs: Dock-Side Monitors

EM: Electronic Monitoring

ER: Electronic Reporting

GOA: Gulf of Alaska

MCS: Monitoring, Control, and Surveillance

NOAA: National Oceanic and Atmospheric Association

NMFS: National Marine Fisheries Service

MSY: Maximum Sustainable Yield

SBA: Standards-Based Approach

U.S.: United States

VMS: Vessel Monitoring Systems

Executive Summary

At-Sea Observers (ASOs) and Electronic Monitoring (EM) are critical components of fishery monitoring, control, and surveillance systems (MCS). EM is receiving much attention due to improving technologies that lower the costs of EM systems and increase their application to a broader range of MCS tasks. To evaluate the growing importance of EM and the associated challenges, opportunities, and costs, we reviewed the EM literature, conducted background interviews with EM and ASO stakeholders, and created an easy to use but comprehensive financial spreadsheet to analyze EM and ASO cost drivers. The overall results showed that the use of EM in fisheries is still uncommon but that the use of EM technology is rapidly gathering momentum. The technology is maturing and operationally robust and EM can perform some functions to a higher level of accuracy than ASO's, but is also limited in performing some of the essential tasks conducted by ASOs. The review revealed a number of principles essential to successful EM programs. For example, successful EM is often an integrated part of fisheries management systems and not just a data collection technology. Successful EM programs have clearly defined objectives which drive collaboration and cost effective management. Well-designed EM programs are also based on clear standards, although these standards may be complex given the diverse elements of EM. Successful EM programs also manage expectations and ensure that EM is aligned with the capacity, regulatory environment, and culture of management agencies and industries. Collaboration across agencies and industries is essential to the successful implementation of EM. Collaboration helps players understand the perspectives of other team members, and to realize the tradeoffs inherent in balancing the quantity/quality of the data and the costs to achieve different levels of "compliance". Finally, a basic and fundamental principle is that poorly performing and financially stressed fisheries cannot support effective EM or ASO monitoring programs.

We found that the marketplace for EM and ASO services is complex but has potential for significant growth. In general, EM is not a perfect substitute for ASO but is often a complement. We anticipate seeing increasing and creative combinations of EM and ASO over time. Who pays for EM and ASO can differ given that fisheries management is moving towards cost-recovery approaches where fishermen pay for management costs including fishery monitoring. The implementation of potentially less expensive methods of monitoring will foster opportunities for change, innovation, and a greater focus on cost effectiveness. The literature review and financial analysis showed that EM may be within 50% to 150% of the costs of ASOs depending on program objectives, characteristics of the fishery, and the resource management system. Although there are consistencies among certain categories of costs, the overall cost of EM is not uniform across fisheries and fleets (irrespective of whether an agency or industry pays this cost). Economies of scale play an important role. The spreadsheet modelling and analysis of cost drivers revealed that if levels of fishing effort are very low, regardless of the other characteristics of the fishery or program standards, ASOs are generally less expensive than EM systems. As fishing effort increases, however, EM systems become relatively more attractive especially when there are low level requirements of video review, large and geographically dispersed fisheries, and higher levels of observer coverage.

Challenges, Opportunities, and Costs of Electronic Fisheries Monitoring

Introduction

At-Sea (human) Observers (ASOs) and increasingly, Electronic Monitoring (EM) are critical components of fishery monitoring, control and surveillance (MCS) systems. These systems support collection of essential fisheries data and help ensure compliance with fisheries management regulations. Fisheries monitoring is growing in importance given the expansion of quota-based management and greater requirements for compliance with catch-based harvest limits. EM in particular is receiving attention due to improvements in key technologies including electronics, camera/optic systems, computer systems, and recognition algorithms. These technological improvements lower the cost of EM systems and increase their application to a broader range of MCS tasks. This is particularly important given that the fishing industry is being asked to shoulder an ever-higher proportion of MCS costs. In some cases, EM may be a complement to ASO systems; in other cases it may be a direct substitute. Whether a complement or substitute, it provides fishing industries and management agencies with choices among competing approaches. Although comparing the technical performance of various approaches to fishery monitoring may be relatively straight forward, determining the costs of these approaches for a particular fishery can be complex given the diverse characteristics of individual fisheries and management systems.

This report draws on a comprehensive review of EM literature, interviews with fisheries stakeholders with EM experience, and the results from a financial model created for this study. Section I highlights key issues, trends, and topics relevant to the decision to adopt EM based on a review of literature from national and international case studies as well as interviews with individuals involved with the implementation and management of EM projects in the United States. Section II focuses on cost issues based on literature review, interviews, and a financial spreadsheet model designed to illustrate key EM and ASO cost scenarios. The spreadsheet itemizes potential costs involved in the deployment of both EM and ASM and is designed to be generalizable to a wide range of fisheries and a wide range of management goals and data collection standards. Section III summarizes key findings from the research and makes recommendations for addressing major EM implementation and operational challenges. Appendices summarize the background interviews (Appendix I) and the Excel Spreadsheet Model (Appendix II).

Section I: Status, Trends, and Issues in the Implementation and use of EM in the U.S.

In the U.S., the use of EM is still primarily in the "experimental" stage. Experimental EM typically is used by a few vessels in a fishery to test the efficacy of technology and, in most cases, to compare EM data to those provided by ASOs. Examples of largely experimental EM include the New England Electronic Monitoring Project (Pria et al. 2014) and the Maine Coast Community Sector EM Initiative (Ecotrust Canada 2016). A smaller number of EM programs have moved to the fleet trial stage where technical, operational and/or regulatory adjustments are still being made as part of EM implementation. Examples of EM programs at this stage of development include the Pacific Groundfish EM programs for the whiting, fixed gear, and trawl fisheries (PFMC 2016), and the Alaskan North Pacific Fisheries Management Council EM Program (Loefflad et al. 2014).

In Alaska, EM is fully operational in four fisheries to verify compliance with regulations for catch sorting and weighing. Three of the programs are in the Bering Sea and Aleutian Islands (BSAI) fisheries and one in the Gulf of Alaska (GOA) fishery (Cahalan, et al. 2014). These fisheries include the BSAI non-pollock and pollock trawl fisheries, the BSAI longline fishery for Pacific cod, and the Central GOA Rockfish Program fishery. These programs require at least one observer on board while the vessel is fishing so they differ from new EM programs where observers are generally not required. In the trawl fisheries, the imagery feed helps ensure species are not presorted or discarded before an observer is able to obtain a sample. In the catcher/processor longline fishery for Pacific cod, cameras are used to monitor compliance with regulations that require all retained Pacific cod to be weighed on a flow scale. Imagery required for compliance monitoring may be viewed in real-time by the observer and/or periodically collected and checked by management agency staff. The use of EM in the fixed gear, small boat fishery for halibut and sablefish in Alaska is in a pre-implementation phase and is expected to become operational in 2018.

The Atlantic pelagic longline fishery has fully implemented EM to monitor Bluefin tuna bycatch, and two New England groundfish sectors voluntarily employ EM for quota monitoring and to ensure compliance with maximized retention regulations. The Pacific groundfish EM programs for the whiting, fixed gear, and trawl fisheries will become operational in the near future (PFMC 2016). Although not a U.S. fishery, similarities with many U.S. fisheries makes the British Columbian groundfish hook and line fishery a useful comparator for U.S. west coast fisheries. This fishery is one of the few large fisheries where EM has become and continues to be a routine component of MCS (Stanley 2014).

One of the key management objectives of EM in the U.S. is accurate accounting of vessel landings and of bycatch/discards of fish and interactions with protected species. Catch share programs, in particular, depend on accurate and timely catch reporting, and the majority of EM programs in the U.S. are being implemented in, or associated with, catch share fisheries. Another common management objective is to track interactions with protected species. Measuring the biological characteristics of catch and the measurement of fishing effort are typical scientific goals of EM programs and can be some of the most challenging to integrate into EM. EM can also play an important role in identifying non-compliance with fishing rules such as restrictions on the use of fishing gear, spatial restrictions and the handling and catch of protected species. A stated goal of EM is often cost-effectiveness, but it is common to look at the enforcement, management and science goals as primary goals and cost effectiveness as a secondary objective contingent on the specification of the primary objective(s) (NOAA 2013b).

Our review of the literature and discussions with stakeholders suggest that major challenges can arise when EM initiatives move from the experimental stage to the implementation stages. Experimental programs tend to be treated as proof of concept scientific and technical studies. But fully operational programs need to address much broader regulatory, management, and fleet wide MCS requirements and convince a much wider range of fisherman to participate in, and comply with, requirements of the EM program.

When moving from trial to implementation, management agency culture can play a major role in determining whether the transition is successful. Agency attitudes can vary between different divisions and be significantly influenced by the level of industry interest and their capacity to take on EM responsibilities, as well as the prevailing regulatory environment. Agencies may be limited by regulatory requirements and legal issues, and may be constrained in their capacity to develop creative and cost effective EM programs. Higher levels of industry engagement in implementation can lead to more flexibility and success in implementation especially where clear EM performance standards are in place. Industry and the EM providers can then work with management agencies to implement the most efficient EM systems.

It is clear from our reviews and discussions that EM technology is rapidly maturing and operationally robust and can be used to monitor many types of fishing activities including landings, discards and interactions with threatened and endangered species (NOAA 2013a). EM is especially effective and efficient with respect to monitoring fishermen behavior such as discarding and quantifying fishing effort. There can be major challenges, however, when it is necessary to identify individual retained species or discard species when the catch is composed of many similar species, the weather and lighting conditions are poor, or there is a high volume of fish flowing across the camera frame (Hedley and Catchpole 2015; NOAA 2013a; Wallace et al. 2013).

Perhaps because of its relative newness, EM has yet to be operationally integrated with other mature and widely used technologies such as electronic reporting (ER) which includes electronic logbooks. Though the potential for the integration of EM with ER exists, and clear synergies are recognized (Lowman 2013; WWF 2015; NOAA 2013a), limited financial and staff resources may leave agencies and industry with only enough capacity to focus on one system at a time.

Key issues in EM Initiatives

Implementing EM is not just about introducing a new technology to acquire data as an alternative to ASO (Stanley et al. 2015). It is about creating new management and information systems with attendant governance, regulatory and structural change in a fishery that builds on, integrates with, and improve on the timeliness, quality, and value of existing ASO programs (Singer 2014). To achieve their full potential, EM-based information systems require the integration of EM and ASO with ER and shore-side/supply chain reporting. Such integration requires clear objectives and standards for each component of the system. EM derived information needs to be cost effective, timely, useful and legally acceptable for all participants.

An often cited problem in the literature and the stakeholder interviews about EM programs is that agencies often do not clearly articulate the level and types of biases and imprecision in the compliance data they are willing, or not willing, to accept (Stanley et al. 2015). This issue can critically undermine EM success and if not carefully considered within the larger EM project framework, may limit opportunities for rewarding fishermen that reduce error. “Sliding standards” are also a commonly cited problem. This refers to the situation where agencies and scientists may increasingly raise the standards for data quality, accuracy, and precision once they understand EM/ASO capabilities. Although EM standards may need to be specific for each fishery situation, principles guiding the design of EM standards can be applicable to most fisheries.

Developing and aligning incentives across agencies and industry players is highlighted in the literature and by the stakeholder interviewed as key to implementing cost-effective EM. Poorly aligned incentives can undermine EM (and ASO programs) and encourage non-compliance. This can be especially true when there are severe problems in the fishery including inadequate monitoring, presence of major quota constraining choke species, severe budget constraints, and financial hardship. If fishermen, skippers, and vessel owners believe in, and want EM to work because it provides major benefits, they will invest the time and resources necessary to develop successful EM programs; conversely, if the underlying incentives are not aligned fishermen will not make the required investments necessary to develop successful cost-effective EM programs. Industry leaders play an especially critical role for helping to drive development and adoption of EM. Often when an industry is facing serious management and financial problems, leaders may lack the necessary focus to support development and implementation of EM (Stanley et al. 2015).

There are a variety of potential incentives to drive successful development and adoption of EM including: 1) developing EM in conjunction with experimental fishing permits that provide additional quota to fishermen; 2) using EM to verify logbook data accuracy that can support use of fisheries dependent data in science and management; 3) encouraging fishermen to design efficient systems based on their ideas and transparency in costs and standards, rather than being burdened with costly and inflexible systems designed by others; 4) rewarding good behavior and record keeping with lower review and video audit costs; and 5) receiving financial remuneration for providing EM data to science centers, universities, and other organizations. Although upfront subsidies for trial programs may encourage some fishermen to participate, the lack of long-term subsidies to the full industry, as well as concern about future costs and “who pays”, can ultimately undermine long term participation and success. Aligned incentives across industry, management agencies, and scientists can encourage collaboration and a culture of trust. This is especially important for EM if it is developed in a culture of distrust where perverse incentives diminish the reputation of the industry and color the attitudes of the agencies about the behavior and integrity of fishermen. Trust is key and a critical metric -- success can be measured by the degree of trust of both industry and agencies in EM programs.

The most successful EM programs appear to be collaborative programs. Collaborations between scientists, enforcement officers, managers, technologists, and industry at the beginning of an EM project lead to an understanding of each other's perspectives and expectations and a better more resilient program design. As an EM program evolves, ongoing collaboration is needed to evaluate the tradeoffs between the quality of the data and the costs to deliver on the objectives of the program. Collaboration also helps adaptively manage the program for efficiency, resolve vessel-specific implementation challenges, and to identify opportunities for new and innovative avenues of EM program development.

Adaptation, Innovation, and Incentives – the Case of EM in the British Columbia Groundfish Hook and Line Fishery

The British Columbia hook and line ground fish EM program involves some 200 active vessels making 1300 trips to catch 140 fish species spending 11,500 days at sea per year. The ex-vessel value of the catch is US$68 million. The program was introduced in conjunction with the transition to individual vessel quotas in the fishery and the need for much greater fidelity in catch accounting. Several elements contribute to the success of the program. First, the system does not focus on any one MCS component, recognizing that the system is made up of interdependent components including full (100%) independent dockside monitoring, full video capture of fishing events and vessel monitoring at sea, 10% partial review of the video imagery from each trip, and full coverage of fisher logbooks. Each element, though having individual weaknesses, is designed to mutually support the others. Second, a risk/benefit analysis is central to the program. As the incremental costs of satisfying additional information needs, often for research purposes, became apparent, the design change had to be justified from a cost–benefit viewpoint. Third, collaboration and partnership is the foundation on which the EM program is built. Canadian management agencies were willing to give up a command-and-control approaches and give industry the autonomy to solve operational issues with the program, only engaging in an oversight and performance evaluation role. This gave participants in the program a sense of ownership and more practically, provided the EM program an ability to be flexible, responsive and entrepreneurial that would not be possible under a government run system. Fourth, the program is adaptive, designed to continually improve. For example, early on in the program, a vessel receiving poor audit scores of its logbook against EM video would complain that the poor score was a one-off event. The scoring system was quickly changed to include not only the evaluation of the results of the most recent trip but also consideration of the average score over the preceding 12 months. Log book accuracy is now so good that the fishery did not have to increase the amount of video audit for any vessel in 2012 or 2013. Under the EM audit rules, vessels directly pay for increased video review. Finally, the program has a clear objective -- adequate catch monitoring of over-fished and rebuilding rockfish stocks – especially yellow eye rockfish. EM program managers could assume that if the monitoring were adequate for yelloweye and other overfished rockfish then it would suffice for other quota species. A detailed retrospective view of the ingredients of success in the BC hook and line groundfish EM program can be found in Stanley et al. (2015).

The presence or absence of clear standards can fundamentally lead to the success or failure of EM initiatives (Stanley et al. 2015). The development and use of *standards* is fundamental to any fishery management process. In fact, a *standard* – or its synonyms *criterion, target, norm, value, benchmark, rule* – is fundamental to any systematic process designed to achieve some measurable goal. Standards for EM, however, can be complicated because they must be applied to many elements of the EM process including data requirements, monitoring equipment, data confidentiality, data ownership, etc. But if well-defined, a standards-based approach (SBA) can provide a coherent framework for building a successful EM program.

The major components of an SBA-EM programming would include: 1) the overall goal(s) of the EM program; 2) input, process, or performance standards whose achievement correlates with EM goal achievement; 3) incentives and strategies which encourage managers, scientists, fishermen, and technologists to achieve EM standards; 4) evaluation; and, 5) revision and adaptation of the EM program. A credible standards-based approach must also be consistent with relevant policies and legal fishery mandates, achieve its goals at the lowest cost or greatest benefits, and be fair and equitable (see for example NOAA (2013a)).

For EM standards to work they need to be effectively designed and integrated with risk-based and precautionary management approaches. Standards may also need to be dynamic and reflect the status of the fishery. For example, standards can be designed to recognize the uncertainty of information with respect to the status of the stocks including stock size relative to key reference points. For example, the same precision or accuracy of information for stocks that are in a rebuilding mode may not be as important for stocks that are at a level of maximum sustainable yield (MSY).

Section II: EM Markets, Costs, and Financial Analysis

National and international markets for EM and ASO services are increasingly competitive. There are at least a half dozen EM companies and a much larger number of ASO companies competing for market share. For EM and ASO there are three categories of providers: private for profits companies, non-profit organizations, and state, regional, or federal governments. EM providers interviewed for this project indicated that profit margins for the provision of EM services are relatively low and are generally representative of a maturing and competitive industry.

ASO and EM can be substitutes when the monitoring program requirements are narrowly defined (e.g., in the case of compliance with discard bans). In other cases, ASO and EM may not be substitutes depending on program goals, management requirements, and characteristics of the fishery. Given the nature of small markets and the fixed costs associated with each approach, any increase in the use of EM may decrease the demand for ASO (or vice versa), thereby reducing supply, and increasing average ASO costs. Although it is possible that one approach could dominate the market over time, the fact that these approaches are often complements may limit supply effects. For example, in the BSAI and GOA fisheries, EM is used by ASOs while onboard the vessels to increase their efficiency and effectiveness (Bonney et al. 2009).

An overriding issue is the major role that government agencies play in these markets. If agencies expect EM providers to reduce costs, be competitive, and risk capital, they have a responsibility to support business environments that reward creation of intellectual property and new technologies. This is especially true given that the markets for these services are relatively small. Management systems that reward and encourage innovation and entrepreneurship in developing cost-effective monitoring programs will help produce the most successful programs. If markets function properly, we may expect to see a variety of combinations of ASO and EM evolving over time in ways that achieve management and monitoring objectives while lowering costs. The increasing adoption of cost recovery and quota-based/rights based fisheries in the U.S. and around the globe will drive greater industry engagement in designing, implementing, and managing monitoring programs. Poorly articulated and conflicting objectives can be a major driver of cost in EM programs especially when moving from trial to implementation phases of EM. EM programs will usually have a mix of management, scientific, enforcement and cost effectiveness goals which complicates their design and success (NOAA 2013a; 2013b).

Although cost recovery is increasingly common for ASOs, EM programs are often established with the explicit intent of moving to the recovery of costs from industry (NOAA 2013a). Once initial grants (government and foundation-based) for EM trials are expended, management agencies may lack the discretionary resources to fund and support EM programs without cost recovery. Agencies may be required to fund established ASO programs as well as support new EM programs, and imposing cost recovery to new EM programs is easier than applying it to established ASO programs. Fishermen may end up paying substantially more for an EM program than for an ongoing ASO program, even though the overall program costs of EM may be less.

Management, enforcement, and science objectives for EM may conflict with cost effectiveness. Management agencies must carefully evaluate the costs and benefits of specific design alternatives in meeting program objectives. A basic question is how fast, accurate, and comprehensive does the information obtained from EM need to be in order to meet program objectives? The answer has a direct impact on costs (NOAA 2013a). Perhaps the clearest example of this impact on costs is the census versus audit approach to EM video analysis (Stanley et al. 2011, NOAA 2013a; Mangi et al. 2015). This issue is described in more length in the text box “Video Sampling Rates: A Major Driver of Cost.”

The costs of implementing EM, or any other method of fishery monitoring, depend highly on the *cost drivers* that are particular to each fishery. Cost drivers are characteristics either of the management system (e.g. program goals and standards) or the fishery (e.g. number of vessels, geographic isolation, vessel behavior and gear type) that affect both the level and the relative differences in costs of implementing different systems. For example, an EM system that requires all catch to be identified and measured at sea will likely result in different costs compared to a system that is designed to ensure that no catch is discarded at sea. Or, an ASO monitoring system designed for a geographically dispersed fishery made up of small vessels that make relatively short trips, will likely incur different costs than a similar system for a fishery that is focused in one port and is made up of large vessels that make long trips.

Cost of EM Compared to ASO in North American Fisheries
Costs for EM vary considerably depending on the management objectives of the program (Brannan 2015). In the Alaska rockfish fisheries, EM costs depended on the number of days fished. Based on the cost data collected EM was cheaper than ASO for vessels that would be fishing for more than 30% of the lease period for EM equipment and for vessels that would be using EM in lieu of an observer for more than seven fishing days a year (Bonney et al. 2009). A preliminary cost estimate for the use of EM in the Alaska Pacific Cod Pot fishery is $287 to $433 per day, depending on a 15% or 30% level of data review. The average daily cost for onboard observer monitoring under the North Pacific restructured observer program in 2014 was $1,067. This study by Buckelew et al. (2015) concluded that EM was both feasible and may provide a cost effective monitoring tool, particularly for under 60 foot vessels where there are logistical and safety concerns with onboard observers.
The British Columbia groundfish hook and line fishery has estimated EM costs of US$9,000 per vessel and US$0.16c per kg landed (Stanley et al. 2011; Stanley et al. 2014). These costs represented 3.2% of the total landed value in 2009 but relative costs vary among vessels from less than 1% to greater than 20% of landed value. Of the total cost, the EM component accounts for 70%, dockside monitoring 25%, and hails and logbooks 2.5% each. Brannan (2015) reports these figures equate to $350/day (10% review) for EM compared to $708/day for ASO in the fishery. The US shore-based Pacific whiting fishery EM program had a 2007-2010 average annual cost of $6.03 per metric tonne, $254 per sea day, 3.6% of the landed catch value, or 30% of the industry funded component of an at-sea observer (agency costs not included). The EM costs reflect the total program cost, including program planning, equipment provision, field data collection and all the steps required to produce a finished data set. EM equipment provision and field service were the largest cost component, over twice the cost of data analysis and reporting components (McElderry 2014). Recent estimates for EM costs in the West coast limited entry groundfish trawl fishery calculate that shoreside whiting vessels can save $183 per day using EM rather than an observer (depending on auditing and storage costs which will decrease the savings). A mothership catcher vessel may save roughly $2,400 per trip using EM rather than an observer (Pacific Fisheries Management Council 2016). Comparisons of EM and ASO costs like those reported here should be treated with some caution, since the accuracy and completeness of the cost data on EM and ASO data collection programs are difficult to determine (NOAA 2013a). Fixed and overhead costs are often not reported for ASO programs and are also not considered in the cost reporting for "on-off" EM trials. In ASO programs the costs of labor attrition and replacement costs are rarely fully accounted for. Thus, while informative, the reported costs of EM programs compared to ASO programs should not be considered authoritative.

EM costs differ from those of ASO. EM start-up costs are relatively high per vessel because of the cost of equipment including multiple cameras, sensors and data storage drives. EM equipment also needs maintenance and periodic upgrading. Many terabytes of video must be stored and retrievable for several years and up to a decade in some cases. Review of video by trained analysts is also costly and is highly dependent on the required sampling of the video. This ranges from 5% to 100% of video footage depending on the fishery and the MCS regime in place. These costs are structurally different from the costs of ASO that focus on the availability and cost of individual observers.

Many of the fixed costs of implementing EM, for example, the purchase cost of cameras, hard drives and long-term data storage are mostly known and generally consistent across case studies. Other costs, however, are dependent on the objectives (and thus the standards) of the EM program, as well as the characteristics of a particular fishery. For example, video review costs depend on the level of mandated video sampling (5-100%) as well as the goals of the review (estimating discard volumes versus species identification, size of individual fish etc.). Equipment installation and maintenance costs are likely to depend on the geographic isolation of the fishery. In addition, internal agency costs related to both the management of EM and ASO are difficult to determine because cost accounting for compliance purposes is rarely carried out with the necessary fidelity to accurately assign costs to ASO or EM. Some agency cost data are available from different jurisdictions, especially where there is cost recovery and cost accounting of either some or all ASO and EM costs. The British Columbia groundfish hook and line fishery is a good example of where cost data is generally complete and transparent.

As well as program standards, the characteristics of a fishery, such as how geographically isolated the fishery is, how dispersed it is (i.e. how many ports are included in the fishery), and the number of vessels in the fishery all affect the relative costs of EM and ASOs. There is evidence that for small and/or remote fisheries, the costs of EM may be greater than comparable ASO programs because ASO costs for these fisheries are often a part of a larger regional ASO program (Bonney et al. 2009). In contrast, EM systems remain bespoke, standalone systems and the costs of setting up these systems and the costs of running an EM program absent an established EM infrastructure are high (Diver 2012).

Although there are consistencies among certain categories of costs, the overall cost of EM is not uniform across fisheries and fleets (irrespective of whether an agency or industry pays this cost). Economies of scale play an important role. Our review of cases and stakeholder interviews, indicate that EM costs are generally lower than the comparable level of at sea observer coverage for the same monitoring objectives for medium to large fisheries. For example, a case study comparing the costs of on-board observers and EM using data from the Scottish catch quota monitoring scheme indicated that although costs varied greatly depending on a range of factors (in particular the numbers of analysts, equipped vessels and observers), EM costs are high in year 1 but are much reduced in subsequent years and cost per haul were cheaper for EM. Comparing the cost of a single observer against a single EM vessel and analyst over 10 years indicated that EM costs were less than half that of the observer-covered vessel (Dinsdale 2013).

The decision on how best to monitor a fishery can, and should, be informed by previous experiences in the implementation of fishery monitoring systems. Recently, the high level of interest in EM as a viable monitoring option has meant that these experiences have been documented widely and with increasing regularity. However, even though many studies have compared the costs of EM systems to ASO-based systems, there is no general consensus on how the costs of EM and ASOs compare. This is because monitoring costs under these two programs differ according to different sets of cost drivers.

An EM/ASO Financial Model and Analysis of Cost Drivers

To illustrate how the costs of implementing monitoring system may be affected by the characteristics of a particular fishery, a spreadsheet model was designed that relates cost drivers to the total costs of implementing various fishery monitoring systems. The model is "populated" with contemporary estimates of monitoring costs in order to provide a flexible tool which managers and stakeholders can use to help determine which monitoring systems make financial sense for their fishery and their specific operation. Although the decision process on which system(s) to implement also requires balancing broader management goals that may be hard to quantify, our model compares systems from a purely financial perspective.

The costs in the spreadsheet model can be used represent four methods of fishery monitoring: 1) camera-based electronic monitoring (EM), 2) at-sea observers (ASOs), 3) dock-side monitors (DSMs), and 4) vessel monitoring systems (VMS). The key drivers in the model include:

- Fishery scale: the number of vessels in the fishery;
- Gear type: the gear type used and the characteristics of the hauls/sets;
- Effort level: the number of fishing days per year per gear type;
- Geographic dispersion of the fishery: the number of ports in the fishery and their degree of geographic isolation and dispersion;
- Program goals: marine mammal monitoring, discard compliance monitoring, catch identification and quantification; and
- Program standards: percentage of fishing effort observed, percentage of video data collected, percentage of video data reviewed, length of time required for video data storage.

Video Sampling Rates: A Major Driver of Cost

In most cases where EM is used, video footage is available for very close to 100% of fishing events. While digital recognition technology is being developed that may make human review redundant, the amount of footage that is viewed by a human reviewer for the purposes of data recording is a major driver of cost. Under a ***census*** *approach data are recorded using 100% of the usable footage while under an* ***audit*** *approach a randomly selected subset of the footage is selected for review. The census approach offers close to 100% detection of non-compliance with regulations, and allows for a potentially more accurate estimate of catches and discards. The audit approach is also capable of detecting potential breaches of rules and regulations and may serve as an effective deterrent against rule-breaking by fishermen, and provide statistically relevant data for management and assessment use. Although the audit methodology can be satisfactory when used in a fleet-wide situation, or when vessels have many fishing events on a given trip, it is less suitable for individual trips by smaller vessels with few fishing events unless the review rate is close to 100% (Stanley et al. 2011). In a third option, the randomly reviewed fraction of EM imagery can be used to audit electronic or paper-based logbooks. In this option, there is a second catch accounting mechanism to benchmark vessel compliance with catch limits and, in aggregate, catch estimates against total allowable catches. The percentage of review of camera footage of fishing events that is needed for management, scientific or compliance objectives has the potential to profoundly impact costs. If a random or audit approach is sufficient, EM costs can be much lower. Costs of video review include review infrastructure (e.g. computers, software, building costs), reviewer training (although many reviewers are ex-observers and do not require much training), and personnel costs. (for an illustration of the impact of*

These cost drivers affect different components of the total costs for implementing each monitoring system. In order to capture this dynamic, we defined 12 categories of costs that are mutually exclusive and exhaustive – all possible costs can be attributed to a category. The categories are shown in Table 1.

Cost estimates for each category were obtained from a wide variety of reports. Some reports were peer-reviewed, but most were grey literature technical reports documenting trial EM programs. These estimates were then refined using informal stakeholder interviews with several EM and ASO service providers. A major issue in defining cost categories and then trying to ‘fill in the blanks’ with information from reports and interviews, is that most estimates of costs are either incomplete, highly aggregated, or poorly categorized.

A: Program Management	Costs relating to management of a monitoring program including standards development, auditing, support staff, management personnel, and overhead costs.
B: Hiring/Training/Certification	Costs for hiring, certification, training, and debriefing observers, at sea monitors, and dockside monitors.
C: Equipment Purchase	All costs associated with purchasing EM equipment.
D: Equipment Maintenance	Relates to the costs of maintaining/re-calibrating EM equipment including salary, per diem, travel etc. of technicians.
E: Equipment Installation	Relates to the installation costs of EM equipment and including the costs of training and certifying technicians that are capable of installing and maintaining equipment.
F: Data Transmission	For EM this represents the costs for using broadband, satellite, or other electronic system to transmit video data and/or the costs of a courier to replace hard drives. For ASOs and DSMs this includes the costs of getting data from the vessel to the fishery management agency.
G: Data Review/Processing	For ASOs/DSMs this includes the costs of checking and transcribing data into spreadsheet form for use by fishery managers. For EM this includes the costs of reviewing video data according to the goals of the program and checking and processing such data until it is in spreadsheet form and ready for use by fishery managers.
H: Data Storage/Archiving	Includes the infrastructure, personnel, and overhead costs of data storage.
I: Vessel Costs	Includes the costs incurred by the vessel in accommodating an EM or ASO monitoring system on the vessel including the costs of changed fish handling processes, infrastructure change, and cost of missed fishing opportunities.
J: Observer Deployment Costs	Includes all costs of deploying observers (not including agency training and certification costs). Includes salary, gear, equipment, per diems, travel, accommodation, field coordination etc.
K: Dockside Monitor Deployment Costs	Includes all costs of deploying dockside monitors (not including agency training and certification costs). Includes salary, gear, equipment, per diems, travel, accommodation, field coordination etc.
L: Other Costs	Costs that are not included elsewhere.

Table 1: Cost categories of implementing a fishery monitoring system.

Thus, some of the categories have relatively reliable cost estimates, while other categories have unreliable estimates. The categories that contain the *most reliable* cost estimates are C: equipment purchase, D: equipment installation, E: equipment maintenance, and J: observer deployment costs. The categories that have *moderately reliable* cost estimates are F: data transmission and G: data review and processing. The categories that we have *unreliable* estimates are: A: program management, B: hiring/training/certification, I: vessel costs, and K: dockside monitor deployment costs. To overcome data limitations, spreadsheet model users can insert their own cost estimates as well as specify the percentage of each cost category that is payable by the fishing industry. They can also determine government's share of costs (if any) in order to reflect the actual costs payable by the vessel owner. The distribution of costs that we were able to derive from the recent literature are shown in Table 2. These costs were derived from fisheries in the U.S., Canada, Europe, and Australia, all with a particular set of cost drivers associated with them.

EM: Initial Costs ($)	***Low***	***High***	***Mean***	***Reference***
Program Management	24,004	111,920	81,893	1,8
Equipment Purchase	5,210	14,876	10,595.21	2,3,5,6,7,8,10,11,12,13
Equipment Maintenance				
Equipment Installation	1,440	3,980.81	3,011.84	1,5,6,8,11,12,13
Data Transmission				
Data Review/Processing				
Data Storage/Archiving				
Vessel Costs				
Other Costs				
EM: Annual Costs ($)	***Low***	***High***	***Mean***	***Reference***
Program Management	21,916	189,880	152,806	1,4,6,7,8,10,11
Equipment Purchase				
Equipment Maintenance	395	4,088.3	1,908.6	1,4,5,7,8,10,11
Equipment Installation				
Data Transmission	199.04	3,433	1,216.3	1,5,6,8,11
Data Review/Processing	357	26,589	5,911.33	1,5,6,7,8,11
Data Storage/Archiving	56,884.31	65,652	45,356.3	6,8
Vessel Costs				
Other Costs				
ASO: Annual Costs ($)	***Low***	***High***	***Mean***	***Reference***
Program Management Hiring/Training/Certification	393,237	2,509,395	1,391,154	2,3,6
Data Transmission				
Data Review/Processing	96,000	960,000	528,000	8
Data Storage/Archiving	216,000	2,160,000	1,188,000	8
Observer Deployment Costs	344	1,170.72	677.32	2,3,5,6,8,10,14
Vessel Costs				
Other Costs				

Table 2: Initial and Annual Costs of EM and ASO monitoring systems.

Grey boxes are either non-applicable categories or missing data. Green boxes are those cost items with relatively reliable data. Copies of the input and output pages of the Excel spreadsheet model are shown in Appendix II.

To illustrate application of the financial model, we developed four scenarios that show the relative benefits of either an EM or ASO system and the "tipping points" when an EM system becomes more (or less) cost effective. These four scenarios represent cases that highlight unique fishery and EM/ASO program characteristic including 1) Varying ASO Monitoring Rate, 2) Fixed-Rate ASO Coverage, 3) Fleet Size and Fleet Dispersion Effects and 4) Fixed EM Video Review Rate.

Figure 1 illustrates the *Varying EM/ASO Monitoring Coverage* scenario. In this case the monitoring costs for a large 301 vessel trawl fishery that is somewhat geographically isolated depends on the level of monitoring coverage required. The costs of monitoring for an EM system are compared to the costs of an ASO system for a range of coverage levels (observer coverage levels vs video review rates). Due to the large fixed costs of the EM system, the EM system is more expensive than the ASO system under lower coverage levels; the opposite is true at high coverage levels. The two systems have the same cost at around a 55% coverage level.

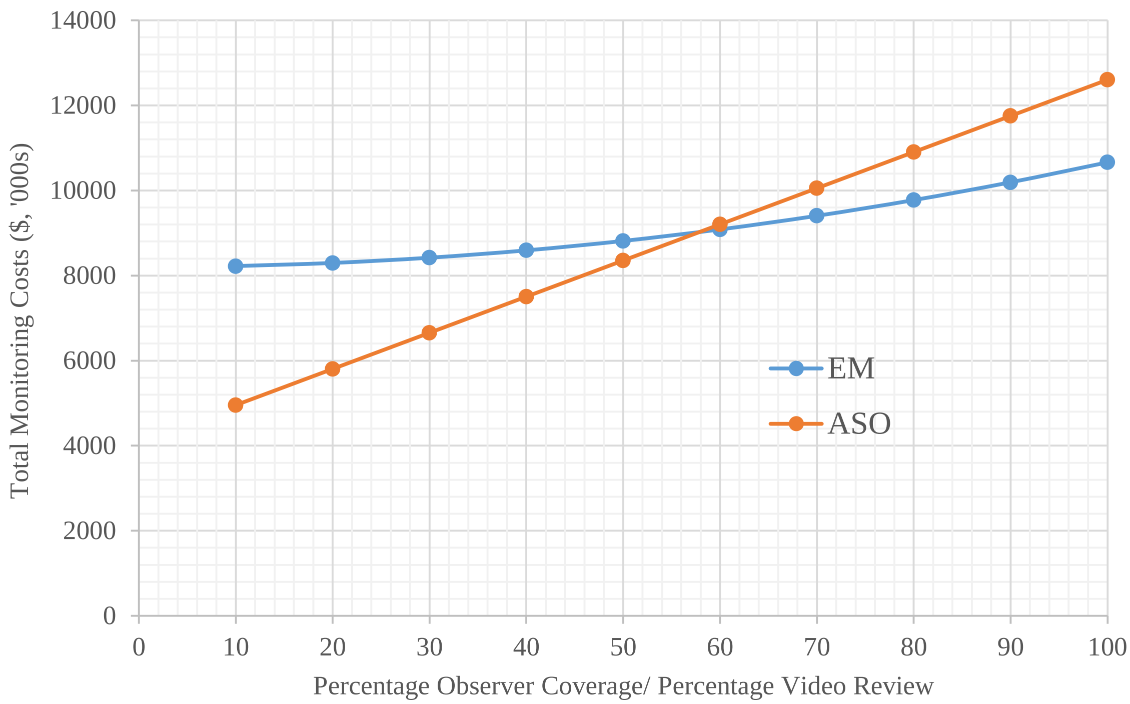

Figure 1: *Varying EM/ASO Monitoring Coverage* -- The net present value of monitoring costs over a 5 year time period with a 5% discount rate for an EM system and an ASO system for a moderately isolated 301 vessel fishery spread over 6 ports with vessels that average 4 hauls per fishing day. The goals of the program include seabird/mammal monitoring and catch/discard quantification and identification.

Although Scenario 1 compares video review rate directly to observer coverage rates, it is often the case in fisheries that the observer coverage rate is relatively low and that one of the goals of implementing an EM system is to increase coverage levels at a lower cost. Figure 2 illustrates how the costs of an EM system compare to those of an ASO system when observer coverage is fixed at 10% of fishing days. Given high fixed costs of equipment purchase and installation, EM is always more expensive than ASOs if the number of days fished in the fishery is relatively low. When the number of fishing days increases EM becomes relatively less expensive than ASOs for lower video review rates. However, as the video review rate increases these increased costs result in EM becoming more expensive than ASOs, even in cases where vessels fished every day of the month.

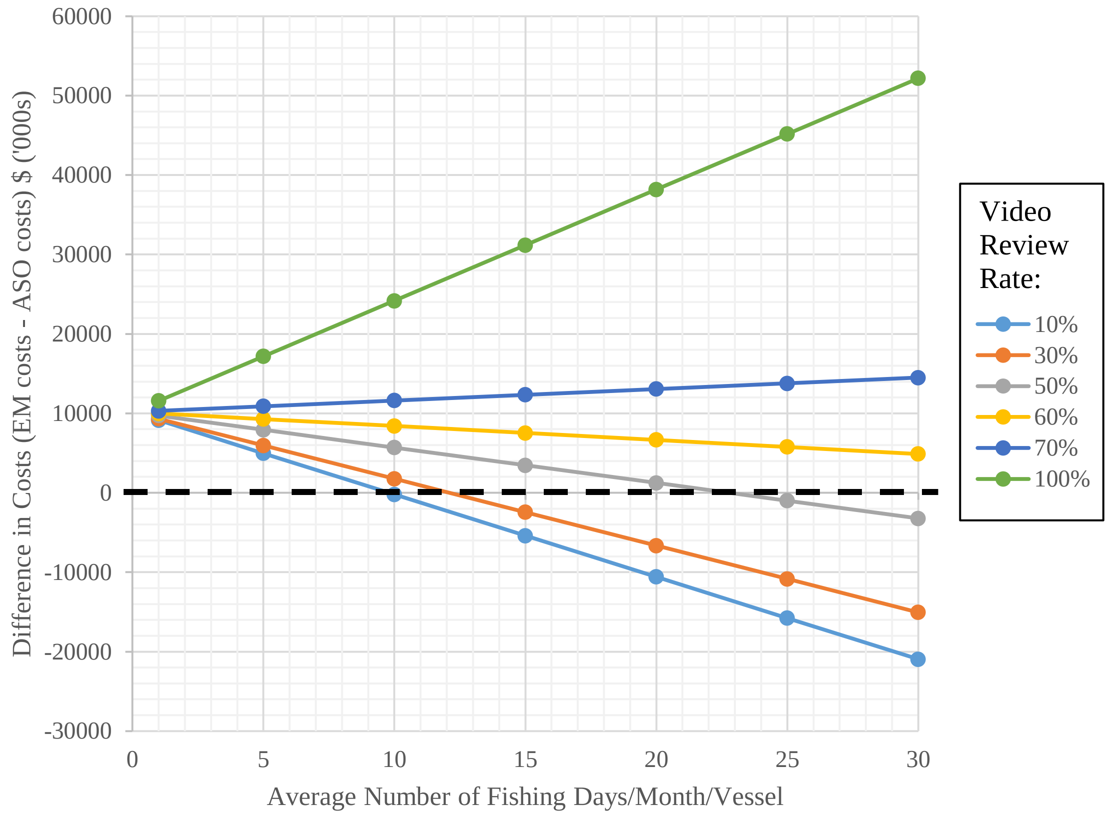

Figure 2: *Fixed-Rate ASO Coverage* – The net present value of *total fishery* costs over a 5 year time period with a 5% discount rate for an EM system and an ASO system with a 10% observer coverage requirement for a highly isolated 301 vessel fishery spread over 6 ports with vessels that average 4 hauls per fishing day. The goals of the program include seabird/mammal monitoring and catch/discard quantification and identification

Scenario 3 *Fleet Size and Fleet Dispersion Effects* is shown in Figure 3 and illustrates how fishery characteristics may affect the relative costs of EM and ASOs. In this example fishery 1 is a small 3 vessel fishery based in a single port that is not geographically isolated; fishery 2 is a 30 vessel fishery based out of 3 ports that are moderately isolated; and fishery 3 is a 301 vessel fishery based out of 6 ports that are highly isolated. Figure 3 shows that at low levels of fishing effort EM is more expensive than ASOs due to high fixed costs. As the level of effort in the fishery increases ASOs become relatively more expensive. However, this changes at different rates for each of the three fisheries. EM for fishery 3, which is highly isolated and spread over more ports, is relatively more expensive than for the smaller fisheries that are less dispersed. However as fishing effort increases, the rate at which the cost of both systems become equal (the 'threshold point') also increases. This is due to relatively high costs of providing ASOs in this fishery that are not outweighed by similar increases in EM-related data transmission, equipment installation, and equipment maintenance costs for this geographically isolated fishery.

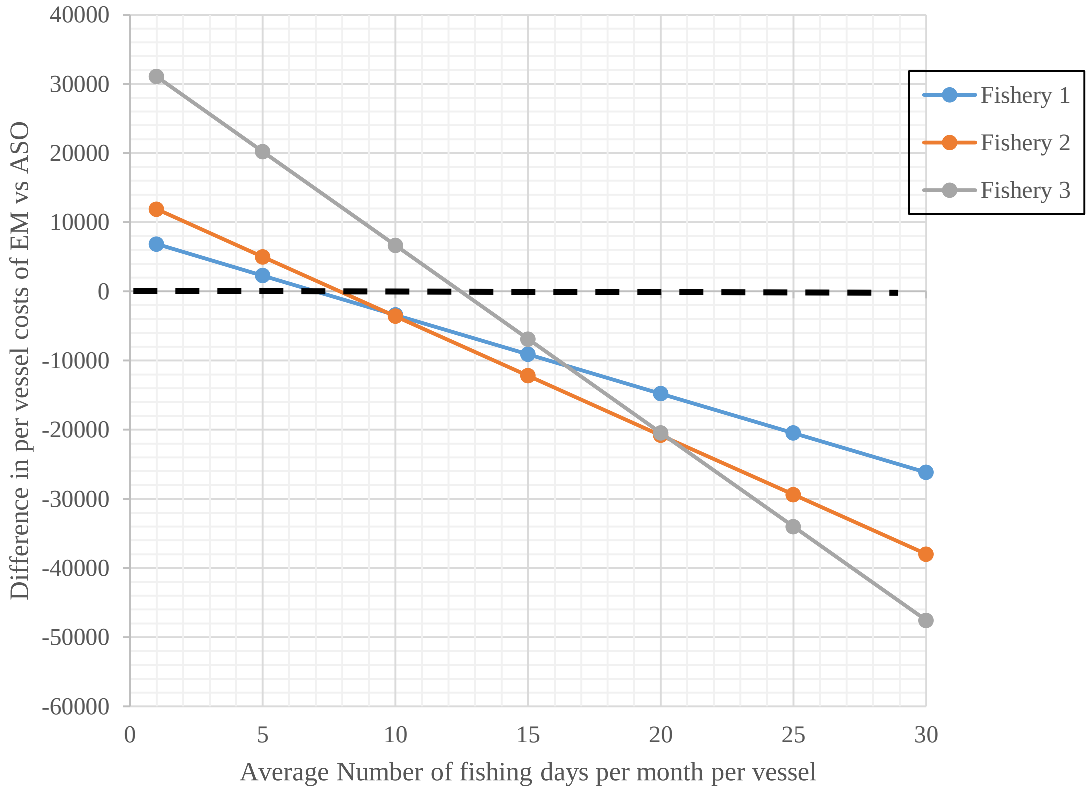

Figure 3: *Fleet Size and Fleet Dispersion Effects* – The net present value of the difference in *per vessel* costs of an EM and ASO system over a 5 year horizon with a 5% discount rate for three different fisheries. Fishery 1 is a small 3 vessel fishery based in a single port that is not geographically isolated; fishery 2 is a 30 vessel fishery based out of 3 ports that are moderately isolated; fishery 3 is a 301 vessel fishery based out of 6 ports that are highly isolated. The video review and observer coverage rates are set at 10% for each fishery. All other cost drivers are the same for each fishery.

Another way of comparing the costs of EM and ASOs is to fix the level of EM video review and determine how the level of observer coverage required in the fishery affects the relative costs of the two systems. Scenario 4 *Fixed EM Video Review Rate* (Figure 4) illustrates this situation for a large, geographically isolated fishery with the same cost drivers as in Figure 2. For low levels of fishing effort EM is always more expensive than ASOs. However, as average effort in the fishery increases EM becomes less expensive than ASOs when ASO coverage requirements are greater than approximately 25%. As the level of observer coverage required increases EM becomes less expensive much faster.

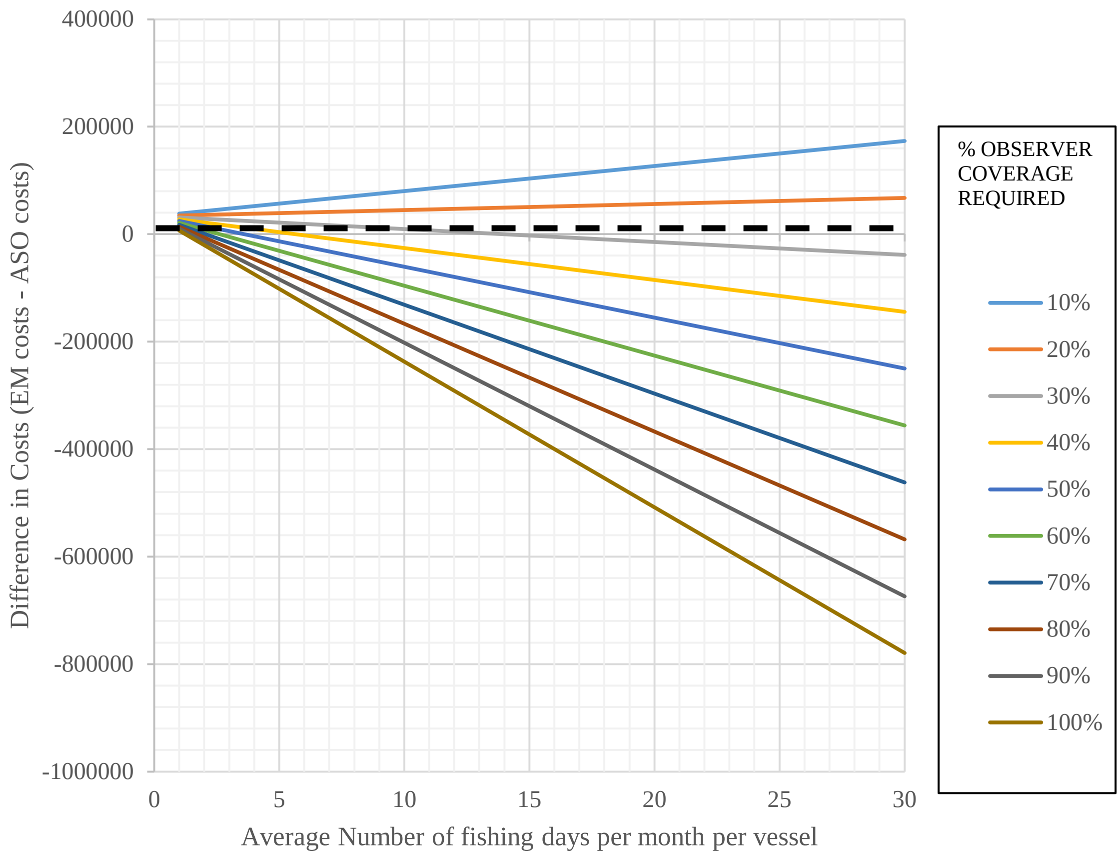

Figure 4: *Fixed EM Video Review Rate* -- The net present value of the difference in *per vessel* costs over a 5 year horizon with a 5% discount rate for an EM system with 100% video review and an ASO system with varying levels of observer coverage requirements. The fishery is a 301 vessel trawl fishery that is geographically isolated and spread over 6 ports.

Although these examples are based on hypothetical fisheries and using just the cost categories that we have reasonable data for (all other cost categories are assumed to be the same for each monitoring system), they serve to illustrate the potential usefulness of the spreadsheet model for fishery stakeholders for examining how the cost drivers that correspond to their particular fishery determine the relative costs of implementing an EM and/or an ASO-based system. In particular, if levels of fishing effort are very low, regardless of the other characteristics of the fishery or program standards, ASOs are generally less expensive than EM systems. As fishing effort increases, however, EM systems become relatively more attractive for 1) lower levels of video review of hauls, 2) geographically dispersed fisheries over many ports, and 3) higher levels of observer coverage. The spreadsheet model (shown in the appendix) can accommodate new estimates of costs input directly by stakeholders or agencies based on their own knowledge of likely costs.

Section III: Key Findings and Recommendations

This section highlights the key findings and recommendations of this report based on the literature review and case studies, informant discussions and interviews, and analysis of the financial spreadsheet model.

The use of EM for fisheries MCS is still uncommon: The use of EM is still rare although significant industry, NGO, and government agency interest exists in exploring its application. We are reaching a 'tipping point' where the use of electronic technology (including electronic reporting) is rapidly gathering momentum.

EM technology is maturing and operationally robust: EM technology has been tested, utilized, and compared to human observers in many different applications. EM can directly substitute for many human observer functions, can perform some functions to a higher level of accuracy (such as monitoring of sporadic events that occur over long time periods), but is also restricted, as a stand-alone technology, of performing some of the essential tasks performed by ASOs (such as biological sampling).

EM is part of an integrated fisheries management system and not just a data collection technology: Although it is common to think of EM as purely a data collection methodology, much of its utility is likely to arise from its integration with an overall electronic fisheries MCS system.

Clearly articulated objectives for EM reduce costs: Defining the objectives of a monitoring program that are clearly articulated and developed in conjunction with EM providers, fishermen, and fishery managers can foster cost effectiveness, especially when moving from a trial phase to an implementation phase.

The Structure of EM costs differ from ASO costs – scale is critical: The costs of ASOs to a fishing vessel are normally realized as purely "variable" costs – they are paid for on a 'per day' basis. EM, however, requires significant initial investment in equipment, installation, and training as a fixed cost. Depending on required video review rates and storage costs, variable costs of EM are potentially much lower than the variable cost of an ASO which makes the scale of fishing effort important. In general, if a vessel does not fish many days, or is required to be observed on only a small percentage of trips, EM is likely to be more expensive than ASO; the converse also holds.

EM and ASO costs can differ significantly: The literature review and financial analysis shows that EM may be within 50% to 150% of the costs of ASO depending on 1) program objectives, 2) characteristics of the fishery, 3) the scale, diversity and distribution of the fleet, 4) organization, cooperation, and sophistication of the fleet, and 5) type of resource management system.

Who pays for EM and ASO can differ: Fisheries management is moving towards a cost-recovery paradigm where fishermen are expected to pay for the costs of management, which includes fishery monitoring. The implementation of a new, potentially less expensive method of fishery monitoring brings with it the opportunity for change, innovation, and greater focus on cost effectiveness.

The marketplace for EM and ASO services is complex: The marketplace for EM products and services is relatively small but has the potential to grow significantly. It is also intertwined with the market for observer services. EM is not always a substitute for ASO but may often be a complement. In the future we should expect to find creative combinations of EM and ASO to best meet regulatory compliance and data needs at the lowest cost levels. Government and industry attitudes towards new monitoring technologies has the potential to significantly alter the future of these markets.

The presence or absence of clear standards can fundamentally lead to the success or failure of EM initiatives: Standards for EM are complex because they must be applied to many elements of the EM process including data requirements, monitoring equipment, data confidentiality, data ownership, etc. But well-defined and cooperatively developed standards can help provide a coherent framework for building successful EM programs. We recommend that the United States conduct a national workshop focused on designing principles and guidelines for developing standards-based approaches for EM.

Expectations need to be reasonable and aligned with the capacity, regulatory environment, and culture of management agencies and industry: Agency, NGO and industry views about the capabilities of EM as a technology and the ability to integrate EM with existing fishing and agency management practices can often be too optimistic. Changing methods and new technologies can also challenge industry and management agency culture and legal precedent. EM introduction is often hampered by uncertainty caused by changes in costs, overall agency and wider industry commitment to EM programs, shifting goal posts during introduction, regulatory barriers, and legal challenges to programs. In order to develop cost effective and innovative EM systems, management agencies should support entrepreneurship and innovation based on understanding markets for monitoring systems, as well as incentives within their own fisheries and agencies to drive down costs and improve performance. Poorly managed and financially stressed fisheries cannot support effective EM or ASO monitoring. The cumulative outcome of misplaced expectations and institutional inertia can result in the failure of EM programs to progress beyond the experimental stage.

Collaboration is essential to the implementation of EM: The greater the collaboration between scientists, enforcement officers, managers, technologists, and industry during the trial, implementation and operational phases of an EM project, the greater its chances of success. Each player must strive to understand the perspectives of other team members and realize the tradeoffs that may be inherent in balancing the quantity/quality of the data and the costs to achieve different levels of "compliance". By structuring the program using a collaborative approach, players will discover approaches for aligning incentives and increasing trust among the participating partners.

Learning from the experience of others: There have been many EM experimental programs and pilot projects across U.S. fleets, regions, and fisheries. These programs did and are providing important information, experiences, and ideas. We recommend conducting a national survey of participants in EM programs to determine experiences, lessons learned, approaches for improving programs, and ideas for reducing costs. The results of the survey could be used to structure a national workshop for improving both EM, ER and ASO programs.

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(bracketed numbers refer to cost estimate sources in Table 2)

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Appendix I: Key Issues Raised in Discussions with Industry and Agency Stakeholders on EM and ASO

The following bulleted lists summarizes major issues raised by industry, non-governmental organizations, and agency informants during discussions and interviews. The issues are listed under relevant topic-headings but there is considerable overlap for some issues across topics.

The Marketplace for EM and HM Services

- Half a dozen or so companies provide EM services besides government. The market is now becoming very competitive. Note there are three categories of providers: private for profits, non-profits, and government.
- If government agencies expect industry to reduce costs, be competitive, and risk capital, they have a responsibility to help create a business environment to reward creation of intellectual property, new technologies, etc. This is especially important give that the markets for these services are relatively small.
- Need a management system that rewards thinking innovatively and entrepreneurially with the development and use of EM for a variety of applications (e.g., shoreside EM, crew biological monitors monitored by EM, ASO managing EM,). Expect to see a variety of combinations of ASO and EM evolving over time in creative ways to achieve management and monitoring objectives while lowering costs.
- How do you stimulate competition in small markets for EM providers? Besides being a risky business it is important to make the costs transparent. The EM market intersects the human observer/monitoring market which increases the necessity of transparent costs.
- Cost recovery is expected to increase around the globe over time and industry will be expected to shoulder a greater share of monitoring costs.
- EM is a competitive and not highly profitable industry. Difficult to average more than 5% real profits over time.
- ASO and EM may be almost pure “substitutes” when the program requirements are narrowly defined (e.g., compliance). In other case ASO and EM may not be substitutes depending on program goals, management requirements, and characteristics of the fishery. Given the nature of small markets and the fixed costs associate with each approach, any increase in the use of EM may decrease the demand for ASO (or vice versa), reducing supply, and increasing average costs. While theoretically possible that one approach may dominate the market over time (including consideration of expected future cost and technology trends), the fact that these approaches are often complements may limit supply effects.

Designing EM Programs

Structuring the Program

- Developing a successful "program framework" for initiating and operating EM is the single biggest challenge – not the technology.
- Program elements may be completely managed by industry or in combination with government.
- When almost totally private (e.g., application of EM in the British Columbia hook and line fishery) the focus is on developing transparent standards and well-crafted audit systems that reward compliance.
- It is critical that industry be fully engaged in designing the EM program.
- All key players, including agencies and industry, must work together to fully design an EM program based on transparent and smart standards, incentives, and a focus on helping to reduce costs.
- Best programs are designed and implement by teams of scientists (including statisticians), managers, technologists, and industry at the beginning of the EM project. Each player must strive to understand the perspective of the other team members and realize the tradeoffs that may be inherent in balancing the quantity/quality of the data and the costs to achieve different levels of "compliance". Need to structure the program within a decision science framework.
- EM must be perceived as a "system" -- not a camera – that includes a variety of elements. Integrating the system together to be efficient and meet the standards and data needs for specific fisheries is fundamental.
- Important common goals of EM include reducing costs of monitoring and confirming logbooks.
- Major problem is confusion regarding whether EM pilot projects are "science projects" or "regulatory projects". Confusion regarding goals is one of the leading causes of program problems.
- Use EM within a management framework that establishes trust and confidence that can deliver increasingly creative and cost effective approaches for collecting needed information.
- Need research to determine the "optimal" video review rate (5%, 10%, 20% etc.). Are these decisions made outside the EM program or as part of a larger decision science management framework?
- Loss of privacy to fishermen is the single biggest concern of EM by some vessels and skippers; other argue the crew and skipper adapt over time and don't even consider the presence of cameras.

Managing Expectations

- The "shiny bauble syndrome" plagues expectation about EM. Many in management believe that EM is capable of delivering more than its actual capabilities and lack understanding of what it can produce.
- There are also unrealistic expectations regarding costs and technology. There are unrealistic expectations for EM including costs which technology.
- There are relatively high expectations on EM technology improving but mixed perceptions on how rapidly costs will decrease and technology improve.

Role of Government in Supporting Rational Management

- Where there are well developed privileges and property rights, strong fishery management and fleet coordination, and cost recovery, risks and costs of EM are generally reduced due to the incentives for the fleet to coordinate and meet management requirements.
- Fisheries that have less than 100% coverage may create perverse incentives to cheat and reduces the incentives to cooperate which undermines the creation of trust. There are cases of some fishermen volunteering their vessel for 100% EM coverage in order to be seen as a trusted source of information.
- Agencies can become so worried about regulatory and legal issues that they are not free to think creatively in designing efficient and cost effective programs.
- Some of the best EM programs are where agencies do not feel the need to "meddle".
- U.S. fishery management councils often have poorly articulated and conflicting objectives with respect to EM.
- Overall program guidelines/principles should be developed and communicated and important EM objectives clearly articulated even if there may be conflicting or non-complementary objectives (e.g., low cost vs near 100% statistical certainty). This may require thoughtful discussion and tradeoff analysis.
- Need EM experimentation across fleets and regions and fisheries. These "experiments" are providing important information, experiences, and ideas.
- Some Science Centers may have the wrong "culture" to embrace collaborative research and use of E-Monitoring data. Changing cultures can be complicated and require a long term approach.
- Who are the customers for using EM technology use? If customers are perceived as only the agencies and not the fishing industry this can create problems. Depending on the customer, technology companies may not look at costs the same way.
- Major agency turf battles over EM and observers complicates achieving success. The fishing industry is often more pragmatic and sees EM as a tool, and not part of some bureaucratic "empire".
- Some individuals unwilling to embrace new technologies and a changing paradigm – this can create significant political and bureaucratic inertia.
- Some agency folks believe they should review and audit and don't believe this should be an industry responsibility. Industry typically has a more pragmatic perspective based on standards and costs.

- Structuring EM and ASO from a regulatory perspective is challenging. If programs are not flexible using performance standards, there is concern that government could lock in obsolescence.

Incentives, Disincentives, and Trust

Industry

- Perverse management incentives can undermine EM and ASO and encourage cheating and undermine the program. Especially problematic when there is a small percentage of observer coverage due to major choke species, budget constraints and unprofitable fisheries.
- If fishermen, skippers, and vessel owners truly want cameras and EM to work -- it will work. But if the underlying incentives aren't aligned then they won't make it work.
- Industry leaders are important for making fundamental change—but if industry is facing immediate and serious management problems they will lack the focus and incentives to drive longer term thinking and support creative development and implementation of EM.
- If industry has no underlying incentive and EM is "forced" on them, the result will be higher EM costs for both implementation and operations.
- Typically, if there is 100% vessel coverage, the program can support lower review rates and decrease costs. Fishermen with good records may be incentivized by reducing their review rates and costs. Especially true when EM is integrated with logbooks and consistency in records reduces fishermen costs.
- What are the key incentives to drive fleets to use EM—subsidies? access to more quota? new areas open to fishing?
- One key incentive is based on the strong desire of the industry to have their fisheries dependent data used in science and management. Scientists often don't trust logbook data but can use EM to verify logbook data accuracy.
- Another incentive is to use EM in conjunction with experimental fishing permits and the additional available quota.
- Can EM data have a market value?? Can it be sold to science agencies, Universities, and NGO's?
- Pilot projects can be very successful for incentivizing fishermen participation. If the project works it sets the approach and methods – that is it "blazes the trail" to help design efficient systems, reduce costs, and set the standards. Otherwise, fishermen, if not involved, could be shouldering inefficient and costly systems.
- Trust is key. Success can be measured by the degree of trust of both industry and agencies in EM programs and fishermen compliance.
- Need to understand the role of incentives for driving EM related R&D (e.g., computer vision, automatic recognition).

NGO's and Third Parties

- Often the start-up costs are fronted by NGO's and Foundations to encourage participation. However, this can be a double edge sword since actual costs once implemented may fall primarily on industry. Lack of transparency in understanding who pays over time can undermine EM success.

Government

- Drivers for observing are often born out of a culture of distrust: "bad apples" and/or perverse standards driving industry behavior color the attitudes of the agencies about the fundamental character of fishermen. This makes establishing a mutual foundation for developing EM programs very difficult.
- There must be strong management (dis)incentives not to cheat. There must be strong penalties for individuals and fleets in order to align incentives for coordination and compliance.
- How do we honestly grapple with the "observer effect" when there is partial coverage (i.e., fishermen tend to cheat more if observers are not present). The ultimate distrust can undermine cooperation for effective EM and ASO programs.
- If the fishery is already economically distressed, attempts to introduce costly EM will be difficult. What strategies, rewards, incentives will work when this is the prevailing situation?
- Reducing review rates can provide incentives for fishermen to adopt EM, but scientists must be committed to review rates that aren't necessarily the same rate as when there are ASOs.
- A successful approach and incentive is to work via teams to develop cost effective and flexible EM strategies to meet a known and concrete standard.

Costs

Industry

- Costs to industry are problematic. The industry often doesn't pay the full EM costs. This can create a problem since fishermen may not be incentivized to help reduce EM costs.
- Given high program EM fixed costs, there must be strategies to get broader fleet buy in – especially as pilot projects are winding down. What are the key strategies and incentives to get "buy-in"?
- Biggest issue with ASO observers is flexibility and availability—the "planning" costs will be high if a weather window is small and observers are not available. This is especially a problem in remote geographic areas.
- If industry is looking for panaceas from EM they will be disappointed and will undermine EM program success.
- Industry often provides 100's of hours of free upfront costs in upfront pilot project costs but rarely are they compensated. Would compensation improve EM success?
- In some cases, there are there are excessive regulatory burdens for the fleet to enroll in EM. This has the potential to undermine potentially successful programs.

- Experience has shown that when institutional incentives are in alignment, the collective industry will develop their own self-enforcing standards, punish bad performers, and in some cases kick them out of an EFP based EM project.
- Software licensing language by tech providers can be problematic, expensive, and many service costs will fall on industry – the providers don't take enough responsibility.
- Long term requirements to hold data and pay storage costs are a major cost and problem for industry and will undermine EM success.
- When compliance needs are first established via an observer program, it is easier to transition to EM since the compliance requirements and standards are established.

Government

- Audit based analysis is key to cut labor costs—but need cooperation and incentives to make it successful.
- Why can't observers be part timers living in a community? It will reduce observer costs in remote locations. Does it really create too many pressures to encourage "cheating"?
- Who is ultimately responsible for EM costs—industry or government? This is rarely articulated early on which creates problems and confusion.
- EM review costs depend on the fishery and regulations. For example, the West coast whiting fishery has lower costs than the West coast IFQ groundfish fishery.

Technology companies

- Scale and geography are very big issues in considering costs—especially given small markets. No fishery has 1000's of customers but usually a few score or a few hundred at most. Geographically small, diverse and remote fleets significantly increase EM costs.
- Technology companies may provide options for paying for EM equipment and services--for example flat rates, hourly rates, leasing rates, etc.
- Key cost drivers for private companies are often linked to poorly articulate EM project objectives by the agencies and/or multiple conflicting objectives.

Future Expectations

- There are mixed perceptions Mixed views on future costs for EM—some believe will decrease others increase (e.g., service fees will go up) but not as much as human monitors.
- Pilot projects often have many costs subsidized—significant concern what costs will look like in the future as subsidies and support from the NGO's and agencies end.
- E-Monitoring seen as a way to reduce costs given fisheries under huge cost pressure and human costs are expected to increase are expected to increase over time, not decrease.

Standards

- EM and OAS standards need to be intelligently designed and integrated with risk, uncertainty, and precautionary management approaches. Standards may also need to be dynamic and reflect the status of the fishery. For example, do we need the same standards for information if a stock is recovering or their status is uncertain, versus a stock that is rebuilt at MSY levels?
- Agencies often don't articulate the level and types of biases and precision they are willing to accept for EM programs. This is a critical issue that can undermine EM success. There needs to be guidelines and principles for developing the science standards.
- Generally, there are rarely standards for science requirements, confidentiality, data ownership, objectives, etc.
- EM standards need to be program and project specific, but principles guiding standard design can be broad-based.
- There should be opportunities for rewarding fishermen that reduce the error via approaches to "operationalizing" precautionary approaches. Lower error and greater certainty should result in rewards to fishermen and fleets via lower costs, greater quota etc.
- "Sliding standards" are a major problem. Often scientists may not initially understand what EM or OAS are capable of providing. As scientists learn EM/OAS capabilities they may begin to raise the standards in terms of quality, accuracy, precision, etc.
- Rare event fisheries typically require higher data standards.
- Evolving compliance standard is 30% coefficient of variation.
- The Standards issue is complex but must be addressed to drive development of EM.
- Councils may not be the best place to have the conversation about EM/OAS standards. Councils use the data but have many misunderstanding about standards and incentives for designing efficient data systems. They work best by seeing examples of documented standards that have worked in similar fisheries.
- Are there enforced standards for video reviewers? How good are the reviewers? What incentives will drive down reviewer costs?
- The key cost is not video review but storage costs. Need to develop standards on data review and storage. Is three years the government requirement? What are the costs and who pays? Are there incentives to drive down these costs?

Appendix II: The Financial Spreadsheet

You can download the full spreadsheet here.

Input Pages

MONITORING GOALS	
seabird monitoring	☑
marine mammal monitoring	☑
full retention monitoring (compliance)	☐
catch/discard quantification	☑
catch/discard identification	☑
vessel behavior/effort tracking/area management	☑

MONITORING SYSTEMS REQUIRED	
Camera-Based Electronic Monitoring	☑
Human At-Sea Observers/Monitors	☑
Dockside Monitors	☑
Vessel Monitoring Systems	☑

Discount rate (%)
5

FISHERY CHARACTERISTICS				
number of vessels	300			
number of fishing days per month per vessel	30			
number of fishing ports in fishery	6			
geographic isolation of ports	1	◉ HIGH	○ MEDIUM	○ LOW
length of time each camera needs to record video				
trawl hauls per fishing day	4			
length of each haul deployment (mins)	15			
length of each haul at fishing depth (mins)	210			
length of each haulback (mins)	60			
longline/ pots sets per fishing day average	0			
length of each set deployment (mins)	40			
length of each set retrieval (mins)	180			

PROGRAM STANDARDS	
% of days observed	10
% of hauls/sets observed per day observed	100
% of days reviewed	60
% of hauls/sets reviewed per day reviewed	100
Number of years to store video data	5
% of fishing days monitored dockside	100

COST CATEGORY: WHO PAYS?	industry %	gov/other %
Program Management	100	0
Hiring/Training/Certification	100	0
Equipment Purchase	100	0
Equipment Maintenance	100	0
Equipment Installation	100	0
Data Transmission	100	0
Data Review/Processing	100	0
Data Storage/Archiving	100	0
Vessel Costs	100	0
Other Costs	100	0
Observer Deployment Costs	100	0
Dockside Monitor Deployment Costs	100	0
TOTAL	100	0

EM Cost Calculation Pages

COST VARIABLES

# vessels	300
# fishing days/year	108000
# cameras	4

# hours video per year	
seabird/marine mammal	2052000
catch/discard monitoring	432000

# hours video reviewed per year	
seabird/marine mammal	1231200
catch/discard monitoring	259200

discount factor	
year 1	1
year 2	0.952380952
year 3	0.907029478
year 4	0.863837599
year 5	0.822702475

CALCULATED COST PARAMETERS

	Per Fleet Costs		Per Vessel Costs		Per Hour Costs
Category	Initial	Annual	Initial	Annual	Hourly
Program Management*	0				
Equipment Purchase			10595.21		
Equipment Maintenance				3908	
Equipment Installation			3440		
Data Transmission				3433	
Data Review/Processing					38.46
Data Storage/Archiving		2153550			
Vessel Costs					
Other Costs					
TOTAL					

CALCULATED COSTS (fleetwide and on annual basis)

Per Fleet Costs		Per Vessel Costs		Per Hour Costs
INITIAL	ANNUAL	INITIAL	ANNUAL	ANNUAL
0	0	0	0	0
0	0	3178563	0	0
0	0	0	1172400	0
0	0	1032000	0	0
0	0	0	1029900	0
0	0	0	0	5831766.72
0	2153550	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0

Base Cost Parameters	Fleet Costs		Vessel Costs		Per Hour Costs
Category	Initial	Annual	Initial	Annual	Hourly
Program Management*	0				
Equipment Purchase			7595.21		
Equipment Maintenance				1908	
Equipment Installation			1440		
Data Transmission				199	
Data Review/Processing					38.46
Data Storage/Archiving		216000			
Vessel Costs					
Other Costs					
TOTAL					

COSTS	*YEAR 1*		*YEAR 2*		*YEAR 3*		*YEAR 4*		*YEAR 5*	
	Industry	Government	Industry	Government	Industry	Government	Industry	Government	Industry	Government
Program Management	0	0	0	0	0	0	0	0	0	0
Equipment Purchase	3178563	0	0	0	0	0	0	0	0	0
Equipment Maintenance	1172400	0	1172400	0	1172400	0	1172400	0	1172400	0
Equipment Installation	1032000	0	0	0	0	0	0	0	0	0
Data Transmission	1029900	0	1029900	0	1029900	0	1029900	0	1029900	0
Data Review/Processing	5831766.72	0	5831766.72	0	5831766.72	0	5831766.72	0	5831766.72	0
Data Storage/Archiving	2153550	0	2153550	0	2153550	0	2153550	0	2153550	0
Vessel Costs	0	0	0	0	0	0	0	0	0	0
Other Costs	0	0	0	0	0	0	0	0	0	0
TOTAL	14398179.72	0	10187616.72	0	10187616.72	0	10187616.72	0	10187616.72	0
DISCOUNTED TOTAL	14398179.72	0	9702492.114	0	9240468.68	0	8800446.362	0	8381377.488	0

ASO Cost calculation Pages

COST VARIABLES

# vessels	300
# fishing days/year	108000
# cameras	4

discount factor	
year 1	1
year 2	0.952380952
year 3	0.907029478
year 4	0.863837599
year 5	0.822702475
year 6	0.783526166

CALCULATED COST PARAMETERS

Calculated Cost Parameters	Per Fleet Costs		Per Vessel Costs		Per Day
Category	Initial	Annual	Initial	Annual	Daily
Program Management*					
Hiring/Training/Certification*					
Data Transmission					
Data Review/Processing		903000			
Data Storage/Archiving					
Vessel Costs					
Other Costs					
Observer Deployment Costs					646.95
TOTAL					

CALCULATED COSTS

Per Fleet Costs		Per Vessel Costs		Per Day
INITIAL	ANNUAL	INITIAL	ANNUAL	ANNUAL
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	903000	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	6987060
0	903000	0	0	6987060

Base Cost Parameters	Fleet Costs		Vessel Costs		Per Day
Category	Initial	Annual	Initial	Annual	Daily
Program Management*					
Hiring/Training/Certification*					
Data Transmission					
Data Review/Processing		96000			
Data Storage/Archiving					
Vessel Costs					
Other Costs					
Observer Deployment Costs					344
TOTAL					

COSTS	*YEAR 1*		*YEAR 2*		*YEAR 3*		*YEAR 4*		*YEAR 5*	
	Industry	Government	Industry	Government	Industry	Government	Industry	Government	Industry	Government
Program Management	0	0	0	0	0	0	0	0	0	0
Hiring/Training/Certification	0	0	0	0	0	0	0	0	0	0
Data Transmission	0	0	0	0	0	0	0	0	0	0
Data Review/Processing	903000	0	903000	0	903000	0	903000	0	903000	0
Data Storage/Archiving	0	0	0	0	0	0	0	0	0	0
Vessel Costs	0	0	0	0	0	0	0	0	0	0
Other Costs	0	0	0	0	0	0	0	0	0	0
Observer Deployment Costs	6987060	0	6987060	0	6987060	0	6987060	0	6987060	0
TOTAL	7890060	0	7890060	0	7890060	0	7890060	0	7890060	0
DISCOUNTED TOTAL	7890060	0	7514342.857	0	7156517.007	0	6815730.483	0	6491171.888	0

Output Page

Present Discounted Value of Costs ($)

Electronic Monitoring		Human Observers		Dockside Monitors		Vessel Monitoring Systems	
PDV ($)		PDV ($)		PDV ($)		PDV ($)	
Industry	54350326.47	Industry	54785273.38	Industry	59421210.07	Industry	2404641.163
Government	0	Government	0	Government	0	Government	0
Total	54350326.47	Total	54785273.38	Total	59421210.07	Total	2404641.163